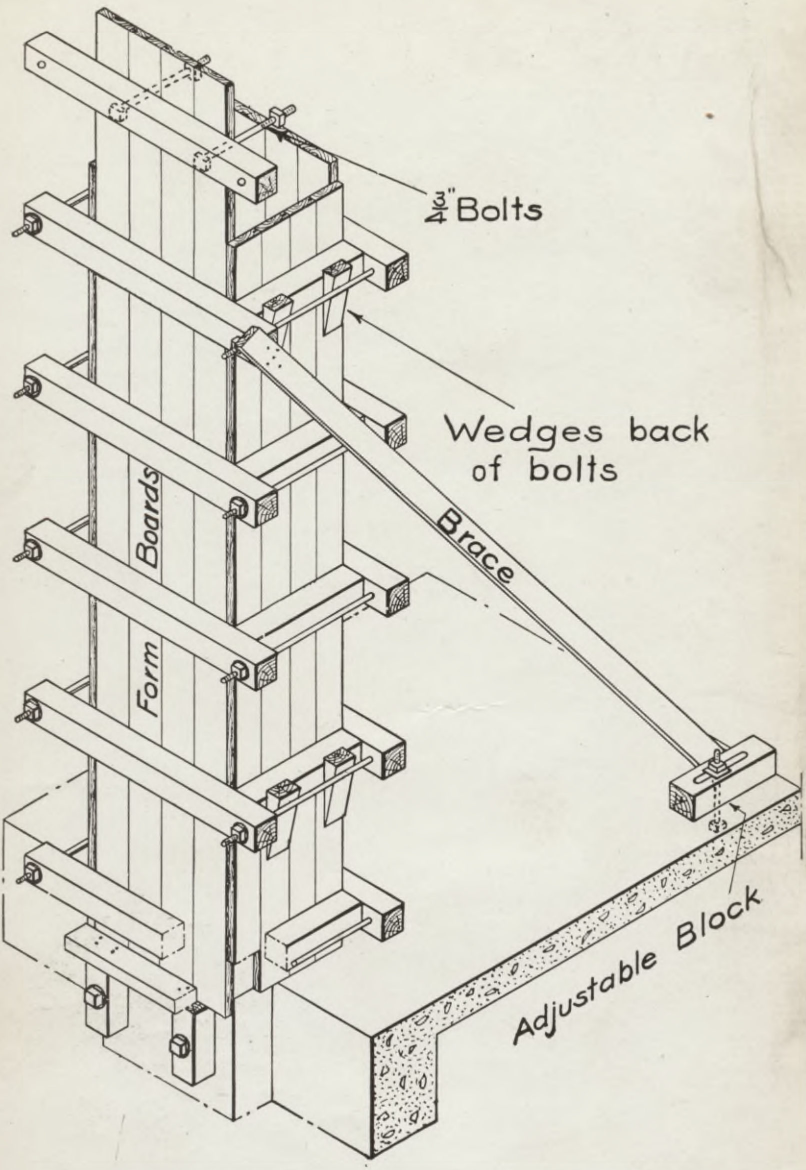
PARTIAL REFERENCE INDEX



Design of Form for Wall Columns
(See p. 494)

CONCRETE COSTS

TABLES AND RECOMMENDATIONS FOR ESTIMATING THE TIME AND COST OF LABOR OPERATIONS IN CONCRETE CONSTRUCTION AND FOR INTRODUCING ECONOMICAL METHODS OF MANAGEMENT

BY

FREDERICK W. TAYLOR, M.E., Sc.D.

AND

SANFORD E. THOMPSON, S.B.

Member American Society of Civil Engineers

Consulting Engineer

AUTHORS OF

A TREATISE ON CONCRETE, PLAIN AND REINFORCED

FIRST EDITION

FIRST ISSUE, FIVE THOUSAND

NEW YORK

JOHN WILEY & SONS

London: CHAPMAN & HALL, Limited

1912

By the same Authors

CONCRETE

PLAIN AND REINFORCED

SECOND EDITION

8vo XLI + 807 pages, 249 figures, Cloth, $5.00

PUBLISHED BY JOHN WILEY & SONS

WAVERLY PRESS
BALTIMORE, MARYLAND
U. S. A.

INTRODUCTION

BY FREDERICK W. TAYLOR

It is hoped that this book will be used:

(1) By architects, engineers, and contractors in making accurate estimates of the cost of concrete works and structures.

(2) By contractors, superintendents, and foremen to help them to so lay out and plan their work that their materials will be more economically handled and used than in the past, and that each workman will do more and better work than heretofore.

(3) To assist in the introduction of the principles of Scientific Management in the building trades.

The writer fully realizes that for several years to come this third use will be subordinate to the other two; and yet so thoroughly convinced is he of the ultimate triumph of the principles of Scientific Management that he hopes and firmly believes that the promotion of this cause will be in the end the most important function of the book.

The distinctive feature of this book is that the information given in its tables, etc., as to how long workmen should take to do all kinds of tasks, has been obtained by watching one man after another while they were doing a day's work and noting with a stop-watch the time taken in doing each small element of their trade.

Heretofore the best knowledge of the time required to do work of this character has been obtained by keeping records of the pay, and sometimes of the time of gangs, or groups, of workmen while they were doing whole jobs of work, or at best, quite large sections of a contract. From the standpoint of the contractor, however, it is unfortunate that no two jobs are exactly alike. And, in fact, in most cases the difference in the conditions of apparently similar jobs is so great that the records of the time and cost of one job enable the estimator merely to make a good guess at the cost of the next.

A far more accurate plan for estimating costs is the method adopted in this book of dividing each kind of work into a series of small elementary operations and of then timing and recording each of these "unit times" and, finally, of adding together the proper series of unit times in figuring the cost of a new job. This method is new in the building trades, although it has been successfully practiced for years in many large machine shops and in engineering and manufacturing establishments in this country.

From 1879 to 1882, as gang boss and foreman in the machine shop of the Midvale Steel Company of Philadelphia, the writer had a continuous struggle with his men while trying to get them to do a proper day's work under the old piece-rate system.

During this time it was over and over again brought home to him that the chief cause for disagreement and discord between himself and his men lay in the fact that neither he nor they knew how long it ought to take to do a given job. Their knowledge was more accurate than his, and they fully realized that under the piece-work system it was for their interest to keep the management ignorant as to how fast they could work; so that a considerable part of the ingenuity and of the time of each workman was given over to seeing how slow he could go and still convince his boss that he was doing his best.

This "soldiering" and deliberate deceit on the part of the men leads the foreman who does his duty to try to force them to do a proper day's work. And, under this type of management, just in proportion to the energy and resourcefulness of the foreman, the relations between the management and the men become bitter and antagonistic.

With the object of removing the chief cause for discord, the writer made a systematic effort to educate those in the management and also the men as to how fast work of all kinds should be done.

He made a careful analysis of the movements of workmen in one job after another, eliminated all of the useless motions, and substituted fast for slow and inefficient movements. And then he studied with a stop-watch the time which a first-class man should take to make each of the elementary movements into which all kinds of work may be sub-divided. By adding together the proper series of these "unit times" (as they are called), the correct speed for doing any kind of work was obtained; and it was found almost invariably that by this method the men could be shown how to work far more efficiently than they had before and with but little greater effort to themselves. This enabled us to pay them a substantial premium or bonus (an increase of 30% or more in their wages) whenever they did the tasks which were assigned them in the proper times, and still leave a good profit for the Company.

When these men found that we were deliberately planning to give them a large increase in pay, instead of trying to cut down their wages, they ceased to be our antagonists and coöperated most heartily in introducing the new system.

In from six to eight years the application of this time study to a large range and variety of work had resulted in such great economy in the many trades practised in the Midvale Steel works that the writer decided to give his whole time to systematizing other companies along similar lines.

Five years devoted to this kind of systematizing followed, and in 1894 Mr. Sanford E. Thompson, who had been coöperating with the writer during much of this period, joined him in an effort to apply these principles to the building trades.

We were sure that the application of motion and time study to the building trades would be followed by the same useful results as had been obtained in industrial work; and it was our judgment that the necessary "time study" could be quickly made.

In the latter supposition, however, we were wrong. During the past seventeen years Mr. Thompson and his able assistants have devoted practically their whole time to a minute, painstaking study of the building trades, and this is the first book resulting from his work which deals with the time and cost problem. In justice to Mr. Thompson, however, it should be understood that this does not constitute the only fruit of his seventeen years of labor. Besides publishing "Concrete, Plain and Reinforced" he has accumulated the data and prepared the tables for books on the following trades, which we hope to publish within a few years: earthwork; bricklaying; lathing; plastering; carpentry; slating; and many of the smaller trades.

The work of writing a book of this sort divides itself into three sections:

(1) Analysis, *i.e.*, analyzing all of the work in a given trade into its small elements; separating the efficient from the inefficient movements of the workmen; and then studying with a stop-watch the proper time for making each elementary movement.

(2) Synthesis, *i.e.*, making this time study practically useful by grouping together the proper series of movements for doing each class of work; summing up these "unit times," and adding the proper time allowance for unavoidable delays and accidents, etc.; and, finally, classifying and tabulating these data so as to place them in the simplest and most convenient form for practical use.

(3) Proof, *i.e.*, testing the value of the data and tables contained in the book by computing from the book the time it ought to take to build a structure about to be erected, and then comparing the "*book* time and cost" with the "*actual* time and cost" of the structure.

It has been a surprise to us to find that the time required for "Analysis," *i.e.*, direct time study, is but a small fraction of the time afterward spent in "Synthesis" and "Proof," *i.e.*, making our data practically useful and then assuring ourselves that we had not made any mistake or omitted any important factors.

Another important feature, one that has entailed quite as much labor as the fundamental information on times and costs, has been a study of the methods of the leading contractors. From these we have selected the best features and suggested designs and plans embodying them.

Times and costs are of comparatively little value without a knowledge of the best way to use them. In the introduction of scientific management, either in the shop or field, the first essential, before tasks can be set, is the introduction of standard and systematic methods for handling the materials and for teaching and instructing the workmen. For example, in the making up of forms as much saving can be effected by up-to-date design, proper routing of the lumber through the mill saw to the carpenters, and the instruction of the workmen, as in the actual introduction of tasks and bonuses.

The authors have found it necessary, therefore, even though the book is larger than first intended, to present descriptive material such, for example, as the layout of the work and the designs of forms, in full detail and with numerous illustrations of practical methods.

The writer wishes to make it clear that the greater part of the credit (if there is any) for producing this book belongs to Mr. Thompson. The writer's part has been mainly that of suggesting the general methods to be followed and then acting as advisor, critic and financier for the enterprise.

It is our firm conviction that the introduction of the principles of Scientific Management into this field will produce the same beneficent results that have been secured elsewhere: that high wages earned by the workman and a low labor cost secured by the employer will convince both sides that it is for the interest of each to have the welfare of the other at heart; that friendly coöperation is better than suspicious watchfulness or open antagonism; that peace is better than war. And if this book helps in bringing about this result it will have fulfilled its most important object.

PREFACE

Designed to meet the needs of the contractor, as well as of the engineer and architect, the field of this book is so broad that it has necessitated the treatment of unit times and costs of concrete construction from the standpoint of rough approximate estimates; of accurate detailed estimates; of economical layout of work; and of scientific management with task and bonus.

The times and costs are based usually upon average conditions and average workmen, instead of on scientifically managed operation, because at the time of the issue of this first edition the application of scientific management to construction work has but barely begun, and cannot furnish adequate material for extended study on that basis. A marked development is taking place, however, among the more advanced contractors and builders in the direction of better organization, and of closer attention to the smaller details of estimating and of management that lead to an increase in efficiency and a consequent reduction in cost. This fact may serve to justify the minute subdivision of the matter of the book to readers who would otherwise think it excessively detailed. Such subdivision seems required by the rapidly increasing refinement of building construction work. The book presents many suggestions bearing on the practical introduction of systematic methods into construction operations.

Approximate costs of miscellaneous concrete work, and cost data taken chiefly from engineering literature, are presented in Chapters I and II. This material is useful simply as a guide in making very rough estimates, and is not intended for accurate computation.

Approximate costs of reinforced concrete buildings are given in Chapter III in terms of cost per square foot of floor surface. The tables and curves cover a wide range of areas and types of buildings, and the values include all miscellaneous details, such as windows, stairs, elevators, etc., but exclude interior finish. The tables and curves in this chapter will give the owner, the builder, the architect, and the engineer, a general idea of the probable cost of a contemplated building; and also a means of comparing the cost of different designs.

Labor costs in general are discussed in Chapters IV and V, which also consider practical ways of organizing construction work along scientific management lines. Methods of making time studies, planning the work, and setting tasks are discussed.

Proportioning of concrete is taken up in Chapter VI which discusses the subject chiefly from the standpoint of economical selection and proportioning of the materials.

Quantities of materials required for a cubic yard of concrete are shown by tables given in Chapter VII; while a series of tables showing the cost of materials, based on definite prices of cement, sand, and stone is presented in Chapter VIII.

Labor costs of the operations of preparing the materials for concrete and of mixing them are treated in Chapters IX to XIII inclusive. Many illustrative examples are given and tables of times and costs are presented in such detail as to be applicable to the various conditions met with in ordinary practice. These chapters cover the excavating and crushing of stone for concrete, the handling and transporting of materials, the mixing of concrete by hand, the layout and cost of plant, and the cost of mixing concrete by machine. In Chapter XII, on plant costs, are brief descriptions of actual layouts with drawings prepared by the authors. This material, and also the references to literature tabulated at the end of several of the chapters, will be found of considerable value in preparing economical designs for concrete plants.

Form construction is treated in detail in Chapters XIV, XV, and XVI. These chapters contain comparatively few tables on costs, but the material is presented as an aid to the design and building of forms in the cheapest and best manner. Some thirty-five original drawings, most of them in isometric view, show the important details of form design as developed by the authors after a thorough study of the methods in use by the best practical constructors.

Tables for use in the preparation of form designs and of estimates make up most of the remainder of the volume, Chapters XVII and XXIII inclusive. The tables of concrete volumes, Chapter XVII, and of steel, Chapter XVIII, are arranged for use in taking off quantities from plans, while Chapter XXI furnishes tables of quantities of lumber for forms. These tables will assist in estimating the cost of materials as well as labor, and the values are given in such a way that they can be readily taken off for estimates. Tables showing the length of times it takes to perform different operations, and the tables of unit times of individual operations, will be appreciated by those who wish to go into a thorough study of the problems of estimating costs and developing economy in construction. Tables of strength of forms in Chapter XX give dimensions of lumber and spacing of supports for different conditions. Times and costs of placing steel, Chapter XIX, and building forms for reinforced concrete construction, Chapter XXII, are arranged for practical use in making up estimates. Much of the material in these chapters, especially the values of unit times in Chapter XXII, will serve as an indirect aid to the fixing of tasks or the setting of piece rates. The studies for these tables and also the designs of forms in Chapter XVI have been made largely by Mr. William O. Lichtner, or under his direct supervision.

An outline for making up estimates on building construction gives special importance to Chapter XXIII. This includes an example showing the methods of using the tables of volumes and the tables of times and costs in practical estimates.

The authors desire to express their appreciation of the courtesies extended to them by a number of the foremost builders of reinforced concrete construction. Without such coöperation and permission to visit work in progress and to take notes upon the operations in detail, it would have been impossible to prepare a comprehensive and fair summary, or to obtain the unit values and the records of actual times and costs that were essential to the compiling of the tables throughout the book. The following construction companies, though representing only a few of those who have kindly permitted us to make extended visits to their construction jobs, have given us especially valuable assistance: Aberthaw Construction Company, John G. Brown, Ferro-Concrete Construction Company, Benjamin Fox, Incorporated, R. H. Howes Construction Company, and Turner Construction Company. In addition to these companies the authors desire to acknowledge assistance, through correspondence or personal interview, from the following: Leslie H. Allen, Allis-Chalmers Company, Robert Anderson, William P. Anderson, Austin Manufacturing Company, John Ayer, C. Kemble Baldwin, C. E. Bilger, George A. Brown, Robert B. Campbell, C. H. Cartlidge, J. H. Chubb, D. Henry Cram, C. C. Crossley, J. G. Crowdes, B. H. Davis, A. G. Diamond, Eureka Machine Co., Farrell Foundry and Machine Company, Wm. B. Fuller, Frank B. Gilbreth, Herbert W. Goddard, B. H. Hardaway, R. M. Henderson, Chester J. Hogue, Benjamin A. Howes, W. A. Hoyt, Ingersoll-Rand Company, Charles F. Knowlton, B. F. Leffler, Wm. O.

Lichtner, Lidgerwood Manufacturing Company, Emile Low, Massachusetts Broken Stone Company, The McKelvey Machinery Co., Metcalf and Eddy, DeWitt V. Moore, H. I. Moyer, Municipal Engineering and Contracting Company, A. J. O'Connell, W. W. Patch, Geo. Patnoe, Perrin, Seamans & Co., J. P. H. Perry, Harris P. Ralston, A. W. Ransome, Ransome Concrete Machinery Company, Redwood Manufacturing Co., J. C. Riley, Robins Conveying Belt Company, Roche-Bruner Company, John Rice, Simpson Brothers Corporation, T. L. Smith Company, Edward Smulski, E. P. Stiles, Ross F. Tucker, M. C. Tuttle, W. H. Weston, W. W. Wilson, J. O. Winston.

Cuts have been kindly furnished by Allis-Chalmers Co., Austin Manufacturing Co., Blaw Collapsible Steel Centering Co., H. K. Porter, Rancome Concrete Machinery Co., Sherburne & Co., E. C. Stearns & Co.

FREDERICK W. TAYLOR,
SANFORD E. THOMPSON.

January 1912.

CONTENTS

CHAPTER I

Approximate Costs of Miscellaneous Concrete Work

CHAPTER II

Approximate Cost Data on Concrete Structures

CHAPTER III

Approximate Costs of Reinforced Concrete Buildings

CHAPTER IV

Determination of Labor Cost

CHAPTER V

Task-Work in Construction

CHAPTER VI

Proportioning Concrete

CHAPTER VII

Tables of Quantities of Materials for Concrete and Mortar

CHAPTER VIII

Cost of Concrete Materials

CHAPTER IX

Excavating and Crushing Stone for Concrete

CHAPTER XI

Labor of Hand Mixing

CHAPTER XII

Machinery Plants for Mixing and Handling Concrete

CHAPTER XVI

Forms for Reinforced Concrete

CHAPTER XX

Tables for Designing Forms

CHAPTER XXI

Tables of Quantities of Lumber for Forms

CHAPTER XXII

Tables of Times and Costs of Labor on Forms

CHAPTER XXIII

Estimates for Reinforced Concrete Construction

ILLUSTRATIONS

CHAPTER I

APPROXIMATE COSTS OF MISCELLANEOUS CONCRETE WORK

Cost data from actual construction records are of little value unless accompanied by complete information in regard to local conditions. Even then, such cost will not apply with any exactness to jobs having different characteristics. One's own private notes, if kept in full detail, are much more valuable than data from other sources because the local conditions are thoroughly known and can be allowed for when applying the values to other work. The only accurate method of making estimates, without personal knowledge of the type of work under consideration and without private records of such work, is by the use of unit costs or unit times so arranged as to fit the ordinary conditions met with in practice. The use of unit times and costs is discussed at length in subsequent chapters and many values are presented there for various operations in concreting.

If a rough estimate is required where time is too short to go into details, the approximate values given in the present chapter will be useful. Because of the various sources from which these are drawn, the reader is cautioned against assuming them to be strictly accurate. In general, published records of costs are apt to be somewhat low, first, because there is always more danger of omitting than of adding items; and, second, because a job that costs high is not generally thought worth description. The values in this chapter and the next are therefore more for guesswork than for accurate estimates. Any close estimate should be made according to the general scheme outlined in Chapter XXIII.

The information in the present chapter includes:

TABLE 1. APPROXIMATE COSTS OF COMPLETED STRUCTURES (See p. 3)

The costs given in this table are the approximate costs of completed structures, based chiefly on published cost data such as are entered on pages 16 to 31.

The total costs—including excavation, forms, steel, and miscellaneous work, —are divided, as the case may be, by the number of cubic yards, square yards, or feet which they contain. The costs of the larger structures are thus in terms of a cubic yard. For sidewalks and pavements, the costs are expressed in terms of a square yard and for piles and curbing, in terms of a linear foot.

It is evident from the wide range in costs that the values can be used only for rough approximations.

The costs include an allowance for superintendence, overhead charges, and general expense but do NOT include any allowance for home-office expenses and profit.

Item		Cost per Cubic Yard	
		Range	Average
(1)	Mass foundations	$4.00 to $9.00	$7.00
(2)	Mass concrete as in a dam, etc	6.00 to 9.00	7.50
(3)	Mass concrete as in a lock	9.00 to 16.00	12.50
(4)	Bridge piers and abutments	7.00 to 15.00	10.50
(5)	Large arches 125-foot span and over	12.00 to 28.00	19.00
(6)	Arches 50 to 125-foot span	7.00 to 18.00	11.50
(7)	Small arches, 30 to 50-foot span	5.00 to 17.00	9.50
(8)	Small arches of less than 30-foot span, culverts, etc	5.00 to 12.00	9.50
(9)	Girder bridges	7.00 to 18.00	12.50
(10)	*Conduits, sewers, etc	5.00 to 16.00	9.50
(11)	*Tunnels, tunnel lining, and subways	6.00 to 42.00	15.00
(12)	Core walls, gravity retaining walls, etc	6.00 to 8.00	7.00
(13)	Reinforced retaining walls	12.00 to 15.00	13.50
(14)	*Reservoirs, filters, etc	6.00 to 23.00	10.50
(15)	Tanks, standpipes, etc	4.00 to 20.00	12.00
(16)	Building construction, total structures	8.00 to 26.00	14.00
(17)	Walls in building construction	12.00 to 25.00	17.50
(18)	Encasing structural steel in concrete	14.00 to 21.00	18.50
(19)	Concrete pipe	11.00 to 15.00	12.50
		Cost per Linear Foot	
(20)	Concrete piles	0.51 to 1.60	1.15
		Cost per Square Yard	
(21)	Concrete pavements,	1.15 to 1.45	1.25
(22)	*Concrete base for brick or asphalt paving	0.36 to 0.86	0.55
		Cost per Square Foot	
(23)	*Granolithic sidewalks	0.12 to 0.23	0.17
		Cost per Linear Foot	
(24)	*Curbing	0.30 to 0.45	0.35

*Costs do not include cost of excavation.

Cost data on actual structures are presented in Chapter II.

For approximate costs of reinforced concrete buildings of different sizes, reference should be made to Chapter III.

Many of the items in the tables which follow have been taken from recent descriptions of construction plants and of structures. Others have been drawn directly from the authors' notes or compiled from detailed tables in other parts of this book.

An allowance has been made in all the costs for superintendence, overhead charges, and general expense, but in no case are home-office expenses and profit included. Prices cover all ordinary ranges in wages and costs of materials.

APPROXIMATE COST OF COMPLETED STRUCTURES

An engineer occasionally desires to make a very rough estimate or guess of the cost of a structure based on a cost per cubic yard that includes not only the concrete but other parts of the work. For such an estimate, Table 1, page 2, will be useful. Although the range in cost for each type of structure is so large that it is impossible to make an exact estimate, if a man knows whether the particular work is intricate or simple and whether the costs of materials and labor are high or low, he can select an approximate value based on judgment.

COST OF MIXING AND PLACING CONCRETE

In Table 1, the costs include materials and labor not only for the concrete but for practically all of the construction. To give a similar range and average cost for different structures of the labor of mixing and placing the concrete and of the cost of labor plus the cost of the cement, sand, and stone, Table 2, page 4, has been prepared.

The values, as in Table 1, are based chiefly on average costs in printed literature and cover the ranges in cost of materials and of labor that are liable to occur in ordinary practice. Because of the great variation shown, the costs should be used only for the roughest estimates. For exact estimates, reference should be made to the detailed information in Chapters X to XIII.

A comparison of different items in the table shows the lower cost in structures that are apt to contain large quantities of concrete and in those where lean mixtures are permissible. On the other hand, if the concrete has to be elevated, as in building construction, or carried a long distance, as in tunnel work, the labor cost will run high.

TABLE 2. APPROXIMATE COSTS OF MIXING AND PLACING CONCRETE IN DIFFERENT STRUCTURES (See p. 3)

Costs are for concrete only and do not include excavation, forms, steel, or miscellaneous items.

The costs of materials include only cost of cement and aggregates for the concrete and do not include forms or other items.

Costs have been made up from a number of different jobs for each class of work. Wages range from 15 to 25 cents per hour.

Costs include an allowance for superintendence, overhead charges and general expense, but do NOT include home-office expenses or profit.

For costs of mixing and placing concrete under different specified conditions, see tables in Chapter XIII. For costs of materials for different prices of cement and aggregates, see Tables 29 to 36, pages 159 to 166.

Item	Cost per Cubic Yard	
	Range	Average
(1) Mass concrete as in dams, piers, foundations, etc.		
Labor only	$0.75 to $2.50	$1.25
Material and labor	3.00 to 9.00	5.50
(2) Concrete in tunnels and conduits		
Labor only	1.00 to 3.00	2.00
Material and labor	4.50 to 8.00	6.25
(3) Concrete reservoirs and standpipes		
Labor only	0.75 to 3.00	1.50
Material and labor	3.50 to 13.00	7.00
(4) Concrete buildings		
Labor only	0.75 to 4.00	1.50
Material and labor	4.50 to 9.00	6.50
(5) Concrete bridges		
Labor only	0.50 to 2.50	1.50
Material and labor	4.00 to 8.00	6.00
(6) Concrete sewers		
Labor only	0.75 to 1.75	1.50
Material and labor	3.50 to 8.00	6.00
(7) Granolithic sidewalks		
Labor only	1.00 to 3.00	1.75
Material and labor	6.25 to 9.00	7.00
(8) Granolithic sidewalks		
Labor only	2¢ to 4¢ per sq. ft.	2¾¢ per sq. ft.
Material and labor	5¢ to 14¢ per sq. ft.	10½¢ per sq. ft.

APPROXIMATE COSTS OF MISCELLANEOUS FORMS

Costs of forms for reinforced concrete structures are treated thoroughly in Chapters XVI and XXII and reference should be made to the tables there given if accurate estimates are required. For arch centering, see Chapter XV.

For approximate costs for rough estimates, the values in Table 3 may be used, selecting a price by judgment from the range in costs. The wide range in each class of work illustrates the variations due to different conditions.

The first items in Table 3, referring to building construction, are compiled from the more exact tables in the chapters which follow. They are based on carpenter labor at fifty cents ($0.50) per hour and apply to ordinary contract conditions but not to task-work or scientific management. The other costs are chiefly made up from published literature and the conditions governing them may be obtained from the sources given.

The costs of form construction include approximate values both for material and for labor in terms of per square foot of surface in contact. Most printed costs are given in terms of per cubic yard of concrete, but such costs are valueless to use for other structures unless the thicknesses of concrete are identical. For example, the forms for a wall or pier two feet thick may cost the same per square foot of surface area as for an eight-foot wall or pier; if expressed in cubic yards of concrete, the form cost with the two-foot wall would be four times that of the eight-foot wall.

In entering the costs, in cases where the superintendence, overhead charges, and general expense were not included in the reference, 15% has been added to allow for these items, but no allowance has been made for profit or home-office expenses.

Besides Table 3 on approximate costs of forms, which gives the values in terms of per square foot of area of contact, Tables 4 and 5 give costs for use in building construction in terms of per square foot of surface of contact and in terms of per 1000 feet B. M. These costs are made up from the tables in Chapter XXII and are more accurate than the over-all costs given in Table 3. It will be noticed that the cost per square foot of contact surface varies more than the cost per 1000 feet B. M.

The costs apply to forms for members of economically designed section supporting average loads and, in case of columns, to average sizes.

Since these tables give merely average costs without allowing for difference in dimensions, the values are not sufficiently exact for accurate estimates. For accurate estimates the tables in Chapter XXII should be used.

TABLE 3. APPROXIMATE COSTS OF MISCELLANEOUS FORMS (See p. 5)

Item	Cost per Square Foot		Authority	Reference
	Range	Average		
(1) Building construction				
(a) Column forms, labor only	8 to 22¢	10¢	The authors	Chapter XXII
Material and labor	10 to 25¢	12¢	The authors	Chapter XXI
(b) Beam forms, labor only	4 to 14¢	5¢	The authors	Chapter XXII
Material and labor	5 to 18¢	7¢	The authors	Chapter XXI
(c) Slab forms, labor only	1½ to 4¢	2½¢	The authors	Chapter XXII
Material and labor	3 to 6¢	4¢	The authors	Chapter XXI
(d) Wall forms, labor only	6 to 12¢	8½¢	The authors	Chapter XXII
Material and labor	7 to 15¢	10¢	The authors	Chapter XXI
(2) Sewer forms				
29-foot sewer, 162 feet long		10¢*		Eng. Contr. Feb. 20, 1907, p. 76
4½-foot sewer, 2 miles long		1¢	W. G. Taylor	Eng. News, Mar. 26, 1908, p. 333.
(3) Forms for tunnel lining				
Labor		8.9c		Eng. Contr. July 7, 1909, p. 20
Material and labor		11¢	H. A. Young	
(4) Steel forms for 4 by 5-foot conduit (Includes rental of forms and lumber for centering).		3¢	C. R. Gow	Jour. Assn.Eng. Socs. Dec. 1910, p. 243.
(5) Foundation forms				
Labor only	5 to 10¢	7¢	The authors	
Material and labor	7 to 14¢	10¢	The authors	
(6) Pier forms				
Labor only	28 to 52¢	42¢	From actual costs on large railroad	
Material and labor				
(7) Groined arch forms				
Labor only		4½¢	W. B. Fuller	Trans. Am.Soc. Civ.Engs.Vol. XLIII, p. 305
Material and labor		7¢		
(8) Arch bridge forms	(See Chapter XV)			
(9) Girder bridge forms				
Labor only	4 to 7¢	5¢		
Material and labor	6 to 16¢	12¢		
(10) Retaining wall forms				
Labor only	7 to 14¢	12¢		
Material and labor	9 to 18¢	16¢	The authors	
(11) Manhole form 4 × 6 feet, 5-foot headroom				
Material and labor		$36.00 each		Eng. Contr. Oct. 28, 1908, p. 271
(12) Oiling forms				
Labor only		0.05¢		Cement Age, Jan. 1908, p. 100
(13) Cleaning forms		½¢		Cement Age, Jan. 1908, p. 100
(14) Placing and removing stair forms		1½¢ per sq. ft. of tread	The authors	
(15) Sewer forms, steel, rental		2¢		Eng. Contr. Jan. 27, 1909, p. 65

* This high cost is due chiefly to the short length of sewer.

TABLE 4. AVERAGE COSTS OF LABOR ON FORMS PER SQUARE FOOT OF CONTACT AREA (See p. 5)

Costs are for labor only and are average values for average interior members. Exterior members cost about 50% more to "Place and Remove" than interior members.

Costs are based on carpenter labor at 50¢ per hour.

Costs include everything except profit and home-office expenses.

Costs of "Making Forms" are based on all sawing being done on mill saw.

If sawed by hand, "Making" costs from 30% to 50% higher.

COST IN DOLLARS PER SQUARE FOOT OF CONTACT AREA.

	Making Forms			Place and Remove Forms 1st Time			Place and Remove Forms After 1st Time			Remake, Place and Remove Forms		
Columns												
Story Heights*	6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $
1-in. lumber	0.047	0.039	0.040	0.147	0.099	0.086	0.127	0.081	0.072	0.162	0.111	0.099
2-in. lumber	0.061	0.051	0.052	0.171	0.115	0.099	0.155	0.098	0.088	0.211	0.145	0.128
Beams												
Lengths†	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $
1-in. lumber	0.026	0.020	0.022	0.057	0.047	0.047	0.050	0.046	0.040	0.078	0.056	0.053
2-in. lumber	0.030	0.023	0.025	0.067	0.055	0.055	0.058	0.050	0.049	0.098	0.071	0.067
Girders												
Lengths†	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $
1-in. lumber	0.028	0.022	0.025	0.071	0.052	0.050	0.057	0.053	0.040	0.101	0.069	0.063
2-in. lumber	0.033	0.025	0.028	0.083	0.062	0.059	0.069	0.053	0.051	0.126	0.086	0.079
Slabs (for beam and girder construction)												
Panels per Bay‡	1 $	2 $	3 $	1 $	2 $	3 $	1 $	2 $	3 $	1 $	2 $	3 $
1-in. lumber	0.009	0.008	0.008	0.027	0.025	0.024	0.021	0.019	0.017	0.023	0.021	0.019
1¼-in. lumber	0.010	0.009	0.008	0.028	0.026	0.025	0.021	0.020	0.018	0.024	0.021	0.019

* From surface to surface of floor.

† From center to center of supports.

‡ With one panel per bay there are no intercepting beams; with 2 panels, one intercepting beam; and with 3 panels, 2 intercepting beams.

TABLE 5. AVERAGE COSTS OF LABOR ON FORMS PER 1000 FT. B. M. (See p. 5)

Costs are for labor only and are average values for average interior members. Exterior members cost about 50% more to "Place and Remove" than interior members.

Costs are based on carpenter labor at 50¢ per hour.

Costs include everything except profit and home-office expenses.

Costs of "Making Forms" are based on all sawing being done on mill saw.

If sawed by hand, "Making" costs from 30% to 50% higher.

COST IN DOLLARS PER 1000 Ft. B. M.

Columns

	Making Forms			Place and Remove Forms 1st Time			Place and Remove Forms After 1st Time			Remake, Place and Remove Forms		
Story Heights*	6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $
1-in. lumber	16.78	12.88	11.50	51.40	31.74	24.24	44.18	25.94	20.39	56.08	35.58	27.70
2-in. lumber	15.36	12.36	11.28	41.94	27.24	21.76	38.12	23.26	19.30	51.54	34.16	27.96

Beams

	Making Forms			Place and Remove Forms 1st Time			Place and Remove Forms After 1st Time			Remake, Place and Remove Forms		
Lengths†	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $
1-in. lumber	6.52	5.22	5.71	13.92	11.66	11.71	12.20	10.14	10.25	19.44	14.12	13.40
2-in. lumber	6.20	4.92	5.33	13.49	11.32	11.33	12.36	10.01	10.13	19.94	14.60	13.81

Girders

	Making Forms			Place and Remove Forms 1st Time			Place and Remove Forms After 1st Time			Remake, Place and Remove Forms		
Lengths†	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $
1-in. lumber	7.30	5.73	6.34	17.58	13.06	12.40	14.15	10.91	10.53	24.94	17.15	15.84
2-in. lumber	6.91	5.39	5.97	16.94	12.70	12.12	14.09	10.86	10.49	25.66	17.64	16.26

Slabs (for beam and girder construction)

	Making Forms			Place and Remove Forms 1st Time			Place and Remove Forms After 1st Time			Remake, Place and Remove Forms		
Panels per Bay‡	1 $	2 $	3 $	1 $	2 $	3 $	1 $	2 $	3 $	1 $	2 $	3 $
1-in. lumber	3.52	3.24	3.16	10.70	10.10	9.50	8.25	7.60	6.95	9.10	8.25	7.40
$1\frac{1}{4}$-in. lumber	3.80	3.48	3.04	11.15	10.55	9.90	8.55	7.90	7.25	9.55	8.55	7.70

* From surface to surface of floors.

† From center to center of supports.

‡ With one panel per bay, no intercepting beam; with 2 panels, one intercepting beam; and with 3 panels, 2 intercepting beams.

APPROXIMATE COSTS OF LABOR ON STEEL REINFORCEMENT

In the erection of steel reinforcement, the cost per pound of the operations—handling, bending, cutting, and placing—increases as the sizes of the bars decrease, because of the greater amount of time required in handling the smaller bars. In some kinds of construction, however, like reinforced buildings, the variation in different members will average up, to a certain extent, so that a lump sum per pound for labor on reinforcement can be used without great error.

For accurate estimates, the work must be separated as in the tables in Chapter XIX.

In Table 6, a few costs are given, made up from these tables. The remaining costs are general and are drawn from various authorities, as noted. The range in values covers different conditions and also different wage rates ranging from 25¢ to 50¢ per hour. The average values cited by the authors are based on 30¢ per hour.

TABLE 6. APPROXIMATE COSTS OF LABOR ON STEEL REINFORCEMENT (See p. 9)

Allowance has been made for superintendence, overhead charges, and general expenses, but NOT for home office-expenses or profit.

Item	Cost per Pound		Authority	Reference
	Range	Average		
(1) Building construction				
(a) Bending, as for beams or girders	0.15 to 0.35¢	0.25¢	The authors	Chapter XIX
(b) Fabricating and placing	0.25 to 0.4¢	0.30¢	The authors	Chapter XIX
Total cost of placing steel	0.4 to 0.75¢	0.55¢	The authors	Chapter XIX
(2) Cost of handling and placing straight bars, as in a retaining wall	0.12 to 0.21¢	0.14¢	The authors	
(3) Cost of handling, bending, and placing steel, as in a floor or box culvert	0.18 to 0.32¢	0.21¢	The authors	
(4) Cost of handling, bending, and placing steel, as in an arch	0.14 to 0.26¢	0.18¢	The authors	
(5) Cost of handling, cutting, bending, and placing steel (average value for all kinds of work)		0.40¢	L. C. Wason	Con. Eng. Jan. 1909, p. 12
(6) Cost of handling, bending, and placing steel in roof of car barn		0.40¢		Eng. Contr. Nov. 2, 1910, p. 378.
(7) Cost of handling, bending, and placing steel with clips in standpipe		0.45¢	G. H. Snell	Eng. Rec. Sept. 29, 1906, p. 346
(8) Bending and placing steel in covered reservoir				
Floor		0.23¢	W. C. Mabee	Eng. News, Oct. 15, 1908, p. 409
Walls		0.57¢		
Cover		0.32¢		
Average of whole reservoir		0.31¢		

TABLE 7. APPROXIMATE COSTS OF FINISHING CONCRETE SURFACES

Costs do not include cost of materials.
Data is from actual work as recorded by different authorities.
Costs include allowance for superintendence, overhead charges, and general expense, but NO allowance for profit and home-office expenses.

Item	Approximate Cost per Square Foot	Authority	Reference
(1) Troweling granolithic floor finish (mason's work)	1¢	The authors	
(2) Facing placed at same time as backing	4¢		Cement Age, Nov. 1910, p. 284
(3) Finishing surface with cement wash	¾¢	The authors	
(4) Bush hammering	2½ to 10¢	The authors	
(5) Crandalling, common labor	6¢		Cement Age, Nov. 1910, p. 284
(5) Crandalling, skilled labor	11¢		
(6) Picking surface, when green	1¢		Cement Age, Nov. 1910, p. 284
(6) Picking surface, 2 days old	2 to 3¢		
(7) Tooling, when green	4 to 5¢		Cement Age, Nov. 1910, p. 284
(7) Tooling, when hard	6 to 11¢		
(8) Tooling ornamental blocks	30¢		Eng. Contr., May 22, 1907, p. 227
(9) Finishing surface with carborundum brick and water	1½ to 3 ¢	J. H. Chubb	Concrete Surfaces published by the Universal Portland Cement Co.
(10) Brushing surface	1½ to 4 ¢	J. H. Chubb	Concrete Surfaces published by the Universal Portland Cement Co.
(11) Sandblasting hard surface	3¢	J. H. Chubb	Concrete Surfaces published by the Universal Portland Cement Co.
(12) Washing finished surface with acid	¼ to ¾¢	J. H. Chubb	Concrete Surfaces published by the Universal Portland Cement Co.

TABLE 8. APPROXIMATE COSTS OF MISCELLANEOUS DETAILS OF CONCRETE WORK*

Costs include allowances for superintendence, overhead charges, and general expense, but NO allowance for profit or home-office expenses.

Labor on Mixing Plant. No material included

Item	Approximate Average Costs
Labor to unload from cars and set up mixer and engine, including all steam connections	$65.00
If mixer has side loader, add	15.00
Labor to unload from cars and set up hoisting engine	40.00
Labor to unload and build elevator tower 60 feet high, including installing concrete bucket, sheaves, etc., and hoppers and gates for discharging at floor	60.00
Add for each additional 10 feet of height	10.00

*The authors are indebted to the Aberthaw Construction Company for this table which has been especially prepared for this book.

TABLE 8.*—Continued

Labor on Mixing Plant—continued

Item	Approximate Average Costs
Labor to unload industrial track and cars and set up on horses; labor making horses not included.....	$0.02½ per lin. ft.
Moving same up from floor to floor and resetting....	0.03 per lin. ft.

Fixtures in Concrete

Cast iron sockets with tapped holes for bolts (up to ¾")	$0.06 each
Slotted sockets for ⅜-inch bolts....................	0.20 each
Slotted sockets for ½-inch bolts....................	0.35 each
Slotted sockets for ⅝-inch bolts....................	0.50 each
Labor setting above sockets........................	0.05 each
Steel corners and curbing, including fixing in place..	0.25 per lin. ft.
Safety treads..................................	1.40 per sq. ft.
Fixing safety treads in place......................	0.10 per sq. ft.

TABLE 9. COSTS OF MISCELLANEOUS WORK ENTERING INTO COMPLETED BUILDING*

Costs include subcontractors' profit because they relate to work usually sublet by the concrete contractor.

Prices are approximate and will vary greatly if quantity is small or site of work far away or difficult of access.

Windows

Item	Approximate Average Costs
Large factory windows with plank frames, 2-inch sash, single thick glass, transom, and staff beads	$0.20 to 0.25 per sq. ft.
Large factory windows with box frames, double hung sash, glass, pulleys, weights, cord, and staff beads	0.23 to 0.28 per sq. ft.
Sheet metal windows with pivoted sash, wire glass..	0.70 to 1.00 per sq. ft.
Sheet metal windows, double hung sash, wire glass...	0.80 to 1.20 per sq. ft.
Add if clear polished wire glass, about.............	1.00 per sq. ft.
Cost of labor setting large windows................	0.08 to 0.12 per sq. ft.

Roofing

Five-ply tar and gravel roofing....................	$5.00 per square†
Plastic slate roofing, and flashings................	4.75 per square†
Ready roofings..................................	2.50 to 3.50 per square†
Corrugated iron, No. 22 gage......................	0.12 per sq. ft.
Copper flashings................................	0.30 to 0.35 per lb.
Zinc flashings..................................	0.20 per sq. ft.
Copper roof pans with sleeves and strainers........	5.00 each

*The authors are indebted to the Aberthaw Construction Company for this table, which has been especially prepared for this book.

†A square is 100 square feet.

TABLE 9.*—Continued

Flooring

Item	Approximate Average Costs
1-inch maple, at $32.00 per 1000 ft. B.M., including waste, nails, and laying	$5.50 per square†
2 or 3-inch spruce sub-flooring and screeds at $23.00 per 1000 ft. B.M., including waste, nails, and laying	31.00 per 1000 ft. B.M.
Terrazzo paving, laid complete	0.20 per sq. ft.
"Battleship" linoleum, laid complete	1.40 per sq. yd.

Plastering and Metal Lathing

Two-coat work (on brick or concrete)	$0.30 to 0.35 per sq. yd.
Three-coat work (on lath)	0.35 to 0.40 per sq. yd.
Cement plastering, float finish 2 coats	0.40 to 0.45 per sq. yd.
Metal lathing complete	0.35 per sq. yd.
Fur and lath walls	0.70 per sq. yd.
Suspended lathing to ceiling of top floor, including hangers	1.20 per sq. yd.
2-inch metal partition, lathed one side	0.85 per sq. yd.
3-inch metal partition, lathed both sides	1.25 per sq. yd.
4-inch metal partition, lathed both sides	1.50 per sq. yd.

Brickwork‡ and Tile

12-inch walls, brick at $8.00 per 1000, including labor, mortar, and stage	$17.00 to 20.00 per 1000
For 8-inch walls, add to labor cost	4.00 to 6.00 per 1000
For 12-inch curtain walls, including veneering columns and wall beams, add to labor cost	5.00 per 1000
4-inch terra cotta partitions	0.10 per sq. ft.
6-inch terra cotta partitions	0.14 per sq. ft.
8-inch terra cotta walls	0.20 per sq. ft.
8-inch concrete block walls	0.28 per sq. ft.
10-inch concrete block walls	0.32 per sq. ft.
12-inch concrete block walls	0.35 per sq. ft.

Painting

2 coats on windows, both sides measured	$0.20 to 0.25 per sq. yd.
2 coats flat surface	0.15 per sq. yd.
Cold water paint, walls and ceilings, one coat hand work or two coats sprayed	0.05 to 0.07 per sq. yd.

*The authors are indebted to the Aberthaw Construction Company for this table, which has been especially prepared by them for this book.

†A square is 100 square feet.

‡In measuring brickwork allow 22½ brick to the cubic foot. The authors.

APPROXIMATE COST OF CONCRETE BRIDGE ABUTMENTS FOR STEEL HIGHWAY BRIDGES*

The values in the tables are from curves made up by Mr. Bilger from actual costs, plus 30% for incidentals and contractor's profit, of abutments built from plans of the Illinois Highway Commission.

The curves for the plain concrete abutments were plotted from the actual costs of nearly thirty bridges on file with the Commission, and for the reinforced concrete abutments from the actual costs of fifteen bridges. These curves were developed as a means of making approximate field estimates of the costs of a pair of abutments without calculating the quantities in detail.

The principal items to be averaged in determining the actual cost of the concrete per cubic yard in different places were:

(1) The cost of the aggregate at the bridge site per cubic yard of concrete.

(2) The cost of the cement at the bridge site per cubic yard of concrete.

(3) The cost of excavation per cubic yard of concrete.

The cost of mixing and placing and the cost of forms were practically constant for each type of abutment. The proportions of the concrete for the reinforced abutments were taken as 1:2½:4, and for the plain abutments 1:3:5.

TABLE 10. APPROXIMATE COSTS OF PLAIN CONCRETE BRIDGE ABUTMENTS FOR STEEL HIGHWAY BRIDGES

Assumption: Base at any section of abutment proper or wings, 33% of total height at that section; footings 18 inches deep and project 9 inches on each side beyond wall proper; back of wall vertical; wing walls 12 inches wide on top; total thickness of abutment proper on top varies from 20 to 32 inches, 8 inches of which is for parapet.

H = total height of wall. R = clear roadway of steel superstructure.

W = length of one wing measured on the stream side of the wing.

TOTAL COST OF TWO PLAIN CONCRETE ABUTMENTS

$H^2(R+2W)$	Cost at Bridge Site of Cement and Aggregate for One Cubic Yard of Concrete			
	$3.00	$4.00	$5.00	$6.00
5000..........	$600	$690	$790	$870
10000..........	1050	1220	1390	1550
15000..........	1540	1790	2000	2240
20000..........	2020	2330	2610	2920
25000..........	2500	2890	3210	3600

Note:—Cost is proportional to the square of the total height.

*Abstract from paper read by H. E. Bilger before Illinois Society of Engineers and Surveyors, Jan. 1911.

TABLE 11. APPROXIMATE COSTS OF REINFORCED CONCRETE BRIDGE ABUTMENTS FOR STEEL HIGHWAY BRIDGES

Assumption: For heights up to 30 feet, at any section of abutment proper, or at wings, width of base 33% of total height at that section; depth of footing about 18 inches; wall proper 12 inches thick at top and from 18 inches to 24 inches at top of footing; three 12-inch buttresses behind main wall and 6 to 7 feet apart behind wings;

H = total height of wall.

R = clear roadway of steel superstructure.

W = length of one wing measured on the stream side of wing.

TOTAL COST OF TWO REINFORCED CONCRETE ABUTMENTS

H (R + 2W)	Cost at Bridge Site of Cement and Aggregate for One Cubic Yard of Concrete				
	$3.00	$4.00	$5.00	$6.00	$7.00
500..........	$880	$950	$1020	$1100	$1200
1000..........	1800	2000	2190	2360	2520
1500..........	2780	3030	3320	3600	

NOTE:—Cost is proportional to total height.
About 70 pounds of reinforcement used per cubic yard of concrete.

CHAPTER II

APPROXIMATE COST DATA ON CONCRETE STRUCTURES

Although records of costs of completed structures are of little value for new estimates unless complete descriptive details are given, they are useful frequently for rough approximation.

Instead of following the more usual plan of arranging such data for each job just as given by the estimator, the table which follows has been compiled by (1) carefully selecting from published literature, records that give details in fairly complete form, and (2) arranging these so that the prices on different jobs may be compared at a glance. This ease of comparison will more than compensate for the lack of some of the detailed information on each job that is necessarily omitted.

An engineer or an architect may be obliged to make an offhand approximate estimate upon a class of work with which he is not especially familiar. In such a case if he has at hand a list of actual costs in more or less detail, tabulated so that they may be easily scanned, he may be able to select values based on conditions similar to the proposition he is studying. The table is useful in this case or where the engineer wishes to check a more exact estimate.

In order that further details may be obtained readily upon any particular job on the list, the authority for each cost and the reference from which it is obtained are given in the table. These references may be looked up whenever more information is needed.

Since the data in this chapter are all taken from printed literature, the authors present them merely on the authority of each individual writer. The results cannot be expected to apply exactly to other conditions than those described. For an accurate estimate by an engineer, an architect, or a contractor, the work must be carefully separated into divisions, the fineness of which must be governed by the degree of exactness desired, and the labor and materials considered separately. The probable cost of each part, or division, must then be determined after the general plan outlined in Chapter XXIII. The information provided in subsequent chapters will furnish the material for such exact estimates.

TABLE 12. COST DATA ON ACTUAL STRUCTURES

(See p. 15)

FOUNDATIONS

Name	Description	Rate of Labor per Hour or per Day	Miscellaneous	Forms: Cost of Labor (per Cubic Yard of Concrete)	Forms: Total Cost (per Cubic Yard of Concrete)	Proportions of Concrete
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Engine Foundations.		Laborer 25¢ Carpenter 30¢		$0.55		1:2:5
Office Foundation, Springfield, Mass. W.W.		Laborer $1.75 Carpenter 3.50 Engineer 3.75	$0.78	0.98	$1.21	
Regulator House Foundation Springfield, Mass. W.W.		Laborer $1.75 Carpenter 3.50 Engineer 3.75	0.72	0.93	1.17	
Engine Foundation,		Laborer $1.50 Carpenter 2.50	0.20	0.38	0.50	1:3½:6
Tank Foundation, Porterville, Cal. W.W.	75 000 gal. on 6-post steel tower		0.42	0.18	0.18[a]	1:3:5

RETAINING WALLS

Name	Description	Rate of Labor per Hour or per Day	Miscellaneous	Forms: Cost of Labor	Forms: Total Cost	Proportions of Concrete
Cantilever wall, Newton Upper Falls, Mass......	16 ft. high 250 ft. long	Laborer $2.00 Carpenter 3.82		$2.75	$3.91	
Cantilever wall...........	16 ft. high	Laborer 20¢ Carpenter 50¢			3.60	
Cantilever wall...........	8 ft. high	Laborer 20¢ Carpenter 50¢			6.23	

BUILDINGS

Costs of Buildings Should Not be Figured by the Cubic Yard (See Chapter XXIII)

Name	Description	Rate of Labor per Hour or per Day	Miscellaneous Items, Cost per Cubic Yard of Concrete	Part of Structures	Forms: Cost of Labor (per Cu. Yd. of Concrete)	Forms: Total Cost (per Cu. Yd. of Concrete)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Car Barn, Harrisburgh, Pa.	75×360 ft.	Laborer $1.25 Carpenter 2.50	$0.16	Total structure	$3.25	$4.58
Paper Mills, Milford, N. J.	Av. width 68 ft. length 934 ft.		0.38	Total structure	3.45	4.84
Factory, Walkerville, Ont.	100×100 ft.	Laborer 17½¢ Carpenter 35¢	1.96	Total structure	2.82	8.79

a Old lumber was used in forms and no value was given.

NOTE:—Except when noted, costs do not include the cost of construction plant, depreciation, repairs, superintendence, or engineering.

FOUNDATIONS

Total Cost of Material per Cubic Yard of Concrete	Cost of Mixing and Placing per Cubic Yard of Concrete	Total Quantity of Concrete in Cubic Yards	Steel: Weight Lb. (per Cubic Yard of Concrete)	Steel: Cost of Placing (per Cubic Yard of Concrete)	Steel: Total Cost (per Cubic Yard of Concrete)	Total Cost of Materials and Labor per Cubic Yard of Concrete	Authority
(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
$4.00	$0.90	95				$7.20	Eng. Contr. May 31, 1911, p. 614
3.76	1.05	271				6.80[b]	Chas. R. Gow, Jour. Assn. Eng. Socs., Dec. 1910, p. 240
3.76	0.64					6.29[b]	Chas. R. Gow, Jour. Assn. Eng. Socs., Dec. 1910, p. 240
2.51	0.92	350				4.13	Eng. Contr. Mar. 31, 1909, p. 234
5.86	1.27	105				7.73	P. E. Harroun, Trans. Am. Soc. Civ. Engs. Vol. LIV, p. 258

RETAINING WALLS

(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
$3.57	$1.35	277	120	$0.06	$2.02	$12.03[b]	Eng. Rec., Mar. 11, 1911, p. 271
4.75	1.25		115		3.46	12.26	The authors
4.75	1.25		97		2.91	15.14	The authors

BUILDINGS

Proportions of Concrete	Concrete: Cost of Materials (per Cu. Yd. of Concrete)	Concrete: Cost of Mixing & Placing (per Cu. Yd. of Concrete)	Concrete: Total Quantity of Concrete Cu. Yd.	Steel: Cost (per Cu. Yd. of Concrete)	Steel: Cost of Bending and Placing (per Cu. Yd. of Concrete)	Steel: Total Cost (per Cu. Yd. of Concrete)	Total Cost of Materials and Labor per Cu. Yd. of Concrete	Authority
(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1:2:4	$3.48	$2.21		$0.91	$0.09	$1.00	$11.43[c]	Mason D. Pratt Eng. Contr., Jan. 19, 1910, p. 56
1:3:6 1:3:5 1:2:4	3.30	1.50	8000	1.75	0.30	2.05	12.07	Eng. Rec., Jan. 31, 1909, p. 124
1:2:4	5.16	1.36	847	2.75	0.26	3.01	19.88[c]	Eng. Rec., Mar. 5, 1908, p. 252

b Includes superintendence. *c* Includes all costs except supervision.

TABLE 12. COST DATA ON ACTUAL STRUCTURES—Cont.

(See p. 15)

FLOORS

Name	Description	Rate of Labor per Hour	Miscellaneous Items per Square Foot of Floor Surface	Structure
(1)	(2)	(3)	(4)	(5)
Power House, Chicago		Laborer 20¢ Carpenter 60¢	Engineering and Superintendence $0.02	Arch and I-beam floor
Car House, Chicago			Coke $0.02	End floors Service floors Office floors Pit floors Reinforced floors
Power House, Chicago Drainage Canal	Balcony floors	Laborer 17½ to 20¢	Surfacing floor and finishing ceiling $0.10	Arch and I-beam floor
Experiment Station Bldg., Purdue University	First floor	Laborer 20¢	Tile $0.06 Superintendence $0.03	Reinforced floor
Experiment Station Bldg., Purdue University	Second floor	Laborer 20¢	Tile $0.06 Superintendence $0.01	Reinforced floor

TUNNELS

Name	Description	Rate of Labor per Day	Miscellaneous Items Cost per Cu. Yd. of Concrete
(1)	(2)	(3)	(4)
Irrigation Tunnel, Cal.	6 × 7 ft. 1740 ft. long	Laborer $2.50 to $2.75 Carpenter 4.00	$0.48
Tunnel, Huntley Irrigation Works, Montana	9 × 9 ft. 375 ft. long Top and sides 8 inches thick Bottom 6 inches	Laborer $2.40 Carpenter $4.00 to $5.00	0.63
Tunnel, Belle Fourche Irrigation Project	8 × 8 ft 1306 ft. long	Laborer $2.30	3.44[a]

[a] Includes plant, depreciation, superintendence, engineering, etc.

NOTE:—Except when noted, costs do not include cost of construction plant, depreciation, repairs, superintendence, or engineering.

FLOORS

Forms: Cost of Labor per Sq. Ft. of Floor Surface	Forms: Total Cost per Sq. Ft. of Floor Surface	Proportions of Concrete	Concrete: Cost of Materials per Square Foot of Floor Surface	Concrete: Cost of Mixing & Placing per Square Foot of Floor Surface	Concrete: Total Area Square Feet	Steel: Cost per Sq. Ft. of Floor Surface	Steel: Cost in Place per Sq. Ft. of Floor Surface	Total Cost of Materials and Labor per Square Foot of Floor Surface	Authority
(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
$0.08	$0.13		$0.10	$0.08	500	I-beams $0.11		$0.44	Eng. Contr. Mar. 15, 1911, p. 297
			0.06	0.06	63600			0.14	Eng. Contr. Nov. 2, 1910, p. 378
			0.09	0.10	11920			0.19	
			0.08	0.10	8793			0.18	
			0.07	0.07	58560			0.14	
0.07	0.08		0.09	0.06	37048	wire netting 0.02		0.25	
0.05	0.10	1:2½:4½ Surfacing 1:2	0.13	Placing only 0.06	18300	Expanded metal 0.04		0.43	L. K. Sherman Eng. Contr. May 25, 1910, p. 469
	0.06	1:2:4	0.05	0.04			$0.07	0.31	Prof. W. K. Hatt Eng. Contr. Oct. 13, 1909, p. 306
	0.05	1:2:4	0.05	0.04			0.07	0.29	Prof. W. K. Hatt Eng. Contr. Oct. 13, 1909, p. 306

TUNNELS

Forms: Cost of Labor per Cubic Yard of Concrete	Forms: Total Cost per Cubic Yard of Concrete	Proportions of Concrete	Concrete: Cost of Materials per Cubic Yard of Concrete	Concrete: Cost of Mixing & Placing per Cubic Yard of Concrete	Concrete: Total Quantity of Concrete Cu. Yd.	Total Cost of Materials and Labor per Cu. Yd. of Concrete	Authority
(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$0.74	$0.82		$4.20	$0.97[b]	1500	$6.47	W. D. Rohan Eng. Contr. July 6, 1910, p. 2
1.88	2.48	1:2½:5½	3.43	2.73	421	9.27	Henry A. Young Eng. News Feb. 4, 1909, p. 128
0.58	1.08	1:2½:5	4.28	0.99	1595	9.79[a]	Eng. Rec. Oct. 24, 1908, p. 471

b Concrete was mixed in a vertical gravity chute 75 ft. long.

TABLE 12. COST DATA ON ACTUAL STRUCTURES—Cont.

(See p. 15)

TUNNELS

Name	Description	Rate of Labor per Day	Miscellaneous Items Cost per Cu. Yd. of Concrete
(1)	(2)	(3)	(4)
Tunnel	7 × 7 ft. 434 ft. long 6 inches thick	Laborer $2.25 Carpenter 3.50	
Gunnison Tunnel, Montrose, Col.	11 × 12 ft. 31 000 ft. long	Laborer $3.00	$0.21
R. R. Tunnel	1000 ft. long	Laborer $2.00	1.20
Single track R.R. Tunnel	4000 ft. long	Laborer $1.75 Carpenter 2.50	1.09 4.78

DAMS

Name	Description	Rate of Labor per Day	Miscellaneous Items Cost per Cubic Yard of Concrete	Excavation		Cost of Foundation per Cubic Yard of Concrete	Cost of Machinery and Tools per Cu. Yd. of Concrete
				Cost per Cu. Yd. of Material	Cost per Cu. Yd. of Concrete		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Granite Reef Dam, Arizona	26 ft. high 1000 ft. long	Laborer $2.00 to $3.00 Carpenter $3.50 to $5.00	Main Dam North End Intake South End Intake	$2.33 1.14 1.63			
Core wall, Springfield, Mass., W.W.	1 to 25 ft. high 3 ft. thick	Laborer $1.75 Carpenter 3.50 Engineer 3.75	$0.65				
Core wall in wing dam, Moline, Ill.	10-21 ft. high 2,178 ft. long	Laborer $1.25 Carpenter 2.50	2.86		$0.11		
Dam near Chicago	490-ft. spillway 25% rubble	Laborer $2.00 Carpenter 2.75 Engineer 3.00					$0.12
Corbett Diversion Dam, Shoshone Irrigation	Deck & Buttresses 400 ft. long	Laborer $2.75 Carpenter 3.75	2.78[c]	2.72	6.60	$0.43[b]	1.09

a Includes tools, lighting, superintendence, work train, and engineering.
b Puddle foundation.
c Includes superintendence and engineering.

NOTE:—Except when noted, costs do not include costs of construction plant, depreciation, repairs, superintendence, or engineering.

TUNNELS

Forms: Cost of Labor per Cubic Yard of Concrete	Forms: Total Cost per Cubic Yard of Concrete	Proportions of Concrete	Concrete: Cost of Materials per Cubic Yard of Concrete	Concrete: Cost of Mixing & Placing per Cubic Yard of Concrete	Concrete: Total Quantity of Concrete Cu. Yd.	Total Cost of Materials and Labor per Cu. Yd. of Concrete	Authority
(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$5.47	$18.80	1:3:5	$7.15	$10.60	148	$36.55	Clarence Mayer Eng. Contr. July 8, 1908, p. 34
0.67		1:2½:5	4.65	1.25	885	6.78	F. W. Hanna Eng. Rec. May 30, 1908, p. 692
			2.80	1.75	3200	5.75[a]	Eng. Contr. Aug. 14, 1907, p. 100
0.95		1:3:5	Sides $3.16 Arch $3.22	Sides $0.84 Arch $2.00	About 13 500	Sides $6.04[d] Arch $10.35[d]	Eng. Contr. July 17, 1907, p. 36

DAMS

Forms: Cost of Labor per Cubic Yard of Concrete	Forms: Total Cost per Cubic Yard of Concrete	Proportions of Concrete	Total Cost of Material per Cubic Yard of Concrete	Cost of Mixing and Placing per Cubic Yard of Concrete	Total Quantity of Concrete in Cubic Yards	Steel: Weight Lb. per Cubic Yard of Concrete	Steel: Cost of Placing per Cubic Yard of Concrete	Steel: Total Cost per Cubic Yard of Concrete	Total Cost of Materials and Labor per Cu. Yd. of Concrete	Authority
(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
	$0.47		$4.16	$0.63				$0.035	$7.01[e]	Eng. Rec. May 20, 1911 p. 560
	1.52		4.20	1.15				0.019	8.12[e]	
	1.58		4.14	1.22				0.030	8.54[e]	
$0.17	0.31		3.76	0.93	1155				5.65[e]	C. R. Gow Jour. Assn. Eng. Socs. Dec. 1910, p. 241
0.25	0.81	1:5	2.60	0.53	4339			0.02	6.93[a]	Eng. Rec. Feb. 6, 1909 p. 157
	0.62	1:2½:5	4.03	1.27	30 000				6.04	Eng. Contr. Oct. 7, 1908 p. 215
			5.93	6.63	4951	64.5	$0.54	2.19	25.65	Eng. Rec. Aug. 22, 1908 p. 219

d Includes plant, depreciation, superintendence, lighting, work train, engineering, and incidentals.
e Includes equipment, depreciation, superintendence and engineering.

TABLE 12. COST DATA ON ACTUAL STRUCTURES—Cont.

(See p. 15)

DAMS

Name	Description	Rate of Labor per Day		Miscellaneous Items Cost per Cubic Yard of Concrete	Excavation		Cost of Foundation per Cubic Yard of Concrete	Cost of Machinery and Tools per Cu. Yd. of Concrete
					Cost per Cu. Yd. of Material	Cost per Cu. Yd. of Concrete		
(1)	(2)	(3)		(4)	(5)	(6)	(7)	(8)
Dam, Hot Springs, S. D.	22 ft. high							
Lock on Rough River, Ky.	189 ft. long 24 ft. high 27 ft. wide			$0.43				
Dam, Richmond, Ind.	120 ft. long	Laborer Carpenter	$1.50 2.50	0.28		$0.96		

PIERS

Name	Description	Rate of Labor per Day		Miscellaneous Items Cost per Cubic Yard of Concrete	Excavation: Cost per Cu. Yd. of Material	Excavation: Cost per Cu. Yd. of Concrete	Cost of Foundation per Cubic Yard of Concrete	Cost of Machinery and Tools per Cu. Yd. of Concrete
Piers for C.N.O.Ry. Ottawa	Footings for Viaduct	Laborer Carpenter	$1.75 2.50	$1.53	$0.77	$0.95		
Piers for Bridge No. 1	20 ft. long 15 ft. high 4 ft. wide	Laborer Carpenter	$2.00 2.80	0.21[a]	1.04	3.47		
Piers for Bridge No. 2. Huntley, Project, Montana	2 Piers 11 ft. 6 in. high	Laborer Carpenter	$2.00 2.80	0.65[a]	0.68	0.52		
Abutments and Culverts K.C.O. B. & E. Ry.								
Piers for Calf Killer Bridge	2 End Piers 1 Middle Pier 2 Stem walls	Laborer Carpenter	$1.75 3.00	0.89[a]		0.64		
Concrete pier	Base, 12×18 ft. Bottom, 7×13 ft. Top, 5×11 ft.	Laborer Carpenter Engineer	$2.00 3.00 3.00	3.54	0.57	0.33	$1.76[b]	$1.20
Burdick Road Bridge Barge Canal, N. Y.	2 Piers	Laborer Carpenter Engineer	$1.50 3.00 2.25			0.48		
Roberts Road Bridge, Barge Canal, N. Y.	2 Piers	Laborer Carpenter Engineer	$1.50 3.00 2.25			0.48		

a Includes superintendence and engineering.
b Pile foundation.

NOTE:—Except when noted, costs do not include cost of construction plant, depreciation, repairs, superintendence, or engineering.

DAMS

Forms: Cost of Labor per Cubic Yard of Concrete	Forms: Total Cost per Cubic Yard of Concrete	Proportions of Concrete	Total Cost of Material per Cubic Yard of Concrete	Cost of Mixing and Placing per Cubic Yard of Concrete	Total Quantity of Concrete in Cubic Yards	Steel: Weight Lb. per Cubic Yard of Concrete	Steel: Cost of Placing per Cubic Yard of Concrete	Steel: Total Cost per Cubic Yard of Concrete	Total Cost of Materials and Labor per Cu. Yd. of Concrete	Authority
(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
			$6.92	$0.76	675				$7.68	S. H. Lea Eng. Rec. May 9, 1908 p. 623
$1.27	$2.17		6.69	1.43	3680				10.72[c]	Eng. News Jan. 9, 1908 p. 34
	0.61		2.29	1.01				$0.44	5.59	Eng. Contr. June 6, 1906 p. 155

PIERS

(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
$0.19	$0.50		$4.48	$1.10	712				$8.77[d]	J. H. Ryckman Eng. Rec. Jan. 23, 1909 p. 110
1.03	1.42		3.20	1.30	130				9.60[a]	H. A. Young Eng. Contr. Dec. 30, 1908 p. 445
1.04	2.11	1:2¾:7 1:2¼:5½	3.09	1.24	99				7.61[a]	(same)
1.98	2.67	1:3:5	3.63	0.74			$0.10		7.14	Ry. Age Aug. 2, 1907 p. 143
0.95	2.17		1.86	0.93	460				6.49[a]	Eng. Rec. Sept. 28, 1907 p. 340
0.24	1.06		3.20	1.46	100				12.55	Eng. Contr. May 29, 1907 p. 237
2.06	2.70	1:2:4 1:2½:5	4.67	2.25	275	37		$0.97[e]	11.07	Emile Low Eng. Contr. May 15, 1907 p. 215
1.98	2.67	1:2:4 1:2½:5	4.52	2.20	254	39		0.97[e]	10.84	(same)

c Includes cost of construction plant and depreciation.
d Includes equipment, depreciation, superintendence, and engineering.
e Cost of placing steel is included in cost of mixing and placing concrete.

TABLE 12. COST DATA ON ACTUAL STRUCTURES.—Cont.

(See p. 15)

RESERVOIRS

Name	Description	Rate of Labor per Day	Miscellaneous Items. Cost per Cubic Yard of Concrete	Excavation	
				Cost per Cu. Yd. of Excavation	Cost per Cu. Yd. of Concrete
(1)	(2)	(3)	(4)	(5)	(6)
Covered Reservoir, Indianapolis Water Co.	377 × 257 ft. Capacity 5 500 000 gal.	Laborer $1.70 Carpenter 3.00	$1.13	By machine $0.19 Teams $0.28	$1.56
Concrete Reservoir, Pomona, Cal.	78 × 41 ft. 12 ft. high	Laborer $1.75 to 2.00 Carpenter 3.97			
Concrete Reservoir.	Cap. 75 000 gal. Slab roof	Laborer $1.50 Carpenter 3.50	1.70	0.90	6.25
Reservoir, Fort Meade, So. Dakota.	Two equal compartments each 50 × 60 ft. Cap. 500 000 gal.	Laborer $2.75 Carpenter 3.50		0.49	1.57
Standpipe, Attleboro, Mass.	106 ft. high. Cap. 1 500 000 gal.				
Reservoir, Astoria Water Co.	Cap. 6 250 000 gal.				

BRIDGES, ARCHES, AND CULVERTS

Name	Description	Rate of Labor per Hour or per Day	Miscellaneous Items, Cost per Cubic Yard of Concrete	Excavation		Cost of Foundation per Cubic Yard of Concrete	Machinery and Tools, Cost per Cubic Yard of Concrete
				Cost per Cu. Yd. of Excavation	Cost per Cu. Yd. of Concrete		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Highway Bridge..........	145-ft. main span, 2 half arches 37-ft. span, 18-ft. roadway	Carpenter 30 to 40¢. Laborer 17½ to 25¢.		$0.64	$0.43		
Arch Bridge No. 1. L. C. and M.R.R., N. Y.	20-ft. span	Laborer $1.30 Carpenter 1.75 Engineer 2.00	$1.97[a]		0.67		
Arch Bridge No. 2. L. C. and M.R.R., N.Y.	34-ft. span 17-ft. rise		1.28[a]		0.24		

a Includes superintendence.

NOTE:—Except as noted, costs do not include cost of construction plant, depreciation, repairs, superintendence, or engineering.

RESERVOIRS

Forms: Cost of Labor (Cost per Cu. Yd. of Concrete)	Forms: Total Cost (Cost per Cu. Yd. of Concrete)	Proportions of Concrete	Total Cost of Material per Cu. Yd. of Concrete	Cost of Mixing and Placing per Cubic Yard of Concrete	Total Quantity of Concrete in Cubic Yards	Cost of Steel per Cubic Yard of Concrete	Total Cost of Materials and Labor per Cu. Yd. of Concrete	Authority
(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	$1.39	1:6	$2.24	Floor $0.76 Walls 0.61 Cover 0.74	5195	$2.64	$9.90	Wm. Curtis Mabee Eng. News Oct. 15, 1908, p. 408
	0.76	1:2:4	4.50	1.09	148		6.35[b]	Charles Kerby Fox Eng. Contr. Apr. 15, 1908, p. 220
$2.41	4.26	varied	3.95	0.95	83	4.76	21.06	Eng. Contr. Nov. 6, 1907, p. 256
	2.96	1:2:4	7.85	1.72	710	4.96	19.55	Eng. Contr. Feb. 27, 1907, p. 91
	2.65	1:2:4	8.70	2.60	770		16.25[c]	Eng. Rec. Sept. 29, 1906, p. 344
		1:0:7:	4.56	0.67	678		5.23	Arthur L. Adams, Trans. Am. Soc. Civ. Engs., Vol. XXXVI, p. 1
		3.5:6.5	4.76	1.07	603		5.83	

BRIDGES, ARCHES, AND CULVERTS

Forms: Cost of Labor (per Cubic Yard of Concrete)	Forms: Total Cost (per Cubic Yard of Concrete)	Proportions of Concrete	Total Cost of Material per Cu. Yd. of Concrete	Cost of Mixing and Placing per Cu. Yd. of Concrete	Total Quantity of Concrete in Cubic Yards	Steel: Weight Lb. (per Cubic Yard of Concrete)	Steel: Cost of Bending and Placing (per Cubic Yard of Concrete)	Steel: Total Cost (per Cubic Yard of Concrete)	Total Cost of Materials and Labor per Cu. Yd. of Concrete	Authority
(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
$2.37				$0.74	874	75	$0.40			John McMichaels, Eng. Contr. June 7, 1911, p. 642
2.89	$3.84		1.39[a]	1.21	561			1.06	$10.14[a]	Eng. Contr. June 15, 1910, p. 541
0.87	1.40		0.94[a]	1.08	1804			0.15	4.09[a]	Eng. Contr. June 15, 1910, p. 541

b Cost of ½-inch finish coat, materials, and labor was $26.35 per cu. yd.
c Does not include cost of steel.

TABLE 12. COST DATA ON ACTUAL STRUCTURES.—Cont.

(See p. 15)

BRIDGES, ARCHES, AND CULVERTS

Name	Description	Rate of Labor per Day	Miscellaneous Items. Cost per Cubic Yard of Concrete	Excavation: Cost per Cu. Yd. of Material	Excavation: Cost per Cu. Yd. of Concrete	Cost of Foundation per Cubic Yard of Concrete	Machinery and Tools, Cost per Cubic Yard of Concrete
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Lamb Highway Girder Bridge, Ill.	20-ft. opening 16-ft. roadway				\$1.45		
White Highway Girder Bridge, Ill.	25-ft. opening 16-ft. roadway				1.67		
Schoeber Highway Girder Bridge, Ill.	35-ft. opening 16-ft. roadway				0.73		
Cligett Highway Girder Bridge, Ill.	40-ft. opening 16-ft. roadway				2.56		
Mud Creek Highway Girder Bridge, Ill.	60-ft. opening 16-ft. roadway				2.33		
Railway Trestle, Catskill Mountain, N. Y.	3-ft. gage		\$6.82[a]		0.56		
Highway Bridge, St. Boniface, Man.	30-ft. span 80-ft. roadway 6-ft. rise			\$0.38	2.33	2.10[b]	\$0.13
Stony Run Highway Arch Bridge, Md.	57-ft. span 70-ft. roadway	Laborer \$1.75 Carpenter 3.50 Engineer 4.00	0.31		9.75		1.16 1.16
Painesville R. R. Bridge, Ohio	3 spans 69 ft. 8½ inches, 160 ft., 69 ft. 8½ inches.	Laborer \$1.60 Carpenter 2.50	0.51[a]	1.00	0.59	3.69[c]	0.78
Coal Trestle, Easton, Pa.	114 ft. long	Laborer \$1.50 Carpenter 3.00 Engineer 1.70	0.25				
R.R. Bridge, Easton, Pa.	16-ft. span 13 ft. high						
Highway Girder Bridge, Green Co., Ia.	16-ft. span 22 ft. wide		0.40		0.38	0.14	

a Includes superintendence.
b Includes piles.
c Includes cofferdam and piles.

NOTE:—In columns where two values are given the first applies to the substructure and the second to the superstructure.

Except as noted, costs do not include cost of construction plant, depreciation, repairs, superintendence, or engineering.

BRIDGES, ARCHES, AND CULVERTS

Forms: Cost of Labor (per Cubic Yard of Concrete)	Forms: Total Cost (per Cubic Yard of Concrete)	Proportions of Concrete	Total Cost of Material per Cubic Yard of Concrete	Cost of Mixing and Placing per Cu. Yd. of Concrete	Total Quantity of Concrete in Cubic Yards	Steel: Weight Lb. (per Cubic Yard of Concrete)	Steel: Cost of Bending and Placing (per Cubic Yard of Concrete)	Steel: Total Cost (per Cubic Yard of Concrete)	Total Cost of Materials and Labor per Cu. Yd. of Concrete	Authority
(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
	$1.74	1:2½:4	$4.03	$1.27	82	25 156		$1.37	$9.86	A. N. Johnson Eng. Rec. Feb. 5, 1910, p. 163
	2.72	1:2½:4	3.76	2.07	65	35 207		2.48	12.70	A. N. Johnson Eng. Rec. Feb. 5, 1910, p. 163
	1.34	1:2½:4	4.21	1.02	124	44 171		2.23	9.53	A. N. Johnson Eng. Rec. Feb. 5, 1910, p. 163
	2.15	1:2½:4	4.83	1.55	127	35 175		2.01	13.10	A. N. Johnson Eng. Rec. Feb. 5, 1910, p. 163
	1.62	1:2½:4	3.92	1.14	206	33 210		2.43	11.44	A. N. Johnson Eng. Rec. Feb. 5, 1910, p. 163
$3.58	8.33	1:2:4	6.72	1.94	125		1.12	4.89	29.25[a]	C. C. Mitchell Eng. Rec. Feb. 20, 1909, p. 216
0.74	1.31		5.06	2.05	872		0.15	1.78	14.76	Eng. Contr. Feb. 3, 1909, p. 86
3.19	1.16 4.78		3.58 4.53	1.18	1295 3710	99	0.93	3.73	15.96[e] 15.38[e]	B. T. Fendall Eng. Contr. Aug. 4, 1909, p. 87
0.50	0.90	1:2:4	2.18	0.67[d]	25150			1.20	10.52[a]	B. R. Leffler Eng. Contr. Sept. 15, 1909, p. 222
1.21	2.18	1:2:4 and 1:3:6	3.15	0.94	116	132		2.63	9.15	Eng. Contr. Feb. 5, 1908, p. 79
0.52	0.84		2.86	0.86	98			0.18	4.74	Eng. Contr. Feb. 5, 1908, p. 79
0.29	0.38		3.02	0.38	73	110		1.18	5.88	Eng. Contr. Sept. 4, 1907, p. 140

d Includes labor in reinforcement.

e Includes plant cost.

TABLE 12. COST DATA ON ACTUAL STRUCTURES.—Cont.

(See p. 15)

SEWERS

Name	Description	Rate of Labor per Hour or per Day	Miscellaneous Items Cost per Cubic Yard of Concrete	Cost of Tools per Linear Ft. of Sewer	Excavation: Depth, Feet	Excavation: Cost per Linear Foot of Sewer	Excavation: Cost per Cubic Yard of Concrete	Forms: Cost of Labor (Per Linear Foot of Sewer)	Forms: Total Cost (Per Linear Foot of Sewer)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
So. Outfall Sewer, Louisville, Ky.	8 to 15-ft. diameter 24 000 ft. long				22 to 49	$13.60			
Sewer, Richmond, Ind.	54-inch diameter 48-inch diameter 42-inch diameter	Laborer 20¢	$0.23						$0.13[a] 0.12[a] 0.12[a]
Sewer, Mt. Gilead, Ohio.	36-inch circular 400 ft. long	Laborer $2.00							
Inverted Siphon, Sun River Project	5½-ft. diameter 1565 ft. long	Laborer $2.25 to 2.75 Carpenter $3.50						$3.25[b]	4.66[b]
Sewer, Fond du Lac, Wis.	30-inch diameter 1400 ft. long		0.11	0.027		0.26	$2.36		0.15[b]
Sewer, Charleston, W. Va.	72-inch diameter 54-inch diameter	Laborer $1.75 to 2.00 Team 3.00 to 4.00			12 20	 3.05			
Sewer, Waterbury, Conn.	53 by 54-inch diameter	Laborer 17½¢ Team 50¢							0.33
Pressure Sewer, Waterbury, Conn.	24-inch diameter	Laborer 17½¢ Team 50¢	0.16					0.12	0.23[a]
Sewer, So. Bend, Ind.	72-inch diameter 1700 ft. long	Laborer 18½¢ Carpenter 25¢		0.50		2.80		0.80	
Sewer, So. Bend, Ind.	66-inch diameter 2500 ft. long	Laborer 18½ to 22½¢	0.39	0.50				0.45	0.80
Sewer, St. Louis, Mo.	29×18.6 ft. 162 ft. long	Laborer 17½ to 30¢ Carpenter 55¢					Earth 0.38 Rock 1.00	0.25[d]	1.50[d]

a Steel forms.
b Per cubic yard.
c Per pound.

NOTE:—Except when noted, costs do not include cost of construction plant, depreciation, repairs, superintendence, or engineering.

SEWERS

Proportions of Concrete	Concrete: Cost of Materials per Linear Foot of Sewer	Concrete: Cost of Labor per Linear Foot of Sewer	Cost of Labor per Cubic Yard	Steel: Weight lb. per Linear Foot of Sewer	Steel: Cost of Bending and Placing per Linear Foot of Sewer	Steel: Total Cost per Linear Foot of Sewer	Total Cost of Materials and Labor per Linear Foot of Sewer	Total Cost of Materials and Labor per Cubic Yard of Concrete	Authority
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
					$0.02½[c]			$6.50	Eng. Contr. July 6, 1910, p. 10
	$0.46	$0.23				$0.30	$1.35		Frederick Charles Eng. News, Feb. 3, 1910, p. 119
	0.53	0.19				0.25	1.08		
	0.37	0.19				0.24	0.91		
1:2:3	0.52	0.39					0.91	4.46	Eng. Contr. Nov. 10, 1909, p. 410
1:2:4	9.26[b]	3.32[b]			1.43[b]	5.53[b]		35.87[d]	Eng. Rec. June 5, 1909, p. 716
1:5	0.42	0.19					1.14[e]	10.25	Eng. Contr. Jan. 27, 1909, p. 65
	{Bottom 0.48	0.22							C. A. Bingham Eng. News, May 21, 1908, p. 572
	{Arch 1.22	0.55				0.77			
	{Bottom 0.76	0.26							
	{Arch 1.67	0.33				0.65			
1:7½		0.57	$2.86	17	0.14	0.57	2.97	8.02	W. G. Taylor Eng. News, Mar. 26, 1908, p. 333
	1.12	0.37	2.59	7½	0.15	0.34	2.22[f]	8.25[f]	W. G. Taylor Eng. News, Mar. 26, 1908, p. 335
Arch 1:2:4 Invert 1:3:6						0.30	9.00		A. J. Hammond Eng. Rec. Mar. 7. 1907, p. 337
	1.55	0.65	1.09			0.50	4.39	7.39	A. J. Hammond Eng. News, Dec. 13, 1906, p. 618
Invert 1:3:6 Arch 1:2:5	3.67[b]		0.74	55[b]	0.14[b]	1.24[b]		7.15	Eng. Contr. Feb. 20, 1907, p. 76

d Includes cost of construction, plant, depreciation, etc.
e Tools, engineering and frost preventative included.
f Lead expansion joints included.

TABLE 12. COST DATA ON ACTUAL STRUCTURES.—Cont.
(See p. 15)

PAVEMENTS

Name	Description	Rate of Labor per Day	Miscellaneous Items. Cost per Square Foot	Excavation Cost per Square Foot	Foundation: Depth Inches	Foundation: Cost per Square Foot	Forms: Cost of Labor per Square Foot	Forms: Total Cost per Square Foot	Cost of Material per Square Foot
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Concrete Pavement, Port Henry N.Y.	21 ft. wide 986 ft. long 9 in.. thick		$0.02	$0.02				$0.01	$0.05
Concrete Pavement, Windsor, Ont.				0.01					0.08
SIDEWALKS									
Cement Walks in Salt Lake City, Utah.	4 in. thick								
Cement Walks in Chicago.	5 in. thick		$0.02[c]			$0.02			$0.06
Cement Walk	6 ft. wide 575 ft. long								0.08
Cement Walk	5 ft. wide 380 ft. long 6 in. thick								0.08
Cement Walk on Michigan Ave., Chicago, Ill.	25 ft. wide 3466 ft. long 5 in. thick		0.01[c]		12	0.05			0.08
Cement Walk, Nelson, B.C.	14½ ft. wide 990 ft. long 6 in. granite curb	Laborer $3.00							
Cement Walk	4 ft. wide 455 ft long. 6 in. curb	Laborer $2.00			4				
Cement Walk	5 ft. wide 625 ft. long 6 in. curb	Laborer $1.80			4				
Cement Walk	6 ft. wide	Laborer $2.00			9	0.01			0.07
Cement Walk, Port Henry, N.Y.	5 ft. 6 in. wide 1040 ft. long 5 in. thick		0.02	0.01			$0.01	$0.02	0.03

a Business streets. *b* Residential streets.

NOTE:—Foundations for sidewalks are cinders unless noted.

Except when noted, costs do not include cost of construction plant, depreciation, repairs, superintendence, or engineering.

PAVEMENTS

Cost of Mixing and Placing per Square Foot	Base		Granolithic Surface		Cost of Surfacing per Square Foot[e]	Total Area in Square Feet	Total Quantity of Concrete in Cubic Yards	Total Cost of Materials and Labor per Sq. Ft.	Authority
	Proportion of Concrete	Thickness Inches	Proportion of Concrete	Thickness Inches					
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
$0.02	1:8					20 706	575	$0.12	Witherbee, Sherman & Co., Mineville, N. Y.
0.02	1:3:7	4	1:2:4	2		184 500		0.11	Eng. Contr. Dec. 20, 1907, p. 288

SIDEWALKS

(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
	1:3:5	3	1:1:1	1				$0.16	Eng. Rec. Oct. 1, 1910, p. 377
0.03	1:2½:5	4¼	1:1½	¾				0.13[c]	N. E. Murray Eng. Contr. Feb. 2, 1910, p. 109
0.02						3450		0.10	Eng. Contr. Mar. 17, 1909, p. 214
0.03						1900		0.11	Eng. Contr. Mar. 17, 1909, p. 214
0.04						86 650		0.14[c, d]	Eng. Contr. Dec. 9, 1908, p. 395
	1:8	4½[a] 3¾[b]	1:2½	1½ 1¼		14 310		0.27	Eng. Contr. Dec. 2, 1908, p. 373
		3½		1		1820		0.18[d]	Eng. Contr. Oct. 7, 1908, p. 222
		3½		1		3125		0.20[d]	Eng. Contr. Oct. 7, 1908, p. 222
0.02	1:2½:5	4	1:1½	¾	$0.01			0.11	C. W. Boynton Eng. Contr. Aug. 26, 1908, p. 132
0.01						5720	88	0.10	Witherbee, Sherman & Co., Mineville, N.Y.

c Includes superintendence. *d* Includes curb. *e* Usually included in col. (11).

The data given in the preceding table, as stated at the beginning of the chapter, should be used only in connection with very rough approximations. For accurate estimates reference should be made to chapters that follow.

The total costs in each case are the sums of the costs in the preceding columns. The items included in the totals can therefore be determined by inspection.

CHAPTER III

APPROXIMATE COSTS OF REINFORCED CONCRETE BUILDINGS

The curves and tables in this chapter give approximate total average costs for buildings of reinforced concrete of different dimensions and height.* All details of the construction—not only the concrete, forms, and reinforcement, but also windows, stairs, roof covering, and plumbing—are included in the total. Interior finish, which varies widely with the type of construction, is not included. The range in value covers dimensions from 25 by 50 feet to 150 by 600 feet; and from one story up to ten stories in height.

The curves are made up from the tables of unit costs and times in succeeding chapters. The results have been carefully checked by estimates made by a number of contractors who are specialists in reinforced concrete building construction.

Methods of making up more exact estimates are described in full in Chapter XXIII, to which reference should be made for all matter requiring detailed computation. The curves in the present chapter should never be used for regular estimates although they will be found of considerable value for checking.

USE OF CURVES AND TABLES

Values such as are given in the curves and tables are of general value to the owner, the engineer, the architect, and the contractor.

(1) The curves are of use to the owner:

(*a*) To obtain a close idea of what a reinforced concrete building ought to cost him.†

*The general scheme corresponds to that adopted by Mr. Charles T. Main for buildings of mill construction—timber frame with brick walls—in a paper read before the New England Cotton Manufacturers' Association, April 1904, printed in *Engineering News*, January 27, 1910, page 96, and *Engineering Record*, January 29, 1910, page 126.

†In comparing other types of construction, note that costs do not include interior finish.

(*b*) To determine the size of building that will pay him best from an investment standpoint.

(2) The curves are of use to the engineer and architect:
(*a*) To make for the owner an approximate estimate direct from the curves, adding thereto the proposed interior finish;
(*b*) To check the bids of contractors and builders;
(*c*) To compare the costs of buildings of different shapes to see how the layout affects the cost;
(*d*) To compare the costs of buildings of different heights to determine the reduction in cost per square foot of floor area as the number of stories is increased.

(3) The curves are of use to the contractor:
(*a*) To check his own accurate estimates;
(*b*) To compare buildings of different sizes and shapes;
(*c*) To compare the actual costs of his completed buildings with average curves.

An examination of the curves shows that the variations in unit costs of different buildings are not due necessarily to the variation in cost of materials, nor to the amount of profit required by the contractor, nor to his method of making the estimate; but, on the other hand, the variation may be due chiefly to differences in the design of the buildings.

For studying different designs of construction, the curves are especially interesting. The effect upon the unit price per square foot of floor area occasioned by a change in width and length of building or by the addition of another floor is surprising. The builder of a factory must be governed in his layout to a great extent by the location of the departments and machinery, but frequently there is a choice between different designs which will appreciably affect the cost of construction. On the other hand there is sometimes less variation in cost than one would suppose.

As an illustration, suppose there is the question whether a factory shall be built one story high, 50 feet in width by 200 feet long, or two stories high, 50 feet wide by 100 feet long. A comparison of the curves shows there is a difference of only five cents per square foot of floor area, the cost for the one-story building, 200 feet long, being $1.25 per square foot of floor area, and, for the two-story building 100 feet long, $1.30 per square foot.

If the building is to be only 25 feet wide and 200 feet long, a one-story building would cost about $1.60 per square foot of floor area as compared with $1.77 per square foot for the two-story 100-foot building. In both cases, the lower cost of the one-story building is due to the following causes: No forms needed for the first floor, smaller exterior wall surface, and roof forms cheaper than the larger forms needed for the floor in the two-story building which must be remade for the roof.

Comparing two buildings, each 50 feet wide by 200 feet long, one of them one story in height and the other two stories, the cost of the one-story building would be approximately $1.25 per square foot, whereas the cost of the two-story building would be about $1.14 per square foot measured over the area of the two floors. The lower cost of the higher building is due to the two following causes: (1) less materials, as forms are used twice, and (2) the cost of the first floor are distributed to two floors instead of one.

In a similar manner, approximate comparisons may be made without the necessity of making full computations for various designs.

VARIABLES AFFECTING COSTS OF REINFORCED CONCRETE BUILDINGS

The curves illustrate very clearly the variation in cost due to size and shape. The principal causes for this variation, as discussed more in detail later on, are:

(1) That the small or narrow buildings have greater exterior surface area in proportion to the area of floor and hence cost more; and

(2) That the fewer number of stories a building has, the greater the relative cost because:

(*a*) Forms are not used so many times;

(*b*) The roof cost must be distributed into a smaller floor area.

The chief variables that affect the cost of a building are as follows:

(1) Floor load for which the building is designed.
(2) Height of building.
(3) Area of building.
(4) Shape of building.
(5) Column spacing.
(6) Design of floor system.

It is impossible by ordinary methods of computation to allow for these variables except by selecting buildings of various sizes and working up the complete costs of each. The greatest variable is the item of forms but, by taking values from tables in chapters which follow, it is possible to make up totals which can be compared on the same basis. The method of computing the costs per square foot of floor area by this means is discussed more at length in pages that follow.

THE BASIS OF CURVES

Costs such as are given in the curves and tables in this chapter must be based on clearly defined conditions. If all the assumptions are clearly stated, the values may be used consistently, even when local conditions are quite different from those on which the values are based, by making due allowance for the special items that differ.

The live load selected for the floors is 150 pounds per square foot in addition to the weight of the floor. Other loads, 75 pounds per square foot and 300 pounds per square foot, were also studied to compare the relative costs of construction. The variation in cost due to the load is given on page 44.

The effect upon the cost of different column spacing, taking a range of from 10 to 30 feet on centers, was studied and also the effect of various arrangements of beams: *i.e.*, a comparison between bays with no intermediate beams, one intermediate beam, and two intermediate beams. Variations in cost due to these differences in design are given on page 44.

Variation in cost because of differences in the width and length of building are taken up by means of formulas on page 38.

The basis on which the curves and tables are made is as follows:

(1) Floor loads, 150 pounds per square foot.
(2) Story heights: first floor on a 3-foot fill;
other floors 12 feet from slab surface to slab surface.
(3) Column spacing, 18 feet on centers.
(4) Floor design: girders between columns in one direction; beams between columns in other direction with two intermediate beams.
(5) Excavation and foundations.*

Story Height	Outside Walls per Linear Foot	Inside Walls per Linear Foot
1	$2.00	$1.75
2	2.90	2.25
3	3.80	2.80
4	4.70	3.40
5	5.60	3.90
6	6.50	4.50

*Taken from paper presented before the New England Cotton Manufacturers' Association, April 1904, by Mr. Charles T. Main. Prices revised by Mr. Main to conform to prices prevailing about January 1910.

(6) Filling under first floor: 3-foot fill at 50¢ per cubic yard in place.

(7) Stairs: material and labor, $100 per flight per story.

(8) Stairways and elevator towers:

2 stairways and 1 elevator tower for buildings up to 150 feet long.
2 stairways and 2 elevator towers for buildings up to 300 feet long.
3 stairways and 3 elevator towers for buildings over 300 feet long.

(9) Floor finish: all floors of concrete with granolithic finish.

(10) Walls:

(*a*) Curtain walls between pilasters, 3 feet high and 8 inches thick;

(*b*) Concrete walls for penthouses, 6 inches thick. Dimensions of penthouse are 10 feet by 10 feet;

(*c*) Concrete walls around the elevator and stairway openings are taken 6 inches thick, the elevator opening being 10 by 20 feet and the stairways 10 by 10 feet, these two being adjacent so that the one intermediate 10-foot wall serves for both openings;

(*d*) For toilets, concrete walls 6 inches thick and 20 feet long, one wall for each 5000 square feet of floor space.

Walls 8 inches thick, including reinforcement and forms, $0.35 per square foot.

Walls 6 inches thick, including reinforcement and forms, $0.30 per square foot.

(11) Windows and doors: all openings for windows and doors, $0.40 per square foot.

(12) Roof and flashing: five-ply tar and gravel roofing, $0.60 per square foot.

(13) Plumbing: two fixtures on each floor up to 5000 square feet of floor surface, and one additional fixture for each additional 5000 square feet, $75.00 per fixture.

(14) Labor rates: carpenter labor, $0.50 per hour; steel labor, $0.30 per hour; and common labor, $0.25 per hour.

(15) Concrete in place (including labor and materials): $7.00 per cubic yard, or $0.26 per cubic foot.*

(16) Form lumber: $30.00 per 1000 feet B. M., delivered.

(17) Steel for reinforcement: $37.00 per ton, delivered.

METHOD OF COMPUTING COSTS PER SQUARE FOOT OF FLOOR AREA

In computing the sizes of floor members and the amount of reinforcement, the recommendations of the Joint Committee on Concrete

*An average value for concrete in place is chosen, instead of separating the different parts of the structure, because of the variation in methods of construction. Note that the concrete in walls is taken per square foot of surface area in Item (10).

and Reinforced Concrete* have been followed throughout, assuming the concrete to have a compressive strength of 2000 pounds per square foot at the age of thirty days.

A floor design for the given loading with the column spacing given on page 36 is shown in Fig. 1, page 39. The column dimensions, allowing $1\frac{1}{2}$ inches all around for fireproofing, were figured to correspond to the selected floor loads. With the dimensions thus obtained, the quantity of concrete, the weight of steel, and the cost of forms were obtained directly with the aid of the tables in various chapters in this book.

To provide for the walls, the cost of these was computed and reduced to terms of per linear foot for one story. Not only does the length of the wall itself, with its windows and door areas, affect the cost of the building, but also the wall beams and columns are more expensive to erect than similar interior work. This extra cost of wall construction is not always realized by engineers in making up estimates.

After making the fundamental computations for each part of the building and fixing upon the average costs to use for roofing, etc., as outlined in preceding pages, the final values for the curves were obtained by combination. Having obtained the basic values, it was found convenient to derive a general formula that could be applied to buildings of various dimensions and shapes. The cost was divided into three parts as follows:

Let
A = price per square foot of floor area, independent of the relations of the width to length of building;
S = price per linear foot of side of building;
E = price per linear foot of end of building.

In computing A, the cost of one entire bay including a column is figured. With the system of floor construction selected, we thus include: one interior column + one girder + three beams + slab of an area comprised between four columns. The value of A varies for different floors because of the difference in form costs, due to the number of times the forms are used and to the size of the columns.

In computing S, we must take merely the *extra* cost of the section next to the wall, since our final value for A must be based on total area of floor. The half of each bay next to the wall is different from

*For design of concrete structures see Taylor and Thompson's "Concrete; Plain and Reinforced," second edition, pages 399 to 531.

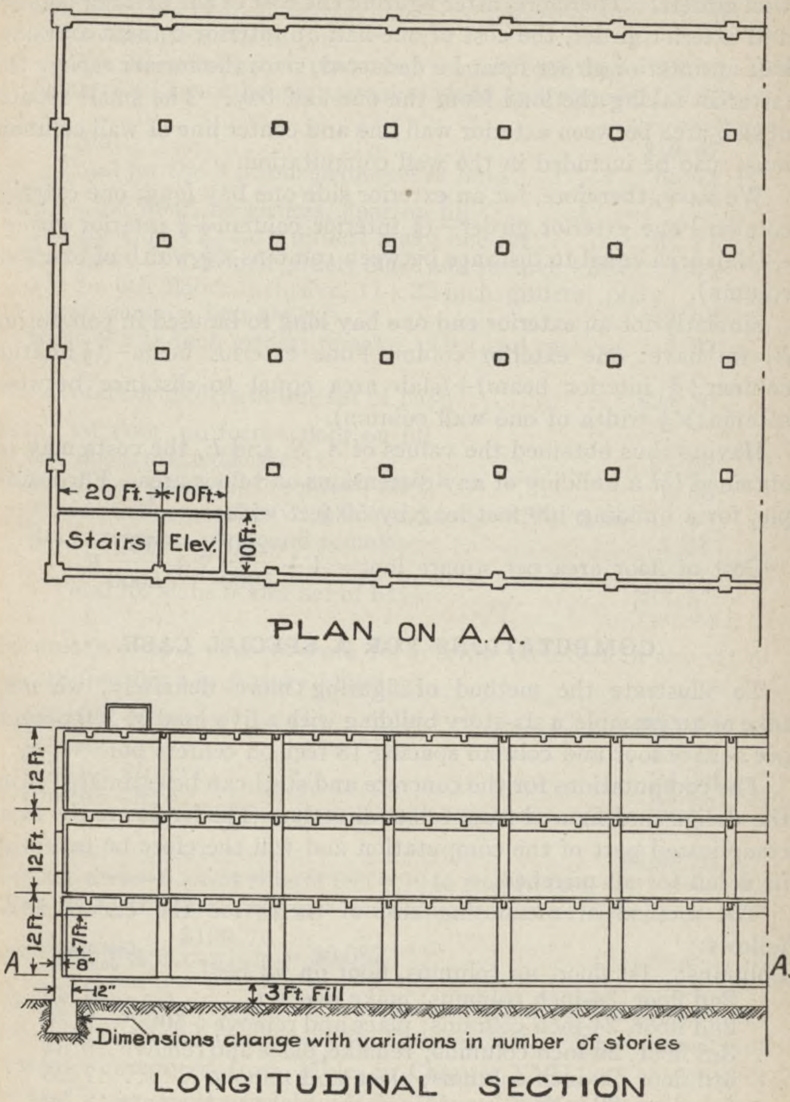


FIG. 1—Plan and Cross-section of Typical Building (See p. 38)

the rest of the floor, since it is partly supported by wall columns and wall girders. Therefore, after figuring the cost of the exterior column and exterior girder, the cost of one-half an interior column and one-half an interior girder must be deducted, since the former *replace* the latter in taking the load from the one-half bay. The small section of slab area between exterior wall line and center line of wall columns must also be included in the wall computation.

We have, therefore, for an exterior side one bay long: one exterior column + one exterior girder — ($\frac{1}{2}$ interior column + $\frac{1}{2}$ interior girder) + (slab area equal to distance between columns $\times \frac{1}{2}$ width of one wall column).

Similarly for an exterior end one bay long to be used in computing E, we have: one exterior column + one exterior beam — ($\frac{1}{2}$ interior column + $\frac{1}{2}$ interior beam) + (slab area equal to distance between columns $\times \frac{1}{2}$ width of one wall column).

Having thus obtained the values of A, S, and E, the costs may be obtained for a building of any dimensions and floor area. For example, for a building 100 feet long by 50 feet wide:

$$\text{Cost of floor area per square foot} = A + \frac{200}{5000}S + \frac{100}{5000}E$$

COMPUTATIONS FOR A SPECIAL CASE

To illustrate the method of figuring more definitely, we may take as an example a six-story building with a live load of 150 pounds per square foot and column spacing 18 feet on centers both ways.

The computations for the concrete and steel can be estimated from the design and figured from tables directly. The forms are the most complicated part of the computation and will therefore be taken up in detail for all members.

The method of computing cost of forms for the curves is as follows:

	Cost of labor on forms
Columns: 1st floor, no columns, floor on fill	
2nd floor, 34-inch columns; make one set	$4.42
2nd floor, 34-inch columns; place and remove + 50%*	9.50
3rd floor, 29-inch columns; remake, place and remove	9.54
4th floor, 29-inch columns; place and remove	7.25
5th floor, 22-inch columns; remake, place and remove	8.50
6th floor, 22-inch columns; place and remove	6.25
Roof, 10-inch columns; remake, place and remove	7.16
Total for columns in one set of bays	$52.62

*50% allowed for slow work in starting construction.

Beams: 1st floor, no beams, floor on fill	
2nd floor, 9 x 19-inch beams; make one set	$1.42
2nd floor, 9 x 19-inch beams; place and remove+50%*	3.20
3rd to 6th floors inclusive, 9 x 19-inch beams; place and remove four times	11.42
Roof: 7 x 15-inch beams; remake, place and remove	3.53
Total	$19.57
Total for the 3 beams in one set of bays	58.71
Girders: 1st floor, no girders, floor on fill	
2nd floor, 11 x 22-inch girder; make one set	$1.71
2nd floor, 11 x 22-inch girder; place and remove+50%*	4.38
3rd to 6th floors inclusive, 11 x 22-inch girders; place and remove four times	13.95
Roof, 9 x 18-inch girder; remake, place and remove	4.82
Total for girders in one set of bays	$24.86
Slabs: 1st floor, no forms, floor on fill	
2nd floor; make one set	$2.08
2nd floor; place and remove+50%*	6.68
3rd to 6th floors inclusive; place and remove four times	19.60
Roof: remake, place and remove	5.21
Total for slabs in one set of bays	$33.57

Summary of cost of form work for interior members in one set of 18 by 18-foot bays in 6-story building:

Interior columns	$52.62
Interior beams	58.71
Interior girders	24.86
Interior slabs	33.57
Total	$169.76

Surface area $=6\times 324$ square feet $=1944$ square feet.

Cost *of form labor only* per one square foot of floor area in a 6-story building $= \frac{\$169.76}{1944} = \$0.087$.

To the cost of the form work must be added the cost of the lumber, which is taken from the tables in Chapter XXI. The quantity of concrete is computed from tables in Chapter XVII and the steel is estimated from tables in Chapter XVIII and XIX. The summary of all these items for the interior work gives us the value designated as A, (page 38):

*50% allowed for slow work in starting construction.

	Cost per square foot of slab area
Labor only on form work, from above	$0.087
Lumber for forms and bracing	0.038
Concrete in all members	0.190
Steel in all members	0.144
Total value for *A*	$0.459

The costs per linear foot of side and end are figured in a similar manner, using the combinations or formulas given on page 40.

With this information, we can compute the cost per square foot of floor area for a 6-story building of any size or shape.

Buildings of other heights are figured similarly.

To this cost of the reinforced concrete must be added the cost of plumbing, stairs, windows, walls, etc., the unit prices for which are given on page 37.

ESTIMATE OF COST OF A CONCRETE BUILDING 90 FEET BY 180 FEET

To illustrate the method of computation still further, a summary is given below of a building of special size showing how the various items are taken up, and also showing a comparison between estimates

	1-Story	3-Story	6-Story
Forms (labor and materials)	$5643	$9677	$15294
Concrete (columns, roof, and floors)	1587	6963	16576
Basement floor	1780	1780	1780
Steel (columns, roof, and floors)	1213	5826	13715
Walls (interior and exterior above footings)	1288	3690	7293
Windows	1510	4530	9060
Fill in cellar	900	900	900
Stairs and elevators		2850	6000
Plumbing	375	825	2250
Foundation and excavation (interior and exterior)	1220	2554	4310
Roof and flashing	1260	1260	1260
Exterior surface finish	94	282	564
Oil and cold water painting	94	282	564
	$16964	$41419	$79566
Add 10% for profit and home-office expenses	1696	4141	7956
Total	$18660	$45560	$87522
Cost per square foot of surface area	$1.15	$0.94	$0.90

for buildings of different heights. The unit costs used in the computations are given in preceding pages.

For low buildings of one or two stories, there is apt to be a greater variation in estimates than for higher ones because the total cost is comparatively small and therefore the amount to allow for profit and home-office expenses is more variable. Also, there are apt to be other fixed charges, like travelling expenses, which will total nearly the same for a low-priced as for a high-priced building, thus giving a higher unit cost. For this reason, the costs for the higher buildings can be accepted as being more exact than for the one-story buildings.

COMPARISON OF COMPUTED COSTS WITH CONTRACTORS' ESTIMATES

To check the values in the tables, several representative contractors, specialists in reinforced concrete building construction, were given the design used for the estimate just given and asked to make up an estimate for a one-story, a three-story, and a six-story building.

The following figures represent the range in prices per square foot of total floor area, omitting, however, the lowest estimate, which was figured with very small overhead charges:

Height of Building	Authors' Estimate	Contractors' Estimate	
		High	Low
One-story	$1.15	$1.30	$1.05
Three-story	0.94	0.99	0.90
Six-story	0.92	0.90	0.86

It is noticeable that the greatest variation is in the one-story building for reasons mentioned in a paragraph above.

EFFECT OF VARIATION IN LOADING ON COSTS

For a one-story building, the loading does not affect the cost because the first floor is assumed to rest on a fill and the roof load is the same for all cases.

Computation of floors for other loadings, assuming also some variation in the floor design to give a construction economical for the loads considered, gives the following amounts to add to or subtract from the costs as given in the curves.

Amounts to Deduct from Curves for 75-Pound Floor Loads and Add to Curves for 300-Pound Floor Loads

Number of Stories	75-Pound Live Load. Deduct	300-Pound Live Load. Add
	per square foot	*per square foot*
One story	$0.00	$0.00
Two stories	0.06	0.06
Four stories	0.10	0.10
Six stories	0.12	0.12
Ten stories	0.12½	0.12½

EFFECT OF COLUMN SPACING ON COSTS

The variation in costs per square foot of floor area due to variation in column spacing is comparatively very small.

Where columns are spaced as far as fifteen feet apart, the cost is about 6 per cent greater than where columns are spaced twenty-five feet apart both ways.

EFFECT OF FLOOR DESIGN ON COSTS

As has been stated, our estimates are based on a floor design with girders between columns in one direction; beams between columns in the other direction; and two intermediate beams in each bay. Computations show that other conditions will change the costs as given in the curves approximately as follows:

(1) One intermediate beam per bay, one-story building: use costs direct from curves.

(2) One intermediate beam per bay, six-story building: add 5% to costs from curves.

(3) No intermediate beam (*i.e.*, square panels), one-story building: add 3% to costs from curves.

(4) No intermediate beams, (*i. e.*, square panels) six-story building: add 15% to costs from curves.

Percentage to add for other story heights may be estimated approximately from these values.

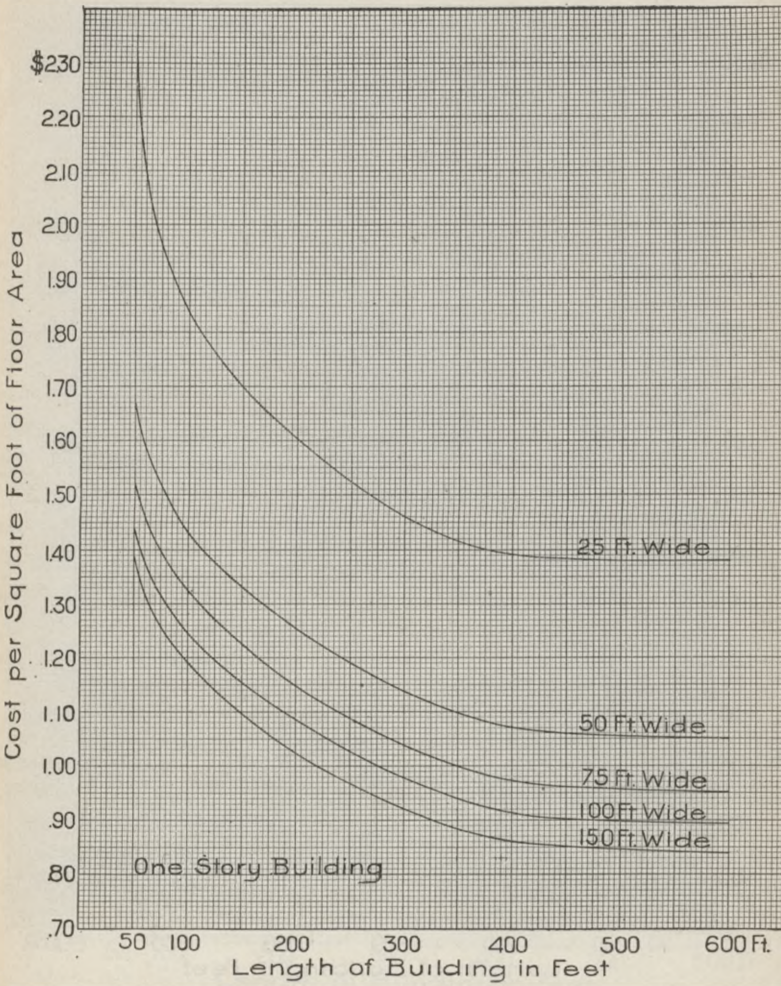


FIG. 2—Curves for Estimating Costs of One Story Building per Square Foot of Floor Area for Different Widths and Lengths of Buildings (See p. 36.)

To obtain costs in terms of per cubic foot of volume divide values above by 12

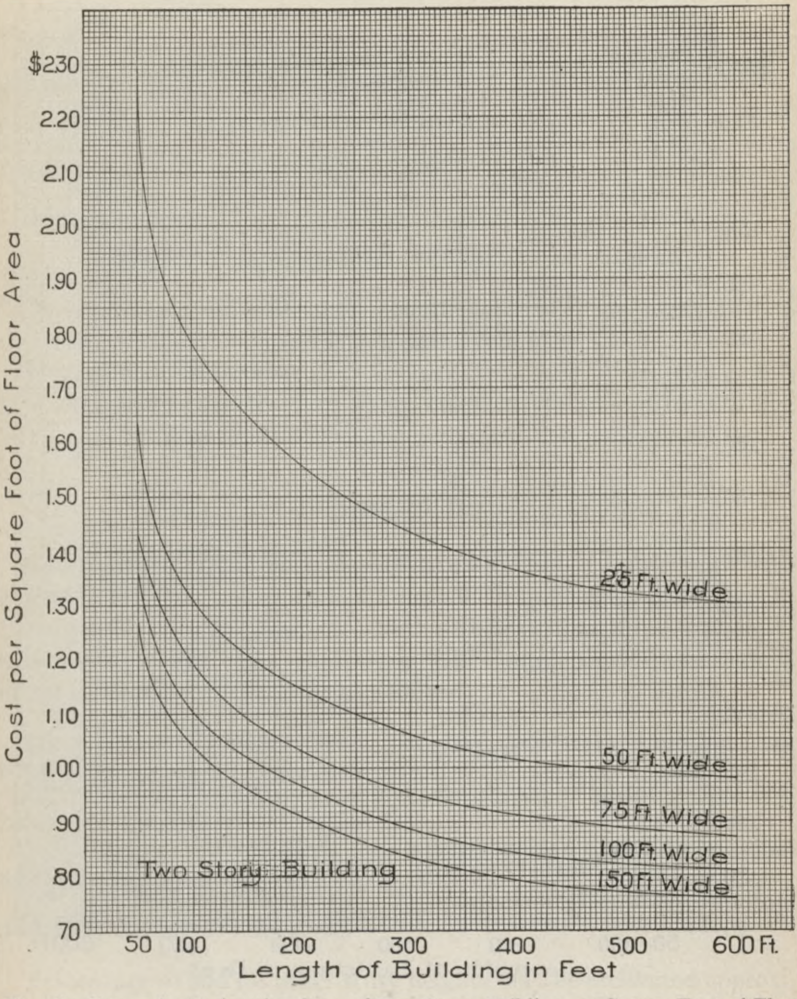


FIG. 3—Curves for Estimating Costs of Two Story Building per Square Foot of Floor Area for Different Widths and Lengths of Buildings (See p. 36)

To obtain costs in terms of per cubic foot of volume divide values above by 12

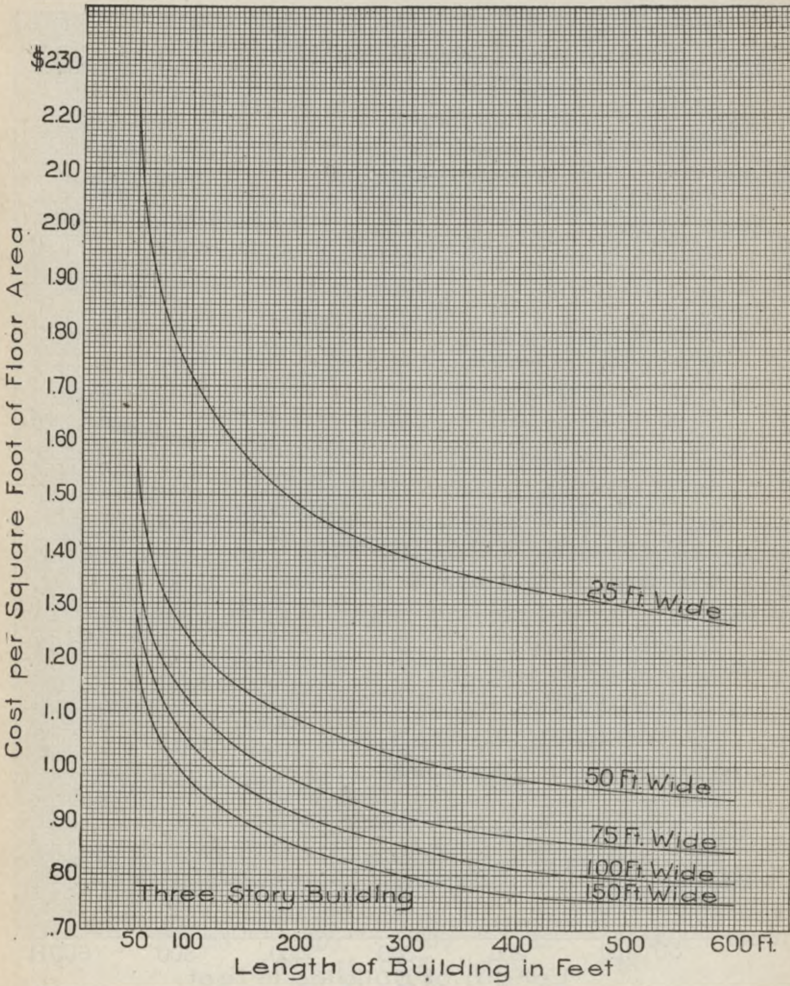


FIG. 4—Curves for Estimating Costs of Three Story Building per Square Foot of Floor Area for Different Widths and Lengths of Buildings (See p. 36)

To obtain costs in terms of per cubic foot of volume divide values above by 12

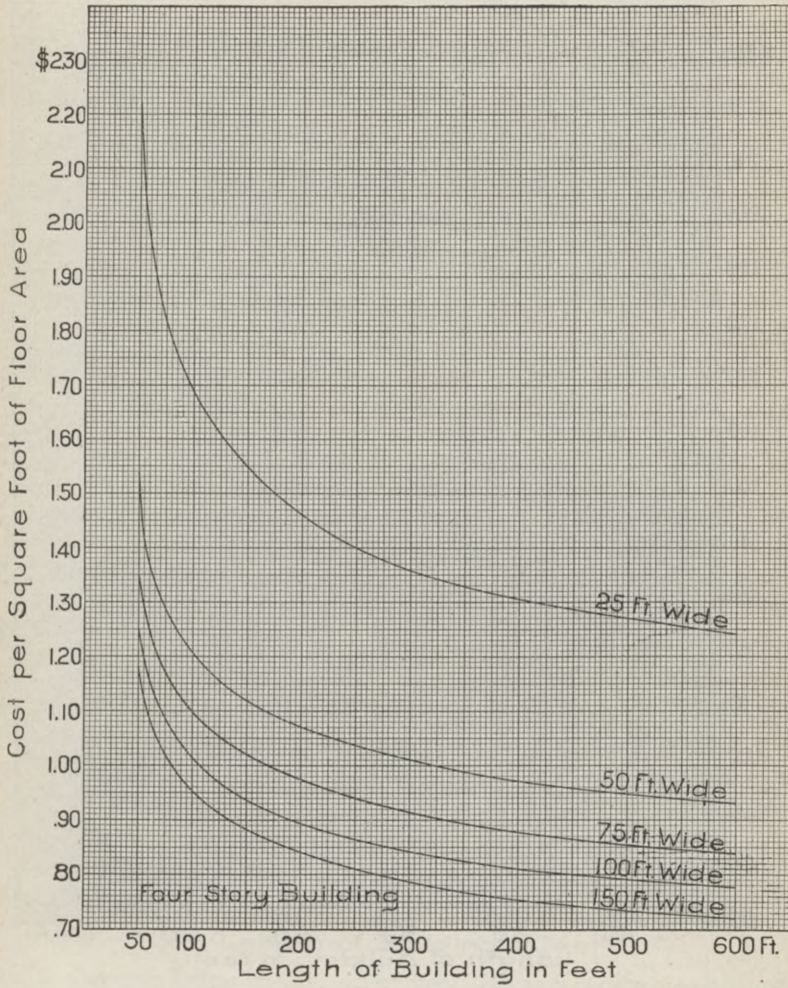


FIG. 5—Curves for Estimating Costs of Four Story Building per Square Foot of Floor Area for Different Widths and Lengths of Buildings (See p. 36)

To obtain costs in terms of per cubic foot of volume divide values above by 12

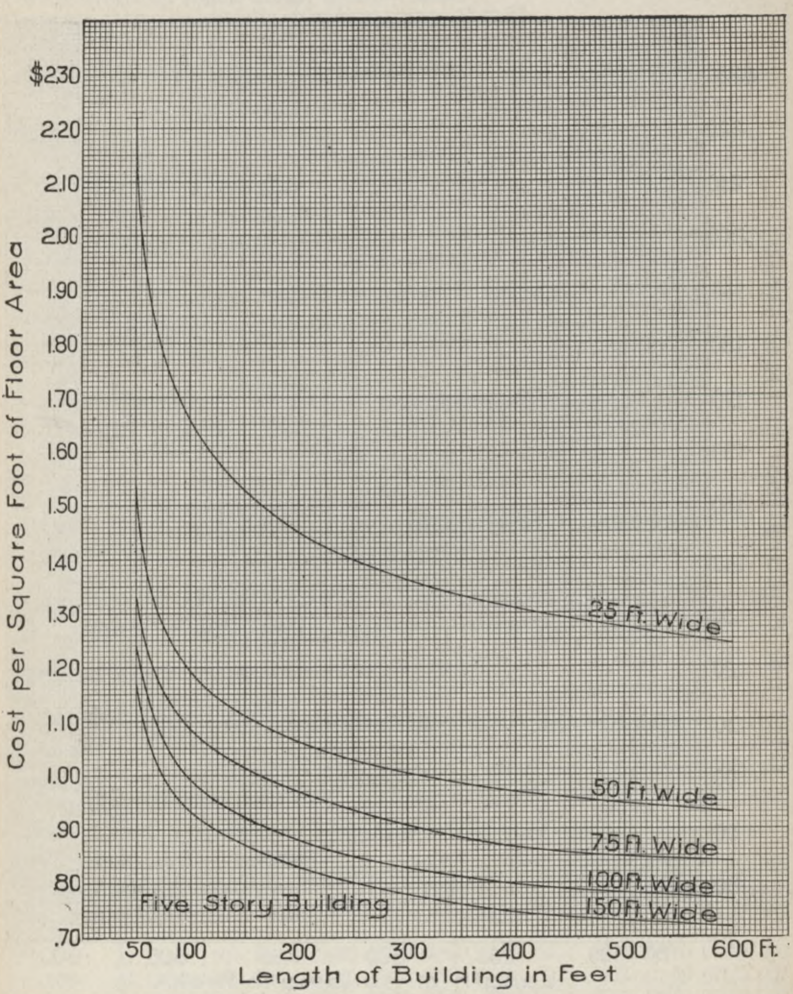


FIG. 6—Curves for Estimating Costs of Five Story Building per Square Foot of Floor Area for Different Widths and Lengths of Buildings (See p. 36)

To obtain costs in terms of per cubic foot of volume divide values above by 12

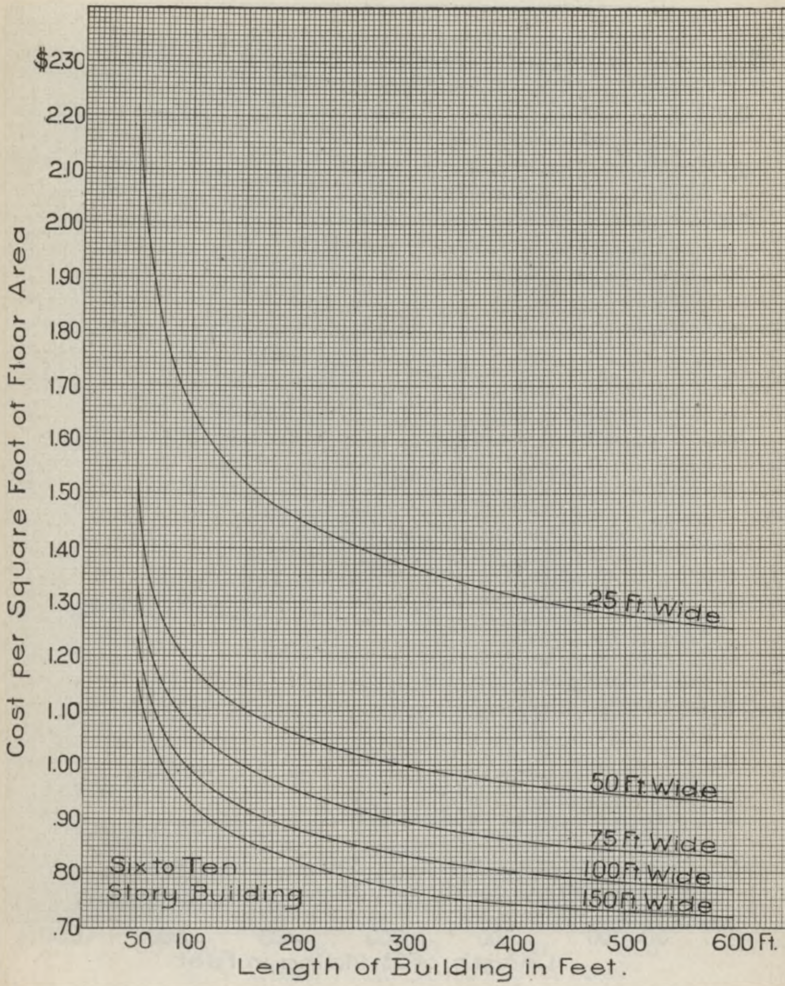


FIG. 7—Curves for Estimating Costs of Six to Ten Story Building per Square Foot of Floor Area for Different Widths and Lengths of Buildings (See p. 36)

To obtain costs in terms of per cubic foot of volume divide values above by 12

TABLE 13. AVERAGE COSTS OF CONCRETE BUILDINGS PER SQUARE FOOT OF FLOOR AREA (See p. 36)

Costs include all items except interior finish.
Costs are shown graphically on curves, pages 45 to 50.

COST IN DOLLARS PER SQUARE FOOT OF FLOOR AREA

Width in Feet	Length of Building in Feet						Length of Building in Feet					
	50 $	100 $	200 $	300 $	400 $	600 $	50 $	100 $	200 $	300 $	400 $	600 $
	1-Story						**2-Story**					
25	2.34	1.83	1.60	1.46	1.40	1.38	2.29	1.77	1.55	1.43	1.37	1.30
50	1.67	1.43	1.26	1.14	1.08	1.05	1.64	1.30	1.15	1.05	1.01	0.98
75	1.52	1.32	1.15	1.03	0.98	0.95	1.44	1.19	1.03	0.96	0.91	0.87
100	1.44	1.24	1.08	0.98	0.91	0.89	1.35	1.10	0.97	0.89	0.84	0.81
150	1.39	1.18	1.03	0.93	0.86	0.84	1.27	1.04	0.91	0.83	0.79	0.76
	4-Story						**6 to 10-Story**					
25	2.22	1.68	1.46	1.37	1.31	1.25	2.22	1.66	1.45	1.35	1.32	1.25
50	1.54	1.20	1.07	1.00	0.97	0.93	1.53	1.18	1.06	1.00	0.97	0.93
75	1.35	1.08	0.96	0.90	0.87	0.84	1.33	1.08	0.96	0.89	0.85	0.83
100	1.25	1.01	0.89	0.83	0.80	0.78	1.24	0.99	0.88	0.82	0.79	0.77
150	1.18	0.95	0.84	0.78	0.75	0.72	1.16	0.93	0.82	0.77	0.75	0.72

TABLE 14. AVERAGE COSTS OF CONCRETE BUILDINGS PER CUBIC FOOT OF VOLUME (See p. 36)

Costs include all items except interior finish

COST IN DOLLARS PER CUBIC FOOT OF VOLUME

Width in Feet	Length of Building in Feet						Length of Building in Feet					
	50 $	100 $	200 $	300 $	400 $	600 $	50 $	100 $	200 $	300 $	400 $	600 $
	1-Story						**2-Story**					
25	0.195	0.153	0.133	0.122	0.117	0.115	0.191	0.147	0.129	0.119	0.114	0.108
50	0.139	0.119	0.105	0.095	0.090	0.087	0.137	0.108	0.096	0.088	0.084	0.082
75	0.126	0.110	0.096	0.086	0.082	0.079	0.120	0.099	0.087	0.080	0.076	0.072
100	0.120	0.104	0.090	0.082	0.076	0.074	0.113	0.092	0.081	0.074	0.070	0.067
150	0.116	0.098	0.086	0.077	0.072	0.070	0.106	0.087	0.076	0.069	0.066	0.063
	4-Story						**6 to 10-Story**					
25	0.185	0.140	0.122	0.114	0.109	0.104	0.185	0.138	0.121	0.112	0.110	0.104
50	0.128	0.100	0.089	0.083	0.081	0.077	0.128	0.098	0.088	0.083	0.081	0.077
75	0.112	0.090	0.080	0.075	0.072	0.070	0.111	0.090	0.080	0.074	0.071	0.069
100	0.104	0.084	0.074	0.069	0.067	0.065	0.103	0.082	0.073	0.068	0.066	0.064
150	0.098	0.079	0.070	0.065	0.063	0.060	0.097	0.077	0.068	0.064	0.062	0.060

CHAPTER IV

DETERMINATIONS OF LABOR COST

The principal object to be attained in construction operations is the same as in factory work. In both cases, the prime object is to get the work done right and at the lowest possible cost. And this, in both cases, must be accomplished through adopting the best and most modern methods of managing the workmen rather than through any system of keeping records. Cost keeping, that is, recording what the work is costing, is in each case only of secondary importance. On the other hand, in construction operations a good system of figuring costs will greatly help the manager or foreman, whose main duty is to plan the work ahead and to systematically adopt the quickest and best methods of doing each kind of work. To be of much help to the foreman or manager, however, the work must be subdivided into a number of separate parts or elements, and the cost of each element must be clearly placed before the foreman at frequent intervals.

Scientific management,* either in the shop or on construction work, does not involve merely the recording of the amount of work accomplished by the men and machinery, nor does it involve merely the introduction of some form of piece or task work by which the men are given an incentive to work at a higher rate of speed. The ultimate aim of scientific management must include these objects, but before accurate records can be made of work which is being done, and before tasks can be given to the men or piece rates can be established, a lot of preparatory work must be done. Men must be taught how to plan work ahead for the various groups of workmen employed on the job, and other men must be trained so that they can show each workman just what he is to do each day and the quickest and best way of doing it. In this way a task can be laid out in advance for each man, and the different workmen can be arranged so that the work of one will

*See "Principles of Scientific Management" and also "Shop Management," by Frederick W. Taylor, published by Harper & Brothers, 1911. These books take up fundamental principles and methods which can be applied to construction operations as well as to the factory.

fit into that of another and the proper oversight and inspection can be provided in a manner quite different from what is customarily employed in day-work methods. In the chapter which follows this, some of the principles of scientific management as applied to construction work are treated briefly. In the present chapter, the methods of determining unit times and costs by time studies, which are not only essential in the introduction of scientific management but also are of very great value in the estimation of costs, are taken up in a general way and then in further detail in Chapter V. The discussion of these methods will illustrate the accuracy with which the times and costs presented later on in this volume have been obtained.

Leading up to this discussion of unit times and unit costs, cost keeping with its various limitations is considered; the variations in costs of similar jobs are illustrated; the methods of determining unit times are described; and finally, as already stated, in the chapter which follows, the possibility is suggested of using such records, when carefully made and recorded, in the establishment of piece rates or tasks.

In subsequent chapters, times and costs in actual construction are discussed and tabulated. Those who desire approximate cost figures for rough estimates may refer to Chapters II and III, where records from a large number of jobs are tabulated.

COST RECORDS

Besides being of use as a preliminary step toward the introduction of scientific management, cost keeping, that is, cost determination of work in progress, is of value to the engineer for making up estimates and checking the work of the builder, and to the builder in bidding on subsequent contracts and keeping track of the cost of the work as it progresses from day to day. In construction work based on the principle of cost-plus-a-fixed-sum and other similar systems, the accurate recording of detail costs on different parts of the work is absolutely essential for submitting the accounts to the owners.

To accomplish any of these aims, the cost records must be accurate enough to serve:

(1) As records for estimating cost of subsequent jobs.

(2) For immediate use.

(a) To determine whether the builder is making or losing money

(b) To fix any point of loss or of too small profit.

(c) As an incentive to the foreman and workmen.

As generally practised, cost keeping is so approximate and inaccurate as to be of comparatively little value for any of these purposes. Some of the reasons for this are outlined more in detail in the pages which follow, but it must be recognized that, at the bottom, the fault lies with the unscientific principle of estimating and recording labor costs that has been generally used.

ESTIMATING MATERIAL VS. ESTIMATING LABOR

The point just made may be illustrated simply by a comparison of the methods now usually employed in estimating materials and in estimating labor. In figuring materials the estimator notes every item, usually taking the schedule from the plans, and by adding a percentage for contingencies reaches a total which will check fairly well with the actual subsequent cost. Before he starts to do any work, he must order the required amount of each material separately, and the cost of each item is carefully looked into to see that the lowest figures are obtained consistent with the quality of the work required.

With labor, on the other hand, the plan heretofore adopted has been largely a system of guess work. Frequently one hundred or more carefully tabulated material items are set down while the estimate for labor is given in one lump sum, and yet the labor may amount to one-fourth or one-third the sum total of the materials. The variation in the actual cost of the labor from that given in the estimate almost always makes the difference between a profit and a loss to the contractor. These "guesses" at labor costs are commonly excused because it is claimed that the work done by different workmen varies to a great extent, or that it is impossible to provide for unforeseen contingencies. This, however, is merely dodging the whole responsibility. The real reason for such approximations is that the contractor usually *does not know*, with any degree of accuracy, the time and cost of doing each kind of work. The variations in output due to the character of the design, or to the materials to be handled, or to methods of management, are far greater than the difference between individual workmen and they can be allowed for in advance. The fact is only just coming to be recognized that it is possible to determine in advance how fast each element of the work should be done nearly as accurately as the cost of the supplies and materials are now determined, and that, once having the fundamental data, it is possible to estimate labor nearly as accurately as material.

DIVISIONS OF TIME AND COST

To reach more exact results in estimating labor items, it is necessary to treat these items as scientifically as the materials side of the question is treated.

The fundamental principle in accurate determinations of labor cost, either for present or future purposes, has been found by the authors, both in shop work and in construction, to lie in the following procedure:

First divide the work into small units, *i.e.*, small elements or operations, then study and accurately determine the cost of each of these small units and finally recombine these unit costs to suit the work under consideration. This is far better than getting an average cost of the work as a whole, as has been the practice in the past.

The methods of separating the operations into units are discussed in further detail in pages which follow. To illustrate the fundamental difference between the usual way of observing the total time it takes to perform a job and, on the other hand, the new way of observing the times of the unit operations, we may take the familiar work of bricklaying.

Let us consider one of the simplest pieces of brickwork, a straight 12-inch wall, that is, a wall 3-brick thick, and 40 feet long between corners. We will assume that four bricklayers are working upon this wall. The usual way, that is, the ordinary way in construction, of measuring the speed of bricklayers is to note the time these four men start at the floor level and the time they complete the wall to a height of, say, 5½ feet, and then figure the number of bricks laid per hour. The result of such observation is absolutely worthless. To show this, let us take the same men and put them on a 12-inch wall, 20 feet long instead of 40 feet, and figure the number of brick laid per day on this wall. The number of brick laid will be less because the corner brick take the longest to lay, and in a 20-foot wall there are more corner brick in proportion to the whole than in a 40-foot wall. Now, take the same men on an 8-inch wall, that is, on a wall 2-brick thick, of the same length, that is, 20 feet, and they will lay fewer brick still. Why? Because now all the brick are face brick, and have to be laid carefully to line. Again, take the same wall with a window opening in it. The number of brick laid per hour will be still smaller. Why? Because the brick at the jamb have to be plumbed. Again, take the same wall having pressed brick on the face, laid with fine buttered joints. There will again be a reduction in the number of brick per hour. Why? Because more motions are required to lay pressed brick with buttered joints.

These points by no means cover all the variations in bricklaying, but are sufficient for illustration.

The records on these different walls will vary, perhaps, from 130 brick per hour laid per bricklayer down to 60 brick per hour. What good are the results? Practically no good at all. For another length of wall, another thickness, another number of openings, another quality of face brick, there will be a different rate of speed. As a matter of fact, actual time-study has shown that the rate per 8-hour day for an average bricklayer will range from 150 brick for an ornamental house front of Roman pressed brick up to 2600 common brick roughly laid in a 32-inch wall. Unless a large number of observations are taken with only one variable, it is perfectly evident that no results can be obtained from over-all times, even by diagrams and curves, that will form an accurate basis for varying conditions. In other words, it is practically impossible by any method of over-all times to estimate how long it will take the same bricklayers to lay up a wall of different design.

Now, start in a different way, and without going into the more minute study of elementary motions, we may consider the unit simply as the time laying one brick. First observe and record the time it takes the bricklayers on the corners to lay and level and plumb one corner brick, averaging the results of a large number of observations. Then make similar observations and average them to see how long it takes the intermediate bricklayers to lay a brick to line overhand, that is, on the face of the wall away from them. Determine a similar time laying a brick on the face nearest them. Again, observe the average time for laying a filling brick in the middle of a wall. Next, find the time to place and plumb a brick at the jamb. And finally, on another wall, find the average time to lay the pressed face brick.

Now, we have data from which, by simple addition and multiplication, it is possible to determine in advance how long it should take these men to lay any wall having these variables and it is a very simple matter in practice, after having determined the unit times, to recombine them to suit any conditions.

What is the present practice in estimating brickwork? Ask a foreman on any bricklaying job how many brick his men are laying in a day? The chances are that he will tell you that it depends entirely on the wall and on the workmen; that one man may lay double the number of bricks another will lay so that it is absolutely impossible to estimate the number. This is a regulation excuse, *i.e.*, the outputs of different men vary so much that no labor estimates are of use. As a matter of fact, if you press this foreman further, you will probably find that his indefiniteness is not because of the variation in what one man will do under different conditions, not because of the variation between the work of different men, but simply because he has no idea of the relative output for different kinds of walls. He does not know. He may be able to give you the number of brick per day the men will average on the particular building his men are working on. He may say 1000 brick per day. Ask him the range in output of the same men on different classes of work, and if he is an experienced foreman or superintendent, he will tell you that the range in an 8-hour day will be from a few hundred up to several thousand, according to the kind of brick and the character of the wall. As already stated, the variation between, for instance, the face brick of an ornamental house front and the brick in a heavy building wall is as great as this. Some foremen and superintendents can guess fairly closely on classes of work with which they are familiar, but when it comes to special work that occurs only occasionally or is outside of their regular line, such, we will say, as narrow pilasters or piers with steel columns imbedded, they may not be able to guess within 50 per cent, and in any case it will be guess work.

The principles, however, apply to practically every kind of work, whether it be in the shop, or out-of-doors, or in the office. The only way to determine the variables in the times or in the costs of doing work is to separate each piece of work into unit operations and determine the times of these unit elements. Having done this, the unit times or the unit costs may be recombined to provide for all other conditions.

In practice, to make time studies that will place the work on the most economical basis, the labor of laying a single brick should be divided into its elementary motions, so as to see whether any of these motions can be left out and the brick be laid just as well. By studying the motions of laying one brick, for example, Mr. Frank B. Gilbreth has been able to reduce the number of motions in ordinary work from 18 to 5.* The saving in actual time of the workmen by such elimination of unnecessary operations has been applied in the

*See "Motion Study," by Frank B. Gilbreth, published by D. VanNostrand Company.

introduction of scientific management in shop work in thousands of cases and can be applied to the various operations of construction work in a similar manner.

Methods of subdividing the work in concrete construction are illustrated near the end of this chapter on page 70 and are also discussed in various places in the other chapters of the book. In fact, nearly all the material in this book is based on time studies of unit operations. The application of unit times and of methods of subdivision to scientific management in construction work is indicated in Chapter V, which follows.

This discussion is not meant to imply that every builder must divide his cost keeping into elementary units. The degree to which such records can be followed is discussed in the pages which follow. The purpose of this elementary division into unit times is (1) to fix actual tasks or piece-rates for the men; (2) to show where unnecessary motions or operations may be eliminated; and (3) to plan the work ahead and prevent waste of time of men and machinery. This really scientific analysis of the work, which enables all operations to be planned ahead, is what produces the vast economies incident to scientific management.

UNIT TIMES

The term "Unit Times" has been used in the preceding pages. This may be defined as follows: "Unit Times" are the times required to perform the elementary or unit operations into which a piece of work may be divided. The purpose of unit times is to separate the elements that are alike in various pieces of work from the elements that vary or which occur a different number of times.

It is evident that the term may apply to different degrees of division. For example, in the construction of the wall cited above, the units consist of the operation of laying one face brick, laying one corner brick, and so on, this degree of separation being all that is required for the purpose. On the other hand, for the elementary time study of motions, the units are taken as the individual motions required in laying a single brick.

Unit costs are the costs of unit operations.

TIME STUDY

"Time Study" is the process of analyzing an operation into its elementary operations and observing the time required to perform them.

These unit times are taken with a view to recombining them into other operations.

COST KEEPING

It is not the purpose of the present volume to take up methods of cost keeping in detail but, before discussing the more important questions of organization, a few general principles will be suggested.* The plan to follow in cost keeping is dependent, in a measure, upon the method of recording the work of each man. Under the ordinary type of management, the timekeeper goes his rounds, and records, frequently by guess, the classes of work upon which the different men are engaged. Under the more systematic plans, where the work of each man or group of men is indicated on separate time cards, the cost records are made up from these cards. The purposes of time-study are entirely different from those of cost-keeping. The aim of time-study is to systematize the work and to set tasks for the workmen, while the aim of cost-keeping is to show how much the work is costing.

Contractors and engineers throughout the country are coming to realize the value of keeping accurate cost records, either separately or in connection with the time keeping, so as to divide the labor costs into the different classes of work, (1) to determine whether the work is being carried out on schedule time, (2) to see whether the costs are falling within the estimates, and (3) (perhaps more important than either) to give each foreman a daily or weekly report showing the cost of the work under his charge so that he can see where he is going wrong before it is too late.

The more advanced construction companies have so organized their records that by ten o'clock each day each foreman is given a record of the work which his men have accomplished on the previous day.

The great difficulty, even with the best organizations, as they have existed in the past, has been that it has been impossible with ordinary methods to divide the work into sections or divisions which can be properly compared one with another. For example, as stated on page 56, in bricklaying a mason one day may lay 2600 brick in a 32-inch wall, while on the next day, working with the same energy and industry, he may lay only 150 brick in an ornamental house front. It is

*Methods of cost keeping on construction work are described in detail by Gillette and Dana, in "Cost Keeping and Management Engineering," The Myron C. Clark Co., Publishers.

evident that records of his work are valueless unless they are accompanied by an exact description of the details of his work and this description frequently has not been given in the past.

Even in the simplest concrete mass work, the labor cost varies with the handling of the raw materials, the output of the mixing machine, the distance to which it is transported, and numerous other variable elements. It is only by careful analysis and study of unit operations and unit times that these may be scheduled in advance so as to bring the time or cost of performing the work under different conditions down to the same basis.

The methods outlined in this chapter and the actual data in chapters that follow indicate the trend of the best and most modern construction management based on scientific principles. From a study of these principles it is evident that cost-keeping is simply a small auxiliary in organization.

DIFFICULTIES OF RECORDING COSTS BY USUAL METHODS

The statement has been made already that the ordinary methods of cost determinations are almost valueless. This applies both to cost keeping as carried out by the builder and to the force account of the supervising engineer. The fundamental reason is that guesswork methods have been used in place of accurate scientific methods.

To obtain cost records that are of value either to the builder or to the engineer, several essential elements must be recognized, even if methods of unit times are not used. These essentials may be outlined as follows:

(1) Accurate subdivision of the work into distinct operations.
(2) Accurate records of time.
(3) Knowledge of exact quantities.
(4) Proper apportionment of cost of plant.
(5) Proper apportionment of general expense.
(6) Proper apportionment of cost of materials.
(7) Full description of each item of work.

(1) Accurate subdivision of each section of the work into its distinctive operations is of prime importance. The methods described on pages 55 to 58 afford the means for dividing the work into its proper elements with great accuracy. The same general scheme of division, however, carried to a lesser degree, may be fol-

lowed in ordinary cost keeping with far better results than have usually been attained.

In the construction of a concrete conduit, for example, the cost records at least should separate the labor into such operations as: lay invert, place and remove centers, lay the arch, place the reinforcing metal (if any is used), and finish the interior. If fewer divisions than these are made, the total costs obtained may some times show the cost to the contractor of this particular job as a whole and may also indicate the probable cost of another conduit of exactly the same design, but these are the limits of their value.

(2) That accurate records are necessary would seem self-evident, but the difficulty in making an exact count of the men at work on the job, and an exact memorandum of the times, is surprising. Generally the men are constantly changing position, and frequently one or more of the men in the gang may have been taken away to fetch material or for some other purpose, so that they are left out in the count. A timekeeper learns to guard against these difficulties to a certain extent, although frequent mistakes are made unless the man is constantly on the spot. The time on force accounts, or even on a contractor's cost keeping records, is often taken by days or half days instead of by hours or quarter hours and the workman's time is charged to the job he is on when the timekeeper makes his round so that the returns are inaccurate. In other cases, a whole day's work is credited to a certain item even when the men leave before quitting time or change on to other work.

(3) Knowledge of the exact quantity of work performed is as necessary as the recording of the times for doing the work. In certain classes of work differences in the condition of the material affect the quantity. For example, in earth work, or in the handling of sand and gravel, not only is it difficult to measure the quantities but there is a large percentage of difference in quantity depending upon whether the material is measured in the cut or loose or shaken.

(4) The cost of the plant, including its first cost, depreciation, repairs, and renewals, is an extremely important item and requires careful judgment in apportioning. The factors which must be taken into account in a concrete mixing plant, for example, and which are more fully discussed in Chapter XII, are the probable value of the plant after this work is complete, the number of days per year in which it can be operated, the time lost in shut-downs for repairs, and the actual cost of repairs and renewals. The cost of tools, such as shovels,

picks, etc., must be included in the cost of plant unless otherwise provided for.

(5) On a small job the general expense is readily apportioned. Upon a large job where the work includes, for example, earth excavation, rock excavation, concrete, and riprap (and often several different classes of each) not only the pay of the foremen, but the salaries of the general superintendent, the contractor's engineer, the timekeeper, and the office force (a part of which is sometimes located on the work and a part at the contractor's general offices) must be fully known, and properly apportioned to each class of work. The method that sometimes has been followed of dividing the total general expense by the number of classes of work into which the job is divided is inaccurate, because one class may cost ten times as much as another. The division by cost is difficult because the cost is not known until after the records are taken. A simple method, which is sufficiently accurate in most cases, is to approximately divide the general expense in proportion to the number of men engaged on each class of work. The division need not be made mathematically but by estimation. The accountant may judge, for example, from inspection of the records that three-tenths of the general expense should go to one class of work, one-tenth to another class of work, and so on.

(6) The cost of materials must be divided among the work actually performed. Materials sufficient to last for several months may be purchased during a single week. If this total cost is divided by the number of yards of concrete laid, for instance, in a week or a month, the result will be very misleading. On one job, for example, the unit cost of a certain class of work, as given in the engineer's cost sheets, varied from 73¢ in one month to 19¢ in another, solely for the reason that most of the materials were purchased the first month and were all charged up to the cost of the work during that month. To provide for this, the accountant should know the approximate amount of material used in a definite quantity of work, and should carry forward the material on hand. If this division is impracticable, the next best way is to keep the material and labor separate and allow the man who is making up the cost sheets to estimate the cost of the material from his knowledge of quantities.

(7) Lack of description renders many careful records of costs absolutely valueless, except for determining whether a contractor is making money. For example, on one job very accurate records of cost of earthwork were made by the engineers, giving the number

of men employed, the number of carts, cost of superintendence, cost of tools, and many other details, while the length of haul or the character of the material handled was not stated. The result was an accurate record of the cost of labor on this particular job, but one which was absolutely useless in estimating the probable cost of other work, of a similar nature, that was being done by the same Engineering Commission. In another case, the times of the men on all classes of work, including the engineer and other men in the various offices of the contractor, were carefully recorded on large cost sheets. The work included several kinds of concrete construction. One kind was found to cost $4.08 per cubic yard, another kind, $6.28, and another kind, $7.98, but nothing was shown on these sheets to indicate the reason for these differences. No definite description was given of the character of either job, and the only means of comparing them would have been to look up the contract and the plan, and then probably find that each class covered so broad a range as to provide no definite information. The amount of information required to properly describe any piece of work depends upon its character and the minuteness of the cost or time observation. If simply general costs are being compiled, the analysis of almost any class of work will show that there are a few, perhaps not over a half dozen, essentials which will usually give reason for an apparently low or for an excessive cost. Although, even with such data, cost keeping will not give the exact basis for estimates that may be obtained with the more scientific methods of unit times described later in the chapter, the results may be recorded in such a way as to aid materially the judgment of an experienced engineer or a contractor.

Analysis of Concrete Labor. For illustration, some of the essential elements that must be recorded for approximate cost records of concrete work are as follows:—proportions; length of haul of sand and stone; length of haul of cement; method of mixing; length of haul of concrete; method of transportation; thickness of wall; reinforcement; surface area of forms; surface finish.

Many of such descriptive items need not be given day after day but a single general statement for each class of work is sufficient.

VARIATION IN COSTS OF SIMILAR JOBS

In the preceding paragraphs reference has been made to the difficulty in obtaining really accurate results by ordinary methods of cost keeping. To illustrate this still more clearly and to show further the need of more thorough treatment even of so simple a piece of work as laying mass concrete, two jobs may be taken which in an ordinary force account would have nearly identical description but which even a superficial study will show to be very different. On page 69 the same problem is treated by the more accurate unit time analysis.

The description of the two jobs illustrates the more important differences which affect the variation in cost of mass concrete.

On Job A the following conditions will be assumed:

1:2:4 hand-mixed concrete.
Gravel screened to separate sand and gravel.
Sand and gravel wheeled in barrows 100 feet.
Cement in barrels hauled 5 miles in wagons.
Wet concrete wheeled 100 feet and dumped to place.
No forms.
Wages of labor, $1.75 per 8-hour day.
Conditions such that concreting must be stopped on the average one hour before quitting time, when men are set to digging.

The actual average cost by the authors' estimate (made directly from tables in Chapter XI) of the labor on the concrete under the above conditions—including placing and ramming and time of foreman and, in addition, 15 per cent for superintendence, overhead charges, etc.—would be $2.51 per cubic yard of concrete in place. An ordinary force account or cost keeping record, if accurately taken, ought to give this figure. On the other hand, if the costs are kept by one who is not constantly on this part of the job, perhaps no allowance may be made for the variable time, averaging one hour per day, upon which the men are at work digging. With this item neglected, the records would show $2.87 per cubic yard for labor.

In this connection it may be well to state that force or cost keeping accounts kept by inexperienced men are apt to indicate a lower cost of work instead of a higher cost, as assumed above, because of the difficulty of taking accurate records.

On Job B the following conditions will be assumed:

1:3:7 hand mixed concrete.
Broken stone delivered to mixing platform, and charged as material.
Sand wheeled 100 feet in barrows.
Wet concrete wheeled 25 feet and dumped to place.
No forms.
Wages of labor, $1.35 per 10-hour day.

The actual average cost, by the authors' estimate—made, as in Job A, from tables in Chapter XI—of the labor of concreting under the above conditions, including placing, ramming, and foreman, and, in addition, 15 per cent for superintendence, overhead charges, etc., would be $0.83 per cubic yard of concrete in place.

If wages are assumed to be the same as on Job A, namely, $1.75 per 8-hour day, the labor cost would be $1.33 per cubic yard of concrete in place.

A comparison of these prices with the cost on Job A, namely, $2.51 per cubic yard for labor with careful time keeping (or $2.87 with a less carefully kept force account), illustrates the variation in cost which may occur on two jobs apparently similar. Yet every one of these variables may be allowed for in advance if the unit costs are known.

In thin walls or conduit construction, the forms are expensive, often costing more than the labor on the concrete. The placing of steel reinforcement also involves additional labor and delays the concreters. In such types of construction, the difference in cost of different jobs will be much greater than in the examples considered. Simple cases have been selected for illustration because in these the differences are less evident. The methods of unit costs account for such variables and are therefore even more valuable in complicated than in simple work.

Every engineer and contractor who is required to make careful estimates of intricate work realizes the inaccuracy of ordinary methods of keeping costs and the necessity for a system by which careful records upon one job will indicate the probable cost of another subsequent job.

On the jobs considered, the cost of Job A gives absolutely nothing upon which to base the estimate for the cost of Job B, except that an experienced man who is right on the job and who is accustomed to guessing may form a fairly close "guess" of the cost of the other work. Innumerable sets of conditions might be cited, similar and yet enough unlike to mislead the judgment.

No doubt very accurate estimates are made by the ordinary guesswork methods by men possessed of extraordinary judgment and who have had years of practice upon the work in question. However, even such men will fall down and will make serious mistakes when called upon to estimate in a line of work with which they have had a very slight experience.

UNIT TIMES AND TIME-STUDIES

The example just given indicates the necessity, in making estimates of construction work, for something more than over-all guesses. The introduction by Mr. Taylor of scientific management into shops and factories showed the possibilities of unit time methods, not only as an aid to shop organization, but as one of the means for eventually introducing scientific methods into out-of-door construction work. The experience obtained in shop management made it clear that methods adapted for finding the proper time for doing work and the proper rates of pay are also useful for making up advance costs, that is, for making estimates. In shop work and in construction work, the objects sought for are fundamentally the same, namely, to determine in each case the time it should take (either under average conditions or under the most favorable conditions) to do a given piece of work.

Before describing the methods adopted in the studies of unit times as applied especially to construction work, we shall discuss briefly the general principles which are applicable to all classes of work.

In 1885 Mr. Taylor, then chief engineer of the Midvale Steel Company, devised a system of management, involving a scientific analysis of the most efficient movements of workmen, followed by a study of the proper time for making each movement, which enabled him to cut down the labor costs in a marked degree—in many cases to one-third or one-quarter the former costs—and at the same time to increase the pay of the employees from 40 per cent to 50 per cent. The secret of his success in fixing rates which proved satisfactory to both employer and employed, which allowed a man to do a maximum day's work and receive therefor a maximum day's pay without fear of being cut, lay in the application of scientific methods to the fixing of these piece-rates and tasks. By the usual methods of rate-fixing, the cost per piece under day-work methods is figured and a guess is made of the time in which a man ought to perform the work when working at a higher speed with the greater incentive of a piece-rate instead of an hour-rate. It has been found that the rate of speed on day-work forms absolutely no basis for the rate which may be expected on piece-work. Consequently this method results in very unequal rates and the necessity of raising or, more often, cutting the rates after the men begin work under them.

Instead of employing this "cut and try" method, Mr. Taylor analyzed each job, and found by careful observation the time required for a first-class man to perform each elementary or unit portion of the job. Then, by combining these units and adding a fixed percentage for rest and necessary delays, an accurate time was obtained which could be used for fixing the rate upon that particular job. Furthermore, these unit times were useful not only for this job, but with a few additional unit times, they fitted other similar jobs. In other words, many unit portions of different jobs are identical, and by combining the unit times in different ways, it was found that tables of times could be compiled suited to all ordinary conditions and materials.

Not only did these methods show how to determine the times for doing work in different ways, but, perhaps still more important, they enabled the time-study man to separate from the useful motions the operations and the motions which were entirely unnecessary. The omission of these motions not only reduced the cost of performing the work but made its performance easier for the workman. In other words, it was found that by eliminating useless motions a job could be accomplished not only in a much less time but with a great deal less effort as well.

The same methods which have been adopted to such a large extent in shop organization have been found to apply to engineering construction. By the adoption of this system, it has been found possible to compile the unit times and costs for various classes of construction work and in the present volume are given the data obtained in the line of concrete construction.

In shop work, the methods of unit times and costs have been used largely for the purpose of introducing scientific management with task-work.* This is its most important object, but, as has already been stated, it is useful in determining the average times and costs as a basis for estimating ordinary work as well as that which is managed under the most approved methods. The larger part of the data and tables in this book are compiled on the latter basis, that is, on the basis of the labor of an average man working by the day for a contractor. Considerable information is presented, however, which will aid the builder who wishes to systematize his work and reduce costs. For example, times and costs are given throughout the book showing the accomplishment of a quick man working steadily. Ultimately, the authors predict that, with the carrying out

*Task-work is defined on p. 86.

of their methods of unit times to logical sequence, piece-work or task-work will be applied more and more to engineering construction. A number of successful instances of its adoption are cited in the present volume. The chapter which follows presents suggestions for such organization.

PRINCIPLES OF UNIT TIMES

The uncertainty of attempting to estimate the probable cost of one job by means of the records of another similar one has been illustrated on page 64. By means of unit times,* on the contrary, nearly all conceivable conditions and contingencies in estimating costs may be allowed for. After construction has commenced, even if some form of task-work or piece-work is not to be introduced, the unit times are useful in connection with the force account or cost keeping.

The method of unit times is best understood by an illustration. We may take the two jobs, A and B, described on page 64, for comparing this method with the usual method of figuring costs. The statement there given presents an analysis of the work in nearly the form necessary for studying its units.

Besides keeping account of the total cost of labor per cubic yard of concrete laid, the separate times are observed of each of the units into which the complete operation is divided. The possibility of such observations and the accuracy which can be attained in recording them are illustrated in connection with the tables presented in subsequent chapters.

A tabulation of the units of Job A, the time of each unit being the sum of the times of all the men except the foreman working upon any one operation, is given in a table on the following page.†

With labor at \$1.75 per day of 8 hours, the rate per minute is $\frac{\$1.75}{8 \times 60} = \$0.0036$. Adding 15 per cent for foreman and 15 per cent extra for superintendance, overhead charges, etc., the rate per minute is \$0.0048 and the cost per cubic yard of concrete is $519.5 \times \$0.0048 = \$2.51$.

The first impression of such an array of figures may be that it is complicated and costly to compile. This is true in comparison

*Unit times are defined on p. 58.

†The times in the tabulation are from Table 55 in Chapter XI.

with the ordinary method of keeping records and making estimates, but the illustrations already given show that the ordinary methods are of very slight value in estimating new work, unless it is absolutely identical with the old, or even of keeping track of progress. The unit values, on the other hand, are capable of application to other jobs. Having once been found, they apply to other places directly. Even if used merely in one job which involves thousands of dollars, the cost is insignificant.

UNIT TIMES ON JOB A

(See Table 55, page 312)

Item	Operation	Time Per Cu. Yd. of Material	Time Per Cu. Yd. of Concrete
		min.	min.
(1)	Screening gravel	93.8	82.5
(2)	Loading gravel into barrows (included in measuring item under mixing).		
(3)	Wheeling gravel 100 feet (25 feet included in measuring item under mixing).		
	Add for additional 75 feet	9.2	8.1
(4)	Loading sand into barrows (included in measuring item under mixing).		
(5)	Wheeling sand 100 feet (25 feet included in measuring item under mixing).		
	Add for additional 75 feet	8.2	3.6
(6)	Loading cement in barrels on to wagons, per bbl.	1.9	3.0
(7)	Hauling cement 5 miles (assuming the time of wagon with 2 horses as equivalent to 2 men), per bbl.	82.5	129.5
(8)	Unloading cement, per bbl	2.9	4.6
(9)	Mixing concrete		236.7
(10)	Loading barrows (included in mixing).		
(11)	Wheeling wet concrete first 25 feet		34.4
(12)	Wheeling additional 75 feet		17.1
(13)	Ramming or puddling (included in mixing).		
	Total time per cubic yard of concrete		**519.5**

To apply the unit tabulation to Job B, page 64, we may select the required units from the given list of times, and adapt them to the 1:3:7 concrete. Items (1), (2), and (3) from unit times on Job A are omitted because broken stone, which is charged as material and therefore does not come into the labor cost, is substituted for gravel. Items (6), (7), and (8) are also omitted because the cement is at hand, and Item (12) is not required as the concrete is only wheeled 25 feet. We thus have for Job B:

UNIT TIMES ON JOB B

(See Table 55, page 312)

Item	Operation	Time Per Cu. Yd. of Material	Time Per Cu. Yd. of Concrete
		min.	min.
(1)	Loading sand into barrows (included in measuring item under mixing).		
(2)	Wheeling sand 100 feet (25 feet included in measuring items under mixing), add for additional 75 feet	8.2	3.6
(3)	Mixing		239.2
(4)	Wheeling wet concrete 25 feet and dumping		34.4
	Total time per cubic yard of concrete		**277.2**

With labor at $1.35 per day of 10 hours and figuring the rate per minute as for Job A, the total cost of Job B per cubic yard of concrete is $0.83 or about one-third the cost on Job A.

It is evident that, with a few additional units, any ordinary job of concrete may be covered. Furthermore, by the employment of the cost tables given in subsequent chapters, any job may be analyzed and the cost obtained directly by combining the proper items from the tables. Operations not covered by the tables may be studied by methods described in the next chapter, or independent investigations may be made by these methods.

EFFECT OF QUALITY OF MEN

In this discussion, the variation in cost due to difference in the quality of the men and the management has not been considered. These variables may never be entirely accounted for in any system of organization, although the introduction of scientific management with task-work largely eliminates them.

The amount of work, performed in a given time by a laborer who is working by the day, does not necessarily vary with the amount of his wages. In general, if a man is paid less than the average wage in the section of the country where he is employed, he will do less than an average day's work. If paid higher than the average wage, he will do a large day's work. But, when paid the average local wages, if these fluctuate from year to year, the laborers will generally do less work in the periods of higher prices than when lower prices prevail, because high prices in a fluctuating market are apt to be the result of scarcity of labor and men are therefore more independent. If working by the day they cannot be hurried, because if discharged, they can easily get another job. In busy times, therefore, a contractor frequently must not only pay higher rates of wages, but he receives, at the same time, less returns for a day's payment. The excess cost due to this cause can be estimated approximately by judgment by an experienced contractor or engineer.

The physical ability of men is a variable which is apt to average itself, except when labor is scarce and it is necessary to employ men unsuited for the work in hand, another disadvantage to the contractor who is paying high wages in busy times.

The temperature may affect the amount of work performed. On a very hot day or a very cold day, men are apt to do less work than when the temperature is moderate. This variable need not be considered except on short jobs performed in exceptional weather. Exceptional climatic conditions, however, such as work in the Tropics or in the Arctic regions require special study to determine the proper percentage to add to average costs of labor.

The quality of the foreman on a construction job under the ordinary type of management produces an astonishing effect on the amount of work accomplished by men on day wages. In certain cases that have come under the observation of the authors, men have accomplished 50 per cent more work in a given time under a first-class foreman than similar men working under exactly the same conditions with a poor foreman over them. This dependence of the contractor upon his foreman—and it is not by any means confined to construction work but is just as much in evidence in old-fashioned factory methods—illustrates the great need of some system of management which will eliminate the variation in cost due to this cause. Functional foremen acting in connection with a planning department, as described on pages 82 to 86, have accomplished this object most successfully in the shops which have adopted scientific management.

ESTIMATES AS ACCURATE AS POSSIBLE

The objection has been raised sometimes by contractors of the old school that, because of these variations in labor costs that are impossible to allow for in advance in day-work operation, it is useless to attempt accurate estimates of labor. As a matter of fact, the actual variation in cost due to the quality of the men seldom amounts, in money value, to nearly so much as the variations in cost due to varying methods of work and local conditions which can be taken care of if the items are properly subdivided. At any rate, any argument for guess-work, based on these reasons, is wrong. The fact that certain variables occur that must be allowed for by judgment simply shows the greater necessity for making provision for all the variations that can be estimated. Furthermore, if a builder has made accurate itemized estimates of labor costs as well as material costs and he finds that this estimate is being exceeded, he knows that something is wrong and it is up to him to determine the cause and if possible to rectify it. Not only this, but even if he has not reached the point where he is ready to introduce a system which is really scientific, the subdivisions which he has used in his estimate will enable him to lay out the work more carefully and will aid him in picking out the weak points.

As management of construction work becomes more scientific and the operations of the various men are planned ahead and tasks laid out, these variables will be eliminated in a very great measure.

CHAPTER V

TASK-WORK IN CONSTRUCTION

The labor question will be reduced to a sound basis when a man is paid, not a lump sum per day regardless of his efficiency, but in accordance with the amount of effective work that he accomplishes. The exact form in which the man is rewarded is of less importance than the general principle that he must receive large pay whenever he does a large day's work. The extra wage may be paid directly as day wages with the understanding that the output per day must equal a certain amount; it may be in form of piece-work, provided the rates are fixed so scientifically that no cutting of rates is permitted; it may be given as a bonus to the man who is efficient; or it may be in the form of task-work where the work of each man is definitely planned in advance and a definite time is scheduled for the accomplishment of each task.

The introduction of any of these forms of remuneration, if they are to prove successful, involves the formation of an organization that will plan ahead the work of each day for each man on the job. The work is thus laid out and instruction cards made that will tell the men or the foreman not only what to do but how to do it in the best possible manner and quickest possible time.

This may seem an insurmountable task on a construction job, involving, as it does, a systematic arrangement of the work until recently unheard of and requiring what is particularly abhorrent to the so-called practical man, a body of clerks on the job engaged in planning the work and taking time-studies upon which to base the tasks. The possibilities of such a system for increasing output and reducing cost are shown, however, in the factories that have adopted scientific management. In these shops, task-work methods have been introduced into most intricate classes of operations, such as miscellaneous machine shop and foundry work, as well as into simpler although still complicated processes,—processes more complicated than any occurring on construction work. Establishments adopting scientific management include steel works, textile manufactories, shoe factories, metal works, printing shops, bleaching works and in fact practically all types of manufacturing plants.

Engineering construction in one respect is less adapted to scientific organization than are manufacturing processes because the jobs are apt to be of short duration. On the other hand, a construction company having once established scientific piece-rates or tasks and systematized the methods of handling them, may use them on subsequent work of a similar nature with but little alteration. Besides this, construction operations are much simpler as a rule than the industrial processes in factories and machine shops.

The trend of construction work is toward better and better organization. Systems of cost keeping are now in successful use in the well-regulated construction companies, which, a few years ago, would have been considered absolutely impracticable. With such systems, the performance of each gang, and sometimes in fact, the performance of the individual man is recorded and tabulated, so as to give the complete costs each day.

The next important step will be to make a thorough and minute study of every element of construction work so as to determine, not only the best, but the cheapest and quickest way of doing each small part of each kind of work; and then will follow, inevitably, the introduction of various forms of payment for the workmen based, not on a uniform day wage, but on actual performance that will reward the workman who accomplishes his work quickly and well.

In the present volume it has been impossible, because of the small number of thoroughly organized jobs, to present complete records of time and cost by first-class men under efficient management. Most of the times and costs, therefore, are based on average conditions and apply more accurately to the estimating and control of construction work where the men are paid by the day than to the higher forms of organization. It is possible however, to use the material presented in the chapters which follow as a basis for organizing the construction work so as to pay the men in proportion to the actual amount of their output.

The first introduction of scientific management is expensive because it involves a complete change in the manner of doing work. In fact, any methods involving the introduction of unit times and costs are costly because of the amount of detail study involved. The preparation and reorganization—the getting ready to produce results—is the most difficult part of the performance, and it should not be entered into without very careful consideration and a thorough understanding of the difficulties. The labor of making the time studies for fixing rates or tasks is large, although it constitutes only one part of the plan of organization, and it is still more difficult and tedious to work up these notes into proper form to obtain averages for the fixing of piece rates or tasks.

In spite of the difficulty and the expense of perfecting an organization that will handle work of this nature according to this method, the introduction of scientific methods into most classes of construction work will pay many times over. On the first job, the overhead charges will be large, but, once established in the organization of a contractor or builder, the systematic handling of men and materials and the increase in output of the workers will lower the total costs to a remarkable degree. In some kinds of work, such as form making, the systematizing has paid for itself from the very beginning, including even the expert work required to introduce the system.

The saving in cost will occur in the following ways:

(1) Materials are handled systematically and therefore more economically.

(2) Materials are placed by laborers in the best positions for economical use.

(3) The skilled workman is instructed exactly how to do his work in the best and most economical way and loses no time waiting for instructions.

(4) No time is lost by skilled workmen in getting materials.

(5) Time is saved all through the job by the elimination of unnecessary operations.

(6) The workman turns out a larger amount of work at a less cost.

(7) Machinery charges are reduced because of larger output per day.

When the men are paid in proportion to the work that they individually do, they have an incentive to perform a quantity of work largely in excess of that to which they are accustomed when working by the day. This, when properly managed, results in higher wages for the workman and lower costs for the employer.

The application of the principles and methods of scientific management to construction work is outlined briefly in the paragraphs which follow.

SCIENTIFIC MANAGEMENT

The difference between the old methods and the new methods of management is discussed by Mr. Taylor in "The Principles of Scientific Management,"* page 35:

Under the old type of management success depends almost entirely upon getting the "initiative" of the workmen, and it is indeed a rare case in which this initiative is really attained. Under scientific management the "initiative" of the workmen (that is, their hard work, their good-will, and their ingenuity) is obtained with absolute uniformity and to a greater extent than is possible under the old system; and in addition to this improvement on the part of the men, the managers assume new burdens, new duties, and responsibilities never dreamed of in the past. The managers assume, for instance, the burden of gathering together all of the traditional knowledge which in the past has been possessed by the workmen and then classifying, tabulating, and reducing this knowledge to rules, laws and formulæ which are immensely helpful to the workmen in doing their daily work. In addition to developing a *science* in this way, the management take on three other types of duties which involve new and heavy burdens for themselves.

These new duties are grouped under four heads:

First. They develop a science for each element of a man's work, which replaces the old rule-of-thumb method.

Second. They scientifically select and then train, teach, and develop the workman, whereas in the past he chose his own work and trained himself as best he could.

Third. They heartily coöperate with the men so as to insure all of the work being done in accordance with the principles of the science which has been developed.

Fourth. There is an almost equal division of the work and the responsibility between the management and the workmen. The management take over all work for which they are better fitted than the workmen, while in the past almost all of the work and the greater part of the responsibility were thrown upon the men.

It is this combination of the initiative of the workmen, coupled with the new types of work done by the management, that makes scientific management so much more efficient than the old plan.

Three of these elements exist in many cases, under the management of "initiative and incentive," in a small and rudimentary way, but they are, under this management, of minor importance, whereas under scientific management they form the very essence of the whole system.

The fourth of these elements, "an almost equal division of the responsibility between the management and the workmen," requires further explanation. The philosophy of the management of "initiative and incentive," makes it necessary for each workman to bear almost the entire responsibility for the general plan as well as for each detail of his work, and in many cases for his implements as

*Harper and Brothers, Publishers, 1911.

well. In addition to this he must do all of the actual physical labor. The development of a science, on the other hand, involves the establishment of many rules, laws, and formulæ which replace the judgment of the individual workman and which can be effectively used only after having been systematically recorded, indexed, etc. The practical use of scientific data also calls for a room in which to keep the books, records, etc., and a desk for the planner to work at. Thus, all of the planning which under the old system was done by the workman, as a result of his personal experience, must of necessity under the new system be done by the management in accordance with the laws of the science; because even if the workman was well suited to the development and use of scientific data, it would be physically impossible for him to work at his machine and at a desk at the same time. It is also clear that in most cases one type of man is needed to plan ahead and an entirely different type to execute the work.

The man in the planning room, whose specialty under scientific management is planning ahead, invariably finds that the work can be done better and more economically by a subdivision of the labor; each act of each mechanic, for example, should be preceded by various preparatory acts done by other men. And all of this involves, as we have said, "an almost equal division of the responsibility and the work between the management and the workman."

To summarize: Under the management of "initiative and incentive" practically the whole problem is "up to the workman," while under scientific management fully one-half of the problem is "up to the management."

Perhaps the most prominent single element in modern scientific management is the task idea. The work of every workman is fully planned out by the management at least one day in advance, and each man receives in most cases complete written instructions, describing in detail the task which he is to accomplish, as well as the means to be used in doing the work. And the work planned in advance in this way constitutes a task which is to be solved, as explained above, not by the workman alone, but in almost all cases by the joint effort of the workman and the management. This task specifies not only what is to be done but how it is to be done and the exact time allowed for doing it. And whenever the workman succeeds in doing his task right, and within the time limit specified, he receives an addition of from 30 per cent to 100 per cent to his ordinary wages. These tasks are carefully planned, so that both good and careful work are called for in their performance, but it should be distinctly understood that in no case is the workman called upon to work at a pace which would be injurious to his health. The task is always so regulated that the man who is well suited to his job will thrive while working at this rate during a long term of years and grow happier and more prosperous, instead of being overworked. Scientific management consists very largely in preparing for and carrying out these tasks.

INTRODUCTION OF SCIENTIFIC MANAGEMENT

The general principles to follow in the introduction of scientific management in the simpler types of work, such as the building trades, are similar to those adopted in the management of shops. They are presented by Mr. Taylor in the same volume from which we have just quoted, page 116:

The science which exists in most of the mechanic arts, is, however, far simpler than the science of cutting metals. In almost all cases, in fact, the laws or rules which are developed are so simple that the average man would hardly dignify them with the name of science. In most trades, the science is developed through a comparatively simple analysis and time study of the movements required by the workman to do some small part of his work, and this study is usually made by a man equipped merely with a stop-watch and a properly ruled notebook. Hundreds of these "time-study men" are now engaged in developing elementary scientific knowledge where before existed only rule of thumb. Even the motion study of Mr. Gilbreth in bricklaying (described on pages 77 to 84) involves a much more elaborate investigation than that which occurs in most cases. The general steps to be taken in developing a simple law of this class are as follows:

First. Find, say, 10 or 15 different men (preferably in as many separate establishments and different parts of the country) who are especially skilled in doing the particular work to be analyzed.

Second. Study the exact series of elementary operations or motions which each of these men uses in doing the work which is being investigated, as well as the implements each man uses.

Third. Study with a stop-watch the time required to make each of these elementary movements and then select the quickest way of doing each element of the work.

Fourth. Eliminate all false movements, slow movements, and useless movements.

Fifth. After doing away with all unnecessary movements, collect into one series the quickest and best movements as well as the best implements.

This one new method, involving that series of motions which can be made quickest and best, is then substituted in place of the ten or fifteen inferior series which were formerly in use. This best method becomes standard, and remains standard, to be taught first to the teachers (or functional foremen) and by them to every workman in the establishment until it is superseded by a quicker and better series of movements. In this simple way, one element after another of the science is developed.

In the same way, each type of implement used in a trade is studied. Under the philosophy of the management of "initiative and incentive" each workman is called upon to use his own best judgment, so as to do the work in the quickest time, and from this results in all cases a large variety in the shapes and types of implements which are used for any specific purpose. Scientific management requires first, a careful investigation of each of the many modifications of the same implement, developed under rule of thumb; and second, after a time study has been made of the speed attainable with each of these implements, that the good points of several of them shall be united in a single standard implement, which will enable the workman to work faster and with greater ease than he could before. This one implement, then, is adopted as standard in place of the many different kinds before in use, and it remains standard for all workmen to use until superseded by an implement which has been shown, through motion and time study, to be still better.

With this explanation it will be seen that the development of a science to replace rule-of-thumb is in most cases by no means a formidable undertaking, and that it can be accomplished by ordinary, every-day men without any elaborate scientific training; but that, on the other hand, the successful use of even the simplest improvement of this kind calls for records, system, and coöperation where in the past existed only individual effort.

There is another type of scientific investigation which has been referred to several times in this paper, and which should receive special attention, namely, the accurate study of the motives which influence men. At first it may appear that this is a matter for individual observation and judgment, and is not a proper subject for exact scientific experiments. It is true that the laws which result from experiments of this class, owing to the fact that the very complex organism—the human being—is being experimented with, are subject to a larger number of exceptions than is the case with laws relating to material things. And yet laws of this kind, which apply to a large majority of men, unquestionably exist as a guide in dealing with men. In developing these laws, accurate, carefully planned, and executed experiments, extending through a term of years, have been made, similar in a general way to the experiments upon various other elements which have been referred to in this paper.

Perhaps the most important law belonging to this class, in its relation to scientific management is the effort which the task idea has upon the efficiency of the workman. This, in fact, has become such an important element of the mechanism of scientific management, that by a great number of people scientific management has come to be known as "task management."

There is absolutely nothing new in the task idea. Each one of us will remember that in his own case this idea was applied with good results in his school-boy days. No efficient teacher would think of giving a class of students an indefinite lesson to learn. Each day a definite, clear-cut task is set by the teacher before each scholar, stating that he must learn just so much of the subject; and it is only by this means that proper, systematic progress can be made by the students. The average boy would go very slowly if, instead of being given a task, he were told to do as much as he could. All of us are grown-up children, and it is equally true that the average workman will work with the greatest satisfaction, both to himself and to his employer, when he is given each day a definite task which he is to perform in a given time, and which constitutes a proper day's work for a good workman. This furnishes the workman with a clear-cut standard, by which he can, throughout the day, measure his own progress, and the accomplishment of which affords him the greatest satisfaction.

The writer has described in other papers a series of experiments made upon workmen, which have resulted in demonstrating the fact that it is impossible, through any long period of time, to get workmen to work much harder than the average men around them, unless they are assured a large and a permanent increase in their pay. This series of experiments, however, also proved that plenty of workmen can be found who are willing to work at their best speed, provided they are given this liberal increase in wages. The workman must, however, be fully assured that this increase beyond the average is to be permanent. Our experiments have shown that the exact percentage of increase required to make a workman work at his highest speed depends upon the kind of work which the man is doing.

It is absolutely necessary, then, when workmen are daily given a task which calls for a high rate of speed on their part, that they should also be insured the necessary high rate of pay whenever they are successful. This involves not only fixing for each man his daily task, but also paying him a large bonus, or premium, each time that he succeeds in doing his task in the given time. It is difficult to appreciate in full measure the help which the proper use of these two elements is to the workman in elevating him to the highest standard of efficiency and speed in his trade, and then keeping him there, unless one has seen first the old plan and afterwards the new tried upon the same man; and in fact until one has seen similar accurate experiments made upon various grades of workmen engaged in doing widely different types of work. The remarkable and almost uniformly good results from the *correct* application of the task and the bonus must be seen to be appreciated.

These two elements, the task and the bonus, (which, as has been pointed out in previous papers, can be applied in several ways), constitute two of the most important elements of the mechanism of scientific management. They are especially important from the fact that they are, as it were, a climax, demanding before they can be used almost all of the other elements of the mechanism; such as a planning department, accurate time study, standardization of methods and implements, a routing system, the training of functional foremen or teachers, and in many cases instruction cards, slide-rules, etc.

PRINCIPLES OF SCIENTIFIC MANAGEMENT

The principles are stated more in detail on page 128 of "Principles of Scientific Management."

The history of the development of scientific management up to date, however, calls for a word of warning. The mechanism of management must not be mistaken for its essence, or underlying philosophy. Precisely the same mechanism will in one case produce disastrous results and in another the most beneficent. The same mechanism which will produce the finest results when made to serve the underlying principles of scientific management, will lead to failure and disaster if accompanied by the wrong spirit in those who are using it. Hundreds of people have already mistaken the mechanism of this system for its essence. Messrs. Gantt, Barth, and the writer have presented papers to the American Society of Mechanical Engineers on the subject of scientific management. In these papers the mechanism which is used has been described at some length. As elements of this mechanism may be cited:

Time study, with the implements and methods for properly making it.

Functional or divided foremanship and its superiority to the old-fashioned single foreman.

The standardization of all tools and implements used in the trades, and also of the acts or movements of workmen for each class of work.

The desirability of a planning room or department.

The "exception principle" in management.

The use of slide-rules and similar time-saving implements.

Instruction cards for the workman.

The task idea in management, accompanied by a large bonus for the successful performance of the task.

The "differential rate."

Mnemonic system for classifying manufactured products as well as implements used in manufacturing.

A routing system.

Modern cost system, etc.

These are, however, merely the elements or details of the mechanism management. Scientific management, in its essence, consists of a certain philosophy, which results, as before stated, in a combination of the four great underlying principles of management:

First. The development of a true science.
Second. The scientific selection of the workman.
Third. His scientific education and development.
Fourth. Intimate friendly coöperation between the management and the men.

In the pages that follow, the methods of applying scientific management to construction work are outlined briefly. The system to be followed is subordinate to the general principles that have just been given. Methods that have proved successful in shop work, however, are also being adopted in construction. These include planning the work, instruction cards, routing the materials, layout of tasks, and inspection of the work in progress. For further and more complete treatment of the subject, reference should be made to Mr. Taylor's book "Shop Management."*

THE PLANNING DEPARTMENT

It is now customary, before beginning a large job in construction, to make a chart that shows graphically the time of beginning and completing each division of the work and, in fact, each class of work on the various divisions. For example, concrete footings may be scheduled to begin April 7th and to be completed April 20th; the making of forms for the columns to begin March 15th; the setting of column forms in basement to begin April 17th and to be completed on April 22nd; and so on. Such a chart, although comparatively new in construction work, is now simply a matter of routine with many construction companies.

In shop work under scientific management, the same principle has been used for many years and has been carried out much more completely. The work that each man should perform is planned out at least a day in advance. He is given the exact time in which he should perform this task in order to earn a very high rate of pay, say, from 25 per cent to 50 per cent above his usual day rate. The department which outlines these tasks is the planning department and it holds the same place, so far as the performance of the work is concerned, as does the drafting room to the designing.

In shop work, the planning is an extremely complicated operation, involving, as it does, a knowledge of the exact location in the shop at all times of every piece in process of manufacture, and a detailed statement of the work which must be done upon it, as well as the time required by a good workman to do this work. Detailed planning as applied to construction work is much simpler. In concreting for example, it involves, as the principal plan, the layout of the number of batches of concrete that should be mixed and the location to which they are to go. Many of the operations are of course more complicated than this and require trained and thoroughly experienced

*Harper and Brothers, Publishers, 1911.

men to put the system into effect. The economy resulting from careful planning, however, just as in shop work, will be shown by the increased output per man; the avoidance of friction between different men and different gangs; the elimination of lost time in looking up work and looking for the foreman; the saving of time of the foreman giving verbal instructions; the elimination of the lost time in beginning new work and changing from one job to another; and the added expertness which will be acquired by the men who have a certain thing to do and are told a definite way to do it.

ROUTING

A complete system of routing the materials so that they will reach the right workman at the right time is absolutely essential for a thoroughly organized shop. In many classes of construction work, also, the materials have to pass through the hands of different workmen and, unless they receive the right materials at the right time, there is delay and time lost by high priced men in going after them when they could as well have been brought by laborers.

For example, in making up forms, the proper sizes of boards or plank should be brought to the carpenter by the gang of laborers. The finished sections should be transported to the building and raised from floor to floor by laborers. Necessary cleats, bolts, V-strips, nails and other items, should be furnished the carpenters in the same way, so as to avoid the loss of their time.

Methods of handling the materials are referred to more fully in Chapter XVI on Forms. Such a system as there outlined should be in charge of one particular man, who is responsible for the proper routing. It has been found in practice that the routing of the lumber and of the finished forms, not only prepares the way for the introduction of task work, but in itself alone effects a great saving in the labor costs.

INSTRUCTION CARDS

If work is planned in advance, it is necessary to tell the workmen HOW to perform it. In shop work, this is accomplished by instruction cards. On these are carefully described the work that must be done. For example, the instruction card in a binding establishment for the laying of the gold leaf on covers of a lot of books shows the sizes of gold leaf needed, the manner of cutting them out of the sheet, and the way in which they are to be placed on the cover. The workman then knows exactly how to proceed, and the saving in time and in gold pays over and over again for the few minutes required to write out the card.

In concrete construction work, the instruction card on form making, for example, consists of a drawing or blue print showing not only the dimensions but, as well, the number of boards in the section of form which is to be made, the location of the cleats, and the number of nails to a cleat. If the same job is to be repeated over and over by different men, the sketches are simply duplicated by carbon paper or blue prints. If the operations are slightly different, the variations may be designated on the same card or a new one made out.

For such work as this, one's first thought is the expense of making the sketches. This, of course, although a small item, is an appreciable one. It must be remembered, however, that the clerical labor in the planning department, not only makes the workman's task easier by telling him just what to do, but indicates the quickest method of doing it so that he may avoid unnecessary operations. It also saves the time of the foreman, who otherwise must give verbal instructions that actually waste a great deal of his time and also the time of the man he is instructing.

In these days of the twentieth century, it is almost inconceivable that a structure should be built without full plans of the structural details being prepared in the drafting room. It is universally recognized that the saving in material is far and away greater than the cost of the drawings. The planning department, described above, and the making up of the instruction cards is to the work of construction what the drafting room is to the design, and the saving in labor of the workmen through the instruction cards corresponds to the saving in material through the drawing up of the details of design.

FUNCTIONAL FOREMAN

In ordinary construction work, the foreman of each gang is supposed to hire his men; lay out and sometimes design the plant; purchase small supplies; give the workmen orders as to what they shall do; advise them how to do each piece of work; reprimand or discharge them if they do not do their work well or quickly; sometimes design certain structural details, such as forms; and at all times keep watch of every man in the gang to see that he is working at full speed.

This multitude of duties limits the number of men that a foreman can handle, so that several bosses are required even on a comparatively small job. It demands, also, such a multitude of qualities in a single man that not one foreman in twenty can handle the work even with a fair measure of economy. Not one foreman in a thousand will attain anywhere near maximum efficiency. In other words, the ordinary system of management expects the impossible.

In ordinary construction, two branches which formerly belonged to the foreman's duties, are separated almost always from them, namely, the design and the inspection. The system of planning, outlined above, separates still another function, that of distributing the work. The planning idea also indicates the advantage of the enlargement of the duties of the inspectors to see that the instruction cards are followed properly. When the piece or task-work involves quality, the products must be inspected and the standard maintained by varying the rate paid the workman in accordance with the quality of his work. By properly adjusting rates in this way, better work is assured than under day-work. Routing involves another function. The fixing of rates or tasks involves still another. The repairs to machinery and tools is also a class of work that well may come under a special foreman or repair boss.

The separation of these functions from the duties of the regular foreman, or gang boss, permits him to handle more men and to perform his other duties more efficiently. As a matter of fact, instead of several foremen performing identical duties with different gangs of men, there will be as many or more foremen but each will handle a certain type of work.

This method results, in construction work, in the separation of the functions of the foremen into:

1. Designer.
2. Instruction card man.
3. Route clerk.
4. Cost and time clerk.
5. Inspector.
6. Gang boss or foreman proper.
7. Repair boss.

On a small job several of these functions may be combined in a single man. This method results, not in an increase in the total force of workers, but in an actual and very considerable reduction of men below the number required under the old system, because under the new system the work is so carefully planned and the teaching and oversight of the workmen is so thorough that the men work more efficiently and a smaller number of workmen can do a given piece of work. The work is simply differently divided, various parts being given to men who can perform the special tasks more efficiently. At the same time the workmen are relieved of the duties of laying out their work and of deciding just how they shall do it, both of which in a complicated job take a great deal of their time. The workmen are capable therefore of turning out much more work even if they do not work at any faster speed. This fact has been proved conclusively in the introduction of scientific management into industrial establishments and similar results are now being attained in construction. The output has been largely increased even before any piece-rates or tasks have been given to the men as a reward for extra effort.

TASK-WORK

The organization that has been described is necessary before tasks can be laid out for the men and definite prices paid them for the performance of a given job. While this work of organization is progressing, however, certain jobs may well be laid out in tasks with a bonus. As has been stated above, even without a change in the methods of paying the men the plan described will result in such a systematization that the economy will be marked. The ultimate aim, however, is the introduction of task-work or some similar method of laying out the work so that each man will be paid in proportion to the amount of work that he accomplishes.

Piece-work consists in paying a man a certain price for the performance of a given job. *Differential piece-rates** are arranged so that a man who does an extra large day's work receives pay not only for the total number of pieces but is given a larger rate per piece.

In *task-work* the time that a man ought to take to do a job when working hard and to the best advantage is fixed in advance and if he accomplishes the task in the fixed time he receives a bonus.

Suppose, for example, it has been found from time study and a combination of the unit times that a carpenter, allowing, say, 20 per cent for unavoidable delays and necessary rest, should make, by working hard, a section of form in 9.5 minutes. If he accomplishes

*This system of piece-work is described in a paper read by Mr. Taylor before The American Society of Mechanical Engineers, Vol. XVI, p. 856, entitled "A Piece-Rate System."

the work in this time or less, he will be given for the period, say, 35 per cent more pay than when he is working simply by the day. If his day rate is $0.50 per hour, his regular pay for 9½ minutes is 7.9¢. Adding 35 per cent will give him a price per form of 10.7¢ provided he makes an acceptable lot of forms in the specified time. In case he fails to make them within the time, he will receive his ordinary day's pay. If he completes 10 sections in 80 minutes instead of 95 minutes, he will be paid his 35 per cent bonus on the full 95 minutes and will at once begin on the next task so that he will receive even higher than the figured rate, and he will have an incentive to work as fast as possible. If any of the forms are imperfect he will receive a smaller rate or else he will be required to repair them in his own time.

For satisfactory task-work, exact knowledge is necessary of the time required to do each branch of the work and scientific methods, such as are outlined in this chapter and in the previous one, must be employed in fixing the tasks.

Great care must be used in setting a rate to be sure that the men can accomplish the work in the given time. If they fail to earn their bonus, they immediately become discouraged. On the other hand, if the time given is longer than necessary, the men will earn more than was planned for them and will probably start "soldiering" so as to prevent their employer from knowing that a wrong task has been set. Accurate fixing of tasks and rates by experienced men is absolutely essential to success.

STEPS IN DETERMINING TIMES AND FIXING TASKS

The steps to be taken in determining unit times and costs are outlined in this chapter. The application of the tables of time and cost, in succeeding chapters, to the fixing of piece-rates or to estimating costs are given in connection with the tables. The processes here described also illustrate the methods followed in compiling the data from which the tables in this book have been computed and they also give the principal steps that are necessary in taking time notes for operations not covered by the tables or upon which comparative values are required.

Time-study by stop-watch observations has been found by the authors to be the most satisfactory, and, in fact, the only way of obtaining accurate data on unit times.

The fundamental principle, as previously stated, lies in separating the time of any operation into smaller times or unit times, for the purpose of using these unit times in various combinations. The purpose of this discussion is to describe the proper methods of obtaining these unit times, of combining them for use in determining costs or for establishing piece-rates or tasks, and, if piece-work or task-work is the object, of putting the rates thus obtained into practical use. The steps which apply only to piece-work or task-work are noted as such.

The essential steps to be taken, which are considered in detail on the pages noted, are as follows:

First. Procure two stop-watches reading preferably to hundredths of a minute instead of to seconds and prepare proper blanks, especially ruled and printed and headed, upon which the times observed can be rapidly and accurately entered. A holder for the watches and blanks in the form of a book or pad facilitates the taking of records. This is more fully discussed on page 89.

Second. Train the man who is to take the observations with the stop-watch in the use of his watch and blanks, by having him observe various kinds of work and record the proper times. See page 90.

Third. Divide the job which is to be observed into definite small parts or units, so that there may be absolute uniformity in comparing and combining the unit times. See page 90.

Fourth. For cost observations, time separately as many men as possible on each operation or unit. For setting tasks, adopt some means for inducing a first-class laborer to work at his best speed, on the job which is to be observed, for at least a long enough time to make necessary unit observations. See page 90.

Fifth. Observe, with the assistance of the stop-watch, or stop-watches, the time required to perform the unit parts of the operation, repeating the observations on each unit until a satisfactory average is obtained. Observe also the time spent by the man or men in resting and all other necessary delays, carefully distinguishing between those that are avoidable and those that are unavoidable. See page 91.

Sixth. Combine the unit times, and decide upon a proper allowance for rest. For cost observation, this time may be at once reduced to cost, and percentages, or separate items, for superintendence and for general expense added to the sum. For piece-work or task-work, rates may be fixed from these times for the job observed, taking care to see that each rate is large enough so that a first-class man will earn considerably more than his regular day wages. See pages 91 and 92.

Seventh. In piece-work or task-work, select one single laborer to start on the work, and never, under any circumstances, start more than one man on a job unless the rate is divided among a gang of men as in mixing the concrete. Continue right on with this one man, or this gang, until they have made an actual success of the work and have succeeded in earning good wages and in turning out the requisite amount of work. See page 92.

Eighth. In applying piece-work or task-work, start one man after another at work. See page 93.

Ninth. Finally, take up other work of similar nature, using, as far as possible, the unit times which have already been fixed in calculating the new costs or the new rates, and fill in the required new units by observations made in a similar way to those already described. See page 93.

These steps may be considered one by one as follows:

(1) **Implements.** The object in using watches whose dials read to hundredths of a minute instead of to seconds is to simplify the clerical work in combining times and working up rates. The construction of the works of the watch is also an important matter. The ordinary stop-watch works entirely from the stem. The first pressure of the stem starts the watch, the second pressure of the stem stops it, and the third pressure sends the hands back to zero. This leads to confusion and occasional error. A much better style of watch for time observations is one in which the starting and stopping of the watch is entirely independent of the movement which throws it back to zero. Such a watch can be constructed so that the pressure of the stem throws the hand back to zero at any time, while the starting and stopping is performed by a slide, or by a push button, on the side of the case. The object of this separation of the movements is to make it possible to stop the watch at any point and start it again from the same point without throwing the hands to zero. It is sometimes desirable, for example, to obtain the exact net time of a man upon a certain operation and it is convenient to have a watch that can be stopped whenever the man stops work, or for a moment turns to some other task, and then started again when he resumes the original operations.

The blanks for recording the time observations may be adapted for a single class of work, or they may be printed so that all kinds of timing can be recorded upon the same form. The latter is the best plan for cost observations on construction work or for introducing piece-work. On page 95, a form of blank is given which the authors have found satisfactory in practical work on engineering construction; a slight variation of the wording adapts it to factory observations also. The methods of entering the times upon this are described in the second step which follows.

It is inconvenient to hold the stop-watch in the hand when taking observations and, to avoid this, a case may be used in the form of a book with pockets to hold the watches, and means of operating them, if desired, without the knowledge of the workman who is being timed; or a board may be arranged to hold the note sheet with a pocket underneath to hold the watch. A watch book is illustrated and described on page 96.

(2) **Training Men to Make Time Study.** The second step, which suggests the training of the man before he actually begins his regular observations, may seem unnecessary. There is, however, a great knack in taking time observations properly and accurately, and there are various methods of taking the times and of handling the watches, some of which are suited to one class of work, while others are suited to different operations.

(3) **Division of Operations into Units.** An analysis of each operation, that is, a division into small parts or units, is one of the most important features. This requires on the part of the observer, not only a thorough knowledge of time-study methods, but also a knowledge of the process upon which the workman is engaged. The study of the process is made by recording the units or elements in each operation and then deciding upon just what units must be selected to satisfy all conditions. The units must be small enough so that they can be recombined to form various complete operations. The advantage of unit time methods, as compared with the taking of over-all times, is discussed on page 55.

The principles and methods of time-study, which involves this analysis of operations, are of so great importance that they are taken up at length on page 94.

(4) **Timing the Men.** The fourth step, when, for the purpose of obtaining records for piece or task-work, a first-class laborer must be induced to work at his best speed, requires considerable tact. Men who work by the day are apt to be opposed to piece-work or task-

work until they see its benefits to themselves. One just reason for this opposition is because piece-work as usually established consists of fixing a rate, and then, as soon as the men make more than day wages, of cutting this rate again and again until they are doing more work than formerly but receiving for it no more pay. Because of this feeling among the men it is usually preferable to adopt task-work, as described on page 86, instead of straight piece-work.

(5) **Observations.** The method of observing the times, mentioned as the fifth step, is considered at length on page 94. As is there stated, the object is to find the net times required by either an average man or by a first-class man to perform each elementary part of the job for which an average cost of a rate is desired, and then to find the percentage of the day required by such a man for rest and other necessary delays.

For very important units which are to be used in combination over and over again in different operations, a large number of times are necessary, often several hundred for each element. For less important units which occur seldom, and the time of which, therefore, constitutes a very small percentage of a man's daily work, but few observations are necessary. Again, the time of some elements will be very uniform, while that of another unit will vary largely. The large variation is most apt to appear in units which occur very seldom, and therefore the variation does not so seriously affect the final average or the fixing of the rate. If large variation occurs in a time unit which is to be used frequently, the only method of allowing for it is to take an extra large number of observations and average them. If this is done, the most extreme differences can be harmonized. Usually large variations will be found to be due to unsystematic arrangements.

(6) **Final Averages and Rate-fixing.** The fixing of the rate or the task, which is considered as the sixth step, is done in the office after the unit times are obtained and averaged. In the first place, a rate per day which the management is willing to permanently pay really good men must be selected. This rate of pay should be high enough so that the men will be induced to perform the largest day's work of which they are capable without physical deterioration. It is no part of this system that men should be overworked, or "speeded up" as it is frequently called, but the tasks should all be set so that a man suited to this class of work will thrive under it and grow stronger through a term of years. It must be borne in mind, however, that

this high wage should be earned only by really good men. One object in systematic task-work is to eliminate from any class of work the sluggards and those who are mentally or physically unfitted for the job. Piece-work or task-work, when properly applied, automatically selects for each class of work the men who are best capable of doing it.

Having selected the rate of pay per day which first-class men may be allowed to earn permanently on piece-work or task-work, reduce this for convenience to rate per minute. Having found the number of minutes in which a first-class man should perform a certain piece of work and added a percentage for rests and other necessary delays, the price per piece is simply the product of this time multiplied by the man's rate per minute. Piece-rate prices may be fixed upon each unit operation or upon each particular job which is distinct in itself. The time for any task is obtained by adding together the unit times of performing the divisions of work of which the job consists. To the time obtained by this summation, an allowance for rest and other necessary delays must always be added.

The method of obtaining this percentage for rest for piece-work rates, or for tasks, is best found by offering one or more first-class men a special incentive to work at a proper rate of speed for an entire day or for several entire days. The actual percentage of rest can thus be found by observation. It is easy to tell whether the man is constantly maintaining his proper rate of speed by taking occasional observations of the time he occupies in doing certain units of an operation and comparing these unit times with the average unit times which were found in previous steps in the time study.

In connection with this rate fixing, it is well to call attention to the fact that the term "first-class" man refers to a workman who is a steady worker and especially adapted for the work which he has to do. In any gang of men there will be an occasional one who is an extraordinary worker. Such a man should earn even higher wages than the rate fixed upon as proper for a first-class man. If it is such extraordinary men as this who are observed in order to obtain unit times, data thus recorded should be corrected to bring them down to values suited to a gang of first-class men employed on task-work.

(7) **Starting Piece-work or Task-work.** The seventh step, which marks the first actual commencement of piece-work, or task-work, is an important one. As noted in the outline, a single worker

should be started on the work, and only one. He should have every possible facility to do his work, and other men should be kept from interfering with him. One of the best men on the job should be selected, and he should be encouraged to make even on the first day larger wages than his regular day rate. If this is impossible on the first day, he should at least be able to see at night that with slight changes in his method of work he can easily reach the speed which will bring him the higher pay. This one man should be kept at work alone until he has made an actual success of the work, so that he is earning the wages selected by the Company as the pay a first-class man should make. To do this, he will, of course, have to turn out the estimated amount of work in the given time.

Although gang-work is always less satisfactory than individual work, the work of several men may depend so closely upon each other that the rate or the task must be made for the gang, and the men of one small gang started together instead of separately.

If more than one man or one gang is started at once, there is apt to be trouble. Some of the men will be apt to make less pay than they ought to make, or will fail in accomplishing the task in the time set—usually because they do not try—and they will talk the matter over and figure out grievances, instead of going at the job in earnest, and may refuse to work.

(8) **Starting other Men.** After one man has made a success of the work and is earning good pay, the eighth step, that of starting other men at work, is more simple. The only safe plan, however, is to put the men on piece-work, or task-work, one after another. The men must be impressed with the fact that the intention of the management is to allow them to earn permanently considerably larger wages per day than they have ever earned on day-work.

(9) **Fixing other Rates.** The fixing and introducing of other rates, the ninth and final step, is accomplished in a similar way to that described for the first rate. The work next selected should be as nearly like the first as possible so that the unit times already obtained will be useful in making up the new rates. This use of the same values in different operations not only greatly facilitates the fixing of rates but also makes it practically certain that the rates will be uniform, that is, that two men of equal ability, working on two different jobs at a similar rate of speed, will earn substantially the same wages per day.

METHODS OF TIME-STUDY

The methods of analyzing operations and making time-studies have been referred to, but the subject is so important that it may well be discussed at length. A description of methods of making time-studies is given in a paper by Mr. Taylor,* of which the following paragraphs apply to this discussion:

In the course of this work, Mr. Thompson has developed what are in many respects the best implements in use, and with his permission some of them will be described. The blank form or note sheet used by Mr. Thompson, shown in Fig. 8, page 95, contains essentially:

(1) Space for the description of the work and notes in regard to it.

(2) A place for recording the total time of complete operations that is, the gross time, including all necessary delays, for doing a whole job or large portions of it.

(3) Lines for setting down the "detail operations," or "units" into which any piece of work may be divided, followed by columns for entering the averages obtained from the observations.

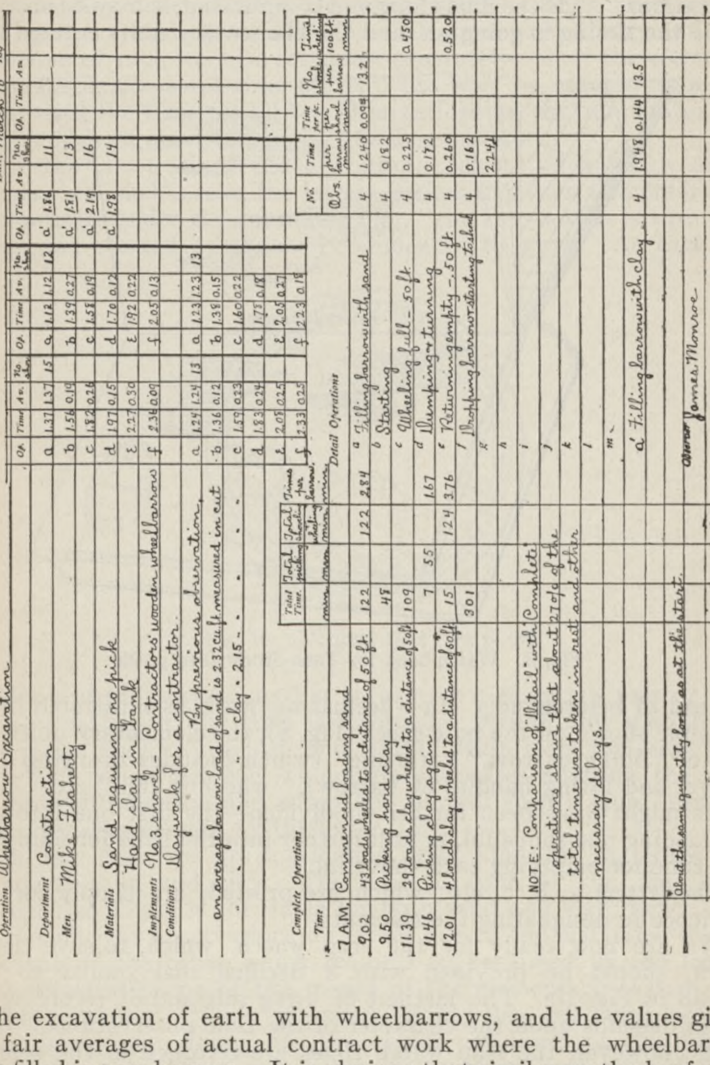
(4) Squares for recording the readings of the stop watch when observing the times of these elements. (If these squares are filled, additional records can be entered on the back.) The size of the sheets, which should be of best quality ledger paper, is 8¾ inches wide by 7 inches long, and by folding in the centre they can be conveniently carried in the pocket, or placed in a case containing one or more stop watches.

This case, or "watch book," is another device of Mr. Thompson. It consists of a frame work, containing concealed in it, one, two or three watches, whose stop and start movements can be operated by pressing with the fingers of the left hand upon the proper portion of the cover of the note-book without† the knowledge

*"Shop Management," by Frederick W. Taylor, a paper read before the American Society of Mechanical Engineers and published by Harper and Brothers, 1911.

†The writer does not believe at all in the policy of spying upon the workman when taking time observations for the purpose of time study. If the men observed are to be ultimately affected by the results of these observations, it is generally best to come out openly, and let them know that they are being timed, and what the object of the timing is. There are many cases, however, in which telling the workman that he was being timed in a minute way would only result in a row and in defeating the whole object of the timing; particularly when only a few time units are to be studied on one man's work, and when this man will not be personally affected by the results of the observations. In these cases, the watch book of Mr. Thompson, holding the watches in the cover, is especially useful. A good deal of judgment is required to know when to time openly or the reverse.

of the workman who is being observed. The frame is bound in a leather case resembling a pocket note-book, and has a place for the note sheets described. A sketch of this watch-book is shown in Fig. 9. The operation selected for illustration on the note sheet


Form C 4, 6-'98. S. E. T.

Operation Wheelbarrow Excavation — Date, March 10 189

Department Construction

Men Mike Flaherty

Materials Sand requiring no pick; Hard clay in bank

Implements No. 3 shovel - Contractors' wooden wheelbarrow

Conditions Daywork for a contractor.

By previous observation, an average barrow load of sand is 2.32 cu. ft. measured in cut; " " " " clay " 2.15 " "

Op.	Time	Av.	No. Shov.	Op.	Time	Av.	No. Shov.	Op.	Time	Av.	No. Shov.	Op.	Time	Av.
a	1.37	1.37	15	a	1.12	1.12	12	a'	1.86		11			
b	1.56	0.19		b	1.39	0.27		a'	1.81		13			
c	1.82	0.26		c	1.58	0.19		a'	2.14		16			
d	1.97	0.15		d	1.70	0.12		a'	1.98		14			
ε	2.27	0.30		ε	1.92	0.22								
f	2.34	0.09		f	2.05	0.13								
a	1.24	1.24	13	a	1.23	1.23	13							
b	1.36	0.12		b	1.38	0.15								
c	1.59	0.23		c	1.60	0.22								
d	1.83	0.24		d	1.75	0.18								
ε	2.08	0.25		ε	2.05	0.27								
f	2.33	0.25		f	2.23	0.18								

Time	Complete Operations	Total Time. min.	Total picking min.	Total shoveling wheeling min.	Times per barrow. min.
7 A.M.	Commenced loading sand				
9.02	43 loads wheeled to a distance of 50 ft.	122		122	2.84
9.50	Picking hard clay	48			
11.39	29 loads clay wheeled to a distance of 50 ft.	109			
11.46	Picking clay again	7	55		1.67
12.01	4 loads clay wheeled to a distance of 50 ft.	15		124	3.76
		301			

NOTE: Comparison of "Detail" with "Complete" operations shows that about 27% of the total time was taken in rest and other necessary delays.

About the same quantity loose as at the start.

	Detail Operations	No. Obs.	Time per barrow min.	Time per ft. per shovel min.	No. shovels per barrow	Time wheeling 100 ft. min.
a	Filling barrow with sand	4	1.240	0.094	13.2	
b	Starting	4	0.182			
c	Wheeling full - 50 ft.	4	0.225			0.450
d	Dumping & turning	4	0.172			
ε	Returning empty - 50 ft.	4	0.260			0.520
f	Dropping barrow starting to shovel	4	0.162			
g			2.241			
h						
i						
j						
k						
l						
m						
a'	Filling barrow with clay	4	1.948	0.144	13.5	

Observer James Monroe

Fig. 8. Specimen Note-sheet (See p. 94)

is the excavation of earth with wheelbarrows, and the values given are fair averages of actual contract work where the wheelbarrow man fills his own barrow. It is obvious that similar methods of analyzing and recording may be applied to work ranging from unloading coal to skilled labor on fine machine tools.

The method of using the note sheets for timing a workman is as follows:

After entering the necessary descriptive matter at the top of the sheet, divide the operation to be timed into its elementary units, and write these units one after another under the heading "Detail Operations." (If the job is long and complicated, it may be analyzed while the timing is going on, and the elementary units entered then

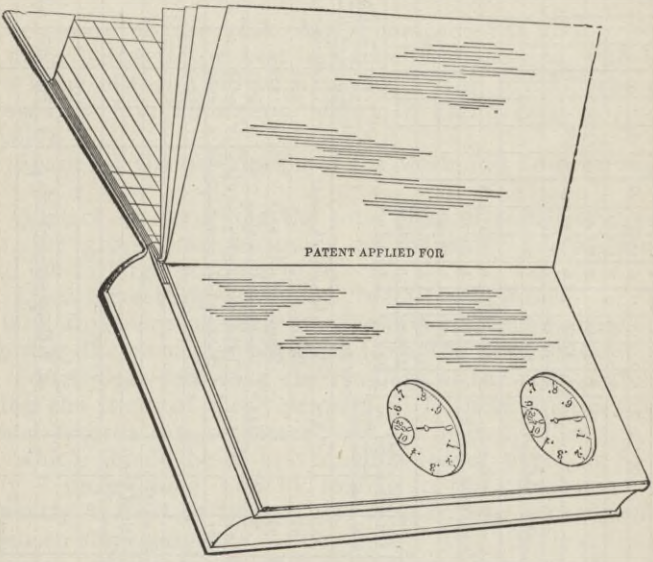


Fig. 9. Watch-book for Time-Study (See p. 95)

instead of beforehand.) In wheelbarrow work, as illustrated in the example shown on the note sheet (Fig. 8), the elementary units consist of "filling barrow," "starting" (which includes throwing down shovel and lifting handles of barrow), "wheeling full," etc. These units might have been further subdivided—the first one into time for loading one shovelful, or still further into the time for filling and the time for emptying each shovelful.

The letters a, b, c, etc., which are printed, are simply for convenience in designating the elements.

We are now ready for the stop watch, which, to save clerical work, should be provided with a decimal dial similar to that shown in Fig. 10. The method of using this and of recording the times depends upon the character of the time observations. In all cases, however, the stop watch times are recorded in the columns headed "Time" at the top of the right-hand half of the note sheet. These columns are the only place on the face of the sheet where stop-watch readings are to be entered. If more space is required for these times, another sheet should be started. The rest of the figures (except those on the left-hand page, which may be taken from an ordinary timepiece) are the results of calculation, and may be made in the office by any clerk.

As has been stated, the method of recording the stop-watch observations depends upon the work which is being observed. If the operation consists of the same element repeated over and over, the time of each may be set down separately; or, if the element is very small, the total time of, say, ten may be entered as a fraction, with the time for all ten observations as the numerator, and the number of observations for the denominator.

In the illustration, the operation consists of a series of elements. In such a case, the letters designating each elementary unit are entered under the columns "Op.," the stop-watch is thrown to zero, and started as the man commences to work. As each new

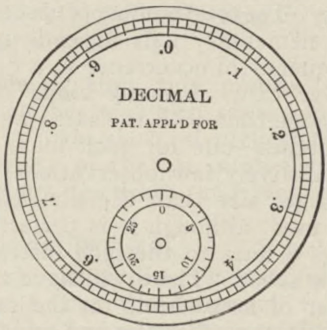


Fig. 10. Decimal Dial (See p. 96)

division of the operation (that is, as each elementary unit or "unit time,") is begun, the time is recorded. During any special delay the watch may be stopped, and started again from the same point, although, as a rule, Mr. Thompson advocates allowing the watch to run continuously, and enters the time of such a stop, designating it for convenience by the letter "Y".

In the case we are considering, two kinds of materials were handled—sand and clay. The time of each of the unit times, except the filling, is the same for both sand and clay; hence, if we have sufficient observations on either one of the materials, the only element of the other which requires to be timed, is the loading. This illustrates one of the merits of the elementary system.

The column "Av." is filled from the preceding column. The figures thus found are the actual net times of the different "unit times." These unit times are averaged and entered in the "Time" column, on the lower half of the right-hand page, preceded, in the "No." column, by the number of observations which have been taken of each unit. These times, combined and compared with the gross times on the left-hand page, will determine the percentage lost in resting and other necessary delays. A convenient method for obtaining the time of an operation, like picking, in which the quantity is difficult to measure, is suggested by the records on the left-hand page.

The percentage of the time taken in rest and other necessary delays, which is noted on the sheet as, in this case, about 27 per cent, is obtained by a comparison of the average net "time per barrow" on the right with the "time per barrow" on the left. The latter is the quotient of the total time shoveling and wheeling divided by the number of loads wheeled.

It must be remembered that the example given is simply for illustration. To obtain accurate average times, for any item of work under specified conditions, it is necessary to take observations upon a number of men, each of whom is at work under conditions which are comparable. The total number of observations which should be taken of any one elementary unit depends upon its variableness and also upon its frequency of occurrence in a day's work.

An expert observer can, on many kinds of work, time two or three men at the same time with the same watch, or he can operate two or three watches—one for each man. A note sheet can contain only a comparatively few observations. It is not convenient to make it of larger size than the dimensions given, when a watch-book is to be used, although it is perfectly feasible to make the horizontal rulings 8 lines to the inch instead of 5 lines to the inch as on the sample sheet. There will have to be, in almost all cases, a large number of note sheets on the same subject. Some system must be arranged for collecting and tabulating these records.

For tabulating the unit times and recording the information taken on the note sheets, sheets of stiff ledger paper 14 by 18 inches are convenient. Horizontal lines are ruled, 6 per inch, every third line brown, and the other two light green. Vertical green lines are placed $\frac{3}{8}$ inch apart, every third line heavy.

The method of combining the unit times on such work as carting and wheelbarrow work is illustrated on pages 233 and 302, and formulas are given there that show how, with a comparatively few units, combinations can be made which will apply to all ordinary conditions.

In the illustration recorded on the note sheet, Fig. 8, page 95, "Filling barrow with sand" is given as a unit. In practice, to provide for other kinds of earth, other sizes of barrow, and difference in shovels, this must be divided into time per shovelful. Or better still, since the filling of the shovel varies with the material, while the throw varies with the distance thrown and the lift, divide into even smaller elements. Quoting again from Mr. Taylor's "Shop Management:"

The division of a given job into its proper elementary units, before beginning the time-study, calls for considerable skill and good judgment. If the job to be observed is one which will be repeated over and over again, or if it is one of a series of similar jobs which form an important part of the standard work of an establishment, or of the trade which is being studied, then it is best to divide the job into elements which are rudimentary. In some cases this subdivision should be carried to a point which seems at first glance almost absurd.

For example, in the case of the study of the art of shoveling earth, handling a shovelful of dirt is subdivided into,

s = "Time filling shovel and straightening up ready to throw," and
t = "Time throwing one shovelful."

The first impression is that this minute subdivision of the work into elements, neither of which takes more than five or six seconds to perform, is little short of preposterous; yet if a rapid and thorough time study of the art of shoveling is to be made, this subdivision simplifies the work, and makes time-study quicker and more thorough.

The reasons for this are twofold:

(1) In the art of shoveling dirt, for instance, the study of fifty or sixty small elements, like those referred to above, will enable one to fix the exact time for many thousands of complete jobs of shoveling, constituting a very considerable proportion of the entire art.

(2) The study of single small elements is simpler, quicker, and more certain to be successful than that of a large number of elements combined. The greater the length of time involved in a single item of time-study, the greater will be the likelihood of interruptions or accidents, which will render the results obtained by the observer questionable or even useless.

There is a considerable part of the work of most establishments that is not what may be called standard work, namely, that which is repeated many times. Such jobs as this can be divided for time study into groups, each of which contains several rudimentary elements. A division of this sort will be seen by referring to the data entered on face of card on Fig. 8, page 95.

In this case, instead of observing, first, the "time to fill a shovel," and then the time to "throw it into a wheelbarrow," etc., a number of these more rudimentary operations are grouped into the single operation of: a = "Time filling a wheelbarrow with any material," and studied as a whole.

In beginning time-studies, great care must be used in the taking of observations. Quoting further from "Shop Management:"

The mistake usually made by beginners is that of failing to note in sufficient detail the various conditions surrounding the job. It is not at first appreciated that the whole work of the time observer is useless if there is any doubt as to even one of these conditions. Such items, for instance, as the name of the man or men on the work, the number of helpers, and exact description of all of the implements used, even those which seem unimportant, such, for instance, as the diameter and length of bolts and the style of clamps used, the weight of the piece upon which work is being done, etc.

It is also desirable that, as soon as practicable after taking a few complete sets of time observations, the operator should be given the opportunity of working up one or two sets at least by summing up the unit times and allowing the proper per cent of rest, etc., and putting them into practical use, either by comparing his results with the actual time of a job which is known to be done in fast time, or by setting a time which a workman is to live up to.

The actual practical trial of the time student's work is most useful, both in teaching him the necessity of carefully noting the minutest details and, on the other hand, convincing him of the practicability of the whole method and in encouraging him in future work.

In making time observations, absolutely nothing should be left to the memory of the student. Every item, even those which appear self-evident should be accurately recorded. The writer, and the assistant who immediately followed him, both made the mistake of not putting the results of much of their time study into use soon enough, so that many time observations which extended over a period of months were thrown away, in most instances because of failure to note some apparently unimportant detail.

It may be needless to state that when the results of time observations are first worked up, it will take far more time to pick out and add up the proper unit times, and allow the proper percentages of rest, etc., than it originally did for the workman to do the job. This fact need not disturb the operator, however. It will be evident that the slow time made at the start is due to his lack of experience, and he must take it for granted that later many short-cuts can be found, and that a man with an average memory will be able with practice to carry all of the important time units in his head.

No system of time study can be looked upon as a success unless it enables the time observer, after a reasonable amount of study, to predict with accuracy how long it should take a good man to do almost any job in the particular trade, or branch of a trade, to which the time student has been devoting himself. It is true that hardly any two jobs in a given trade are exactly the same, and that if a time student were to follow the old method of studying and recording the whole time required to do the various jobs which came under his observation, without dividing them into their elements, he would make comparatively small progress in a lifetime, and at best would become a skilful guesser. It is, however, equally true that all of the work done in a given trade can be divided into a comparatively small number of elements or units, and that, with proper implements and methods, it is comparatively easy for a skilled observer to determine the time required by a good man to do any one of these elementary units.

Having carefully recorded the time for each of these elements, it is a simple matter to divide each job into its elementary units, and by adding their times together, to arrive accurately at the total time for the job. The elements of the art which at first appear most difficult to investigate are the percentages which should be allowed, under different conditions, for rest and for accidental or unavoidable delays. These elements can, however, be studied with about the same accuracy as the others.

Perhaps the greatest difficulty rests upon the fact that no two men work at exactly the same speed. The writer has found it best to take his time observations on first-class men only, when they can be found; and these men should be timed when working at their best. Having obtained the best time of a first-class man, it is a simple matter to determine the percentage which an average man will fall short of this maximum.

It is a good plan to pay a first-class man an extra price while his work is being timed. When workmen once understand that the time-study is being made to enable them to earn higher wages, the writer has found them quite ready to help instead of hindering him in his work.

Sometimes, when the unit times are exceedingly small and an operation is made up of, say, four of these units, the time may be observed by the method of "cycles," that is, instead of recording the time of each unit, the time of, say, two or three units in varying combinations may be recorded and the single times worked up by algebra. This is discussed by Mr. Taylor in "Shop Management."*

To one who has not made a careful study of the matter, it may seem that these small sub-divisions of time are entirely too minute to be of practical use. Perhaps the best answer to this criticism is the fact that they have been employed in the establishment of rates where the pay of the men at work averaged for an entire year within less than 2 per cent of the pay which the rate fixer intended they should earn. In the yard work of the Bethlehem Steel Company,

*Shop Management, p. 172, Harper and Brothers, Publishers, 1911.

for example, it was decided that first-class laborers (who had previously earned on day-work $1.15 per day of ten hours) should earn on piece-work $1.85. After fixing the rates, and afterwards making change in only two out of nearly a hundred rates, the laborers at the end of a year had averaged $1.88 per day.

In many operations it is unnecessary, of course, to make such fine divisions as are given above. For example, if in a certain establishment only one kind, or possibly only two kinds, of material are shoveled, the operation of shoveling may be separated merely into the time per shovelful. There is little danger, however, of making the observation too minute and the units too small. A beginner will invariably tend to the other extreme. As we have said, the degree of subdivision must depend upon the character of the work and its similarity to other operations which are going on.

TASK-WORK IN CONCRETING

In some of the divisions of concrete work, it is impossible to base the pay of each man upon his individual work, so that the gang method of piece-work or task-work must be adopted for at least a part of the operations. In the hand-mixing of concrete, the work of the men is so interchangeable that the rate must be based upon the number of batches mixed per hour, or better still, upon the volume of concrete laid. Even here, however, each man must have a definite set of operations to perform. If certain of the men do more arduous labor or work of a higher class than the others, the rate may be divided so that they shall receive a larger proportion than the others of the rate per batch. The work of supplying the materials for the concrete, if performed by different men, may be based on separate rates. The transporting of the concrete may also have a separate rate when performed by a different gang, provided the gang is large enough so that it can be varied to allow each man to work as hard as he desires, irrespective of the output of the mixing gang. The carpenters building forms can frequently work alone although it is customary to arrange gangs of two.

Rate-fixing from Cost Tables. On the preceding pages are described the methods of fixing the times and the rates of pay in cases where there are no data recorded upon which to base the rates. However, by means of the tables in succeeding chapters, rates may be fixed without the necessity of obtaining new values upon all the unit operations. In order to utilize these tables, rates may be fixed as follows:

(1) Record upon first-class laborers, a large number of times of several unit operations, as described in the fourth and fifth steps on page 88. At least twenty-five observations should be made upon each operation, and enough operations selected to cover, when added together, at least one-quarter of the working time of the men.

(2) Add a percentage to the average of each of these unit times to allow for rest and necessary delay. If first-class men, who are working with some incentive, such as extra pay for that particular day, have been observed, the percentage to add to the net unit times may be in the neighborhood of 30 per cent, but should be selected in each case after very careful study.

(3) Find the relation or ratio of the times just found (after adding the percentage for rest and delay) to the corresponding times for quick men in the tables in this book. This ratio is the sum of the times just found by observation, divided by the sum of the times for first-class men (from the tables) for the same operations.

(4) Assume the ratio thus found to apply not only to these operations, but to each of the other operations which have not been newly timed. Hence, to obtain times applicable to piece-work or task-work multiply the "quick men" times in the tables by this ratio.

(5) Select from the tables the proper combination of operations to satisfy the conditions of the job under consideration, add the times decreased or increased by the ratio, and multiply the sum thus found by the rate per minute corresponding to the rate per hour or per day which the laborer is expected to earn when doing a maximum day's work on piece-work. The fixing of a price for a task has been illustrated on page 91.

A PIECE-WORKER MUST EARN MORE THAN A DAY-WORKER

The rate of pay of each man must be fixed so that when executing piece-work or task-work at the specified speed, he will be able to earn, day after day, a much larger pay than he has been accustomed to receive when at work by the day. The amount of this excess pay should vary with the nature of the work. We may say that it should never be less than 20 per cent greater, and in some cases should be as much as 75 per cent greater. An increase of 35 per cent has been found satisfactory in a large number of cases. When a gang rate is necessary, as in mixing concrete, the amount which men do in excess of average laborers on day-work will be less than when each man is working for himself and consequently the men will be satisfied with a smaller percentage of increase.

A piece-worker or task-worker may be expected to perform from $1\frac{1}{2}$ to 5 times as much work as the average man at work by the day, this measure being due largely to the systematizing and the elimination of unnecessary operations.

AUTOMATIC SELECTION OF MEN

One of the principles of properly applied task-work, as has been stated, is its automatic selection of the men best fitted for the work to be done. After tasks are fixed for mixing concrete, if it is discovered that one or two men are holding back the rest of the gang because they are lazy or not physically adapted to the labor, other and proper laborers must be substituted.

In a set of scientific studies on the labor of loading pig iron on to the cars, which is an extraordinarily severe task, Mr. Taylor found that only 10 per cent of those tried were first-class men, about 25 per cent of the total number could do fairly well, and the remaining 65 per cent were unable to keep up with the work and had to be given some other job to do.

ABILITY TO STAND PIECE-WORK OR TASK-WORK

Actual experience of the authors with piece-work upon heavy labor, as shoveling coal and handling pig iron, indicates that men who are fitted for such heavy work can keep it up day after day, month after month, and year after year without deterioration. Therefore, it need not be feared that men will go beyond their strength when working on concreting by the piece or the task, provided they are physically adapted to the labor.

REDUCTION IN GENERAL EXPENSE

In estimating the saving of cost due to the introduction of any system of increasing the labor output, there is always a large saving in overhead charges, in addition to the actual wage saving, because of the earlier completion of the job. The interest on the cost of the plant and the overhead charges for office rent and salaries are reduced in proportion to the time saved, while the fact that the structure is ready for use ahead of time is frequently of great money value.

BY-PRODUCTS

If the men on any job, or even a few of them, are earning higher pay than usual because of task-work or piece-work, the general tone is improved. One of the most important advantages is that the day-workers catch the spirit and increase their output; the tools and the machinery have to be kept up to the mark; and the men as a whole take an interest in reducing the costs.

SCIENTIFIC MANAGEMENT ON CONSTRUCTION JOBS

At the date of the issue of the first edition of this book, 1912, builders are only just beginning to realize the saving in cost that can be effected on ordinary construction work by systematizing their means of handling workmen. Enough has been accomplished, however, to show that methods adopted by Mr. Taylor in shop management can also be used successfully in construction operations.

One of the classes of work where shop methods have proved especially satisfactory is in the making and erecting of forms for reinforced concrete buildings. An outline of the plans employed in this work will serve as an illustration of such organization.

Form making, as usually carried on, is unsystematic and costly. The approximate quantity of lumber is figured and ordered in random lengths. The foremen are given general floor plans of the building and, from these, they figure out the net dimensions of the forms; they then lay out on each carpenter bench the general makeup of a form section and the carpenters select from the nearest lumber pile the sizes of board or plank that best fit these sections and put the pieces together according to their own judgment.

The methods introduced by Mr. Thompson, with the assistance of Mr. William O. Lichtner, are described in detail in Chapter XVI. In the first place, sketch plans are drawn, and the best arrangement for the benches and all details of the work throughout are studied. The lumber is ordered to length and width that will fit the general run of forms with the least waste and is piled systematically as it is unloaded from the cars. It is then routed by means of tickets to the sawmill, from which it is taken by laborers and piled close to the carpenter benches.

Adopting these methods, i.e., by thoroughly systematizing the work, even without any task-work, two carpenters working an 8-hour day have made day after day 50 sections of beam forms, $18\frac{1}{4}$ inches wide by 20 feet 4 inches long, using $1\frac{1}{4}$-inch lumber and 2 by 3-inch cleats. By taking time-studies and fixing tasks, a still further increase has been effected, so that 60 sections were made per 8-hour day.

The essentials of this scheme involve the principles already discussed in this chapter: the planning of the work in advance; the providing of clerks with special duties or functions to perform; the instructing of the workmen in their duties; the routing (or proper movement) of the materials from one place to another; and, finally, the setting of tasks by means of time-studies.

On other construction work, where skilled labor is necessary, the same methods are applicable. If the work calls only for unskilled labor, such as shoveling, the organization is even simpler, since less routing is required. Even under these conditions, however, it is necessary to follow the same general scheme and have a system of tickets or cards with brief instructions so as to lay out the work in advance and provide means for recording the tasks.

CHAPTER VI

PROPORTIONING CONCRETE

Economical proportioning of concrete does not always consist in using the leanest possible mixture. If the quantity to be laid is small, it is sometimes cheaper to use materials at hand, selecting the proportions arbitrarily and adding an excess of cement to insure the required strength and water-tightness, rather than to make the tests required for the more scientifically proportioned mixture. On the other hand, upon large or important work, it pays from the standpoint of dollars and cents to make thorough studies of the aggregates, carefully grading the materials so as to use the smallest possible quantity of cement, which is always the most expensive ingredient.

This fact has been seriously overlooked in the past, and thousands of dollars sometimes have been wasted on single jobs by neglecting laboratory tests and studies or by errors in theory. By adjusting the proportions of the aggregates instead of selecting them arbitrarily, a concrete of equal density, strength and water-tightness may be made almost always with the use of less cement. On a certain job, for example, where water-tight concrete was required, a net saving was effected of 74 cents per cubic yard by carefully grading the materials. The resulting concrete was as water-tight as the richer mixture, in which the proportions were selected by judgment.

A full description of the principles of proportioning is presented in the authors' complete work "Concrete, Plain and Reinforced" and data relating to sand and stone are given there.

In the present chapter, a few of the more important principles which directly affect the cost of concrete under ordinary conditions are described and instructions are given for the economical selection of sand and stone. These instructions comprise practical rules for the builder.

ROUGH RULES FOR PROPORTIONS

If the work is not expensive or important enough to warrant special proportioning of the materials and grading of the aggregates, the mixture must be chosen more or less arbitrarily. The following general rules indicate the best plan to follow.

(1) Proportion the cement to sand by judgment in accordance with the character of the construction, using a larger percentage of cement with a fine sand than with a coarse sand. (See p. 117.)

(2) Use, as a trial, twice as much of broken stone or gravel as of sand by volume.

(3) Vary the proportion of broken stone or gravel, increasing the quantity if there is an excess of mortar in the concrete as it is being handled and placed and using as much of this coarse aggregate as is possible without producing noticeable voids or stone pockets in the concrete.

(4) In stating the proportions in specifications, always indicate the unit of measurement so as to show clearly the volume or weight of sand to be used to one barrel (4 bags) cement. In standard practice one barrel of cement is assumed to be equivalent to 3.8 cubic feet by volume, so that proportions 1:2:4 require one barrel (4 bags) cement to 7.6 cubic feet sand, measured loosely, to 15.2 cubic feet of stone, measured loosely.

The first three rules, as stated above, are suggested only for work which is not large enough to warrant special tests. Selection of proportions in this manner, while largely a matter of judgment, may give good results in practice, although necessitating a larger quantity of cement and consequently a greater net cost than more scientific proportioning would require.

Rule (2) suggests using twice as much stone as sand. When, however, the coarse aggregate contains a good many small particles, as does crusher-run broken stone or bank gravel even after screening, or when the sand is so fine as to flow readily into the voids of the stone, the proportion of stone may be slightly more than twice the volume of sand. The cement also increases the bulk of the mortar and, therefore, assists in filling the voids in the stone. With such aggregates the volume of the stone sometimes may be made equal to the cement plus twice the volume of sand, thus giving such proportions as 1:1½:4, 1:2:5, 1:2½:6, and 1:3:7.

The correct proportions of sand to stone, after the materials are once chosen, may be determined quite accurately, by an experienced concrete man, by observation of the appearance of the concrete as the work progresses. Too much sand will be indicated by harsh working of the concrete, or by an excess of mortar rising to the top when placing, while, with too little sand, stone pockets are apt to occur on the surfaces, and it is difficult to fill all the voids in the stone. A man skilled in concrete mixing can govern the relative quantities of sand and stone, provided there is no choice in the selection of these materials, by careful inspection of the mixed concrete as it is being transported and placed.

PROPORTIONING BY VOID DETERMINATION

Formerly, the usual method of determining proportions was to find the volume of water that could be poured into the voids of a unit volume of stone and select a volume of sand equal to, or slightly in excess of, the quantity of water. The proportion of cement to sand was determined in a similar manner. In practice, such void tests give no better results than the arbitrary selection described in the previous paragraphs. While the determination of the percentage of voids in sand is interesting in theory, the moisture which the sand contains so affects its volume that this test is of scarcely any value. If the sand is dry, for example, a fine sand with grains of uniform size will have about the same percentage of voids as a coarse sand with uniform grains, but the former will require a much larger proportion of cement to produce mortar of similar strength. On the other hand, if the sand when tested contains natural moisture, the amount of this moisture varies so much from day to day that the original volume of the sand and, in fact, the volume of the voids, may be affected to the extent of 10%, an increase in the percentage of moisture increasing the bulk of the sand and therefore the voids up to a certain point. This is illustrated in Fig. 11, page 110, which gives the results of tests made by Mr. William B. Fuller.

If a small quantity of water is poured into a vessel containing dry sand, the bulk is not increased because of the inertia of the particles, but if the sand after moistening is dumped out and then turned back into the vessel with a shovel or trowel, its bulk will be increased. On the same principle, a sand bank does not swell in bulk during a shower, but the effect of the moisture is shown in the excavated material as soon as it is loosened with the shovel and therefore its loose measurement for concrete or mortar is affected.

The inaccuracy of proportioning the volume of sand to the stone by void determinations is due in part to the difference in the compactness of the materials under varied methods of handling, but more especially to the fact that the actual volume of voids in a coarse aggregate does not usually correspond to the quantity of sand required to fill the voids. The grains of sand thrust apart the particles of stone, since many of these particles are too coarse to enter the voids of the stone.

To illustrate the principle by an extreme example, suppose that we have a mixture in equal parts of 1-inch stone and $\frac{7}{8}$-inch stone. By the usual method of reasoning, if the 1-inch stone has 50% voids, a volume of $\frac{7}{8}$-inch stone would be required equal to 50% of the 1-inch stone in order to fill the voids in the latter. The absurdity of this is

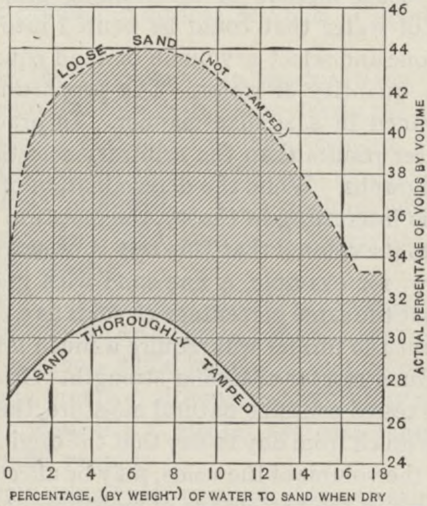


FIG. 11. Percentage of Air plus Water Voids in a Natural Bank Sand containing Varying Percentages of Moisture. (See p. 109.)

apparent, because the two stones are so near of a size that the former cannot fit into the voids of the latter and the bulk of the mixture is scarcely less than the sum of the separate volumes, that is, the mixture has nearly 50% voids. The principle is true, although in a less degree, where the particles of both aggregates are of varying sizes.

PROPORTIONING BY TRIAL MIXES

The comparative value of different materials, provided they are of good quality and contain no harmful impurities, and the best proportions of sand to stone, may be determined by experiment. Mix up trial batches of concrete with the selected percentage of cement and enough water to make a plastic consistency, and find, by these trials, the materials and the proportions which, with a given weight of dry materials (corrected for specific gravity), produce the smallest quantity of concrete. The materials should be measured by weight, corrected, as stated above, for specific gravity. The concrete may be measured in a cylinder such as a piece of 8-inch pipe.

PROPORTIONING BY MECHANICAL ANALYSIS

One of the most scientific methods of proportioning is by mechanical analysis, that is, by the gradations of the sizes of the particles of the different aggregates. Methods of proportioning in this way are fully described in "Concrete, Plain and Reinforced," second edition, pages 193 to 210.

PROPORTIONS OF CONCRETE IN PRACTICE

As a rough guide to the selection of materials for various classes of work, we suggest four proportions which differ from each other only in the relative quantity of cement:

(a) **A Rich Mixture** for columns and other structural parts subjected to high stresses or requiring exceptional water-tightness: Proportions 1:1½:3; that is, one barrel (4 bags) packed Portland cement to 1½ barrels(5.7 cu. ft.) loose sand to 3 barrels (11.4 cu. ft.) loose gravel or broken stone.

(b) **A Standard Mixture** for reinforced floors, beams, and columns, for arches, for reinforced engine or machine foundations subject to vibrations, for tanks, sewers, conduits, and other water-tight work: Proportions 1:2:4; that is, one barrel (4 bags) packed Portland cement to 2 barrels (7.6 cu. ft.) loose sand to 4 barrels (15.2 cu. ft.) loose gravel or broken stone.

(c) **A Medium Mixture** for ordinary machine foundations, retaining walls, abutments, piers, thin foundation walls, ordinary floors, sidewalks, and sewers with heavy walls: Proportions 1:2½:5; that is, one barrel (4 bags) packed Portland cement to 2½ barrels (9.5 cu. ft.) loose sand to 5 barrels (19 cu. ft.) loose gravel or broken stone.

(d) **A Lean Mixture** for unimportant work in masses, for heavy walls, for large foundations supporting a stationary load, and for backing for stone masonry: Proportions

1:3:6; that is, one barrel (4 bags) packed Portland cement to 3 barrels (11.4 cu.ft.) loose sand to 6 barrels (22.8 cu. ft.) loose gravel or broken stone.

The above specifications are based upon fair average practice. If the aggregate is carefully graded and the proportions are scientifically fixed. smaller proportions of cement may be used for each class of work.

PERCENTAGES OF VOIDS IN SAND AND STONE

Tables of Voids. By means of the tables on pages 113 and 114, the voids in sand and gravel and broken stone may be determined simply by weighing the material and then finding the percentage of moisture* contained in it. Since the percentage of moisture by volume is always greater than its percentage by weight, and the two are not proportional to each other, the final column is inserted in the first table for convenience in calculating the moisture by volume.

The specific gravity of any class of stone varies with its texture. Approximate values are given in table on page 115. For accurate work, such as the determination of densities, the specific gravity of the sample to be used must always be tested.

AVERAGE SPECIFIC GRAVITY OF SAND AND STONE

The specific gravity of a substance is the ratio of the weight of a given volume to the weight of the same volume of distilled water at a temperature of 4° Cent. (39°Fahr.). For ordinary tests of stone and sand, the water need not be distilled and may be at ordinary temperature.

A knowledge of the specific gravity of the particles of the sand and stone is important to the engineer as a ready means of determining the percentages of voids.

The uniformity in the specific gravity of different sands is very convenient for calculation. Different authorities who have tested large quantities of sand have reached almost identical conclusions as to the average specific gravity, and all state that it is practically a

* Find the percentage of moisture in the sand as follows: Weigh a sample of the moist sand and dry in an oven at a temperature of at least 212° Fahr. (100° Cent.) until there is no further loss in weight. Weigh the dried sand and express the loss in weight as a per cent of the total weight of the moist sand. The size of the sample to use is governed by the accuracy of the scales.

TABLE 15. PERCENTAGES OF VOIDS IN SAND, GRAVEL, AND BROKEN STONE

(See p. 112)

Percentages of Voids Corresponding to Different Weights per Cubic Foot of Sand, Gravel, and Broken Stone Containing Various Percentages of Moisture

Weight of One Cu. Ft. of Sand or Gravel*	Percentages of Absolute Voids in Material Containing Moisture by Weight† 0%	2%	4%	6%	8%	Moisture by Volume Corresponding to 1% by Weight†
	%	%	%	%	%	%
70	57.6	58.4	59.3	60.1	61.0	1.1
75	54.5	55.4	56.4	57.3	58.2	1.2
80	51.5	52.5	53.4	54.4	55.4	1.3
81	50.9	51.9	52.9	53.9	54.8	1.3
82	50.3	51.3	52.3	53.3	54.3	1.3
83	49.7	50.7	51.7	52.7	53.7	1.3
84	49.1	50.1	51.1	52.2	53.2	1.4
85	48.5	49.5	50.6	51.6	52.6	1.4
86	47.9	48.9	50.0	51.0	52.0	1.4
87	47.3	48.3	49.4	50.4	51.5	1.4
88	46.7	47.7	48.8	49.9	50.9	1.4
89	46.1	47.1	48.2	49.3	50.4	1.4
90	45.5	46.5	47.6	48.7	49.8	1.4
91	44.8	45.9	47.0	48.2	49.2	1.5
92	44.2	45.4	46.5	47.6	48.7	1.5
93	43.6	44.8	45.9	47.0	48.1	1.5
94	43.0	44.2	45.3	46.5	47.6	1.5
95	42.4	43.6	44.7	45.9	47.0	1.5
96	41.8	43.0	44.1	45.3	46.4	1.5
97	41.2	42.4	43.6	44.7	45.9	1.6
98	40.6	41.8	43.0	44.2	45.3	1.6
99	40.0	41.2	42.4	43.6	44.8	1.6
100	39.4	40.6	41.8	43.0	44.2	1.6
101	38.8	40.0	41.2	42.5	43.7	1.6
102	38.2	39.4	40.7	41.9	43.1	1.6
103	37.6	38.8	40.1	41.3	42.5	1.6
104	37.0	38.2	39.5	40.8	42.0	1.7
105	36.4	37.6	38.9	40.2	41.4	1.7
106	35.8	37.0	38.3	39.6	40.9	1.7
107	35.2	36.4	37.7	39.0	40.3	1.7
108	34.6	35.9	37.2	38.5	39.7	1.7
109	33.9	35.3	36.6	37.9	39.2	1.7
110	33.3	34.7	36.0	37.3	38.7	1.8
115	30.3	31.7	33.1	34.5	35.9	1.8
120	27.3	28.7	30.2	31.6	33.1	1.9
125	24.2	25.8	27.3	28.8	30.3	2.0
130	21.2	22.8	24.4	25.9	27.5	2.1
135	18.2	19.8	21.4	23.1	24.7	2.2
140	15.2	16.8	18.5	20.2	21.9	2.2

*Also applicable to broken stones such as granite, conglomerate, and limestone, whose specific gravity averages from 2.6 to 2.7. Table is based on specific gravity of 2.65.

†The per cent of absolute voids given in the columns includes the space occupied by both the air and the moisture. To determine the per cent of air space, multiply the figure in the last column, opposite the weight of sand under consideration, by the per cent of moisture by weight, and deduct result from the per cent already found.

TABLE 16. PERCENTAGES OF VOIDS IN DRY SAND, GRAVEL, AND BROKEN STONE (See p. 112)

Percentages of Voids Corresponding to Different Weights per Cubic Foot of Dry Sand, Gravel, and Broken Stone of Various Specific Gravities

Weight of one cu. ft. of dry broken stone	Percentages of Absolute Voids Corresponding to Specific Gravities of Stone of						
	2.4	2.5	2.6	2.65	2.7	2.8	2.9
	Sandstone		Limestone Conglomerate	Sand Gravel	Granite Slate		Trap
	%	%	%	%	%	%	%
70	53.2	55.0	56.8	57.6	58.4	59.9	61.3
75	49.8	51.8	53.7	54.6	55.4	57.0	58.5
80	46.5	48.6	50.6	51.5	52.4	54.1	55.7
85	43.2	45.4	47.5	48.5	49.5	51.3	53.0
90	39.8	42.2	44.5	45.5	46.5	48.4	50.2
95	36.5	39.0	41.4	42.5	43.5	45.5	47.4
100	33.1	35.8	38.3	39.4	40.6	42.7	44.7
105	29.8	32.6	35.2	36.4	37.6	39.8	41.9
110	26.4	29.4	32.1	33.4	34.6	36.9	39.1
115	23.1	26.2	29.0	30.3	31.6	34.1	36.4
120	19.8	23.0	25.9	27.3	28.7	31.2	33.6
125	16.4	19.8	22.8	24.3	25.7	28.3	30.8
130	13.1	16.6	19.8	21.2	22.7	25.5	28.1
135	9.7	13.3	16.7	18.2	19.7	22.6	25.3
140	6.4	10.1	13.6	15.2	16.8	19.7	22.5

Note.—Average specific gravity of bituminous coal cinders may be taken as 1.5.

constant. Mr. Allen Hazen gives 2.65, Mr. William B. Fuller, 2.64, Mr. R. Feret in France states that "one may without appreciable error adopt an average specific gravity of 2.65 for silicious sands,"* while Mr. E. Candlot gives limits of 2.60 to 2.68 for sands which are not porous.† The specific gravity of calcareous sands averages about 2.69 by absolute determination, or about 2.55 if measured by the total volume of the particles having their pores filled with air.

Gravels also have quite uniform specific gravity. According to Mr. A. E. Schutté, who has tested gravel from more than forty localities in the United States and Canada, an average value is 2.66.

*Bulletin de la Société d'Encouragement pour l'Industrie Nationale, 1897, Vol. II, p. 1591.

†Ciments et Chaux Hydrauliques, 1898, p. 246.

The following table gives average values of various concrete aggregates. In every case, the specific gravity is the ratio of the weight of an absolutely solid unit volume of each material to the weight of a unit volume of water.

Average Specific Gravity of Various Aggregates.

Material	Specific Gravity	Weight of a Solid Cu. Ft. of Rock. lb.	Authority
Sand	2.65	165	Allen Hazen
Gravel	2.66	165	A. E. Schutté
Conglomerate	2.6	162	Robert Spurr Weston
Granite	2.7	168	Edwin C. Eckel
Limestone	2.6	162	Edwin C. Eckel
Trap	2.9	180	Edwin C. Eckel
Slate	2.7	168	Tod's Tables‡
Sandstone	2.4	150	Edwin C. Eckel
Cinders (bituminous)	1.5	95	The authors

‡Encyclopedia Britannica.

METHOD OF DETERMINING SPECIFIC GRAVITY

The specific gravity of a sample of material is determined by dividing its weight by the weight of water which it displaces when immersed.

The size of sample necessary for the accurate determination of the specific gravity of a sand or stone of fairly uniform texture depends chiefly upon the delicacy of the apparatus employed. If scales reading to grams, and measures reading to cubic centimeters, are employed, a sample of 250 grams should give accurate results to two decimal places. With scales reading to $\frac{1}{4}$ ounce, a sample of 4 lb. is necessary for similar accuracy. The water must be maintained at 68° Fahr. (20° Cent.).

The sample may be taken by the method of quartering.*

Before finding the specific gravity of silicious sand, the sample should be dried in an oven at a temperature as high as 212° Fahr. (100° Cent.) until there is no further loss in weight. A porous stone, on the other hand, may be first moistened sufficiently to fill its pores, and then the surfaces of the particles dried by means of blotting paper. The absolute specific gravity of the porous stone may be afterward found by drying in an oven and correcting for the moisture lost.

* Method of quartering is described in Taylor and Thompson's "Concrete Plain and Reinforced," second edition, page 398.

The apparent specific gravity of sand or stone may be determined with an apparatus consisting of scales reading to $\frac{1}{4}$ ounce or to 5 grams, and a tall glass vessel with a reference mark, such as a cylinder or a pharmacist's graduate. The method is as follows:

Make a mark at any convenient place on the neck of the vessel;
Fill the vessel with water at a temperature of 68° Fahr. (20° Cent.) up to this mark;
Take a known weight in grams or ounces of the material;
Pour material into vessel carefully, a few grains at a time, so that no bubbles of air are carried in with it;
Pour out the clear water displaced by the material (leaving water in the vessel up to the level of the mark), and weigh the water poured out. Let

S = Weight of material placed in vessel.
W = Weight of water displaced.

Then

$$\text{Specific gravity of material} = \frac{S}{W} \qquad (1)$$

SELECTION OF SAND

The two most essential qualities to consider in sand are cleanness, that is, freedom from impurities, and coarseness of the grains. The sharpness of the grains and the mineralogical composition, while affecting to a slight extent the strength of the mortar for concrete, are not in themselves characteristics for accepting or rejecting a sand.

Cleanness, meaning by this not so much freedom from fine clayey material as freedom from vegetable matter, is of prime importance, since such impurities may so affect the strength of the mortar as to make even a well graded sand absolutely dangerous to use.*

The fineness of the sand and its percentage of silt passing a sieve having 100 meshes to the linear inch may also be ground for rejection, since a fine sand always makes a weak mortar or concrete.

The testing of the sand by determining the tensile strength of mortar made from it is the simplest means of proving its quality. The Joint Committee on Concrete and Reinforced Concrete in 1908 recommends:

*See Discussion by Sanford E. Thompson on "Impurities in Sand for Concrete," Transactions American Society of Civil Engineers, Vol. LXV, 1909, p. 250.

Fine aggregate consists of sand, crushed stone, or gravel screenings, passing when dry a screen having $\frac{1}{4}$-in. diameter holes. It should be preferably of silicious material, clean, course, free from vegetable loam or other deleterious matter.

A gradation of the grain from fine to course is generally advantageous.

Mortars composed of one part Portland cement and three parts fine aggregate by weight when made into briquets should show a tensile strength of at least 70 per cent of the strength of 1:3 mortar of the same consistency made with the same cement and standard Ottawa sand.

To avoid the removal of any coating on the grains, which may affect the strength, bank sands should not be dried before being made into mortar, but should contain natural moisture. The percentage of moisture may be determined upon a separate sample for correcting weight. From 10 to 40 per cent more water may be required in mixing bank or artificial sands than for standard Ottawa sand to produce the same consistency.

With a clean sand, the comparative values of samples of different coarseness may be estimated by their mechanical analyses, that is, by the percentages passing sieves of different sizes. Limiting qualifications for ordinary work are given by the Committee on Reinforced Concrete of the National Association of Cement Users, 1909:

The relative strength of mortars from different sands is largely affected by the size of the grains. A coarse sand gives a stronger mortar than a fine one, and generally a gradation of grains from fine to coarse is advantageous. If a sand is so fine that more than 10 per cent of the total dry weight passes a No. 100 sieve, that is, a sieve having 100 meshes to the linear inch, or if more than 35 per cent of the total dry weight passes a sieve having 50 meshes per linear inch it should be rejected or used with a large excess of cement.

For the purpose of comparing the quality of different sands a test of the mechanical analysis or granulometric composition is recommended, although this should not be substituted for the strength test. The percentages of the total weight passing each sieve should be recorded. For this test the following sieves are recommended:*

0.250 inch diameter holes.†

No. 8	mesh,	holes	0.0955	inch	width,	No. 23 wire.
No. 20	"	"	0.0335	"	"	, No. 28 "
No. 50	"	"	0.0110	"	"	, No. 35 "
No. 100	"	"	0.0055	"	"	, No. 40 "

* Sheet brass perforated with round holes passes the material more quickly than square holes. Round holes corresponding to sieves No. 8, 20, and 50, respectively are approximately 0.125, 0.050, 0.020 inch diameter.

† A No. 4 sieve, having 4 meshes per linear inch, passes approximately the same size grains as a sieve with 0.25 diameter holes.

The effect of mechanical analysis or granulometric composition upon the strength of mortar is illustrated in the following table. By this table, the relative strength of different sands may be approximately estimated.

Tests by New York Board of Water Supply of 1:3 Mortar Made with Sands of Different Mechanical Analyses.

Percentages Passing Sieves.				Tensile Test. Lb. Per Sq. In.		Compression Test. Lb. Per Sq. In.	
No. 4	No. 8	No. 50	No. 100	7 Days	90 Days	7 Days	90 Days
100	70	12	5	213	613	2690	5640
100	86	21	6	263	412	1915	4660
100	99	26	2	177	325	905	2170
100	97	28	6	178	282	1070	1500
100	94	44	12	139	228	905	1130
100	100	52	14	122	170	275	810
100	100	94	48	80	149	330	490

If the sand is clean, a coarse sand always produces a stronger mortar or concrete than a fine sand. A mixed sand ranging from fine to coarse is best for mortars of moderately lean proportions, such as 1:2½, 1:3, and 1:4.

For watertight concrete, sand may contain considerable fine material, say, up to 10% passing a No. 100 sieve, providing it is free from organic impurities. Because of the bad effects of organic matter, the character of this silt must be carefully determined.

Another test for choosing between two different sands is to make each of them into a mortar with the cement to be used on the work and in the proportions selected for the mortar or concrete, using the same weight of sand and cement in each test. The sand producing the smallest bulk of plastic mortar, as determined by carefully measuring its depth in a deep vessel, such as a graduate of 250 cubic centimeters capacity, is the sand which, in general, will produce the densest and strongest mortar and concrete. When used in concrete the particles of sand may run so coarse as to largely overlap the fine particles of the coarse aggregate, thus producing an excess of grains in the concrete about $\frac{3}{8}$ inch in diameter. For this reason a comparatively fine sand may give a denser concrete than a course sand, the finer grains filling the voids in the stone more readily.

Washing Sand. Sand containing impurities sometimes may be made fit for use by thorough washing in special apparatus, such as is described on page 367.

Changing the Brand of Cement. For some reason, not yet fully determined, a sand containing impurities which prevent hardening under ordinary conditions with a certain cement may be used satisfactorily with a different brand of cement.

SELECTION OF STONE

Either clean gravel or a hard broken stone will produce satisfactory concrete. Sandstone, shale, or very soft limestone gives a concrete of low strength, but may be used in certain cases where the stresses are low.

The percentage of voids in the stone has little effect upon the quality of the concrete provided they are allowed for by correct proportioning. However, if the proportions are selected arbitrarily, the percentage of voids may have an appreciable effect upon the cost of the materials. The stone with the smallest percentage of voids is cheapest from the contractor's standpoint if the measurement of the stone is by volume. This is illustrated in pages which follow.

EFFECT OF PROPORTIONS UPON COST

The effect of the proportions of the materials upon the cost of the concrete is readily determined by simple calculations based upon the quantities of materials required for a cubic yard as given in the tables on pages 150 to 152. Thousands of dollars may be wasted on a single job by using richer proportions than are necessary.

To illustrate the effect upon the cost of needlessly rich proportions, referring to Table 22 on page 151, we see that a 1:2:4 concrete of average materials requires 1.57 barrels for a cubic yard of concrete in place, while 1:3:6 proportions require 1.11 barrels, a difference of 0.46 barrels cement per cubic yard of concrete. If the cement costs $2.00 per barrel delivered on the job, this is equivalent to a difference of 92 cents per cubic yard, which is well worth saving in cases where the leaner mix will give a sufficiently strong and watertight concrete and where the setting qualities of the leaner mixture are satisfactory for the work. If the aggregates are not specially graded, the strength of a 1:3:6 concrete may be estimated as 25% lower than a 1:2:4 concrete.

The difference in cost of concrete in proportions 1:2:4 and 1:2½:5 is illustrated in detail in Example 1.

Example 1. What is the difference in cost of materials for concrete in proportions 1:2:4 and 1:2½:5, based on 3.8 cubic feet per barrel, with cement (delivered) at $2.00 per barrel, sand at 75¢ per cubic yard, and broken stone (with 45% voids) at $1.40 per cubic yard?

Solution: From Table 31, page 167, we find the cost of the materials necessary for a cubic yard of 1:2:4 concrete with the given prices of cement, sand, and stone, to be $4.70 per cubic yard, and for 1:2½:5 concrete from Table 33, page 169 to be $4.23.

The cost of the materials for the 1:2½:5 mixture is thus 47¢ less per cubic yard than the 1:2:4 concrete, or 10% cheaper. The difference in the cost of the labor per cubic yard, which is slight, is discussed in Chapter XIII. The compressive strength of a 1:2½:5 mixture will average about 10% less than that of the 1:2:4, which in this case corresponds to the difference in cost.

A change in the relative proportions of sand and stone may result in a stronger concrete without appreciably increasing the cost. Conversely, the quantity of cement per cubic yard of concrete frequently may be largely reduced, without decreasing the strength, by a change in the relative proportions of sand to stone. With certain aggregates, for example, it may be possible to substitute 1:2:5½ concrete for 1:2½:4 concrete with a resulting strength substantially the same and yet with an appreciable saving in cement. The 1:2½:4 concrete requires (see p. 151) 1.46 barrels cement, while a 1:2:5½ requires only 1.31 barrels, a difference of 0.15 barrels cement to the cubic yard of concrete, that is, at $2.00 per barrel, a difference in cost of 30¢ per cubic yard. Of course many aggregates will not admit of 1:2:5½: proportions, but in almost any case a 1:2¼:5 may be substituted for the 1:2½:4, with a reduction in cost. The relative economy of these mixtures is illustrated in Example 2.

Example 2: With similar materials to those given in Example 1, what is the relative economy of a 1:2½:4 and a 1:2¼:5 mixture?

Solution: Figuring the cost of each proportion, we have from Table 22 by interpolating for the 1:2¼:5 proportions:

	1 : 2½ : 4			1 : 2¼ : 5		
Cement	1.46 bbl.	@ $2.00 =	$2.92	1.35 bbl.	@ $2.00 =	$2.70
Sand	0.51 cu.yd	@ 0.75 =	0.38	0.43 cu.yd.	@ 0.75 =	0.32
Stone	0.82 cu.yd	@ 1.40 =	1.15	0.95 cu.yd.	@ 1.40 =	1.33
Total			$4.45	Total		$4.35

The difference is thus 10¢ per cubic yard in favor of the 1:2¼:5 mixture, but as the compressive strength of these two mixtures is practically identical, the 10¢ per cubic yard is well worth saving.

EFFECT OF THE CHARACTER OF THE STONE UPON THE COST OF CONCRETE

The necessity for selecting a stone of good quality has been referred to on a previous page. In the following pages, the character of the stone is considered simply from the standpoint of cost. The cheapest stone does not necessarily mean the cheapest concrete, because the character of the stone affects the bulk of the set concrete and thus has a direct influence on its cost per cubic yard. The same fact is true of sands, as will be discussed later, and in a less degree of cements. To the contractor paying for the coarse aggregate by the

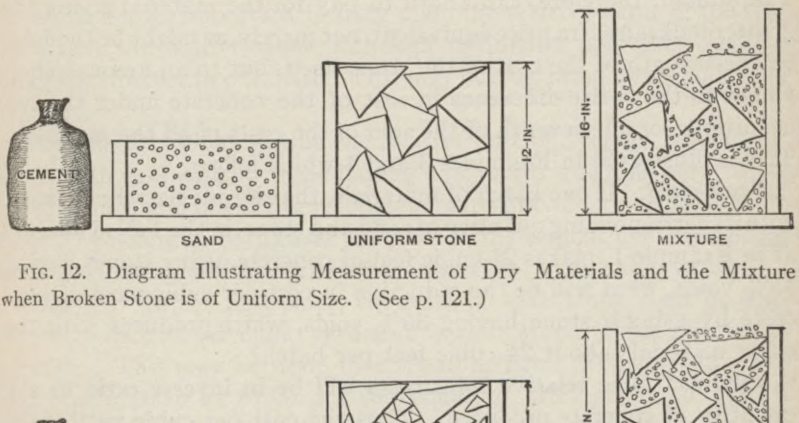


FIG. 12. Diagram Illustrating Measurement of Dry Materials and the Mixture when Broken Stone is of Uniform Size. (See p. 121.)

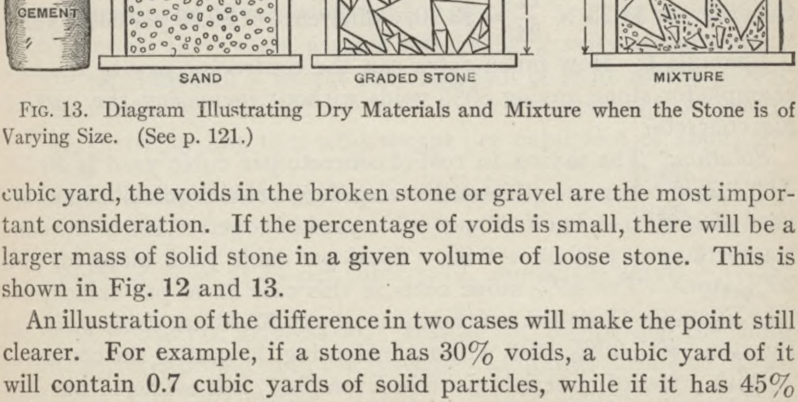


FIG. 13. Diagram Illustrating Dry Materials and Mixture when the Stone is of Varying Size. (See p. 121.)

cubic yard, the voids in the broken stone or gravel are the most important consideration. If the percentage of voids is small, there will be a larger mass of solid stone in a given volume of loose stone. This is shown in Fig. 12 and 13.

An illustration of the difference in two cases will make the point still clearer. For example, if a stone has 30% voids, a cubic yard of it will contain 0.7 cubic yards of solid particles, while if it has 45% voids, a cubic yard will have 0.55 cubic yards of solid stone. Now, since the stone is measured by volume loose, that containing the larger amount of solids will produce, when the solid particles are mixed with the same bulk of cement plus sand plus water, the larger bulk of concrete. Consequently, a given bulk of the concrete made with the 30% stone will contain less cement than the other, and the cost per cubic yard of this concrete will be less in proportion.

To illustrate more specifically, if a batch of concrete with one set of materials makes 21 cubic feet of concrete, while with another set of materials a batch in the same proportions makes 24 cubic feet, conditions which are possible in practice, the materials producing the larger bulk will give a concrete costing one-eighth less than the other. The builder, therefore, can afford to pay for the material giving the greater bulk, an extra price equivalent, not merely, as might be thought, to one-seventh of the cost of the stone itself, but to an amount equivalent to the entire difference in cost of the concrete under the two conditions, or one seventh of the sum of the costs of all the materials. This is illustrated in Examples 3 and 4 which follow.

Example 3: If one batch of materials, that is, one barrel of cement with its corresponding quantity of sand and stone, in the $1:2\frac{1}{2}:5$ mixture as in Example 1, makes 21 cubic feet of concrete, using stones having 45% voids, what will be the reduction in cost per cubic yard of concrete by using a stone having 30% voids, which produces with the other materials about 24 cubic feet per batch?

Solution: The relative total costs will be in inverse ratio to the quantity of concrete produced. Thus the cost per cubic yard of the concrete with the stone having 30% voids will be one-eighth less than the other, or $\$4.23 \times \frac{21}{24} = \$3.70$, a difference of $0.53 per cubic yard.

Example 4: How much extra can the contractor pay in the last example for stone having 30% voids without increasing the cost of his concrete?

Solution: The saving in cost of concrete per cubic yard is $0.53. The $1:2\frac{1}{2}:5$ concrete with stone having 30% voids requires 0.80 cubic yard of stone (see Table 22) per cubic yard of concrete, hence the contractor may pay $\$0.53 \div 0.80 = \$0.66$ per cubic yard more for the 30% stone. The 45% stone costs in this case $1.40 per cubic yard (see Example 1), so the contractor may pay $2.06 per cubic yard for the stone with 30% voids without increasing the cost of the concrete.

With prices of materials given in Example 1, it is evident from Examples 3 and 4 that a difference of 15% in the voids may affect the value of the stone by nearly 50%. A difference of only 5% in the voids may therefore under these conditions affect the comparative cost of two stones by 16%. That is, a stone with 40% voids may be worth to the contractor 16% more than a similar stone with 45% voids.

Gravel is generally cheaper for the contractor than broken stone at the same price per cubic yard because it is apt to contain fewer voids. Similarly, crusher run broken stone is cheaper at the same price per cubic yard than screened broken stone.

If the stone is purchased by weight, the percentage of voids is of less interest to the contractor. In this case, the specific gravity of the stone has an important bearing upon the relative value of the two materials, the lighter stone, although frequently poorer in quality, being the cheaper to purchase. This may be illustrated by the following example.

Example 5: What will be the relative cost of average 1:2½:5 concrete, with broken trap stone having 45% voids at $1.00 per ton of 2000 pounds, and of the same concrete, with gravel having 30% voids at $1.00 per ton, in both cases the price of the cement delivered being $2.00 per barrel, and the price of the sand $0.75 per cubic yard?

Solution: In the first place, the price of each stone must be converted to its cost per cubic yard, as it is the volume which affects the concrete. This may be done directly from Table 37, page 173. We find cost of trap at $1.00 per ton equal to $1.22 per cubic yard if there are 50% voids or $1.46 per cubic yard with 40% voids, so that 45% voids would be $1.34 per cubic yard. Gravel at $1.00 per ton is equivalent to $1.56 per cubic yard.

To compute these costs, assume the specific gravity of the trap as 2.9, corresponding to a weight per cubic foot of solid rock of about 180 pounds (see p. 173) and assume the specific gravity of the gravel as 2.65, corresponding to a solid weight per cubic foot of about 165 pounds. We thus have for the cost of the trap stone $\frac{\$1.00}{2000} \times 180 \times (1 - 0.45) \times 27 = \$1.34$ per cubic yard, and of the gravel $\frac{\$1.00}{2000} \times 165 \times (1 - 0.30) \times 27 = \$1.56$. Instead of comparing the bulk of the concretes produced in the two cases, as in the solution to Example 3, the cost of the concrete in each case may be figured directly, with the same results, by using the quantities in Table 22, page 151.

	With Trap 45% Voids.		With Gravel 30% Voids.	
Cement	1.30 bbl. @ $2.00 =	$2.60	1.13 bbl. @ $2.00 =	$2.26
Sand	0.46 cu.yd. @ 0.75 =	0.34	0.40 cu.yd. @ 0.75 =	0.30
Stone	0.92 cu.yd. @ 1.34 =	1.23	0.80 cu.yd. @ 1.56 =	1.25
Total		$4.17	Total	$3.81

The gravel at $1.00 per ton will therefore make concrete in the given proportions at 36¢ less in price per cubic yard of concrete in place than the broken trap at $1.00 per ton. This is a greater difference than usually will be found between gravel and broken stone, since 30% voids is small for gravel. The case is also uneconomical, as with a gravel of only 30% voids the proportion of the sand should have been decreased and the stone increased.

Such substitution of materials as we have suggested in Examples 3, 4, and 5 must be made with caution and should not be permitted in specifications except with the distinct requirement that it be sanctioned by the engineer, since the excess in bulk produced by different ingredients may reduce the strength of the concrete by decreasing the absolute volume of the cement in a unit volume of the concrete.

These examples therefore apply directly only when the proportions are fixed artificially regardless of the character of the aggregates. For the best practice, the proportions should be varied so as to produce not merely the cheapest concrete but the concrete which will have the required strength, density, and watertightness. A full study of the conditions is therefore essential for each individual case.

EFFECT OF THE QUALITY OF THE SAND UPON THE COST OF THE CONCRETE

In general, the finer the sand the larger the bulk of mortar that it will make in any given proportions. On the other hand and to a still greater degree, the finer the sand the weaker the mortar. It is more harmful, therefore, to increase the bulk of concrete by substitution of fine sand for coarse with the same cement and stone than to use a stone with fewer voids, as explained in the previous paragraph. Any attempt to reduce the cost of the materials for concrete by using a finer sand, therefore, must not be considered for a moment. Economy usually may be effected by selecting sand of the very best quality, that is, sand which will produce the strongest mortar with a given proportion of cement, and then adjusting the proportion of cement to sand so as to produce concrete of a strength just sufficient for the proposed work.

In the table below, data are given selected from the elaborate experiments by Mr. R. Feret which illustrate the relative economy of mortar of different sands. In this table, besides the strength of mortar of several sands mixed in different proportions, the absolute volumes† of the ingredients are tabulated and also the density‡ of the mortars.

TABLE 17. FERET'S TESTS OF DENSITY AND STRENGTH OF MORTARS MADE WITH DIFFERENT SANDS*

Sand	Proportions by Weight	Materials for One Cubic Yard Mortar		Absolute Volume Cement c	Absolute Volume Sand s	Density (c + s)	Strength of Mortar		
		Cement Bbl.	Sand Cu. Yd.				Shearing Lb. per Sq. In.	Tension Lb. per Sq. In.	Compression Lb. per Sq. In.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
G	1:3.2	2.15	1.00	0.155	0.605	0.760	2560	367	4170
	1:2.5	2.59	0.92	0.186	0.559	0.745	2790	421	5210
	1:1.8	3.14	0.82	0.226	0.499	0.725	3580	480	5970
S	1:3.1	2.06	1.04	0.148	0.555	0.703	1810	320	2720
	1:2.5	2.40	0.96	0.173	0.525	0.698	2250	368	3430
	1:2.0	2.84	0.89	0.204	0.486	0.690	2650	415	4380
D	1:3.5	1.64	0.94	0.118	0.485	0.603	768	214	1230
	1:2.4	2.21	0.86	0.159	0.444	0.603	1410	302	1940
	1:1.8	2.71	0.79	0.195	0.409	0.604	2130	364	2840
M	1:3	2.08	1.04	0.150	0.539	0.689	3100	450	4010
C	1:0	7.42	0.00	0.534	0.000	0.534	3680	698	8040

NOTE.—Sand G consists of granitic particles, large and rounded, of which 27 per cent pass a screen having 15 meshes per linear inch.

Sand S is shelly, with medium-sized grains, of which 83 per cent pass a screen having 15 meshes per linear inch.

Sand D is from the French dunes, strongly silicious, fine and rounded, of which 99 per cent pass a screen having 46 meshes per linear inch.

Sand M is ground quartz, with angular grains of three sizes artifically mixed in equal parts.

C is neat cement.

*Compiled from Bulletin de la Société d' Encouragement pour l' Industrie Nationale, 1897, Vol. II, p. 1593.

†Tabulated in "Concrete, Plain and Reinforced," 1911, second edition, p. 136.

‡Absolute volumes of any ingredient of a concrete or mortar represent the ratio of the total volume of the solid particles of the ingredient to the total bulk of concrete. The volume of the solid particles of an ingredient is obtained by dividing its weight by its specific gravity. The sum of the absolute volumes of the dry materials gives the density of concrete or mortar, which may be defined as the ratio of the total volume of the solid particles to the total bulk of concrete, or, in other words, the total volume of solid particles in a unit volume of concrete.

The relative economy of mortars of different sands may be seen by comparison of the quantity of cement used and the strength of the mortars. For example, a mortar of coarse sand in proportions 1:1.8 by weight contained 22.6% cement in absolute volume, corresponding to 3.14 barrels cement in a cubic yard of mortar, while a mixture of the same cement and fine sand in proportions 1:1.8 by weight contained 19.5% cement in absolute volume or 2.71 barrels cement per cubic yard of mortar. The mortar of fine sand therefore contained 14% less cement per cubic yard than the mortar of coarse sand. When, however, we consider the strength of the two mortars at the age of five months, we find the compressive strength of the mortar of coarse sand 5970 pounds per square inch against 2840 pounds per square inch for the mortar of fine sand in the same proportions. Thus, while the mortar of fine sand contained only 14% less cement than the other, its compressive strength was 52% less, or not half the strength of the mortar of coarse sand.

From the same series of tests, it appears that a 1:3 mortar of the coarse sand actually had greater compressive strength than the 1:1.8 mortar of fine sand, the coarse sand making the denser mortar and this largely over-balancing the difference in the nominal proportions.

The method of calculating the weight of cement and the volume of sand per cubic yard of mortar from the absolute volumes of cement and sand in the table is illustrated in Example 6. Example 7 gives the method of determining costs of mortars with different sands for the purpose of comparing the actual economical value of two sands.

Example 6: What will be the number of barrels of cement and the number of cubic yards of loose sand per cubic yard of mortar, in one case for a mortar of coarse sand like G in Table 17, in proportions 1:3 by dry weight—assuming that the sand weighs 104 pounds per cubic foot and contains 3% moisture—and, in another case, for a 1:2 mortar by dry weight of fine sand like D in Table 17,—assuming that it weighs 90 pounds per cubic foot and contains 5% moisture?

Solution: The results may be obtained from columns (3) and (4), Table 17, which have been prepared by the authors. To illustrate the methods of computation, the processes will be given in full. In the table, the quantities of cement and sand are given in terms of absolute volume, which must be reduced to barrels of cement and to cubic yards of loose sand per cubic yard of mortar. Now, 1:3 mortar is not given in the table for sand G, but by interpolation we may estimate for this the absolute volume of cement as 0.164 and of sand as 0.592. Similarly

1:2 mortar of sand D would have an absolute volume of cement 0.183 and of sand 0.421. To convert the absolute volume of cement to barrels per cubic yard, we have simply to multiply it by the factor 13.9, which is the weight of a cubic foot of water, times the specific gravity of the cement, times the number of feet in a cubic yard, divided by the weight of a barrel of cement, or, in figures, $62.4 \times 3.1 \times 27 \div 376 = 13.9$. We have, therefore, in the 1:3 mortar of coarse sand, $0.164 \times 13.9 = 2.28$ barrels Portland cement per cubic yard of mortar and in the 1:2 mortar of fine sand, $0.183 \times 13.9 = 2.54$ barrels cement per cubic yard of mortar. For the two sands, the absolute volume of each gives the ratio of solid grains of sand to the total bulk of the mortar. To reduce this to loose measurement of sand, therefore, find the volume of solids in a unit volume of loose sand. Sand has a specific gravity of 2.65, which, multiplied by the weight of a cubic foot of water, 62.4, gives 165 pounds as the weight of a solid cubic foot of rock of the nature of sand.

Taking now the coarse sand and deducting the moisture, we find that a cubic foot of the sand loose contains $104 - 3.1 = 100.9$ pounds of solid grains, which weight divided by 165 gives 0.61 or 61% solid matter. Similarly, for the fine sand we have $\frac{90-4.5}{165} = 0.518$ or $51\frac{3}{4}\%$ solids. Dividing each of these into the absolute volumes of the sand in the two mortars, we find for the 1:3 mortar of coarse sand $\frac{0.592}{0.610} = 0.97$ cubic yards loose sand per cubic yard of mortar. Similarly, for the 1:2 mortar of fine sand, $\frac{0.421}{0.518} = 0.81$ cubic yards loose sand per cubic yard of mortar.

Example 7: What are the relative costs of the 1:3 mortar of coarse sand and the 1:2 mortar of fine sand in the preceding example, with Portland cement at $2.00 per barrel, the coarse sand at 85¢ per cubic yard, and the fine sand at 50¢ per cubic yard?

Solution: In the solution of the preceding example, the quantities of materials required in a cubic yard of each mortar are computed and they are also given directly in the table. We therefore simply need to multiply these quantities by the unit cost of the materials.

	Mortar of Coarse Sand	Mortar of Fine Sand
Cement	2.28 bbl. @ $2.00 = $4.56	2.54 bbl. @ $2.00 = $5.08
Sand	0.97 cu. yd. @ $0.85 = 0.82	0.81 cu. yd. @ $0.50 = 0.40
Totals	$5.38	$5.48

The cost is slightly in favor of the coarse sand, although the coarse sand costs 41% more per cubic yard than the fine and a larger quantity of it is required. Comparing the two mortars in the table on page 125, however, we find that the 1:3 mortar of coarse sand is stronger and denser than the 1:2 mortar of fine sand, and is therefore the better.

The preceding problems illustrate the necessity for careful comparison of sands, and also how easy it is to fall into the error of using a nominally rich mortar with poor sand when leaner mortar of good coarse sand would be better and cheaper.

It is evident that rational proportioning of ingredients for concrete and mortar is of prime importance, and that money spent in scientific determining of proper ingredients and proportions will not only insure the safety of the structure but in most cases will be more than counterbalanced by the saving in cement. The methods indicated are somewhat scientific, but a study of such principles will well repay anyone who is desirous of producing concrete at the lowest possible cost. Of course if the quantity of cement and sand in a cubic yard of mortar are known by experiment,—and experiment is the proper way to test such materials,—the problem of relative cost in Example 7 may be solved at once without the preliminary calculations in Example 6.

CHAPTER VII

TABLES OF QUANTITIES OF MATERIALS FOR CONCRETE AND MORTAR

The quantities of materials required to make a cubic yard of concrete are an important factor of the cost. Even if the cost is not estimated in advance, the materials always must be ordered ahead, so that the number of barrels of cement and the quantity of sand and stone must be calculated.

Contractors with little experience in concrete construction have frequently lost money by assuming that the quantity of gravel or broken stone plus the quantity of sand is equal to the volume of the finished concrete; thus, by this reasoning, 6 cubic yards of 1:2:4 concrete would require 2 cubic yards of sand and 4 cubic yards of gravel or broken stone. This is entirely wrong, since the grains of sand fill, to a certain extent, the spaces or voids between the larger pebbles. It is incorrect, on the other hand, to figure the quantity of gravel or of broken stone alone as exactly equal to the given volume of the concrete, because the introduction of the mortar, which is always in excess of the actual voids, ordinarily swells the bulk. As a matter of fact, with ordinary proportions the volume of the compacted concrete is apt to be about 10% more than the bulk of the stone or gravel measured loose. The effect of different kinds of aggregates, especially as regards the percentage of voids, has been discussed in the previous chapter on Proportioning, and various cases have been considered with illustrations.

In the present chapter are presented full tables giving the quantities of materials for a cubic yard of concrete under ordinary conditions and also the volume of concrete produced with one barrel of cement and various proportions of aggregate. (See pp. 149 to 157.) To show clearly the principle involved in a concrete mixture, the theory is discussed briefly and formulas for quantities are given. Incidentally, the units of weight and volume are considered and the necessity for accurate statement of proportions is emphasized.

In chapters that follow, tables are given for estimating the sizes and weights of steel rods for reinforcement (Chap. XVIII), the quantity of lumber for forms (Chap. XXI), and the volume of concrete in members of various dimensions (Chap. XVII).

The character of the materials affects the volume of different concretes even when mixed in the same proportions, but, while it is impossible to construct tables which are exactly applicable to all conditions, by basing the values upon average materials the data are of general application. The effect of different percentages of voids in the gravel or broken stone is easily allowed for, but the variations in volume of the concrete or mortar due to difference in the fineness of the sand are more difficult to predicate because of the infinite variety of combinations which occur in nature. Therefore, while the tables in the following pages provide for stone with different percentages of voids, to avoid complications they are based on good quality of medium coarse sand such as is suitable for first-class concrete, giving for comparison (p. 139) a few values for concrete made with fine sand and (p. 149) a table for mortars with fine sand. For closer determinations it is suggested that two or three tests be made of the volume of concrete produced by a batch of the materials to be used, mixed in exactly the proportions specified. Mold this concrete in a form holding not less than one cubic foot, being sure that none of the mix is left over, and, after the concrete has set, measure its volume very exactly. Knowing the weight of cement used in the specimen, compute the quantity of cement per cubic yard of concrete.

The tables are the result of a comparison of tests made in the United States, France and Germany. All available literature was consulted in their preparation, quantities and volumes given by different experimenters were carefully studied, and values were selected which represent average materials and practical conditions. Since the first issue of the tables, the values have been checked repeatedly by comparison with records on construction work.

FULLER'S RULE FOR QUANTITIES

The simplest rule for determining the quantities of materials for a cubic yard of concrete is one devised by William B. Fuller. Expressed in words, it is as follows:

Divide 11 by the sum of the parts of all the ingredients, and the quotient will be the number of barrels of Portland cement required for 1 cubic yard of concrete. The number of barrels of cement thus found, multiplied respectively by the "parts" of sand and stone, will give the number of barrels of each required for 1 cubic yard of concrete, and multiplying these values by 3.8 (the number of cubic feet in a barrel), and dividing by 27 (the number of cubic feet in a cubic yard), will give the quantities of sand and stone, in fractions of a cubic yard, needed for 1 cubic yard of concrete.

To express this rule in the shape of formulas:

Let

c = number of parts cement;

s = number of parts sand;

g = number of parts gravel or broken stone.

Then

$\frac{11}{c+s+g} = P$ = number of barrels Portland cement required for one cubic yard of concrete.

$P \times s \times \frac{3.8}{27}$ = number of cubic yards of sand required for one cubic yard of concrete.

$P \times g \times \frac{3.8}{27}$ = number of cubic yards of stone or gravel required for one cubic yard of concrete.

The following table is made up from Fuller's rule and represents fair averages of all classes of material. The first figure in each proportion represents the unit, or one barrel (4 bags), of packed Portland cement (weighing 376 pounds), the second figure, the number of barrels loose sand (3.8 cubic feet each) per barrel of cement, and the third figure, the number of barrels loose gravel or stone (3.8 cubic feet each) per barrel of cement:

Materials for One Cubic Yard of Concrete

Proportions	Cement Barrels	Sand Cubic yards	Gravel or Stone Cubic yards
1 : 1½ : 3	2.00	0.42	0.84
1 : 2 : 4	1.57	0.44	0.88
1 : 2½ : 5	1.29	0.45	0.91
1 : 3 : 6	1.10	0.46	0.93
1 : 4 : 8	0.85	0.48	0.96

If the coarse material is broken stone screened to uniform size, it will, as is stated above, contain less solid matter in a given volume than an average stone, and about 5 per cent must be added to the quantities of *all* the materials. If the coarse material contains a large variety of sizes so as to be quite dense, about 5 per cent may be deducted from all of the quantities.

Example 1: What materials will be required for six machine foundations, each 5 feet square at the bottom, 4 feet square at the top, and 8 feet high?

Solution: Each pier contains 163 cubic feet, and the six piers therefore contain $\frac{6 \times 163}{27} = 36.2$ cubic yards. If we select proportions 1:2½:5, we find, multiplying the total volume by the quantities given in the table, that there will be required, in round numbers, 47 barrels (or 188 bags) cement, 16½ cubic yards loose sand, 33 cubic yards loose gravel.

WEIGHTS AND VOLUMES

The following weights and volumes are based upon averages of a large number of tests by the authors and other experimenters. The net weights of cement per barrel are the standards recommended by the American Society for Testing Materials.

Portland Cement, weighs per barrel, net	376 lb.
Portland Cement, weighs per bag, net	94 lb.
Natural Cement, weighs per barrel, net	282 lb.
Natural Cement, weighs per bag, net	94 lb.
Cement Barrel weighs from 15 to 30 lb., averaging about	20 lb.
Portland Cement is assumed in standard proportions to weigh per cubic foot	100 lb.
Packed Portland Cement, as in barrels, averages per cubic foot about	115 lb.
Packed Portland Cement based on a barrel holding 3.5 cubic feet, weighs per cubic foot	108½ lb.
Loose Portland Cement averages per cubic foot about	92 lb.
Volume of Cement Barrel, if cement is assumed to weigh 100 lb. per cubic foot	3.8 cu. ft.
American Portland Cement Barrel averages between heads about	3.5 cu. ft.
Foreign Portland Cement Barrel averages between heads about	3.25 cu. ft.
Natural Cement Barrel averages between heads about	3.75 cu. ft.
Weight of Paste of neat Portland cement averages per cubic foot about	137 lb.
Volume of Paste made from 100 pounds of neat Portland cement averages about	0.86 cu. ft.
Volume of Paste made from one barrel of neat Portland cement averages about	3.2 cu. ft.
Weight of Portland Cement Mortar in proportions 1:2½ averages per cubic foot	135 lb.
Weight of Concrete and Mortar varies with the proportions as well as with the materials of which it is composed.	
Weight of Portland Cement Concrete per cubic foot after setting:	
Cinder Concrete averages	112 lb.
Conglomerate Concrete averages	150 lb.
Gravel Concrete averages	150 lb.
Limestone Concrete averages	148 lb.
Sandstone Concrete averages	143 lb.
Trap Concrete averages	155 lb.
Loose Unrammed Concrete is 5% to 25% lighter than concrete in place, varying with the consistency.	

Formerly the net weight per barrel of Portland cement was 380 pounds, of eastern Natural cement, 300 pounds, and of western Natural cement, 265 pounds.

EXPERIMENTS UPON WEIGHT OF CEMENT

Experiments for the Boston Transit Commission upon 31 barrels of Portland cement of American and foreign brands illustrate the variation in weight of the same cement differently compacted. From the summary of these tests presented in the table below, it appears that the same cement may vary in weight from 85 pounds per cubic foot, when sifted, up to 119 pounds per cubic foot, when packed in a barrel. One German cement packed in the original barrel weighs as high as 123 pounds per cubic foot.

Tests of Capacity of Portland Cement Barrels and Weight of Contents
(See p. 133)

Tabulated by the authors from measurements of Boston Transit Commission, 1896, Howard A. Carson, Chief Engineer

No. of Barrels Tested Results Averaged	Brand	Height Between Heads	Average Diameter of Barrel	Average Horizontal Area	Capacity of Barrel Between Heads	Depression of Cement Below Head	Volume of Depression	Volume of Cement per Barrel			Net Weight of Cement per Barrel		Weight per Cubic Foot				Weight of Barrel
								Packed	Loose	Shaken*	Before Dumping	After Dumping	Packed	Loose	Shaken	Sifted	
		ft.	ft.	sq. ft.	cu. ft.	ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
5	A	2.12	1.437	1.622	3.446	0.17	0.235	3.21	3.75	3.432	377.4	376.9	117.5	100.5	109.4	90.6	21.1
6	B	2.19	1.430	1.605	3.495	0.12	0.171	3.35	4.17		381.0		113.8	91.4			29.0
3	C	2.07	1.412	1.571	3.249	0.07	0.096	3.15	4.05		387.0		112.8	94.2			22.7
5	D	2.01	1.407	1.554	3.123	0.07	0.093	3.03	3.99	3.522	373.2	371.4	123.2	93.2	105.5	80.3	25.6
6	E	2.08	1.403	1.546	3.219	0.04	0.059	3.16	4.19		374.2		118.4	89.2			24.3
1	F	2.13	1.38	1.496	3.186	0.03	0.039	3.15	4.27	3.695	378.0	378.0	120.1	88.5	102.3		22.0
5	G	2.01	1.46	1.662	3.327	0.10	0.148	3.21	4.06	3.598	370.7	370.2	115.7	91.4	102.9		23.3
Final Averages		2.09	1.42	1.579	3.292	0.09	0.120	3.18	4.07	3.562†	377.4	374.1†	118.8	92.6	105.1†	85.4†	24.0

NOTE—A and B are American Cements; C, D, E and F are German Cements; G a Danish Cement; Paper weighs about 1 lb.
*Box rocked over bar.
†Partial averages, to be compared only with like brands.

From these experiments the ratios of volume and weights of the same cements in different degrees of compactness may be estimated as follows:

Ratio of volume of packed cement to capacity of barrel between heads	0.97
Ratio of volume packed to volume loose	0.78
Ratio of volume packed to volume shaken	0.88
Ratio of volume loose to volume shaken	1.13
Ratio of weight packed to weight loose	1.28
Ratio of weight packed to weight shaken	1.13
Ratio of weight packed to weight sifted	1.37

SPECIFYING THE PROPORTIONS OF CONCRETE

Proportions must be stated so clearly that there will be no opportunity for disagreement between the engineer and the contractor. There is no objection to stating proportions by parts, giving them in the order of their fineness and separated by colons—1:2:4, for example, meaning one part cement to 2 parts sand to 4 parts stone—but the unit of measurement must be distinctly specified.*

Although cement is now generally packed in bags, a barrel of cement is the commercial unit. The variation in the weight and volume of cement, according as it is loose or packed, has been discussed on page 133. For the sake of uniformity, the standard unit of measurement is now considered as a barrel of cement weighing 376 pounds and assumed to occupy a volume of 3.8 cubic feet. Thus, proportions 1:2:4 represent one barrel (4 bags) cement to 7.6 cubic feet of sand to 15.2 cubic feet of gravel or broken stone. Cement is measured by counting the bags, and sand and stone by measuring the loose volume.

The importance of specifying a definite unit is illustrated by the variety of standards which have been adopted by different engineers. The unit of measurement has been specified variously from 3.1 to 4.5 cubic feet per barrel and 3.5 and 4 cubic feet are still frequently used. The difference in the cost of the concrete with proportions based on these two units is illustrated in the following example.

Example 2: If a contractor, bidding on 1:2½:5 concrete, based his bid on a unit measurement of 4 cubic feet to the barrel and found later that he must measure his materials on a basis of 3.5 cubic feet to the barrel, what would be his loss per cubic yard of concrete with cement at $2.00 per barrel?

Solution: Values are given on pages 150 and 152 for quantities of materials based on both of the units. For the 3.5 unit, assuming 45%

* Formerly, it was common practice with mortar to give the number of parts of sand before the cement, 2 to 1, for example, meaning 2 parts of sand to one part of cement, but, since it is the universal practice in proportioning concrete to give the cement first, the same arrangement should be followed with mortar. Thus 1:2 mortar means one part cement to 2 parts sand.

voids in the stone, 1.39 barrels of cement would be required per cubic yard of concrete, and with the 4 cubic feet unit, 1.24 barrels cement per cubic yard, a difference of 0.15 barrel cement per cubic yard, which at $2.00 per barrel would represent a loss of $0.30 per cubic yard on the contract. On some contracts, this difference might be sufficient to convert a small profit into a loss.

THEORY OF A CONCRETE MIXTURE

The volume of fresh concrete or mortar produced by any mixture of cement and aggregate is equal to the sum of the volume of the *separate particles* of the cement, the sand, and the other dry materials, the water contained in the aggregate and added in mixing, and the small volume of air entrained between the particles. The volume of mortar or concrete when set is not appreciably different from its compacted volume when fresh or green, except that very wet mixtures occupy slightly more space than mixtures of medium consistency, but before setting expel a portion of the water because of the greater specific gravity of the solids. The volumes of the particles of dry materials are termed *absolute volumes* as distinguished from the apparent volumes determined by measuring the materials.*

The fact that water actually occupies space in a mass of fresh concrete or mortar has been entirely ignored by many writers on the subject of concrete mixtures. The fact has been stated (p. 124) that fine sand with cement produces a larger bulk of mortar than coarse sand mixed with cement in the same proportions. While this is due partly to the fact that the finest grains of the sand are nearly the same size as the grains of cement, and therefore force the latter apart, the chief cause is the extra water which the fine sand requires when being gaged. This water occupies actual space in the mass, forming a film around the sand grains so as to keep them apart even as the concrete sets. Mr. R. Feret of France has shown that every sand requires a fixed percentage of water to gage it to plastic consistency. This percentage may vary from 3% to 23% by weight.† It is evident, therefore, that the volume of the water is one of the increments in the volume of concrete and must be considered.

* See page 125.

† See Taylor and Thompson's "Concrete, Plain and Reinforced," second edition, p. 179.

FORMULAS FOR QUANTITIES OF MATERIALS AND VOLUMES

Concrete when it is placed is composed of:

solid particles of cement;
solid particles of sand;
water required for mixing the mortar, plus the entrained air;
solid particles of stone;
water coating particles of stone, plus air voids produced in mixing.

The sum of these volumes, taking the water as the quantity left in the concrete after the excess sometimes used in mixing has been expelled, will be substantially the same as the volume of the set concrete.

As indicated on page 135, the required amount of water varies with the character of the materials, especially with the sand. The percentage of air voids in concrete also varies with the proportions of the mixture, a lean mortar containing more air voids than a rich one. By what appears to be a peculiar coincidence, experiments show that with ordinary bank sand the sum of the water and the air voids in a mortar is approximately constant with different proportions of the same cement and sand.

The above quantities may be expressed as a formula, which will permit the determination of the quantity of concrete with different kinds of sand and stone.

For notation, let

B = number of barrels cement,
Q = quantity of concrete made with B barrels cement,
Q_1 = quantity of concrete made with one barrel cement,
S = volume of loose sand in cubic feet,
G = volume of broken stone or gravel or cinders in cubic feet,
v = absolute voids in sand determined by weight method,
$1 - v$ = volume of solid grains in a unit volume of loose sand,
v' = absolute voids in stone,
$1 - v'$ = volume of solid particles in a unit volume of loose stone,
r = ratio of volume of water plus air entrained in gaging to the sum of the volumes of solid particles of cement and sand,
p = ratio of volume of water coating stone particles plus air voids, due to imperfect mixing, to the sum of the volumes of the solid particles of the stone,

then

$$Q = (1 + r) [1.95^* B + (1 - v) S] + (1 + p) (1 - v') G \quad (1)$$

In this formula v and v' can be determined by experiments for any sand and stone. (See p. 112). The value of p may be taken as 0.08 for all conditions without appreciable error (this value having been found by study of tests), while the value of r is a variable, ranging from 0.30 for very coarse sand to 0.70 for extremely fine sand, with 0.34 for ordinary coarse bank sand; this ratio meaning that the water plus the air voids in ordinary mortar is 34% of the volume of the solid particles. Reducing the formula to ordinary conditions, it becomes

FOR CONCRETE WITH GOOD COARSE SAND†

$$Q = 1.34 \ [1.95^* B + (1 - v) S] + 1.08 \ (1 - v')G \quad (2)$$

Since it is difficult to determine in advance the exact characteristics of the sand to be used for ordinary conditions, a cubic foot of loose moist sand may be assumed to weigh 93 pounds, of which 4 pounds is moisture, leaving 89 pounds of dry grains per cubic foot of sand, which corresponds to 46 % voids or $v = 0.46$. Thus, with average sand, the formula becomes for one barrel of cement

$$Q_1 = 2.61 + 0.723 S + 1.08 (1 - v') G \quad (3)$$

The number of barrels of cement in a cubic yard of concrete is found by dividing 27 (the number of feet in a cubic yard) by the value of Q_1.

Example 3: How many barrels of cement are required for a cubic yard of 1:3:6 concrete, using good coarse sand and crushed stone with 50% voids?

Solution: Taking the volume of a barrel as 3.8 cubic feet, we have for the volume of sand required with one barrel of cement, with the given proportions of concrete, 1:3:6, $S = 3.8 \times 3 = 11.4$ cubic feet,

* This value converts the solid particles of cement into terms of per barrel and may be considered simply as a constant for all cases. It represents $\frac{376}{62.4 \times 3.1}$ in which the numerator is the number of pounds of cement in a barrel and the denominator is the weight of a cubic foot of water times the specific gravity of the cement. The fraction thus represents the ratio of the weight of a barrel of cement to the weight of a solid cubic foot of cement.

† The derivation of the formulas is given more fully in Taylor & Thompson's "Concrete, Plain and Reinforced," second edition, 1911, p. 223.

and for the volume of stone, G = 3.8 × 6 = 22.8 cubic feet. Using in formula (3) these values and the given value for v', we have:

$$Q_1 = 2.61 + (0.723 \times 11.4) + (1.08 \times 0.50 \times 22.8) = 23.2 \text{ cubic feet.}$$

If one barrel of cement will make 23.2 cubic feet of 1:3:6 concrete, in a cubic yard there will be $\frac{27}{23.2}$ or 1.16 barrels of cement. This value may be taken directly from Table 22 on page 151.

FOR CONCRETE WITH VERY FINE SAND

For $v = 0.545$ and $r=0.60$, the formula (3) changes to

$$Q_1 = 1.60\,[1.95 + 0.455S] + 1.08\,(1 - v')G$$

$$Q_1 = 3.11 + 0.728\,S + 1.08\,(1 - v')\,G \qquad (4)$$

The sand to which this formula applies is assumed to be so fine that all of it passes a sieve having 20 meshes per linear inch, and all but about 15% of it passes a sieve having 40 meshes per linear inch. A fine sand like this may be assumed to weigh, loose with natural moisture, about 80 pounds per cubic foot, of which 5 pounds is moisture, leaving 75 pounds of dry grains per cubic foot. The voids, that is, the spaces occupied by air and moisture, in such a sand will run as high as 54½%. (See Table 16, p. 114)

Example 4: What is the quantity of concrete made from one barrel of cement mixed in proportions 1:2:4, by volume, using fine sand having 54½% of voids and broken stone with 45% of voids?

Solution: Assuming the volume of a barrel as 3.8 cubic feet, we have for the volume of sand, S, for a 1:2:4 concrete, 3.8 × 2 = 7.6 cubic feet, and for the volume of stone, G, 3.8 × 4 = 15.2 cubic feet. Substituting these values and the value for v', in formula (4), we have

$$Q_1 = 3.11 + (0.728 \times 7.6) + (1.08 \times 0.55 \times 15.2) = 17.7 \text{ cubic feet.}$$

This value may be taken directly from Table 18, on page 139.

Example 5: How would the result in the preceding example be changed by using dried sand weighing 100 pounds per cubic foot?

Solution: From Table 15, page 113, we find that sand weighing 100 pounds per cubic foot with 0% of moisture has 39.4% voids. Changing in the previous example $v' = 0.545$ to $v' = 0.394$, the volume of concrete per barrel of cement will be

$$Q_1 = 3.11 + (1.60 \times 0.394 \times 7.6) + (1.08 \times 0.55 \times 15.2)$$
$$= 16.96 \text{ cubic feet.}$$

VOLUME OF CONCRETE WITH FINE VS. COARSE SAND

To illustrate the difference in volume of concrete with the same stone but with fine and coarse sand, the following Table 18 is computed for a few ordinary proportions. It will be seen that the values for ordinary coarse sand, which correspond with the values in the tables, pages 151 and 154, are always somewhat less but vary so little from the fine sand quantities that the regular tables may be used for all kinds of sands without appreciable error.

If the fine sand is dried before measuring, its weight per cubic foot will be greatly increased and the bulk of concrete will be still larger than shown in this table.

TABLE 18. MATERIALS AND VOLUMES FOR A CONCRETE MADE WITH FINE VS. COARSE SAND

Based on a Barrel of 3.8 Cubic Feet. Stone with 45% voids.

Proportions by Parts			Proportions by Volume			Quantities of Material Required for One Cubic Yard of Concrete						Average Volume of Concrete in Place Made from One Bbl. of Cement	
						Ordinary Coarse Sand			Fine Sand			Ordinary Coarse Sand	Fine Sand
Cement	Sand	Stone	Packed Cement Bbl.	Loose Sand Cu. Ft.	Loose Stone Cu. Ft.	Cement Bbl.	Sand Cu. Yd.	Stone Cu. Yd.	Cement Bbl.	Sand Cu. Yd.	Stone Cu. Yd.	Cu. Ft.	Cu. Ft.
1	1½	3	1	5.7	11.4	2.00	0.42	0.84	1.93	0.41	0.82	13.5	14.0
1	2	4	1	7.6	15.2	1.57	0.44	0.88	1.53	0.43	0.86	17.2	17.7
1	2½	5	1	9.5	19.0	1.30	0.46	0.92	1.27	0.45	0.90	20.8	21.3
1	3	6	1	11.4	22.8	1.11	0.47	0.94	1.08	0.46	0.92	24.4	24.9

TABLES AND CURVES OF QUANTITIES AND VOLUMES

Tables 21 to 23 give the quantities of cement, sand, and stone required for one cubic yard of concrete in place, while Tables 24 to 26 give the volume of concrete made from one barrel of cement. The first three tables are of use for estimating the quantity of each material required in a certain piece of work, while the second set shows how much concrete can be made with one barrel of cement and the sand and cement in different proportions. In all of the tables, the proportions are expressed by parts and also by volumes, so that there can be no mistake in the method of measuring.

The first six items in the concrete tables, which refer to a mixture of sand and stone, assume that the stone is graded from fine to coarse, so as to contain sufficient fine material to make a dense concrete.

Ordinarily use Table 22 and Table 25, as these are based on standard units.

Values are given for stone with various percentages of voids. The kind of material, usually having the given percentage of voids, is also stated. For ordinary estimates, where the voids are not known in advance, the 45% columns should be used.

The cement is assumed to be American Portland, but European brands will give the same results. Natural cement weighs less per barrel than Portland, but the bulk of paste made from a barrel is nearly the same as from a barrel of Portland cement; therefore, the resulting volumes of Natural cement mortar and concrete in similar proportions will be substantially the same.

The sand is assumed to weigh, loosely measured, 93 pounds per cubic foot, including 4% natural moisture, that is, including about 4 pounds of moisture per cubic foot. This has been found by comparison with a very large number of experiments to represent average conditions for natural sand as it comes from the bank. If the sand is heavier than this, the quantity of cement required for a cubic yard of concrete or mortar will be slightly less than the tabular values.

A comparison of the volume of concrete with coarse and fine sand is illustrated in the table on page 139.

Examples illustrating the use of the tables are given on page 145.

Curves, from which the quantity of cement required in a cubic yard of concrete of different proportions may be taken directly, are given on page 146. These curves correspond with the 45% column of Table 22. Examples of the use of the curves are given on page 144.

Tables of the volume of mortar and quantities of materials required per cubic yard with both coarse and fine sand are given on page 149.

Method of Compiling Tables. The value of tables such as are contained in this chapter depends upon the accuracy with which the figures agree with average conditions occurring in practice.

As is indicated by the discussion on preceding pages, the composition of concrete is more complex than would appear on superficial study, and in order to give quantities and volumes which will apply to different proportions and different conditions, it is necessary not merely to interpolate between the results from experimental tests, but to so thoroughly analyze these tests and compare the results obtained by different experimenters that the causes of the variations may be discovered and provided for.

As a basis for the investigation, the series of tests made by Mr. William B. Fuller, of Little Falls, N. J.,* which cover a very large field, were taken and thoroughly analyzed to determine the effect of the different ingredients in the concrete, and then the results were corrected to bring them into close line with average results of various exact experiments made in the United States and in Europe. To still further provide for the variation which will occur in any tests, the formulas given on page 137 were evolved, and these were used as an aid in computation of the tables. The values obtained therefore are not only rational but they agree with the quantities and volumes obtained in actual construction.

Since the first publication of the tables, several engineers have called the attention of the writers to their practical agreement with actual records. The tables have been compared, for example, with the quantities obtained on several sections of the Metropolitan Water Works of Massachusetts, on the new Croton Dam in New York, and various other large works.

The values in the average tables agree closely with experiments by Mr. Edwin Thacher† when allowance is made for the fact that his unit of measure for sand and stone is a barrel of 4.12 cubic feet. Tests of Mr. Sabin‡ at St. Mary's Falls, Mich., give a smaller quantity of cement per cubic yard than the authors' tables, but Mr. Sabin's tests were made with dried sand weighing 100 pounds per cubic foot, whereas the values given in our tables are based upon sand containing natural moisture. The Michigan sand was also finer than that which we have assumed as an average, so that it produced a larger bulk of mortar using the same proportions.

QUANTITY OF MATERIALS FOR RUBBLE CONCRETE

Rubble concrete is merely plain concrete with large pieces of stone distributed through it. The term includes all classes of concrete in which large stones are placed by hand or by machinery. In some cases,

* See Taylor & Thompson's "Concrete, Plain and Reinforced," second edition, p. 376.

† Johnson's Materials of Construction, fourth edition, 1910, p. 610*a*.

‡ Sabin's "Cement and Concrete," second edition, 1907, p. 193.

the mass may consist essentially of large stones laid in joints of concrete instead of mortar. The volume of rubble concrete produced with a barrel of cement is the quantity of the plain concrete, in the given proportions, plus the sum of the volumes of the large stones imbedded in this concrete. Unless the fundamental principles are understood, errors may easily be made in computing the costs under different conditions.

The cost of rubble concrete in large masses is usually less than that of plain concrete, because the expense of crushing the stones which are used as rubble is saved and the rubble stones replace a mass of mixed cement and aggregate, thereby saving a portion of the cement. Since also the stone is heavier than concrete made from the crushed material, the replacing of portions of the latter by the large stones increases the weight of the concrete and therefore its value for certain classes of construction. Large masses of rubble concrete usually can be laid cheaper than ordinary concrete, but where the mass is small, and separate machinery would be required for handling large stone, its use may not be economical. It is especially adapted for use where the concrete materials are handled with derricks because the same derricks can hook the stone and transport it to place in trays.

In comparison with large masses of rubble masonry laid in cement mortar, rubble concrete of similar quantity is almost invariably cheaper because scarcely any skilled labor is required. In comparing the cost of rubble masonry laid in Natural cement mortar with rubble concrete made with Portland cement, the fact must be considered that a wall of Portland cement rubble concrete may be thinner than one of Natural cement masonry, or it may be made with leaner proportions of cement because of the greater strength of the Portland cement.

The quantity of cement used in rubble concrete varies not only with the proportions of the concrete mixture, but with the percentage of rubble introduced. Much less cement is required in the concrete than in mortar of similar strength, but the concrete joints must be thicker than mortar joints, so that sometimes more cement is required per cubic yard for rubble concrete than for rubble masonry. By using, however, large sized stone spaced as close as practical, the quantity of cement per cubic yard may be brought even below that for rubble masonry, so that expense is saved in materials as well as in labor.

Percentage of Rubble in the Mass. Rubble concrete is best classified with respect to the percentage of large stone or rubble contained in it. This percentage represents the ratio of the sum of the volumes of the pieces of large stone in a unit volume of rubble concrete to the total set volume of the rubble concrete. For example, suppose a cubic yard of rubble concrete contains 9 blocks of stone averaging one cubic foot each in volume, there would then be 9 cubic feet of rubble in a cubic yard of concrete and the percentage of rubble would be $\frac{9}{27} = 33\frac{1}{3}\%$. The percentage of large stone in rubble concrete may vary from 20% to 60% through variation in size and spacing of the large stone in the mass. Where the mass of concrete is large enough to permit it, it is always most economical to use the largest stone which can be handled by the machinery available, because the largest stone replace the greatest quantity of plain concrete and therefore save the largest amount of cement. By using a wet mixed concrete and carefully placing the stone, they may be laid as close together as 3 inches with good results.

Measurement of the Rubble and of the Concrete. The quantity of plain concrete contained in a cubic yard of rubble concrete, and therefore the number of barrels of cement per cubic yard, may be computed if the percentage of rubble is known or is estimated, since the quantity of plain concrete is reduced in proportion to the percentage of rubble. This is illustrated in the following example.

Example 6: If rubble concrete is to contain 60% of rubble stone, the plain concrete being mixed in proportions 1:3:6, how many barrels of cement will be required per cubic yard of the rubble concrete?

Solution: The quantity of the plain concrete in a cubic yard will be reduced 60% by the introduction of the rubble, that is, only 40% of it will be required. From Table 22 on page 151, 1.11 barrels of cement are required per cubic yard of average 1:3:6: concrete, hence $1.11 \times 0.40 = 0.44$ barrels of cement will be necessary per cubic yard of rubble concrete. The quantities of the sand and stone will be reduced in like ratio. The same result may be obtained directly from Table 27 on page 156.

Estimating the Quantity of Rubble. In estimating, it is always necessary to determine the quantity of rubble to use, and this is expressed in several ways which may be illustrated by examples.

(1) By loose measurement of the rubble stone. The volume of loose rubble depends upon the voids, which may vary from 40% to 50% of the total bulk according to the shape of the stones and the method of handling. An average value for voids may be assumed as

45%. Rounded stones like field stones will compact closer and average about 40%.

Example 7: How many cubic yards of loose rubble will be required per cubic yard of rubble concrete containing 20% rubble?

Solution: Assuming the voids in the loose rubble to be 45%, 0.55 of the mass will be solid stones, and since the solid stones are to occupy 20% or 0.20 of the mass of the rubble concrete, there will be required $\frac{0.20}{0.55} = 0.36$ cubic yards of loose rubble per cubic yard of rubble concrete.

(2) By solid ledge measurement of the stone. The quantity of rubble per cubic yard of rubble concrete is then obtained directly from the percentage.

Example 8: How much stone measured in the ledge will be required for a cubic yard of rubble concrete containing 20% rubble?

Solution: Since there is 20% of rubble or 0.20 of the mass of the rubble concrete, the quantity of rock measured in the ledge per cubic yard of rubble concrete will be 0.20 cubic yard.

(3) By weight of the rubble stone. This varies with the specific gravity of the rock, or, in other words, with the weight of a solid cubic foot of the rock.

Example 9: What weight of ordinary limestone will be required for a cubic yard of rubble concrete using 20% rubble?

Solution: Limestone varies greatly in specific gravity, but as no value is given, the specific gravity of the rock may be taken as 2.6; hence the weight of solid rock is $2.6 \times 62.4^* = 162$ pounds per cubic foot. This is $162 \times 27 = 4370$ pounds per cubic yard of the solid rock. With 20% rubble, the weight of large stone required per cubic yard of rubble concrete, since the rubble occupies 20% of the volume, will be $4370 \times 0.20 = 874$ pounds.

EXAMPLES ILLUSTRATING THE USE OF CURVES OF QUANTITIES

Use of Curves. The use of the curves Fig. 14, page 146, is best illustrated by the following examples:

Example 10: Find quantities of materials required for 1000 cubic yards of 1:2½:5 concrete.

* Weight of a cubic foot of water.

Solution: Intersection of dotted horizontal line corresponding to $2\frac{1}{2}$ barrels sand with dotted vertical line corresponding to 5 barrels stone falls on diagonal curve 1.30; hence, 1.30 barrels cement are required per cubic yard, or 1300 barrels cement for 1000 cubic yards concrete. From Note 4 of diagram, $1300 \times 0.141 \times 2\frac{1}{2} = 458$ cubic yards sand will be required, and $1300 \times 0.141 \times 5 = 916$ cubic yards stone required.

Example 11: Find number of barrels cement required for 1000 cubic yards concrete in proportions one barrel cement to 9 cubic feet sand to 18 cubic feet stone.

Solution: Intersection of full cross-section horizontal line, corresponding to 9 cubic feet sand, with vertical line for 18 cubic feet stone, gives 1.37 barrels cement per cubic yard or 1370 barrels for 1000 cubic yards concrete.

Example 12: Find volume of concrete of Example 10 made from one barrel of cement.

Solution: By note 5 of diagram, volume of concrete per barrel cement is 27 divided by the quantity of cement per cubic yard of concrete, or $\frac{27}{1.30} = 20.8$ cubic feet.

EXAMPLES ILLUSTRATING USE OF QUANTITY TABLES

Example 13: Find the quantities of materials required for 1000 cubic yards of $1:2\frac{1}{2}:5$ gravel concrete.

Solution: Table 22, page 151, is to be used ordinarily, since it is based on a barrel of 3.8 cubic feet. From the headings, the 40% columns should be used for gravel aggregate. The required quantities per cubic yard are therefore 1.24 barrels cement, 0.44 cubic yards sand, 0.87 cubic yards stone, and for 1000 cubic yards of concrete there would be required 1240 barrels cement, 440 cubic yards of sand and 870 cubic yards of gravel.

Example 14: What will be the difference in quantity of cement required per cubic yard of 1:2:4 concrete, using a good coarse sand and a very fine sand containing natural moisture?

Solution: By reference to Table 18 on page 139, the quantity of cement per cubic yard using good coarse sand is 1.57 barrels and for fine sand is 1.53 barrels or 0.04 barrels of cement less per cubic yard of concrete for the fine sand than for the coarse. An illustration of the use of dry fine sand is given in Example 5, page 138.

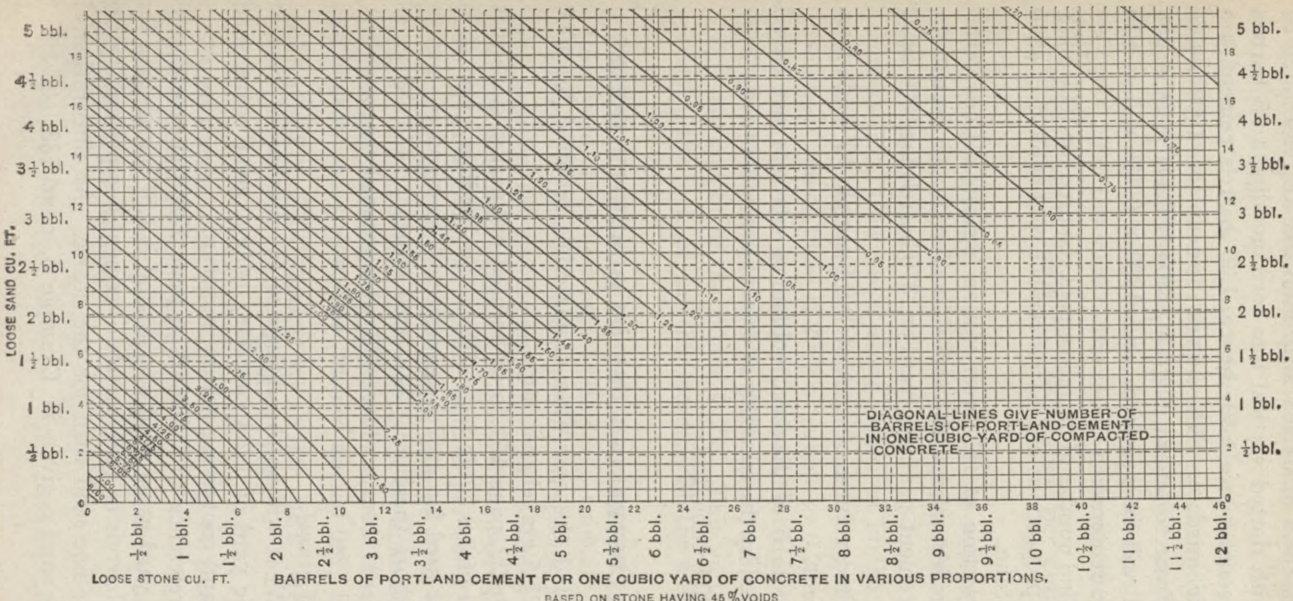


FIG. 14. Diagram giving Barrels of Cement per Cubic Yard of Concrete. (See p. 140 and examples on p. 144.)

1. **Dotted cross section lines** represent barrels, or parts, of sand and stone to one barrel (4 bags) Portland cement weighing 376 lb. and measuring (assumed) 3.8 cu. ft.
2. **Full cross section lines** represent cubic feet of sand and stone to one barrel (4 bags) Portland cement.
3. **Diagonal lines** represent number of barrels of Portland cement in one cubic yard of compacted concrete.
4. **To find number of cubic yards of sand or stone** per cubic yard of concrete, multiply number of barrels cement, as above, by 0.141 times the number of parts of sand or stone.
5. **To find number of cubic feet of concrete,** in any proportions, made from one barrel of cement, divide 27 by the number of barrels of cement per cubic yard, obtained as above.

EXAMPLES OF USE OF VOLUME TABLES

Example 15: How many cubic yards of 1:3:6 concrete can be made with 500 barrels of cement, using broken stone screened to uniform size?

Solution: Referring to Table 25, page 154, the 50% void column should be used for broken stone screened to uniform size. The quantity of concrete made with one barrel of cement is therefore 23.2 cubic feet and the quantity for 500 barrels cement is $23.2 \times \frac{500}{27} = 430$ cubic yards.

EXAMPLES OF USE OF RUBBLE CONCRETE TABLES

Example 16: How much cement will be required per cubic yard of 1:3:6 rubble concrete, using for the rubble large derrick stone of fairly regular shape, spaced in the concrete not less than 3 inches apart?

Solution: Under these conditions it is possible to introduce 60% of rubble into the concrete, that is, to make the concrete so that 60% of the total mass consists of particles of rubble stone. From the 45% void column, Table 27, page 156, since this represents average conditions, the amount of cement per cubic yard with the 60% rubble will be 0.44 barrels cement per cubic yard of rubble concrete.

Example 17: How much cement will be required per cubic yard of 1:3:6 rubble concrete, using as large stones as can be placed by one man and placing them so that they are not nearer together than 5 inches?

Solution: For this concrete, the quantity of rubble in the mass will not be much over 20% of the mass. Referring to Table 27, page 156, we find that 0.89 barrels of cement are required per cubic yard of rubble concrete.

Example 18: Suppose that rubble concrete is being laid, using proportions 1:2½:5 for the plain concrete and a quantity of rubble which, by loose measurement in the car in which it is transported, is found to be 0.58 cubic yard per cubic yard of concrete. What is the percentage of rubble in the rubble concrete and what quantity of cement is being used per cubic yard of rubble concrete?

Solution: The example is somewhat similar to Example 7 on page 144. Assuming loose rubble to have 45% voids, the quantity of solid rubble stone which goes into a cubic yard of the rubble concrete will be $0.58\ (1-0.45) = 0.319$ cubic yards. Hence, the rubble stone will occupy about 32% of the volume of the concrete. From Table

27, page 156, we find that 1:2½:5 concrete will require for 30% rubble, 0.91 barrels cement per cubic yard of rubble concrete, and for 40% rubble, 0.78 barrels cement. Interpolating between the two values, we find that for 32% rubble, 1:2½:5 concrete requires 0.88 barrels cement per cubic yard of rubble concrete.

Example 19: How many cubic yards of 1:2½:5 concrete can be made from 1000 barrels of cement if the concrete contains 40% rubble?

Solution: From Table 28, page 157, using the 45% void column, we find that for 40% rubble, 34.7 cubic feet of concrete can be made from one barrel of cement or from 1000 barrels $\frac{34.7 \times 1000}{27} = 1285$ cubic yards.

TABLE 19. MATERIALS FOR 100 SQUARE FEET OF SLAB OR WALL

Use for Sidewalks, Pavements, Floors, and Walls. Proportions based on a barrel of 3.8 cu. ft. Materials for slabs of greater thickness may be found by combining the values given.

Example: Find quantity of cement per 100 square feet for a wall 14 inches thick, in proportions, 1:2:4.

Solution: A 14-inch wall is equivalent to two 7-inch walls or a 4-inch and a 10-inch wall, hence we have 3.73 × 2 = 7.46 or 2.13 + 5.34 = 7.47 barrels.

	Concrete							Mortar					
Thickness	Proportions 1:2:4 Cement	Proportions 1:2:4 Sand	Proportions 1:2:4 Stone	Proportions 1:3:6 Cement	Proportions 1:3:6 Sand	Proportions 1:3:6 Stone	Thickness	Proportions 1 : 1 Cement	Proportions 1 : 1 Sand	Proportions 1 : 1½ Cement	Proportions 1 : 1½ Sand	Proportions 1 : 2 Cement	Proportions 1 : 2 Sand
in.	bbl.	cu. yd.	cu. yd.	bbl.	cu. yd.	cu. yd.	in.	bbl.	cu. yd.	bbl.	cu. yd.	bbl.	cu. yd.
2½	1.33	0.37	0.75	0.94	0.40	0.80	¼	0.43	0.06	0.34	0.07	0.28	0.08
3	1.61	0.45	0.90	1.13	0.48	0.96	½	0.85	0.12	0.68	0.14	0.56	0.16
3½	1.87	0.52	1.05	1.32	0.56	1.12	¾	1.28	0.18	1.02	0.21	0.85	0.24
4	2.13	0.60	1.19	1.51	0.64	1.28	1	1.70	0.24	1.36	0.29	1.13	0.32
4½	2.39	0.67	1.34	1.70	0.72	1.44	1¼	2.13	0.30	1.70	0.36	1.41	0.40
5	2.66	0.75	1.49	1.89	0.80	1.60	1½	2.56	0.36	2.04	0.43	1.69	0.47
6	3.20	0.90	1.79	2.26	0.96	1.92	1¾	2.98	0.42	2.38	0.50	1.98	0.55
7	3.73	1.05	2.09	2.64	1.12	2.23	2	3.41	0.48	2.72	0.57	2.26	0.63
8	4.27	1.20	2.39	3.02	1.28	2.55	2¼	3.83	0.54	3.06	0.64	2.54	0.71
9	4.81	1.35	2.69	3.39	1.44	2.87	2½	4.25	0.60	3.40	0.71	2.82	0.79
10	5.34	1.50	2.9[illegible]	3.77	1.60	3.19	3	5.10	0.72	4.07	0.86	3.38	0.95

Values for 1:2½:5 concrete may be found by interpolation.

TABLE 20. VOLUME OF PLASTIC MORTAR AND QUANTITIES OF MATERIALS PER CUBIC YARD (See p. 130)

MORTAR WITH ORDINARY COARSE BANK SAND

Relative Proportions by Volume*		Volume of Mortar in Place						Materials for 1 cu. yd. Mortar in Place Based on Barrel of					
		From 1 cu. ft. Cement			From 1 bbl. Cement								
		Based on Portland Cement Weighing			Based on Barrel of			3.5 cu. ft.		3.8 cu. ft.†		4 cu. ft.	
Cement	Sand	108 lbs. per cu. ft.	100 lbs. per cu. ft.†	95 lbs. per cu. ft.	3.5 cu. ft.	3.8 cu. ft.†	4 cu. ft.	Packed Cement	Loose Sand	Packed Cement	Loose Sand	Packed Cement	Loose Sand
		cu. ft.	**cu. ft.**	*cu. ft.*	*cu. ft.*	**cu. ft.**	*cu. ft.*	*bbl.*	*cu. yd.*	**bbl.**	**cu. yd.**	*bbl.*	*cu. yd.*
1	0	0.93	0.86	0.80	3.2	3.2	3.2	8.31		8.31		8.31	
1	½	1.12	1.06	1.02	3.9	4.0	4.1	6.92	0.46	6.73	0.47	6.61	0.49
1	1	1.48	1.42	1.38	5.2	5.4	5.5	5.22	0.68	5.01	0.71	4.88	0.72
1	1½	1.84	1.78	1.74	6.4	6.7	7.0	4.20	0.81	4.00	0.84	3.87	0.86
1	2	2.20	2.14	2.11	7.7	8.1	8.4	3.51	0.91	3.32	0.93	3.21	0.95
1	2½	2.56	2.50	2.47	9.0	9.5	9.9	3.01	0.98	2.84	1.00	2.74	1.01
1	3	2.92	2.86	2.83	10.2	10.9	11.3	2.64	1.03	2.48	1.05	2.39	1.06
1	3½	3.28	3.23	3.19	11.5	12.2	12.8	2.35	1.06	2.20	1.08	2.12	1.10
1	4	3.64	3.59	3.55	12.8	13.6	14.2	2.12	1.10	1.98	1.11	1.90	1.13
1	4½	4.01	3.95	3.91	14.0	15.0	15.6	1.92	1.12	1.80	1.14	1.72	1.15
1	5	4.37	4.31	4.28	15.3	16.4	17.1	1.77	1.15	1.65	1.16	1.58	1.17
1	5½	4.73	4.67	4.64	16.6	17.7	18.5	1.63	1.16	1.52	1.18	1.46	1.19
1	6	5.09	5.03	5.00	17.8	19.1	20.0	1.52	1.18	1.41	1.19	1.35	1.20
1	6½	5.45	5.39	5.36	19.1	20.5	21.4	1.41	1.19	1.32	1.21	1.26	1.21
1	7	5.81	5.76	5.72	20.3	21.9	22.9	1.33	1.21	1.23	1.21	1.18	1.22
1	7½	6.18	6.13	6.08	21.6	23.2	24.3	1.25	1.21	1.16	1.22	1.11	1:23
1	8	6.54	6.48	6.44	22.9	24.6	25.8	1.18	1.22	1.10	1.24	1.05	1.24

MORTAR WITH VERY FINE SAND

1	½	1.26	1.19	1.15	4.4	4.5	4.6	6.16	0.40	6.01	0.42	5.91	0.44
1	1	1.62	1.56	1.51	5.7	5.9	6.0	4.78	0.62	4.59	0.65	4.48	0.66
1	1½	1.98	1.92	1.88	6.9	7.3	7.5	3.79	0.76	3.72	0.78	3.61	0.80
1	2	2.35	2.28	2.24	8.2	8.6	8.9	3.29	0.85	3.12	0.88	3.02	0.90
1	2½	2.71	2.65	2.51	9.5	10.0	10.4	2.85	0.92	2.69	0.95	2.60	0.96
1	3	3.08	3.01	2.97	10.8	11.4	11 8	2.51	0.98	2.37	1.00	2.28	1.01
1	3½	3.44	3.38	3.33	12.0	12.8	13.3	2.24	1.02	2.11	1.04	2.03	1.05
1	4	3.80	3.74	3.70	13.3	14.2	14.8	2.03	1.03	1.90	1.07	1.83	1.08
1	4½	4.17	4.10	4.06	14.6	15.6	16.2	1.85	1.08	1.74	1.10	1.67	1.11
1	5	4.53	4.47	4.43	15.9	16.9	17.7	1.70	1.10	1.59	1.12	1.53	1.13
1	5½	4.90	4.33	4.79	17.1	18.3	19:1	1.58	1.12	1.47	1.14	1.41	1.15
1	6	5.26	5.20	5.15	18.4	19.7	20.6	1.47	1.14	1.37	1 16	1.31	1.17

Note.—Variations in the fineness of the sand and the cement, and in the consistency of the mortar may affect the values by 10% in either direction.

*Cement as packed by manufacturer, sand loose.

†Use these columns ordinarily.

TABLE 21. MATERIALS FOR ONE CUBIC YARD OF CONCRETE

(See p. 139)

BASED ON A BARREL OF 3.5 CUBIC FEET

Proportions by Parts: Cement	Proportions by Parts: Sand	Proportions by Parts: Stone	Proportions by Volumes: Packed Cement, bbl.	Proportions by Volumes: Loose Sand, cu. ft.	Proportions by Volumes: Loose Stone, cu. ft.	Volume of Mortar in Terms of Percentage of Volume of Stone, %	Broken Stone Uniform Size 50% Voids: Cement, bbl.	Broken Stone Uniform Size 50% Voids: Sand, cu. yd.	Broken Stone Uniform Size 50% Voids: Stone, cu. yd.	Broken Stone* Without Dust 45% Voids: Cement, bbl.	Broken Stone* Without Dust 45% Voids: Sand, cu. yd.	Broken Stone* Without Dust 45% Voids: Stone, cu. yd.	Screened Gravel 40% Voids: Cement, bbl.	Screened Gravel 40% Voids: Sand, cu. yd.	Screened Gravel 40% Voids: Stone, cu. yd.	Graded Mixtures 30% Voids: Cement, bbl.	Graded Mixtures 30% Voids: Sand, cu. yd.	Graded Mixtures 30% Voids: Stone, cu. yd.
1		1	1		3.5	101	5.25		0.68	5.07		0.66	4.89		0.63	4.51		0.58
1		2	1		7.0	54	3.84		1.00	3.64		0.94	3.47		0.90	3.09		0.80
1		3	1		10.5	39				2.85		1.11	2.69		1.05	2.35		0.91
1		4	1		14.0	31										1.90		0.99
1		5	1		17.5	27										1.59		1.03
1		6	1		21.0	24										1.37		1.07
1	1	1½	1	3.5	5.2	104	3.37	0.44	0.65	3.26	0.42	0.63	3.15	0.41	0.61	2.95	0.38	0.57
1	1	2	1	3.5	7.0	78	3.02	0.39	0.78	2.89	0.38	0.75	2.78	0.36	0.72	2.58	0.33	0.67
1	1	2½	1	3.5	8.7	64	2.73	0.35	0.88	2.60	0.34	0.84	2.49	0.32	0.80	2.29	0.30	0.74
1	1	3	1	3.5	10.5	54	2.49	0.32	0.97	2.37	0.31	0.92	2.25	0.29	0.88	2.06	0.27	0.80
1	1½	2	1	5.2	7.0	95	2.64	0.51	0.68	2.55	0.49	0.66	2.46	0.47	0.64	2.30	0.44	0.60
1	1½	2½	1	5.2	8.7	78	2.42	0.47	0.78	2.32	0.45	0.75	2.23	0.43	0.72	2.07	0.40	0.67
1	1½	3	1	5.2	10.5	65	2.23	0.43	0.87	2.13	0.41	0.83	2.04	0.39	0.79	1.88	0.36	0.73
1	1½	3½	1	5.2	12.2	56	2.07	0.40	0.94	1.97	0.38	0.89	1.88	0.36	0.85	1.72	0.33	0.78
1	1½	4	1	5.2	14.0	50	1.93	0.37	1.00	1.83	0.35	0.95	1.74	0.34	0.90	1.59	0.31	0.82
1	1½	4½	1	5.2	15.7	45	1.81	0.35	1.05	1.71	0.33	0.99	1.62	0.31	0.94	1.47	0.28	0.86
1	1½	5	1	5.2	17.5	41	1.70	0.33	1.10	1.60	0.31	1.04	1.52	0.29	0.99	1.37	0.26	0.89
1	2	3	1	7.0	10.5	77	2.02	0.52	0.79	1.94	0.50	0.75	1.86	0.48	0.72	1.73	0.45	0.67
1	2	3½	1	7.0	12.2	67	1.89	0.49	0.85	1.80	0.47	0.81	1.73	0.45	0.78	1.59	0.41	0.72
1	2	4	1	7.0	14.0	59	1.77	0.46	0.92	1.69	0.44	0.88	1.61	0.42	0.83	1.48	0.38	0.77
1	2	4½	1	7.0	15.7	53	1.67	0.43	0.97	1.58	0.41	0.92	1.51	0.39	0.88	1.38	0.36	0.80
1	2	5	1	7.0	17.5	48	1.57	0.41	1.02	1.49	0.39	0.97	1.42	0.37	0.92	1.29	0.33	0.84
1	2	5½	1	7.0	19.2	44	1.49	0.39	1.06	1.41	0.36	1.00	1.34	0.35	0.95	1.21	0.31	0.86
1	2	6	1	7.0	21.0	41	1.42	0.37	1.10	1.34	0.35	1.04	1.27	0.33	0.99	1.14	0.30	0.89
1	2½	3	1	8.7	10.5	90	1.84	0.59	0.72	1.78	0.57	0.69	1.71	0.55	0.66	1.60	0.52	0.62
1	2½	3½	1	8.7	12.2	78	1.73	0.56	0.78	1.66	0.53	0.75	1.60	0.52	0.72	1.48	0.48	0.67
1	2½	4	1	8.7	14.0	68	1.63	0.52	0.85	1.56	0.50	0.81	1.50	0.48	0.78	1.38	0.44	0.72
1	2½	4½	1	8.7	15.7	61	1.55	0.50	0.90	1.47	0.47	0.86	1.41	0.45	0.82	1.29	0.42	0.75
1	2½	5	1	8.7	17.5	55	1.47	0.47	0.95	1.39	0.45	0.90	1.33	0.43	0.86	1.22	0.39	0.79
1	2½	5½	1	8.7	19.2	51	1.39	0.45	0.99	1.32	0.42	0.94	1.26	0.41	0.90	1.15	0.37	0.82
1	2½	6	1	8.7	21.0	47	1.33	0.43	1.03	1.26	0.41	0.98	1.20	0.39	0.93	1.09	0.35	0.85
1	2½	6½	1	8.7	22.7	44	1.27	0.41	1.07	1.20	0.39	1.01	1.14	0.37	0.96	1.03	0.33	0.87
1	2½	7	1	8.7	24.5	41	1.22	0.39	1.11	1.15	0.37	1.04	1.09	0.35	0.99	0.98	0.32	0.89
1	3	4	1	10.5	14.0	77	1.52	0.59	0.79	1.46	0.57	0.76	1.40	0.54	0.73	1.30	0.50	0.67
1	3	4½	1	10.5	15.7	69	1.44	0.56	0.84	1.38	0.54	0.80	1.32	0.51	0.77	1.22	0.47	0.71
1	3	5	1	10.5	17.5	62	1.37	0.53	0.89	1.31	0.51	0.85	1.25	0.48	0.81	1.15	0.45	0.75
1	3	5½	1	10.5	19.2	57	1.31	0.51	0.93	1.25	0.48	0.89	1.19	0.46	0.85	1.09	0.42	0.78
1	3	6	1	10.5	21.0	53	1.25	0.48	0.97	1.19	0.46	0.93	1.13	0.44	0.88	1.03	0.40	0.80
1	3	6½	1	10.5	22.7	49	1.20	0.47	1.01	1.14	0.44	0.96	1.08	0.42	0.91	0.98	0.38	0.82
1	3	7	1	10.5	24.5	46	1.15	0.45	1.04	1.09	0.42	0.99	1.03	0.40	0.93	0.94	0.36	0.85
1	3	7½	1	10.5	26.2	43	1.11	0.43	1.08	1.05	0.41	1.02	0.99	0.38	0.96	0.90	0.35	0.87
1	3	8	1	10.5	28.0	40	1.06	0.41	1.10	1.01	0.39	1.05	0.95	0.37	0.99	0.86	0.33	0.89
1	4	5	1	14.0	17.5	77	1.22	0.63	0.79	1.17	0.61	0.76	1.12	0.58	0.73	1.04	0.54	0.67
1	4	6	1	14.0	21.0	65	1.12	0.58	0.87	1.07	0.55	0.83	1.02	0.53	0.79	0.94	0.49	0.73
1	4	7	1	14.0	24.5	56	1.04	0.54	0.94	0.99	0.51	0.90	0.94	0.49	0.85	0.86	0.44	0.78
1	4	8	1	14.0	28.0	50	0.97	0.50	1.01	0.92	0.48	0.95	0.87	0.45	0.90	0.80	0.41	0.83
1	4	9	1	14.0	31.5	45	0.91	0.47	1.06	0.86	0.44	1.00	0.81	0.42	0.94	0.74	0.38	0.86
1	4	10	1	14.0	35.0	41	0.85	0.44	1.10	0.81	0.42	1.05	0.76	0.39	0.98	0.69	0.36	0.89
1	5	10	1	17.5	35.0	48	0.79	0.51	1.02	0.75	0.49	0.97	0.71	0.46	0.92	0.65	0.42	0.84
1	6	12	1	21.0	42.0	46	0.67	0.52	1.04	0.63	0.49	0.98	0.60	0.47	0.93	0.54	0.42	0.84

NOTE.—Variations in the fineness of the sand and the compacting of the concrete may affect the quantities by 10% in either direction.

*Use for average conditions.

TABLE 22. MATERIALS FOR ONE CUBIC YARD OF CONCRETE

(See p. 139)

BASED ON A BARREL OF 3.8 CUBIC FEET

Proportions by Parts			Proportions by Volume			Volume of Mortar in Terms of Percentage of Volume of Stone	Broken Stone Uniform Size 50% Voids			Broken Stone Without Dust 45% Voids*			Screened Gravel 40% Voids			Graded Mixtures 30% Voids		
Cement	Sand	Stone	Packed Cement	Loose Sand	Loose Stone		Cement	Sand	Stone	Cement	Sand	Stone	Cement	Sand	Stone	Cement	Sand	Stone
			bbl.	cu. ft.	cu. ft.	%	bbl.	cu. yd.	cu. yd.	bbl.	cu. yd.	cu. yd.	bbl.	cu. yd.	cu. yd.	bbl.	cu. yd.	cu. yd.
1		1	1		3.8	94	5.09		0.72	4.90		0.69	4.73		0.67	4.33		0.61
1		2	1		7.6	51	3.67		1.03	3.48		0.98	3.30		0.93	2.93		0.82
1		3	1		11.4	36				2.69		1.14	2.54		1.07	2.22		0.94
1		4	1		15.2	29										1.78		1.00
1		5	1		19.0	25										1.49		1.05
1		6	1		22.8	22										1.28		1.08
1	1	1½	1	3.8	5.7	99	3.19	0.45	0.67	3.08	0.43	0.65	2.97	0.42	0.63	2.78	0.39	0.59
1	1	2	1	3.8	7.6	75	2.85	0.40	0.80	2.73	0.38	0.77	2.62	0.37	0.74	2.43	0.34	0.68
1	1	2½	1	3.8	9.5	61	2.57	0.36	0.90	2.45	0.34	0.86	2.34	0.33	0.82	2.15	0.30	0.76
1	1	3	1	3.8	11.4	51	2.34	0.33	0.99	2.22	0.31	0.94	2.12	0.30	0.90	1.93	0.27	0.82
1	1½	2	1	5.7	7.6	93	2.49	0.53	0.70	2.40	0.51	0.68	2.31	0.49	0.65	2.16	0.46	0.61
1	1½	2½	1	5.7	9.5	76	2.27	0.48	0.80	2.18	0.46	0.77	2.09	0.44	0.74	1.94	0.41	0.68
1	1½	3	1	5.7	11.4	64	2.09	0.44	0.88	2.00	0.42	0.84	1.91	0.40	0.81	1.76	0.37	0.74
1	1½	3½	1	5.7	13.3	55	1.94	0.41	0.96	1.84	0.39	0.91	1.76	0.37	0.87	1.61	0.34	0.79
1	1½	4	1	5.7	15.2	49	1.80	0.38	1.01	1.71	0.36	0.96	1.63	0.34	0.92	1.48	0.31	0.83
1	1½	4½	1	5.7	17.1	44	1.69	0.36	1.07	1.60	0.34	1.01	1.51	0.32	0.96	1.37	0.29	0.87
1	1½	5	1	5.7	19.0	40	1.59	0.34	1.12	1.50	0.32	1.06	1.42	0.30	1.00	1.28	0.27	0.90
1	2	3	1	7.6	11.4	75	1.89	0.53	0.80	1.81	0.51	0.76	1.74	0.49	0.74	1.61	0.45	0.68
1	2	3½	1	7.6	13.3	65	1.76	0.49	0.87	1.68	0.47	0.83	1.61	0.45	0.79	1.48	0.42	0.73
1	2	4	1	7.6	15.2	57	1.65	0.46	0.93	1.57	0.44	0.88	1.50	0.42	0.84	1.38	0.39	0.78
1	2	4½	1	7.6	17.1	51	1.55	0.44	0.98	1.48	0.42	0.94	1.41	0.40	0.89	1.28	0.36	0.81
1	2	5	1	7.6	19.0	47	1.47	0.41	1.03	1.39	0.39	0.98	1.32	0.37	0.93	1.20	0.34	0.84
1	2	5½	1	7.6	20.9	43	1.39	0.39	1.08	1.31	0.37	1.01	1.25	0.35	0.97	1.13	0.32	0.87
1	2	6	1	7.6	22.8	40	1.32	0.37	1.11	1.25	0.35	1.06	1.18	0.33	1.00	1.06	0.30	0.89
1	2½	3	1	9.5	11.4	87	1.72	0.61	0.73	1.66	0.58	0.70	1.60	0.56	0.68	1.49	0.52	0.63
1	2½	3½	1	9.5	13.3	75	1.62	0.57	0.80	1.55	0.55	0.76	1.49	0.52	0.73	1.38	0.49	0.68
1	2½	4	1	9.5	15.2	66	1.52	0.54	0.86	1.46	0.51	0.82	1.40	0.49	0.79	1.29	0.45	0.73
1	2½	4½	1	9.5	17.1	60	1.44	0.51	0.91	1.37	0.48	0.87	1.31	0.46	0.83	1.20	0.42	0.76
1	2½	5	1	9.5	19.0	54	1.37	0.48	0.96	1.30	0.46	0.92	1.24	0.44	0.87	1.13	0.40	0.80
1	2½	5½	1	9.5	20.9	49	1.30	0.46	1.01	1.23	0.43	0.95	1.17	0.41	0.91	1.07	0.38	0.83
1	2½	6	1	9.5	22.8	46	1.24	0.44	1.05	1.17	0.41	0.99	1.11	0.39	0.94	1.01	0.36	0.85
1	2½	6½	1	9.5	24.7	42	1.18	0.42	1.08	1.12	0.39	1.02	1.06	0.37	0.97	0.96	0.34	0.88
1	2½	7	1	9.5	26.6	40	1.13	0.40	1.11	1.07	0.38	1.05	1.01	0.36	0.99	0.91	0.32	0.90
1	3	4	1	11.4	15.2	76	1.42	0.60	0.80	1.36	0.57	0.77	1.30	0.55	0.73	1.21	0.51	0.68
1	3	4½	1	11.4	17.1	68	1.34	0.57	0.85	1.28	0.54	0.81	1.23	0.52	0.78	1.13	0.48	0.72
1	3	5	1	11.4	19.0	61	1.28	0.54	0.90	1.22	0.52	0.86	1.17	0.49	0.82	1.07	0.45	0.75
1	3	5½	1	11.4	20.9	56	1.22	0.52	0.94	1.16	0.49	0.90	1.11	0.47	0.86	1.01	0.43	0.78
1	3	6	1	11.4	22.8	52	1.16	0.49	0.98	1.11	0.47	0.94	1.05	0.44	0.89	0.96	0.41	0.81
1	3	6½	1	11.4	24.7	48	1.12	0.47	1.02	1.06	0.45	0.97	1.01	0.43	0.92	0.92	0.39	0.84
1	3	7	1	11.4	26.6	45	1.07	0.45	1.05	1.01	0.43	0.99	0.96	0.40	0.95	0.87	0.37	0.86
1	3	7½	1	11.4	28.5	42	1.03	0.44	1.09	0.97	0.41	1.02	0.92	0.39	0.97	0.83	0.35	0.88
1	3	8	1	11.4	30.4	40	0.99	0.42	1.11	0.93	0.39	1.05	0.88	0.37	0.99	0.80	0.34	0.90
1	4	5	1	15.2	19.0	76	1.13	0.64	0.80	1.08	0.61	0.76	1.04	0.59	0.73	0.96	0.54	0.68
1	4	6	1	15.2	22.8	64	1.04	0.59	0.88	0.99	0.56	0.84	0.95	0.54	0.80	0.87	0.49	0.73
1	4	7	1	15.2	26.6	55	0.96	0.54	0.95	0.92	0.52	0.91	0.88	0.50	0.87	0.80	0.45	0.79
1	4	8	1	15.2	30.4	49	0.90	0.51	1.01	0.85	0.48	0.96	0.81	0.46	0.91	0.74	0.42	0.83
1	4	9	1	15.2	34.2	44	0.84	0.47	1.06	0.80	0.45	1.01	0.76	0.43	0.96	0.68	0.38	0.86
1	4	10	1	15.2	38.0	40	0.79	0.44	1.11	0.75	0.42	1.06	0.71	0.40	1.00	0.64	0.36	0.90
1	5	10	1	19.0	38.0	47	0.73	0.52	1.03	0.69	0.49	0.97	0.66	0.46	0.93	0.60	0.42	0.84
1	6	12	1	22.8	45.5	46	0.62	0.52	1.04	0.58	0.49	0.98	0.56	0.47	0.94	0.50	0.42	0.84

NOTE.—Variations in the fineness of the sand and the compacting of the concrete may affect the quantities by 10% in either direction.

***Use for average conditions.**

TABLE 23. MATERIALS FOR ONE CUBIC YARD OF CONCRETE

(See p. 139)

BASED ON A BARREL OF 4 CUBIC FEET

Proportions by Parts			Proportions by Volumes			Volume of Mortar in Terms of Percentage of Volume of Stone	Broken Stone Uniform Size 50% Voids			Broken Stone Without Dust 45% Voids*			Screened Gravel 40% Voids			Graded Mixtures 30% Voids		
Cement	Sand	Stone	Packed Cement	Loose Sand	Loose Stone		Cement	Sand	Stone	Cement	Sand	Stone	Cement	Sand	Stone	Cement	Sand	Stone
			bbl.	cu. ft.	cu. ft.	%	bbl.	cu. yd.	cu. yd.	bbl.	cu. yd.	cu. yd.	bbl.	cu. yd.	cu. yd.	bbl.	cu. yd.	cu. yd.
1		1	1		4	89	4.99		0.74	4.80		0.71	4.62		0.69	4.23		0.63
1		2	1		8	49	3.57		1.06	3.37		1.00	3.20		0.95	2.84		0.84
1		3	1		12	35				2.60		1.16	2.45		1.09	2.13		0.95
1		4	1		16	28										1.71		1.01
1		5	1		20	24										1.43		1.06
1		6	1		24	22										1.22		1.08
1	1	1½	1	4	6	96	3.08	0.46	0.68	2.97	0.44	0.66	2.87	0.42	0.64	2.69	0.40	0.60
1	1	2	1	4	8	73	2.74	0.41	0.81	2.63	0.39	0.78	2.52	0.37	0.75	2.33	0.34	0.69
1	1	2½	1	4	10	59	2.47	0.37	0.91	2.35	0.35	0.87	2.25	0.33	0.83	2.06	0.31	0.76
1	1	3	1	4	12	50	2.25	0.33	1.00	2.13	0.32	0.95	2.03	0.30	0.90	1.85	0.27	0.82
1	1½	2	1	6	8	92	2.39	0.53	0.71	2.30	0.51	0.68	2.22	0.49	0.66	2.07	0.46	0.61
1	1½	2½	1	6	10	74	2.18	0.48	0.81	2.09	0.46	0.77	2.01	0.45	0.74	1.86	0.41	0.69
1	1½	3	1	6	12	62	2.01	0.45	0.89	1.91	0.42	0.85	1.83	0.41	0.81	1.68	0.37	0.75
1	1½	3½	1	6	14	54	1.86	0.41	0.96	1.77	0.39	0.92	1.68	0.37	0.87	1.54	0.34	0.80
1	1½	4	1	6	16	48	1.73	0.38	1.03	1.64	0.36	0.97	1.56	0.35	0.92	1.42	0.32	0.84
1	1½	4½	1	6	18	43	1.62	0.36	1.08	1.53	0.34	1.02	1.45	0.32	0.97	1.31	0.29	0.87
1	1½	5	1	6	20	39	1.52	0.34	1.13	1.43	0.32	1.06	1.35	0.30	1.00	1.22	0.27	0.90
1	2	3	1	8	12	74	1.81	0.54	0.80	1.74	0.52	0.77	1.67	0.50	0.74	1.54	0.46	0.68
1	2	3½	1	8	14	64	1.69	0.50	0.88	1.61	0.48	0.83	1.54	0.46	0.80	1.42	0.42	0.74
1	2	4	1	8	16	56	1.58	0.47	0.94	1.51	0.45	0.89	1.44	0.43	0.85	1.32	0.39	0.78
1	2	4½	1	8	18	51	1.49	0.44	0.99	1.41	0.42	0.94	1.34	0.40	0.89	1.23	0.36	0.82
1	2	5	1	8	20	46	1.40	0.42	1.04	1.33	0.39	0.98	1.26	0.37	0.93	1.15	0.34	0.85
1	2	5½	1	8	22	42	1.33	0.39	1.08	1.26	0.37	1.03	1.19	0.35	0.97	1.08	0.32	0.88
1	2	6	1	8	24	39	1.26	0.37	1.12	1.19	0.35	1.06	1.13	0.34	1.00	1.02	0.30	0.91
1	2½	3	1	10	12	86	1.65	0.61	0.73	1.59	0.59	0.71	1.53	0.57	0.68	1.42	0.52	0.63
1	2½	3½	1	10	14	75	1.55	0.57	0.80	1.48	0.55	0.77	1.42	0.52	0.74	1.32	0.49	0.68
1	2½	4	1	10	16	66	1.46	0.54	0.87	1.39	0.51	0.82	1.33	0.49	0.79	1.23	0.46	0.73
1	2½	4½	1	10	18	59	1.38	0.51	0.92	1.31	0.48	0.87	1.25	0.46	0.83	1.15	0.43	0.77
1	2½	5	1	10	20	54	1.31	0.48	0.97	1.24	0.46	0.92	1.18	0.44	0.87	1.08	0.40	0.80
1	2½	5½	1	10	22	49	1.24	0.46	1.01	1.18	0.44	0.96	1.12	0.41	0.91	1.02	0.38	0.83
1	2½	6	1	10	24	45	1.18	0.44	1.05	1.12	0.41	1.00	1.06	0.39	0.94	0.96	0.36	0.85
1	2½	6½	1	10	26	42	1.13	0.42	1.09	1.07	0.40	1.03	1.01	0.37	0.97	0.92	0.34	0.89
1	2½	7	1	10	28	39	1.08	0.40	1.12	1.02	0.38	1.06	0.96	0.36	1.00	0.87	0.32	0.90
1	3	4	1	12	16	75	1.35	0.60	0.80	1.30	0.58	0.77	1.25	0.56	0.74	1.15	0.51	0.68
1	3	4½	1	12	18	67	1.28	0.57	0.85	1.23	0.55	0.82	1.18	0.52	0.79	1.08	0.48	0.72
1	3	5	1	12	20	60	1.22	0.54	0.90	1.16	0.52	0.86	1.11	0.49	0.82	1.02	0.45	0.76
1	3	5½	1	12	22	55	1.16	0.52	0.95	1.11	0.49	0.90	1.06	0.47	0.86	0.97	0.43	0.79
1	3	6	1	12	24	50	1.11	0.49	0.99	1.06	0.47	0.94	1.01	0.45	0.90	0.92	0.41	0.82
1	3	6½	1	12	26	48	1.06	0.47	1.02	1.01	0.45	0.97	0.96	0.43	0.92	0.87	0.39	0.84
1	3	7	1	12	28	44	1.02	0.45	1.06	0.97	0.43	1.01	0.92	0.41	0.95	0.83	0.37	0.86
1	3	7½	1	12	30	42	0.98	0.44	1.09	0.93	0.41	1.03	0.88	0.39	0.98	0.79	0.35	0.88
1	3	8	1	12	32	39	0.94	0.42	1.11	0.89	0.40	1.05	0.84	0.37	1.00	0.76	0.34	0.90
1	4	5	1	16	20	75	1.08	0.64	0.80	1.03	0.61	0.76	0.99	0.59	0.73	0.92	0.55	0.68
1	4	6	1	16	24	63	0.99	0.59	0.88	0.95	0.56	0.84	0.91	0.54	0.81	0.83	0.49	0.74
1	4	7	1	16	28	55	0.92	0.54	0.95	0.88	0.52	0.91	0.83	0.49	0.86	0.76	0.45	0.79
1	4	8	1	16	32	48	0.86	0.51	1.02	0.81	0.48	0.96	0.77	0.46	0.91	0.70	0.42	0.83
1	4	9	1	16	36	43	0.80	0.47	1.07	0.76	0.45	1.01	0.72	0.43	0.96	0.65	0.39	0.87
1	4	10	1	16	40	40	0.75	0.44	1.11	0.71	0.42	1.05	0.67	0.40	0.99	0.61	0.36	0.90
1	5	10	1	20	40	47	0.70	0.52	1.04	0.66	0.49	0.98	0.63	0.47	0.93	0.57	0.42	0.84
1	6	12	1	24	48	46	0.59	0.52	1.05	0.56	0.50	1.00	0.53	0.47	0.94	0.48	0.43	0.85

NOTE.—Variations in the fineness of the sand and the compacting of the concrete may affect the quantities by 10% in either direction.

*Use for average conditions.

TABLE 24. VOLUME OF CONCRETE FROM ONE BARREL OF CEMENT (See p. 139)

BASED ON A BARREL OF 3.5 CUBIC FEET

Proportions by Parts			Proportions by Volume			Volume of Mortar in Terms of Percentage of Volume of Stone	Average Volume of Concrete Made from One Barrel Cement				
Cement	Sand	Stone	Cement	Sand	Stone		Broken Stone Uniform Size 50% Voids	Broken Stone without Dust 45% Voids*	Screened Gravel 40% Voids	Graded Mixtures 30% Voids	Graded Mixtures 20% Voids
			bbl.	cu. ft.	cu. ft.	%	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.
1		1	1		3.5	101	5.1	5.3	5.5	6.0	6.4
1		2	1		7.0	54	7.0	7.4	7.8	8.7	9.6
1		3	1		10.5	39		9.5	10.0	11.5	12.8
1		4	1		14.0	31				14.2	16.0
1		5	1		17.5	27				17.0	19.2
1		6	1		21.0	24				19.7	22.4
1	1	1½	1	3.5	5.2	104	8.0	8.3	8.6	9.1	9.7
1	1	2	1	3.5	7.0	78	8.9	9.3	9.7	10.5	11.2
1	1	2½	1	3.5	8.7	64	9.9	10.4	10.8	11.8	12.7
1	1	3	1	3.5	10.5	54	10.8	11.4	12.0	13.1	14.2
1	1½	2	1	5.2	7.0	95	10.2	10.6	11.0	11.7	12.5
1	1½	2½	1	5.2	8.7	78	11.2	11.6	12.1	13.0	14.0
1	1½	3	1	5.2	10.5	65	12.1	12.7	13.2	14.4	15.5
1	1½	3½	1	5.2	12.2	56	13.0	13.7	14.4	15.7	17.0
1	1½	4	1	5.2	14.0	50	14.0	14.8	15.5	17.0	18.5
1	1½	4½	1	5.2	15.7	45	14.9	15.8	16.6	18.3	20.0
1	1½	5	1	5.2	17.5	41	15.9	16.8	17.8	20.0	21.6
1	2	3	1	7.0	10.5	77	13.4	13.9	14.5	15.6	16.8
1	2	3½	1	7.0	12.2	67	14.3	15.0	15.6	17.0	18.3
1	2	4	1	7.0	14.0	59	15.3	16.0	16.8	18.3	19.8
1	2	4½	1	7.0	15.7	53	16.2	17.0	17.9	19.6	21.3
1	2	5	1	7.0	17.5	48	17.1	18.1	19.0	20.9	22.8
1	2	5½	1	7.0	19.2	44	18.1	19.1	20.2	22.2	24.3
1	2	6	1	7.0	21.0	41	19.0	20.2	21.3	23.6	25.8
1	2½	3	1	8.7	10.5	90	14.6	15.2	15.8	16.9	18.0
1	2½	3½	1	8.7	12.2	78	15.6	16.2	16.9	18.2	19.6
1	2½	4	1	8.7	14.0	68	16.5	17.3	18.0	19.6	21.1
1	2½	4½	1	8.7	15.7	61	17.5	18.3	19.2	20.9	22.6
1	2½	5	1	8.7	17.5	55	18.4	19.4	20.3	22.2	24.1
1	2½	5½	1	8.7	19.2	51	19.4	20.4	21.4	23.5	25.6
1	2½	6	1	8.7	21.0	47	20.3	21.4	22.6	24.8	27.1
1	2½	6½	1	8.7	22.7	44	21.2	22.5	23.7	26.2	28.6
1	2½	7	1	8.7	24.5	41	22.2	23.5	24.8	27.5	30.1
1	3	4	1	10.5	14.0	77	17.8	18.5	19.3	20.8	22.3
1	3	4½	1	10.5	15.7	69	18.7	19.6	20.4	22.1	23.8
1	3	5	1	10.5	17.5	62	19.7	20.6	21.6	23.4	25.3
1	3	5½	1	10.5	19.2	57	20.6	21.7	22.7	24.8	26.8
1	3	6	1	10.5	21.0	53	21.6	22.7	23.8	26.1	28.4
1	3	6½	1	10.5	22.7	49	22.5	23.7	25.0	27.4	29.9
1	3	7	1	10.5	24.5	46	23.5	24.8	26.1	28.7	31.4
1	3	7½	1	10.5	26.2	43	24.4	25.8	27.2	30.1	32.9
1	3	8	1	10.5	28.0	40	25.3	26.9	28.4	31.4	34.4
1	4	5	1	14.0	17.5	77	22.2	23.2	24.1	26.0	27.9
1	4	6	1	14.0	21.0	65	24.1	25.2	26.4	28.6	30.9
1	4	7	1	14.0	24.5	56	26.0	27.3	28.6	31.3	33.9
1	4	8	1	14.0	28.0	50	27.9	29.4	30.9	33.9	36.9
1	4	9	1	14.0	31.5	45	29.8	31.5	33.2	36.6	40.0
1	4	10	1	14.0	35.0	41	31.7	33.6	35.4	39.2	43.0
1	5	10	1	17.5	35.0	48	34.2	36.1	38.0	41.8	45.5
1	6	12	1	21.0	42.0	46	40.5	42.8	45.0	49.6	54.1

Note.—Variations in the fineness of the sand and the compacting of the concrete may affect the volumes by 10% in either direction.

*Use for average conditions.

TABLE 25. VOLUME OF CONCRETE FROM ONE BARREL OF CEMENT (See p. 139)

BASED ON A BARREL OF 3.8 CUBIC FEET

Proportions by Parts			Proportions by Volume			Volume of Mortar in Terms of Percentage of Volume of Stone	Average Volume of Concrete Made from One Barrel Cement				
Cement	Sand	Stone	Cement	Sand	Stone		Broken Stone Uniform Size 50% Voids	**Broken Stone Without Dust 45% Voids***	Screened Gravel 40% Voids	Graded Mixtures 30% Voids	Graded Mixtures 20% Voids
			bbl.	cu. ft.	cu. ft.	%	cu. ft.	**cu. ft.**	cu. ft.	cu. ft.	cu. ft.
1		1	1		3.8	94	5.3	5.5	5.7	6.2	6.7
1		2	1		7.6	51	7.4	7.8	8.2	9.2	10.2
1		3	1		11.4	36		10.0	10.6	12.2	13.6
1		4	1		15.2	29				15.2	17.1
1		5	1		19.0	25				18.2	20.6
1		6	1		22.8	22				21.1	24.0
1	1	1½	1	3.8	5.7	99	8.5	8.8	9.1	9.7	10.3
1	1	2	1	3.8	7.6	75	9.5	9.9	10.3	11.1	11.9
1	1	2½	1	3.8	9.5	61	10.5	11.0	11.5	12.6	13.6
1	1	3	1	3.8	11.4	51	11.5	12.2	12.8	14.0	15.2
1	1½	2	1	5.7	7.6	93	10.8	11.3	11.7	12.5	13.3
1	1½	2½	1	5.7	9.5	76	11.9	12.4	12.9	13.9	15.0
1	1½	3	1	5.7	11.4	64	12.9	13.5	14.1	15.4	16.6
1	1½	3½	1	5.7	13.3	55	13.9	14.6	15.4	16.8	18.2
1	1½	4	1	5.7	15.2	49	15.0	15.8	16.6	18.2	19.9
1	1½	4½	1	5.7	17.1	44	16.0	16.9	17.8	19.7	21.5
1	1½	5	1	5.7	19.0	40	17.0	18.0	19.1	21.1	23.2
1	2	3	1	7.6	11.4	75	14.3	14.9	15.5	16.7	18.0
1	2	3½	1	7.6	13.3	65	15.3	16.0	16.8	18.2	19.6
1	2	4	1	7.6	15.2	57	16.3	17.2	18.0	19.6	21.3
1	2	4½	1	7.6	17.1	51	17.4	18.3	19.2	21.0	22.9
1	2	5	1	7.6	19.0	47	18.4	19.4	20.4	22.5	24.5
1	2	5½	1	7.6	20.9	43	19.4	20.5	21.7	23.9	26.2
1	2	6	1	7.6	22.8	40	20.4	21.7	22.9	25.4	27.8
1	2½	3	1	9.5	11.4	87	15.7	16.3	16.9	18.1	19.3
1	2½	3½	1	9.5	13.3	75	16.7	17.4	18.1	19.6	21.0
1	2½	4	1	9.5	15.2	66	17.7	18.5	19.3	21.0	22.6
1	2½	4½	1	9.5	17.1	60	18.7	19.6	20.6	22.4	24.3
1	2½	5	1	9.5	19.0	54	19.8	20.8	21.8	23.9	25.9
1	2½	5½	1	9.5	20.9	49	20.8	21.9	23.0	25.3	27.6
1	2½	6	1	9.5	22.8	46	21.8	23.0	24.3	26.7	29.2
1	2½	6½	1	9.5	24.7	42	22.8	24.2	25.5	28.2	30.8
1	2½	7	1	9.5	26.6	40	23.9	25.3	26.7	29.6	32.5
1	3	4	1	11.4	15.2	76	19.1	19.9	20.7	22.4	24.0
1	3	4½	1	11.4	17.1	68	20.1	21.0	21.9	23.8	25.6
1	3	5	1	11.4	19.0	61	21.1	22.1	23.2	25.2	27.2
1	3	5½	1	11.4	20.9	50	22.1	23.3	24.4	26.7	28.9
1	3	6	1	11.4	22.8	52	23.2	24.4	25.6	28.1	30.6
1	3	6½	1	11.4	24.7	48	24.2	25.5	26.9	29.5	32.2
1	3	7	1	11.4	26.6	45	25.2	26.7	28.1	31.0	33.8
1	3	7½	1	11.4	28.5	42	26.2	27.8	29.3	32.4	35.5
1	3	8	1	11.4	30.4	40	27.3	28.9	30.6	33.8	37.1
1	4	5	1	15.2	19.0	76	23.9	24.9	25.9	28.0	30.0
1	4	6	1	15.2	22.8	64	25.9	27.2	28.4	30.8	33.3
1	4	7	1	15.2	26.6	55	28.0	29.4	30.8	33.7	36.6
1	4	8	1	15.2	30.4	49	30.0	31.7	33.3	36.6	39.9
1	4	9	1	15.2	34.2	44	32.1	33.9	35.8	39.4	43.1
1	4	10	1	15.2	38.0	40	34.1	36.2	38.2	42.3	46.4
1	5	10	1	19.0	38.0	47	36.9	38.9	41.0	45.1	49.2
1	6	12	1	22.8	45.5	46	43.7	46.2	48.6	53.6	58.5

NOTE.—Variations in the fineness of the sand and the compacting of the concrete may affect the volumes by 10% in either direction.

***Use for average conditions.**

TABLE 26. VOLUME OF CONCRETE FROM ONE BARREL OF CEMENT (See p. 139)

BASED ON A BARREL OF 4 CUBIC FEET

Proportions by Parts			Proportions by Volume			Volume of Mortar in Terms of Percentage of Volume of Stone	Average Volume of Concrete Made from One Barrel Cement				
Cement	Sand	Stone	Cement	Sand	Stone		Broken Stone Uniform Size 50% Voids	Broken Stone Without Dust 45% Voids*	Screened Gravel 40% Voids	Graded Mixtures 30% Voids	Graded Mixtures 20% Voids
			bbl.	cu. ft.	cu. ft.	%	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.
1		1	1		4	89	5.4	5.6	5.8	6.4	6.9
1		2	1		8	49	7.6	8.0	8.4	9.5	10.5
1		3	1		12	35		10.4	11.0	12.7	14.2
1		4	1		16	28				15.8	17.8
1		5	1		20	24				18.9	21.5
1		6	1		24	22				22.1	25.1
1	1	1½	1	4	6	96	8.8	9.1	9.4	10.0	10.7
1	1	2	1	4	8	73	9.8	10.3	10.7	11.6	12.4
1	1	2½	1	4	10	59	10.9	11.5	12.0	13.1	14.2
1	1	3	1	4	12	50	12.0	12.7	13.3	14.6	15.9
1	1½	2	1	6	8	92	11.3	11.7	12.2	13.0	13.9
1	1½	2½	1	6	10	74	12.4	12.9	13.5	14.5	15.6
1	1½	3	1	6	12	62	13.5	14.1	14.8	16.0	17.3
1	1½	3½	1	6	14	54	14.5	15.3	16.0	17.6	19.1
1	1½	4	1	6	16	48	15.6	16.5	17.3	19.1	20.8
1	1½	4½	1	6	18	43	16.7	17.7	18.6	20.6	22.5
1	1½	5	1	6	20	39	17.8	18.9	19.9	22.1	24.3
1	2	3	1	8	12	74	14.9	15.6	16.2	17.5	18.8
1	2	3½	1	8	14	64	16.0	16.7	17.5	19.0	20.5
1	2	4	1	8	16	56	17.1	17.9	18.8	20.5	22.3
1	2	4½	1	8	18	51	18.1	19.1	20.1	22.0	23.9
1	2	5	1	8	20	46	19.2	20.3	21.4	23.5	25.7
1	2	5½	1	8	22	42	20.3	21.5	22.7	25.1	27.4
1	2	6	1	8	24	39	21.4	22.7	24.0	27.6	29.2
1	2½	3	1	10	12	86	16.3	17.0	17.6	18.9	20.2
1	2½	3½	1	10	14	75	17.4	18.2	18.9	20.5	22.0
1	2½	4	1	10	16	66	18.5	19.4	20.2	21.9	23.7
1	2½	4½	1	10	18	59	19.6	20.6	21.5	23.5	25.4
1	2½	5	1	10	20	54	20.7	21.8	22.8	25.0	27.2
1	2½	5½	1	10	22	49	21.8	22.9	24.1	26.5	28.9
1	2½	6	1	10	24	45	22.8	24.1	25.4	28.0	30.6
1	2½	6½	1	10	26	42	23.9	25.3	26.7	29.5	32.3
1	2½	7	1	10	28	39	25.0	26.5	28.0	31.0	34.0
1	3	4	1	12	16	75	20.0	20.8	21.7	23.4	25.1
1	3	4½	1	12	18	67	21.0	22.0	23.0	24.9	26.8
1	3	5	1	12	20	60	22.1	23.2	24.3	26.4	28.6
1	3	5½	1	12	22	55	23.2	24.4	25.6	28.0	30.3
1	3	6	1	12	24	50	24.3	25.6	26.9	29.5	32.1
1	3	6½	1	12	26	48	25.4	26.8	28.2	31.0	33.8
1	3	7	1	12	28	44	26.4	27.9	29.4	32.5	35.5
1	3	7½	1	12	30	42	27.5	29.1	30.8	34.0	37.2
1	3	8	1	12	32	39	28.6	30.3	32.0	35.5	39.0
1	4	5	1	16	20	75	25.0	26.1	27.2	29.3	31.5
1	4	6	1	16	24	63	27.2	28.5	29.8	32.4	35.0
1	4	7	1	16	28	55	29.3	30.8	32.4	35.4	38.4
1	4	8	1	16	32	48	31.5	33.2	34.9	38.4	41.9
1	4	9	1	16	36	43	33.6	35.6	37.5	41.4	45.3
1	4	10	1	16	40	40	35.8	38.0	40.1	44.4	48.8
1	5	10	1	20	40	47	38.7	40.9	43.0	47.3	51.7
1	6	12	1	24	48	46	45.9	48.5	51.1	56.3	61.4

NOTE.—Variations in the fineness of the sand and the compacting of the concrete may affect the volumes by 10% in either direction.

*Use for average conditions.

TABLE 27. MATERIALS FOR ONE CUBIC YARD OF RUBBLE CONCRETE (See p. 141)

BASED ON A BARREL OF 3.8 CUBIC FEET

Percentage of Rubble in Total Volume of Concrete	Proportions of Plain Concrete by Parts			Proportions of Plain Concrete by Volume			Broken Stone Uniform Size 50% Voids			Broken Stone Without Dust 45% Voids*			Screened Gravel 40% Voids			Graded Mixtures 30% Voids		
	Cement	Sand	Stone	Packed Cement	Loose Sand	Loose Stone	Cement	Sand	Stone	Cement	Sand	Stone	Cement	Sand	Stone	Cement	Sand	Stone
				bbl.	cu. ft.	cu. ft.	bbl.	cu. yd.	cu. yd.	bbl.	cu. yd.	cu. yd.	bbl.	cu. yd.	cu. yd.	bbl.	cu. yd.	cu. yd.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
20%	1	2	3	1	7.6	11.4	1.51	0.43	0.64	1.45	0.41	0.61	1.39	0.39	0.59	1.29	0.36	0.54
	1	2	4	1	7.6	15.2	1.32	0.37	0.74	1.25	0.35	0.70	1.20	0.34	0.67	1.10	0.31	0.62
	1	2	5	1	7.6	19.0	1.18	0.33	0.82	1.11	0.31	0.78	1.06	0.30	0.74	0.96	0.27	0.67
	1	2½	4	1	9.5	15.2	1.22	0.43	0.69	1.17	0.41	0.66	1.12	0.39	0.63	1.03	0.36	0.58
	1	2½	5	1	9.5	19.0	1.10	0.38	0.77	1.04	0.37	0.74	0.99	0.35	0.70	0.90	0.32	0.64
	1	2½	6	1	9.5	22.8	0.99	0.35	0.84	0.94	0.33	0.79	0.89	0.31	0.75	0.81	0.29	0.68
	1	3	5	1	11.4	19.0	1.02	0.43	0.72	0.98	0.42	0.69	0.94	0.39	0.66	0.86	0.36	0.60
	1	3	6	1	11.4	22.8	0.93	0.39	0.78	0.89	0.38	0.75	0.84	0.35	0.71	0.77	0.33	0.65
	1	3	7	1	11.4	26.6	0.86	0.36	0.84	0.81	0.34	0.79	0.77	0.32	0.76	0.70	0.30	0.69
30%	1	2	3	1	7.6	11.4	1.32	0.37	0.56	1.27	0.36	0.53	1.22	0.34	0.52	1.13	0.32	0.48
	1	2	4	1	7.6	15.2	1.15	0.32	0.65	1.10	0.31	0.62	1.05	0.29	0.59	0.97	0.27	0.55
	1	2	5	1	7.6	19.0	1.03	0.29	0.72	0.97	0.27	0.69	0.92	0.26	0.65	0.84	0.24	0.59
	1	2½	4	1	9.5	15.2	1.06	0.38	0.60	1.02	0.36	0.57	0.98	0.34	0.55	0.90	0.32	0.51
	1	2½	5	1	9.5	19.0	0.96	0.34	0.67	0.91	0.32	0.64	0.87	0.31	0.61	0.79	0.28	0.56
	1	2½	6	1	9.5	22.8	0.87	0.31	0.74	0.82	0.29	0.69	0.78	0.27	0.66	0.71	0.25	0.60
	1	3	5	1	11.4	19.0	0.90	0.38	0.63	0.85	0.36	0.60	0.82	0.34	0.57	0.75	0.32	0.53
	1	3	6	1	11.4	22.8	0.81	0.34	0.69	0.78	0.33	0.66	0.74	0.31	0.62	0.67	0.29	0.57
	1	3	7	1	11.4	26.6	0.75	0.32	0.74	0.71	0.30	0.69	0.67	0.28	0.67	0.61	0.26	0.60
40%	1	2	3	1	7.6	11.4	1.13	0.32	0.48	1.09	0.31	0.46	1.04	0.29	0.44	0.97	0.27	0.41
	1	2	4	1	7.6	15.2	0.99	0.28	0.56	0.94	0.26	0.53	0.90	0.25	0.50	0.83	0.23	0.47
	1	2	5	1	7.6	19.0	0.88	0.25	0.62	0.83	0.23	0.59	0.79	0.22	0.56	0.72	0.20	0.50
	1	2½	4	1	9.5	15.2	0.91	0.32	0.52	0.88	0.31	0.49	0.84	0.29	0.47	0.77	0.27	0.44
	1	2½	5	1	9.5	19.0	0.82	0.29	0.58	0.78	0.28	0.55	0.74	0.26	0.52	0.68	0.24	0.48
	1	2½	6	1	9.5	22.8	0.74	0.26	0.63	0.70	0.25	0.59	0.67	0.23	0.56	0.61	0.22	0.51
	1	3	5	1	11.4	19.0	0.77	0.32	0.54	0.73	0.31	0.52	0.70	0.29	0.49	0.64	0.27	0.45
	1	3	6	1	11.4	22.8	0.70	0.29	0.59	0.67	0.28	0.56	0.63	0.26	0.53	0.58	0.25	0.49
	1	3	7	1	11.4	26.6	0.65	0.27	0.63	0.61	0.26	0.59	0.58	0.24	0.57	0.52	0.22	0.52
50%	1	2	3	1	7.6	11.4	0.94	0.27	0.40	0.90	0.26	0.38	0.87	0.24	0.37	0.80	0.22	0.34
	1	2	4	1	7.6	15.2	0.82	0.23	0.46	0.78	0.22	0.44	0.75	0.21	0.42	0.69	0.20	0.39
	1	2	5	1	7.6	19.0	0.74	0.20	0.52	0.70	0.20	0.49	0.66	0.18	0.46	0.60	0.17	0.42
	1	2½	4	1	9.5	15.2	0.76	0.27	0.43	0.73	0.26	0.41	0.70	0.24	0.40	0.64	0.22	0.36
	1	2½	5	1	9.5	19.0	0.68	0.24	0.48	0.65	0.23	0.46	0.62	0.22	0.44	0.56	0.20	0.40
	1	2½	6	1	9.5	22.8	0.62	0.22	0.52	0.58	0.20	0.50	0.56	0.20	0.47	0.50	0.18	0.42
	1	3	5	1	11.4	19.0	0.64	0.27	0.45	0.61	0.26	0.43	0.58	0.24	0.41	0.54	0.22	0.38
	1	3	6	1	11.4	22.8	0.58	0.24	0.49	0.56	0.24	0.47	0.52	0.22	0.44	0.48	0.20	0.40
	1	3	7	1	11.4	26.6	0.54	0.22	0.52	0.50	0.22	0.49	0.48	0.20	0.48	0.44	0.18	0.43
60%	1	2	3	1	7.6	11.4	0.76	0.21	0.32	0.72	0.20	0.30	0.70	0.20	0.30	0.64	0.18	0.27
	1	2	4	1	7.6	15.2	0.66	0.18	0.37	0.63	0.18	0.35	0.60	0.17	0.34	0.55	0.16	0.31
	1	2	5	1	7.6	19.0	0.58	0.16	0.41	0.56	0.16	0.39	0.53	0.15	0.37	0.48	0.14	0.34
	1	2½	4	1	9.5	15.2	0.61	0.22	0.34	0.58	0.20	0.33	0.56	0.20	0.32	0.52	0.18	0.29
	1	2½	5	1	9.5	19.0	0.55	0.19	0.38	0.52	0.18	0.37	0.50	0.18	0.35	0.45	0.16	0.32
	1	2½	6	1	9.5	22.8	0.50	0.18	0.42	0.47	0.16	0.40	0.44	0.16	0.38	0.40	0.14	0.34
	1	3	5	1	11.4	19.0	0.51	0.22	0.36	0.49	0.21	0.34	0.47	0.20	0.33	0.43	0.18	0.30
	1	3	6	1	11.4	22.8	0.46	0.20	0.39	0.44	0.19	0.38	0.42	0.18	0.36	0.38	0.16	0.32
	1	3	7	1	11.4	26.6	0.43	0.18	0.42	0.40	0.17	0.40	0.38	0.16	0.38	0.35	0.15	0.34

NOTE.—Variations in the fineness of the sand and the compacting of the concrete may affect the quantities by 10% in either direction.

*Use for average conditions.

TABLE 28. VOLUME OF RUBBLE CONCRETE FROM ONE BARREL OF CEMENT (See p. 141)

BASED ON A BARREL OF 3.8 CUBIC FEET

Percentage of Rubble in Total Volume of Concrete	Proportions of Plain Concrete by Parts: Cement	Sand	Stone	Proportions of Plain Concrete by Volume: Cement, bbl.	Sand, cu. ft.	Stone, cu. ft.	Average Volume of Rubble Concrete Made from One Barrel Cement: Broken Stone Uniform Size 50% Voids, cu. ft.	Broken Stone Without Dust 45% Voids*, cu. ft.	Screened Gravel 40% Voids, cu. ft.	Graded Mixtures 30% Voids, cu. ft.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	1	2	3	1	7.6	11.4	17.9	18.6	19.4	20.9
	1	2	4	1	7.6	15.2	20.4	21.5	22.5	24.5
	1	2	5	1	7.6	19.0	23.0	24.2	25.5	28.1
	1	2½	4	1	9.5	15.2	22.0	23.1	24.1	26.2
20%	1	2½	5	1	9.5	19.0	24.8	26.0	27.2	29.9
	1	2½	6	1	9.5	22.8	27.3	28.8	30.4	33.4
	1	3	5	1	11.4	19.0	26.4	27.6	29.0	31.4
	1	3	6	1	11.4	22.8	29.0	30.5	32.0	35.1
	1	3	7	1	11.4	26.6	31.5	33.4	35.1	38.8
	1	2	3	1	7.6	11.4	20.4	21.3	22.2	23.9
	1	2	4	1	7.6	15.2	23.3	24.6	25.7	28.0
	1	2	5	1	7.6	19.0	26.3	27.7	29.2	32.1
	1	2½	4	1	9.5	15.2	25.3	26.4	27.6	30.0
30%	1	2½	5	1	9.5	19.0	28.3	29.7	31.2	34.2
	1	2½	6	1	9.5	22.8	31.2	32.9	34.7	38.2
	1	3	5	1	11.4	19.0	30.2	31.6	33.2	36.0
	1	3	6	1	11.4	22.8	33.2	34.9	36.6	40.2
	1	3	7	1	11.4	26.6	36.0	38.2	40.2	43.0
	1	2	3	1	7.6	11.4	23.8	24.8	25.8	27.8
	1	2	4	1	7.6	15.2	27.2	28.7	30.0	32.7
	1	2	5	1	7.6	19.0	30.7	32.3	34.0	37.5
	1	2½	4	1	9.5	15.2	29.5	30.8	32.2	35.0
40%	1	2½	5	1	9.5	19.0	33.0	34.7	36.3	39.8
	1	2½	6	1	9.5	22.8	36.3	38.4	40.5	44.5
	1	3	5	1	11.4	19.0	35.2	36.8	38.7	42.0
	1	3	6	1	11.4	22.8	38.7	40.7	42.7	46.8
	1	3	7	1	11.4	26.6	42.0	44.5	46.8	51.7
	1	2	3	1	7.6	11.4	28.6	29.8	31.0	33.4
	1	2	4	1	7.6	15.2	32.6	34.4	36.0	39.2
	1	2	5	1	7.6	19.0	36.8	38.8	40.8	45.0
	1	2½	4	1	9.5	15.2	35.4	37.0	38.6	42.0
50%	1	2½	5	1	9.5	19.0	39.6	41.6	43.6	47.8
	1	2½	6	1	9.5	22.8	43.6	46.0	48.6	53.4
	1	3	5	1	11.4	19.0	42.2	44.2	46.4	50.4
	1	3	6	1	11.4	22.8	46.4	48.8	51.2	56.2
	1	3	7	1	11.4	26.6	50.4	53.4	56.2	62.0
	1	2	3	1	7.6	11.4	35.8	37.2	38.8	41.8
	1	2	4	1	7.6	15.2	40.8	43.0	45.0	49.0
	1	2	5	1	7.6	19.0	46.0	48.5	51.0	56.3
	1	2½	4	1	9.5	15.2	44.3	46.3	48.3	52.5
60%	1	2½	5	1	9.5	19.0	49.5	52.0	54.6	59.8
	1	2½	6	1	9.5	22.8	54.5	57.5	60.8	66.8
	1	3	5	1	11.4	19.0	52.8	55.3	58.0	63.0
	1	3	6	1	11.4	22.8	58.0	61.0	64.0	70.3
	1	3	7	1	11.4	26.6	63.0	66.8	70.3	77.5

NOTE.—Variations in the fineness of the sand and the compacting of the concrete may affect the quantities by 10% in either direction.

***Use for average conditions.**

CHAPTER VIII

COST OF CONCRETE MATERIALS

Tables are presented in this chapter for estimating the cost of the materials for plain and rubble concrete from given costs of the cement, sand, and stone delivered on the work.

The effect of the quality and of the proportions of the materials upon the cost has been discussed in the preceding chapter. Costs of the labor of concreting as well as costs and quantities of materials for forms, reinforcing steel, and concrete members are treated fully in subsequent chapters.

METHOD OF COMPILING COST TABLES

The cost of materials is governed by the quantity of each ingredient contained in a cubic yard of concrete in place, and Tables 29 to 36, pages 165 to 172, are therefore computed from the Quantity Tables in Chapter VII, as illustrated below in Example 1.

To avoid complication, the tables are based upon materials of average quality and character, so that they furnish data sufficiently close for all ordinary estimates. The effect upon the cost of varying the percentages of voids in the aggregate is shown on page 160. For a comparison of different aggregates from the standpoint of net cost per cubic yard of concrete, or of cost based on strength of concrete, the cost may be computed as in Example 1, directly from the Quantity Tables, selecting the percentages of voids in the aggregates and the other characteristics to agree with the given conditions.

Example 1: What will be the cost per cubic yard of materials for 1:2½:5 concrete, with Portland cement at $2.00 per barrel delivered on the job, sand at $1.00 per cubic yard delivered, and broken stone with 45% voids, at $2.00 per cubic yard delivered?

Solution: The quantity of each material in a cubic yard of concrete is taken directly from Table 22, page 151, from which we have

Cement..	1.30 bbl.	@ $2.00	=	$2.60
Sand..	0.46 cu. yd.	@ 1.00	=	0.46
Stone..	0.92 cu. yd.	@ 2.00	=	1.84
Total cost of materials per cubic yard of concrete..................				$4.90

This value may be taken directly from Table 33, page 169.

BASIS OF TABLES

The tables are accurate enough for ordinary use without correction for variations in quality of materials.

The tables are based on the following assumptions:

(1) Proportions are based on a barrel of Portland cement (or 4 bags) weighing 376 pounds net, or 100 pounds per cubic foot. One part of sand or stone by volume, corresponding to one barrel of cement, is thus substantially 3.8 cubic feet.

(2) Broken stone or gravel when measured loose is assumed to have 45% voids, this figure being selected as an average value. For stone with other percentages of voids, however, the cost for any selected proportions may be readily computed by multiplying by one of the ratios given on page 160. The stone is measured by the cubic yard, but if purchased by the ton the equivalent price per cubic yard is obtained directly from Table 37, page 173.

(3) The sand is assumed to be of good quality and fairly coarse. Measured loose, with natural moisture as it comes from the bank, its average weight is 92 pounds per cubic foot and, deducting the moisture assumed as 3%, the net weight of the dry sand particles in a cubic foot of bank sand is 89 pounds.*

This figure has been selected as a fair average weight for ordinary bank sand, in its natural state, when the volume is measured in bulk as in proportioning concrete. If artificially dried, an average weight, loose, is about 100 pounds per cubic foot, while 105 pounds per cubic foot may be called an average weight of sand in its natural state packed in the bank. If sand containing natural moisture is loosely measured in a cubic foot, or smaller, measure, the weight is apt to range from 75 to 95 pounds, according to the percentage of moisture, coarseness of sand, and method of placing in the measure.

Fine sand produces a larger bulk of mortar than coarse sand, sometimes as much as 10% more, in which case, since the mortar may occupy one-half the volume of the concrete, the bulk of the concrete may be increased 5%. This increase in bulk reduces the quantity of cement per cubic yard of concrete, and therefore slightly lessens its

* This corresponds to 46% air plus water voids or 44% air voids. To those accustomed to measuring voids in sand by pouring water into it, these percentages doubtless will appear high; however, the method of pouring in water has been proved inaccurate because of the entraining of air, sometimes giving a result as much as 10% lower than the true voids.

cost; but, as discussed in Chapter VI, the strength is reduced in still larger ratio with a resulting poor economy.

Dry sand will weigh more per cubic foot, when measured loose, than the same sand with natural moisture,—this singular fact having been proved repeatedly by experiment,*—and the same volume will therefore make a larger bulk of concrete and mortar, thus reducing the quantity of cement per cubic yard of concrete perhaps 5%.

The uses of the tables are illustrated in Examples 2 to 6, pages 162 and 163.

EFFECT ON COST OF VOIDS IN BROKEN STONE

Different percentages of voids in the broken stone affect the volume of the concrete made and therefore alter the cost of materials per cubic yard of concrete.

The values in the tables, pages 165 to 172, are based on 45% voids in the broken stone and may be corrected for other percentages of voids as follows:

If stone has 50% voids, multiply the costs in the tables by 1.05.
If stone has 40% voids, multiply the costs in the tables by 0.95.
If stone has 30% voids, multiply the costs in the tables by 0.87.

COST OF STONE BY WEIGHT VS. MEASURE

If the cost of stone is in ton measurement, it may be converted into cost per cubic yard by the use of Table 37, page 173. The relation of the weight to the volume of two kinds of broken stone or gravel varies with their specific gravities and their percentages of voids. The weight per cubic yard of broken stone may range from one ton (of 2000 pounds) to 1.5 tons, varying with the specific gravity of the rock and the percentage of voids in the broken stone. It is thus impossible to give an exact figure, but for rough estimates where the specific gravity of the stone is unknown, it may be assumed for an approximation that one ton of broken stone measures 20 cubic feet, which corresponds to 100 pounds per cubic foot.

The table is computed from a formula derived in the following manner:

*See page 109; also Taylor & Thompson's "Concrete, Plain and Reinforced," second edition, p. 176.

Let

C_y = cost per cubic yard of broken stone.

C_t = cost per ton (of 2000 lb.) of stone.

W = weight of broken stone in tons per cubic yard.

g = specific gravity of stone.

v = per cent voids in broken stone.

The cost per cubic yard of the stone is equal to the cost per ton multiplied by the number of tons per cubic yard or

$$C_y = WC_t \qquad (1)$$

Expressing the weight, W, in terms of the specific gravity and percentage of voids in the stone, and using 62.4 pounds as the weight of water per cubic foot,

$$C_y = \frac{62.4g\ (1 - v)\ 27}{2000} C_t$$

or

$$C_y = 0.842g\ (1 - v)\ C_t \qquad (2)$$

The use of Table 37 is illustrated in Example 7, page 163.

COST OF MATERIALS FOR RUBBLE CONCRETE

The cost of rubble concrete is governed by the percentage of rubble stone placed in the mass and by the proportions of the concrete in which this is imbedded. In making an estimate, the cost of the rubble stones and of the plain concrete must be figured separately.

The cost of the rubble itself ordinarily consists in the labor items of quarrying, transporting and placing, and for this, reference may be made to Chapters IX and X. This labor cost may be reduced to price per cubic yard of the rubble and figured in the same way as materials. If the rubble is purchased, as is sometimes the case, it will at once come under the head of material.

No separate tables of cost of rubble concrete are presented because, having estimated the percentage and the cost of the rubble, the values for the concrete are readily obtained from the other tables. The prices for the cement, sand, and broken stone or gravel may be figured from the quantity of materials, or from Cost Tables 29 to 36, as illustrated in Example 8, page 163.

The quantity of rubble in rubble concrete may vary under ordinary working conditions from 20% of the mass to 50%; that is, the solid stones of the rubble may occupy from 20% to 50% of the total volume of the structure. (See p. 143.) The lower figure, 20%, may be assumed for "one-man" or "two-men" stone, such as are laid in a wall 4 or 5 feet thick, and the 50% for stone (running up to 2 yards each) placed by a derrick in a large mass of concrete, such as the interior of a dam. In a few cases, as high as 55% to 60% of rubble has been employed. For example, in the dam of the Jersey City Water Supply Company at Boonton, N. J., 55% of the mass consisted of rubble.

It is difficult to place rubble stone at night, because of shadows cast, and allowance must be made for this in determining the total rubble in a dam.

EXAMPLES FOR TABLES OF COST OF MATERIALS

The total cost of materials per cubic yard of concrete, when the prices of the raw materials delivered are all known, is obtained directly from the tables as in Example 2. The examples which follow this illustrate various ways of using the tables.

Example 2: What will be the cost of materials per cubic yard of concrete in place, proportions 1:2½:5, with Portland cement at $2.00 per barrel delivered on the job, sand at $1.00 per cubic yard, and broken stone with 45% voids at $2.00 per cubic yard?

Solution: From Table 33, we find the cost to be $4.90.

Example 3: What will be the difference in cost if the stone has 40% instead of 45% voids?

Solution: From the paragraph on page 160, the cost must be multiplied by the ratio 0.95, thus giving $4.90 × 0.95 = $4.65.

Example 4: Estimate the saving in Example 2 if sand costs $0.80 instead of $1.00 per cubic yard.

Solution: Interpolating between the prices $4.79 with sand at $0.75 per cubic yard, and $4.90 with sand at $1.00 per cubic yard, the cost of materials per cubic yard of concrete becomes $4.81.

Example 5: What will be the cost of materials per cubic yard of concrete with cement and sand as in Example 2 and the coarse aggregate, broken trap rock with 45% voids, costing $1.80 per ton of 2000 pounds?

Solution: By interpolation in Table 37, the cost per cubic yard of the stone is found to be $2.41 and, using this value in Table 33, the total cost of materials per cubic yard of concrete will thus be $5.28.

Example 6: If very fine sand is employed, what will be the cost of the 1:2½:5 concrete in Example 2?

Solution: For answer reference must be made to Table 18, page 139 and the materials taken separately:

Cement	1.27 bbl.	@ $2.00 =	$2.54
Fine sand	0.45 cu. yd.	@ 1.00 =	0.45
Stone	0.90 cu. yd	@ 2.00 =	1.80
Total cost of materials per cubic yard of concrete			$4.79

Although this result is $0.11 less than with ordinary coarse sand, as shown in Example 2, the strength of the concrete is reduced in so much larger ratio that the fine sand should not be used.

EXAMPLES FOR TABLE OF COST OF STONE BY WEIGHT VS. MEASURE

The following example illustrates the application of the table.

Example 7: If unscreened crusher run broken trap stone is purchased at $2.00 per ton of 2000 pounds, what will be its equivalent price per cubic yard to use in estimating the cost of materials for concrete in preceding tables.

Solution: Table 37 gives equivalent price per yard as $2.92 if stone has 40% voids, or $2.43 if stone has 50% voids. The footnote states that for stone containing dust the lower per cent applies, hence we may estimate the corresponding price per yard at $2.92.

EXAMPLES OF FINDING COST OF RUBBLE CONCRETE

Example 8: What will be the cost per cubic yard of the materials for a wall of rubble concrete 10 feet thick, of which 40% of the mass is estimated to be solid rubble stone and the remainder 1:2½:5 concrete, with cement at $2.00 per barrel delivered, sand at $0.75 per cubic yard delivered, broken stone at $1.50 per cubic yard delivered, rubble at $0.75 per cubic yard measured loose?

Solution: If the wall were of plain concrete, the cost of materials from Table 33, page 169, would be $4.33 per cubic yard, but since only 60% of the material is concrete, this cost is reduced to $4.33 × 0.60 = $2.60 per cubic yard. To this must be added the cost of the rubble. Assuming the voids in the loose rubble to be 45%, the cost of a solid cubic yard of rubble is $\frac{\$0.75}{1.00-0.45} = \$1.36$, hence, the cost of rubble per cubic yard of the rubble concrete is $1.36 × 40% = $0.55. The total cost of materials for the rubble concrete is thus $3.15.

Example 9: What will be the cost under the same conditions as those named in Example 8, except that the trap rubble is purchased at price of $1.00 per short ton of 2000 pounds?

Solution: For accuracy, the specific gravity of this particular trap should be determined. As no figure is given, assume average value (p. 173) of 2.9, or 180 pounds of solid rock per cubic foot. The volume of solid rock in a ton is therefore $\frac{2000}{180} = 11.11$ cubic feet, or 0.412 cubic yards, and the cost per cubic yard is $\frac{\$1.00}{0.412} = \$2.43$. The cost of rubble in a cubic yard of concrete (since 40% of the mass is rubble) is $2.43 × 0.40 = $0.97. Adding this to cost of plain concrete in Example 8, amounting to $2.60, gives $3.57 per cubic yard of rubble concrete as the cost of the materials. Average specific gravities for different rock are given in footnote to Table 37, on page 173.

TABLE 29. COST OF MATERIALS FOR ONE CUBIC YARD OF 1:1½:3 CONCRETE

For basis of table see page 159. If stone is purchased by the ton see page 173. Costs for materials only, delivered on job. For labor see Chap. X, XI and XIII.

Cement per Bbl.	Sand at 75¢ per Cubic Yard — Price of Stone per Cubic Yard								
	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80
$	$	$	$	$	$	$	$	$	$
0.60	2.02	2.35	2.52	2.69	2.86	3.03	3.20	3.53	3.86
0.70	2.22	2.55	2.72	2.89	3.06	3.23	3.40	3.73	4.06
0.80	2.42	2.75	2.92	3.09	3.26	3.43	3.60	3.93	4.26
0.90	2.62	2.95	3.12	3.29	3.46	3.63	3.80	4.13	4.46
1.00	2.82	3.15	3.32	3.49	3.66	3.83	4.00	4.33	4.66
1.10	3.02	3.35	3.52	3.69	3.86	4.03	4.20	4.53	4.86
1.20	3.22	3.55	3.72	3.89	4.06	4.23	4.40	4.73	5.06
1.30	3.42	3.75	3.92	4.09	4.26	4.43	4.60	4.93	5.26
1.40	3.62	3.95	4.12	4.29	4.46	4.63	4.80	5.13	5.46
1.50	3.82	4.15	4.32	4.49	4.66	4.83	5.00	5.33	5.66
1.60	4.02	4.35	4.52	4.69	4.86	5.03	5.20	5.53	5.86
1.70	4.22	4.55	4.72	4.89	5.06	5.23	5.40	5.73	6.06
1.80	4.42	4.75	4.92	5.09	5.26	5.43	5.60	5.93	6.26
1.90	4.62	4.95	5.12	5.29	5.46	5.63	5.80	6.13	6.46
2.00	4.82	5.15	5.32	5.49	5.66	5.83	6.00	6.33	6.66
2.10	5.02	5.35	5.52	5.69	5.86	6.03	6.20	6.53	6.86
2.20	5.22	5.55	5.72	5.89	6.06	6.23	6.40	6.73	7.06
2.30	5.42	5.75	5.92	6.09	6.26	6.43	6.60	6.93	7.26
2.40	5.62	5.95	6.12	6.29	6.46	6.63	6.80	7.13	7.46
2.50	5.82	6.15	6.32	6.49	6.66	6.83	7.00	7.33	7.66
3.00	6.82	7.15	7.32	7.49	7.66	7.83	8.00	8.33	8.66
4.00	8.82	9.15	9.32	9.49	9.66	9.83	10.00	10.33	10.66
5.00	10.82	11.15	11.32	11.49	11.66	11.83	12.00	12.33	12.66

Cement per Bbl.	Sand at $1.00 per Cubic Yard — Price of Stone per Cubic Yard								
	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80
$	$	$	$	$	$	$	$	$	$
0.60	2.12	2.45	2.62	2.79	2.96	3.13	3.30	3.63	3.96
0.70	2.32	2.65	2.82	2.99	3.16	3.33	3.50	3.83	4.16
0.80	2.52	2.85	3.02	3.19	3.36	3.53	3.70	4.03	4.36
0.90	2.72	3.05	3.22	3.39	3.56	3.73	3.90	4.23	4.56
1.00	2.92	3.25	3.42	3.59	3.76	3.93	4.10	4.43	4.76
1.10	3.12	3.45	3.62	3.79	3.96	4.13	4.30	4.63	4.96
1.20	3.32	3.65	3.82	3.99	4.16	4.33	4.50	4.83	5.16
1.30	3.52	3.85	4.02	4.19	4.36	4.53	4.70	5.03	5.36
1.40	3.72	4.05	4.22	4.39	4.56	4.73	4.90	5.23	5.56
1.50	3.92	4.25	4.42	4.59	4.76	4.93	5.10	5.43	5.76
1.60	4.12	4.45	4.62	4.79	4.96	5.13	5.30	5.63	5.96
1.70	4.32	4.65	4.82	4.99	5.16	5.33	5.50	5.83	6.16
1.80	4.52	4.85	5.02	5.19	5.36	5.53	5.70	6.03	6.36
1.90	4.72	5.05	5.22	5.39	5.56	5.73	5.90	6.23	6.56
2.00	4.92	5.25	5.42	5.59	5.76	5.93	6.10	6.43	6.76
2.10	5.12	5.45	5.62	5.79	5.96	6.13	6.30	6.63	6.96
2.20	5.32	5.65	5.82	5.99	6.16	6.33	6.50	6.83	7.16
2.30	5.52	5.85	6.02	6.19	6.36	6.53	6.70	7.03	7.36
2.40	5.72	6.05	6.22	6.39	6.56	6.73	6.90	7.23	7.56
2.50	5.92	6.25	6.42	6.59	6.76	6.93	7.10	7.43	7.76
3.00	6.92	7.25	7.42	7.59	7.76	7.93	8.10	8.43	8.76
4.00	8.92	9.25	9.42	9.59	9.76	9.93	10.10	10.43	10.76
5.00	10.92	11.25	11.42	11.59	11.76	11.93	12.10	12.43	12.76

Cement per Bbl.	Sand at $1.25 per Cubic Yard — Price of Stone per Cubic Yard								
	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80
$	$	$	$	$	$	$	$	$	$
0.90	2.82	3.15	3.32	3.49	3.66	3.83	4.00	4.33	4.66
1.00	3.02	3.35	3.52	3.69	3.86	4.03	4.20	4.53	4.86
1.10	3.22	3.55	3.72	3.89	4.06	4.23	4.40	4.73	5.06
1.20	3.42	3.75	3.92	4.09	4.26	4.43	4.60	4.93	5.26
1.30	3.62	3.95	4.12	4.29	4.46	4.63	4.80	5.13	5.46
1.40	3.82	4.15	4.32	4.49	4.66	4.83	5.00	5.33	5.66
1.50	4.02	4.35	4.52	4.69	4.86	5.03	5.20	5.53	5.86
1.60	4.22	4.55	4.72	4.89	5.06	5.23	5.40	5.73	6.06
1.70	4.42	4.75	4.92	5.09	5.26	5.43	5.60	5.93	6.26
1.80	4.62	4.95	5.12	5.29	5.46	5.63	5.80	6.13	6.46
1.90	4.82	5.15	5.32	5.49	5.66	5.83	6.00	6.33	6.66
2.00	5.02	5.35	5.52	5.69	5.86	6.03	6.20	6.53	6.86
2.10	5.22	5.55	5.72	5.89	6.06	6.23	6.40	6.73	7.06
2.20	5.42	5.75	5.92	6.09	6.26	6.43	6.60	6.93	7.26
2.30	5.62	5.95	6.12	6.29	6.46	6.63	6.80	7.13	7.46
2.40	5.82	6.15	6.32	6.49	6.66	6.83	7.00	7.33	7.66
2.50	6.02	6.35	6.52	6.69	6.86	7.03	7.20	7.53	7.86
3.00	7.02	7.35	7.52	7.69	7.86	8.03	8.20	8.53	8.86
4.00	9.02	9.35	9.52	9.69	9.86	10.03	11.20	10.53	10.86
5.00	11.02	11.35	11.52	11.69	11.86	12.03	12.20	12.53	12.86

Cement per Bbl.	Sand at $1.50 per Cubic Yard — Price of Stone per Cubic Yard								
	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80
$	$	$	$	$	$	$	$	$	$
0.90	2.93	3.26	3.43	3.60	3.77	3.94	4.11	4.44	4.77
1.00	3.13	3.46	3.63	3.80	3.97	4.14	4.31	4.64	4.97
1.10	3.33	3.66	3.83	4.00	4.17	4.34	4.51	4.84	5.17
1.20	3.53	3.86	4.03	4.20	4.37	4.54	4.71	5.04	5.37
1.30	3.73	4.06	4.23	4.40	4.57	4.74	4.91	5.24	5.57
1.40	3.93	4.26	4.43	4.60	4.77	4.94	5.11	5.44	5.77
1.50	4.13	4.46	4.63	4.80	4.97	5.14	5.31	5.64	5.97
1.60	4.33	4.66	4.83	5.00	5.17	5.34	5.51	5.84	6.17
1.70	4.53	4.86	5.03	5.20	5.37	5.54	5.71	6.04	6.37
1.80	4.73	5.06	5.23	5.40	5.57	5.74	5.91	6.24	6.57
1.90	4.93	5.26	5.43	5.60	5.77	5.94	6.11	6.44	6.77
2.00	5.13	5.46	5.63	5.80	5.97	6.14	6.31	6.64	6.97
2.10	5.33	5.66	5.83	6.00	6.17	6.34	6.51	6.84	7.17
2.20	5.53	5.86	6.03	6.20	6.37	6.54	6.71	7.04	7.37
2.30	5.73	6.06	6.23	6.40	6.57	6.74	6.91	7.24	7.57
2.40	5.93	6.26	6.43	6.60	6.77	6.94	7.11	7.44	7.77
2.50	6.13	6.46	6.63	6.80	6.97	7.14	7.31	7.64	7.97
3.00	7.13	7.46	7.63	7.80	7.97	8.14	8.31	8.64	8.97
4.00	9.13	9.46	9.63	9.80	9.97	11.14	11.31	10.64	10.97
5.00	11.13	11.46	11.63	11.80	11.97	12.14	12.31	12.64	12.97

TABLE 30. COST OF MATERIALS FOR ONE CUBIC YARD OF 1:1½:4 CONCRETE

For basis of table see page 159. If stone is purchased by the ton see page 173. Costs for materials only, delivered on job. For labor see Chap. X, XI and XIII.

Cement per Bbl.	Sand at 75¢ per Cubic Yard									Sand at $1.00 per Cubic Yard								
	Price of Stone per Cubic Yard									Price of Stone per Cubic Yard								
	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80
$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
0.60	1.87	2.26	2.45	2.64	2.83	3.02	3.22	3.60	3.98	1.96	2.35	2.54	2.73	2.92	3.11	3.31	3.69	4.07
0.70	2.04	2.43	2.62	2.81	3.00	3.20	3.39	3.77	4.16	2.13	2.52	2.71	2.90	3.09	3.29	3.48	3.86	4.25
0.80	2.21	2.60	2.79	2.98	3.17	3.37	3.56	3.94	4.33	2.30	2.69	2.88	3.07	3.26	3.46	3.65	4.03	4.42
0.90	2.38	2.77	2.96	3.15	3.34	3.54	3.73	4.11	4.50	2.47	2.86	3.05	3.24	3.43	3.63	3.82	4.20	4.59
1.00	2.56	2.94	3.13	3.32	3.52	3.71	3.90	4.28	4.67	2.65	3.03	3.22	3.41	3.61	3.80	3.99	4.37	4.76
1.10	2.73	3.11	3.30	3.49	3.69	3.88	4.07	4.46	4.84	2.82	3.20	3.39	3.58	3.78	3.97	4.16	4.55	4.93
1.20	2.90	3.28	3.47	3.67	3.86	4.05	4.24	4.63	5.01	2.99	3.37	3.56	3.76	3.95	4.14	4.33	4.72	5.10
1.30	3.07	3.45	3.64	3.84	4.03	4.22	4.41	4.80	5.18	3.16	3.54	3.73	3.93	4.12	4.31	4.50	4.89	5.27
1.40	3.24	3.62	3.82	4.01	4.20	4.39	4.58	4.97	5.35	3.33	3.71	3.91	4.10	4.29	4.48	4.67	5.06	5.44
1.50	3.41	3.79	3.99	4.18	4.37	4.56	4.76	5.14	5.52	3.50	3.88	4.08	4.27	4.46	4.65	4.85	5.23	5.61
1.60	3.58	3.97	4.16	4.35	4.54	4.73	4.93	5.31	5.69	3.67	4.06	4.25	4.44	4.63	4.82	5.02	5.40	5.78
1.70	3.75	4.14	4.33	4.52	4.71	4.90	5.10	5.48	5.87	3.84	4.23	4.42	4.61	4.80	4.99	5.19	5.57	5.96
1.80	3.92	4.31	4.50	4.69	4.88	5.08	5.27	5.65	6.04	4.01	4.40	4.59	4.78	4.97	5.17	5.36	5.74	6.13
1.90	4.10	4.48	4.67	4.86	5.06	5.25	5.44	5.82	6.21	4.18	4.57	4.76	4.95	5.15	5.34	5.53	5.91	6.30
2.00	4.27	4.65	4.84	5.03	5.23	5.42	5.61	5.99	6.38	4.36	4.74	4.93	5.12	5.32	5.51	5.70	6.08	6.47
2.10	4.44	4.82	5.01	5.21	5.40	5.59	5.78	6.16	6.55	4.53	4.91	5.10	5.30	5.49	5.68	5.87	6.25	6.64
2.20	4.61	4.99	5.18	5.38	5.57	5.76	5.95	6.34	6.72	4.70	5.08	5.27	5.47	5.66	5.85	6.04	6.43	6.81
2.30	4.78	5.16	5.36	5.55	5.74	5.93	6.12	6.51	6.89	4.87	5.25	5.45	5.64	5.83	6.02	6.21	6.60	6.98
2.40	4.95	5.33	5.53	5.72	5.91	6.10	6.29	6.68	7.06	5.04	5.42	5.62	5.81	6.00	6.19	6.38	6.77	7.15
2.50	5.12	5.50	5.70	5.89	6.08	6.27	6.46	6.85	7.23	5.21	5.59	5.79	5.98	6.17	6.36	6.55	6.94	7.32
3.00	5.98	6.36	6.55	6.74	6.94	7.13	7.32	7.70	8.09	6.07	6.45	6.64	6.83	7.03	7.22	7.41	7.79	8.17
4.00	7.69	8.07	8.26	8.45	8.65	8.84	9.03	9.41	9.80	7.78	8.16	8.35	8.54	8.74	8.93	9.12	9.50	9.89
5.00	9.40	9.78	9.97	10.16	10.36	10.55	10.74	11.12	11.51	9.49	9.87	10.06	10.25	10.45	10.64	10.83	11.21	11.60

Cement per Bbl.	Sand at $1.25 per Cubic Yard									Sand at $1.50 per Cubic Yard								
	Price of Stone per Cubic Yard									Price of Stone per Cubic Yard								
	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80
$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
0.90	2.56	2.95	3.14	3.33	3.52	3.72	3.91	4.29	4.68	2.65	3.04	3.23	3.42	3.61	3.81	4.00	4.38	4.77
1.00	2.74	3.12	3.31	3.50	3.70	3.89	4.08	4.46	4.85	2.83	3.21	3.40	3.59	3.79	3.98	4.17	4.55	4.94
1.10	2.91	3.29	3.48	3.67	3.87	4.06	4.25	4.64	5.02	3.00	3.38	3.57	3.76	3.96	4.15	4.34	4.73	5.11
1.20	3.08	3.46	3.65	3.85	4.04	4.23	4.42	4.81	5.19	3.17	3.55	3.74	3.94	4.13	4.32	4.51	4.90	5.28
1.30	3.25	3.63	3.82	4.02	4.21	4.40	4.59	4.98	5.36	3.34	3.72	3.91	4.11	4.30	4.49	4.68	5.07	5.45
1.40	3.42	3.80	4.00	4.19	4.38	4.57	4.76	5.15	5.53	3.51	3.89	4.09	4.28	4.47	4.66	4.85	5.24	5.62
1.50	3.59	3.97	4.17	4.36	4.55	4.74	4.94	5.32	5.70	3.68	4.06	4.26	4.45	4.64	4.83	5.03	5.41	5.79
1.60	3.76	4.15	4.34	4.53	4.72	4.91	5.11	5.49	5.87	3.85	4.24	4.43	4.62	4.81	5.00	5.20	5.58	5.96
1.70	3.93	4.32	4.51	4.70	4.89	5.08	5.28	5.66	6.05	4.02	4.41	4.60	4.79	4.98	5.17	5.37	5.75	6.14
1.80	4.10	4.49	4.68	4.87	5.06	5.26	5.45	5.83	6.22	4.19	4.58	4.77	4.96	5.15	5.35	5.54	5.92	6.31
1.90	4.27	4.66	4.85	5.04	5.24	5.43	5.62	6.00	6.39	4.36	4.75	4.94	5.13	5.33	5.52	5.71	6.09	6.48
2.00	4.45	4.83	5.02	5.21	5.41	5.60	5.79	6.17	6.56	4.54	4.92	5.11	5.30	5.50	5.69	5.88	6.26	6.65
2.10	4.62	5.00	5.19	5.39	5.58	5.77	5.96	6.34	6.73	4.71	5.09	5.28	5.48	5.67	5.86	6.05	6.43	6.82
2.20	4.79	5.17	5.36	5.56	5.75	5.94	6.13	6.52	6.90	4.88	5.26	5.45	5.65	5.84	6.03	6.22	6.61	6.99
2.30	4.96	5.34	5.54	5.73	5.92	6.11	6.30	6.69	7.07	5.05	5.43	5.63	5.82	6.01	6.20	6.39	6.78	7.16
2.40	5.13	5.51	5.71	5.90	6.09	6.28	6.47	6.86	7.24	5.22	5.60	5.80	5.99	6.18	6.37	6.56	6.95	7.33
2.50	5.30	5.68	5.88	6.07	6.26	6.45	6.64	7.03	7.41	5.39	5.77	5.97	6.16	6.35	6.54	6.73	7.12	7.50
3.00	6.16	6.54	6.73	6.92	7.12	7.31	7.50	7.88	8.26	6.25	6.63	6.82	7.01	7.21	7.40	7.59	7.97	8.35
4.00	7.87	8.25	8.44	8.63	8.83	9.02	9.21	9.59	9.98	7.96	8.34	8.53	8.72	8.92	9.11	9.30	9.68	10.07
5.00	9.58	9.96	10.15	10.34	10.54	10.73	10.92	11.30	11.69	9.67	10.05	10.24	10.43	10.63	10.82	11.01	11.39	11.78

TABLE 31. COST OF MATERIALS FOR ONE CUBIC YARD OF 1:2:4 CONCRETE

For basis of table see page 159. If stone is purchased by the ton see page 173. Costs for materials only, delivered on job. For labor see Chap. X, XI and XIII.

Cement per Bbl.	Sand at 75¢ per Cubic Yard									Sand at $1.00 per Cubic Yard								
	Price of Stone per Cubic Yard									Price of Stone per Cubic Yard								
	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80
$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
0.60	1.80	2.15	2.33	2.50	2.68	2.86	3.03	3.38	3.74	1.91	2.26	2.44	2.61	2.79	2.97	3.14	3.49	3.84
0.70	1.96	2.31	2.48	2.66	2.84	3.01	3.19	3.54	3.89	2.07	2.42	2.59	2.77	2.95	3.12	3.30	3.65	4.00
0.80	2.11	2.47	2.64	2.82	2.99	3.17	3.35	3.70	4.05	2.22	2.58	2.75	2.93	3.10	3.28	3.46	3.81	4.16
0.90	2.27	2.62	2.80	2.98	3.15	3.33	3.50	3.86	4.21	2.38	2.73	2.91	3.09	3.26	3.44	3.61	3.97	4.32
1.00	2.43	2.78	2.96	3.13	3.31	3.48	3.66	4.01	4.36	2.54	2.89	3.07	3.24	3.42	3.59	3.77	4.12	4.47
1.10	2.58	2.94	3.11	3.29	3.46	3.64	3.82	4.17	4.52	2.69	3.05	3.22	3.40	3.57	3.75	3.93	4.28	4.63
1.20	2.74	3.09	3.27	3.45	3.62	3.80	3.97	4.33	4.68	2.85	3.20	3.38	3.56	3.73	3.91	4.08	4.44	4.79
1.30	2.90	3.25	3.43	3.60	3.78	3.96	4.13	4.48	4.84	3.01	3.36	3.54	3.71	3.89	4.07	4.24	4.59	4.95
1.40	3.06	3.41	3.58	3.76	3.94	4.11	4.29	4.64	4.99	3.17	3.52	3.69	3.87	4.05	4.22	4.40	4.75	5.10
1.50	3.21	3.56	3.74	3.92	4.09	4.27	4.44	4.80	5.15	3.32	3.67	3.85	4.03	4.20	4.38	4.55	4.91	5.26
1.60	3.37	3.72	3.90	4.07	4.25	4.43	4.60	4.95	5.31	3.48	3.83	4.01	4.18	4.36	4.54	4.71	5.06	5.42
1.70	3.53	3.88	4.06	4.23	4.41	4.58	4.76	5.11	5.46	3.64	3.99	4.17	4.34	4.52	4.69	4.87	5.22	5.57
1.80	3.68	4.04	4.21	4.39	4.56	4.74	4.92	5.27	5.62	3.79	4.15	4.32	4.50	4.67	4.85	5.03	5.38	5.73
1.90	3.84	4.19	4.37	4.54	4.72	4.90	5.07	5.42	5.78	3.95	4.30	4.48	4.65	4.83	5.01	5.18	5.53	5.89
2.00	4.00	4.35	4.53	4.70	4.88	5.05	5.23	5.58	5.93	4.11	4.46	4.64	4.81	4.99	5.16	5.34	5.69	6.04
2.10	4.16	4.51	4.68	4.86	5.04	5.21	5.39	5.74	6.09	4.27	4.62	4.79	4.97	5.15	5.32	5.50	5.85	6.20
2.20	4.31	4.66	4.84	5.02	5.19	5.37	5.54	5.90	6.25	4.42	4.77	4.95	5.13	5.30	5.48	5.65	6.01	6.36
2.30	4.47	4.82	5.00	5.17	5.35	5.52	5.70	6.05	6.40	4.58	4.93	5.11	5.28	5.46	5.63	5.81	6.16	6.51
2.40	4.63	4.98	5.15	5.33	5.51	5.68	5.86	6.21	6.56	4.74	5.09	5.26	5.44	5.62	5.79	5.97	6.32	6.67
2.50	4.78	5.13	5.31	5.49	5.66	5.84	6.02	6.37	6.72	4.89	5.24	5.42	5.60	5.77	5.95	6.13	6.48	6.83
3.00	5.57	5.92	6.10	6.27	6.45	6.62	6.80	7.15	7.51	5.68	6.03	6.21	6.38	6.56	6.73	6.91	7.26	7.62
4.00	7.14	7.49	7.67	7.84	8.02	8.19	8.37	8.72	9.07	7.25	7.60	7.78	7.95	8.13	8.30	8.48	8.83	9.18
5.00	8.71	9.06	9.24	9.41	9.59	9.76	9.94	10.29	10.64	8.82	9.17	9.35	9.52	9.70	9.87	10.05	10.40	10.75

Cement per Bbl.	Sand at $1.25 per Cupic Yard									Sand at $1.50 per Cubic Yard								
	Price of Stone per Cubic Yard									Price of Stone per Cubic Yard								
	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80	$0.60	$1.00	$1.40	$1.20	$1.60	$1.80	$2.00	$2.40	$2.80
$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
0.90	2.49	2.84	3.02	3.20	3.37	3.54	3.72	4.08	4.43	2.60	2.95	3.13	3.31	3.48	3.65	3.83	4.19	4.54
1.00	2.65	3.00	3.18	3.35	3.53	3.70	3.88	4.23	4.58	2.76	3.11	3.29	3.46	3.64	3.81	3.99	4.34	4.69
1.10	2.80	3.16	3.33	3.51	3.68	3.86	4.04	4.39	4.74	2.91	3.27	3.44	3.62	3.79	3.97	4.15	4.50	4.85
1.20	2.96	3.31	3.49	3.67	3.84	4.02	4.19	4.55	4.90	3.07	3.42	3.60	3.78	3.95	4.13	4.30	4.66	5.01
1.30	3.12	3.47	3.65	3.82	4.00	4.18	4.35	4.70	5.06	3.23	3.58	3.76	3.93	4.11	4.29	4.46	4.81	5.17
1.40	3.28	3.63	3.80	3.98	4.16	4.33	4.51	4.86	5.21	3.39	3.74	3.91	4.09	4.27	4.44	4.62	4.97	5.32
1.50	3.43	3.78	3.96	4.14	4.31	4.49	4.66	5.02	5.37	3.54	3.89	4.07	4.25	4.42	4.60	4.77	5.13	5.48
1.60	3.59	3.94	4.12	4.29	4.47	4.64	4.82	5.17	5.53	3.70	4.05	4.23	4.40	4.58	4.75	4.93	5.28	5.64
1.70	3.75	4.10	4.28	4.45	4.63	4.80	4.98	5.33	5.68	3.86	4.21	4.39	4.56	4.74	4.91	5.09	5.44	5.79
1.80	3.90	4.26	4.43	4.61	4.78	4.96	5.14	5.49	5.84	4.01	4.37	4.54	4.72	4.89	5.07	5.25	5.60	5.95
1.90	4.06	4.41	4.59	4.76	4.94	5.12	5.29	5.64	6.00	4.17	4.52	4.70	4.87	5.05	5.23	5.40	5.75	6.11
2.00	4.22	4.57	4.75	4.92	5.10	5.27	5.45	5.80	6.15	4.33	4.68	4.86	5.03	5.21	5.38	5.56	5.91	6.26
2.10	4.38	4.73	4.90	5.08	5.26	5.43	5.61	5.96	6.31	4.49	4.84	5.01	5.19	5.37	5.54	5.72	6.07	6.42
2.20	4.53	4.88	5.06	5.24	5.41	5.59	5.76	6.12	6.47	4.64	4.99	5.17	5.35	5.52	5.70	5.87	6.23	6.58
2.30	4.69	5.04	5.22	5.39	5.57	5.74	5.92	6.27	6.62	4.80	5.15	5.33	5.50	5.68	5.85	6.03	6.38	6.73
2.40	4.85	5.20	5.37	5.55	5.73	5.90	6.08	6.43	6.78	4.96	5.31	5.48	5.66	5.84	6.01	6.19	6.54	6.89
2.50	5.00	5.36	5.53	5.71	5.88	6.06	6.24	6.59	6.94	5.11	5.47	5.65	5.82	5.99	6.17	6.35	6.70	7.05
3.00	5.79	6.15	6.32	6.49	6.67	6.84	7.02	7.37	7.73	5.90	6.25	6.43	6.60	6.78	6.95	7.13	7.48	7.84
4.00	7.36	7.71	7.89	8.06	8.24	8.41	8.59	8.94	9.29	7.47	7.82	8.00	8.17	8.35	8.52	8.70	9.05	9.40
5.00	8.93	9.28	9.46	9.63	9.81	9.98	10.16	10.51	10.86	9.04	9.39	9.57	9.74	9.92	10.09	10.27	10.62	10.97

TABLE 32. COST OF MATERIALS FOR ONE CUBIC YARD OF 1:2:5 CONCRETE

For basis of table see page 159. If stone is purchased by the ton see page 173. Costs for materials only, delivered on job. For labor see Chap. X, XI and XIII.

Cement per Bbl.	Sand at 75¢ per Cubic Yard — Price of Stone per Cubic Yard									Sand at $1.00 per Cubic Yard — Price of Stone per Cubic Yard								
	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80
$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
0.60	1.71	2.11	2.30	2.50	2.69	2.89	3.09	3.48	3.87	1.81	2.21	2.40	2.60	2.79	2.99	3.19	3.58	3.97
0.70	1.85	2.24	2.44	2.64	2.83	3.03	3.22	3.62	4.01	1.95	2.34	2.54	2.74	2.93	3.13	3.32	3.72	4.11
0.80	1.99	2.38	2.58	2.78	2.97	3.17	3.36	3.76	4.15	2.09	2.48	2.68	2.88	3.07	3.27	3.46	3.86	4.25
0.90	2.13	2.52	2.72	2.92	3.11	3.31	3.50	3.90	4.29	2.23	2.62	2.82	3.02	3.21	3.41	3.60	4.00	4.39
1.00	2.27	2.66	2.86	3.05	3.25	3.45	3.64	4.03	4.43	2.37	2.76	2.96	3.15	3.35	3.55	3.74	4.13	4.53
1.10	2.41	2.80	3.00	3.19	3.39	3.58	3.78	4.17	4.56	2.51	2.90	3.10	3.29	3.49	3.68	3.88	4.27	4.66
1.20	2.55	2.94	3.14	3.33	3.53	3.72	3.92	4.31	4.70	2.65	3.04	3.24	3.43	3.63	3.82	4.02	4.41	4.80
1.30	2.69	3.08	3.28	3.47	3.67	3.86	4.06	4.45	4.84	2.79	3.18	3.38	3.57	3.77	3.96	4.16	4.55	4.94
1.40	2.83	3.22	3.41	3.61	3.81	4.00	4.20	4.59	4.98	2.93	3.32	3.51	3.71	3.91	4.10	4.30	4.69	5.08
1.50	2.96	3.36	3.55	3.75	3.94	4.14	4.34	4.73	5.12	3.06	3.46	3.65	3.85	4.04	4.24	4.44	4.83	5.22
1.60	3.10	3.50	3.69	3.89	4.08	4.28	4.48	4.87	5.26	3.20	3.60	3.79	3.99	4.18	4.38	4.58	4.97	5.36
1.70	3.24	3.64	3.83	4.03	4.22	4.42	4.62	5.01	5.40	3.34	3.74	3.93	4.13	4.32	4.52	4.72	5.11	5.50
1.80	3.38	3.77	3.97	4.17	4.36	4.56	4.75	5.15	5.54	3.48	3.87	4.07	4.27	4.46	4.66	4.85	5.25	5.64
1.90	3.52	3.91	4.11	4.30	4.50	4.70	4.89	5.28	5.68	3.62	4.01	4.21	4.40	4.60	4.80	4.99	5.38	5.78
2.00	3.66	4.05	4.25	4.44	4.64	4.84	5.03	5.42	5.82	3.76	4.15	4.35	4.54	4.74	4.94	5.13	5.52	5.92
2.10	3.80	4.19	4.39	4.58	4.78	4.98	5.17	5.56	5.96	3.90	4.29	4.49	4.68	4.88	5.08	5.27	5.66	6.06
2.20	3.94	4.33	4.53	4.72	4.92	5.11	5.31	5.70	6.09	4.04	4.43	4.63	4.82	5.02	5.21	5.41	5.80	6.19
2.30	4.08	4.47	4.67	4.86	5.06	5.25	5.45	5.84	6.23	4.18	4.57	4.77	4.96	5.16	5.35	5.55	5.94	6.33
2.40	4.22	4.61	4.80	5.00	5.20	5.39	5.59	5.98	6.37	4.32	4.71	4.90	5.10	5.30	5.49	5.69	6.08	6.47
2.50	4.36	4.75	4.94	5.14	5.34	5.53	5.73	6.12	6.51	4.46	4.85	5.04	5.24	5.44	5.63	5.83	6.22	6.61
3.00	5.05	5.44	5.64	5.83	6.03	6.23	6.42	6.81	7.21	5.15	5.54	5.74	5.93	6.13	6.33	6.52	6.91	7.31
4.00	6.44	6.83	7.03	7.22	7.42	7.62	7.81	8.20	8.60	6.54	6.93	7.13	7.32	7.52	7.72	7.91	8.30	8.70
5.00	7.83	8.22	8.42	8.61	8.81	9.01	9.20	9.59	9.99	7.93	8.32	8.52	8.71	8.91	9.11	9.30	9.69	10.08

Cement per Bbl.	Sand at $1.25 per Cubic Yard — Price of Stone per Cubic Yard									Sand at $1.50 per Cubic Yard — Price of Stone per Cubic Yard								
	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80
$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
0.90	2.33	2.72	2.92	3.12	3.31	3.51	3.70	4.10	4.49	2.43	2.82	3.02	3.22	3.41	3.61	3.80	4.20	4.59
1.00	2.47	2.86	3.06	3.25	3.45	3.65	3.84	4.23	4.63	2.57	2.96	3.16	3.35	3.55	3.75	3.94	4.33	4.73
1.10	2.61	3.00	3.20	3.39	3.59	3.78	3.98	4.37	4.76	2.71	3.10	3.30	3.49	3.69	3.88	4.08	4.47	4.86
1.20	2.75	3.14	3.34	3.53	3.73	3.92	4.12	4.51	4.90	2.85	3.24	3.44	3.63	3.83	4.02	4.22	4.61	5.00
1.30	2.89	3.28	3.48	3.67	3.87	4.06	4.26	4.65	5.04	2.99	3.38	3.58	3.77	3.97	4.16	4.36	4.75	5.14
1.40	3.03	3.42	3.61	3.81	4.01	4.20	4.40	4.79	5.18	3.13	3.52	3.71	3.91	4.11	4.30	4.50	4.89	5.28
1.50	3.16	3.56	3.75	3.95	4.14	4.34	4.54	4.93	5.32	3.26	3.66	3.85	4.05	4.24	4.44	4.64	5.03	5.42
1.60	3.30	3.70	3.89	4.09	4.28	4.48	4.68	5.07	5.46	3.40	3.80	3.99	4.19	4.38	4.58	4.78	5.17	5.56
1.70	3.44	3.84	4.03	4.23	4.42	4.62	4.82	5.21	5.60	3.54	3.94	4.13	4.33	4.52	4.72	4.92	5.31	5.70
1.80	3.58	3.97	4.17	4.37	4.56	4.76	4.95	5.35	5.74	3.68	4.07	4.27	4.47	4.66	4.86	5.05	5.45	5.89
1.90	3.72	4.11	4.31	4.50	4.70	4.90	5.09	5.48	5.88	3.82	4.21	4.41	4.60	4.80	5.00	5.19	5.58	5.98
2.00	3.86	4.25	4.45	4.64	4.84	5.04	5.23	5.62	6.02	3.96	4.35	4.55	4.74	4.94	5.14	5.33	5.72	6.12
2.10	4.00	4.39	4.59	4.78	4.98	5.18	5.37	5.76	6.16	4.10	4.49	4.69	4.88	5.08	5.28	5.47	5.86	6.26
2.20	4.14	4.53	4.73	4.92	5.12	5.31	5.51	5.90	6.29	4.24	4.63	4.83	5.02	5.22	5.41	5.61	6.00	6.39
2.30	4.28	4.67	4.87	5.06	5.26	5.45	5.65	6.04	6.43	4.38	4.77	4.97	5.16	5.36	5.55	5.75	6.14	6.53
2.40	4.42	4.81	5.00	5.20	5.40	5.59	5.79	6.18	6.57	4.52	4.91	5.10	5.30	5.50	5.69	5.89	6.28	6.67
2.50	4.56	4.95	5.14	5.34	5.54	5.73	5.93	6.32	6.71	4.66	5.05	5.24	5.44	5.64	5.83	6.03	6.42	6.81
3.00	5.25	5.64	5.84	6.03	6.23	6.43	6.62	7.01	7.41	5.35	5.74	5.94	6.13	6.33	6.53	6.72	7.11	7.51
4.00	6.64	7.03	7.23	7.42	7.62	7.82	8.01	8.40	8.80	6.74	7.13	7.33	7.52	7.72	7.92	8.11	8.50	8.90
5.00	8.03	8.42	8.62	8.81	9.01	9.21	9.40	9.79	10.19	8.13	8.52	8.72	8.91	9.11	9.31	9.50	9.89	10.29

TABLE 33. COST OF MATERIALS FOR ONE CUBIC YARD OF 1:2½:5 CONCRETE

For basis of table see page 159. If stone is purchased by the ton see page 173. Costs for materials only, delivered on job. For labor see Chap. X, XI and XIII.

Cement per Bbl.	Sand at 75¢ per Cubic Yard									Sand at $1.00 per Cubic Yard								
	Price of Stone per Cubic Yard									Price of Stone per Cubic Yard								
	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80
$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
0.60	1.68	2.05	2.23	2.41	2.60	2.78	2.97	3.33	3.70	1.80	2.17	2.35	2.53	2.72	2.90	3.09	3.45	3.82
0.70	1.81	2.18	2.36	2.54	2.73	2.91	3.10	3.46	3.83	1.93	2.30	2.48	2.66	2.85	3.03	3.22	3.58	3.95
0.80	1.94	2.31	2.49	2.67	2.86	3.04	3.23	3.59	3.96	2.06	2.43	2.61	2.79	2.98	3.16	3.35	3.71	4.08
0.90	2.07	2.44	2.62	2.80	2.99	3.17	3.36	3.72	4.09	2.19	2.56	2.74	2.92	3.11	3.29	3.48	3.84	4.21
1.00	2.20	2.57	2.75	2.93	3.12	3.30	3.48	3.85	4.22	2.32	2.69	2.87	3.05	3.24	3.42	3.60	3.97	4.34
1.10	2.33	2.70	2.88	3.06	3.25	3.43	3.61	3.98	4.35	2.45	2.82	3.00	3.18	3.37	3.55	3.73	4.10	4.47
1.20	2.46	2.83	3.01	3.19	3.38	3.56	3.74	4.11	4.48	2.58	2.95	3.13	3.31	3.50	3.68	3.86	4.23	4.60
1.30	2.59	2.96	3.14	3.32	3.51	3.69	3.87	4.24	4.61	2.71	3.08	3.26	3.44	3.63	3.81	3.99	4.36	4.73
1.40	2.72	3.09	3.27	3.45	3.64	3.82	4.00	4.37	4.74	2.84	3.21	3.39	3.57	3.76	3.94	4.12	4.49	4.86
1.50	2.85	3.22	3.40	3.58	3.77	3.95	4.14	4.50	4.87	2.97	3.34	3.52	3.70	3.89	4.07	4.26	4.62	4.99
1.60	2.98	3.35	3.53	3.71	3.90	4.08	4.27	4.63	5.00	3.10	3.47	3.65	3.83	4.02	4.20	4.39	4.75	5.12
1.70	3.11	3.48	3.66	3.84	4.03	4.21	4.40	4.76	5.13	3.23	3.60	3.78	3.96	4.15	4.33	4.52	4.88	5.25
1.80	3.24	3.61	3.79	3.97	4.16	4.34	4.53	4.89	5.26	3.36	3.73	3.91	4.09	4.28	4.46	4.65	5.01	5.38
1.90	3.37	3.74	3.92	4.10	4.29	4.47	4.66	5.02	5.39	3.49	3.86	4.04	4.22	4.41	4.59	4.78	5.14	5.51
2.00	3.50	3.87	4.05	4.23	4.42	4.60	4.79	5.15	5.52	3.62	3.99	4.17	4.35	4.54	4.72	4.90	5.27	5.64
2.10	3.63	4.00	4.18	4.36	4.55	4.73	4.92	5.28	5.65	3.75	4.12	4.30	4.48	4.67	4.85	5.04	5.40	5.77
2.20	3.76	4.13	4.31	4.49	4.68	4.86	5.05	5.41	5.78	3.88	4.25	4.43	4.61	4.80	4.98	5.17	5.53	5.90
2.30	3.89	4.26	4.44	4.62	4.81	4.99	5.18	5.54	5.91	4.01	4.38	4.56	4.74	4.93	5.11	5.30	5.66	6.03
2.40	4.02	4.39	4.57	4.75	4.94	5.12	5.30	5.67	6.04	4.14	4.51	4.69	4.87	5.06	5.24	5.42	5.79	6.16
2.50	4.15	4.52	4.70	4.88	5.07	5.25	5.43	5.80	6.17	4.27	4.64	4.82	5.00	5.19	5.37	5.55	5.92	6.29
3.00	4.80	5.17	5.35	5.53	5.72	5.90	6.08	6.45	6.82	4.92	5.29	5.47	5.65	5.84	6.02	6.20	6.57	6.94
4.00	6.10	6.47	6.65	6.83	7.02	7.20	7.38	7.75	8.12	6.22	6.59	6.77	6.95	7.14	7.32	7.50	7.87	8.24
5.00	7.40	7.77	7.95	8.13	8.32	8.50	8.68	9.05	9.42	7.52	7.89	8.07	8.25	8.44	8.62	8.80	9.17	9.54

Cement per Bbl.	Sand at $1.25 per Cubic Yard									Sand at $1.50 per Cubic Yard								
	Price of Stone per Cubic Yard									Price of Stone per Cubic Yard								
	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80
$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
0.90	2.31	2.68	2.86	3.04	3.23	3.41	3.60	3.96	4.33	2.42	2.79	2.97	3.15	3.34	3.52	3.71	4.07	4.44
1.00	2.44	2.81	2.99	3.17	3.36	3.54	3.72	4.09	4.46	2.55	2.92	3.10	3.28	3.47	3.65	3.83	4.20	4.57
1.10	2.57	2.94	3.12	3.30	3.49	3.67	3.85	4.22	4.59	2.68	3.05	3.23	3.41	3.60	3.78	3.96	4.33	4.70
1.20	2.70	3.07	3.25	3.43	3.62	3.80	3.98	4.35	4.72	2.81	3.18	3.36	3.54	3.73	3.91	4.09	4.46	4.83
1.30	2.83	3.20	3.38	3.56	3.75	3.93	4.11	4.48	4.85	2.94	3.31	3.49	3.67	3.86	4.04	4.22	4.59	4.96
1.40	2.96	3.33	3.51	3.69	3.88	4.06	4.24	4.61	4.98	3.07	3.44	3.62	3.80	3.99	4.17	4.35	4.72	5.09
1.50	3.09	3.46	3.64	3.82	4.01	4.19	4.38	4.74	5.11	3.20	3.57	3.75	3.93	4.12	4.30	4.49	4.85	5.22
1.60	3.22	3.59	3.77	3.95	4.14	4.32	4.51	4.87	5.24	3.33	3.70	3.88	4.06	4.25	4.43	4.62	4.98	5.35
1.70	3.35	3.72	3.90	4.08	4.27	4.45	4.64	5.00	5.37	3.46	3.83	4.01	4.19	4.38	4.56	4.75	5.11	5.48
1.80	3.48	3.85	4.03	4.21	4.40	4.58	4.77	5.13	5.50	3.59	3.96	4.14	4.32	4.51	4.69	4.88	5.24	5.61
1.90	3.61	3.98	4.16	4.34	4.53	4.71	4.90	5.26	5.63	3.72	4.09	4.27	4.45	4.64	4.82	5.01	5.37	5.74
2.00	3.74	4.11	4.29	4.47	4.66	4.84	5.02	5.39	5.76	3.85	4.22	4.40	4.58	4.77	4.95	5.13	5.50	5.87
2.10	3.87	4.24	4.42	4.60	4.79	4.97	5.16	5.52	5.89	3.98	4.35	4.53	4.71	4.90	5.08	5.27	5.63	6.00
2.20	4.00	4.37	4.55	4.73	4.92	5.10	5.29	5.65	6.02	4.11	4.48	4.66	4.84	5.03	5.21	5.40	5.76	6.13
2.30	4.13	4.50	4.68	4.86	5.05	5.23	5.42	5.78	6.15	4.24	4.61	4.79	4.97	5.16	5.34	5.53	5.89	6.26
2.40	4.26	4.63	4.81	4.99	5.18	5.36	5.54	5.91	6.28	4.37	4.74	4.92	5.10	5.29	5.47	5.65	6.02	6.39
2.50	4.39	4.76	4.94	5.12	5.31	5.49	5.67	6.04	6.41	4.50	4.87	5.05	5.23	5.42	5.60	5.78	6.15	6.56
3.00	5.04	5.41	5.59	5.77	5.96	6.14	6.32	6.69	7.60	5.15	5.52	5.70	5.88	6.07	6.25	6.43	6.80	7.17
4.00	6.34	6.71	6.89	7.07	7.26	7.44	7.62	7.99	8.36	6.45	6.82	7.00	7.18	7.37	7.55	7.73	8.10	8.47
5.00	7.64	8.01	8.19	8.37	8.56	8.74	8.92	9.29	9.66	7.75	8.12	8.30	8.48	8.67	8.85	9.03	9.40	9.77

TABLE 34. COST OF MATERIALS FOR ONE CUBIC YARD OF 1:2½:6 CONCRETE

For basis of table see page 159. If stone is purchased by the ton, see page 173. Costs for materials only, delivered on job. For labor see Chap. X, XI and XIII.

Cement per Bbl.	Sand at 75¢ per Cubic Yard — Price of Stone per Cubic Yard								
	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80
$	$	$	$	$	$	$	$	$	$
0.60	1.60	2.00	2.20	2.40	2.59	2.79	2.99	3.39	3.78
0.70	1.72	2.12	2.31	2.51	2.71	2.91	3.11	3.50	3.90
0.80	1.84	2.23	2.43	2.63	2.83	3.03	3.22	3.62	4.02
0.90	1.96	2.35	2.55	2.75	2.94	3.14	3.34	3.74	4.13
1.00	2.07	2.47	2.67	2.86	3.06	3.26	3.46	3.85	4.25
1.10	2.19	2.58	2.78	2.98	3.18	3.38	3.58	3.97	4.37
1.20	2.31	2.70	2.90	3.10	3.30	3.49	3.69	4.09	4.48
1.30	2.42	2.82	3.02	3.21	3.41	3.61	3.81	4.21	4.60
1.40	2.54	2.94	3.13	3.33	3.53	3.73	3.93	4.32	4.72
1.50	2.66	3.05	3.25	3.45	3.65	3.84	4.04	4.44	4.84
1.60	2.77	3.17	3.37	3.57	3.76	3.96	4.16	4.56	4.95
1.70	2.89	3.29	3.48	3.68	3.88	4.08	4.28	4.67	5.07
1.80	3.00	3.40	3.60	3.80	4.00	4.20	4.39	4.79	5.19
1.90	3.12	3.52	3.72	3.92	4.12	4.31	4.51	4.91	5.30
2.00	3.24	3.64	3.84	4.03	4.23	4.43	4.63	5.02	5.42
2.10	3.36	3.76	3.95	4.15	4.35	4.55	4.74	5.14	5.54
2.20	3.48	3.87	4.07	4.27	4.47	4.66	4.86	5.26	5.65
2.30	3.59	3.99	4.19	4.38	4.58	4.78	4.98	5.38	5.77
2.40	3.71	4.11	4.30	4.50	4.70	4.90	5.10	5.49	5.89
2.50	3.83	4.22	4.42	4.62	4.82	5.01	5.21	5.61	6.00
3.00	4.41	4.81	5.01	5.20	5.40	5.60	5.80	6.19	6.59
4.00	5.58	5.98	6.18	6.37	6.57	6.77	6.97	7.36	7.76
5.00	6.75	7.15	7.35	7.54	7.74	7.94	8.14	8.53	8.93

Cement per Bbl.	Sand at $1.00 per Cubic Yard — Price of Stone per Cubic Yard								
	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80
$	$	$	$	$	$	$	$	$	$
0.60	1.70	2.10	2.30	2.50	2.69	2.89	3.09	3.49	3.88
0.70	1.82	2.22	2.41	2.61	2.81	3.01	3.21	3.60	4.00
0.80	1.94	2.33	2.53	2.73	2.93	3.13	3.32	3.72	4.12
0.90	2.06	2.45	2.65	2.85	3.04	3.24	3.44	3.84	4.23
1.00	2.17	2.57	2.77	2.96	3.16	3.36	3.56	3.95	4.35
1.10	2.29	2.68	2.88	3.08	3.28	3.48	3.68	4.07	4.47
1.20	2.41	2.80	3.00	3.20	3.40	3.59	3.79	4.19	4.58
1.30	2.52	2.92	3.12	3.31	3.51	3.71	3.91	4.31	4.70
1.40	2.64	3.04	3.23	3.43	3.63	3.83	4.03	4.42	4.82
1.50	2.76	3.15	3.35	3.55	3.75	3.94	4.14	4.54	4.94
1.60	2.87	3.27	3.47	3.67	3.86	4.06	4.26	4.66	5.05
1.70	2.99	3.39	3.58	3.78	3.98	4.18	4.38	4.77	5.17
1.80	3.10	3.50	3.70	3.90	4.10	4.30	4.49	4.89	5.29
1.90	3.22	3.62	3.82	4.02	4.22	4.41	4.61	5.01	5.40
2.00	3.34	3.74	3.94	4.13	4.33	4.53	4.73	5.12	5.52
2.10	3.46	3.86	4.05	4.25	4.45	4.65	4.84	5.24	5.64
2.20	3.58	3.97	4.17	4.37	4.57	4.76	4.96	5.36	5.75
2.30	3.69	4.09	4.29	4.48	4.68	4.88	5.08	5.48	5.87
2.40	3.81	4.21	4.40	4.60	4.80	5.00	5.20	5.59	5.99
2.50	3.93	4.32	4.52	4.72	4.92	5.11	5.31	5.71	6.10
3.00	4.51	4.91	5.11	5.30	5.50	5.70	5.90	6.29	6.69
4.00	5.68	6.08	6.28	6.47	6.67	6.87	7.07	7.46	7.86
5.00	6.85	7.25	7.45	7.64	7.84	8.04	8.24	8.63	9.03

Cement per Bbl.	Sand at $1.25 per Cubic Yard — Price of Stone per Cubic Yard								
	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80
$	$	$	$	$	$	$	$	$	$
0.90	2.16	2.55	2.75	2.95	3.14	3.34	3.54	3.94	4.33
1.00	2.27	2.67	2.87	3.06	3.26	3.46	3.66	4.05	4.45
1.10	2.39	2.78	2.98	3.18	3.38	3.58	3.78	4.17	4.57
1.20	2.51	2.90	3.10	3.30	3.50	3.69	3.89	4.29	4.68
1.30	2.62	3.02	3.22	3.41	3.61	3.81	4.01	4.41	4.80
1.40	2.74	3.14	3.33	3.53	3.73	3.93	4.13	4.52	4.92
1.50	2.86	3.25	3.45	3.65	3.85	4.04	4.24	4.64	5.04
1.60	2.97	3.37	3.57	3.77	3.96	4.16	4.36	4.76	5.15
1.70	3.09	3.49	3.68	3.88	4.08	4.28	4.48	4.87	5.27
1.80	3.20	3.60	3.80	4.00	4.20	4.40	4.59	4.99	5.39
1.90	3.32	3.72	3.92	4.12	4.32	4.51	4.71	5.11	5.50
2.00	3.44	3.84	4.04	4.23	4.43	4.63	4.83	5.22	5.62
2.10	3.56	3.96	4.15	4.35	4.55	4.75	4.94	5.34	5.74
2.20	3.68	4.07	4.27	4.47	4.67	4.86	5.06	5.46	5.85
2.30	3.79	4.19	4.39	4.58	4.78	5.98	5.18	5.58	5.97
2.40	3.91	4.31	4.50	4.70	4.90	5.10	5.30	5.69	6.09
2.50	4.03	4.42	4.62	4.82	5.02	5.21	5.41	5.61	6.20
3.00	4.61	5.01	5.21	5.40	5.60	5.80	6.00	6.39	6.79
4.00	5.78	6.18	6.38	6.57	6.77	6.97	7.17	7.56	7.96
5.00	6.95	7.35	7.55	7.74	7.94	8.14	8.34	8.73	9.13

Cement per Bbl.	Sand at $1.50 per Cubic Yard — Price of Stone per Cubic Yard								
	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80
$	$	$	$	$	$	$	$	$	$
0.90	2.27	2.66	2.86	3.06	3.25	3.45	3.65	4.05	4.44
1.00	2.38	2.78	2.98	3.17	3.37	3.57	3.77	4.16	4.56
1.10	2.50	2.89	3.09	3.29	3.49	3.69	3.89	4.28	4.68
1.20	2.62	3.01	3.21	3.41	3.61	3.80	4.00	4.40	4.79
1.30	2.73	3.13	3.33	3.52	3.72	3.92	4.12	4.52	4.91
1.40	2.85	3.25	3.44	3.64	3.84	4.04	4.24	4.63	5.03
1.50	2.97	3.36	3.56	3.76	3.96	4.15	4.35	4.75	5.15
1.60	3.08	3.48	3.68	3.88	4.07	4.27	4.47	4.87	5.26
1.70	3.20	3.60	3.79	3.99	4.19	4.39	4.59	4.98	5.38
1.80	3.31	3.71	3.91	4.11	4.31	4.51	4.70	5.10	5.50
1.90	3.43	3.83	4.03	4.23	4.43	4.62	4.82	5.22	5.61
2.00	3.55	3.95	4.15	4.34	4.54	4.74	4.94	5.33	5.73
2.10	3.67	4.07	4.26	4.46	4.66	4.86	5.05	5.45	5.85
2.20	3.79	4.18	4.38	4.58	4.78	4.97	5.17	5.57	5.96
2.30	3.90	4.30	4.50	4.69	4.89	5.09	5.29	5.69	6.08
2.40	4.02	4.42	4.61	4.81	5.01	5.21	5.41	5.80	6.20
2.50	4.14	4.53	4.73	4.93	5.13	5.32	5.52	5.92	6.31
3.00	4.72	5.12	5.32	5.51	5.71	5.91	6.11	6.50	6.90
4.00	5.89	6.29	6.49	6.68	6.88	7.08	7.28	7.67	8.07
5.00	7.06	7.46	7.66	7.85	8.05	8.25	8.45	8.84	9.24

TABLE 35. COST OF MATERIALS FOR ONE CUBIC YARD OF 1:3:6 CONCRETE

For basis of table see page 159. If stone is purchased by the ton see page 173. Costs for materials only, delivered on job. For labor see Chap. X, XI and XIII.

Cement per Bbl.	Sand at 75¢ per Cubic Yard									Sand at $1.00 per Cubic Yard								
	Price of Stone per Cubic Yard									Price of Stone per Cubic Yard								
	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80
$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
0.60	1.58	1.96	2.15	2.33	2.52	2.71	2.90	3.27	3.65	1.70	2.08	2.27	2.45	2.64	2.83	3.02	3.39	3.77
0.70	1.69	2.07	2.26	2.44	2.63	2.82	3.01	3.38	3.76	1.81	2.19	2.38	2.56	2.75	2.94	3.13	3.50	3.88
0.80	1.80	2.18	2.37	2.56	2.74	2.93	3.12	3.50	3.87	1.92	2.30	2.49	2.68	2.86	3.05	3.24	3.62	3.99
0.90	1.92	2.29	2.48	2.67	2.86	3.04	3.23	3.61	3.98	2.04	2.41	2.60	2.79	2.98	3.16	3.35	3.73	4.10
1.00	2.03	2.40	2.59	2.78	2.97	3.15	3.34	3.72	4.09	2.15	2.52	2.71	2.90	3.09	3.27	3.46	3.84	4.21
1.10	2.14	2.51	2.70	2.89	3.08	3.26	3.44	3.83	4.20	2.26	2.63	2.82	3.01	3.20	3.38	3.56	3.95	4.32
1.20	2.25	2.62	2.81	3.00	3.19	3.38	3.56	3.94	4.32	2.37	2.74	2.93	3.12	3.31	3.50	3.68	4.06	4.44
1.30	2.36	2.74	2.92	3.11	3.30	3.49	3.68	4.05	4.43	2.48	2.86	3.04	3.23	3.42	3.61	3.80	4.17	4.55
1.40	2.47	2.85	3.03	3.22	3.41	3.60	3.79	4.16	4.54	2.59	2.97	3.15	3.34	3.53	3.72	3.91	4.28	4.66
1.50	2.58	2.96	3.14	3.33	3.52	3.71	3.90	4.27	4.65	2.70	3.08	3.26	3.45	3.64	3.83	4.02	4.39	4.77
1.60	2.69	3.07	3.26	3.44	3.63	3.82	4.01	4.38	4.76	2.81	3.19	3.38	3.56	3.75	3.94	4.13	4.50	4.88
1.70	2.80	3.18	3.37	3.56	3.74	3.93	4.12	4.50	4.87	2.92	3.30	3.49	3.68	3.86	4.05	4.24	4.62	4.99
1.80	2.91	3.29	3.48	3.67	3.85	4.04	4.23	4.61	4.98	3.03	3.41	3.60	3.79	3.97	4.16	4.35	4.73	5.10
1.90	3.03	3.40	3.59	3.78	3.96	4.15	4.34	4.72	5.09	3.15	3.52	3.71	3.90	4.08	4.27	4.46	4.84	5.21
2.00	3.14	3.51	3.70	3.89	4.08	4.27	4.45	4.83	5.21	3.26	3.63	3.82	4.01	4.20	4.39	4.57	4.95	5.33
2.10	3.25	3.62	3.81	4.00	4.19	4.38	4.56	4.94	5.32	3.37	3.74	3.93	4.12	4.31	4.50	4.68	5.06	5.44
2.20	3.36	3.73	3.92	4.11	4.30	4.49	4.67	5.05	5.43	3.48	3.85	4.04	4.23	4.42	4.61	4.79	5.17	5.55
2.30	3.47	3.84	4.03	4.22	4.41	4.60	4.78	5.16	5.54	3.59	3.96	4.15	4.34	4.53	4.72	4.90	5.28	5.66
2.40	3.58	3.96	4.14	4.33	4.52	4.71	4.90	5.27	5.65	3.70	4.08	4.26	4.45	4.64	4.83	5.02	5.39	5.77
2.50	3.69	4.07	4.26	4.44	4.63	4.82	5.01	5.38	5.76	3.81	4.19	4.38	4.56	4.75	4.94	5.13	5.50	5.88
3.00	4.25	4.62	4.81	5.00	5.19	5.37	5.56	5.94	6.31	4.37	4.74	4.93	5.12	5.31	5.49	5.68	6.06	6.43
4.00	5.36	5.73	5.92	6.11	6.30	6.48	6.67	7.05	7.42	5.48	5.85	6.04	6.23	6.42	6.60	6.79	7.17	7.54
5.00	6.47	6.84	7.03	7.22	7.41	7.59	7.78	8.16	8.53	6.59	6.96	7.15	7.34	7.53	7.71	7.90	8.28	8.65

Cement per Bbl.	Sand at $1.25 per Cubic Yard									Sand at $1.50 per Cubic Yard								
	Price of Stone per Cubic Yard									Price of Stone per Cubic Yard								
	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80
$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
0.90	2.16	2.53	2.72	2.91	3.10	3.28	3.47	3.85	4.22	2.28	2.65	2.84	3.03	3.22	3.40	3.59	3.97	4.34
1.00	2.27	2.64	2.83	3.02	3.21	3.39	3.58	3.96	4.33	2.39	2.76	2.95	3.14	3.33	3.51	3.70	4.08	4.45
1.10	2.38	2.75	2.94	3.13	3.32	3.50	3.68	4.07	4.44	2.50	2.87	3.06	3.25	3.44	3.62	3.80	4.19	4.56
1.20	2.49	2.86	3.05	3.24	3.43	3.62	3.80	4.18	4.56	2.61	2.98	3.17	3.36	2.55	3.74	3.92	4.30	4.68
1.30	2.60	2.98	3.16	3.35	3.54	3.73	3.92	4.29	4.67	2.72	3.10	3.28	3.47	3.66	3.85	4.04	4.41	4.79
1.40	2.71	3.09	3.27	3.46	3.65	3.84	4.03	4.40	4.78	2.83	3.21	3.39	3.58	3.77	3.96	4.15	4.52	4.90
1.50	2.82	3.20	3.38	3.57	3.76	3.95	4.14	4.51	4.89	2.94	3.32	3.50	3.69	3.88	4.07	4.26	4.63	5.01
1.60	2.93	3.31	3.50	3.68	3.87	4.06	4.25	4.62	5.00	3.05	3.43	3.62	3.80	3.99	4.18	4.37	4.74	5.12
1.70	3.04	3.42	3.61	3.80	3.98	4.17	4.36	4.74	5.11	3.16	3.54	3.73	3.92	4.10	4.29	4.48	4.86	5.23
1.80	3.15	3.53	3.72	3.91	4.09	4.28	4.47	4.85	5.22	3.27	3.65	3.84	4.03	4.21	4.40	4.59	4.97	5.34
1.90	3.27	3.64	3.83	4.02	4.20	4.39	4.58	4.96	5.33	3.39	3.76	3.95	4.14	4.32	4.51	4.70	5.08	5.45
2.00	3.38	3.75	3.94	4.13	4.32	4.51	4.69	5.07	5.45	3.50	3.87	4.06	4.25	4.44	4.63	4.81	5.19	5.57
2.10	3.49	3.86	4.05	4.24	4.43	4.62	4.86	5.18	5.56	3.61	3.98	4.17	4.36	4.55	4.74	4.92	5.30	5.68
2.20	3.60	3.97	4.16	4.35	4.54	4.73	4.91	5.29	5.67	3.72	4.09	4.28	4.47	4.66	4.85	5.03	5.41	5.79
2.30	3.71	4.08	4.27	4.46	4.65	4.84	5.02	5.40	5.78	3.83	4.20	4.39	4.58	4.77	4.96	5.14	5.52	5.90
2.40	3.82	4.20	4.38	4.57	4.76	4.95	5.14	5.51	5.89	3.94	4.32	4.50	4.69	4.88	5.07	5.26	5.63	6.01
2.50	3.93	4.31	4.50	4.68	4.87	5.06	5.25	5.62	6.00	4.05	4.43	4.62	4.80	4.99	5.18	5.37	5.74	6.12
3.00	4.49	4.86	5.05	5.24	5.43	5.61	5.80	6.18	6.55	4.61	4.98	5.17	5.36	5.55	5.73	5.92	6.30	6.67
4.00	5.60	5.97	6.16	6.35	6.54	6.72	6.91	7.29	7.66	5.72	6.09	6.28	6.47	6.66	6.84	7.03	7.41	7.78
5.00	6.71	7.08	7.27	7.46	7.65	7.83	8.02	8.40	8.77	6.83	7.20	7.39	7.58	7.77	7.95	8.14	8.52	8.89

TABLE 36. COST OF MATERIALS FOR ONE CUBIC YARD OF 1:3:7 CONCRETE

For basis of table see page 159. If stone is purchased by the ton see page 173. Costs for materials only, delivered on job. For labor see Chap. X, XI and XIII.

Cement per Bbl.	Sand at 75¢ per Cubic Yard — Price of Stone per Cubic Yard								
	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80
$	$	$	$	$	$	$	$	$	$
0.60	1.51	1.92	2.12	2.31	2.51	2.71	2.91	3.30	3.70
0.70	1.62	2.02	2.22	2.42	2.61	2.81	3.01	3.40	3.80
0.80	1.72	2.12	2.32	2.52	2.71	2.91	3.11	3.51	3.90
0.90	1.82	2.22	2.42	2.62	2.81	3.01	3.21	3.61	4.00
1.00	1.93	2.32	2.52	2.72	2.92	3.11	3.31	3.71	4.10
1.10	2.03	2.42	2.62	2.82	3.02	3.21	3.41	3.81	4.20
1.20	2.13	2.52	2.72	2.92	3.12	3.32	3.51	3.91	4.31
1.30	2.23	2.62	2.82	3.02	3.22	3.42	3.61	4.01	4.41
1.40	2.33	2.73	2.92	3.12	3.32	3.52	3.72	4.11	4.51
1.50	2.43	2.83	3.02	3.22	3.42	3.62	3.82	4.21	4.61
1.60	2.53	2.93	3.13	3.32	3.52	3.72	3.92	4.31	4.71
1.70	2.63	3.03	3.23	3.42	3.62	3.82	4.02	4.41	4.81
1.80	2.73	3.13	3.33	3.53	3.72	3.92	4.12	4.52	4.91
1.90	2.83	3.23	3.43	3.63	3.82	4.02	4.22	4.62	5.01
2.00	2.94	3.33	3.53	3.73	3.93	4.12	4.32	4.72	5.11
2.10	3.04	3.43	3.63	3.83	4.03	4.22	4.42	4.82	5.21
2.20	3.14	3.53	3.73	3.93	4.13	4.33	4.52	4.92	5.32
2.30	3.24	3.63	3.83	4.03	4.23	4.43	4.62	5.02	5.42
2.40	3.34	3.74	3.93	4.13	4.33	4.53	4.73	5.12	5.52
2.50	3.44	3.84	4.04	4.23	4.43	4.63	4.83	5.22	5.62
3.00	3.95	4.34	4.54	4.74	4.94	5.13	5.33	5.73	6.12
4.00	4.96	5.35	5.55	5.75	5.95	6.15	6.34	6.74	7.13
5.00	5.98	6.36	6.56	6.76	6.96	7.15	7.35	7.75	8.14

Cement per Bbl.	Sand at $1.00 per Cubic Yard — Price of Stone per Cubic Yard								
	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80
$	$	$	$	$	$	$	$	$	$
0.60	1.62	2.03	2.23	2.42	2.62	2.82	3.02	3.41	3.81
0.70	1.73	2.13	2.33	2.53	2.72	2.92	3.12	3.51	3.91
0.80	1.83	2.23	2.43	2.63	2.82	3.02	3.22	3.62	4.01
0.90	1.93	2.33	2.53	2.73	2.92	3.12	3.32	3.72	4.11
1.00	2.04	2.43	2.63	2.83	3.03	3.22	3.42	3.82	4.21
1.10	2.14	2.53	2.73	2.93	3.13	3.32	3.52	3.92	4.31
1.20	2.24	2.63	2.83	3.03	3.23	3.43	3.62	4.02	4.42
1.30	2.34	2.73	2.93	3.13	3.33	3.53	3.72	4.12	4.52
1.40	2.44	2.84	3.03	3.23	3.43	3.63	3.83	4.22	4.62
1.50	2.54	2.94	3.13	3.33	3.53	3.73	3.93	4.32	4.72
1.60	2.64	3.04	3.24	3.43	3.63	3.83	4.03	4.42	4.82
1.70	2.74	3.14	3.34	3.53	3.73	3.93	4.13	4.52	4.92
1.80	2.84	3.24	3.44	3.64	3.83	4.03	4.23	4.63	5.02
1.90	2.94	3.34	3.54	3.74	3.93	4.13	4.33	4.73	5.12
2.00	3.05	3.44	3.64	3.84	4.04	4.23	4.43	4.83	5.22
2.10	3.15	3.54	3.74	3.94	4.14	4.33	4.53	4.93	5.32
2.20	3.25	3.64	3.84	4.04	4.24	4.44	4.63	5.03	5.43
2.30	3.35	3.74	3.94	4.14	4.34	4.54	4.73	5.13	5.53
2.40	3.45	3.85	4.04	4.24	4.44	4.64	4.84	5.23	5.63
2.50	3.55	3.95	4.15	4.34	4.54	4.74	4.94	5.33	5.73
3.00	4.06	4.45	4.65	4.85	5.05	5.24	5.44	5.84	6.23
4.00	5.07	5.46	5.66	5.86	6.06	6.25	6.45	6.85	7.24
5.00	6.09	6.47	6.67	6.87	7.07	7.26	7.46	7.86	8.25

Cement per Bbl.	Sand at $1.25 per Cubic Yard — Price of Stone per Cubic Yard								
	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80
$	$	$	$	$	$	$	$	$	$
0.90	2.04	2.44	2.64	2.84	3.03	3.23	3.43	3.83	4.22
1.00	2.15	2.54	2.74	2.94	3.14	3.33	3.53	3.93	4.32
1.10	2.25	2.64	2.84	3.04	3.24	3.43	3.63	4.03	4.42
1.20	2.35	2.74	2.94	3.14	3.34	3.54	3.73	4.13	4.53
1.30	2.45	2.84	3.04	3.24	3.44	3.64	3.83	4.23	4.63
1.40	2.55	2.95	3.14	3.34	3.54	3.74	3.94	4.33	4.73
1.50	2.65	3.05	3.24	3.44	3.64	3.84	4.04	4.43	4.83
1.60	2.75	3.15	3.35	3.54	3.74	3.94	4.14	4.53	4.93
1.70	2.85	3.25	3.45	3.64	3.84	4.04	4.24	4.63	5.03
1.80	2.95	3.35	3.55	3.75	3.94	4.14	4.34	4.74	5.13
1.90	3.05	3.45	3.65	3.85	4.04	4.24	4.44	4.84	5.23
2.00	3.16	3.55	3.75	3.95	4.15	4.34	4.54	4.94	5.33
2.10	3.26	3.65	3.85	4.05	4.25	4.44	4.64	5.04	5.43
2.20	3.36	3.75	3.95	4.15	4.35	4.55	4.74	5.14	5.54
2.30	3.46	3.85	4.05	4.25	4.45	4.65	4.84	5.24	5.64
2.40	3.56	3.96	4.15	4.35	4.55	4.75	4.95	5.34	5.74
2.50	3.66	4.06	4.26	4.45	4.65	4.85	5.05	5.44	5.84
3.00	4.17	4.56	4.76	4.96	5.16	5.35	5.55	5.95	6.34
4.00	5.18	5.57	5.77	5.97	6.17	6.36	6.56	6.96	7.35
5.00	6.20	6.58	6.78	6.98	7.18	7.37	7.57	7.97	8.36

Cement per Bbl.	Sand at $1.50 per Cubic Yard — Price of Stone per Cubic Yard								
	$0.60	$1.00	$1.20	$1.40	$1.60	$1.80	$2.00	$2.40	$2.80
$	$	$	$	$	$	$	$	$	$
0.90	2.15	2.55	2.75	2.95	3.14	3.34	3.54	3.94	4.33
1.00	2.26	2.65	2.85	3.05	3.25	3.44	3.64	4.04	4.43
1.10	2.36	2.75	2.95	3.15	3.35	3.54	3.74	4.14	4.53
1.20	2.46	2.85	3.05	3.25	3.45	3.65	3.84	4.24	4.64
1.30	2.56	2.95	3.15	3.35	3.55	3.75	3.94	4.34	4.74
1.40	2.66	3.06	3.25	3.45	3.65	3.85	4.05	4.44	4.84
1.50	2.76	3.16	3.35	3.55	3.75	3.95	4.15	4.54	4.94
1.60	2.86	3.26	3.46	3.65	3.85	4.05	4.25	4.64	5.04
1.70	2.96	3.36	3.56	3.75	3.95	4.15	4.35	4.74	5.14
1.80	3.06	3.46	3.66	3.86	4.05	4.25	4.45	4.85	5.24
1.90	3.16	3.56	3.76	3.96	4.15	4.35	4.55	4.95	5.34
2.00	3.27	3.66	3.86	4.06	4.26	4.45	4.65	5.05	5.44
2.10	3.37	3.76	3.96	4.16	4.36	4.55	4.75	5.15	5.54
2.20	3.47	3.86	4.06	4.26	4.46	4.66	4.85	5.25	5.65
2.30	3.57	3.96	4.16	4.36	4.56	4.76	4.95	5.35	5.75
2.40	3.67	4.07	4.26	4.46	4.66	4.86	5.06	5.45	5.85
2.50	3.77	4.17	4.37	4.56	4.76	4.96	5.16	5.55	5.95
3.00	4.28	4.67	4.87	5.07	5.27	5.46	5.66	6.06	6.45
4.00	5.29	5.68	5.88	6.08	6.28	6.47	6.67	7.07	7.46
5.00	6.31	6.69	6.89	7.09	7.29	7.48	7.68	8.08	8.47

TABLE 37. COST OF STONE BY WEIGHT VERSUS MEASURE

Cost per cu. yd. = sp. gr. stone × 0.842 (1 − % voids) × cost per ton. (See p. 160.)

Cost per Ton of 2000 lbs.	Equivalent Average Cost per Cubic Yard*									
	Trap		Granite and Slate		Limestone and Conglomerate		Sandstone		Gravel	
$	50% voids $	40% voids $	50% voids $	40% voids $	50% voids $	40% voids $	50% voids $	40% voids $	40% voids $	30% voids $
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
0.90	1.09	1.31	1.02	1.23	0.98	1.18	0.91	1.09	1.20	1.40
1.00	1.22	1.46	1.13	1.36	1.09	1.31	1.01	1.22	1.34	1.56
1.10	1.34	1.60	1.25	1.50	1.20	1.44	1.11	1.34	1.47	1.72
1.20	1.46	1.75	1.36	1.64	1.31	1.58	1.21	1.46	1.60	1.87
1.30	1.58	1.90	1.47	1.77	1.42	1.71	1.32	1.58	1.74	2.03
1.40	1.70	2.04	1.59	1.91	1.53	1.84	1.42	1.70	1.87	2.18
1.50	1.82	2.19	1.70	2.04	1.64	1.97	1.52	1.82	2.01	2.34
1.60	1.95	2.33	1.18	2.18	1.75	2.10	1.62	1.95	2.14	2.49
1.70	2.07	2.48	1.93	2.31	1.86	2.23	1.72	2.07	2.27	2.65
1.80	2.19	2.63	2.04	2.45	1.97	2.36	1.82	2.19	2.41	2.81
1.90	2.30	2.77	2.16	2.59	2.08	2.49	1.92	2.31	2.54	2.96
2.00	2.43	2.92	2.27	2.72	2.19	2.62	2.02	2.43	2.67	3.12
2.10	2.55	3.06	2.38	2.86	2.30	2.75	2.12	2.55	2.81	3.27
2.20	2.67	3.21	2.50	3.00	2.40	2.89	2.22	2.67	2.94	3.43
2.30	2.80	3.35	2.61	3.13	2.52	3.02	2.33	2.79	3.08	3.58
2.40	2.92	3.50	2.73	3.27	2.63	3.15	2.43	2.92	3.21	3.74
2.50	3.04	3.65	2.84	3.40	2.74	3.28	2.53	3.04	3.34	3.90
2.60	3.16	3.79	2.95	3.54	2.85	3.41	2.63	3.16	3.48	4.05
2.70	3.28	3.94	3.06	3.68	2.95	3.54	2.73	3.28	3.61	4.21
2.80	3.40	4.08	3.18	3.81	3.06	3.68	2.83	3.40	3.74	4.36
2.90	3.53	4.23	3.29	3.95	3.17	3.80	2.93	3.52	3.88	4.52
3.00	3.65	4.38	3.40	4.08	3.28	3.94	3.04	3.64	4.01	4.68

*Use columns of higher % of voids if dust or sand is thoroughly screened out and measurement is loose.

Use values half way between those given if screened stone is shaken down in wagons or carts and for average values where conditions are indefinite.

Use columns of lower % of voids if stone or gravel contains dust or sand and is measured loose.

If cost is quoted per long ton of 2240 pounds the costs per cubic yard in this table should be decreased 10%.

Note: In calculating this table the specific gravities and weights of the different rocks are estimated to average as follows:

Rock	Specific Gravity	Weight per Cubic Foot of Solid Rock
Trap	2.9	180
Granite and slate	2.7	165
Limestone	2.6	160
Sandstone	2.4	150
Sand or gravel	2.65	165

CHAPTER IX

EXCAVATING AND CRUSHING STONE FOR CONCRETE

The drilling and blasting of rock and the crushing of the excavated stone is taken up from the standpoint of estimating the cost of crushed stone for concrete. The conditions considered apply therefore to those most commonly met with in concrete construction.

The tables at the end of the chapter sub-divide the costs of both drilling and crushing into unit operations, but these are taken up in less detail and with less elaborate provision for variables than the regular concrete operations considered in subsequent chapters, because stone crushing is by no means common to all concrete work. However, for ordinary estimating, the variables incident to local conditions may be allowed for by looking up the references to the text as noted in the tables opposite the various items.

Such reliable records of piece-work operations have been obtained (see page 178) that columns of piece-work costs for different kinds of rock are given.

For a permanent plant, it is economical to install large crushers and more expensive machinery for handling the materials, so as to reduce the costs below those given in the tables. For drilling the rock, well drills, boring a hole 5 or 6 inches in diameter, are sometimes used for the first blasts. The rock then is broken up by smaller drills only to a size to be handled with derricks, and these pieces dumped into a large crusher which breaks them to a size which will enter smaller crushers. The advantages of well drills even in large plants are somewhat uncertain, depending upon the depth of hole that can be drilled and relative time of setting the drill under the local conditions. Some plants have used well drills and, after trial, have gone back to the ordinary type.*

From a large permanent plant, crushed trap rock frequently can be purchased at a cheaper price per cubic yard or per ton than is given in the tables of costs, and concreting that is carried on in the vicinity of established crushing plants can be done more cheaply by

See description of plant at Gary, Ill., in *Engineering News*, October 21, 1909, p. 421.

purchasing the stone ready crushed than by setting up a crusher at a ledge and preparing the stone on a small scale. For such large plants, however, many of the notes in this chapter will apply, and the costs may be adapted to them, or at least used as a basis of estimating, by substituting the increased output and at the same time the increased cost of plant in place of the values assumed in the table.

The cost of rock excavation is more variable than that of most items of construction. In drilling, for example, the quantity of output is influenced by the character of the rock, not merely by its hardness but by its seaminess and its action under the drill, a soft rock being sometimes more difficult to drill than a hard rock because of the accumulation of soft dust in the bottom of the hole; and even with the same rock the height of the face, the manner of placing the holes, the size and type of drill, the strength of the explosives, and many other details, influence the cost. Economical production depends therefore, not only upon proper handling of the men and tools, but to a very great extent upon the skill of the superintendent in adapting himself to the local conditions.

In the operations of crushing there are fewer variables, although the hardness and structure of the rock and the class of crusher affect the output.

The large part which the machinery plays in the work of excavating and of crushing, and the consequent variation in the wages of the workmen and the irregularity of the output because of different conditions, make it advisable to present a comparatively few values—actual averages, not theoretical—in sufficient detail and with the conditions so clearly stated, that they may be readily changed to apply to various characteristics and conditions.

CLASSIFICATION OF ROCK

Rock for blasting will be classified as follows:

Very Hard Rock, such as hard close grained trap.

Hard Rock, such as ordinary trap, granite, quartzite, gneiss, hard schist, and conglomerate.

Medium Rock, such as limestone of medium hardness and very hard slate.

Soft Rock, such as shale, soft slate, and sandstone.

In some of the tables, soft rock is further distinguished by a supplementary division with *very soft rock*.

This classification is exceedingly arbitrary, but, because of the variation in any one rock, it is fairer to group the different kinds than to endeavor to give each one in detail.

The crushing strength, which is a measure of the hardness, will run over 30 000 pounds per square inch for rock classified as "very hard," while, for the soft rocks, as low a strength as 5000 pounds per square inch may be found.

DRILLING BY MACHINE DRILLS

The estimating of the cost of getting out rock is somewhat simplified in this book because the data may be confined to rock suitable for crushing for concrete. This eliminates full consideration of the softer rocks and avoids the necessity of including special conditions, such as trench excavation, tunneling, and under-water work; and we may consider merely the excavation of a medium hard or of a hard rock with a quarry face of such height as to give good working economy.

OUTPUT OF ROCK DRILLS

The output from any particular ledge in rock excavation is governed by the location of the holes and the total number and depth of holes which can be drilled in a day. Therefore, to determine the output from any ledge, the total number of feet that a drilling machine can drill per day must be known or estimated, and also the number of cubic yards of rock that can be blown out per foot of hole. Most of the other expenses connected with blasting may be assumed to vary proportionally with the daily output.

In shallow cuts, the time lost in changing from one hole to another appreciably reduces the amount of excavation, but in getting out rock for concrete the depth of the cut can be usually fixed to suit the drillers so that this takes care of itself.

The quantities given in paragraphs which follow and the data in the table apply to work with ordinary steam or compressed air drills, using bits ranging from, say, $3\frac{1}{4}$-inch in starting, down to $1\frac{3}{4}$-inch for the deep holes. The outputs and the costs in the tables represent average of actual work.

Variation in output is occasioned not only by the quality of the rock, but also to a surprising degree through the variation in efficiency of the men and the management. The averages given must be taken, therefore, simply as an approximate guide to results that may be expected.

Very Hard Rock. A fine grained trap is one of the hardest rocks to drill. Sometimes, in exceedingly hard trap, an average speed of 2 linear feet of hole per drill per hour is as great as can be maintained. Variations may occur as wide as from 2 linear feet of hole per hour for a hard, seamy trap, up to 4.2 linear feet of hole per hour for a hard trap without seams. For hard rock of this character, it is customary to use a strong explosive, such as a 60% or a 75% dynamite. Railroads frequently prohibit the shipment of dynamite stronger than 60%.

Such extremes show the necessity in works of magnitude for a careful examination of the local conditions by a man experienced in rock work.

The average output in Table 40 for very hard rock is taken as 1.5 cubic yards per hour. As the rock becomes even slightly softer the outputs rapidly increase to those that are given in the following paragraph.

Hard Rock. For hard rock as classified on page 175 to include such rocks as ordinary trap, granite, quartzite, gneiss, hard schist, and conglomerate, an average day's work for an ordinary steam drill is about 4 linear feet of hole per hour. For example, if the depth of the hole is 16 feet, $2\frac{1}{2}$ holes may be assumed as an average work for 10 hours or 2 holes in 8 hours. In estimating, one cubic yard of rock of this class, as measured in the ledge, may be taken as an average output per linear foot of hole drilled. The average output per drill is, therefore, 4 cubic yards of solid rock per hour.

These values are somewhat conservative for granite, since under good conditions an average speed of 5 linear feet per drill per hour can be obtained, while in some cases 6 linear feet per hour is not an excessive run.

In ordinary trap, leaving out of consideration the very hard rock under the preceeding heading, the range is usually between 3 and 5 linear feet per hour with an average of about $3\frac{1}{2}$ feet.

Medium Hard Rock. In medium rock, such as limestone of medium hardness and very hard slate, an average rate of speed for a drill may be assumed as 6 linear feet of hole per hour with $1\frac{1}{4}$ cubic yards output per linear foot. This is equivalent to an output of 7.5 cubic yards of solid ledge per hour.

It is sometimes possible with average workmen to obtain a considerably higher output than $1\frac{1}{4}$ cubic yards per foot of drilling. In limestone of good quality a product of $1\frac{1}{2}$ or even $1\frac{3}{4}$ cubic yards per foot is sometimes attained.

These averages apply to conditions which are apt to occur in connection with concrete construction.

In large permanent plants or plants designed simply for excavation, that is, where the stone is wasted instead of crushed and where holes may range from 20 to 45 feet in depth, we have occasionally records for medium hard rock as high as 20 to 25 feet per hour. Such variations as these indicate the tremendous opportunity for scientific management by which even the smaller plants may approach more nearly to the large ones.

Soft Rock. Rock such as shale and slate makes a concrete of low strength and its use should be avoided unless ample allowance is made in the design for the lower strength. Concrete with sandstone for the coarse aggregate may not be more than one-half or one-third as strong as good limestone concrete, while shale is even poorer aggregate than sandstone.

Sandstone drills easily and records show that an average of 10 linear feet of hole per drill per hour is not excessive. An output of $2\frac{1}{2}$ cubic yards per foot of hole is conservative with such material, thus making a final output of 25 cubic yards per hour. In certain cases a record of 15, and occasionally 25, linear feet per drill per hour has been reached, and by springing the hole and using black powder, it has been found possible to reach an output of 5 to 10 cubic yards per foot of hole. A similar high output may sometimes be attained with shale, but frequently a soft rock like this may be harder to drill than granite because of the rapid filling of the holes with sludge, and this output may fall as low as 3.5 linear feet drilled per hour.

Because of such variation soft rock has an additional classification in the table of *very soft rock.*

TASK-WORK IN DRILLING

In rock excavation, as in all other operations, the introduction of task-work or efficient piece-work must be preceded by scientific organization and by time studies such as are outlined briefly in Chapters IV and V. The work of every man should be laid out in advance and a definite time schedule made up for the performance of each job. This involves a thorough study of the methods of work, the character of the materials, the nature of the machinery, and the time of performance of the individual unit operations.

An excellent example of what may be accomplished in this line is found in the record of yearly operation of The General Crushed Stone Company of Easton, Pennsylvania.*

Two kinds of rock are excavated for crushing at this plant, limestone and quartzite. Records for 1903, 1904, and 1905 show for each of these rocks in each year an amount of drilling of over 100,000 linear feet. In the quartzite rock the average rate of drilling for eight drills, during the years 1904–5, was 7.56 linear feet of hole per drill per hour. During the same years, in the limestone, an average of 10.9 feet of hole per hour was maintained with 7 drills. These figures correspond to a rate in quartzite of 76 feet of hole per drill per 10-hour day, and in the limestone of 109 linear feet per drill per 10-hour day. These outputs have been maintained in recent years.

Records of these quarries from 1904 to 1908 give an average of 2.1 tons of rock per foot of drilling in quartzite and 3.0 tons per foot in limestone.

The cost of labor, including repair work and powder men, averaged, during these years of piece-work, 6.2¢. per ton of quartzite rock and 3.6¢. per ton of the limestone. The fuel charged to drilling the quartzite averaged about 0.6¢. per ton of rock.

The quartzite occurs in thin laminations, making an angle of about 15° with the horizontal, and works somewhat like limestone in general characteristics.

The holes were drilled about 20 feet deep. The limestone is hard and tough with horizontal stratification. The drills were Ingersol-Sargent of Type F. 9, driven by compressed air, the pressure at the drills varying from 60 to 80 pounds.† A drill of $3\frac{1}{4}$-inch diameter was used for the "starter," the diameter decreasing by $\frac{1}{8}$ or $\frac{3}{16}$ to a final diameter of about $1\frac{3}{4}$ inches at the bottom of the hole. The record of each drill was taken from a tag which the drill man fastened to the plug in his hole after measuring the depth. The powder man checked the length and turned the tag into the timekeeper's office. To avoid collusion between the drill man and the powder man, the depth of the holes in such cases can be checked occasionally by a higher official and to positively prevent cheating, a large deduction may be made from the piece-rate for any hole which was measured long.

* General averages of the work at these quarries are given in Engineering-Contracting, May 16, 1906, p. 138, and further details have been obtained from correspondence and conference through the courtesy of Mr. John Rice, Vice President.

† Pressure at receiver 90 to 100 pounds.

The rates paid to drill man and helper were $6\frac{1}{2}$ cents per foot in quartzite and $4\frac{1}{2}$ cents per foot in the limestone, the two men thus together averaging about $5.00 per day. These wages,* coupled with the fact that the Company was willing to pay the given rates permanently so that there was no fear of their being cut down as soon as the men earned good pay, induced the men to make the high record.

Another example of the difference between piece-work and day labor is very well shown by operations in British Columbia.† These mines contain a vein of such variable hardness that it was thought impracticable to measure the linear feet of heading and the work was not sufficiently well organized, to separate the amount of material taken out per gang. The superintendent found that, though the number of feet drilled per day varied greatly, for a whole month it was nearly constant so that a contract was made each month with each gang as to price per foot drilled. Tools are repaired free and all blasting is done in such a way that the drill gangs will not be bothered by smoke.

Before this system went into effect the miners received $3.50 per day and the cost of stoping out ore was $0.86 per ton, while under the new system the miners earn from $4.00 to $4.25 per day and the cost per ton of ore is $0.48. Under the new system the efficiency of the men is nearly doubled, and their wages increased about 20%. The men are contented, there is no danger of strike and a better spirit prevails between the men and the management.

This method of payment, by monthly contract, is not nearly so effective as daily task-work, where allowance is made for variation in quantity of material handled, and the result is therefore all the more remarkable.

EXPLOSIVES

The character of explosives for any quarry must be governed by the hardness and seaminess of the rock and the purpose for which the rock is to be used, that is, whether it is to be broken up fine or left in large pieces. The class to be selected must be determined by practical knowledge or by experiments upon the particular work.

* At the date and locality referred to these were high rates.

† Described before the American Institute of Mining Engineers, in paper by Carl R. Davis entitled "The Operations of the Hole Contract System in the Center Star and War Eagle Mines, Rossland, B. C." See abstract in *Engineering News*, December 4, 1902, p. 483.

General rules suitable for large quarries with a variety of rock are suggested as follows:*

For most classes of rock, where the ledge is solid and free from open seams, a 50% dynamite is economical.

If the seams are close and the rock not too hard, 40% dynamite is most effective. Where the rock is very seamy or disintegrated, granulated dynamite, which is about 25%, is better than the more powerful explosives.

Frequently a 60% dynamite is used to best advantage in a very hard dense trap, and especially in getting out bottom in such material. This general scheme is varied by such characteristics as the pitch of the rock, the distance of the holes back from the face, and whether the rock is bound in on each side of the set of holes.

An approximate idea of the cost of explosives for hard and medium rock may be obtained from the table below.

Cost of Explosives from Records of the General Crushed Stone Company for the Year 1905.†

Materials	Weight of rock per cu. yd.	Cost of dynamite		Cost of fuse, caps, wire, electric exploders	
		per ton of rock	per cu. yd. of ledge	per ton of rock	per cu. yd. of ledge
	tons	$	$	$	$
Hard, dense trap	2.60	$0.060	$0.156	$0.0075	$0.0195
Quartzite	2.27	0.032	0.073	0.0030	0.0068
Limestone	2.27	0.026	0.059	0.0025	0.0056

The given costs include the cost of dynamite used in charging block holes. Trap was drilled and blasted in large pieces and then broken up by dynamite charged in block holes, drilled in many cases by baby drills. The least amount of additional drilling was required by the limestone. The separate cost of dynamite used in charging block holes in the above mentioned record is obtainable only for quartzite, for which it runs from $0.005 to $0.015 per ton or $0.0114 to $0.0340 per cubic yard of solid rock, and these values may be deducted from those in the table to obtain the costs of dynamite for large steam drills alone.

* Based on personal correspondence with Mr. John Rice.

† Personal correspondence.

TABLE OF COST OF ROCK EXCAVATION

Table 39, page 208, as already indicated, is made up from data averaged from a large number of jobs, and based on certain assumptions of wages and unit costs which are definitely stated. The authors realize that it is impossible to fit costs to all conditions, and even if the averages are correct, local circumstances will cause considerable variation from the averages. However, with the cost data presented in detail and sub-divided into units, it is possible with a very little figuring to correct any of the items which disagree with the local conditions.

The drill outputs upon which the costs are based are given in Table 40, page 210.

The tables present (1) means of quickly estimating the cost of excavating rock for crushing where the local characteristics are but little known by the estimator and therefore where average figures must be used and considered simply as approximate; (2) means of exact estimating where many local details, such as probable output of a drill, are known; (3) means of determining the economical layout of the plant; and (4) data for the fixing of piece-rates or tasks.

Tables 39 and 40, pages 208 and 210, are for practical estimates. The units into which the cost is divided in the tables are taken up first and briefly discussed and on pages 203 and 204 a number of examples are given to illustrate the use of the tables.

Cost of Rock in Ledge. The value of the rock in the ledge at the quarry is taken in Table 39 at the rate of $0.05 per cubic yard in place for hard rock, $0.03 for soft rock and $0.02 for very soft rock. Frequently in engineering construction the rock is obtained free of cost by the contractor and this item can be omitted entirely. In any case, the value of the rock is apt to be known, and can be introduced in the table in place of the sum given.

Stripping Soil. The cleaning of the earth from the top of the ledge is another item which is given in the table at a flat rate, the sum of $0.03 per cubic yard of rock being selected as a fair average figure. The cost of stripping per cubic yard of rock varies with the ratio of the depth of the soil to the total depth of rock cut, the distance to which the earth must be hauled, and the character of the earth. When the approximate average depth of the earth and the depth of the rock cut is known, a more definite value for the cost of stripping per cubic yard of solid rock may be obtained.

The cost per cubic yard of earth is reduced to cost in terms of per cubic yard of rock by simple proportions, which may be expressed by the following formula.

Let

d = average depth of rock cut in feet.
h = average height of soil above rock in feet.
c = cost of stripping per cubic yard of solid ledge.
s = cost of stripping per cubic yard of soil.
w = cost of wheeling per 100 feet per cubic yard of soil.
l = distance in hundreds of feet soil is wheeled.

Then

$$c = \frac{h}{d}(s + lw) \qquad (1)$$

Table 41, page 211, gives the average unit cost of stripping soil and wheeling for different conditions. The values are taken from the authors' notes on earthwork and represent averages made up from a large number of jobs. The following example illustrates the use of the table with the formula above.

Example 1: Stripping soil. What is the cost per cubic yard of rock of stripping medium gravel from the top of ledge and wheeling in wheelbarrow a distance of 250 feet, when the depth of the soil is 3 feet and the total depth of rock to be excavated is 35 feet?

Solution: In formula (1) substitute the given values of h, d, and l and take those for s and w from Table 41. For medium gravel loaded from level ground, the cost of loosening, loading, etc., is s = \$0.220. The cost of wheeling this earth in wheelbarrows a distance of 250 feet is $2.5\,w = 2.5 \times \$0.056 = \$0.140$. Then $c = \frac{3}{35}(\$0.220 + \$0.140)$ = \$0.031 per cubic yard of rock. The same result would be obtained for a depth of 6 feet of gravel overlying a ledge to be excavated to a depth of 70 feet.

Explosives. The subject of explosives has been treated already under a separate heading. (See p. 180). The unit values in the table are based upon the records of the General Crushed Stone Company after having been checked by comparison with a number of other actual jobs.

Caps, Fuse, etc. The costs of these are also based on the itemized records of the General Crushed Stone Company. (See p. 181).

Coal. The cost of coal for running the plant, when purchased at the price of \$4.00 per ton delivered on the job, averages \$2.30 per day per drill. This cost per day per drill has been accepted as constant for all kinds of rock. With this assumption, the cost per unit of weight or volume is therefore inversely proportional to the total number of yards excavated per drill per day.

When the price of coal differs from $4.00 per ton, the cost of coal per cubic yard of stone or per ton of course changes proportionally. Correction of the average value thus may be made readily. (See Example 4, p. 204).

Oil and Waste. The cost of these materials is based on average records which were found to be $0.029 per hour per drill. Oil alone is sometimes figured at one quart per drill per day.

Repairs. The cost of actual repairs is a variable item but, when depreciation is taken as a separate item, is comparatively small and may be taken at the average figure given without appreciable error.

Depreciation and Interest. The amount to charge to the excavation for interest and depreciation must be based on the first cost of the plant, its life, and the number of working days it is operated in a year.

The cost of machinery varies from year to year and the freight charges also differ for different localities, but an approximate average value of plant per drill may be taken as follows:

Assume cost of plant per drill	$1000.00	
Assume depreciation at 25% per year		$250.00
Interest on first cost 6%		60.00
Total depreciation and interest per year		$310.00

Assume number of working days in a year 150.

On this basis, charge per day is $\frac{310}{150} = \$2.07$

The depreciation of excavating plants will vary with the character of the rock, which affects the wear and tear on the drills, and will also vary with the different parts of the machinery, some parts requiring replacement every year, while some of the stationary machinery in a fixed plant may last as long as 10 years.

The percentage given, therefore, is an approximation, as is also the cost of the plant itself, and may be changed to suit local conditions. If deemed desirable, the depreciation can be figured independently for different parts of the machinery. It is not strictly correct to figure the interest for the entire period on the first cost with no allowance for depreciation, but the error involved is slight.

Labor Costs. The base cost of labor per drill per day may be taken as follows:

One drill man	$3.00
One drill helper	2.00
½ fireman @ $2.50	1.25
¼ blacksmith @ $3.00	.75
¼ blacksmith helper @ $2.00	.50
¼ foreman @ $4.00	1.00
Total wages per day per drill	$8.50
Add 15% for superintendence, overhead charges and contingencies	1.28
Total cost per drill per day	$9.78

This does not include the expense of the home office or profit.

The cost of labor in Table 39, page 208, is made up in this way. The wages are selected to represent average rates and the arrangement of workmen, average conditions. For any other assumptions, however, either in rates of labor or composition of gangs, the cost may be readily changed and the values in the table adjusted accordingly. The method of procedure in such a case is clearly shown in Example 4, page 204.

If preferred, instead of charging a portion of the foreman's wages to each drill gang, his cost might have been taken as a percentage as in concrete mixing, page 287.

From comparison of the unit cost of excavation by day-work and by task-work or piece-work, it is evident that, because of the greater output per day in task-work or piece-work, all the items are smaller than in day-work, except the costs of rock and explosives, which are independent of the rapidity of the work. It is also evident that, although in piece-work the cost of labor per cubic yard to the owners or contractors is smaller than in day-work, the laborers earn more per day than in day-work. (See p. 180). The advantage of the task-work or piece-work over the day-work to the owner or contractor is (1) the smaller unit cost of labor; (2) the larger output, thus reducing cost of the plant and of the running expenses per cubic yard; and (3) the more rapid progress, an item often of great importance, especially in concrete work.

The piece-work rates of labor in Table 39 are based on actual costs covering a period of several years.

Overhead Charges and Contingencies. In unit costs of each item in Table 39, 15% is included for overhead plant charges and contingencies. To these costs should also be added a percentage for profit and home office expense. In day-work by the city, profit is not likely to be included in an estimate, but, on the other hand, the labor expense almost invariably is much more than in contract work, and the plant charge is apt to be higher because in operation fewer days per year. These more than balance any computed profit, so that for city work by the day, from 10% to 50% should be added to the final figures given.

Division of Table 39. Table 39 is divided in groups for different kinds of rock, each group being sub-divided into two parts, (a) and (b), for convenience in adjusting the table to local conditions. Group (a) consists of items, such as cost of stone, which are constant per unit measure of stone, that is, independent of the output. The items in group (b), such as cost of labor, on the other hand, are constant per day per drill, so the cost per unit of weight and per volume of rock changes proportionally with the output. The unit costs, as well as totals, are given per day per drill, and also per ton, per cubic yard of solid stone, and per cubic yard of stone measured loose. The relation of these different measures to each other are shown in Table 42, page 211. Note the difference in cost of work by day-work and piece-work methods.

TABLE OF RATES OF DRILLING AND OUTPUT IN DIFFERENT ROCK

The character of different rocks, even of the same kind, varies so widely, not only in hardness but in seaminess and in stratification, that any figures for rate of drilling or output are simply of an approximate nature; nevertheless, estimates must be made even where the work is of an indefinite character and it is advisable, therefore, in the opinion of the authors, to present approximate averages even where the variations due to local conditions are large. The engineer or contractor who is inexperienced in this class of work should use caution in applying values to such work without consulting practical men who are familiar with it.

Table 40, page 210, gives rates of drilling per hour based on ordinary conditions in the rocks specified, both for day-work and for work carried on by the piece or by the task. (See p. 178). "Day-work" applies to work done by contract where the men are paid by the hour or the day, or where conditions correspond to this. In work done by a city by day laborers, the output is usually much lower than the average. The average output per hour is based on the quantity of rock assumed to be blown out per foot of hole drilled, as given in columns (14) to (19).

The quantities and outputs are given in terms of per ton of 2000 pounds; per cubic yard of rock measured in the ledge; and per cubic yard of crushed stone. These various units are compared in Table 42, page 211.

The spacing of drill holes calls for mature judgment and experience, and must be governed by the depth of drilling, the toughness of the rock, and the size to which it is desired to break the rock. Block holing and sledging are expensive, so that for a small crusher it is advisable to space the original holes quite close together and use plenty of explosives so as to break up the rock into small pieces. With this in view, columns (7) and (8) are given, suggesting spacing for rock of different quality. With a larger spacing of holes, the quantity of rock per foot of hole will be considerably greater and the output per drill also greater, but because of the extra work required in block holing and sledging, the final cost may not be reduced *to* any great extent.

The table illustrates very clearly the advantages of introducing task-work or piece-work. Many instances may be cited in rock excavation where this has proved very effective. A very good example of work done under the bonus system is shown in the construction of the Los Angeles Aqueduct and described on page 224. In the comparison in the table, the increase in output per drill is nearly 100%. The cost will not be reduced in corresponding proportion because the men at work by the piece or the task must receive higher pay per day and because some of the items do not vary directly with the output. More clerical labor is required also to plan out the tasks, although this is far overbalanced by the results of more systematic methods.

TABLE FOR CONVERTING WEIGHTS TO VOLUMES

Table 42, page 211, gives figures which may be used for changing the weight of rock into terms of per cubic yard measured solid in the ledge or measured crushed with 45% voids. These conversion values are based on the specific gravities, which are approximate averages for the different rock. The range is great enough so that values for rocks of other specific gravities may be interpolated.

STONE CRUSHING

Only average costs are given in Table 43 of Cost of Stone Crushing, page 212. The differences in the character of the rock, the speed with which it can be crushed, the size of the broken stone, and of not less importance, the organization of the gang, will vary the output of the crusher and the cost of the crushed stone to a very large extent. In city work, for example, especially in plants to which laborers have been transferred because unable to work where their failings will be readily noticed by the public, the cost may run double or even three times as great as the corresponding values in the table. On the other hand, with a large plant and first-class organization, especially if task-work is introduced, the costs may be as much as one-third below those given in the tables. In correcting for better organized work, care must be used to select just the right items. For example, if the output of the crusher is larger than scheduled, this may not necessarily reduce the cost of the sledging, loading, or hauling of the stone to the crusher, because a larger gang will be required for the extra product. However, where the output is increased in one part of the gang, the general speed of all the men is apt to be increased so as to slightly reduce the cost in all departments. If task-work is introduced, the entire gang will be encouraged to work at higher speed, provided they are allowed a sufficient increase in earnings.

The crushing tables may be used (1) for working estimates where the exact local conditions are unknown and therefore average values must be used; (2) for exact estimates where the local characteristics are so clearly defined that the items in the tables may be specially selected and, if necessary, corrected so that they will accurately apply to the case at hand; (3) for economical layout of the gang and the plant; and (4) for the fixing of piece-rates or tasks.

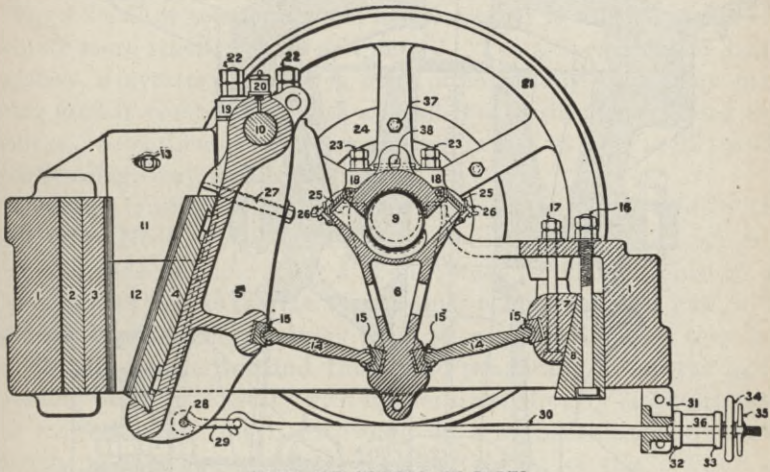
STONE CRUSHING PLANT

The type of crusher plant which it may be economical to select for crushing stone for concrete may range from a portable jaw crusher with engine located on the edge of a bank so that the product falls by gravity into a pile to be used immediately, up to a crusher of large capacity provided with automatic charging arrangements, elevators, screens, and bins.

In the design of the plant, greatest economy will be attained when the sum of the running expenses per cubic yard or per ton of rock and the portion of the first cost, interest, and depreciation which must be charged to every cubic yard or ton of rock, is a minimum.

Stone crushers are of two general types—jaw crushers and gyratory crushers. A typical jaw crusher is shown in cross-section in Fig. 15, and a gyratory crusher in Fig. 16, page 190.

The size of a jaw crusher is designated by the opening into which the stone is introduced, thus a 9 × 15-inch crusher has jaws 15 inches in width with a 9-inch space between the two jaws at the top. A duplex



NAME AND NUMBER OF PARTS

1 Main Frame	11 Upper Half Cheek Plate	21 Balance Wheel	30 Spring Rod
2 Round Back	12 Lower Half Cheek Plate	22 Bolt for Swing Jaw Shaft Cover	31 Spring Bar
3 Fixed Jaw Plate	13 Bolt for Cheek Plate	23 Bolt for Main Bearing	32 Washer
4 Swing Jaw Plate	14 Toggle	24 Pulley	33 Washer
5 Swing Jaw	15 Toggle Bearing	25 Grease Box Cover	34 Hand Wheel
6 Pitman	16 Bolt for Wedge	26 Bolt and Thumb Screw	35 Thumb Nut
7 Toggle Block	17 Bolt for Toggle Block	27 Bolt for Swing Jaw Plate	36 Rubber Spring
8 Wedge	18 Cover for Main Bearing	28 Shackle Pin	37 Bolt for Pulley
9 Eccentric Shaft	19 Cover for Swing Jaw Shaft	29 Spring Rod Shackle	38 Grease Box Cover on Main Bearing
10 Swing Jaw Shaft	20 Grease Cup		

FIG. 15. Jaw Crusher (See p. 189)

crusher has two pairs of jaws operated by the same shaft but working alternately by means of different eccentrics. Single jaw crushers range in size from $1\frac{1}{2}$ by 3 inches to 24 by 36 inches and even larger. The most common sizes for a small temporary plant for furnishing stone for concrete are 10 by 20-inch and 9 by 15-inch. A 9 by 15-inch crusher cannot be depended upon to furnish stone for more than 75 cubic yards of concrete per 10-hour day.

The size of the stone passing through the jaws, one of which is fixed and the other hinged at the top so as to swing back and forth through a very small arc, is regulated by the opening at the bottom of the swing jaw. The motion is imparted by the eccentric shaft, which, in revolving, raises and lowers the "pitman," whose lower end is connected by toggles with the lower end of the movable jaw.

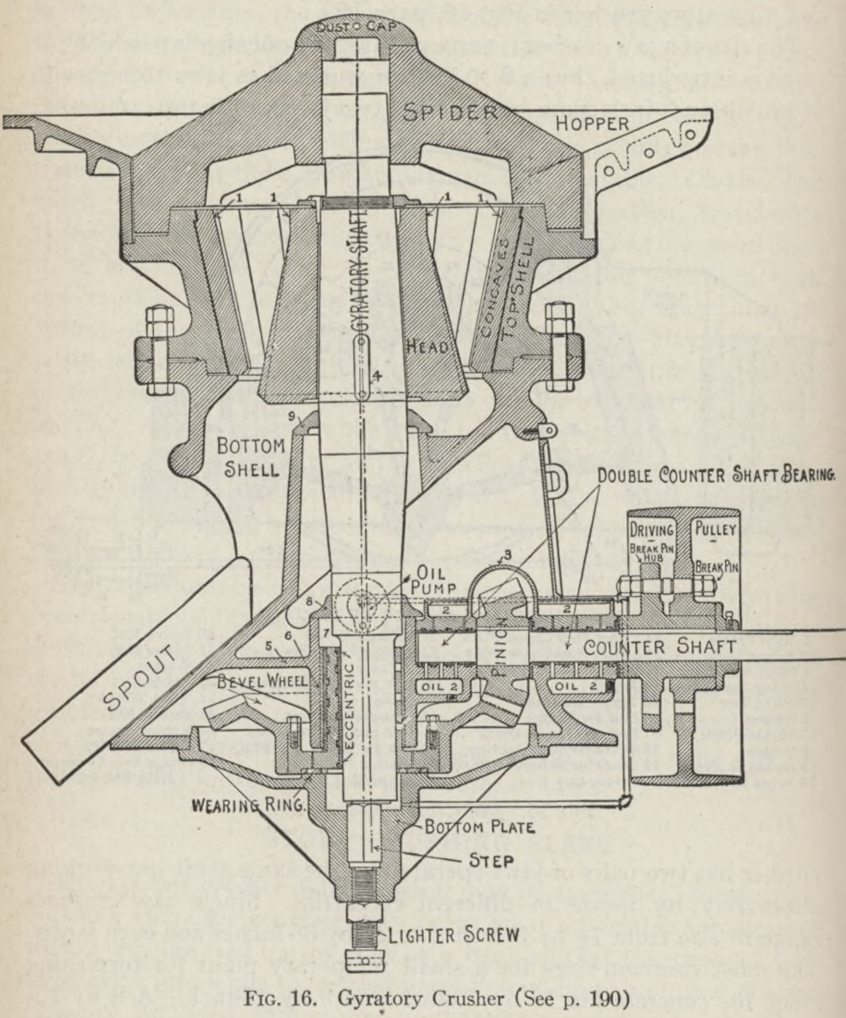


Fig. 16. Gyratory Crusher (See p. 190)

The gyratory crusher consists essentially of a cone with a gyratory motion set within an inverted conical chamber or shell. The size of the crusher is determined by the width of the opening between the top of the cone and the shell, and by the length of opening between spider arms.. Because of the curve, the opening will not take so large stone as its dimensions would indicate. The gyratory motion of the cone shaft is produced by an eccentric keyed to its lower end. As the shaft revolves, the cone is given a rocking motion which continually directs it toward, and then away from, different portions of the shell. The size of the broken stone is regulated by raising or lowering the cone on the shaft.

For a small or temporary job, a jaw crusher is usually preferable because more readily set up and moved. For a fixed plant of large capacity, a gyratory crusher is more often selected, this frequently being used in combination with a small jaw crusher for crushing the tailings. Sometimes a large jaw crusher, in size as large as 42 by 60-inch opening, may feed the gyratory.

Gyratory crushers ordinarily range in size from No. 0, or 4 by 15-inch, up to No. 8, which has an 18 by 68-inch opening. An opening 18 inches wide will take about a 12-inch stone. Still larger crushers of the rotary as well as the jaw type are also made for special jobs, with which it is possible to use very large pieces of rock just as they are handled by the derrick and thus avoid practically all of the hand breaking which is necessary with smaller sizes. In very large quarries, the rock after blasting is excavated by a steam shovel and passed directly to this large crusher; then the output of this crusher is crushed to the size desired in auxiliary jaw or small gyratory crushers. This plan of crushers in series is referred to more in detail on page 199.

Whatever type of crusher is selected, it should be of a capacity somewhat in excess of that actually required for the concrete mixture. In all classes of machinery, it is advisable to make an allowance below the catalogue figures, and this is especially necessary in crushing machinery, because it is apt to require repairs that will necessitate a shutdown and the storage of stone.

The gyratory crusher is ordinarily provided with chilled iron wearing surfaces. With a very hard rock this will not stand, and a head of manganese steel should be substituted. For a very hard rock, also, an extra large shaft of nickel steel should be used in place of the standard shaft. Extra fittings should be kept always on hand in case of breakdown. Even short delays are expensive, since plant costs, and often labor costs, go on just the same even if there is no output. The less time required for repairs or for replacing defective parts, the less will be these costs.

CRUSHER SCREENS AND BINS

Rotating screens for broken stone are usually made in sections, varying in length from 3 to 5 feet, so that they can be bolted together and give as many divisions of size as are required. The cylinders vary in diameter from 24 inches up to 60 inches. The mesh of a rotating screen must be about 25% smaller in diameter than the required size for the stone, since there is more or less wear on the screen that enlarges the holes, and because an allowance is necessary to exclude the oblong pieces whose longest dimension is above the limit. For concrete, unless two or more sizes of stone are mixed, only two sizes of mesh are required, one of these ¼-inch to separate the dust, and the other 1½, 2, or 2½ inch, as the case may be, to throw out the coarse stuff or tailings. In mass concrete, it is usually necessary only to separate the dust, which then may be used as sand.

If the stone must be elevated from the crusher to the stone bins, the latter should be located high enough to avoid hand labor in carrying the stone to the mixer. The crushed stone should fall directly from the bins into the mixer or hopper or else into the vehicle or on to the belt that transports it to the mixer.

Size of Stone for Concrete. The sizes into which stone for concrete should be crushed and screened depends upon the character of the work to be done. In large mass concrete, such as dam construction, pieces may run up to 3-inch diameter or even larger, the maximum size being governed (1) by the capability of the mixer and conveying machinery or vehicles to handle the large stone without separation from the rest of the concrete and (2) by the spacing of the large rubble stones in the concrete. It is poor economy in rubble concrete to use such large stones in the coarse aggregate as to necessitate excessively large joints beween the rubble stones. In reinforced concrete, the maximum size of stone is sometimes specified as ¾-inch or 1-inch while in larger members 1½-inch or even 2-inch stone may be used.

If broken stone screenings are used for sand, the fixing of the allowable percentage of the dust is as important as the specification for maximum size, in order to give proper grading in sizes of particles. If natural sand is available and does not cost, delivered on the job, more than 50¢ to 75¢ per yard, the screenings from the regular crushers may be simply mixed with the sand, so as not to waste it, and considered as a part of the sand in measuring the proportions.

If natural sand is expensive, because of long haul, for example, it is frequently economical to use all crushed stone. The percentage of dust, that is, of material finer than a No. 100 sieve, that will be obtained from a crusher will depend upon the character of the rock and also upon the crusher. For making sand, a portion of the stone that has passed the large crushers is usually run through rolls that give as small a percentage of fine as is possible. In certain kinds of rock, even the rolls give an excess of dust, and it is then possible to screen out some of this by vibrating screens. In certain classes of work, such as heavy dam construction, a large percentage of dust is beneficial because it permits a leaner mixture, the dust acting with the cement to increase the density and make the mass more watertight. To obtain a large percentage of dust, ring rolls may be used. In one case, for example, after thorough tests and the selection of special crushers, Mr. Thompson recommended for dam construction as lean a mixture as one part cement to $4\frac{1}{2}$ parts screenings—of which slightly over 20% passed a No. 100 sieve—to $6\frac{1}{2}$ parts coarser stone above $\frac{1}{4}$-inch size.

OUTPUT OF CRUSHERS

The capacity of any crusher, that is, the quantity of broken stone that it will turn out per hour or per day, is dependent not only upon the size of the crusher, but upon the hardness and texture of the stone and the sizes of the largest particles of stone which pass through it.

The difference in quality of the stone makes the output of any crusher variable, and renders it impossible to present accurate values for the product. To indicate in a general way the relative output of different sizes and types, Table 44, page 214, of catalogue capacities is given.

As already stated, the size of the crusher should be always in excess of that actually required for the concrete as shown by catalogue outputs, not only because machinery catalogues in general are likely to err on the side of too great an output, but also because allowance must be made in practice for unavoidable delays which are bound to occur through breakdowns or other stoppages of the machinery or bad weather, so that continuous feeding at a normal rate of output cannot be counted upon.

For example, the output of a 9 by 15-inch jaw crusher set for 2-inch stone, with a small percentage of tailings, based on actual records obtained by the authors from a number of jobs, averages about 65 cubic yards or, say, 78 tons in 10 hours, with correspondingly smaller output for an 8-hour or a 9-hour day. This estimate allows for unavoidable delays and occasional short shut-downs occurring throughout the day, that is, it may be taken as the average output per day during a week's run. Comparing Table 38, made up in this way, with Table 44, we find the nominal capacities much less than those given in the catalogues. While for soft rock, easily crushed, such a crusher will

TABLE 38. APPROXIMATE AVERAGE OUTPUTS OF STONE CRUSHERS IN HARD ROCK

(See p. 194)

Size of Crusher	Output Per Hour					
	Tons (2000 lb.)		Cubic Yards Solid		Cubic Yards Loose*	
	2½ inch stone	1½ inch stone	2½ inch stone	1½ inch stone	2½ inch stone	1½ inch stone
Jaw 9 × 15-inch....	9.0	6.0	3.8	2.6	7.0	4.6
Jaw 10 × 20-inch....	15.0	10.0	6.3	4.2	11.6	7.7
Gyratory No. 3.....	10.0	6.5	4.2	2.8	7.7	5.0
Gyratory No. 4.....	17.5	12.0	7.4	5.1	13.5	9.3
Gyratory No. 5.....	25.0	17.0	10.6	7.2	19.3	13.1
Gyratory No. 6.....	30.0	20.0	12.7	8.5	23.2	15.4

* Assuming 45% voids.
NOTE:—The output will increase as the rock becomes softer.

undoubtedly come up to the nominal capacity, it is always wise, as in purchasing machinery of all kinds, to make a liberal allowance for contingencies. This is specially necessary in crushing stone for concrete, because, if the supply of stone falls short, the concrete gang must work on short time and the construction be correspondingly delayed.

MECHANICAL ANALYSES OF CRUSHER PRODUCTS

In the diagram, Fig. 17, curves are shown, based in part on tests made by crusher manufacturers and in part on tests of the authors', giving the gradation of sizes of grains of the material passing through crushers set to different sizes.

To reduce the percentage of fines, a crusher is usually set so that 15% of its product is larger than the desired size. The horizontal line at 85% corresponds, therefore, to the desired size of stone. To find from the curve how much 1-inch stone, for example, there is in the product of a crusher set for a 2½-inch output, follow the diagonal line which crosses the 85% line at 2½-inch diameter back to the 1-inch diameter and we find 29%.

TABLE OF CRUSHER OUTPUTS AND COST OF STONE CRUSHING (See p. 212)

Table 43, page 212, is made up from data averaged from a number of jobs and is based on definitely stated assumptions of wages and unit costs. The individual items in the cost table are taken up in detail in the text under separate headings so as to show clearly how to vary the unit costs to satisfy local conditions. It must be noted that Table 43 does not include the cost of the drilling or blasting of the rock,

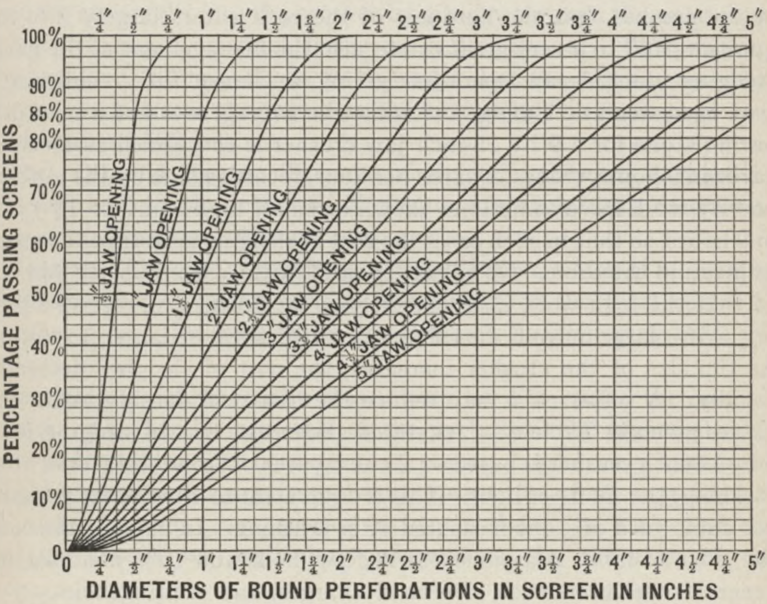


FIG. 17. Percentage of Sizes of Crushed Stone Produced by Ordinary Crushers (See p. 194)

which is presented in Table 39 and described on the preceding pages. It is assumed that the rock in blasting is blown out in comparatively small pieces, which require, however, some breaking with hand sledges or by holes drilled with hand drills and blown with small charges of explosives. The use of the tables for other conditions than those assumed in figuring are illustrated in the examples, pages 204 to 207. It will be noted that the tables give the cost per day of 10 hours for the plant and the gang. This length of day is selected simply for convenience in computation, although a crushing plant is more apt to work 8 or 9 hours per day. The prices are readily altered to correspond to other lengths of day. The columns which follow these give the costs for both 2½-inch and 1½-inch stone in terms of per ton of 2000 pounds and per cubic yard of solid rock, and per cubic yard of loose crushed stone. These three sets of columns are independent of the length of the day.

Sledging. The time required to break the rock small enough to go into the crusher is an extremely variable item. Not only is it dependent upon the size of the blasted stones and the size of the openings in the crusher, but the hardness of the rock enters largely into the question, and to a very great extent also the management of the gang. Sledging stone is an operation giving a chance for "soldiering," that is, systematic loafing, and while the average work of a man preparing stone for a 9 by 15-inch jaw crusher is considered as 18 cubic yards in 9 hours, that is, 2 yards per hour, records made by the authors on city work have sometimes shown as small an output as 1¾ yards in 9 hours, so that in such cases the cost of sledging is 10 times as much as given in the table. On the other hand, with tasks properly laid out so that the men work independently of each other and receive a high reward for large output, the tabular quantities will be largely exceeded. As the size of the crusher increases, the cost of sledging decreases rapidly. A softer rock may reduce the cost considerably below the values given in Table 43. As stated above, the cost of sledging for a 9 by 15-inch crusher is based on 2 cubic yards of stone (measured after crushing) per man per hour. This is equivalent to 30 minutes per man per cubic yard of stone measured after crushing. In figuring the cost, the price of labor is assumed at 20¢ per hour and 15% is added for general superintendence, overhead charges, and contingencies.

In large plants, larger crushers are used and the cost of sledging consequently is reduced. In some cases, as already stated, the crushers may be large enough to receive stone of derrick size.

Loading and Hauling Rock. The loading and hauling items in the table are based on hauling by carts, and represent the average from a number of jobs based on a labor cost of 20¢ per hour, with a single cart and horse at 20¢ and a double cart at 40¢ per hour, a teamster being added at the rate of 20¢; making the total cost of single cart and teamster 40¢ and of double cart and teamster 60¢. The distance from ledge to crusher is assumed to be about 200 feet and for longer hauls than this 1⅓¢ per cubic yard may be added for each additional 100-

foot haul. The costs are based on a cart or car holding about $33\frac{1}{2}$ cubic feet. If larger vehicles are used, the cost of loading will remain approximately the same, but the cost of hauling will be reduced in inverse proportion to the capacity.

For small quarries, either single or double carts drawn by horses are commonly used, while in large quarries, cars running on track are more economical. These cars may be run by gravity to the foot of an incline, and then hauled up to the crusher by the engine that runs the crusher. The track, just as it reaches the crusher, turns up on an angle of 45°, so that the stone falls into the crusher by gravity through the unlatching of the swinging door which forms the end of the car. With such an arrangement, the haul is apt to be longer, but the cost for the same distance is less and the values in the table apply in such cases to a haul of about 500 feet.

Fuel, Oil, and Waste. The cost of fuel, oil, and waste is based on coal delivered on the job at $4.00 per ton and incidentals determined from actual costs on different jobs.

Repairs. The cost of repairs is a variable item, which in a crushing plant amounts to an appreciable percentage of the total cost. As in other cases, the costs given are obtained by averaging costs on various jobs.

In certain cases where the rock is very hard to crush, the cost for repairs, or rather for renewals of the parts, may be higher than is given in the table. The bearings of a gyratory crusher may have to be rebabbitted very frequently and large quantities of oil may have to be used. In such cases, special estimates should be made and the crushers should be particularly adapted to the character of the stone.

Depreciation and Interest. For a small crusher, such as a 10 by 20-inch jaw crusher or a No. 4 gyratory, with an average daily capacity of 150 tons, the initial cost, including bins and elevators; may be taken, in round numbers, at $2500. In printed statements of costs of crushed stone, the interest and depreciation upon the plant frequently are omitted altogether, so that the costs as given are lower than the true figures. At least 20% depreciation per year must be counted on for the entire plant in addition to the interest on the first cost of the machinery. The charge per day, assuming that the crushing plant for preparing stone for concrete is in operation 150 days in the year, may be made up as follows:

Assume cost of crusher and plant	$2500.00	
Assume depreciation at 20% per year		$500.00
Interest on first cost @ 6%		150.00
Total depreciation and interest per year		$650.00

$$\text{On this basis, charge per day is } \frac{650}{150} = \$4.33$$

The depreciation of 20% per year may appear somewhat large, but in view of renewal of parts that may be required and alteration in plant, a large value is best to use.

For crushers of the other sizes, the depreciation and interest on plant is estimated in a similar way, basing them on the respective initial cost.

Labor at Crusher. The number of men required to run a crusher is substantially the same, regardless of the size of the crusher. For the smallest size, at least two men are required for feeding, and as the capacity increases, it is necessary, in order to feed fast enough, to arrange automatic dumping from a hopper or car, so that the same two men can handle the work. In a large plant it will be economical to employ also a machinist, and in some cases a fireman, in addition to the engineman will be required.

An ordinary gang for a crusher is represented in the following table, wages of common labor being assumed at $2.00 per day of 10 hours. These wages may be varied to suit local conditions and a correction made in the total for substitution in the table. This is simply for the crusher gang and does not include the rock excavation or the hauling.

Foreman, one-half time, @ $4.00	$2.00
Engineman	3.00
Two men feeding crusher @ $2.00	4.00
One bin man	2.00
One extra man	2.00
Total wages per day of 10 hours	$13.00
Add 15% for superintendence, overhead charges and incidentals	1.95
Total cost of labor at crusher per 10 hour day	$14.95

To this labor cost, profit and a proportion of charges for the central office expenses should be added.

LARGE CRUSHERS

The tables by no means cover the range in sizes of crushers that are in common use in large plants. However, by following out the principles laid down in the text and used in the compilation of the tables, it will be comparatively easy for the estimator to adapt the costs given to plants of different size and capacity from those scheduled.

When large crushers are used, they are generally set so as to give a product so coarse that it requires re-crushing in smaller machines. That is, the crushers are placed in series.

CRUSHERS IN SERIES

In a large plant, as has been indicated already, it is economical to install two or more crushers, the first to take the stone as it comes from the blast or from the stone breakers and crush it into large pieces; this to be followed by one or more smaller machines which re-crush all the stones that are caught on a screen of the required size. Because of the large size of the product of the first crusher, its capacity is much greater than if it reduced the stone to the final size required for the concrete aggregate.

A large crushing plant in the vicinity of Boston uses a 34 by 42-inch jaw crusher for the stone just as it comes from the quarry. This quarried stone, which varies in size up to cubic yard pieces, is loaded by a steam shovel into cars and dumped from them into the 34 by 42-inch crusher. From this crusher the stone, which is 8 or 9 inches in size, is delivered to two No. 6 gyratory crushers and crushed in these to pass a 2½-inch ring. The tailings are then run through a No. 4 or a No. 5 gyratory crusher and reduced to the size required. For very fine stone, a No. 2 or a No. 3 crusher is used.

The cost of crushed stone in a complex plant where the crushers are arranged in series will be governed largely by the final output and by the initial cost of the machinery. The number of men required will not vary greatly from the number required for a single crusher, because the intermediate screening and the handling of the material from one crusher to another is done by machinery. As a matter of fact, the number of men required for an equivalent output will be less in the larger plant, so that there will be an appreciable saving in labor cost. This saving will be balanced in part by the increase in the depreciation and interest charges per day in the larger plant. If the quantity of stone that can be used per day is limited by the mixing machinery, and if the job is a short one, the depreciation and interest on the larger initial cost may be so great as to make the smaller plant more economical. These various factors must be carefully balanced in designing a plant, as it is very easy to lose money by introducing too expensive machinery.

It is evident from the above discussion that if machinery is introduced beyond that covered by the table, the cost of the output should be reduced rather than increased.

By reference to the text describing the makeup of the table (see p. 195) it is possible with comparatively little computation, provided one has a knowledge of the process of stone crushing, to alter certain items in the table and arrive at a result which will provide accurately for the variables incident to any particular job.

COST OF STONE CRUSHING BY CITY LABOR

A careful analysis of the actual cost of crushing stone for macadam in a large gyratory crusher was made by Mr. Albert F. Noyes, City Engineer of Newton, Mass. His prices are based on common labor at $1.75 per day of nine hours, drill men at $3.00, drill helpers at $1.75, engineman for crusher at $2.00, and two one-horse carts with driver at $5.00. The detail costs per cubic yard of crushed stone were as follows:

COST PER CUBIC YARD OF QUARRYING AND CRUSHING HARD GREEN TRAP AT NEWTON, MASS.*

Labor of steam drilling	$0.092
Coal, oil, waste, powder, drilling, and repairs for drilling and blasting	0.084
Sharpening drills and tools	0.069
Breaking stone for crusher	0.279
Filling carts with rough stone	0.098
Carting stone to crusher	0.072
Feeding crusher	0.053
Engineman of crusher	0.031
Coal, oil, and waste for crusher	0.079
Repairs	0.041
Total cost per cubic yard of crushed stone	$0.898

* Annual Report of Newton City Engineer for 1891.

The total cost of jaw crushing of conglomerate ledge stone drilled by hand, Mr. Noyes gives as $1.113 per cubic yard; of crushing trap cobble stone wheeled to crusher in barrows, as $0.445 per cubic yard; and of crushing granite cobble stone hauled in carts, as $0.372 per cubic yard.

These costs are based upon an output per hour of 7.7 cubic yards hard green trap, 8.9 cubic yards conglomerate ledge, 11.8 cubic yards trap cobble stone, and 9 cubic yards granite cobble stone.* In estimating other cases, the conditions, as well as the wages paid per day, must be taken into account.

The total costs are about one-third higher than average values on ordinary contract work figured from the Tables 39 and 43, pages 208 and 212. Some of the individual items, however, are low for work done by city labor and compare favorably with the same work done by contract.†

During the years 1905, 1906, and 1907, the stripping, quarrying, and hauling the stone for crushers operated by the city of Boston‡ was done almost entirely by contract. The cost of both rock excavation and dirt stripping averaged $0.70 per ton. For one plant, the average percentage of stripping was over 40% of the total excavation, so that, at $0.70 per ton, the total cost to the city of stripping, quarrying and delivering the stone to the crusher was $1.17 per ton of stone. This illustrates the enormous waste that is frequently present in city work.

The average cost§ of the crushed stone produced by the city of Boston at its own crushers during the years 1905, 1906, and 1907, was $1.98 per ton at the crushers. On a five years' contract, stone could have been bought f.o.b. any railroad siding in Boston for $1.10 to $1.30 per ton. This price includes freight. The price at the crusher would not have been much over half this, and checks with the values for day-work in large plants given in Tables 39 and 43. This difference in price again shows the waste that often occurs when work is done by city labor.

* Annual Report of Newton City Engineer for 1891.

† Cost per cubic yard of stone crushing for pavement in various towns is given in Report Massachusetts Highway Commission, 1895, p. 38, and further data in *Engineering News*, Mar. 27, 1902, p. 258, and Jan. 15, 1903, p. 55.

‡ From Report of Mr. Samuel Whinery, made to the Boston Finance Commission, Vol. IV, p. 30.

§ From Report of Mr. Samuel Whinery, made to the Boston Finance Commission, Vol. IV, p. 31.

In order to demonstrate whether work could be done at a reasonable cost by day labor, by the Boston Street Department, a test-run, lasting $3\frac{1}{2}$ months, was made in 1908 at one of the city's crushing plants. The costs were carefully recorded, and from the report made to the Boston Finance Commission by Messrs. Metcalf & Eddy, the following has been abstracted.

The force, consisting of 48 men picked from the various street department districts and in some degree acquainted with rock work, was for the most part composed of young and vigorous men.

During the test 8953 tons of stone were crushed, at an expense to the city of $1.075 per ton. The report states:

These figures make no allowance for the cost of the quarry to the city or the cost of administration and clerical service at the office, the latter of which is estimated at $0.05 per ton of output.

This experiment has been carried out under the very best conditions. The quarry and crusher selected were the most favorable of any which the city has worked in the past, and produced crushed stone in 1905 more cheaply than any other. Of the five crushers operated in 1905 the Chestnut Hill Avenue crusher yielded the smallest output at a cost of $1.148. . . . The cost of producing crushed stone during the test was therefore reduced less than 8 cents below the cost of producing crushed stone at this crusher during the year 1905.

A contractor might produce crushed stone at the Chestnut Hill Avenue crusher for about one-half of the cost of crushed stone during the test-run. This, however, would probably not include the contractor's profit and would necessitate his having an abundant market which would enable him to work the plant to its maximum capacity.

HANDLING AND TRANSPORTING BROKEN STONE

Times and costs of handling and transporting broken stone are given in the tables in Chapter X.

DATA ON BROKEN STONE

Broken stone is often sold by weight instead of by the cubic yard, because of the variation in volume due to handling or transporting. A cubic yard of broken trap stone may vary in weight from 2400 to 2700 pounds.* If measured after carting some distance, broken stone will weigh about 10% heavier per cubic yard than at the crusher,

*For data on weights, see paper by William E. McClintock in Journal Association Engineering Societies, Vol. XI, p. 424.

because of the settling. The authors have found by repeated measurements that 100 pounds per cubic foot is a fair average weight for screened trap rock after it has been shaken down by hauling, although when measured loose in a small measure an average weight is about 90 pounds per cubic foot. Crusher run, or other stone having a variety of sizes, is about 10% heavier than this because it contains less voids, and 100 pounds per cubic foot is a fair average weight. Stones having lower specific gravities than trap are correspondingly lighter in weight. Comparisons of weight and measure are given in Table 42, page 211.

EXAMPLES

To illustrate the use of the tables of both rock excavation and stone crushing, a number of examples are given. These might be extended indefinitely, especially if large plants with crushers in series were illustrated more fully.

EXAMPLES OF ROCK EXCAVATION

Example 2: What is the cost per cubic yard of limestone excavated under conditions similar to those assumed in Tables 39 to 40, with the exception that the average day's work is 55 feet instead of 60 feet of hole per drill?

Solution: With an output of 1.25 cubic yards of stone per foot of hole (See Table 40), the total mass of excavated rock will be 68.8 cubic yards of solid rock. Divide the total expense per gang per day independent of the output, which is given as total (b) in Table 39 and amounts to $15.02, by the volume of excavated rock, and obtain the cost per cubic yard as $0.218. To this amount, add the cost of rock in ledge, cost of stripping of soil and cost of explosives, caps and fuses—which, from the same table, is $0.176—and the total cost per cubic yard of solid rock will be $0.218 + $0.176 = $0.394, as against $0.377 given in the table for limestone, in which 60 feet of hole are drilled per day per drill.

Example 3: What is the cost per ton (2000 pounds) of granite drilled and blasted by a contractor whose men are employed by day-work when the cost of the plant is $1500 per drill and runs on an average 250 days a year while the other items affecting cost are assumed as in Tables 39 and 40?

Solution: Assuming the depreciation of the plant at $\frac{1}{4}$ of the initial cost and the interest at 6% (see p. 184), the total cost of plant per year will be \$375 + \$90 = \$465, and $\frac{\$465}{250}$ = \$1.86 per working day. This value substituted in Table 39, column (5), for the item "Depreciation and interest," gives a total cost per gang per day of \$14.81 instead of the \$15.02 in the table. Dividing this cost by the weight of excavated granite, which we accept in accordance with the Table 40 as 91 tons per day per drill, and adding to this the total (a) from the second group from Table 39, the total cost per ton of granite will be $\frac{\$14.81}{91}$ + \$0.100 = \$0.263.

Example 4: Find the cost of excavation per cubic yard of solid rock of slowdrilling shale, when the rate of drilling per day per drill is 70 feet of hole, the cost of labor per day, \$11.50, and the cost of coal per ton \$4.50, other items being assumed the same as in Tables 39 and 40.

Solution: Assuming an output of 1.5 cubic yards per foot of hole (see p. 210), the daily output is 70 × 1.50 = 105 cubic yards. The cost of coal per day per drill changes in the ratio of 4.5 to 4.0 and is \$2.30 $\times \frac{4.5}{4.0}$ = \$2.59. Adding to the cost of labor and the cost of coal the rest of the items from Table 39, the total will be \$11.50 + \$2.59 + \$2.07 + \$0.58 + \$0.29 = \$17.03 instead of \$15.02 in the table. Dividing the cost by the number of cubic yards and adding the total (a) from Table 39, from the group corresponding to this kind of rock, the cost of excavation per cubic yard of shale in ledge will be $\frac{\$17.03}{105}$ + \$0.156 = \$0.318 against \$0.280 given in the table.

EXAMPLES OF CRUSHING STONE

Example 5: Find average cost for crushing to $2\frac{1}{2}$-inch size one cubic yard of stone measured in the ledge when the cost of the 9 by 15-inch jaw crusher and of the plant connected with it is \$3500, the number of working days of the plant 175 per year, the rate of interest 7% and the cost of repairs \$4.50 per day, while the other items affecting the cost are as assumed in Table 43?

Solution: Assuming the depreciation of the plant at 20% and the interest at 7% of the initial cost, and proceeding as shown on page 197, the depreciation and interest per year will be \$700 + \$245 = \$945. Dividing this sum by the assumed number of working days gives the plant cost per day as $\frac{\$945}{175} = \$5.40$. By substituting the values found for depreciation and interest and the assumed cost of repairs in the second group in Table 43, corresponding to 9 by 15-inch crusher, in sub-division (b), column (5), the new "Total (b)" per day of 10 hours will be \$27.50. From the output of this crusher measured in cubic yards of solid stone, we have $\frac{\$27.50}{38} = \$0.724$ per cubic yard. Adding this to the "Total (a)" in column (10), \$0.455, gives \$0.724 + \$0.455 = \$1.179, as the required cost for crushing stone.

Example 6: Find approximate cost of crushing stone per ton when output of 1½-inch stone of a No. 4 gyratory crusher is 85 cubic yards of stone measured crushed, instead of 93 as given in the table, and the cost of labor is \$13.00 instead of \$14.85.

Solution: The items in the group (a) are independent of the output, so that "Total (a)" from column (9) may be taken without any change. The values which differ from those assumed in the table are in group (b). Substituting in group (b) the cost of labor = \$13.00 for \$14.85, the "Total (b)" becomes \$27.89 per day of 10 hours. To obtain the cost per ton, divide this sum by the output in tons. From Table 42 we find that 85 cubic yards of crushed stone (assuming it as granite) are equivalent to $85 \times 1.25 = 106.2$ tons. Dividing the "Total (b)" by this output measured in tons $\frac{\$27.89}{106.2} = \$0.263$, and adding to it the "Total (a)" from the Table, the required total cost per ton will be \$0.263 + \$0.175 = \$0.438.

Example 7: Find the cost per cubic yard of stone in loose measurement for crushing stone to 1½-inch size by using a No. 6 gyratory crusher when the cost of sledging is \$0.060 per cubic yard instead of \$0.053, and the length of haul to crusher is 500 feet.

Solution: The cost of hauling 200 feet to crusher per cubic yard of stone measured loose is given in Table 43, column (13), as \$0.068. Since cost of hauling is proportional to the length of haul, the cost of hauling 500 feet will be $\frac{500}{200} \times \$0.068 = \$0.170$. Substitute in the group for No. 6 gyratory crusher and in column (13) the new values for sledging and hauling, and the "Total (a)" will be \$0.298 as compared with \$0.189

given in the table. Adding the "Total (b)" from the same group and same column, the cost of crushing stone will be \$0.298 + \$0.277 = \$0.575 per cubic yard of $1\frac{1}{2}$-inch stone measured loose.

Example 8: What will be the difference in cost of crushed stone when the output of a No. 4 gyratory crusher is 120 cubic yards of $2\frac{1}{2}$-inch crushed stone measured loose instead of 135 cubic yards while other conditions are as assumed in the table?

Solution: Items in group (a) will not be affected by the change in the output. All costs given in group (b) will change in inverse ratio to the change in output. Therefore, instead of changing every item, we may multiply "Total (b)" by $\frac{135}{120}$; the ratio of the outputs, and add the new value to the unchanged "Total (a)" to obtain the desired "grand total." The cost per ton of stone is thus $\frac{135}{120} \times \$0.170 + \$0.175 = \$0.366$ instead of \$0.345 given in the table.

Example 9: What will be the cost per ton for crushing stone to $2\frac{1}{2}$-inch size by a 9 × 15-inch jaw crusher, when the cost of common labor is assumed at \$1.50 per day of 10 hours instead of at \$2.00 as given in the table?

Solution: The wages of the rest of the men may be assumed as decreased in the same proportion, making the cost of labor per day $\$14.85 \times \frac{\$1.50}{\$2.00} = \$11.14$. Similarly, to find the required cost per ton of stone crushed to $2\frac{1}{2}$-inch size, substitute in column (8) $\frac{\$1.50}{\$2.00} \times 0.165 = \$0.124$ for \$0.165, thus changing the "grand total" from \$0.463 to \$0.422.

Example 10: What is the approximate average cost per ton of crushing stone in a large stationary plant costing about \$25000 and having a capacity of 100 tons per hour, when the blasted rock is loaded by steam shovel into cars; dumped into a 12 by 36-inch jaw crusher, which reduces the stone to 6-inch cubes; taken by belt conveyor to two No. 6 gyratory crushers and crushed to $2\frac{1}{2}$-inch size and under, the tailings being further reduced in a No. 3 gyratory crusher?

Solution: Assuming the depreciation 20% of the total cost, we have,

Depreciation .... 0.20 × \$25000 =	\$5000
Interest at 6%	1500
Total cost per year	\$6500

A large plant must run a greater part of the time in order to be successful, and taking 250 days per year as the average number of days in operation,

$$\text{Total daily plant cost} = \frac{\$6500}{250} = \$26$$

The maximum capacity of the plant is given as 1000 tons per day of 10 hours, but it is not often that a plant runs up to its maximum capacity. In this case, assuming the average daily output as 750 tons,

$$\text{Plant cost per ton} = \frac{\$26.00}{750} = \$0.035$$

Comparing the case under consideration with the items in Table 43, page 212:

There is no charge for sledging as the stone is practically all small enough to be loaded by steam shovel.

The items for loading and hauling are smaller than given in the table if the same distance is considered, for there is no manual labor. We therefore may take $0.03 for each of these items.

Fuel, which is practically constant for different sizes of plant, is taken at $0.02 per ton.

The costs of oil and waste and of repairs are taken at $0.001 and $0.03 respectively.

The value for depreciation and interest has been figured above.

The labor cost may be taken with safety at the same value as is given in the table for a single No. 6 gyratory crusher, $0.05 per ton, since the extra men required for the large plant would be balanced by the increased output.

Summarizing these items:

Sledging	$0.000
Loading cars	0.030
Hauling 200 feet	0.030
Fuel	0.020
Oil, waste	0.001
Repairs	0.030
Depreciation and interest	0.035
Labor	0.050
Total cost per ton	$0.196

The approximate total cost of crushing under ordinary conditions at this plant may therefore be taken at $0.196 per ton of crushed stone.

TABLE 39. COST OF DRILLING AND BLASTING ROCK FOR CRUSHED STONE* (See p. 182)

Based on common labor at 20 cents per hour. Includes 15% for superintendence, overhead charges, etc. Profit not included.
For sledging, transporting and crushing see Table 43. For handling stone see Chapter X.
For outputs see Table 38, also see page 193 and examples page 203. See important foot-notes.

Classification of Rock		Unit Items	Page References	Cost per 10 Hr. Day per Drill				Cost of Excavation					
				Day Work		Piece Work		Per Ton (2000 lb.)		Per Cubic Yard of Solid Stone		Per Cubic Yard of Crushed Stone	
				Output cu. yd.	Cost $	Output cu. yd.	Cost $	Day Work $	Piece Work $	Day Work $	Piece Work $	Day Work $	Piece Work $
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Very Hard Rock as Very Hard Trap	(a)	Cost of rock in ledge	182	15 cu. yd. Solid Stone 27 cu. yd. Crushed Stone	0.75	28 cu. yd. Solid Stone 52 cu. yd. Crushed Stone	1.40	0.020	0.020	0.050	0.050	0.028	0.028
		Stripping soil	182		0.75		0.84	0.020	0.012	0.050	0.030	0.028	0.017
		Explosives	183		3.03		5.66	0.080	0.080	0.202	0.202	0.112	0.112
		Caps, fuse, etc.	183		0.30		0.57	0.008	0.008	0.020	0.020	0.011	0.011
		Total (a) (see Note)			4.83		8.47	0.128	0.120	0.322	0.302	0.179	0.168
	(b)	Coal @ $4.00 per ton	183		2.30		2.30	0.061	0.031	0.153	0.082	0.085	0.044
		Oil and waste	184		0.29		0.29	0.008	0.004	0.019	0.010	0.011	0.006
		Repairs	184		0.58		0.58	0.015	0.008	0.039	0.021	0.022	0.011
		Depreciation and interest	184		2.07		2.07	0.054	0.029	0.138	0.074	0.077	0.040
		Labor	185		9.78		12.70	0.257	0.177	0,652	0.454	0.362	0.244
		Total (b) (see Note)			15.02		17.94	0.395	0.249	1.001	0.641	0.557	0.345
		Grand Total			19.85		26.41	0.523	0.369	1.323	0.943	0.736	0.513
Hard Rock as Ordinary Trap, Granite, Conglomerate	(a)	Cost of rock in ledge	182	40 cu. yd. Solid Stone 73 cu. yd. Crushed Stone	2.00	76 cu. yd. Solid Stone 138 cu. yd. Crushed Stone	3.80	0.022	0.022	0.050	0.050	0.028	0.028
		Stripping soil	182		2.00		2.28	0.022	0.013	0.050	0.030	0.028	0.017
		Explosives	183		4.60		8.74	0.051	0.051	0.115	0.115	0.063	0.063
		Caps, fuse, etc.	183		0.46		0.87	0.005	0.005	0.012	0.012	0.006	0.006
		Total (a) (see Note)			9.06		15.69	0.100	0.091	0.227	0.207	0.125	0.114
	(b)	Coal @ $4.00 per ton	183		2.30		2.30	0.025	0.013	0.058	0.030	0.034	0.017
		Oil and waste	184		0.29		0.29	0.003	0.002	0.007	0.004	0.004	0.002
		Repairs	184		0.58		0.58	0.006	0.003	0.014	0.008	0.008	0.004
		Depreciation and interest	184		2.07		2.07	0.023	0.012	0.052	0.027	0.028	0.015
		Labor	185		9.78		12.70	0.108	0.074	0.245	0.167	0.134	0.092
		Total (b) (see Note)			15.02		17.94	0.165	0.104	0.376	0.236	0.208	0.130
		Grand Total			24.08		33.63	0.265	0.195	0.603	0.443	0.333	0.244

Medium Rock as Limestone	(a)	Cost of rock in ledge	182	75 cu. yd. Solid Stone 136 cu. yd. Crushed Stone	3.75	136 cu. yd. Solid Stone 247 cu. yd. Crushed Stone	6.80	0.023	0.023	0.050	0.050	0.028	0.028
		Stripping soil	182		3.75		4.08	0.023	0.014	0.050	0.030	0.028	0.017
		Explosives	183		5.18		9.38	0.032	0.032	0.069	0.069	0.038	0.038
		Caps, fuse, etc	183		0.52		0.94	0.003	0.003	0.007	0.007	0.004	0.004
		Total (a) (see Note)			13.20		21.20	0.081	0.072	0.176	0.156	0.098	0.087
	(b)	Coal @ $4.00 per ton	183		2.30		2.30	0.014	0.008	0.031	0.017	0.017	0.009
		Oil and waste	184		0.29		0.29	0.002	0.001	0.004	0.002	0.002	0.001
		Repairs	184		0.58		0.58	0.004	0.002	0.008	0.004	0.004	0.002
		Depreciation and interest	184		2.07		2.07	0.013	0.007	0.028	0.015	0.015	0.008
		Labor	185		9.78		12.70	0.060	0.043	0.130	0.093	0.072	0.051
		Total (b) (see Note)			15.02		17.94	0.093	0.061	0.201	0.131	0.110	0.071
		Grand Total			28.22		39.14	0.174	0.133	0.377	0.287	0.208	0.158
Soft Rock as Shale	(a)	Cost of rock in ledge	182	120 cu. yd. Solid Stone 218 cu. yd. Crushed Stone	3.60	228 cu. yd. Solid Stone 415 cu. yd. Crushed Stone	6.84	0.014	0.014	0.030	0.030	0.017	0.017
		Stripping soil	182		6.00		6.84	0.023	0.014	0.050	0.030	0.028	0.017
		Explosives	183		8.28		15.73	0.032	0.032	0.069	0.069	0.038	0.038
		Caps, fuse, etc	183		0.83		1.57	0.003	0.003	0.007	0.007	0.004	0.004
		Total (a) (see Note)			18.71		30.98	0.072	0.063	0.156	0.136	0.087	0.076
	(b)	Coal @ $4.00 per ton	183		2.30		2.30	0.009	0.005	0.019	0.010	0.011	0.006
		Oil and waste	184		0.29		0.29	0.001	0.001	0.002	0.001	0.001	0.001
		Repairs	184		0.58		0.58	0.002	0.001	0.005	0.003	0.003	0.001
		Depreciation and interest	184		2.07		2.07	0.008	0.004	0.017	0.009	0.010	0.005
		Labor	185		9.78		12.70	0.037	0.026	0.081	0.056	0.045	0.031
		Total (b) (see Note)			15.02		17.94	0.057	0.037	0.124	0.081	0.070	0.044
		Grand Total			33.73		48.92	0.129	0.100	0.280	0.215	0.157	0.120
Very Soft Rock as Sandstone	(a)	Cost of rock in ledge	182	250 cu. yd. Solid Stone 455 cu. yd. Crushed Stone	5.00	475 cu. yd. Solid Stone 864 cu. yd. Crushed Stone	9.50	0.010	0.010	0.020	0.020	0.011	0.011
		Stripping soil	182		12.50		14.25	0.025	0.015	0.050	0.030	0.028	0.017
		Explosives	183		17.25		32.78	0.034	0.034	0.069	0.069	0.038	0.038
		Caps, fuse, etc	183		1.72		3.28	0.003	0.003	0.007	0.007	0.004	0.004
		Total (a) (see Note)			36.47		59.81	0.072	0.062	0.146	0.126	0.081	0.070
	(b)	Coal @ $4.00 per ton	183		2.30		2.30	0.005	0.002	0.009	0.005	0.005	0.003
		Oil and waste	184		0.29		0.29	0.001	0.001	0.001	0.001	0.001	0.001
		Repairs	184		0.58		0.58	0.001	0.001	0.002	0.001	0.001	0.001
		Depreciation and interest	184		2.07		2.07	0.004	0.002	0.008	0.004	0.005	0.002
		Labor	185		9.78		12.70	0.019	0.013	0.039	0.027	0.021	0.015
		Total (b) (see Note)			15.02		17.94	0.030	0.019	0.059	0.038	0.033	0.022
		Grand Total			51.49		77.75	0.102	0.081	0.205	0.164	0.114	0.092

*Costs are based on average conditions. Handling and transporting stone after crushing are not included in this table. See references in column (3) for application to local conditions.

NOTE:—Unit costs in groups (a) are not dependent upon the output so that for other outputs than given the unit costs remain the same and the cost per day per drill increases in proportion to the increased output.

Unit costs in groups (b) decrease with the increased output since the cost per day of these items is assumed to be constant.

TABLE 40. APPROXIMATE DRILL OUTPUT AND SPACING OF HOLES IN DIFFERENT ROCK (See p. 186)

Classification of Rock	Examples of Rock	Average Specific Gravity	Weight of Rock: Solid Stone, Per cu. ft., lb.	Weight of Rock: Solid Stone, Per cu. yd., Tons (2000 lb.)	Weight of Rock: Crushed Stone* Per cu. yd., Tons (2000 lb.)	Approximate Spacing of Holes: Distance from Face, ft.	Approximate Spacing of Holes: Distance Apart, ft.	Quantity of Rock per Foot of Hole: Tons (2000 lb.)	Quantity of Rock per Foot of Hole: Cubic Yards Solid Stone	Quantity of Rock per Foot of Hole: Cubic Yards Crushed Stone*	Approximate Rate of Drilling per Hour: Day Work, ft.	Approximate Rate of Drilling per Hour: Piece Work, ft.	Approximate Output per Hour per Drill: Day Work, Tons (2000 lb.)	Day Work, Cubic Yards Solid Stone	Day Work, Cubic Yards Crushed Stone*	Piece Work, Tons (2000 lb.)	Piece Work, Cubic Yards Solid Stone	Piece Work, Cubic Yards Crushed Stone*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Very Hard Rock	Exceedingly hard, close grained Trap....	3.0	187	2.53	1.39	4.5	4.5	1.90	0.75	1.36	2.0	3.8	3.8	1.5	2.7	7.2	2.8	5.2
Hard Rock	Trap, Conglomerate, Granite..	2.7	168	2.28	1.25	5.2	5.2	2.27	1.00	1.82	4.0	7.6	9.1	4.0	7.3	17.2	7.6	13.8
Medium Rock	Ordinary Limestone..........	2.6	162	2.19	1.20	5.8	5.8	2.74	1.25	2.27	6.0	10.9	16.4	7.5	13.6	29.8	13.6	24.7
Soft Rock	Soft Limestone, Shale, Sandstone	2.6	162	2.19	1.20	6.4	6.4	3.28	1.50	2.73	8.0	15.2	26.2	12.0	21.8	49.8	22.8	41.5
Very Soft Rock	Sandstone	2.4	150	2.02	1.11	8.2	8.2	5.05	2.50	4.55	10.0	19.0	50.5	25.0	45.5	96.0	47.5	86.4

* Assuming 45% voids.

TABLE 41. COST OF STRIPPING SOIL AND WHEELING

(See p. 182)

Based on labor at 20 cents per hour. Includes 15% for superintendence, overhead charges, etc. Profit not included.

Material	Wheelbarrows				Single Carts			
	Loosening, Loading and Dumping (Values of *s* per cubic yard p. 183)			Cost of wheeling per 100 feet (Values of *w* per cubic yard p. 183)	Loosening, Loading and Dumping (Values of *s* per cubic yard p. 183)			Cost of hauling per 100 feet (Values of *w* per cubic yard p. 183)
	Picked and loaded from level ground	Picked and loaded from face cutting	Plowed and loaded from level ground		Picked and loaded from level ground	Picked and loaded from face cutting	Plowed and loaded from level ground	
	$	$	$	$	$	$	$	$
Gravelly loam	0.172	0.174	0.156	0.052	0.260	0.292	0.246	0.013
Gravel, medium	0.220	0.176	0.164	0.056	0.322	0.312	0.268	0.014
Clay or compact gravel	0.274	0.246	0.200	0.056	0.386	0.390	0.314	0.014
Hardpan	0.408	0.336	0.236	0.064	0.510	0.474	0.344	0.016

NOTE: The costs of loosening, loading, and dumping barrows assume that each man loads his own barrow. If other men load, the costs are slightly greater.

TABLE 42. SPECIFIC GRAVITY, WEIGHTS, AND VOLUMES FOR DIFFERENT KINDS OF ROCKS (See p. 187)

For reducing weights to volumes and vice versa.

To convert cubic yards of solid rock to tons, multiply by column (4).

To convert tons to cubic yards of solid rock, multiply by column (5).

To convert cubic yards of broken stone to tons, multiply by column (6).

To convert tons to cubic yards of broken stone, multiply by column (7).

Kind of Material	Specific Gravity	Weight per Cu. Ft.	Solid Rock		Broken Stone 45% Voids	
			Tons per cu. yd.	Cu. yd. per ton	Tons per cu. yd.	Cu. yd. per ton
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Sandstone	2.4	150	2.03	0.49	1.13	0.89
Limestone, Conglomerate	2.6	162	2.18	0.46	1.20	0.83
Granite, Slate	2.7	168	2.27	0.44	1.25	0.80
Trap	2.9	180	2.43	0.41	1.34	0.75

TABLE 43. AVERAGE COST OF CRUSHING HARD ROCK INCLUDING SLEDGING (See p. 195)

Based on common labor at 20 cents per hour. Includes 15% for superintendence, overhead charges, etc. Profit not included. Costs are based on average conditions. See references in column (3) for application to local conditions.

Unit costs in group (a) are not dependent upon the output so that for other outputs than given, the unit costs remain the same and the cost per day per crusher increases in proportion to the increased output.

Unit costs in group (b) decrease with increased output since the cost per day of these items is constant.

For drilling and blasting, see Table 39, page 208. For handling crushed stone, see Chapter X.

Size of Crusher	Unit Items	Page of Reference	Cost per Day of 10 Hours: 2½-inch Stone, Output cu. yd.	Cost per Day of 10 Hours: 2½-inch Stone, Cost $	Cost per Day of 10 Hours: 1½-inch Stone, Output cu. yd.	Cost per Day of 10 Hours: 1½-inch Stone, Cost $	Cost per Ton (2000 lb): 2½-inch Stone $	Cost per Ton (2000 lb): 1½-inch Stone $	Cost per Cubic Yard of Solid Stone: 2½-inch Stone $	Cost per Cubic Yard of Solid Stone: 1½-inch Stone $	Cost per Cubic Yard of Crushed Stone: 2½-inch Stone $	Cost per Cubic Yard of Crushed Stone: 1½-inch Stone $
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Jaw Crusher 9 × 15-inch	(a) Sledging rock for crusher	196	38 cu. yd. Solid Stone 70 cu. yd. Crushed Stone	8.00	26 cu. yd. Solid Stone 46 cu. yd. Crushed Stone	5.35	0.089	0.089	0.209	0.209	0.115	0.115
	(a) Loading carts or cars	196		4.68		3.12	0.052	0.052	0.123	0.123	0.068	0.068
	(a) Hauling 200 ft. to crusher	196		4.68		3.12	0.052	0.052	0.123	0.123	0.068	0.068
	Total (a) (see Note)			17.36		11.59	0.193	0.193	0.455	0.455	0.251	0.251
	(b) Fuel at $4.00 a ton	197		2.50		2.50	0.028	0.041	0.066	0.096	0.036	0.054
	(b) Oil, waste, etc	197		0.25		0.25	0.003	0.004	0.007	0.010	0.004	0.005
	(b) Repairs	197		3.20		3.20	0.036	0.053	0.084	0.123	0.046	0.068
	(b) Depreciation and interest	197		3.46		3.46	0.038	0.058	0.091	0.133	0.050	0.073
	(b) Labor at crusher	198		14.85		14.85	0.165	0.248	0.390	0.570	0.214	0.314
	Total (b) (see Note)			24.26		24.26	0.270	0.404	0.638	0.932	0.350	0.514
	Grand Total			41.62		35.85	0.463	0.597	1.093	1.387	0.601	0.765
Jaw Crusher 10 × 20-inch	(a) Sledging rock for crusher	196	51 cu. yd. Solid Stone 94 cu. yd. Crushed Stone	8.80	34 cu. yd. Solid Stone 62 cu. yd. Crushed Stone	5.87	0.073	0.073	0.173	0.173	0.094	0.094
	(a) Loading carts or cars	196		6.39		4.21	0.052	0.052	0.123	0.123	0.068	0.068
	(a) Hauling 200 ft. to crusher	196		6.39		4.21	0.052	0.052	0.123	0.123	0.068	0.068
	Total (a) (see Note)			21.58		14.29	0.177	0.177	0.419	0.419	0.230	0.230
	(b) Fuel at $4.00 a ton	197		2.50		2.50	0.021	0.031	0.049	0.073	0.026	0.040
	(b) Oil, waste, etc	197		0.25		0.25	0.002	0.003	0.005	0.007	0.003	0.004
	(b) Repairs	197		4.00		4.00	0.033	0.050	0.078	0.118	0.043	0.065
	(b) Depreciation and interest	197		4.33		4.33	0.036	0.054	0.085	0.127	0.046	0.070
	(b) Labor at crusher	198		14.85		14.85	0.124	0.186	0.292	0.437	0.158	0.239
	Total (b) (see Note)			25.93		25.93	0.216	0.324	0.509	0.762	0.276	0.418
	Grand Total			47.51		40.22	0.393	0.501	0.928	1.181	0.506	0.648

Gyratory Crusher No. 3	(a)	Sledging rock for crusher	196	42 cu. yd. Solid Stone 77 cu. yd. Crushed Stone	8.00	28 cu. yd. Solid Stone 50 cu. yd. Crushed Stone	5.20	0.080	0.080	0.189	0.189	0.104	0.104
		Loading carts or cars	196		5.20		3.38	0.052	0.052	0.123	0.123	0.068	0.068
		Hauling 200 ft. to crusher	196		5.20		3.38	0.052	0.052	0.123	0.123	0.068	0.068
		Total (a) (see Note)			18.40		11.96	0.184	0.184	0.435	0.435	0.240	0.240
	(b)	Fuel at $4.00 a ton	197		2.50		2.50	0.025	0.036	0.059	0.089	0.032	0.050
		Oil, waste, etc	197		0.25		0.25	0.003	0.004	0.006	0.009	0.003	0.005
		Repairs	197		4.00		4.00	0.040	0.062	0.095	0.143	0.052	0.079
		Depreciation and interest	197		4.33		4.33	0.043	0.067	0.103	0.154	0.057	0.085
		Labor at crusher	198		14.85		14.85	0.148	0.229	0.354	0.530	0.195	0.292
		Total (b) (see Note)			25.93		25.93	0.259	0.398	0.617	0.925	0.339	0.511
		Grand Total			44.33		37.89	0.443	0.582	1.052	1.360	0.579	0.751
Gyratory Crusher No. 4	(a)	Sledging rock for crusher	196	74 cu. yd. Solid Stone 135 cu. yd. Crushed Stone	12.24	51 cu. yd. Solid Stone 93 cu. yd. Crushed Stone	8.51	0.071	0.071	0.168	0.168	0.093	0.093
		Loading carts or cars	196		9.10		6.24	0.052	0.052	0.123	0.123	0.068	0.068
		Hauling 200 ft. to crusher	196		9.10		6.24	0.052	0.052	0.123	0.123	0.068	0.068
		Total (a) (see Note)			30.44		20.99	0.175	0.175	0.414	0.414	0.229	0.229
	(b)	Fuel at $4.00 a ton	197		3.00		3.00	0.017	0.025	0.041	0.059	0.022	0.032
		Oil, waste, etc	197		0.25		0.25	0.001	0.002	0.003	0.005	0.002	0.003
		Repairs	197		5.59		5.59	0.032	0.046	0.075	0.110	0.041	0.060
		Depreciation and interest	197		6.05		6.05	0.035	0.050	0.082	0.119	0.045	0.065
		Labor at crusher	198		14.85		14.85	0.085	0.124	0.200	0.291	0.110	0.160
		Total (b) (see Note)			29.74		29.74	0.170	0.247	0.401	0.584	0.220	0.320
		Grand Total			60.18		50.73	0.345	0.422	0.815	0.998	0.449	0.549
Gyratory Crusher No. 5	(a)	Sledging rock for crusher	196	106 cu. yd. Solid Stone 193 cu. yd. Crushed Stone	13.25	72 cu. yd. Solid Stone 131 cu. yd. Crushed Stone	9.01	0.055	0.052	0.123	0.123	0.068	0.068
		Loading carts or cars	196		13.00		8.85	0.052	0.052	0.123	0.123	0.068	0.068
		Hauling 200 ft. to crusher	196		13.00		8.85	0.052	0.052	0.123	0.123	0.068	0.068
		Total (a) (see Note)			39.25		26.71	0.156	0.156	0.369	0.369	0.204	0.204
	(b)	Fuel at $4.00 a ton	197		4.00		4.00	0.016	0.024	0.038	0.056	0.021	0.031
		Oil, waste, etc	197		0.30		0.30	0.001	0.002	0.003	0.004	0.002	0.002
		Repairs	197		7.99		7.99	0.032	0.047	0.075	0.111	0.041	0.061
		Depreciation and interest	197		9.55		9.55	0.038	0.056	0.090	0.133	0.049	0.073
		Labor at crusher	198		14.85		14.85	0.059	0.087	0.140	0.206	0.077	0.113
		Total (b) (see Note)			36.69		36.69	0.146	0.216	0.346	0.510	0.190	0.280
		Grand Total			75.94		63.40	0.302	0.372	0.715	0.879	0.394	0.484
Gyratory Crusher No. 6	(a)	Sledging rock for crusher	196	127 cu. yd. Solid Stone 232 cu. yd. Crushed Stone	12.30	85 cu. yd. Solid Stone 154 cu. yd. Crushed Stone	8.20	0.041	0.041	0.096	0.096	0.053	0.053
		Loading carts or cars	196		15.60		10.40	0.052	0.052	0.123	0.123	0.068	0.068
		Hauling 200 ft. to crusher	196		15.60		10.40	0.052	0.052	0.123	0.123	0.068	0.068
		Total (a) (see Note)			43.50		29.00	0.145	0.145	0.342	0.342	0.189	0.189
	(b)	Fuel at $4.00 a ton	197		6.00		6.00	0.020	0.030	0.017	0.071	0.026	0.039
		Oil, waste, etc	197		0.35		0.35	0.001	0.002	0.003	0.004	0.002	0.002
		Repairs	197		10.38		10.38	0.034	0.052	0.082	0.122	0.045	0.067
		Depreciation and interest	197		11.25		11.25	0.037	0.056	0.088	0.132	0.048	0.073
		Labor at crusher	198		14.85		14.85	0.050	0.074	0.117	0.175	0.064	0.096
		Total (b) (see Note)			42.83		42.83	0.142	0.214	0.337	0.504	0.185	0.277
		Grand Total			86.33		71.83	0.287	0.359	0.679	0.846	0.374	0.466

TABLE 44. CAPACITIES OF ROCK CRUSHERS (See p. 193)

Dimensions, Weights, Capacities, and Required Power Based on Manufacturers' Lists.

No.	Dimensions of Each Receiving Opening about (inches)	Capacity per Hour According to Character of Rock in Tons of 2000 Pounds to Pass Through a Ring of $2\frac{1}{2}$ inches	Smallest Size of Product of Machine (inches)	Weight of Breaker (pounds)	Horse Power Required*
	GYRATORY CRUSHERS				
3	7×22	15	$1\frac{3}{8}$	14000	
4	8×30	30	$1\frac{1}{2}$	20900	14–21
5	10×38	50	$1\frac{3}{4}$	31200	22–30
6	12×44	70	2	45500	28–45
$7\frac{1}{2}$	14×52	80	$2\frac{1}{2}$	64800	50–75
8	18×68	130†	$3\frac{1}{2}$	100000	70–110
	JAW CRUSHERS				
3	$7\frac{1}{2}$×13	8–12		6500	12
4	9×15	12–18		9100	15
$4\frac{1}{2}$	10×20	16–24		13500	18
5	11×26	25–40		19800	25

All values given in this table are catalogue values and outputs are larger than can be maintained day after day. The size of openings are not standard for all crushers but are given here as average values. This list includes only the usual and not the extra small or extra large size machines.

* This does not include power for screens and elevators.

† Passing through a $3\frac{1}{2}$-inch ring.

REFERENCE LIST OF STONE CRUSHING PLANTS

Location	Rock	Number and Size of Crushers	Method of Supplying Crushers	Method of Handling Materail from Crushers	Average Output per Hour Cu. Yd.	Reference
Los Angeles, Cal.		1 No. 12-K Gyratory 2 No. 5-K Gyratory 1 No. 2-D Gyratory	Gravity from bins	24-inch conveyors to storage bins	200	Eng. News, June 8, 1911, p. 688
Southern California	Trap	1 No. 6 Gyratory 1 No. 4 Gyratory 1 swing hammer pulverizer	Gravity from bins	Belt conveyor to screens over storage bins	100	Eng. Rec., May 20, 1911, p. 553
Bergin Hill	Trap rock	1 No. 10 Gyratory 4 No. 6 Gyratory	Dump cars from quarry	Belt conveyors and distributing stacker	50	Eng. Rec., Aug. 13, 1910, p. 179
San Francisco	Hard basalt	2 No. 6 Gyratory 1 No. 3 Gyratory	Cars hauled by 10-ton engine dumping to bins which feed crushers	Bucket elevators, to bins, then by belt conveyors 640 feet to bunkers at tide water	60	Eng. Rec., Aug. 6, 1910, p. 149
Chicago	Limestone	1 No. 21 Gyratory 2 No. 9 Gyratory 4 No. 6 Gyratory	Dump cars, bucket conveyors and belt conveyors	Belt conveyors to bins	300	Eng. Contr., June 1, 1910, p. 495
Broad River, S. C.*		1 No. 10-K Gyratory 1 No. 5-K Gyratory 1 No. 5-D Gyratory	Cableway direct from quarry	Bucket elevators		Eng. Rec., Apr. 2, 1910, p. 379
Havre de Grace	Hard trap	1 No. 21 Gyratory 4 No. 6 Gyratory	10-ton side dump cars from quarry	Belt conveyors to bins		Eng. Rec., Apr. 2, 1910, p. 446
Olive Bridge Dam, N.Y.		1 No. 9 Gyratory 2 No. 6 Gyratory	Derricks handling 4-yard steel skips from flat cars	Inclined belt conveyor	200	Eng. Rec., Apr. 13, 1909, p. 380
Boonton, N. J.	Granite	1 No. 8 Gyratory 1 No. 6 Gyratory	6 derricks with 90-feet masts handling stone direct from quarry. Also handled by cars	Belt conveyors to bins	30	Eng. Rec. Mar. 20, 1909, p. 315
North LeRoy, N. Y.	Hard limestone	1 No. 10 Gyratory 1 jaw 1 No. 6 Gyratory	Skip cars on incline	Screens to elevated bins	200	Eng. Rec. Apr. 4, 1908, p. 403
Gary, Ill.	Limestone	1 No. 9 Gyratory 2 No. 6 Gyratory 2 No. 5 Gyratory	4-ton dump cars on incline	Bucket elevators and belt conveyors to secondary crushers or to bins	300	Eng. Rec., Mar. 30, 1907, p. 420

*See p. 360

REFERENCE LIST OF ROCK QUARRYING PLANTS

Location	Kind of Rock	Depth of Holes in Feet	Number and Size of Drills	Method of Handling rock	Average Output Cubic Yards per Hour	Reference
Southern California	Hard trap	24 ft.	3-$3\frac{1}{4}$ in.	2-ton dump cars	100	Eng. Rec., May 20, 1911, p. 553
San Francisco	Hard basalt	Average 20 ft.		Loaded by hand to bottom dump cars on radial tracks	50	Eng. Rec., Aug. 6, 1910, p. 149
Chicago	Limestone	40 ft.	Well drills	Steam shovels and dump cars run by electricity	300	Eng. Contr., June 1, 1910, p. 495
Ashokan Reservoir, N. Y.	Hard bluestone	16 to 22 ft.	10	Derricks to flat cars	200	Eng. Rec., Apr. 2, 1910, p. 404
North LeRoy, N. Y.	Hard limestone	10 to 16 ft.	$3\frac{5}{8}$ in. and plug	By hand and by steam shovel to dump cars	200	Eng. Rec., Apr. 4, 1908, p. 403
Gary, Ill.	Limestone	30 to 40 ft.	12-2 in. and 5 in.	Loaded by hand into 4-ton cars on branch tracks	300	Eng. Rec., Mar. 30, 1907, p. 420
South Bethlehem, Penn.	Quartzite and limestone	14 to 20 ft.	16-$3\frac{5}{8}$ in.	By steam shovels to dump cars		Eng. Contr., May 16, 1906, p. 138

CHAPTER X

HANDLING AND TRANSPORTING MATERIALS

Although the handling and transporting of materials for concrete are really a part of the operation of concreting, they are considered here in a separate chapter because they apply to both hand and machine mixing. Many of the times and costs also, as well as the miscellaneous information, will be found useful in considering various kinds of labor which are not directly connected with the handling of materials to be used in actual concrete work.

Many of the times and costs given in this chapter are also presented in different form in the chapters which follow on mixing concrete. In the present chapter, the values are in terms of per cubic yard of aggregate or per barrel of cement, while in the mixing chapters, similar items are given based on the unit of the volume of concrete produced. For such labor as actually forms a part of the concrete operations, it is therefore more convenient to refer to the items in the tables of concrete mixing in the chapters which follow.

The tables, then, at the end of this chapter give miscellaneous data on weights and volumes of cements, weights of concrete, and capacities, of wheelbarrows under different conditions (p. 259); also times and costs of handling and transporting concrete materials, including screening sand and gravel, loading and hauling sand and broken stone or gravel, and handling cement (pp. 261 to 267). The costs may be used directly for estimates of labor in connection with the handling of materials for concrete.

INACCURACY OF USUAL METHODS OF STATING COSTS

The usual method of presenting cost data is to give records of costs of individual jobs. If the conditions are stated fully, such records are of considerable value to the engineer or the contractor. However, as a matter of fact, most cost records omit the most essential descriptive notes. In hauling, the distance hauled is frequently not given, the size of loading gang may not be stated or the exact character of the material handled. Even if these are given in full, the units are apt to be stated in such a way that they do not apply to a job of slightly different characteristics. For example, suppose that on a certain job the cost is given of loading and hauling gravel 500 feet and the rate paid for labor and the size of gang is stated in full. Upon what basis would the cost of hauling the same material 1000 feet be determined? It certainly will not cost double, because the cost of loading is the same in each case. Even if the time of the loaders is given separately from that of the carts and their teamsters, the problem cannot be solved because the time of the cart while it is being loaded, the time dumping, and the time turning and backing at the bank are not given. These are important items which do not vary with the length of the haul, so that even the cost of the carts and teamsters will not vary directly with the distance hauled, and on short hauls the variation will be very far from a direct ratio.

Thus, even for so simple an operation as hauling gravel, in order to make a given set of times or costs apply to another job with the same material and the same men, the only difference being in the length of haul, it is necessary to study the separate times and costs for each of the elements of the job, so that they can be re-combined to suit the new conditions. This is simply one illustration of the absolute necessity of determining unit times and costs by the methods which are described more fully in Chapter IV and which have been followed in compiling the tables in this book.

Another reason why a record of costs of one actual job fails to furnish data for another job which is nearly the same, is that the two jobs are rarely done under exactly the same conditions. The new job frequently includes operations not carried on in the old one. For example, in the case just considered, the gravel in one case may be shoveled from a loose bank and screened by machinery at the mixer, while in the other case the gravel may have to be picked or it may have to be screened at the bank or the quantity may be so small that the teamster loads his own cart, and all of these items affect the cost of hauling.

Again, a record of costs of actual work is seldom published unless it is fairly low. A contractor or engineer hesitates to publish high costs even when there are extenuating circumstances.

These are some of the reasons why cost data as usually given, even if the units are accurately described, are looked upon by many engineers as of little practical value in estimating on new work.

METHOD OF COMPILING TABLES

To provide for such differences and to present costs which are really applicable to all ordinary conditions, instead of presenting data on individual jobs—more or less incomplete and unsatisfactory—the times given in this chapter and those that follow are obtained by time-study. First, the operation is divided into its elements; second, the time is observed for *each* element on a number of different jobs; third, the times required to do each of the individual elements which are identical on the different jobs are averaged; and, finally, these elements or units are recombined so as to suit the new job on which an estimate is to be made. By this method, a man can pick out the exact information which he needs for any particular piece of work. In the original time-studies made by the authors, it was necessary to divide the different operations into even smaller units than those which are given in the tables. These small elements which were studied are not always recorded in the tables because the man who is to make the estimate does not need his information subdivided to the same extent as the man who compiles the tables. For this reason, many of the original unit values have been combined before tabulating.

In screening sand and gravel, for example, where the values of the items are made up as described on page 228, the information was obtained by observing various jobs and measuring by shovelfuls the amount of gravel thrown on the screen, and determining the amount caught and that passing through the meshes. On the other hand, in the practical tables to be used in estimating on work or in arranging gangs, times and cost per cubic yard instead of by the shovelful are given.

The study of loading on page 233, and of hauling on pages 236 to 241 affords a good illustration of the results that can be obtained by unit time-study.

All the costs and times in this chapter and in the chapters which follow are made up on this general plan and are based on an accurate study of the average time required to do each of the elementary operations, which, added together, make up the whole job. Each of these elements has been studied by the authors, not in one job only but in many different jobs, so that the times which they have adopted in working up the tables represent a fair average of a large variety of practical work. The results have been carefully checked by comparison with over-all times.

MISCELLANEOUS CONCRETE DATA

Table 49 on page 259 presents a lot of miscellaneous data with reference to concrete materials, which will be found useful for various purposes.

The weights of cement per barrel and bag are those recommended by the American Society for Testing Materials and adopted by cement manufacturers in the United States. The volumes and weights of cement and concrete under various conditions are the result of the authors' investigations and tests, and represent carefully prepared averages.

As stated in Item (6), in proportioning concrete, cement is assumed to weigh 100 pounds per cubic foot, this corresponding to a barrel volume of 3.76, or in round numbers, 3.8 cubic feet. The adoption of these units is discussed on page 132.

Wheelbarrow Loads. Barrow loads are based, not on the measured capacity of a wheelbarrow, but on the actual quantity of material handled as obtainable from averages of a large number of loads. The wood barrow is the old style form of contractor's wheelbarrow, and the iron wheelbarrow is the type shown in Fig. 18, which has supplanted the wood barrow for handling earth.

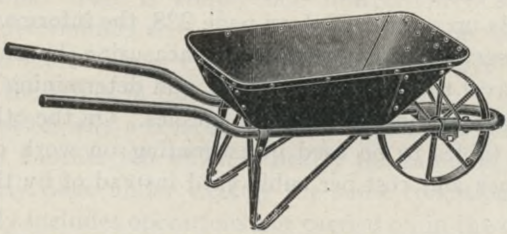


FIG. 18. Iron Wheelbarrow. (See p. 220)

For measuring concrete materials, however, it is not good practice to use barrows of this type because there is so much variation in the loads due to the variation in the heaping of the barrow. Even with careful workmen and although during a test, consecutive loads may run very uniform, there is a tendency as the work proceeds from day to day to either gain or lose on the correct quantity. An unscrupulous contractor also may gradually increase the amount of sand and gravel without its being noticeable for some time. To illustrate the inaccuracy, it will be seen from the table that 3.5 cubic feet of sand is a large barrow load on a short haul. If, now, the proportions of concrete are 1:2:4, with a 4-bag batch 7.6 cubic feet of sand are required, and this is a large quantity for two barrow loads and too small a quantity for three loads. If, then, three barrows are used to a batch, there is naturally a tendency to heap them and give an excess of sand.

To avoid such inaccuracy, it is becoming the general practice to use special barrows constructed with sides more nearly vertical, so that the surface of the material may be nearly level for each load and therefore more uniform. A special type of barrow which is easily wheeled and dumped on a level run, such as should be provided for concrete work, may measure up to 4½ cubic feet capacity, and thus frequently reduce the number of men to a gang.

Where indefinite measures are used, inaccurate measurement is apt to come back on to the contractor because a careful engineer or

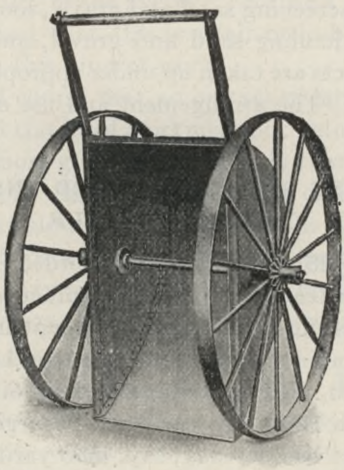


FIG. 19. 2-Wheel Hand Cart. (See p. 222)

inspector requires measurement on the safe side, and too little sand or gravel in a batch of concrete means a corresponding increase in the quantity of cement used.

In handling the concrete after mixing, as large a barrow should be used as a man can handle when filled. For concrete mixed to dry consistency, which was formerly used, the ordinary contractor's barrow served fairly well because it could be heaped. Wet concrete for reinforced concrete construction settles to a level in a barrow so that the quantity carried in a barrow of ordinary type, as shown in Table 49, is very small. The special 2-wheel concrete barrows or carts, such as are illustrated in Fig. 19, require wide runs or platforms, but the quantity of concrete handled in them is so much greater that the extra time for making and placing suitable runs is more than made up by extra work performed by each man. Such heavy barrows cannot be used where the concrete must be pushed up an incline.

The time for filling a barrow with concrete under different conditions and the work done by a man in concreting is taken up in Table 55, page 312.

TABLE OF HANDLING AND TRANSPORTING CONCRETE MATERIALS

Table 50, page 261, presents times and costs of the preliminary operations which have to be done in preparing for concreting. The items included are screening sand and gravel, loosening gravel at the bank, loading and hauling sand and gravel, and handling cement. These various subjects are taken up under appropriate headings in the pages which follow. The arrangement and use of each table will be described later.

TIME IN MINUTES PER CUBIC YARD INSTEAD OF CUBIC YARDS PER HOUR

In Table 50, page 261, the times are recorded in minutes per cubic yard for one man instead of giving the number of yards handled per day. This simplifies the calculations by permitting the times of various items to be combined, that is, added together in the same way that costs are added. Thus, if the screening of gravel in Item (2) and the loosening in Item (13) each had been given in terms of the number of yards per 10-hour day, say, 90.5 yards loosened and 13.4 yards screened, it would have been necessary to find the times per cubic yard before combining the two operations. By the new method, the times are simply added together, and the time for one man to loosen and screen one cubic yard of gravel is at once found to be 51.4 minutes. With a little practice it is easy to "think" in minutes per cubic yard instead of in cubic yards per day, and so avoid the division altogether. On the other hand, if volumes per hour or per day are required, they can be obtained readily by dividing the number of minutes in an hour or in a day by the time in minutes given in the table. Thus, the quantity of gravel loosened and screened per 10-hour day in the above mentioned case is $\frac{60 \times 10}{51.4} = 11.7$ cubic yards.

ARRANGEMENT OF TIMES AND COSTS IN TABLE

The costs, except those in the last column of the table, are computed on a basis of labor at 10¢ per hour, since costs at other rates per hour or per day are most easily figured from them. The last column is calculated on a basis of labor at 20¢ per hour, to be used for estimates upon work where that happens to be the rate per day or where, the rate being unknown, it is desired to assume this price for an approximation.

The average times and costs represent the labor in contract work under ordinary conditions with fair superintendence. Quick times and costs represent the labor of experienced men working industriously, although by the day and not by the piece. These values for quick men are figured at 70% of the average, because a large number of observations have shown that this is a fair ratio between average and quick laborers upon this kind of work.

It is recognized of course that no one set of labor values will apply to all conditions and classes of workmen, but values made up as these have been will be more generally applicable than any other method of presentation of costs. If it is found through careful observation that a gang of men works slower or faster than the average times in the table, the times and costs of labor by this same class of workmen on other kinds of work may be corrected in like proportion.

Many of the operations given in Table 50 are frequently performed with no foreman or superintendent in sight, and, unless there is some other incentive, this always means slower work. While it is impossible to accurately allow for such conditions, it is safe practice to add 50% to the times and costs where work is performed by the day without supervision. On piece-work or task-work, oversight is only necessary to insure quality and proper arrangement of the gang.

City Work. City work by day labor is carried on almost invariably at an appreciably lower rate of speed than contract work, although there are occasional exceptions to this rule where the engineer and foreman are exerting special efforts and working against records made in contract work. It is an exceedingly difficult problem to keep a gang of city laborers up to average speed day in and day out because there is usually no incentive to exertion and the men have but little fear of discharge. The only solution of the problem, in all probability, lies in the adoption of methods of piece or task-work so that men shall receive automatically a bonus for exceptional efforts.

In the construction of the Los Angeles Aqueduct all bids were rejected by the Board of Public Works because so much higher than the engineers' estimate, and day-work was installed. Through the exceptional organization effected by Mr. Mulholland, the City Engineer, acting in coöperation with Lieut. Gen. A. R. Chaffee, Chairman of the Board of Public Works, not only has the cost been low but the speed has been much greater than estimated.

In hauling and tunneling, the bonus system was adopted. The city was ready to share with the men any advantage it might gain from quick completion of the work. In the tunnels, the work to be done was studied by the engineers in charge and estimates made of the distance to be accomplished in a stated time. A premium was then paid to the men, dependent upon the difficulties encountered, for every foot that this distance was exceeded.

The elimination of politics, the advancement of the deserving, and the rewards for extra work, have created intense rivalry in the different camps. Ten day reports of the work accomplished by each camp are sent to every other camp and, as no one likes to stand at the foot of the list, every crew is jealous of its labor makeup and all laggards are weeded out.

Such examples as this illustrate the fact that city work *can* be efficient, provided politics are entirely eliminated and the work is planned and carried out by men who know how to effect an organization and install methods such as are practiced by the most up to date contractors.

To use the tables in this book for estimates of day labor for a city, it is necessary, under present methods of management, to add from 25% to 100% to the average times and costs. This is so wide a range as to be very indefinite, and yet it is not greater than exists in different cities.*

To determine what percentage to use to correct the items in the table, so as to apply them to any city work, it is necessary to compare a few actual records, taken from work going on, with the times and costs in this book for the same work, and find the ratio between them. This same ratio may then be used with fair accuracy for other operations.

Task-Work. Piece-work or preferably task-work, introduced in

* See Report of the Boston Finance Commission, Vol. III, 1909, by Messrs. Metcalf and Eddy.

such a way as to induce a man to work at his maximum continuous rate of speed, will greatly increase the output not only of city work but of all classes of work. In figuring the costs, however, by piece-work methods, considerably higher wages per day must be paid to the men to induce them to continuously maintain a high rate of speed. The percentage of increase to ordinary daily wages which they must earn depends upon the character of the work. In shop work, a 30% increase in wages earned per day over regular day rates has been found to be the smallest that will induce a man to work at the highest speed which he can maintain without overexertion. If men work in gangs, their increased output is always less than when they work on individual tasks.

Neither the average times nor the quick times in the tables apply directly to piece-work or task-work but they may be used as a basis for fixing rates or tasks. To determine the proper values to use, multiply the values in the tables by a ratio to be obtained in each case by observations on the job itself. Methods of making such observations and of correcting the values in the table are discussed in Chapter V.

Rates per Hour. The rates of 10¢ per hour and 20¢ per hour and the basis of 10 hours for a day's work, which the authors use in certain of their tables etc., are not selected as proper rates or length of day for economical results, but are merely chosen for convenience in calculation. For other rates and other lengths of day, the 10¢ prices given should be multiplied by the required rate per hour pointed off one decimal point to the right. Thus if the average cost of screening one cubic yard of sand for concrete at 10¢ per hour is \$0.074, the cost at $12\frac{1}{2}$¢ (\$0.12$\frac{1}{2}$) per hour is $\$0.074 \times 1.2\frac{1}{2} = \$0.093$ per cubic yard. If the wage rate is \$1.65 per 8-hour day, the average cost would be $\$0.074 \times \frac{\$16.5}{8} = \$0.153$ per cubic yard.

The unit times in the tables were obtained by time-studies on actual work. The values in the cost columns were found directly by multiplying the time of one man by the cost per minute of the laborer. There are also included in this unit of cost the wages of a foreman working with an average sized gang. In concrete work, an average gang is taken as 13 men, this number being the actual average of a large number of gangs observed. The wages of the foreman are assumed to be double the laborer's rate. The cost per minute, with an allowance of 15% for office and other general expenses and contingencies, is thus:

	10c. Rate	20c. Rate
Laborer one hour	$0.10	$0.20
One foreman to 13 laborers	0.0154	0.0308
Total per hour	$0.1154	$0.2308
Total per minute	$0.00192	$0.00384
Plus 15%	0.00029	0.00058
Rate per minute @ 10¢ per hour	$0.00221	
Rate per minute @ 20¢ per hour		$0.00442

If greater accuracy is desired in allowing for foreman, or if a different percentage is selected for general expenses and other contingencies a new rate per minute may be readily figured. And the costs can be obtained by multiplying the times by this new rate.

Time per One man vs. Time per Gang. Although an operation may be performed either by one man or by gangs of different sizes, in order to be able to compare the work of gangs of different sizes and for convenience in figuring costs, the times are reduced throughout to "time per one man."

To thoroughly understand the discussions in this and in subsequent chapters, the reader who is not experienced in time studies should familiarize himself with the distinction between time per one man and time per gang of men or time per team.

"Time per one man" is the time in which one man can perform a certain operation, and it is also, if the men work upon any operation in a gang, *the sum of the individual times of all the men in the gang.*

"Time per gang" is the actual time which the whole gang spends on the work, that is, it is the time which elapses between the start and the finish of a certain operation. The time per gang may be converted into the time per one man by multiplying it by the number of men in the gang. For example, if five men are working in a gang and 30 minutes elapse between the time of starting an operation and the time of finishing it, the "time per gang" will be 30 minutes and the "time per one man" $5 \times 30 = 150$ minutes.

If, on the other hand, it has been found that the "time per one man" on a certain operation is 250 minutes and 5 men are to perform the work, the "time per gang" of 5 men should be $\frac{250}{5} = 50$ minutes.

"Time per team" is the time which the whole team spends in doing a certain work and corresponds to the time per gang. The gang, however, in this case consists of one man and one or two horses, whichever the case may be. To convert the time per team to the time per one man, there must be found the relation of the value of the time of a horse including vehicle to the value of the time of a laborer. If, for example, a team of 2 horses with teamster costs 60¢ per hour, while the wages of a laborer are 20¢ per hour, we see that the cost of the two horses alone is 60¢ − 20¢ = 40¢ per hour, and consequently the cost of a horse and vehicle is equivalent to the cost of a man.

Under average conditions the assumption that the time of a horse (including vehicle) is equivalent to the time of a man is nearly true, so this assumption has been made all through the book. To illustrate a case however where this is not true, if we take the cost of a double team and teamster at 40¢ per hour and the wages of a laborer at $17\frac{1}{2}$¢ per hour, the cost of the 2 horses with the cart is 40¢ − $17\frac{1}{2}$¢ = $22\frac{1}{2}$¢ and the cost of one horse is $11\frac{1}{4}$¢ per hour. Under these conditions the cost of a horse is 65% of the cost of a man and the cost of team and teamster is equivalent to the cost of $1 + (2 \times 0.65) = 2.3$ men.

Allowance for Rest and Delays. The times in the tables include rest and delays, so that no extra allowance need be made for these. It is always necessary, when timing men, to make an allowance for rest and unavoidable delays. For work of a similar character, the percentage of delay has been found to be very uniform. In concrete operations, the time based on daily output averages 30% greater than the time actually taken in doing each individual operation, hence this percentage has been added before computing the times and costs given in the tables.

HAND SCREENING

The time and cost of hand screening depends upon the total amount of material handled rather than upon the quantity of sand or gravel produced.

The ratio of the portion of particles caught on the screen to that passing affects largely the cost of screening. The smaller this ratio, *i.e.*, the smaller the quantity of particles caught on the screen, the less work is needed in shoveling away from the screen. For material passing the screen, the screen frequently may be placed over a hole so that the time spent in moving screens may be reduced to practically nothing. The cost of screening is the largest when the gravel is screened to remove only the fine grains, because in such a case most of the material is caught upon the screen and must be handled twice, that is, first thrown upon the screen and then shoveled away.

Table 50, page 261, gives times of screening sand and gravel for different conditions met with in practice.

An average laborer, properly superintended, will throw about 20 cubic yards of material against a screen in a 10-hour day, but in estimating the cost, this rate cannot be used directly because allowance must be made for shoveling material out of the way and moving the screen. In Table 50, the times and costs are taken directly from averages of screening on actual jobs where sand and gravel of ordinary character were being used, and the assumptions of the amount wasted and passing the screen are thus also based on average conditions. The values do not apply directly to task-work.

Gravel is sometimes screened to remove the coarse pebbles and produce a sand for mortar or concrete, while in other cases it is screened to remove the sand from the gravel so as to use the latter for a coarse aggregate.

When dividing the work of screening into unit operations, it will be seen that the screening to remove coarse particles (see Items (1) and (2) in the table), when most of the material passes the screen, consists of different operations than screening to remove fine grains (Item (3)) where only a comparatively small quantity of fine grains pass the screen.

Consider for the first case the screening when the coarse stuff is wasted, *i.e.*, Item (1), Screening sand to remove small stones, and Item (2), Screening gravel to remove large stones, we find in both cases that the work may be divided into the same unit operations, as follows:

(a) Shoveling material to screen.

(b) Shoveling away the coarse stuff.

(c) Shoveling away the screened material from the face of the screen.

(d) Odd work, as moving the screen and leveling piles.

The times of the individual operations, however, are different for screening the sand and the gravel because of the greater labor of handling gravel.

For ordinary sand containing about 15% of gravel stones that must be screened out so that the sand can be used for mortar, the net time throwing one shovelful to screen, based on a large number of observations on ordinary contract work, is 0.114 minutes per shovelful. Adding 30%, which has been found to be the correct allowance in work of this character for delays occurring throughout the day, gives 0.148 minutes per shovelful. The average capacity of a shovel in this material on ordinary construction work is 0.162 cubic foot,* thus giving 0.914 minutes per cubic foot, or 24.7 minutes per cubic yard, for throwing material to screen. This, then, may be taken as the value for (a), shoveling material to screen, for sand. This time shoveling to screen has been found by observations to be, on the average, about 74% of the whole operation of screening. Hence total time per cubic yard of unscreened gravel is $\frac{24.7}{0.74} = 33.3$ minutes. The other items, which constitute 26% of the time of screening, vary both with the conditions and with the relative amount of material caught on and passing the screen. Either of two methods may be followed in finding the values of these items: the quantity of each kind of material may be estimated and the time per cubic foot handling each material may be figured, or the time of each item may be taken as a percentage of the total time. By the latter method, it is found that under ordinary conditions with about 15% of material caught on the screen and 85% passing the screen, the percentage of total time of (b), shoveling away the coarse stuff, is 14%; of (c), shoveling away or leveling the screened material, 10%; and of (d), odd work, 2%. Expressing these in times, we have therefore: (a) 24.7 minutes; (b) 4.6 minutes; (c) 3.3 minutes, and (d) 0.7 minutes, making a total of 33.3 minutes per cubic yard of sand before screening and, allowing for the 15% of stones screened out, $\frac{33.3}{0.85}$ or 39.2 minutes per cubic yard of screened sand.

For gravel which is screened for the purpose of removing large stones, the labor of shoveling is greater, because the stones are harder to handle and the time per cubic yard to screen is 33.0 minutes instead of 24.7 minutes. With the same assumptions as in screening sand and assuming that 15% of the gravel is coarse stone which has to be wasted, we have a total of $\frac{33}{0.74} = 44.6$ minutes as the time per cubic yard of unscreened gravel and $\frac{44.6}{0.85} = 52.5$ minutes per cubic yard of gravel which has passed the screen.

*Experiments made by Mr. Taylor show that the correct weight of a shovelful of material handled by a first-class man in 20½ pounds. For sand weighing 100 pounds per cubic foot this would be 0.205 cubic foot per shovel instead of 0.162 cubic foot.

If either sand or gravel has noticeably more or less than 15% of coarse material to be screened out, the time will vary accordingly. Strictly speaking, there would be a greater variation in the item (d), odd work, etc., than in the other items, but since this is a comparatively small proportion of the total time, it is sufficient for practical purposes to simply correct the total.

Now, in considering the second case (Item (3)), in which the gravel is screened for the purpose of removing the sand, which is wasted and hence not counted in the measurement, let us assume that it is required to screen the gravel over a $\frac{3}{8}$-inch screen to remove 50% of sand, this being a fair average figure. The operation for each cubic yard of total material handled now consists of

(e) Shoveling unscreened gravel to screen......	29.6 min.
(f) Shoveling away gravel caught on screen, amounting to 50% of the total, into a pile, 25.4 × 0.50............................	12.7 min.
(g) Shoveling away sand and odd work.........	4.6 min.
Total time per cubic yard of gravel thrown to screen..	46.9 min.

Since the sand, assumed to represent 50% of the original material, is wasted, the total time per cubic yard of gravel caught on the screen is 2 × 46.9 = 93.8 minutes, as given in Table 50, Item (3). Item (4) in the table is the same as (3) except that material is measured on both sides of screen so that the original time of 46.9 minutes is taken.

INCLINED SCREEN FED BY CARTS, DERRICK BUCKETS OR ENDLESS CHAIN.

Occasionally, where the ground permits, gravel or stone may be dumped directly from wagons or cars into a chute, and thence flow over an inclined screen by gravity. More frequently the material must be raised to the screen by derricks or endless chain elevators.

The slope of an inclined screen may vary from 35° to 45° from the horizontal according to the character of the material. A flatter slope will pass more fine, although more liable to clog with moist material. Coarser screens are required to pass material of a given size than in hand screening.

On a large job in Everett, Mass., an endless chain elevator, supplied by carts, raised sand and gravel to an inclined screen at the rate of 300 to 350 cubic yards in 10 hours and an even larger quantity could have been handled if the material had been supplied with no delays. The screen consisted of two parts, each about 8 feet long, the upper part formed by iron slats about 2 inches apart and the lower wire screen having square $\frac{3}{4}$-inch meshes.

For the piers of the Cambridge Bridge, Boston, the gravel for the concrete was brought in scows and dumped in the water close to the temporary pier, then raised by a rehandling dredge with an orange peel bucket of $1\frac{1}{4}$ cubic yards nominal capacity to an inclined screen. The capacity of the dredge was in the neighborhood of 200 cubic yards of gravel per 10 hours. The bucket emptied into a hopper above the screen and a heavy screen, hinged at the top, of parallel bars about 3 inches apart and 15 feet long, and placed above the regular 1 by $\frac{3}{4}$-inch screen, separated the stones too large for the concrete and broke the fall against the screen. The material passing through the 1 by $\frac{3}{4}$-inch screen was used as sand. Notwithstanding the very large mesh, the sand passing the screen was not much coarser than sand screened by hand through a $\frac{3}{8}$-inch mesh sieve because, to prevent clogging, the slope of such a screen must be steep enough to allow a rapid flow of the gravel.

The lower end of the screens was about 20 feet above the ground. The coarse material fell back into the river while the finer gravel and sand dropped into bins. From these the gravel and sand were carried by bucket conveyors to bins over the mixer, from which they fell into measuring hoppers as used.

The cost of screening by this method depends both upon local conditions and the quantity screened. The average total cost for labor and apparatus may be assumed to be from 4 to 8 cents per cubic yard when large quantities of sand or gravel are handled at once.

LOOSENING GRAVEL WITH PICKS

Item (8) in Table 50, page 261, gives times and costs of loosening the gravel in a bank for shoveling. The gravel is assumed to be that suitable for use in concrete work which requires but little labor in loosening.

In loosening gravel in a bank for concrete, assuming 5 shovelers per cart each holding a cubic yard, one man with pick is required to $6\frac{1}{2}$ men shoveling. The average time required by 5 men to load a cart (see Table 45, p. 234) is $\frac{29\frac{1}{2}}{5}$, or 5.9 minutes. The shovelers wait $2\frac{1}{2}$

minutes (see Table 45) while the cart is being changed, and this must be added to the time of the men shoveling, making 8.4 minutes. Therefore, a man can loosen gravel for $\frac{8.4}{6.6} = 1.27$ carts, or $6\frac{1}{2}$ men. If fewer men load, the shovelers will lose less time waiting while the carts are changed and therefore the man loosening cannot keep so many busy.

LOADING AND TRANSPORTING MATERIALS

The times and costs of loading and transporting sand and gravel in wheelbarrows are given in Items (6), (7), (9), (10), and (11), page 261, and by carts in Tables 51 to 53, pages 263 to 267. The times were obtained from different jobs by dividing each kind of work into unit operations, the net time of each operation being determined in a sufficient number of cases to obtain a fair average. Unavoidable delays, which, in order to make the times correspond to actual conditions, must also be taken into account, were determined by observation and timing and afterwards added to the net times, so that the times in the table represent those which can be maintained throughout the day in ordinary contract work. In piece or task-work, laid out with an incentive in the form of extra pay for the men who do a large day's work, a higher rate of speed will be maintained than is given by either the average or the quick times. Methods of determining the proper tasks are discussed on page 87.

Loading must be sub-divided into the operations of shoveling and changing carts. Dumping should also be considered, for it is a constant as well as loading. The time for each of these items was determined by the above described method. The total operation is represented by a formula which can be readily adjusted for special conditions. The derivation of the formula and its use under different conditions is given in the pages which follow.

The times and costs given in the table are about 20% larger than would be necessary in well organized jobs of earth excavation, because in concrete work hauling and loading may not be very systematically arranged. If the work is exceptionally well organized, this extra percentage may be deducted when making an estimate.

Since the time and cost of loading sand or gravel does not depend upon the length of haul (except for long hauls as noted on page 239), while the time and cost of hauling increases with the longer haul, the cost of loading and of hauling must be considered separately.

LOADING SAND AND GRAVEL.

The loading of sand or gravel into carts appears to be a simple operation, but it is really made up of a number of variable parts. The time required to load a cart depends not only upon the kind of material but also upon the size and arrangement of the gang. For example, the time of the horse and cart waiting while the cart is being loaded varies inversely with the number of loaders. In short hauls, this constitutes a considerable item of expense. On the other hand, if the loading gang is too large, the time which the shovelers lose waiting while carts are being changed is greater. Again, if the teamster helps the other men to load or if he loads the cart himself alone, the cost varies appreciably.

Formulas for Loading and Dumping Carts. The different conditions can be most readily considered by the use of formulas. These may be made either on the basis of the time loading one cart or in the more general terms of time per cubic yard. The latter is the more convenient to use if the times are properly chosen:

Let

g = time of shoveling per cubic yard in minutes per one man.

c = time of changing carts at face cutting per cubic yard in minutes per team.

d = time of dumping per cubic yard in minutes per team.

n = number of men shoveling.

m = ratio of cost of the team and teamster to cost of labor of one man.

Then:

Time per cubic yard loading materials where the teamster does not help load $= [g + nc] + \left[m\left(\frac{g}{n} + c + d\right) \right]$ (1)

The values of the quantities in the formula, for different conditions, are given in the table below.

To understand the formula, note that it is divided by square brackets into two parts. The first part represents the time of the loading gang reduced to time of one man (see p. 222), and consists of the time of actual shoveling, g, plus the time of the shoveling gang waiting for change of carts, nc. The second part of the formula consists of the time of the teamster with his team waiting during the loading of the cart, $m\frac{g}{n}$, plus the time of the teamster with his team while changing carts, $m\,c$, plus the time dumping, $m\,d$.

TABLE 45. TIMES OF SHOVELING, CHANGING CARTS, AND DUMPING (See p. 233)

Times of Shoveling are given per one man and times of Changing Carts and Dumping are given per cart for average and for large loads.

Allowance has been made for delays occuring throughout the day.

Average Values of Constants in Formulas (1), (2), and (3) pages 233 to 236.

Kind of Cart	Material	Load	Capacity of Cart Cu. Ft.	Time of Shoveling per One Man *g*				Time of Changing Carts per Cart *c*		Time of Dumping per Cart *d*		Ratio of Cost of Team and Teamster to cost of One Man *m*
				Min. per Cu. yd.		Min. per Cart						
				Average Men	Quick Men	Average Men	Quick Men	Min. per Cu. Yd.	Min. per Cart	Min. per Cu. Yd.	Min. per Cart	
Double Cart	Sand	Large load	35.5	19.7	13.7	25.9	18.0	1.9	2.5	1.1	1.5	3
	Sand	Average load	29.5	19.7	13.7	21.5	15.0	2.3	2.5	1.4	1.5	3
	Gravel	Large load	33.5	29.5	20.5	36.6	25.4	2.0	2.5	1.2	1.5	3
	Gravel	Average load	27.0	29.5	20.5	29.5	20.5	2.5	2.5	1.5	1.5	3
Single Cart	Sand	Large load	17.0	19.7	14.0	12.4	8.8	3.2	2	1.3	0.8	1.5
	Sand	Average load	14.0	19.7	14.0	10.3	7.3	3.9	2	1.5	0.8	1.5
	Gravel	Large load	16.0	29.7	20.8	17.6	12.3	3.4	2	1.3	0.8	1.5
	Gravel	Average load	13.0	29.7	20.8	14.3	10.0	4.2	2	1.7	0.8	1.5

All times of shoveling in the above table are given as times per one man. That is, for example, one man should shovel gravel into a double cart at the rate of one cubic yard in 29.5 minutes and keep this speed up throughout the day.

The above values may be substituted in formula (1). Assume the cost of the teamster with his team of two horses and cart equivalent to the cost of 3 unskilled laborers, and the ratio in the above equation for double carts becomes 3. For single carts if there is one teamster for two carts the ratio is $1\frac{1}{2}$. For any other condition, the ratio may be readily found.

Substituting these values in formula (1), page 233, we have, from Table 45, for average loads:

Time of loading and dumping gravel, double carts average loads

$$= [29.5 + 2.5n] + \left[3\left(\frac{29.5}{n} + 2.5 + 1.5\right)\right] \text{minutes}$$

or, for 4 men loading (where n is 4) = 73.6 minutes per cubic yard.

Time of loading and dumping gravel, single carts average loads

$$= [29.7 + 4.2n] + \left[1\tfrac{1}{2}\left(\frac{29.7}{n} + 4.2 + 1.7\right)\right] \text{ minutes}$$

or, for 3 men loading (where n is 3) = 65.7 minutes per cubic yard.

Time of loading and dumping sand, double carts average loads

$$= [19.7 + 2.3n] + \left[3\left(\frac{19.7}{n} + 2.3 + 1.4\right)\right] \text{ minutes}$$

or, for 4 men loading (where n is 4) = 54.8 minutes per cubic yard.

Time of loading and dumping sand, single carts average loads

$$= [19.7 + 3.9n] + \left[1\tfrac{1}{2}\left(\frac{19.7}{n} + 3.9 + 1.5\right)\right] \text{ minutes}$$

or, for 3 men loading (where n is 3) = 49.4 minutes per cubic yard.

Formulas for Loading if Teamster Loads. In the above formulas, it is assumed that the teamster does not load. Where the teamster helps the other men in loading, the formula may be easily adjusted by taking out from the second part of equation (1) the time of the teamster waiting. This second term in square brackets may be written $\left[m\frac{g}{n} + m(c + d)\right]$ in which $\frac{g}{n}$ represents the time of shoveling per gang, which, multiplied by m, gives $m\frac{g}{n}$, the time of waiting of the teamster and horses during shoveling. When the teamster loads, the shoveling gang increases in number by one, so that the time of shoveling per gang will be $\frac{g}{n+1}$ instead of $\frac{g}{n}$. Since the teamster loads, his time is included in g in the first part of the equation, and consequently must be deducted from the time of waiting of the team. The time of the horses spent while waiting during loading may be thus represented by $(m-1)\frac{g}{n+1}$.

Formula (1) thus changes to

Time per cubic yard loading and dumping when teamster helps

$$= [g + nc] + \left[(m-1)\frac{g}{n+1} + m(c + d)\right] \qquad (2)$$

When teamster loads alone, n in the above formula becomes zero, and the fraction $\frac{g}{n+1}$ in (2) becomes g, therefore

Time per cubic yard loading and dumping when teamster loads alone

$$= g + \left[(m-1)\ g + m\ (c + d)\right]$$
$$= m\ (g + c + d) \qquad (3)$$

Formulas (2) and (3) may be readily reduced to minutes by substituting the values of constants in the table on page 234.

The times obtained from formulas (1) to (3) are given in terms of per one man.

Times and costs for various conditions based on these formulas and those that follow are given in Table 51, page 263. Sometimes it is necessary to know how long it takes a gang to load a cart, $(g + nc)$, and how long the team waits between hauls, $\left(\frac{g}{n} + c + d\right)$.

Example 1: How many double carts will 4 men load per day of 10 hours with average and with large loads? What is the time spent by the team between hauls for average loads?

Solution: With 4 men shoveling, time per gang, from Table 45, page 234, is $\frac{29.5}{4} + 2.5 = 9.88$ minutes per average load or $\frac{36.6}{4} + 2.5 = 11.65$ minutes per large load per gang. This gang, if properly supplied with carts, should load $\frac{600}{9.88} = 61$ average loads or $\frac{600}{11.65} = 51\frac{1}{2}$ large loads per day. The time spent by the team between hauls is $\frac{29.5}{4} + 2.5 + 1.5 = 11.38$ minutes per team for average loads.

HAULING ON SHORT HAULS

On short hauls, the amount of work done depends upon the time of loading rather than on the time of hauling, for more time is required to load than the horses need for rest.

With only one or two men loading, it is frequently economical on short hauls for the horses to change carts rather than for them to wait for the carts to be loaded. The time of hauling per hundred feet for short hauls may be taken as 0.9 minutes per team per load, this time including the time hauling the load 100 feet, plus the time returning empty. For the total time of loading and hauling, the time of hauling per 100 feet and return multiplied by the distance hauled must be added to the time of loading.

For short hauls, in addition to notation on page 233, let

l = distance hauled one way in hundreds of feet or in miles.

t_s = actual time of hauling 100 feet or per mile and return, per cubic yard, for the different conditions of load, etc.

Then

Time per cubic yard loading and hauling materials

$$= (g + nc) + \left[m \left(\frac{g}{n} + c + d \right) \right] + m\,(l \times t_s) \qquad \text{(1a)}$$

Where teamster helps load

$$= (g + nc) + \left[(m - 1) \left(\frac{g}{n+1} \right) + m\,(c + d) \right] + m\,(l \times t_s) \qquad \text{(2a)}$$

and when teamster loads alone

$$= m\,(g + c + d) + m\,(l \times t_s) \qquad \text{(3a)}$$

TABLE 46. TIMES OF HAULING IN DOUBLE CARTS (See pp. 236 and 238)

Values of Constants t_l and t_s in Formulas (1a), (2a), and (3a) page 237 and (1b), (2b), and (3b) page 238

Material	Load	Long Haul: Time per Cubic Yard per Cart for Travel of One Mile Including Return t_l			Short Haul: Time per Cubic Yard per Cart for Travel, Including Return, t_s	
		Based on 17 Miles in 10 Hours min.	Based on 20 Miles in 10 Hours min.	Based on 17 Miles in 8 Hours min.	Of 100 Ft. min.	Of One Mile min.
Sand	Large	53.65	45.65	42.95	0.69	36.15
	Average	64.60	54.90	51.70	0.82	43.50
Gravel	Large	56.90	48.35	45.50	0.73	38.30
	Average	70.55	60.00	56.45	0.90	47.50

NOTE:—For values of g, c and m see Table 45, page 234.

The values of t_s, as times per cubic yard per team, are given in Table 46 and the time for loading in Table 51, page 263. For example, for a large load of gravel hauled $\frac{1}{4}$ mile, with two men and teamster loading, the total time would be $62.8 + 3\ (\frac{1}{4} \times 38.30) = 91.5$ min. The time of loading and hauling for different loads etc., can be taken directly from Fig. 20, page 243 or, where the travel is 17 miles per day of 10 hours, from Table 52, page 264. The limits between short and long haul may be taken from Table 47, page 239.

HAULING ON LONG HAULS

On long hauls, the work that a team can do is limited by the distance a horse travels per day. The average horse can travel 17 miles, that is $8\frac{1}{2}$ miles hauling a load and $8\frac{1}{2}$ miles returning with empty cart, on an ordinary road, up hill and down. On macadam roads, this distance may be increased to about 20 miles per day. These rates can be maintained day in and day out for 6 days in the week.

The time of traveling 17 miles is $\frac{17 \times 52.8 \times 0.9}{2} = 404$ minutes and the remainder of the day is required for rest. In long hauls, the time required to load is not enough to give the horses their necessary rest between trips so that the time of the team waiting while the cart is changed, loaded, and dumped, does not enter into the formula for long hauls.

For long hauls, in addition to notation on page 233, let

l = distance hauled one way in miles.

t_l = time per team per cubic yard per mile of actual hauling and return plus time required for rest.

Time per cubic yard loading and hauling materials

$$= (g + n\,c) + m\,(l \times t_l) \qquad \text{(1b)}$$

Where teamster helps load, time loading and hauling

$$= \left(\frac{n\,g}{n+1} + n\,c\right) + m\,(l \times t_l) \qquad \text{(2b)}$$

and where teamster loads alone, time loading and hauling

$$= m\,(l \times t_l) \qquad \text{(3b)}$$

The value of t_l may be taken from Table 46 on page 237, or the total time of hauling taken directly from Table 52, if the distance traveled is 17 miles per 10 hour day. Fig. 21, page 245, gives times of hauling for different loads and different rates of travel.

LIMITS OF LONG AND SHORT HAULS

The limit between a long and a short haul is governed by the time required for loading and the distance which the horse travels in a day. A short haul changes to a long haul when the time of the team waiting to be loaded, plus the time changing carts and dumping, is equal to the time required by the horses for rest between trips. This limit varies with the different arrangement of gang, the speed of loading, and with the different materials, as well as with the distance which a horse travels per day and the length of day. Values for the limits of long and short hauls are given in Table 47, page 239.

TABLE 47. LIMITS OF LONG AND SHORT HAULS (See p. 239)

Limits are given for different travels of a double team per day and different lengths of day.

Number of Men Shoveling	Travel per Day	Length of Day	Size of Load: Large, Sand, Average Men	Large, Sand, Quick Men	Large, Gravel, Average Men	Large, Gravel, Quick Men	Average, Sand, Average Men	Average, Sand, Quick Men	Average, Gravel, Average Men	Average, Gravel, Quick Men
	Miles	Hours	Miles	Miles	Miles	Miles	Miles	Miles	Miles	Miles
	17	10	1.30	0.96	1.76	1.28	1.11	0.83	1.45	1.06
One man....	20	10	2.39	1.76	3.25	2.35	2.04	1.52	2.68	1.95
	17	8	3.35	2.46	4.54	3.29	2.86	2.12	3.75	2.74
	17	10	0.74	0.56	0.97	0.73	0.64	0.50	0.82	0.62
Two men...	20	10	1.35	1.04	1.78	1.34	1.18	0.92	1.50	1.15
	17	8	1.90	1.46	2.50	1.87	1.65	1.39	2.10	1.59
	17	10	0.55	0.43	0.74	0.50	0.49	0.39	0.60	0.47
Three men..	20	10	1.01	0.80	1.30	1.00	0.89	0.72	1.10	0.87
	17	8	1.41	1.12	1.80	1.41	1.25	1.00	1.54	1.21
	17	10	0.45	0.37	0.57	0.45	0.41	0.34	0.49	0.40
Four men...	20	10	0.84	0.68	1.05	0.83	0.75	0.62	0.91	0.74
	17	8	1.17	0.95	1.47	1.17	1.05	0.87	1.27	1.03
	17	10	0.40	0.33	0.49	0.40	0.36	0.30	0.43	0.35
Five men*..	20	10	0.74	0.61	0.91	0.73	0.66	0.56	0.79	0.66
	17	8	1.03	0.85	1.27	1.01	0.93	0.78	1.11	0.91

*Maximum number of men that can shovel into one cart without being in each other's way.

The following example illustrates these limits.

Example 2: For a haul of 1000 feet each way can a team travel 17 miles per 10-hour day and, if not, how much time per team is wasted?

Solution: In order to cover 17 miles per day the number of round trips would need to be $\frac{17 \times 5280}{2 \times 1000} = 45$. The time traveling 17 miles is 404 minutes, so 196 minutes would be left for loading the cart, turning, and dumping 45 times, which gives $\frac{196}{45} = 4.36$ minutes per cart. Now, for a gang of 5 men, the largest gang economical in this kind of work, the time of shoveling an average load would be $\frac{g}{5}$ minutes per cubic yard per gang, which for gravel for average men (see p. 234) becomes $\frac{29.5}{5} = 5.9$ minutes. By adding to it the time of turning the cart, $c = 2.5$ minutes, and dumping, $d = 1.5$ minutes, we obtain the average time per team spent between hauls, $5.9 + 2.5 + 1.5 = 9.9$ minutes per cubic yard, while the time per team, assuming a large load, will be $\frac{36.6}{5} + 2.5 + 1.5 = 11.3$ minutes per gang. In such a case the time of loading would limit the number of trips to 20*, and the maximum total distance covered would be $20 \times 2000 = 40\,000$ feet, or about $7\frac{1}{2}$ miles. The net time consumed in traveling this distance would be 180 minutes; thus the team would waste in waiting $404 - 180 = 224$ minutes per team, which waste, however, is unavoidable because of the time required to load.

Example 3: For a haul of $4\frac{1}{4}$ miles each way is the time required for rest by the team sufficient to load the carts?

Solution: The number of trips per day in order not to exceed a total distance of 17 miles is $\frac{17}{4.25 \times 2} = 2$. The time of hauling will be 404 minutes per team, so the remaining 196 minutes constitute the time per gang available for loading 2 cartloads and turning and dumping twice. This time is by far larger than is necessary.

Comparing the two cases shown above, we see that in the first case

* To obtain the number of trips let s = number of round trips in 600 minutes. Equate the sum of the total times of loading, $11.3s$ minutes and the total time of hauling, $\frac{1000 \times 0.9 \times 2}{100} = 18\,s$ minutes per day and solve the equation for s. $11.3\,s + 18\,s = 600$ or $s = 20$.

the number of trips was limited by the time necessary for loading carts, and in the other case by the time required for the horses to rest. The haul, in the first case, is a short haul and in the second case, a long haul.

WHEELBARROW WORK

The time of loading wheelbarrows is based on the assumption that the wheeler loads his own barrow. This arrangement is found by observations and time study to be the most economical, because with more men loading, more or less time is wasted in waiting for barrows and changing them. Therefore, if possible, the gang should be so arranged as to give room for each man to load his own barrow. Sometimes, however, when the speed of the work is of great importance, other arrangements of gang may be preferable. The times and costs in such cases may be obtained by adding certain percentages to the costs given in the table. For example, when two men load and the wheeler does not load, add 35% to the times and costs of loading, and when one man loads with the wheeler, add 25%.

Mr. Taylor found in his experiments at the Bethlehem Steel Works, that the time of carrying a load up or down a slope increases about 5% for every 4 degrees increase in slope. This law holds for men with no load although the increase in time is not so rapid. It applies also to men pushing wheelbarrows up or down a slope. In wheelbarrow work, the load is usually decreased because of the increase in pull on the arms either going up or down a slope.

A comparison of the items for hauling with carts and wheelbarrows indicates that wheelbarrow work may be economical up to a distance of about 250 feet. This is shown by Fig. 20, page 243.

CURVES FOR HAULING

In Figs. 20 and 21, pages 243 and 245, times and costs are given of loading and hauling gravel for different arrangements of gangs. Curves are based on ordinary 2-horse or double carts, or dumping wagons, holding a large load.

Fig. 20 gives times and costs for loading, hauling, and dumping gravel per cubic yard of loose material on short hauls for wheelbarrow work when wheeler loads alone, and for cart work by double teams for gangs of three different sizes. The time and cost for loading and dumping alone may be obtained for each case by taking the ordinate of the corresponding curve for a haul of zero feet. Thus, for example, for wheelbarrow work we find the time of loading per cubic yard by determining, on the first vertical line, the height from the zero point to the intersection of the line with the curve for wheelbarrows. For wheelbarrows, the time so obtained is 35 minutes per cubic yard. This value, deducted from the value of loading, hauling, and dumping for any distance, gives the time of hauling alone. The curves in the figure are based upon the values for unit operations given in the tables. The lengths of haul are given in feet, the times are in minutes per cubic yard, and the costs in dollars per cubic yard. The costs are based on a rate of 20¢ per hour plus the usual percentages for superintendence, overhead charges, etc. The time of labor includes a certain per cent of the foreman's time. (See p. 226). The cost of 2 horses with cart is assumed to be equivalent to that of 2 men. From this diagram the relative economy of hauling by different methods is evident. In order not to complicate the diagram, only four different cases are there considered. For other cases not given in the diagram, curves may be easily plotted and the results compared. For example, similar curves may be made for different arrangements of gangs, for single instead of double carts, for different lengths of travel of a horse, for different capacities of carts (see p. 249), and for other vehicles such as cars.

Fig. 21, page 245, gives times and costs of loading, hauling, and dumping gravel for long hauls. The scale of distances is smaller than in Fig. 20, and is expressed in miles. The times are given in minutes and the cost in dollars, based, as in Fig. 20, on the rate of 20¢ per hour, with the same allowances for superintendence and overhead charges. Two sets of curves will be noticed in the diagram, one set in solid black lines representing values for a 10-hour day, and the other set of dash lines giving values for a working day of 8 hours.

The curves in this figure are broken lines, the breaks occurring at the limits of short and long hauls. It is seen that this limit is different for different numbers of loaders and for different lengths of day. Thus, for a 10-hour day, for four men loading and teamster not loading, the limiting haul is 0.57 miles, while with teamster loading alone, this distance changes to 1.76 miles. For an 8-hour working day, the lines for short hauls coincide with the corresponding lines for short hauls for a 10-hour day. The limiting hauls, however, are longer for an 8-hour day than for a 10-hour day.

The unit times of loading are accepted as given in Table 51, and a

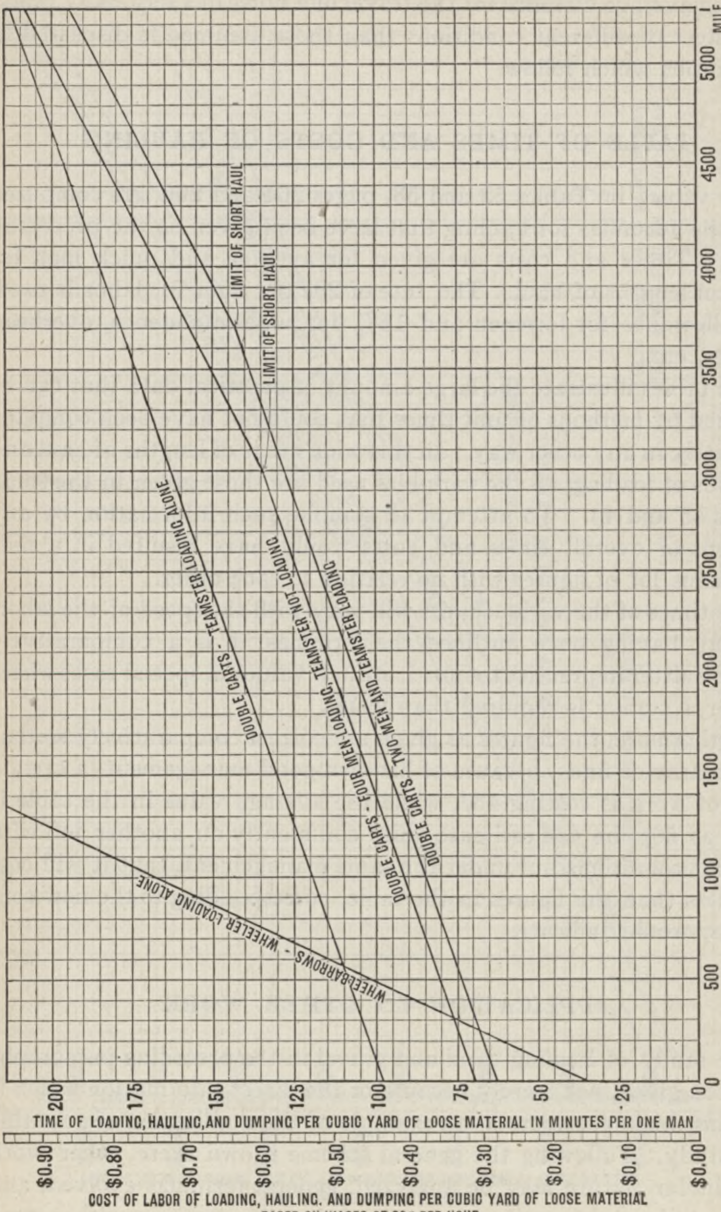


FIG. 20. Diagram giving Times and Costs of Loading, Hauling by Double Carts and Wheelbarrows, and Dumping Gravel per Cubic Yard for Short Hauls. (See p. 236.) **Capacity of Carts 33½ cubic feet. Capacity of Wheelbarrcws 3 cubic feet.**

limiting average distance for the travel of a horse in a day, as 17 miles. The effect of different conditions than those assumed is discussed in paragraphs which follow.

TABLE OF TIMES AND COSTS OF HAULING

The values in Tables 52 and 53, pages 264 and 266, are computed from the formulas for hauling that have been given on the preceding pages. Times and costs are given for average and quick men for different lengths of haul. The rate of 20¢ per hour for labor is used, plus allowance for foremen and 15% for superintendence, overhead charges, etc.

The tables illustrate the large amount of practical data that can be obtained by methods of unit times that could not have been compiled accurately in any other way. In this wide range of lengths of haul and methods of loading, all the variables used are those given in the small Tables 45 and 46. To attempt to compile such information by any methods of overall times and costs would have resulted in a miscellaneous lot of figures with no relation to each other.

The times of the various units will vary with the speed of the laborers, but, having once outlined the formulas, it is a comparatively simple matter in practice to substitute new values in special cases where greater accuracy is required than usual.

Furthermore, the figures as given are correct comparatively so that if a contractor finds, because of his own good management, a certain piece of work is costing 45¢, while the average value in the table is given as 50¢, he can estimate quite confidently on another job with different conditions but under the same management, that it will cost 10% less than the figures in the table, corresponding to the new conditions, would indicate.

APPLICATION TO OTHER WORK

The study of hauling sand and gravel in the preceding paragraphs has been given, not merely because of the direct information which it contains, but even more as an example of the application of scientific time-study. Following the general scheme shown there, other work of a similar nature may be analyzed, general formulas evolved, and constants in the formulas determined by observations with a stop watch. The formulas then may be used either for estimating times and

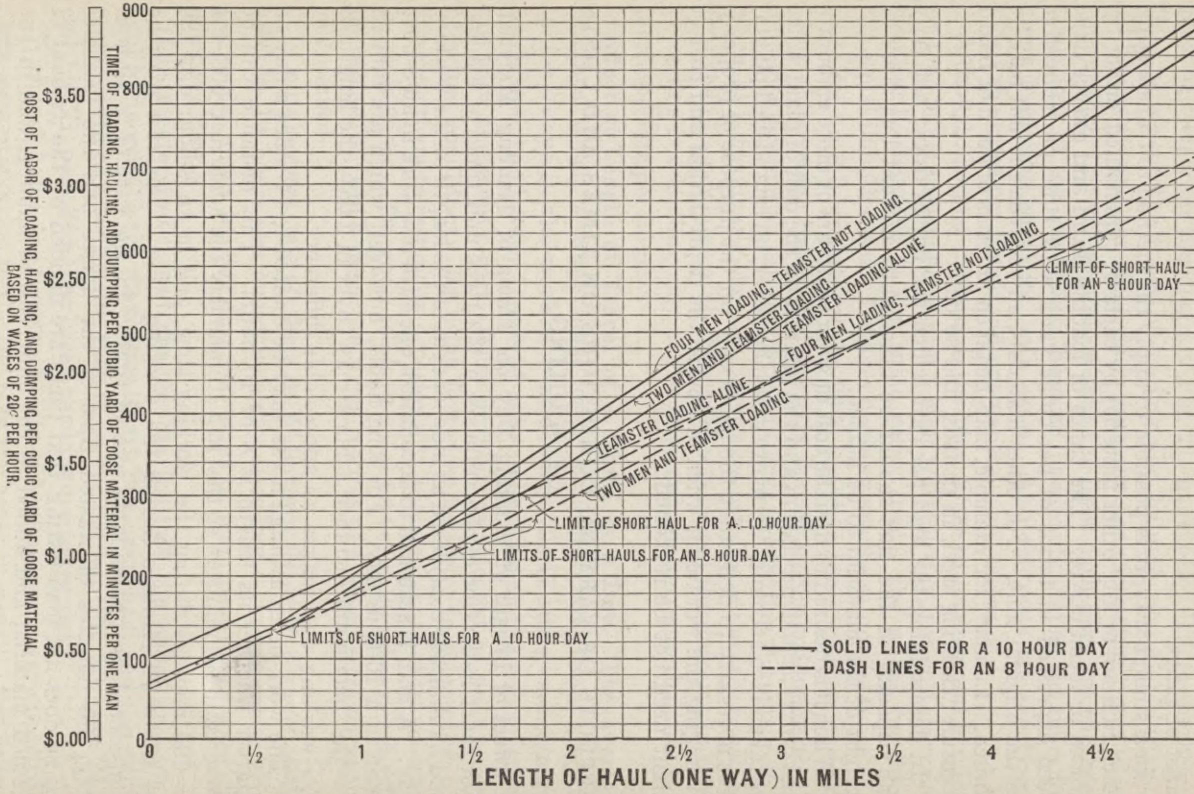


FIG. 21. Diagram giving Times and Costs of Loading, Hauling by Double Carts, and Dumping Gravel, per Cubic Yard for Long Hauls. (See p. 238.) **Capacity of Cart 33½ Cubic Feet.**

costs or for the purpose of determining the most economical arrangement of gangs.

In a similar way, it is possible to apply the method to transporting steel, lumber, or any other material by carts or cars hauled either by horses or locomotives. The times of loading sand and gravel have been expressed in terms of per cubic yard with time per shovelful as the original unit. For other materials, any convenient unit may be chosen. Lumber, for example, may be taken in terms of per foot board measure; carrying steel, in pounds, and so on.

In determining the load per cart which the horses draw, not only the capacity of the cart should be taken into account but also the weight of the material to be hauled.

When it is desired to find the cost of work with cars or more elaborate machinery, the depreciation and the interest on the cost of plant must be taken into account. In many cases, however, on established plants, it is necessary to determine the times only for the purpose of properly arranging the workmen, when of course the depreciation and cost of plant need not be reckoned.

EFFECTS OF VARYING CONDITIONS ON TIMES AND COSTS OF HAULING

Effect of Length of Working Day on Times of Hauling Material. For short hauls (for explanation see p. 236) the unit times of loading and hauling are considered as independent of the length of the working day. A man is assumed to accomplish one-fifth less work in an 8-hour than in a 10-hour day. For long hauls, however, which are limited by the maximum distance a horse may cover in a day, the length of the working day makes an appreciable difference.

The work of an average horse may be limited to 17 miles a day no matter whether its length is 8 or 10 hours. This distance can be covered in 404 minutes, so that in a 10-hour day the horse rests 600–404 = 196 minutes during the working time, and in an 8-hour day 480 – 404 = 76 minutes during the working time. This rest may be considered as unavoidable loss of time. In the case of a 10-hour day, 196 minutes of wasted time of the horses and the teamster (if he does not load during that time) are divided by the amount of hauled material and added to the unit cost of hauling, and in the other case in an 8-hour day only 76 minutes per team are so distributed.

The effect of the length of a working day on the time of hauling may be seen from the diagram Fig. 21, page 245. There the heavy lines represent the times of loading and hauling material during a 10-hour day and the light dash lines the corresponding times in an 8-hour day. It will be noticed that the light dash lines are the continuations of the heavy ones, because, as already stated, the times for short hauls are equal for both cases. Also the costs are equal provided the rates per hour (and not per day) are the same.

Although, as just explained, the total times of loading and hauling on long hauls are smaller for an 8-hour working day, the cost does not necessarily decrease in the same ratio, unless the wages per hour are equal in both cases. If wages per hour are the same, the times and costs for an 8-hour day will be 20% less than for a 10-hour day because the average travel of a horse is limited by his endurance to 17 miles per day and he can travel this distance in less than 8 hours. But when, as is frequently the case, the wages per day are nearly equal, so that the rate per hour in the 8-hour day is larger, the decrease in time of loading and hauling may not be large enough to counterbalance the increased rate per hour.

Effect of Length of Travel of a Horse in a Day. The average distance which a work horse can travel in a day and keep it up for 6 days in the week is considered to be 17 miles, on ordinary roads, uphill and down, that is 8½ miles under load and 8½ miles returning with the empty cart. This distance is selected as an average of actual conditions. By using first-class horses or in some cases by allowing them to rest a day occasionally, a longer length of travel may be maintained. On good roads, a total travel of 20 miles per day is not excessive, while there are a few records of a 25-mile travel being maintained.

In certain cases, one of them in Watertown N. Y.,* a travel of 24 miles in 10 hours was maintained day after day. On one contract in the south, mules hauling 1½ cubic yards of loam per trip traveled 28 miles per day.

This greater travel will change the limit of the short and long haul by increasing the maximum length of a short haul and the minimum length of a long haul; that is, in the curves, (Fig. 20, page 243, and Fig. 21, page 245,) the break would move to the right.

With long hauls, the times and costs of hauling would vary nearly in an inverse proportion to the travel of the horse in a day. For exam-

* Personal correspondence with Mr. J. W. Thompson.

ple, if the horses travel 20 miles per day instead of 17, there would be a decrease in the times and costs of hauling on long hauls of about 15%.

Effect of Speed of Horse. The average speed of a horse on ordinary roads is 47.5 minutes per mile or 0.9 minutes per 100 feet of round trip, hauling loaded cart and returning with empty one. This allows 10% for stops and delays. If this rate of travel per mile is increased, the limit of short and long haul will be increased and the cost of hauling per cubic yard will also be less, providing other conditions remain the same. For example, the speed of a quick horse has been found to average 0.77 min. per 100 feet of round trip and with 2 men and teamster loading a double cart with a large load of gravel, for a haul of ½ mile, the decrease in cost would be about 7%, due to increase of speed of the horse. In some cases, it is possible to choose the horses, and in that case, it is just as possible to get quick horses as it is quick men.

Effect of Larger Cart Loads. On good roads, sideboards or carts of special design will permit larger than average loads. A large load for an ordinary cart with sideboards may be taken at 42 cubic feet for sand and at 39 cubic feet for gravel measured in the cart. This would reduce the cost of hauling on long hauls in nearly inverse proportion, that is, nearly 15% below the values for large carts given in Table 53, page 266.

In cities and towns having fairly level paved streets or macadamized roads, 3 to 3½ tons or over 60 cubic feet of broken stone are in many cases a regular load for a 2-horse team. There is difficulty in carrying so much sand or gravel as this because of the heights to which the stuff must be thrown in loading the cart. Sometimes, however, carts may be filled from derrick buckets, elevated chutes, or bins. Contractors would do well to consider the use, for sand and gravel, of carts of special size and shape whenever the roads warrant extra heavy loads.

Table 48 illustrates the effects of different cart capacities, different travels, and different lengths of day upon the times and costs for long and short hauls. These materials are loaded directly from bins into carts.

Hauling by Motor Trucks. Motor trucks have been used successfully for transporting material on long hauls where the roads were good.*

* See paper by Mr. C. R. Gow, *Journal Association of Engineering Societies*, December, 1910.

Mr. Gow used one truck to take the place of four double teams on a haul of about five miles.

Economy of Arrangement of Gang. For the greatest economy, the gang of shovelers should be made larger for short hauls and smaller for long hauls, and if possible arranged in such a way that the time of waiting of the team for loading is no longer than is actually needed for rest. The number of men in a shoveling gang may not usually

TABLE 48. TIMES AND COSTS OF HAULING MATERIALS IN DOUBLE CARTS OF DIFFERENT CAPACITIES (See p. 248)

Costs are per cubic yard of material loaded from bins.

Cost of labor 20¢ per hour plus allowance for foreman and 15% for superintendence, overhead charges, etc.

Times are expressed as times per one man.

Travel per Day	Length of Day	Capacity of Cart													
		20 Cu. Ft.		30 Cu. Ft.		40 Cu. Ft.		50 Cu. Ft.		60 Cu. Ft.		70 Cu. Ft.		80 Cu. Ft.	
		1 Ton		1½ Tons		2 Tons		2½ Tons		3 Tons		3½ Tons		4 Tons	
		Time	Cost	Time	Cost	Time	Cost	Time	Cost	Time	Cost	Time	Cost	Time	Cost
Miles	Hours	Min.	$	Min.	$	Min.	$	Min.	$	Min.	$	Min.	$	Min.	$
Long Haul, Times and Costs per Mile															
17	10	285	1.26	190	0.84	143	0.63	114	0.50	95	0.42	81	0.36	71	0.31
20	10	243	1.07	162	0.72	122	0.54	97	0.43	81	0.36	69	0.31	61	0.27
17	8	229	1.01	152	0.67	114	0.50	92	0.41	76	0.34	65	0.29	57	0.25
Short Haul, Times and Costs per 100 Feet															
Hauling per 100 ft.		3.65	.016	2.43	.011	1.82	.008	1.46	.006	1.22	.005	1.04	.005	0.91	.004

For short hauls add for loading, 0.93 minutes to total times or $0.004 to total costs per cubic yard.

exceed 5 men because with a larger number the men will be in each other's way. For long hauls, the necessary rest for the horses gives the teamster time enough to load his own cart so that it is most economical for the teamster to load alone. (See Fig. 21, page 245).

In arranging a gang of shovelers, enough carts should be provided so that the shovelers will not waste time waiting for carts. On the other hand, the number of carts should not be excessive or these will waste time waiting for the shovelers. While it may be impossible to arrange the gang so that no time shall be wasted between carts, these delays may be reduced to a minimum by a through study of the conditions.

Formulas (1) to (3) in connection with Table 45 may be used as guides to the economical arrangement of the gang of shovelers and in determining the number of carts. (See Example 9.) Frequently, by adopting such methods of study of the local conditions, the cost of one or two men may be saved entirely or the same amount of work can be accomplished with one cart less.

The diagram in Fig. 21, page 245, gives the times of loading, hauling and dumping gravel per cubic yard on long hauls for different sizes of gang. These times multiplied by the cost per man per minute (see p. 226) give the costs per cubic yard.

Effect of Quick Men and Good Organization. The time of handling material varies largely with the quality of the workmen and their organization. Good organization means properly arranged gangs, so that but little time is lost in waiting and in other avoidable delays, while the unavoidable delays are also reduced to a minimum. With quick men, the loading is done faster, so that more teams per day can be used with the same gang. The increased speed in loading largely reduces the cost because, as is evident from formulas (1) and (2), pages 233 and 235, it not only decreases the actual time of the loaders but also reduces the time of waiting of the team and the teamster.

It is evident, therefore, for quick men that the times of handling material are greatly reduced below the average. Observations and records show that with quick men working under good superintendence, the times and costs may be reduced 30% below the average. This ratio is used therefore in making up in the table the columns headed "quick men." It must be noticed that the costs with the quick men are given only with the 10¢ per hour rate, so that they must always be corrected according to the wages paid per day.

A 30% reduction in times and costs is really equal to nearly 50% increase in the amount of work which a man does in a day. More exactly, the increase is $\frac{30}{70} = 43\%$. The times given for quick men are still larger than are required in piece-work or task-work since, when working with an incentive, less time is lost in rest and delay. The quick times, therefore, must be reduced still further by multiplying by a ratio to be determined by time-studies. Task-work and the fixing of rates is discussed on page 103.

HANDLING AND TRANSPORTING CEMENT

The items in Table 50, page 262, for handling and transporting cement, like those for other materials, are based upon the average and quick results upon a large number of jobs. For determining the time or cost of transportation to any distance, the time or cost loading plus the time or cost unloading is added to the unit time or cost of hauling multiplied by the number of miles of haul.

EXAMPLES

The tables in this chapter are of an elementary character and, for estimating the total cost of concrete, the tables in the following chapters will be found more convenient, as they are given in terms of a cubic yard of concrete and thus may be directly combined. The tables in the present chapter provide for cases where the labor on the materials themselves must be estimated without reference to the quantity of concrete made from them.

The use of Table 50, page 261, is illustrated in the following examples:

Screening Sand. *Example 4:* How many cubic yards of sand for concrete will an average laborer screen from bank gravel in 9 hours, the gravel which is caught on the screen requiring to be shoveled to one side?

Solution: Since from Table 50, Item (1), the time for an average man to screen one cubic yard of sand (this time includes the labor of throwing the coarse stuff to one side) is 39.2 minutes, in 9 hours or 540 minutes he will screen $\frac{540}{39.2} = 13\frac{3}{4}$ cubic yards.

Hauling Gravel. *Example 5:* Find the average cost per cubic yard based on labor at $1.40 per day of 9 hours for loosening, loading, and hauling gravel for concrete a distance of $2\frac{1}{2}$ miles with teamster loading alone.

Solution: Referring to Table 50, Item (8), and Table 52, estimating first for labor at $1.00 per day of 10 hours, and then converting this to the specified wages, as follows:

Item (8), (Table 50), Loosening gravel	6.6 min.
From Table 52, Loading and hauling gravel $2\frac{1}{2}$ miles for 9-hour day with teamster loading alone	$529 \times 0.90 = 476.0$ min.
Total time required	482.6 min.

482.6 min. at \$1.00 per day of 10 hours allowing for foreman and 15% for superintendence, overhead charges, etc. = \$1.068. At \$1.40 for a 9-hour day = $\$1.068 \times \frac{10}{9} \times \$1.40 = \$1.66$.

Hauling Cement. *Example 6:* Find the cost of delivering 1000 barrels Portland cement, packed in barrels, a distance of 1½ miles from the railroad station to the job, including rolling the barrels 150 feet to the pile in the cement shed, with labor based on \$1.40 per day of 9 hours, and 2-horse team with teamster at \$4.50 per day of 9 hours.

Solution: The unit operations involved are represented in the table by Items (12), (14), (15), and (18), cost columns of which include foreman's wages. As in Example 5, the cost at \$1.00 per day of 10 hours is first found, and then converted into cost at \$1.40 per 9 hours for laborers, and \$1.50 per 9 hours for horses and teamsters, that is, \$4.50 for two horses and one teamster.

Item (12) Loading wagons per barrel	\$0.004
Item (15) Unloading wagons per barrel	0.003
Item (18) Rolling barrels 150 feet (\$0.004 × 1½)	0.006
Total labor per barrel @ \$1.00 per 10-hour day	\$0.013
Total labor @ \$1.40 per 9 hours is \$0.013 × $\frac{10}{9}$ × \$1.40 =	\$0.020
Item (14) Hauling cement per barrel 1½ miles @ \$0.037 per mile	\$0.056
Hauling cement with labor @ \$1.50 per 9-hour day is \$0.056 × $\frac{10}{9}$ × \$1.50 =	\$0.093
Total cost per barrel for delivering	\$0.113
Total cost for delivering 1000 barrels	\$113.00

Example 7: What will be the difference in cost in Example 6 if the cement is shipped in bags?

Solution: The cost of hauling is the same as in the preceding case. For the other unit operations, select Items (13), (16), and (19), Table 50.

Item (13) Loading wagons per barrel	\$0.008
Item (16) Unloading wagons per barrel	0.001
Item (19) Carrying bags 150 feet (0.013 × 1½)	0.020
Total labor per barrel @ \$1.00 per 10-hour day	\$0.029
Total labor @ \$1.40 per 9 hours is \$0.029 × $\frac{10}{9}$ × \$1.40 =	\$0.045

This cost is much larger than in the preceding example, the difference amounting for the entire 1000 barrels to a sum of \$25.00.

Wheelbarrow Loads per Yard. *Example 8:* How many iron wheelbarrow loads of average size will be required to convey one cubic yard of wet concrete?

Solution: From Item (36) on page 260, an average load for an ordinary contractors' barrow is 1.3 cubic feet of wet concrete measured in place, hence one cubic yard of 27 cubic feet will require $\frac{27}{1.3} = 20.8$ barrow loads. The number of loads and the cost would be reduced by using a larger barrow.

Economical Gang for Carting. *Example 9:* Find an economical arrangement for gangs of average men under ordinary management handling and delivering gravel from a bank 3000 feet distant from the job when the rate of delivery should be 65 cubic yards of gravel per day of 10 hours.

Solution: The gravel must be loosened, screened, loaded, and transported, for which work 4 different gangs are necessary. From Item (8) we find that the average time of loosening one cubic yard of gravel is 6.6 minutes; hence one man should loosen $\frac{600}{6.6} = 91$ cubic yards of gravel in one day. Since 65 cubic yards per day are needed, one man loosening will be sufficient.

Assuming that the gravel is screened to remove sand, the time per cubic yard from Item (3), page 261, is 93.8 minutes and the number of cubic yards screened by one man is $\frac{600}{93.8} = 6.4$ cubic yards per day of 10 hours; hence to screen 65 cubic yards of gravel, 10 men are needed.

The loading gang will be found in the following way. Since 65 cubic yards of gravel must be loaded per day, the time will be $\frac{600}{65} = 9.2$ minutes per cubic yard per gang, which time includes the time of waiting during change of carts.

Subtracting this time of waiting, or 2 minutes per cubic yard for large carts, we have for the actual time of shoveling per gang, $9.2 - 2.0 = 7.2$ minutes per cubic yard. Dividing the time per cubic yard required by one man (Table 45, p. 234) by 7.2 we have $29.5 \div 7.2 = 4.1$ as the number of men required to load 65 cubic yards per day.

Since we cannot have a fraction of a man, the loading gang may be either 4 or 5 men. With 4 men shoveling, the time per gang would be $\frac{29.5}{4}$

+ 2.0 = 9.4 minutes per cubic yard and the amount loaded about 64 cubic yards, but by referring to the work of the man loosening, above, we see that he should have one-third of his time to spare, so that he can shovel during this time. Even without this help, the 4 men could easily work enough harder to load the 65 yards if they found it necessary to do so.

The number of carts necessary to keep the shovelers busy all the time may be found by a comparison of the time of hauling and dumping with the time of loading. From Fig. 20, page 243, the time of loading and hauling 3000 feet is 135 minutes. Subtracting the time of loading or 69 minutes, we have 66 minutes as the time of hauling for one man. Hence, the time of hauling is 22.0 minutes per team and the time of loading, including waiting for change of carts, as found above, is 9.2 minutes per cubic yard per gang of 4 men working all the time and one man, the man loosening, a small part of the time. The number of carts loaded by one gang while one cart is hauled and dumped is $\frac{22.0 + 1.2}{9.2} = 2.5$ and the number of carts required to keep the men busy would be $2.5 + 1 = 3.5$. The number of teams must be either 3 or 4. In the first case, the shoveling gang would waste time between loads in waiting for carts unless otherwise employed, and the amount of gravel hauled would be smaller than required, while in the other case, the men would not load the cart in time and the teams would have to wait.

At least two plans are possible to avoid this waiting. Engage an extra shoveler so that the time per cubic yard loading a large cart would be reduced to 7.9 minutes per gang, when 3 carts could be loaded while the fourth is being hauled and dumped; or else, still better, engage first-class men and pay them a slightly higher rate per day with the understanding that their extra pay depends upon their keeping the teams busy and handling full loads. A still more economical plan, feasible with good macadam roads, is to increase the capacity of the carts by side boards, so that they will hold $33.5 \times \frac{4}{3} = 44.7$ cubic feet. This is a large load, but can be hauled on comparatively level ground by a good pair of horses.

Wheeling Sand. *Example 10:* Find cost with labor at $1.75 per day of 9 hours of loading sand in barrows and wheeling 250 feet when one man assists the wheeler in loading and one foreman superintends 18 laborers.

Solution: The assumptions in the above example differ largely from those on which the table is based, therefore, to adjust the cost it is better to deal with unit times than with unit costs.

In Table 50, Item (6), the time of loading per cubic yard of sand when wheeler loads alone is 27.2 minutes. For our case this time must be increased 25% (see footnotes in Table 50, p. 261), becoming 27.2 + 6.8 = 34 minutes. With the assumed cost of labor and arrangement of gang, the cost per hour is

One laborer @ $1.75 per 9 hours	$0.194
One foreman for 18 laborers @ $3.50 per 9 hours	0.022
Cost of labor per hour	$0.216
Add 15 per cent for superintendence, overhead charges, etc.	0.032
Total cost of labor per hour	$0.248

The rate of pay of one man is thus $\frac{\$0.248}{60} = \$0.0041$ per minute. Multiplying this by the number of minutes per cubic yard, the cost is $34 \times \$0.0041 = \$0.139$ per cubic yard for loading.

The time of wheeling sand per 100 feet is 9.5 minutes (see Table 50, Item (7)) and hence for 250 feet is $9.5 \times 2.5 = 23.8$ minutes. Multiplying this time by the rate per minute found above gives the cost of wheeling as $23.8 \times \$0.0041 = \$0.097$. Adding to this the cost of loading, the required cost becomes $\$0.139 + \$0.097 = \$0.236$ per cubic yard.

Hauling Gravel. *Example 11:* Find the cost of loading gravel per cubic yard for a large load and hauling it $2\frac{1}{2}$ miles when the cost of labor is $1.75 per 9 hours.

Solution: From the diagram, Fig. 21, page 245, it is evident that for a haul of this length, the most economical arrangement of gang is for the teamster to load his own cart, in which case the total time of loading, hauling, and dumping is 427 minutes per cubic yard for a 10-hour day or $427 \times 0.90 = 384$ minutes for a 9-hour day. This time multiplied by the cost per minute (see p. 226) gives $384 \times \$0.00022 \times \frac{\$1.75}{9} = \$1.64$ as the cost per cubic yard of gravel.

Example 12: Is it cheaper to haul gravel from a bank $1\frac{1}{2}$ miles away where a horse can travel 17 miles per day with an average load or from another bank 2 miles away, with exceptionally good horses, that can travel 20 miles per day with a large load, teamster loading alone and labor at $2.00 per day of 10 hours?

Solution: From Table 53, the cost of hauling gravel per cubic yard $1\frac{1}{2}$ miles with average load (17 miles travel per day), is \$1.40. Cost of hauling 2 miles with large load (17 miles travel per day) is \$1.51. But, where material is hauled 2 miles, the team travels more miles per day which increases the amount hauled per day by 18%. Hence \$1.51 $\times$ (1 $\div$ 1.18) = \$1.28 is the cost for hauling 2 miles under those conditions. Therefore, hauling from the further bank with first class horses is cheaper than the shorter haul with average horses.

Example 13: With labor at \$2.00 per day of 10 hours and the ordinary travel of a team 17 miles per day, what will it cost to deliver 100 yards of sand per day to mixer two miles from bank? The sand contains 15% of stones and must be screened for mortar. How many men and how many carts are required?

Solution:

Item (1) from Table 50. Screening sand, per cubic yard of screened sand	\$0.173
From Table 53, Loading (large load) and hauling 2 miles per cubic yard	1.420
Total cost of screening and hauling sand per cubic yard	\$1.593

100 yards per day of screened gravel are required so that the time per cubic yard will be $\frac{600}{100} = 6$ minutes, and the number of men required to screen one yard in 6 minutes will be from Item 1, page 261 $\frac{39.2}{6} = 7$.

A team requires 70.55 minutes (see p. 237) to make a round trip of a mile including time to rest, thus giving 70.55 $\times$ 2 = 141.10 min. per round trip per team.

The number of trips per day will be $\frac{600}{141.10} = 4+$ and the amount of sand hauled per day per team will be $\frac{4 \times 35\frac{1}{2}}{27} = 5.26$ cubic yards.

The number of teams required will be $\frac{100}{5.26} = 19$.

Therefore the total number of men required to deliver 100 yards of sand per day are 7 men screening and 19 men and their teams hauling. The cost per cubic yard has been figured from the table but this cost makes no allowance for times of men and teams beyond just the required number. In the above example, the teams would make a little more than 4 trips a day, so this extra time will be wasted as well as part of the time of one man screening. If the cost of this time wasted is figured, as will be the case in the actual work, the actual cost of the teams and men would be

19 teams with their teamsters @ $6.00 per day	$114.00
7 men screening @ $2.00 per day	14.00
Total cost of men and teams	$128.00
Add 15 per cent for foreman and 15 per cent extra for superintendence, overhead charges, etc	41.00
Total cost per 100 cubic yards	$169.00
Actual cost per cubic yard	$1.69

or $0.10 more than figured from the table.

This difference shows that the layout of the work is not the most economical and that some other arrangements should be made, such as 4 trips in three days and 5 trips on the fourth day.

Example 14: There is a gravel bank ½ mile away from mixer where the gravel contains sand that must be screened out. The road from this bank is only fair and a team can haul an average load. Another gravel bank 1 mile away is reached by a good road, over which a large load can be hauled. The gravel from this latter bank contains some large stones which must be removed. With labor at $2.00 per day of 10 hours and teams traveling 17 miles per day, which is the cheaper bank to use?

Solution: For the cost per cubic yard from the nearer bank:

Item (3) Table 50, Cost of screening gravel to remove sand per cubic yard of screened gravel	$0.412
From Table 53, Cost loading and hauling ½ mile two men and teamster per cubic yard	0.610
Total cost	$1.022

For the cost per cubic yard from the further bank:

Item (2) Table 50, Cost of screening gravel to remove stones, per cubic yard of screened gravel	$0.231
From Table 53, Cost loading and hauling 1 mile (one man and teamster loading) per cubic yard	0.830
Total cost of gravel hauled 1 mile per cubic yard	$1.061

It is thus $0.04 per cubic yard cheaper to haul gravel from nearer bank.

Example 15: What is the cost of hauling 100 cubic yards of gravel, average loads, in double carts 3 miles, the average daily travel of team being 17 miles in 10 hours?

Solution: From Table 53, the cost of hauling 1 cubic yard of gravel, average load, 3 miles with teamster loading alone, is $2.81 for average man. For 100 yards, the total cost would be $281.

Example 16: What is the cost per cubic yard of hauling sand, large loads, ½ mile, when a horse travels 17 miles in 10 hours, average men shoveling?

Solution: From Table 53, the cost per cubic yard of hauling sand in large loads ½ mile, with two men and teamster shoveling, is $0.44.

MISCELLANEOUS CONCRETE DATA

The weights of cement per barrel and bag are those recommended in the Standard Specifications of the American Society for Testing Materials and adopted by cement manufacturers in the United States. The values for the volumes and weights of cement and concrete under various conditions are the result of the authors' investigations and tests,* and represent carefully prepared averages. (See p. 133.)

In proportioning concrete, cement is assumed to weigh 100 pounds per cubic foot, this corresponding to a barrel volume of 3.76 or, in round numbers, 3.8 cubic feet. The adoption of these units is discussed on page 134.

The capacities of wheelbarrows and carts as given in the table have been found by measurement of actual loads on a large number of jobs in different sections of the country. The size of carts will vary somewhat but the values here given are average values and can be used for ordinary conditions. If a contractor uses carts of different size than given here he can correct the values in the tables accordingly. This is discussed on page 248.

TABLE 49. MISCELLANEOUS CONCRETE DATA (See p. 259)

DESCRIPTION

Weights of Cement

Item		Lb.
(1)	Portland Cement per barrel net	376
(2)	Portland Cement per bag net	94
(3)	Natural Cement per barrel net	282
(4)	Natural Cement per bag net	94
(5)	Cement barrel weighs from 15 to 30 pounds, averaging	20
(6)	Portland Cement in standard proportioning per cubic foot	100
(7)	Packed Portland Cement, as in barrels, averages per cubic foot	115
(8)	Packed Portland Cement, based on a barrel of 3.5 cubic feet capacity per cubic foot	108½
(9)	Loose Portland Cement averages per cubic foot	92

Ratios of Weights of Portland Cement

		Cu. Ft.
(10)	Approximate ratio of weight of cement packed to standard weight	1.08
(11)	Approximate ratio of weight of cement packed to weight loose	1.28
(12)	Approximate ratio of weight of cement packed to weight shaken	1.13
(13)	Approximate ratio of weight of cement packed to weight sifted	1.37

*These tests are fully discussed in Taylor and Thompson's "Concrete, Plain and Reinforced," second edition, p. 217.

Volumes of Cement

		Cu. Ft.
(14)	Volume of cement barrel if cement is assumed to weigh 100 pounds per cubic foot	3.8
(15)	American Portland Cement barrel averages between heads	3.5
(16)	Foreign Portland Cement barrel averages between heads	3.25
(17)	Natural cement barrel averages between heads	3.75

Weights and Volumes of Neat Cement Paste

		Lb.
(18)	Weight of paste of neat Portland cement per cubic foot	137
		Cu. Ft.
(19)	Volume of paste made from 100 pounds of neat Portland cement	0.86
(20)	Volume of paste made from one barrel of neat Portland cement	3.2

Weights of Concrete and Mortar*

		Lb.
(21)	Weight of Portland cement mortar in proportions 1 : 2½, per cubic foot	135
(22)	Weight of cinder concrete per cubic foot	112
(23)	Weight of conglomerate concrete	150
(24)	Weight of gravel concrete	150
(25)	Weight of limestone concrete	148
(26)	Weight of sandstone concrete	143
(27)	Weight of trap concrete	155

Loads of Wheelbarrows

		Cu. Ft.
(28)	Wood wheelbarrows, average load of broken stone or gravel	2.4
(29)	Wood wheelbarrows, average load of sand	2.5
(30)	Iron wheelbarrows, average load of broken stone or gravel	2.7
(31)	Iron wheelbarrows, average load of sand	3.0
(32)	Large load of broken stone or gravel on short haul	3.0
(33)	Large load of sand on short haul	3.5
(34)	Average load of concrete †for iron barrow	1.9
(35)	Large load of concrete †for iron barrow	2.2
(36)	Average load of very wet concrete for iron barrow	1.3
		Shovelful
(37)	Number of shovelfuls of concrete per iron barrow in an average load	13
(38)	Number of shovelfuls of concrete per iron barrow in a large load	15
(39)	Barrows of special volumes are made for measuring sand and stone	

Loads of Concrete Carts

		Cu. Ft.
(40)	Average load of Ransome Cart	4½
(41)	Capacity of Ransome Cart, water measure	6¾

Loads of Carts ‡

		Cu. Ft.
(42)	Double cart, average load of broken stone or gravel	27
(43)	Double cart, average load of sand	29½
(44)	Double cart, large load of broken stone or gravel	33½
(45)	Double cart, large load of sand	35½
(46)	Single cart, average load of broken stone or gravel	13
(47)	Single cart, average load of sand	14
(48)	Single cart, large load of broken stone or gravel	16
(49)	Single cart, large load of sand	17

*Weight of concrete and mortar varies with the proportions as well as with the materials composing them. Loose unrammed concrete is 5 per cent to 25 per cent lighter than concrete in place, varying with the consistency.

†Concrete is assumed to be of medium consistency unless otherwise stated.

‡These values are given as loose measurements.

TABLE 50. HANDLING AND TRANSPORTING CONCRETE MATERIALS. (See p. 222)

Costs include foreman for each gang of 13 men plus 15 per cent for superintendence, overhead charges, etc., but do not include office expenses or profit.

Double teams with teamster are taken as 3 times the cost of a man.

For other rates per hour, multiply the 10¢ per hour costs by the required rate per hour, pointing off one place to the left.

Times and costs of loading and unloading unless otherwise stated, allow for carrying or rolling the cement about 25 feet.

Item	Unit Operation	Unit Time Expressed as Time of One Man		Unit Cost of Labor		
				10 Cents Per Hour		20 Cts. per Hour
		Average Men	Quick Men	Average Men	Quick Men	Average Men
		min.	min.	$	$	$
	Screening Sand and Gravel for Concrete (See p. 227)					
		Per Cubic Yard of Loose Materials		@10c		20c
(1)	Screening sand to remove small stones per cu. yd. of screened sand........	39.2	27.4	0.087	0.061	0.173
(2)	Screening gravel to remove coarse stones per cu. yd. of screened gravel	52.5	36.7	0.116	0.081	0.231
(3)	Screening gravel to remove sand, per cu. yd. of screened gravel..........	93.8	65.4	0.206	0.144	0.412
(4)	Screening gravel to separate sizes, materials measured on both sides of screen..........................	46.9	32.8	0.103	0.072	0.206
(5)	Screening gravel by power through inclined or revolving screens, all materials measured, approximate cost			0.038	0.027	0.057
	Handling Sand (See p. 241)					
	For loading carts and hauling see Tables 51 to 53, pages 263 to 267.............					
(6)	*Loading wheelbarrows, wheeler loading his own barrow....................	27.2	19.0	0.060	0.042	0.120
(7)	Wheeling barrows, 3 cubic feet capacity, 100 feet and return................	9.5	6.8	0.021	0.015	0.042
	Handling Broken Stone or Gravel (See p. 241)					
(8)	Loosening gravel in bank with pick....	6.6	4.6	0.014	0.010	0.029
(9)	If broken stone is shoveled from top of pile, add to times loading..........	19.6	13.7	0.043	0.030	0.087
(10)	*Loading wheelbarrows, wheeler loading his own barrow....................	35.0	24.5	0.077	0.054	0.155
(11)	Wheeling barrow, 3 cubic feet, capacity 100 feet and return..................	9.5	6.8	0.021	0.015	0.042

*When two men load and wheeler does not, add 35%, and when one man helps wheeler add 25% to these values.

TABLE 50. HANDLING AND TRANSPORTING CONCRETE MATERIALS—Continued. (See p. 222.)

See important notes page 261.

Item	Unit Operation	Unit Time Expressed as Time of One Man: Average Men	Unit Time Expressed as Time of One Man: Quick Men	Unit Cost of Labor, 10 Cents Per Hour: Average Men	Unit Cost of Labor, 10 Cents Per Hour: Quick Men	Unit Cost of Labor, 20 Cts. per Hour: Average Men
		min.	min.	$	$	$
	Handling Portland Cement (See p. 251)					
		Per Barrel of Cement				
				@10c		20c
(12)	*Loading barrels of Portland cement into wagons	1.9	1.3	0.004	0.003	0.008
(13)	*Loading bags of Portland cement into wagons	3.8	2.6	0.008	0.006	0.017
(14)	Hauling Portland cement in 2-horse wagons per mile	16.5	14.0	0.037	0.031	0.073
(15)	*Unloading barrels of Portland cement from wagons	1.6	1.1	0.003	0.002	0.007
(16)	*Throwing off bags of Portland cement from wagons	0.9	0.6	0.001	0.001	0.004
(17)	*Unloading from wagons and carrying bags of Portland cement about 30 ft.	2.9	2.0	0.006	0.004	0.013
(18)	Rolling Portland cement in barrels by hand per 100 feet	1.8	1.3	0.004	0.003	0.006
(19)	Carrying Portland cement in bags per 100 feet (one man)	6.0	4.2	0.013	0.010	0.027
(20)	Loading bags of Portland cement from cars to trucks	1.8	1.3	0.004	0.003	0.008
(21)	Hauling bags of Portland cement on trucks into storehouse	3.6	2.6	0.008	0.006	0.016
(22)	Piling bags of Portland cement in storehouse	3.6	2.6	0.008	0.006	0.016
	Handling Natural Cement (See p. 251)					
		Per Barrel of Cement				
(23)	*Loading barrels of natural cement into wagons	1.9	1.3	0.004	0.003	0.008
(24)	*Loading bags of natural cement into wagons	2.9	2.0	0.006	0.004	0.013
(25)	Hauling natural cement in 2-horse wagons per mile	12.7	10.8	0.028	0.024	0.056
(26)	*Unloading barrels of natural cement from wagons	2.0	1.4	0.004	0.003	0.009
(27)	*Throwing off bags of natural cement from wagons	0.7	0.4	0.001	0.001	0.003
(28)	*Unloading from wagons and carrying bags of natural cement about 30 feet	2.2	1.6	0.005	0.003	0.010

*If haul is less than ½ mile, add 50 per cent to times and costs loading and unloading to allow for time of teams waiting.

TABLE 51. TIMES AND COSTS OF LOADING AND DUMPING SAND AND GRAVEL PER CUBIC YARD FOR DOUBLE CARTS. (See p. 233)

Times given are times for double carts per one man and include allowance for rest and necessary delays occurring throughout the day.

Times and costs include not only the time of the shovelers but also the time of the team and teamster waiting for load, changing carts, and dumping.

Costs include foreman for each gang of 13 men plus 15 per cent for superintendence, overhead charges, etc., but do not include office expenses or profit.

Labor 20¢ per hour.

Number of Men Loading	Large Load				Average Load			
	Sand		Gravel		Sand		Gravel	
	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men
TIMES OF LOADING AND DUMPING								
	min.	min.	min.	min.	min.	min.	min.	min.
Teamster	68.2	50.1	98.2	71.1	70.1	52.2	100.5	73.5
One man	90.0	65.7	130.0	93.6	92.0	68.2	132.5	96.5
One man and Teamster	50.4	38.3	70.7	52.6	52.7	40.8	73.5	55.5
Two men	62.1	47.2	87.5	65.0	64.8	50.1	90.8	68.4
Two men and Teamster	45.7	35.7	62.8	47.7	48.5	38.6	66.2	51.1
Three men	54.2	42.2	74.6	56.5	57.2	45.5	78.5	60.4
Three men and Teamster	44.3	35.2	60.0	46.3	47.4	38.5	63.8	50.2
Four men	51.2	40.5	69.4	53.4	54.6	44.2	73.6	57.8
Four men and Teamster*	44.3	35.7	59.0	46.3	47.7	39.4	63.3	50.7
Five men*	50.2	40.3	67.0	52.4	53.8	44.4	71.7	57.3
COSTS OF LOADING AND DUMPING								
	$	$	$	$	$	$	$	$
Teamster	0.301	0.221	0.434	0.313	0.310	0.231	0.444	0.325
One man	0.398	0.290	0.575	0.414	0.407	0.301	0.586	0.426
One man and Teamster	0.223	0.169	0.312	0.232	0.233	0.180	0.325	0.245
Two men	0.274	0.209	0.387	0.287	0.286	0.221	0.401	0.302
Two men and Teamster	0.202	0.157	0.278	0.211	0.214	0.171	0.293	0.226
Three men	0.240	0.186	0.330	0.250	0.253	0.201	0.347	0.026
Three men and Teamster	0.196	0.156	0.265	0.205	0.209	0.170	0.282	0.222
Four men	0.226	0.179	0.307	0.236	0.241	0.195	0.325	0.255
Four men and Teamster*	0.196	0.157	0.261	0.205	0.211	0.174	0.280	0.224
Five men*	0.222	0.178	0.296	0.232	0.238	0.196	0.317	0.253

*Maximum number of men that can shovel into one cart without being in each other's way.

Note—Capacity of Carts

Large load of gravel, 33½ cubic feet, loose measurement.
Average load of gravel, 27 cubic feet loose measurement.
Large load of sand, 35½ cubic feet loose measurement.
Average load of sand, 29½ cubic feet, loose measurement.

TABLE 52. TIMES PER CUBIC YARD OF LOADING AND HAULING SAND AND GRAVEL (See p. 244)

Times given are times per one man and include allowance for rest and necessary delays occurring throughout the day.

17 miles travel for horse per 10-hour day.

GRAVEL

Number of Men Loading	Size of Load	Distance Hauled									
		¼ Mile		½ Mile		¾ Mile		1 Mile		1¼ Mile	
		Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men
		min.	min.	min.	min.	min.	min.	min.	min.	min.	min.
Teamster	large	126	99	154	128	182	157	211	186	239	215
	average	136	109	171	145	207	180	242	216	278	264
One man	large	158	122	186	150	214	180	243	208	271	237
	average	168	132	203	167	239	203	274	226	310	287
One man and teamster	large	99	81	128	110	156	140	188	183	230	225
	average	109	91	145	126	180	171	230	224	282	277
Two men	large	115	93	145	122	174	153	208	196	250	238
	average	127	104	162	159	199	184	243	237	297	290
Two men and teamster	large	91	76	120	105	155	146	198	189	240	231
	average	103	85	137	124	183	177	237	230	290	283
Three men	large	103	85	132	113	166	155	208	198	250	241
	average	114	102	150	133	196	186	250	239	301	292
Three men and teamster	large	88	75	117	108	158	150	200	193	240	236
	average	98	85	137	128	189	181	243	234	295	287
Four men	large	100	82	129	115	168	158	210	201	252	243
	average	110	93	146	136	200	189	252	242	304	295
Four men and teamster*	large	88	75	119	111	162	154	204	196	247	239
	average	100	86	142	132	195	185	248	238	300	290
Five men*	large	96	81	126	118	170	160	211	200	253	246
	average	108	92	150	138	202	191	255	244	308	297

SAND

Number of Men Loading	Size of Load	¼ Mile Average Men	¼ Mile Quick Men	½ Mile Average Men	½ Mile Quick Men	¾ Mile Average Men	¾ Mile Quick Men	1 Mile Average Men	1 Mile Quick Men	1¼ Mile Average Men	1¼ Mile Quick Men
Teamster	large	95	77	122	104	149	131	176	160†	202	201
	average	103	84	136	117	169	150	202	193	244	244
One man	large	117	92	144	119	171	146	198	177†	224	217
	average	125	100	158	133	191	166	224	209	266	258
One man and teamster	large	78	65	105	92	134	129	175	170	214	210
	average	88	73	120	106	160	154	208	202	256	251
Two men	large	89	74	115	101	144	139	184	179	224	219
	average	98	82	130	115	171	163	220	212	268	260
Two men and teamster	large	72	62	100	94	137	134	177	174	218	214
	average	81	71	116	110	165	159	212	207	262	255
Three men	large	82	69	109	101	146	141	186	181	227	221
	average	90	78	125	117	172	165	222	214	270	262
Three men and teamster	large	70	62	100	97	140	137	181	178	221	218
	average	80	71	120	114	170	162	217	210	266	259
Four men	large	78	67	107	103	148	143	188	183	229	224
	average	88	76	127	119	175	168	223	216	273	265
Four men and teamster*	large	71	62	104	100	144	140	184	181	225	221
	average	80	72	122	117	172	165	220	213	269	262
Five men*	large	78	67	111	105	151	145	191	186	231	226
	average	87	77	130	122	178	170	226	218	273	267

*It was found that 5 men was the greatest number that could shovel into one cart without being in each other's way.

†Long haul.

All values to the left of the heavy line are computed for short haul and those to the right for long haul.

TABLE 52. LOADING AND HAULING—Continued

Capacity of Carts.
Large load of gravel, 33½ cubic feet loose measurement.
Average load of gravel, 27 cubic feet loose measurement.
Large load of sand, 35½ cubic feet loose measurement.
Average load of sand, 29½ cubic feet loose measurement.

GRAVEL

DISTANCE HAULED

1½ Mile		1¾ Mile		2 Mile		2½ Mile		3 Mile		4 Mile		5 Mile	
Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men
min.	min.	min.	min.	min.	min.	min.	min.	min.	min.	min.	min.	min.	min.
267	255†	296	296	341	341	427	427	513	513	684	684	855	855
317	317	370	370	423	423	529	529	635	635	846	846	1058	1058
299	278†	328	319	373	364	459	449	545	534	716	705	887	875
349	340	402	393	455	446	561	552	667	657	878	869	1090	1081
272	268	315	311	358	353	444	439	530	524	701	695	872	865
334	330	387	383	440	436	546	541	652	647	863	859	1075	1070
292	281	335	324	375	366	461	451	547	537	718	707	889	878
351	343	405	395	458	448	564	554	670	660	881	872	1093	1083
282	274	325	317	365	359	451	445	537	530	708	700	879	871
341	336	395	388	448	441	554	547	660	653	871	865	1083	1076
292	283	335	326	377	369	465	454	549	539	720	710	891	880
354	345	407	398	460	451	564	557	672	662	883	874	1095	1086
284	278	327	321	369	364	455	449	541	534	712	705	890	881
347	340	400	393	453	446	559	551	665	657	876	869	1088	1081
295	286	337	329	379	371	465	456	551	542	722	712	893	883
357	348	410	400	463	453	569	559	675	665	886	877	1098	1088
289	282	331	324	373	367	459	452	545	538	716	708	887	879
352	343	404	396	457	449	563	555	669	661	880	872	1092	1084
296	288	339	331	381	374	467	459	553	544	724	715	895	885
360	350	412	403	465	456	571	562	677	667	888	879	1100	1091

SAND

241	241	281	281	321	321	402	402	483	483	645	645	806	806
292	292	340	340	388	388	485	485	582	582	775	775	968	968
263	257	303	297	343	338	424	418	505	498	667	659	828	820
314	306	362	355	410	403	507	500	604	597	797	790	990	984
253	250	293	290	333	331	414	411	495	492	657	653	818	813
304	299	352	348	400	396	497	493	594	590	787	783	980	977
265	259	305	300	345	340	426	420	507	501	669	662	830	823
316	308	364	357	412	405	509	502	606	599	799	793	992	986
258	255	298	295	338	335	419	416	500	496	662	657	823	818
310	304	358	352	406	401	503	498	600	594	793	788	986	982
267	262	307	302	347	342	427	423	508	503	670	664	831	825
317	311	366	359	415	408	512	504	609	601	802	795	995	989
262	258	302	298	342	339	423	419	504	500	666	661	827	821
314	307	362	356	410	404	507	501	604	598	797	791	990	985
269	264	309	304	349	344	430	425	510	505	672	666	833	827
321	313	369	361	417	410	514	507	611	604	804	797	997	991
265	261	305	301	345	342	426	422	506	503	668	664	829	824
317	310	365	359	413	407	510	504	607	601	800	794	993	988
271	266	311	306	352	347	432	427	513	507	674	669	835	830
323	315	371	364	419	412	516	509	613	606	806	800	999	993

If the travel of the team is 20 miles per 10 hours instead of 17 miles multiply the above values by 0.85.

If the travel of the team is 17 miles per 8 hours instead of per 10 hours multiply the above values by 0.80.

TABLE 53. COSTS PER CUBIC YARD OF LOADING AND HAULING SAND AND GRAVEL (See p. 244)

Costs include foreman for each gang of 13 men plus 15 per cent for superintendence, overhead charges, etc., but do not include office expenses or profit.
Labor 20¢ per hour. 17 miles travel for horse per 10 hour day.

GRAVEL

Number of Men Loading	Size of Load	¼ Mile Average Men	¼ Mile Quick Men	½ Mile Average Men	½ Mile Quick Men	¾ Mile Average Men	¾ Mile Quick Men	1 Mile Average Men	1 Mile Quick Men	1½ Mile Average Men	1½ Mile Quick Men
		$	$	$	$	$	$	$	$	$	$
Teamster	large	0.56	0.44	0.68	0.57	0.81	0.69	0.93	0.82	0.99	0.95
	average	0.60	0.48	0.76	0.64	0.92	0.79	1.07	0.95	1.23	1.17
One man	large	0.70	0.54	0.82	0.63	0.95	0.80	1.07	0.92	1.20	1.05
	average	0.74	0.58	0.90	0.74	0.99	0.90	1.21	0.99	1.37	1.27
One man and teamster	large	0.44	0.36	0.57	0.49	0.69	0.62	0.83	0.81	1.02	0.99
	average	0.48	0.40	0.64	0.56	0.79	0.76	1.02	0.99	1.25	1.22
Two men	large	0.51	0.41	0.64	0.54	0.77	0.77	0.91	0.86	1.10	1.05
	average	0.56	0.46	0.72	0.70	0.88	0.81	1.07	1.05	1.31	1.28
Two men and teamster	large	0.40	0.37	0.53	0.46	0.69	0.65	0.87	0.83	1.06	1.02
	average	0.46	0.38	0.61	0.55	0.81	0.78	1.05	1.02	1.28	1.25
Three men	large	0.46	0.38	0.58	0.50	0.73	0.69	0.91	0.87	1.10	1.07
	average	0.50	0.45	0.66	0.59	0.87	0.82	1.17	1.06	1.33	1.29
Three men and teamster	large	0.39	0.33	0.52	0.48	0.70	0.66	0.88	0.85	1.06	1.04
	average	0.43	0.38	0.61	0.57	0.86	0.80	1.07	1.03	1.30	1.27
Four men	large	0.44	0.36	0.57	0.51	0.74	0.70	0.92	0.88	1.11	1.07
	average	0.49	0.41	0.65	0.60	0.88	0.83	1.11	1.07	1.34	1.30
Four men and teamster*	large	0.39	0.31	0.53	0.49	0.72	0.68	0.90	0.86	1.09	1.06
	average	0.44	0.38	0.63	0.58	0.86	0.82	1.10	1.05	1.33	1.28
Five men*	large	0.42	0.36	0.56	0.52	0.75	0.71	0.93	0.88	1.12	1.09
	average	0.48	0.41	0.66	0.61	0.89	0.84	1.13	1.08	1.36	1.31

SAND

Number of Men Loading	Size of Load	¼ Mile Average Men	¼ Mile Quick Men	½ Mile Average Men	½ Mile Quick Men	¾ Mile Average Men	¾ Mile Quick Men	1 Mile Average Men	1 Mile Quick Men	1½ Mile Average Men	1½ Mile Quick Men
Teamster	large	0.42	0.34	0.54	0.46	0.66	0.58	0.78	0.71	0.89	0.88
	average	0.46	0.31	0.60	0.52	0.75	0.66	0.89	0.85	1.08	1.08
One man	large	0.52	0.41	0.64	0.53	0.76	0.64	0.87	0.78	0.99	0.95
	average	0.55	0.44	0.70	0.59	0.84	0.73	0.99	0.92	1.18	1.14
One man and teamster	large	0.34	0.29	0.46	0.41	0.59	0.57	0.77	0.75	0.95	0.93
	average	0.39	0.32	0.53	0.47	0.71	0.68	0.92	0.89	1.13	1.11
Two men	large	0.39	0.32	0.51	0.45	0.64	0.61	0.81	0.79	0.99	0.97
	average	0.43	0.36	0.57	0.51	0.76	0.72	0.97	0.94	1.18	1.15
Two men and teamster	large	0.31	0.27	0.44	0.41	0.61	0.59	0.78	0.77	0.96	0.95
	average	0.36	0.31	0.51	0.49	0.73	0.70	0.94	0.91	1.16	1.13
Three men	large	0.36	0.31	0.48	0.45	0.65	0.62	0.82	0.80	1.00	0.98
	average	0.40	0.35	0.55	0.52	0.76	0.73	0.98	0.95	1.19	1.16
Three men and teamster	large	0.31	0.27	0.44	0.43	0.62	0.61	0.80	0.79	0.77	0.96
	average	0.35	0.31	0.53	0.50	0.75	0.72	0.96	0.93	1.18	1.14
Four men	large	0.35	0.30	0.47	0.46	0.65	0.63	0.83	0.81	1.01	0.99
	average	0.39	0.34	0.56	0.53	0.74	0.74	0.99	0.95	1.21	1.17
Four men and teamster*	large	0.31	0.27	0.46	0.44	0.64	0.62	0.81	0.81	0.99	0.98
	average	0.35	0.32	0.54	0.52	0.76	0.73	0.97	0.94	1.19	1.16
Five men*	large	0.35	0.30	0.49	0.46	0.67	0.64	0.84	0.82	1.02	0.99
	average	0.39	0.34	0.58	0.54	0.79	0.75	0.99	0.96	1.21	1.18

*It was found that 5 men was the greatest number that could shovel into one cart without being in each other's way.

†Long Haul.

All values to the left of the heavy line are computed for short haul and those to the right for long haul.

TABLE 53. LOADING AND HAULING—Continued

Capacity of Carts.
Large load of gravel, 33½ cubic feet loose measurement.
Average load of gravel, of 27 cubic feet loose measurement.
Large load of sand, 35½ cubic feel loose measurement.
Average load of sand, 29½ cubic feet loose measurement.

GRAVEL

DISTANCE HAULED

1½ Mile		1¾ Mile		2 Mile		2½ Mile		3 Mile		4 Mile		5 Mile	
Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men
$	$	$	$	$	$	$	$	$	$	$	$	$	$
1.18	1.13†	1.31	1.31	1.51	1.51	1.89	1.89	2.27	2.27	3.02	3.02	3.78	3 78
1.40	1.40	1.64	1.64	1.87	1.87	2.34	2.34	2.81	2.81	3.74	3.74	4.68	4.68
1.32	1.23†	1.45	1.42	1.65	1.61	2.03	1.98	2.41	2.36	3.16	3.12	3.92	3.87
1.54	1.50	1.78	1.74	2.01	1.97	2.48	2.44	2.95	2.90	3.88	3.84	4.82	4.78
1.20	1.18	1.39	1.37	1.58	1.56	1.96	1.94	2.34	2.32	3.10	3.07	3.85	3.39
1.48	1.46	1.71	1.69	1.94	1.93	2.41	2.39	2.88	2.86	3.81	3.80	4.75	4.73
1.29	1.24	1.48	1.43	1.66	1.62	2.04	1.99	2.42	2.37	3.17	3.12	3.91	3.88
1.55	1.52	1.79	1.75	2.02	1.98	2.49	2.45	2.96	2.92	3.89	3.85	4.83	4.79
1.25	1.21	1.44	1.40	1.61	1.59	1.99	1.97	2.37	2.34	3.13	3.09	3.88	3.85
1.51	1.49	1.75	1.71	1.98	1.95	2.45	2.42	2.92	2.89	3.85	3.82	4.79	4.76
1.29	1.25	1.48	1.44	1.67	1.63	2.06	2.01	2.43	2.38	3.18	3.14	3.94	3.89
1.56	1.52	1.80	1.76	2.03	1.99	2.49	2.46	2.97	2.93	3.90	3.86	4.84	4.80
1.26	1.23	1.45	1.42	1.63	1.61	2.01	1.98	2.39	2.36	3.15	3.12	3.93	3.89
1.53	1.50	1.77	1.74	2.00	1.97	2.47	2.44	2.94	2.90	3.87	3.84	4.81	4.78
1.30	1.26	1.49	1.45	1.67	1.64	2.06	2.02	2.44	2.40	3.19	3.15	3.95	3.90
1.58	1.54	1.81	1.77	2.05	2.00	2.51	2.47	2.98	2.94	3.92	3.88	4.85	4.81
1.28	1.69	1.46	1.43	1.65	1.62	2.03	2.00	2.41	2.38	3.16	3.13	3.92	3.88
1.56	1.51	1 79	1.75	2.02	1.98	2.49	2.45	2.96	2.92	3.89	3.85	4.83	4.79
1.31	1.27	1.50	1.46	1.68	1.65	2.06	2.03	2.44	2.40	3.20	3.16	3.96	3.91
1.59	1.55	1.82	1.78	2.06	2.02	2.52	2.48	2.99	2.95	3.92	3.89	4.86	4.82

SAND

1½ Mile		1¾ Mile		2 Mile		2½ Mile		3 Mile		4 Mile		5 Mile	
Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men
1.07	1.07	1.24	1.24	1.42	1.42	1.78	1.78	2.13	2.13	2.85	2.85	3.56	3.56
1.29	1.29	1.50	1.50	1.71	1.71	2.14	2.14	2.57	2.57	3.43	3.43	4.28	4.28
1.16	1.14	1.34	1.31	1.52	1.49	1.87	1.85	2.23	2.20	2.95	2.91	3.66	3.62
1.39	1.35	1.60	1.57	1.81	1.78	2.24	2.21	2.67	2.64	3.52	3.49	4.38	4.35
1.12	1.11	1.30	1.28	1.47	1.46	1.83	1.82	2.19	2.17	2.90	2.89	3.62	3.59
1.34	1.32	1.56	1.54	1.77	1.75	2.20	2.18	2.63	2.61	3.48	3.46	4.33	4.32
1.17	1.14	1.35	1.33	1.52	1.50	1.88	1.86	2.24	2.21	2.96	2.93	3.67	3.64
1.40	1.36	1.61	1.58	1.82	1.79	2.25	2.22	2.68	2.65	3.53	3.51	4.38	4.36
1.14	1.13	1.32	1.30	1.49	1.48	1.85	1.84	2.21	2.19	2.93	2.90	3.64	3.62
1.37	1.34	1.58	1.56	1.79	1.77	2.22	2.20	2.65	2.63	3.51	3.48	4.36	4.34
1.18	1.16	1.36	1.33	1.53	1.51	1.89	1.87	2.25	2.22	2.96	2.94	3.67	3.65
1.40	1.37	1.62	1.59	1.83	1.80	2.26	2.23	2.69	2.66	3.54	3.51	4.40	4.37
1.16	1.14	1.33	1.32	1.51	1.50	1.87	1.85	2.23	2.21	2.94	2.92	3.66	3.63
1.39	1.36	1.60	1.57	1.81	1.79	2.24	2.21	2.67	2.64	3.52	3.50	4.38	4.35
1.19	1.17	1.37	1.34	1.54	1.52	1.90	1.88	2.25	2.23	2.97	2.94	3.68	3.66
1.42	1.38	1.63	1.60	1 84	1.81	2.27	2.24	2.70	2.67	3.55	3.52	4.41	4.38
1.17	1.15	1.35	1.33	1.52	1.51	1.88	1.87	2.24	2.22	2.95	2.94	3.66	3.64
1.40	1.37	1.61	1.59	1.83	1.80	2.25	2.23	2.68	2.66	3.54	3.51	4.39	4.37
1.20	1.18	1.37	1.35	1.53	1.52	1.91	1.89	2.27	2.24	2.98	2.96	3.69	3.67
1.43	1.39	1.64	1.61	1.85	1.82	2.28	2.25	2.71	2.68	3.56	3.54	4.41	4.38

If the travel of the team is 20 miles per 10 hours instead of 17 miles multiply the above values by 0.85 and if the travel of the team is 17 miles per 8 hours instead of per 10 hours, multiply the above values by 0.80 providing the rates per hour are the same.

REFERENCE LIST OF GRAVEL SCREENING AND WASHING PLANTS

Location	Number and Kind of Screens	Method of Handling Material to Screens	Method of Washing	Gallons of Water Used per Minute	Method of Handling Screened Material	Number of men	Average Output Cubic Yards per Hour	Reference
Columbus, O.	2 revolving	$1\frac{1}{2}$-yard dump cars to hopper, to belt conveyor on incline to screen house	Sand washed by spiral conveyors		Gravity to storage bins, then to wagons or cars	9	40	Eng. Rec., Sept. 10, 1910, p. 295
Chicago. Ill.	4 conical revolving	Belt conveyor	Water piped to each screen		Elevated bins for stone and gravity dump hopper for fine material			Eng. Contr., June 1, 1910, p. 497
Thornton, Ill.	4 sets conical revolving	Belt conveyor	Water flowing down and through screens with the gravel and sand	500 to 700	Direct from screens to bins		150	Eng. Rec., May 14, 1910, p. 634
Herkimer, N. Y.	1 grizzly 1 revolving	Scraper bucket to inclined belt conveyor	Water flowing down chutes into revolving screen and spiral conveyors washing the sand		From screens to bins or to belt conveyor. Sand by bucket elevator to bins	14	70	Eng. Rec., May 7, 1910, p. 611
Holly, Col.	1 revolving	Wagons dumping to feeding bin	Water piped to screen	10 to 15	Direct from screen to bin	1	10	Eng. Rec., Feb. 5, 1910, p. 144
Plainfield, Ill.	4 conical revolving	Inclined belt conveyor	Water flowing down chutes into screens and by water jets on to gravel screens	500	Direct from screens to bins or carts	15	100	Eng. Rec., Jan. 15 1910, p. 94
Tippecanoe River	None	Shoveled from scow to submerged platform in old mill roll	By the natural flow of water in the roll		Shoveled			Eng. Rec., Nov. 13, 1909, p. 551

REFERENCE LIST OF GRAVEL SCREENING AND WASHING PLANTS

Location	Number and Kind of Screens	Method of Handling Material to Screens	Method of Washing	Gallons of Water Used per Minute	Method of Handling Screened Material	Number of Men	Average Output Cubic Yards per Hour	Reference
Yonkers, N. Y.	2 inclined	Shoveled to chute at top of plant	Water flowing down chute and through screens with gravel and sand, sand washed in box.		Direct from screens to bins or carts		20	Eng. Rec., June 26, 1909, p. 805
R. F. & P. R.R.	2 double inclined	Steam shovel to cars to inclined conveyor	Water flowing down chutes and through screens with gravel	800	Direct from screens to bins	8	120 to 150	Eng. News, Apr. 15, 1909, p. 406
Pleasant Lake, Ind.	4 inclined	Dump cars to hopper	Water flowing down chutes and through screens with gravel	2400	Direct from screens to cars		400	Eng. Rec., Mar. 20, 1909, p. 316
South Memphis, Tenn.	4 inclined	From barges by overhead carrier	Water flowing down chutes and through screens with gravel	1500	Direct from screens to elevated bins		200	Eng. Rec., Mar. 20, 1909, p. 316
St. Charles, Ill.	1 conical rotary and 4 flat	Inclined belt conveyor	Water flowing down chutes and through screens		Chutes from screens to bins		60	Eng. News, Aug. 1, 1907, p. 105
Horatio, Ark.	None	Dump cars	Spiral conveyors in tanks with the gravel and water		Bucket conveyors to bins		125	Eng. News, Apr. 1, 1907, p. 105

CHAPTER XI

LABOR OF HAND MIXING

Although upon all extensive operations concrete is now mixed by a machine, hand mixing is necessary and may be even economical under certain conditions, (1) where the quantity of concrete is so small as to prohibit the expense of purchasing or renting a mixer, (2) where concrete is laid in so thin a layer or at so many different places that the cost of the frequent moving of a mixer counterbalances the saving otherwise realized, and (3) in beginning large jobs before the machinery has arrived or where the work is slow at the start. The cost by hand mixing, therefore, should be estimated not only when it obviously is the only method to use, but also to determine whether hand work may not be the cheaper.

Notwithstanding that comparative tests have usually shown machinery-mixed concrete to be the stronger, with careful superintendence, hand mixing will give first-class results. Concrete of wet consistency, soft enough to flow sluggishly, such as is used in building construction, is less easily worked by hand than a mixture of stiffer plastic consistency.

The cost of mixing by hand varies with local conditions, but when, as is usually the case on any particular job, the local characteristics are known, it is possible to estimate the cost very closely instead of making it a matter of mere guess. To be sure, the experienced engineer or contractor may guess quite accurately, but almost anyone will fall down once in a while and make a mistake which may amount to a large percentage of the cost, enough to make a difference between profit and loss, when conditions are different from those with which he is familiar. With the proper data at hand, it is just as easy and takes no more time to estimate accurately than to study the problem carefully enough to hazard a guess which will include all of the variables.

The tables in this chapter furnish means for estimating the cost of the labor of mixing concrete by hand under almost any conditions that are likely to be met with in practice.

The principal table, Table 55, (p. 312), gives costs and also times for mixing concrete under various conditions, the different operations being sub-divided so that the proper units to use on any particular job may be selected and combined. The different parts of the table are described more fully on page 282 and the pages which follow, and the method of using is also illustrated by examples (p. 300). A table of examples, Table 56, (p. 318), gives the times and costs for a number of selected conditions that are frequently met with in practice.

Before discussing costs in detail, methods of mixing by hand are briefly outlined (p. 272) and, on page 277, the arrangement of a number of gangs, selected from actual construction work, is given, together with their output, and this output is compared in each case with an estimate made up from the tables. Further on, the time mixing one batch of concrete is taken up in detail to illustrate the variation in time with different methods of handling the materials (p. 278). Also, in this connection, the unit operations or elements of hand mixing are considered in still greater detail (p. 290), so as to illustrate the application of unit times to the economical arrangement of a gang.

The tables presented and the method of taking up the subject are entirely different from the plan usually followed in published articles or books giving records of special jobs. In Chapters I and II, selected cost data of this kind are presented, but these or similar records are of comparatively little value because they seldom apply exactly to another job and, even if the costs are separated into units, it is difficult to pick out the proper ones for any other case. Furthermore, there is no means of knowing whether the records happen to be for average conditions or for an unusual case where, for some unexplained reason, the costs are higher or lower than the average.

By the methods adopted by the authors, the work is not only separated into elements or units but each unit is an average time or cost, based on records from a number of jobs, and is on the same basis as all the other units. To satisfy any ordinary local conditions, therefore, the proper units may be selected and combined directly. A set of values for quick men working under good conditions provides for exceptional cases and furnishes a basis for the introduction of piece-work or some similar method of remuneration. Furthermore, if conditions upon any particular job are extraordinary, as in work in the tropics, or in other places where labor is very inferior, the values can be corrected by an estimated ratio, using, however, the same ratio to apply to all the various items.

METHODS OF MIXING BY HAND

The strength of hand-mixed concrete is but little affected by the system employed in mixing the materials, provided they are turned in a proper manner and a sufficient number of times to incorporate them thoroughly. Some engineers prefer to make the cement and sand into a mortar, while others do not add the water until the final turning. Excellent work is produced by both methods but the latter is slightly more economical because shoveling the mortar on to the stone involves more labor than handling the dry mixed cement and sand. For example, comparative tests show that it costs less to mix the cement and sand dry, shovel the mixture on to the stone, and turn three times than to make a mortar, shovel it on to the stone, and turn only twice. Still other methods are sometimes employed, so that they all may be summarized as follows:

(1) Cement and sand mixed dry and shoveled on to the stone or gravel, leveled off, and wet as the mass is turned.*

(2) Cement and sand mixed dry, and the stone or gravel dumped on top of it, leveled off, and wet as the mass is turned.

(3) Cement and sand mixed with water into a mortar which is shoveled on to the gravel or stone, and the mass turned with shovels.

(4) Cement and sand mixed with water into a mortar, the gravel or stone spread on top of it, and the mass turned with shovels.

(5) Gravel or stone, sand and cement, spread in successive layers, mixed slightly and shoveled into a circle or crater, water poured into the center, and the mass mixed with shovels and hoes.

The last method is applicable only where a small amount of concrete is to be mixed on the ground with no mixing platform or mortar box.

Mixing of the sand and cement must be done just before they are needed. If mixed more than half an hour in advance, the natural moisture, which all sands contain, will make the cement set and cake.

For the convenience of the inexperienced, the following directions for the work of a small gang of six men with foreman may be useful. They are given merely for illustration and must be more or less varied to suit local circumstances.

*This method is described in detail in following pages.

Directions for Mixing Concrete. Assume a gang of four men to wheel and mix the concrete, with two other men to look after the placing and ramming.

When starting a batch, two mixers shovel or wheel sand into the measuring box or barrel—which should have no bottom or top—level it and lift off the measure, leveling the sand still further if necessary. They then empty the cement on top of the sand, level it to a layer of even thickness, and turn the dry sand and cement with shovels three times, as described below, after which the mixture should be of uniform color.

While these two men are mixing sand and cement, the other two fill the stone measure about half full, then the two sand men take hold with them and complete filling it. The stone measure is lifted, the broken stone or gravel hollowed out slightly in the center, and the mixture of sand and cement shoveled on top in a layer of nearly even thickness.* A definite number of pails are filled with water and poured directly on the top of these layers, greater uniformity being thus attained than by adding the water directly from a hose. After soaking in slightly, the mass is ready for turning.

The method illustrated in Fig. 22 of turning with shovels materials which have already been spread in layers is as follows:

Two men, *a* and *b*, with square pointed shovels, stand facing each other at one end of the pile to be turned, one working right-handed and the other left-handed. Each man pushes his shovel along the platform under the pile, lifts the shovelful, turns with it, and then turning the shovel completely over, and with a spreading motion drawing the shovel toward himself, deposits the material about 2 feet from its original position. Repetitions of this operation will form a flat ridge of the material, on a line with the pile as it originally lay, and flat enough so that the stones will not roll. As soon as, but not before, a single ridge is complete, two other men, *c* and *d*, should start upon this ridge, turning the materials for the second time, as shown in the illustration, and forming as before a flat ridge and finally a level pile which gradually replaces the last. A third mixing is accomplished in a similar way.

Fig. 22 gives the position of the piles as the concrete is being turned. A portion of the original layers is shown at *p*, the ridge formed by

*Some engineers prefer to spread the stone on top of the sand and cement, while others prefer to mix the water with the sand and cement before adding them to the stone.

men *a* and *b* shoveling from pile *p* is shown at *q*, and the beginning of the ridge formed by men *c* and *d* is shown at *rr*. The third turning is not shown.

After the material has been turned twice, as described, and as soon as the third turning has been commenced, two of the mixers who have finished turning may load the concrete into barrows and wheel to place. They should fill their own barrows and, after the mass

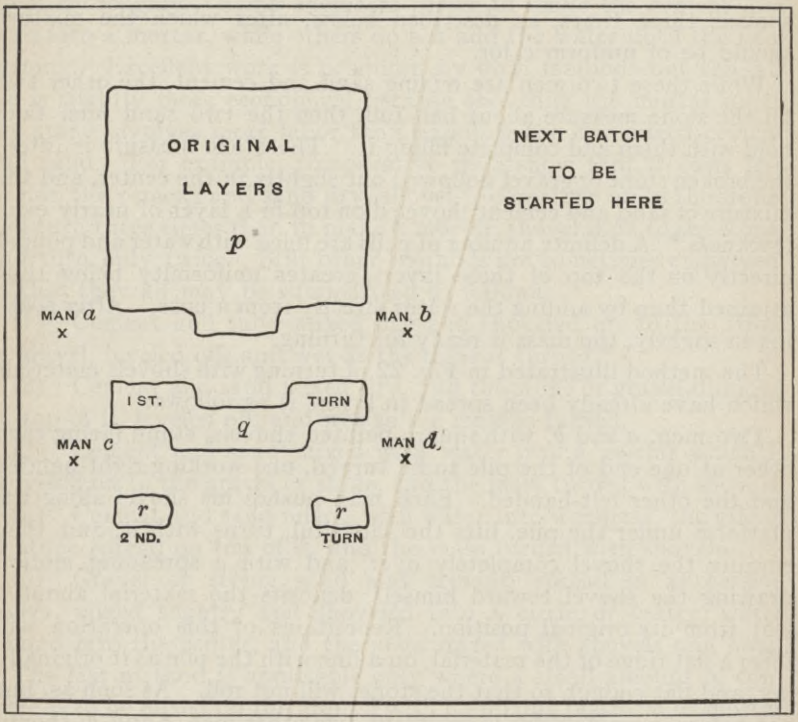


FIG. 22. Position of Men and Concrete on Platform while Turning. (*See p.* 273)

has been completely turned for the third time by the other two men, the latter should start filling the stone measure for the next batch.

If the concrete is not wheeled over 50 feet, four experienced men ought to mix and wheel on the average about $10\frac{1}{2}$ batches in ten hours. This figure is based on proportions $1:2\frac{1}{2}:5$, and assumes that a batch consists of one barrel (four bags) Portland cement with 9.5 cubic feet of sand and 19 cubic feet of gravel or stone.

Assuming, as given on page 151, that 1.30 barrels of cement are required for 1 cubic yard of concrete, one barrel of cement—that is, one batch—will make 0.77 cubic yard of concrete; hence $10\frac{1}{2}$ batches mixed and wheeled by four men in ten hours are equivalent to 8.1 cubic yards of concrete. This is for the very simplest kind of concreting and makes no allowance for the labor of supplying materials to the mixing platform or for building forms. Quantities laid under other conditions may be obtained from Table 55, page 312.

The systematic arrangement of the men in pairs and insistance upon their shoveling from the bottom of the pile and then turning their shovels completely over, are essential for thorough mixing. In the final wet mixing, the materials should be turned in this way two or three times.

For wetting the concrete, some engineers specify spraying with the hose but in practice this offers no special advantage over ordinary galvanized iron buckets, while with these the quantity can be gaged more accurately by filling the required number of buckets in advance. Nearly all the water can be poured on the dry materials before commencing to turn, and the remainder used to wet up occasional dry spots.

The quantity of water is regulated by the appearance of the concrete after placing. In a thin wall, the water will rise to the surface through successive layers so that the first batches in a day's work require the most water.

The rule may be made in hand mixing to use as much water as can be thoroughly incorporated with the materials. Concrete thus made will be so soft or "mushy" that it will run off the shovel unless handled quickly.

Placing Concrete. The concrete may be transported and handled by any means that will not cause the materials to separate. If mixed wet it may be dropped directly from shovels or barrows to place, or it may be run down in an inclined pipe or chute. The layers should be about 6 inches thick. For a dry or a jelly-like mixture, common square ended rammers are employed and the mass must be rammed until the mortar flushes to the surface. Wet concrete must be merely puddled or "joggled" to expel the air and surplus water. Before placing a fresh layer upon work which has set, the surface must be cleaned of dirt and scum, and thoroughly wet.

Methods ot Measuring Materials. In practice, cement should invariably be measured by weight, the weight being determined not by scales but by counting the packages, since bags or barrels of cement have standard weights.* A batch of ordinary size consists of four bags (or one barrel) of cement with the required proportions of sand and stone. Two bags of cement with the proper quantity of sand and stone are suitable for a small batch.

The volumes of sand and stone or other aggregate should be distinctly stated in the proportions in terms of the number of cubic feet of each material to a barrel of cement, or else by parts, coupled with the explanation that one part, or barrel, represents a definite volume, such as 3.8 cubic feet. In specifications where the proportions are given by parts with no unit of measurement, the contractor undoubtedly has the legal right to base the volumes of aggregate on the loose measurement of cement, hence the necessity for exact statement of units. (See p. 134).

For measuring the sand and stone when they have to be brought to the mixing board for hand mixing, a common contractor's wheelbarrow, although frequently used, is not exact enough for the purpose, and a special deep-bodied barrow of one of the types now on the market should be used. This can be levelled off and give definite accurate volumes for each batch (see Fig. 18, p. 220).

When the ordinary wheelbarrow is used for bringing the materials to the mixing board or when they are piled close enough to shovel direct, bottomless boxes are best for measuring both the sand and stone. Even if the materials are measured in the barrows, they have to be dumped upon a platform and spread, so the only extra labor in using the bottomless box is in lifting it after measuring, and this but little more than offsets the leveling off of the material in the measuring barrow. The bottomless box is not quite so accurate a measure as a properly designed barrow, because an unscrupulous contractor can more easily heap the materials in the box when the inspector's back is turned. For easy turning, the measuring boxes cannot be more than 8 or 9 inches deep, so that a very slight increase in the depth of the stone produces a very appreciable increase in its volume and thus a leaner concrete.

Barrels or sometimes half barrels are used for measuring occasionally, but are not so good as the other methods mentioned because more leveling is required after emptying.

The materials for the concrete ought, of course, to be deposited as

*See page 132.

near the work as possible. Since more sand and stone than cement are always used, they should be dumped nearer the mixer than the cement pile. The cement, whether it comes in bags or barrels, must be sheltered from the rain. Covering with plank is insufficient. Bags should be protected from moist atmosphere; a cellar is likely to be too damp. To keep the sand and stone as near the mixing platform as possible, it may be advantageous to haul the materials as they are required from day to day. If the sand or stone pile is at any time farther from the measuring boxes than a man can profitably throw with shovels without walking, say, more than 8 or 10 feet, the foreman should not hesitate to have it loaded into wheelbarrows and dumped into the measuring boxes. Materials can be wheeled in barrows to a distance of 10 to 25 feet from the platform at about the same cost that they can be shoveled direct with a long throw.

ARRANGEMENT OF MIXING GANGS

Distribution of Mixing Gang. Whatever the methods of mixing, the chief requisites for economy are such an arrangement of the gang that each man will have definite duties and that the men on one set of operations are of the right number to perform their work in the same length of time required by another set of men to perform a different operation or set of operations. A gang should be as large as practicable to lessen the cost of superintendence and general expense.

The best plan, where the size of the gang can be regulated to suit, is to give each man a single operation to perform. For example, let one man or set of men wheel and measure all the sand; let another set of men mix the sand and cement; let a third set be continually employed measuring the gravel or stone; a fourth mixing the mass, while one or two of their number supply water; a fifth filling the barrows and wheeling the concrete to place; and still another set leveling the concrete and ramming or puddling.

It is generally economical to have two batches of concrete in preparation at once, although one set of men usually can measure and mix the sand and cement for two mixing gangs. While one batch of concrete is being shoveled to place or wheeled in barrows, the other batch, either in a different location on the same platform or on a separate platform, may be spread and mixed.

To illustrate different arrangements of gangs in various classes of work, the number of men and the work which each has performed on several actual jobs is given below. The local conditions are briefly described, the amount of concrete laid per day is stated, and comparison made with the quantity which would be estimated from tables at the end of the chapter.

(1) Gang on a large subway tunnel, materials close at hand, the cement and sand being mixed into a mortar and spread on to the gravel before turning it; the concrete shoveled directly to place.

One foreman with 2 gangs consisting in all of 19 men, each gang divided as follows:

2 men mixing mortar.

4 men shoveling stone, mixing concrete and shoveling concrete directly to place.

1 man assisting to shovel concrete, washing gravel and other odd work.

2 men in excavation receiving concrete and ramming it.

1 extra man working with both gangs carrying water and on odd work.

This double gang mixed about 64 batches per day of 10 hours. The proportions were 1:2½:4, and, since for gravel concrete (gravel being assumed to have 40 per cent voids), we find from Table 22, on page 151, that 1.40 barrels cement are required per cubic yard, this quantity divided into 64 batches per day gives an output of about 46 cubic yards per day of 10 hours.

To compare this with the average quantity which would be estimated from our tables, we may refer to Table 55. The time of one man mixing and placing concrete as per Item (10), Column (2), is 236.9 minutes. Adding to this the time of Item (12), 12.2 minutes,—since the sand and cement were mixed into mortar,—gives 249.1 minutes per man, or for the gang of 19 men (not including foreman) a time of 13.1 minutes per cubic yard. Dividing this into 600 minutes gives 46 cubic yards per day, which corresponds exactly with the quantity actually made.

(2) Gang laying concrete on a large arch. The men building forms are not included, and the thickness of the concrete is such that little more time is required ramming than for ordinary concrete work.

One sub-foreman.

8 men, in 2 gangs of 4 men each, shoveling stone, mixing mortar, mixing concrete, and shoveling concrete.

1 man wetting concrete and helping mix.

1 boy at water valve.

2 men wheeling concrete.

2 men on odd work, breaking up barrels, picking large stone from pile, etc.

4 men placing and leveling concrete on top of brick arches.

This gang mixed 50 to 60 batches per day of 10 hours on an average.

From Table 22, page 151, assuming 45 per cent voids in the stone, a cubic yard of concrete in the proportions 1:2½:4, requires 1.46 barrels cement, which divided into 50 batches and 60 batches respectively, gives an average output of from 34 to 41 cubic yards per day of 10 hours.

Referring now to Table 55, calculating in the same way as for gang (1) and calling the mixing gang (exclusive of men wheeling concrete and doing odd work) 15½ men, assuming the sub-foreman the equivalent of 1½ men an average gang should mix about 37 cubic yards per day of 10 hours. This agrees with the average output given above.

(3) Gang for a 6-inch foundation for a street pavement. Two mixing platforms were used.

One foreman.

2 men mixing mortar in one mortar box.

4 men shoveling stone alternately into 2 measuring boxes.

4 men working alternately on the 2 mixing platforms, spreading mortar on stone, mixing concrete and shoveling to place.

3 men leveling and ramming concrete and also assisting to shovel to place.

1 man carrying water and on other odd work.

Quantity laid per day of 10 hours averaged from 40 to 46 batches. Proportions were 1:2:5, hence from Table 22, page 151, assuming 45 per cent voids in the stone, 1.39 barrels of cement are required per cubic yard. Dividing this into the number of batches per day, we find the total quantity of concrete laid ranged between 29 and 33 cubic yards per day.

From Table 55, Items (10)+(12), Column (12), we find 243.1 minutes as the average time for one man to mix one cubic yard, or, for a gang of 14 men, 17½ minutes per cubic yard. Dividing this into the number of minutes in a day, 600, gives 34 cubic yards per day of 10 hours. In this case the gang were evidently working a little below average speed.

(4) Gang laying concrete for invert of a small sewer. The gravel pile averages about 20 feet from the platform, and the average wheelbarrow haul for the concrete is about 50 feet.

2 men mixing paste.

4 men measuring gravel, mixing, and wheeling concrete.

2 men placing and ramming invert.

This gang laid about 18 batches per day of 9 hours. Proportions were 1:2:5, hence from Table 22, page 151, since gravel has about 40 per cent voids, we find 1.32 barrels cement per cubic yard of concrete, which divided into 18 batches gives $13\frac{3}{4}$ cubic yards as a regular day's work of 9 hours.

In estimating the output of this gang from Table 55, allowance must be made for several operations in addition to the mixing and placing. These may be tabulated as follows, all the times being taken from Column (12):

	Minutes
Mixing and placing, Item (10)	239.2
Add for mixing sand and cement into a mortar, Item (12)	3.9
Add for wheeling concrete 50 feet, Items (22) + (23)	29.2
Add for forming small invert by templet, Item (20)	20.0
Add for extra ramming in small invert or arch, Item (21)	9.7
Total time	302.0

For a gang of 8 men, this amounts to 37.75 minutes per cubic yard, or dividing this into 540 minutes, gives $14\frac{1}{4}$ cubic yards per 9 hours. This is very close to the quantity regularly laid.

(5) Mixing gang on a core wall for a dike. A large mixing platform was located 30 to 50 feet distant from excavation and the cement and sand were mixed dry and spread on the stone; the concrete was wheeled in barrows.

One foreman.

1 man wheeling sand to measuring box.

2 men opening cement, mixing sand and cement dry, working alternately on the two ends of the mixing platform.

3 or 4 men shoveling gravel into bottomless box, working alternately at each end of platform.

6 men mixing concrete (turning it 3 times) working alternately at each end of the platform.

2 water men.

4 men wheeling concrete, each filling his own barrow.

4 men leveling and ramming.

Average quantity laid per day of 10 hours was about 65 batches, with a maximum of about 90 batches. The proportions were 1:2:5, and, since, from Table 22, page 151, 1.32 barrels of cement are required per cubic yard where the stone has 40 per cent voids, the average quantity of concrete laid per day was about 49 cubic yards, and the maximum quantity about 68 cubic yards per day.

To compare this output with an estimate, reference must be made again to Table 55. Since the concrete was wheeled an average distance of about 40 feet, the time of this must be added to the mixing. From Table 55, Column (12) we have

	Minutes
Mixing and placing, Item (10)	239.2
Wheeling concrete 25 feet, Item (22)	25.3
Wheeling additional 15 feet, Item (23) $\frac{15}{25} \times 3.9$	2.3
Total time	266.8

For the gang of $22\frac{1}{2}$ men, this is equal to 11.9 minutes per cubic yard, or, dividing this into 600 minutes, gives $50\frac{1}{2}$ cubic yards per day of 10 hours. This agrees within $1\frac{1}{2}$ yards with the average work accomplished.

(6) Another gang made up substantially like gang (5), but consisting of exceptionally well trained Italian laborers under a hustling foreman, averaged about 90 batches, or 68 cubic yards per day of 10 hours.

As stated above, an average day's work for such a gang, estimated from Table 55, is $50\frac{1}{2}$ cubic yards of concrete, but reference to the "Quick" column of the same table shows what quick men working under the best conditions should do.

Referring then to Column (13) and using the same items as in the estimate for gang (5), namely (10), (22) and (23), we have $167.0 + 17.7 + \left(\frac{15}{25} \times 2.7\right) = 186.3$ minutes per man or 8.3 minutes per gang of $22\frac{1}{2}$ men per cubic yard. This is equivalent to 72 cubic yards per day. Gang (6) was therefore working at nearly the maximum speed which could be expected with well arranged contract work.

The observations upon the gangs described above do not represent unusual work. They were selected at random and the comparisons with our table were not made until after they were tabulated. Those who are not familiar with concrete work may obtain from them an idea of the general practice followed by contractors. As will be seen by noticing the variation in the distribution of the gang where the conditions are similar, the work in some cases could have been done more economically by dropping a man or changing a man from one place to another.

On page 306, are tabulated the estimated performances of average gangs under specified conditions.

DESCRIPTION OF TABLES OF LABOR OF HAND MIXING

The purpose of the tables has been referred to at the beginning of the chapter. For an approximate estimate, Table 56, page 318, is convenient for selecting times and costs under definitely assumed conditions. The items in this table illustrate also the variation in cost which must be expected in work of the same men when the conditions on the particular job vary.

Table 55, page 312, from which Table 56 is made up, gives the times and costs of the different unit items which may be combined to suit the job under consideration, and should be used ordinarily for making an estimate of time or cost.

The times and costs in this table are made up from averages based on more than twenty-five actual jobs, each one of which was subdivided into its elementary or unit operations, thus making allowance for differences in conditions and methods. The times of the separate detail units were obtained by stop-watch observations, and these elementary or unit times were carefully checked in the usual manner by summing them up and comparing them with the number of cubic yards of concrete actually laid per day by the various gangs. The general plan followed is described in more detail in Chapter IV, page 68, and illustrated on page 290.

Divisions of Table 55. For convenience in selecting the items to use for any required conditions, the table is divided into several principal divisions, including:

Mixing and Laying Concrete.
Transporting Concrete in Barrows and Carts.
Handling Stone and Gravel by Carts.
Handling Sand by Carts.
Handling Cement.
Screening Sand and Gravel.

The way to use the items under each of these divisions is described in detail on page 291.

Values Based on Per Cubic Yard of Concrete. For convenience in estimating, all of the values in Tables 55 and 56 are figured in terms of per cubic yard of concrete instead of in terms of per batch of concrete or per cubic yard of material. By this plan the costs of any items selected from the proper columns may be added together directly with no correction for the proportions of concrete or the quantity of each material used.

For example, in Table 55, the cost of loading double carts with sand and hauling 100 feet with labor at 20 cents per hour, Item (32), for 1:2:4 concrete is 11.3 cents per cubic yard of concrete, *not* 11.3 cents per cubic yard of sand. Since there is 0.44 cubic yard of sand in an average cubic yard of 1:2:4 concrete, the cost per cubic yard of sand for loading and hauling 100 feet would be $\frac{11.3}{0.44} = 25.7$ cents. This value may be checked by adding to the value given for 4 men loading an average load of sand in Table 51, or 24.1 cents, the cost of hauling 100 feet, or 1.2 cents, giving a total of 25.3 cents.

Times and Costs per Batch of Concrete. The time mixing one batch of concrete is more often required than the time per cubic yard, since the time per batch affects the arrangement of the gang and therefore the output per day.

To find the time per batch based on the time of one man, the times given in Table 55 have simply to be divided by 27, the number of cubic feet in a cubic yard, and then multiplied by the number of cubic feet in a batch of concrete as obtained from Tables 24 to 26 on pages 153 to 155.

For example, the time for mixing and placing one cubic yard of 1:2:4 concrete, Item (10), is given in Table 55 as 236.7 minutes. Since from Table 25 on page 154 there are 17.2 cubic feet of concrete in a batch, the time per batch would be $236.7 \times \frac{17.2}{27} = 151.0$ minutes; or, if there are 8 men per gang, the time to mix one batch of concrete should be about 19 minutes. This change in values is readily made with the slide rule by setting 17.2 on 27 and opposite 236.7 reading 151.0.

Tables for Labor Only. Tables 55 and 56 are for labor only, with no reference to cost of materials. The items include, however, the labor of getting and transporting raw materials, so that where the sand and gravel are hauled directly from a public pit, the cost of the cement and the lumber, if forms are needed, are the only extra items. In any case, knowing the price of cement per barrel and of the sand, stone, or other aggregates per cubic yard, the cost of the materials per cubic yard of concrete can be obtained directly from Tables 29 to 36, pages 165 to 172, and where the excavating and crushing of the stone must be included in the estimate, reference may be made to Chapter IX. Forms are treated in Chapter XVI.

Proportions. Table 55 covers proportions ranging from 1:1:3 to 1:3:6, being divided into 3 sets of columns distinguished by the ratio of the quantity of sand to stone.

The necessity for separate values for different proportions may be questioned, since the cost of mixing and placing, Item (10), is so nearly alike in the different cases. However, if reference is made to the items in the lower part of the table, which apply to the transporting of the materials and the concrete and to the screening of the aggregates, it will be seen that the difference is sufficient to warrant this separation.

The cause for the variation in these latter items is due to the relative quantities of the different ingredients. This is more noticeable for the sand and stone than for the cement, since the cement is always smallest in quantity. An average 1:1:3 concrete, for example, requires 0.31 cubic yards of sand for a cubic yard of concrete, whereas a 1:3:6 concrete requires 0.47 cubic yards. The quantity of stone in the two cases, on the other hand, is the same, 0.94 cubic yard per cubic yard of concrete. If, then, the sand is an expensive part of the work and must be hauled for some distance, the variation in cost of labor with the two proportions will be considerable and should be taken into account.

In considering the items of handling materials and screening, it must be borne in mind that times and costs are given in terms of per cubic yard of concrete in place and not in terms of per cubic yard of the sand and stone. If times and costs are desired per cubic yard of the raw material, reference should be made to Table 50, page 261.

Character of Materials. The materials for the concrete, upon which the tables are based, are the ordinary materials used in concrete work, but the use of other materials of different character will affect the time and cost so slightly as to be negligible.

The tables are made out for Portland cement, as referred to in Table 55, because this is used so universally for concrete, but they also apply to Natural cement except that the cost per barrel of handling the latter is slightly lower because of the lighter weight of the packages. Unless it is hauled a considerable distance, however, —in which case reference should be made to Table 50, page 261,—

this difference will not appreciably affect the total cost of the concrete, so that the tables may be used for any cement.

The sand may be taken directly from a gravel bank or from cars or barges without appreciably affecting the cost of handling.

Either broken stone or gravel may be used for the concrete to be estimated. There is but little difference in the cost of handling broken stone and gravel unless the broken stone is to be shoveled from the top or the side of a pile, in which case the labor of handling is largely increased and reference may be made to Item (9) in Table 50, page 261. In general, the difference due to the character of the stone need not be considered in assuming the labor time or cost.

Unit Times Expressed as the Time of One Man. The size of a concrete gang depends upon the output required; the number of men in the gang, provided it is economically arranged, may make but little difference in the cost of the work. To provide for this variation in size of the gang and to make the tables more convenient to use, the times are expressed in terms of "one man." This does not mean literally that one man in the given time can accomplish the job, although this might be so, but it means that the time given is the sum of the times of all the men added together.

Thus, if on a certain operation, 4 men accomplish the result in 3 minutes, the time of one man is given as 12 minutes.

For uniformity, all of the times are carried out to tenths of minutes, although this is frequently a finer division than is really necessary.

Wages of a Horse Assumed Equal to Wages of a Man. In the time columns, the time of a horse with his cart is considered to be equal in value to the time of one man. In hauling and carting, for example, the time for a 2-horse cart with teamster is taken as three times the actual time of the team, so that the costs may be figured directly from the times, then added together, without adding the extra figures required for the different rate of pay of the teams. For example, the "time per one man" for Item (33), with 1:2:4 proportions, where the teamster loads his cart, is 32.2 minutes per cubic yard of concrete, while the time of the team with its teamster, considered as a gang, is this value divided by 3 or 10.7 minutes. In considering the transporting items when other men load, the number of men in the entire gang must be divided into the times given.

In most sections of the country the ratio given will be approximately correct. For instance, where common labor is $2.00 per day, the cost of a double cart with teamster is likely to average about $6.00 per day.

Unit Costs. The accuracy of the methods of unit costs and the principles involved are discussed more in detail on page 288.

For reasons described in preceding paragraphs, no correction is needed for gangs of different size in ordinary estimating, provided the arrangement of the gangs is fairly economical.

Wages Assumed in Cost Columns. The costs in Table 55 are figured on two different bases, at 10 cents per hour and at 20 cents per hour. Neither of these rates is selected as the proper wages to be paid in different cases because this must depend entirely upon local and economical conditions. The basis of 10 cents per hour is given simply because values from this rate are so readily converted into other rates of wages. Thus, if cost of mixing and placing with the 10-cent rate is $0.52, the cost with wages at 19 cents per hour will be $\$0.52 \times \frac{19}{10} = \$0.99$. In other words, multiply by the required rate per hour and move the decimal point one place to the left.

CARE MUST BE TAKEN NEVER TO USE THE 10¢ VALUES WITHOUT CONVERSION UNLESS WAGES TO BE PAID ARE ACTUALLY AS LOW AS THIS.

The last column in each set is based on wages at 20 cents per hour, and may be used for approximate estimates of concrete work where the wages are unknown and the required accuracy of the result is not sufficient to warrant correcting for them.

The 20 cent columns are also convenient to use with a slide rule. For example, if wages are 25 cents instead of 20 cents per hour, the cost of mixing and placing 1:2:4 concrete, Item (10), may be found by setting 20 on 25 on the slide rule, and opposite 1.05 reading 1.31.

Allowances in Figuring Cost. The cost columns in Tables 55 and 56 are obtained by multiplying the items in the columns of "Time of One Man," by the wages of a laborer per minute, including in this unit rate the wages of a foreman working with a gang of average size. In hand-mixed concrete, an average gang is taken as 13 men, this number being the actual average of a large number of gangs observed. A foreman receives higher pay than the laborers and his rate may be assumed as double the laborer's rate without appreciable error. The cost per minute for the 10 cents per hour column is therefore obtained as follows:

Laborer per hour	$0.100
One foreman to 13 laborers, $\frac{\$0.20}{13}$	0.015
Total cost per hour	$0.115

Dividing this result by 60, the number of minutes in an hour, and adding 15 per cent for superintendence, job expenses, contingencies, and use of tools, gives a rate per minute of $0.00221.

In figuring costs based on labor at 20 cents per hour, this rate is doubled, making $0.00442 per minute.

To the costs thus obtained must be added an allowance for the expenses of the central office (as distinguished from the job expenses) and profit, but no further allowance is needed for ordinary contingencies.

The rates given will not be exactly right, even with laborers' pay at wages selected, i.e., 10 cents and 20 cents per hour respectively, when the wages of the foreman are different from those assumed, or the size of the gang working under one foreman is different. The differences due to these causes, however, are so slight, being divided up among a large number of men, that they may generally be neglected. In any particular case, however, the rates may be corrected so as to apply more exactly to the particular job in question by figuring a new rate per minute, allowing for the actual number of men in the gang, the actual rate of wages paid the foreman, and, if desired, a different percentage for superintendence, job expenses, contingencies, and tools, than is given above.

For example, if the gang has 8 men instead of 13 men, and the foreman's wages are 30 cents per hour while the laborers' are 20 cents, and assuming also that the contingencies are 12 per cent instead of 15 per cent, the foreman's wage rate is divided by 8, giving a total per minute of $\left(\$0.20 + \frac{\$0.30}{8}\right) \div 60 \times 1.12 = \$0.00444$ per minute.

Average Man vs. Quick Man. The columns for "Quick Men" are based upon observations on exceptionally experienced men working hard. It was found by averaging a large number of observations that such men accomplish the same work in $\frac{7}{10}$ of the time consumed by the average gang. Since this ratio was also found to apply to the labor of handling materials, it has been possible to adopt it as a uniform ratio between the work of average men under ordinary conditions and quick men under good conditions. For task-work special studies should be made as discussed in Chapter V.

Methods of Mixing and Handling. The methods of mixing and handling adopted in making up the unit times and costs in the tables are those most generally practised in hand-mixed concrete, and which the authors have found to produce first-class concrete in an economical manner. Methods of mixing are taken up in detail on page 272. The unit times are discussed below and the various items are taken up more in detail on page 291.

ACCURACY OF METHODS OF UNIT COST

Costs of hand-mixing are frequently tabulated in print, but almost invariably they are stated in such a way as to be nearly useless for estimating the cost of other jobs. This is because important items of information are missing or else because the conditions do not cover the operations on the other jobs. This point is illustrated in Chapter IV, page 64, where an illustration is given showing how simple changes in conditions so affect the cost of labor that in one case it may be $2.51 per cubic yard of concrete as against $0.83 in another case with the same gang and layout of work. Such variations are illustrated even more strikingly in Table 56, page 318. A careful statement of local conditions is seldom made in published literature, and consequently the wide variations in costs on different jobs are ordinarily charged to a difference in the ability of the men. While this personal element, which can only be allowed for by estimation, is of importance, the largest part of the variation, as a matter of fact, is due to causes readily explainable and which can be foreseen and allowed for.

It is evident that, to be of value, unit costs must be so presented that they can be used directly, and while it is impossible in any tables to allow for all possible differences in conditions and in relative ability of labor—any more than in estimating the cost of materials it is possible to figure in advance the exact quantities or to determine the exact prices that must be paid—labor costs can be figured by experienced men who have the proper unit costs and know the conditions under which the work is to be performed, with as close results as they can estimate the cost of materials.

To illustrate how nearly average tables may represent average conditions, take the examples of the work of several concrete gangs given in the preceding pages 278 to 281. The average quantity of concrete laid per gang varies in the different cases cited from 13¾ to 68 cubic yards and the cost per cubic yard, if figured with wages at $2.00 per day, ranges from about $0.88 to $1.53 per cubic yard, a difference of 74 per cent. On the other hand, leaving out the quick work of gang (6), the average difference between the actual labor cost and the average cost figured from the tables in this book is only 3 per cent with a maximum variation of 10 per cent. On the last job described, with gang (6), which was performed under exceptionally good conditions, the difference between the actual and the estimated cost for quick men is not more than 6%.

UNIT OPERATIONS

The foregoing discussion illustrates how necessary it is in practice, in estimating costs, to consider the work as made up of unit operations, so that, for any particular job, the right operations may be selected and the times and costs of performing these particular operations added together to apply to local conditions. Such a separation of unit operations has been made in Table 55 at the end of this chapter, so that the times and costs can be readily applied to almost any conceivable job of hand-mixed concrete. Machine mixed concrete is considered in Chapter XIII and form construction in Chapter XVI.

In hand-mixed concrete there are, in the first place, the group of operations, nearly the same for different jobs, consisting of measuring and mixing the materials and shoveling the concrete from the mixing board. These items together with the leveling and ramming, which must always be performed when concrete is laid and which do not vary with the distance the materials or concrete are transported, are arranged in Table 55, page 312, under the heading of "Mixing and Laying Concrete." The time and cost of transporting the concrete varies with the distance as well as with the vehicle, and the operations are considered under "Transporting Concrete." Below this, in the table, are the operations for handling the stone, sand, and cement in carts or wagons when they are at a distance from the mixing platform, and finally a few items on screening are given.

The general method of determining the unit times and costs is described in Chapter IV, page 66.

As a basis for the tables on hand-mixed concrete, observations, such as are described on page 290, were made with a stop-watch, and the unit times to perform each individual operation were recorded on a large number of jobs. For example, the watch was started when a gang of men began a batch of concrete and the time recorded for loading barrows, wheeling, dumping into measuring box, wetting, leveling, dumping the cement, mixing the cement and sand, turning the concrete, and so on; at the same time information being noted on the number of shovelfuls, the time filling and throwing one shovel-

TABLE 54. AVERAGE NET AND ACTUAL UNIT TIMES OF MIXING CONCRETE PER 4-BAG BATCH (See p. 290)

Net times are averages of original observations.

Actual times include allowance for rest and necessary delays occurring throughout the day.

Item	Unit Operations	Unit times of one man per barrel of material		Times of one man per 4-bag batch for 1:2:4 mix	
		Net	Actual	Net	Actual
		min.	*min.*	*min.*	*min.*
(1) a	Fixing, and removing bottomless box, and leveling gravel or stone	1.35	1.73	5.4	6.9
(1) b	Shoveling gravel or stone to bottomless box	3.68	4.71	14.7	18.8
(1) c	Wetting gravel or broken stone	0.59	0.75	2.4	3.0
(2) a	Fixing and removing measure for sand	0.30	0.38	0.6	0.8
(2) b	Shoveling sand into measure	3.00	3.84	6.0	7.7
(3) a	Getting cement from pile	2.23	2.85	2.2	2.9
(3) b	Opening cement	1.33	1.70	1.3	1.7
(3) c	Emptying cement	2.69	3.45	2.7	3.4
(4)	Mixing sand and cement (turn 3 times)	2.00	2.56	6.0	7.7
(5)	Spreading sand and cement on stone	1.09	1.39	3.3	4.2
(6)	Wetting and mixing concrete (3 turns)	3.40	4.35	23.8	30.4
(7)	Shoveling concrete to places or to barrows	1.76	2.25	12.3	15.8
(8)	Leveling and tamping concrete	4.30	4.77	30.1	33.4
(9)	Carrying water and other miscellaneous work	1.04	1.33	7.3	9.3
	Total time mixing and placing	28.76	36.06	118.1	146.0

ful, and other small details. To illustrate the arrangement of different gangs and the time it takes under average conditions to perform different parts of the work, Table 54, page 290, has been prepared. This is made up from the same unit times as the more extensive tables at the end of the chapter.

The original time observations were divided into units even finer than are shown in the tables in order to distinguish the small operations and to separate in each case the time lost between operations from the actual time working, so that the averages on the different jobs might be made up from net times and then a percentage added for time necessarily lost through resting or unavoidable delays. This percentage was found by a comparison of the sum of the *net* times on any job with the *total* time as shown by the average results of the total day's work, which were carefully noted in every case. The times and costs, therefore, are actual averages and not theoretical computations. Finally, the results obtained were carefully checked by comparing them with the outputs on a number of jobs. A few of such comparisons are summarized on pages 278 to 281. To still further confirm the final values, which are based on the authors' own records, the results were submitted to several expert concrete men for criticism and checking.

UNIT OPERATIONS OF MIXING CONCRETE IN TABLE 55

The operations of mixing and placing concrete usually can be considered in a group, covering Items from (1) to (9) inclusive, which embraces the process of measuring, mixing, shoveling to place, leveling, and ramming. Since these operations are necessary in almost all work of hand-mixed concrete, the values for these 9 items are added together as Item (10). In certain cases changes or additions are required, as indicated in Items (11) to (21) inclusive, while on most jobs there is extra work transporting concrete or handling the materials, which is taken up in the subsequent items.

All of these items are discussed in paragraphs which follow, in which case direct reference is made to Table 55, page 312, while the illustrations in general refer to 1:2:4 concrete.

Measuring Stone and Sand. There is comparatively little difference in time between the various methods of measuring the stone and sand if the gang is arranged so that the men are all working steadily. Only one case therefore is considered and given in Items (1) and (2). It is somewhat quicker to measure in bottomless boxes than in barrels because the height of lift is less and there is less labor in spreading the materials ready to mix. For example, while the time shoveling a 4-bag batch of stone for 1:2:4 concrete from a pile close to mixing platform into a bottomless box—with no allowance for delays—is about 15 minutes for one man, the time filling the same quantity into barrels is over 20 minutes. It takes longer also to lift up the barrel and spread out the stone than to lift away the shallow bottomless boxes.

The item of measuring and wetting stone includes not only filling the measure but placing it, leveling off the stone, and removing the measure.

Usually a job of hand-mixing can be arranged so that the piles of stone and sand are near enough to the mixing platform for the materials to be readily thrown into the measure. If not, wheelbarrows may be used and the materials dumped into measuring boxes or, by using barrows of special shape (see p. 221) which can be leveled off, the materials can be measured directly in the barrows. If measured in barrows, it has been found by observation that the pile may be 25 feet away without the labor costing appreciably more than shoveling direct from the pile to the mixing box and then removing the mixing box when filled.

If the sand or stone must be wheeled more than 25 feet, reference may be made to Items (16) and (17). Thus when making 1:2:4 concrete, if both the sand and stone have to be wheeled 50 feet, the extra cost, with labor at $2.00 per day, of $0.012 + $0.005 must be added to the total labor of mixing in Item (10), giving $1.062 per cubic yard of concrete instead of $1.045.

Getting and Emptying Cement. Only one item is given for this instead of giving variables for different distances, because the total is small in any case unless the material is handled by carts or wagons. In such cases, the items in the lower part of the table may be used.

Mixing Sand and Cement. Item (4) assumes that the sand and cement are turned with shovels 3 times to mix dry, as this has been found to do the work satisfactorily. If it is turned 4 times, one-third may be added to the cost of this item, which increases the cost of the total only a little over one cent per cubic yard of concrete.

Spreading Sand and Cement on Stone. Items (5) and (6) apply to one particular method of mixing, which, as indicated at the head of the table, assumes the sand and cement to be mixed dry and spread on the stone or gravel, then the concrete turned and wet as it is being turned. The difference in time and cost by other methods is illustrated in Items (11), (12), and (13), which show the values to be added to or deducted from the totals if mixed by other methods. This is illustrated more in detail on a following page, which analyses the difference in cost of different methods of mixing.

Wetting and Mixing Concrete. Item (6) assumes that the concrete is turned three times. If 4 turns are required, the cost of this particular item will be increased one-third and this excess cost may be added to the total. Other methods of mixing are referred to in the preceding paragraph.

Shoveling Concrete to Place. If the men do not need to walk with their shovels, it makes comparatively little difference whether the concrete is shoveled from the mixing platform to place or into barrows or buckets. A difference in height or length of throw increases very quickly the time and the cost. For example, if the concrete is thrown into carts, the times and costs for this particular item will be about 50% greater than given, in addition to the time of cart and teamster waiting for the load.

It is cheaper to wheel the concrete even a short distance than to carry it on shovels. Thus, if it is carried on shovels a distance of 14 feet, which is about a maximum, Item (18) shows that the cost for 1:2:4 concrete, with labor at 20 cents per hour, is increased about 16 cents per cubic yard. By comparison with items (22) and (23), it is evident that the concrete could be wheeled a distance of nearly 100 feet at the same cost as carrying it on shovels 14 feet.

Leveling and Tamping. With wet concrete, the labor of leveling and tamping is small. Item (8) gives the times and costs under ordinary conditions. If the concrete is laid very dry, so as to require extra tamping, the extra cost may be obtained from Item (19), while if placed in a small culvert or arch, the extra work is represented in Items (20) and (21).

Difference in Cost Due to Different Methods of Mixing. Several methods of mixing concrete are outlined on page 272. The one mentioned first is more commonly employed, and for this reason and also because it is an economical method, it is the one selected for itemizing. This method consists of mixing the sand and cement dry, spreading it on the stone, and then wetting and turning at least three times. To illustrate the manner in which the difference in cost by other methods, such as are given in Items (11), (12), and (13), is obtained, we may assume that the cement and sand for 1:2:4 concrete, after being mixed dry, are mixed wet and the mortar spread on the stone or gravel and the whole mass turned twice. In this case the following items, taken from time-studies by the authors, are substituted for the sum of Items (4), (5), and (6), Table 55.

Mixing sand and cement dry, turned twice	8.4 min.
Wetting and mixing sand and cement, turned twice	20.5 min.
Shoveling mortar on the stone	16.2 min.
Mixing concrete with shovels, turned twice	29.2 min.
Total	74.3 min.

The sum of the times of Items (4), (5), and (6), for 1:2:4 concrete is 66.3 minutes, showing a saving of 8.0 minutes per cubic yard by mixing the sand and cement dry instead of into mortar. This agrees with Item (12).

TRANSPORTING CONCRETE

Hand-mixed concrete is usually shoveled to place or conveyed in ordinary wheelbarrows. If the job is large enough to warrant the use of derricks or hoists or cars, a machine mixer would be used, and for such work reference should be made to Chapter XIII. Frequently for the walls of a small building, the concrete may have to be hoisted and carried in buckets, and this is described in a separate paragraph on page 297.

Transporting materials consists of three distinct operations, namely, loading, hauling, and dumping. Frequently such work is further complicated by the arrangement of the loading gang, and sometimes also by the fact that the teamster as well as the horses stop work while the cart is being loaded. However, unless very great accuracy is desired in figuring costs, the values given in Table 55, Items (22) to (27) inclusive, may be used directly.

The problem of transporting gravel in carts is treated quite fully in the preceding chapter on Handling Materials, so as to illustrate the methods of analyzing this class of work and getting at the times and costs in an exact manner. Similar methods may be applied to the handling of concrete when a thorough analysis is required; in fact, such methods have been used by the authors in determining the values in the tables for all operations of transporting. The diagram on page 243, having been made for gravel, cannot be applied directly to transporting concrete, although the general principles are the same. If the haul of concrete is over 150 feet, it is usually more economical to haul in carts than in wheelbarrows.

The times and costs of the first 25 feet of haul of concrete as given in Items (22) and (24) in Table 55 are much greater than for the succeeding distances in the items which follow. Since the shoveling of concrete in barrows is included in Item (7), this might seem incorrect. However, it is due to the fact that the time of a wheeler placing barrow and waiting for his load, as well as the dumping and turning, are included in the time and cost of wheeling the first 25 feet, since they are practically constant for all lengths of haul. The time would be somewhat less if the wheelers loaded their own barrows, but handling concrete is such heavy work that usually it is arranged for the wheelers to rest while other men load their barrows.

Analysis of Wheeling Concrete. Although in ordinary practice the items in the table give the times and costs of wheeling as minutely as is necessary, it may be necessary in certain cases, such as piece-work, for example, to separate the times into smaller elements. An illustration is of interest, therefore, of the methods that may be conveniently applied in such cases. The time of loading the barrows is included in the operations of mixing and laying concrete, in Item (7), so that in connection with the wheeling we have only to consider the barrow work.

After wheeling 25 feet, the wheeler places his barrow, loads it or else, as we shall consider here, waits while it is being loaded by the two concrete men, then travels with full barrow 25 feet, dumps and returns the same distance. Some time is lost, not only in placing his barrow in position ready to load, but in getting started again after loading and in fixing runs, but since these may be considered as constant times per barrow, they are included in the time of dumping which therefore in itself consists of still smaller units. The operation may be conveniently expressed in a formula, in fact, formulas are frequently convenient in analyzing work to allow for the different conditions of the various units.

In addition to the actual work of loading the barrow, the work consists of:

Dumping and miscellaneous work, plus time of wheeler waiting while 2 men load barrow, plus time wheeling 25 feet with load and returning with empty barrow.

There are different ways of taking the above items. One way is to take each of the times per barrow load and then, in order to obtain the result in terms of per cubic yard of concrete, to divide by the number of cubic feet of concrete in a barrow and multiply the result by 27, the number of cubic feet in a cubic yard.

Another plan, and one more easily adaptable to conditions in general, is to express each of the operations in terms of a unit volume of concrete. For example, the dumping and miscellaneous work can be given in time per barrow load and divided by the capacity of a barrow in cubic feet; the waiting for load can be given directly in minutes per cubic foot of concrete; and the time wheeling can be given for a distance of 100 feet, and this divided by the barrow load in cubic feet and corrected by a ratio for the distance under consideration.

Taking then the operations in a formula:

Let

T = total time of labor per cubic yard transporting concrete 25 feet except the actual loading.

g = time for one man to load one cubic foot of concrete.

$\frac{g}{2}$ = time of barrow man waiting while 2 men load one cubic foot of concrete.

d = time dumping, placing barrow, etc.

v = average capacity of a barrow in cubic feet.

t = time traveling 100 feet with load and returning 100 feet with empty barrow.

$\frac{d}{v}$ = time dumping, placing barrow, etc., per cubic foot of concrete.

$\frac{t}{v}$ = time traveling 100 feet and returning per cubic foot of concrete.

27 = number of cubic feet in a cubic yard of concrete.

$$T = 27\left(\frac{d}{v} + \frac{g}{2} + \frac{25}{100}\,\frac{t}{v}\right)$$

Substituting, for the terms of the formula, values found from stop-watch observations by the authors, after adding a percentage for rest and unavoidable delays,

$$T = 27\left(\frac{0.638}{1.9} + \frac{0.916}{2} + \frac{25}{100} \times \frac{1.11}{1.9}\right)$$

$$= 27\left(0.336 + 0.458 + \frac{25}{100} \times 0.584\right) = 25.4 \text{ minutes per cubic yard.}$$

This method may seem somewhat lengthy for obtaining an apparently simple result, and yet such separation of the work into individual operations is the only way to properly compare operations where the conditions as to distance, capacity of barrow, number of men etc., vary. For example, the above formula, without any extra time observations, can be adapted to any distance, to a barrow of any ordinary capacity, and to different methods of loading. The process is really exceedingly simple, being merely a summation of the times which are obtained by observation.

The largest amount of labor involved in such determinations is in taking a sufficient number of observations of unit times, under correct conditions, so as to obtain satisfactory averages adaptable to average men and average conditions, or else, if desired, to times which may be applied to piece-work. The values given above apply to average men under average conditions, the result corresponding to the time in Table 55 for Item (22), Columns (2), (7), and (12).

The time per cubic yard of concrete for wheeling each additional 25 feet is simply

$$\left(\frac{25}{100}\frac{t}{v}\right)27$$

which, substituting values used in formula above, becomes

$$\left(\frac{25}{100}\times 0.584\right)27 = 3.9 \text{ minutes per cubic yard of concrete.}$$

The times and costs of hauling concrete in single carts are similarly made up by the analysis of the operations, the unit times being obtained by averaging a number of observations and then checking up the totals by comparison with over-all times.

HANDLING CONCRETE IN PAILS

Although carrying concrete by hand in small galvanized iron pails is expensive, it is sometimes the only convenient way in which it can be hoisted for building the walls of a small building. This is discussed in detail in Chapter XIII.

HANDLING MATERIALS

In Table 55, page 314, the hauling of stone and sand for concrete is taken up so that estimates may be readily made where the sand or gravel or broken stone is hauled from a bank or car at some distance from the work. A comparison of similar items in the different columns shows the variations in the cost of these items with the different proportions of concrete, because of the varying quantities of each ingredient.

In the previous chapter, page 232, where the items of hauling are discussed more at length, the times and costs are tabulated in terms of per cubic yard of material instead of per cubic yard of concrete.

It should be noted, as already stated, that in the tables in the present chapter the items may be added together directly without correcting for quantities of each material in a cubic yard of concrete, because they are computed directly in terms of per cubic yard of concrete. For example, the cost when making 1:2:4 concrete, of loading sand into double carts and hauling 100 feet with labor at 20¢ per hour is given in Item (32) as $0.113. This allows for the fact that there is less than half a yard of sand in a cubic yard of concrete of the given proportions, the cost of loading and hauling per cubic yard of *sand* from the table in Chapter X being $0.244. The cost of hauling per cubic yard varies inversely with the size of carts, since the *time* of hauling per mile is a constant with any ordinary load.

The loading and hauling of cement is taken up in the tables in the same way as other materials. Natural cement is not considered because it is so seldom used in concreting, but it is included in the previous chapter in Table 50, page 262.

SCREENING SAND AND GRAVEL

The screening of sand and gravel is discussed on page 227, and the tables in the present chapter are made up in similar fashion except that the values are based on the quantity of each material contained in a cubic yard of concrete instead of being in terms of a cubic yard of the material itself.

HOW TO USE TABLES

Table 55, page 312, is intended for general use, since only a few minutes' work is required to select values which will give accurate results. Table 56 page 318, is a compilation of examples, from which may be selected times and costs for certain specified conditions.

For Rough Estimates. Use Table 56, page 318, which gives examples of special conditions. This table is made up from Table 55 and gives so many series of conditions that a selection can be made directly that will fit many cases. By inspecting and comparing different values in the table, it may often admit of a close estimate even when the conditions do not exactly correspond to those given. Note that the wages are assumed at 20¢ per hour, and if other wages are to be paid, a proportionate correction must be made. Allowance has been made in the costs but not in the times, for foreman, superintendence, job expenses, contingenices, and hand tools, but no allowance has been made for home-office expense or profit. The method of making these allowances is described on page 286.

If wages are more or less than 20¢ per hour, the selected cost must be corrected in proportion. Thus, if the rate is 25¢, the cost given in the table must be increased by one-fourth. Whatever profit is assumed to be fair must also be added, allowing also for the share of the home-office expense, in case there is one. This is sometimes done by selecting a single percentage to cover both the home-office expenses and the profit in a manner described more in detail on page 286, or the profit may be considered as a percentage and the expense figured up directly for any particular job.

For Accurate Estimates. Use Table 55, which gives unit times and costs. The use of the table is illustrated in Examples, page 300, and the various items in the table are discussed on pages 291 to 294.

The general operation of making an estimate from Table 55 is as follows:

Select the proper items which apply to the job in question; add together the costs taken from the proper columns and corresponding to the selected items; correct for the rate of wages as described on page 287; add the required amount to cover home-office expenses and profit; note that contingencies are already included in the costs so that no percentage need be added for them; note also that while *times* are for laborers only, not including foreman, so as to make the times useful for estimating the work of a gang as described on page 302, the *costs do* include foreman and superintendent, as described on page 287, so that no further allowance need be made for them. In other words, the costs are all ready for use, with the exception of the addition of a percentage or a definite value to cover home-office expenses and profit.

Proportions. If the proportions of the concrete are such that the parts of stone are double the parts of sand, use the middle columns. If the parts of stone are less than double the sand, use the first set of columns. If the stone is more than double the sand, use the last set of columns.

Times versus Costs. Use the columns of cost for ordinary cost estimates unless one wishes to assume different conditions than those described on page 287.

Average vs. Quick Men. Use average times or costs for ordinary work. Use quick times for extra good men working under exceptional conditions. For piece-work or task-work, properly organized, still shorter times may be used, as described in Chapter V.

Rate per Hour. Use the 20¢ columns if wages are unknown but assumed to be approximately 20¢ per hour.

For other rates of wages, use 10¢ or 20¢ columns, correcting as described on page 287.

Selection of Items. Select the items corresponding to the work under consideration, and add together the times or costs.

HOW TO USE TABLE 55

Example 1: What would be the cost of labor per cubic yard of mixing and laying concrete in proportions 1:2:4 with labor at 25¢ per hour under the following conditions?

Concrete mixed in ordinary way except that stone is dumped on top of sand and cement before making the concrete.

Stone wheeled in barrows 50 feet.

Sand screened to remove coarse particles, then loaded into double carts and hauled 1½ miles.

Concrete shoveled to place.

Cement in bags hauled 2 miles.

Solution: This is a more complicated example than usual, and selection must be made from a number of items, using in this case the 20¢ columns as most convenient, as follows:

	COST OF LABOR AT 20¢ PER HOUR
Item (10) Total labor mixing and placing	$1.045
Item (11) Deduct for different method of mixing	0.015
Total cost of mixing and placing	$1.030
Item (16) Wheeling stone an additional 25 feet	$0.012
Item (40) Screening sand	0.076
Item (35) Loading and hauling sand 1½ miles @ $0.331	0.496
Item (37) Loading cement into wagons	0.026
Item (38) Hauling cement 2 miles @ $0.115	0.230
Item (39) Unloading cement	0.020
Total cost with wages @ 20¢ per hour	$1.890
Add 25 per cent for 25 ¢ rate	0.472
Labor cost with wages @ 25¢ per hour	$2.362
Add 10 per cent for home office expense and profit	0.236
Total cost per cubic yard	$2.598

The cost of materials may be obtained from Table 31 on page 167.

How to Use Tables for Estimating Time

The time that it will take a gang to perform any operation on a cubic yard of concrete, given in Table 55, is found by dividing the time (for average or quick men, as desired) by the number of men in the gang. If team labor is included, consider each horse with its cart as equivalent to one man.

Example 2: How many 4-bag batches of $1:2\frac{1}{2}:4$ concrete should a gang of 8 average men mix and place in 9 hours, assuming that the materials are at hand and the concrete is wheeled 25 feet?

Solution: For $1:2\frac{1}{2}:4$ concrete use the first set of columns, selecting column (2) for this particular work. The total time per one man will be the sum of Items (10) and (22) or $236.9+25.4=262.3$ minutes per cubic yard. Dividing this by the number of men in the gang gives $\frac{262.3}{8}=32.8$ minutes per cubic yard. Referring to Table 25, page 154, we find 18.5 cubic feet of concrete per 4-bag batch, hence the time of the gang per batch, since there are 27 cubic feet in a cubic yard, should be $32.8\times\frac{18.5}{27}=22.5$ minutes per batch. Dividing this into 540, the number of minutes in a 9-hour day, gives 24 batches per day.

Example 3: How many cubic yards of $1:2:4$ concrete can be mixed and laid per 9-hour day under average conditions, using gravel hauled 1000 feet in one double cart where the teamster loads alone?

Solution: Referring to Items (29) and (30) of Table 55, page 317, we have 89.9 minutes for loading and hauling 100 feet enough gravel for one cubic yard of concrete, and 1.9 minutes per hundred feet beyond the first 100 feet. Multiplying the latter by 9 gives 17.1 minutes, which added to 89.9 minutes in Item (29), gives 107.0 minutes. As the time of a horse and cart is assumed to be equal in value to the time of a man and for a double team there are two horses and a teamster, the above time must be divided by 3 to obtain the time per team, which gives 35.7 minutes per cubic yard of concrete. This divided into 540, the number of minutes in a 9-hour day, gives 15 cubic yards of concrete as the quantity for which the team can haul gravel in a 9-hour day.

This does not mean that 15 cubic yards of gravel are hauled, but only enough gravel is hauled to make the 15 cubic yards of concrete.

Example 4: What arrangement should be made to increase the quantity of gravel so as to obtain enough to make more concrete?

Solution: Reference should be made to the preceding chapter, page 249, from which the economical arrangement of the loading and hauling gang can be made. One or two more teams would naturally be added and men provided to assist the teamster in loading so that his team can make more trips.

How to Use Tables for Determining Size of a Gang to Produce a Definite Output

This problem is treated in detail in connection with the arrangement of mixing gangs, page 277.

Ordinarily it is not necessary to go into the matter in so much detail as is there described, but the gang can be approximately determined by direct reference to Table 55, page 312.

For the gang on the concrete—including leveling and ramming but not including the wheeling of the concrete or extra wheeling of the materials—the time per cubic yard of concrete gang can be obtained by dividing the time given in the proper column opposite Item (10) by the number of men in the gang. The time per day divided by the time per cubic yard will give the number of cubic yards of concrete output per day. Similarly, the approximate size of gang can be determined by dividing the time given in the table by the number of minutes which are required per cubic yard to produce the given output per day.

This is illustrated in the following example.

Example 5: How many men in a gang will be required to mix and place concrete at the rate of 27 cubic yards of 1: 2½: 5 concrete per 9-hour day?

Solution: Dividing the required quantity per day into the number of minutes in a day, 540, gives the required speed of 20 minutes per cubic yard. This divided into the time in column (7), Item (10), 236.7 minutes, gives 12 men per gang.

Example 6: In the example above, how many extra men would be required if concrete was wheeled in barrows an average distance of 150 feet?

Solution: Referring to Items (22) and (23), we have 25.4 minutes per cubic yard for the first 25 feet and $3.9 \times 5 = 19.5$ minutes for the remaining 125 feet, or a total of 44.9 minutes per cubic yard.

Dividing this into 540 minutes in a day gives 12 cubic yards for one man. Hence, since 27 cubic yards are mixed, two men wheeling concrete should handle the quantity required, provided they work about 10% faster than the average.

If the concrete had been very wet, Items (24) and (25) would have been used instead of (22) and (23), and 3 men would have been needed.

How to Use Tables for Comparing Methods

By means of the information in tables such as are given in this chapter, the advantage of one method of work over another can be determined, in many cases by inspection. For example, referring to Table 55 for 1:2:4 concrete, page 313, we see that the method of mixing presented in the first ten items is cheaper than if, according to Item (12), the sand and cement are mixed into a mortar and spread on top of the stone. On the other hand, from Item (11), if the stone is dumped on top of the sand and cement, the cost is slightly less than that given in Item (10). On page 293, the relation of the cost of carrying on shovels and of wheeling in barrows is discussed. A comparison of the times and costs of the items of transporting in wheelbarrows and carts indicates the distance to which barrow work may be economically applied. This is also shown by Fig. 20, page 243.

The discussion on page 277, giving the times of work with different gangs, shows the advantages of arranging the men so that each man will have a definite work to do.

UNIT TIMES MIXING CONCRETE BY HAND

Reference has been made (p. 66) to the methods used in determining the times which are given in the tables. As there stated, the individual or unit operations were timed on a large number of jobs, and corresponding operations of each were averaged so that they could be combined to satisfy all ordinary conditions. As an illustration of the principle, the unit times mixing concrete by hand are tabulated in Table 54, page 290, in even more detail than they are given in Table 55, page 312.

In the first two columns of figures, in order to distinguish between different proportions of cement to sand to stone, the units are given in terms of per one barrel, which, in proportioning, constitutes one part when a batch is based on one barrel, or 4 bags, of cement. To maintain the proper relations between the different items, this same unit is carried through into the mixing of the concrete. In this way the unit times per barrel can be changed into times per batch for any proportions by multiplying the unit time per barrel by the number of barrels or parts in a batch. For example, if the proportions are 1:2:4 as given in the last two columns of the table below, the times of the operations relating to stone alone, such as (1a) (1b) (1c), are multiplied by 4; the times relating to sand, such as (2a) (2b), are multiplied by 2, and those relating to cement such as (3a) (3b) (3c) are multiplied by 1, that is, they are the same per batch as per barrel. In a similar way, Items (4) and (5) are multiplied by the number of barrels of cement plus sand, that is, by 3. Items (6) (7) and (8) are applied to the concrete by multiplying by the total number of barrels of material in a batch of the given proportion, that is, by $1+2+4=7$, to obtain the time per batch.

By using the times per barrel, and multiplying by the number of parts as described in the last paragraph, the unit times per batch for any proportions of concrete can be determined.

The unit times per cubic yard may be obtained by multiplying the time per batch by the number of batches in a cubic yard. If this is unknown, reference may be made to the values in Table 25, page 154. The number of batches in a cubic yard of concrete will be the quotient of 27 (the number of cubic feet in a cubic yard) divided by the volume of concrete selected from this table.

Although the individual unit times per batch vary greatly for different proportions, it has been found by comparing figures that the total time per cubic yard for different proportions of mix are substantially alike. This may be explained by the fact that the total weight of concrete does not vary greatly with different ordinary proportions so that about the same weight of material must be handled in each case.

As usual in stating times, they are expressed in terms of the time of one man. For example, if 4 men are shoveling gravel as per Item (1b), the net time per gang per barrel will be $\frac{3.68}{4} = 0.92$.

Both sets of values, that is, the values per barrel and per cubic yard, are given net and actual. The net times are the times of the operations as actually observed with the stop-watch. As in all other classes of work, there is a certain percentage which must be allowed for rest and for the delays occurring throughout the day.

For hand-mixed concrete, it has been found that, on an average, the percentage is 28% except in the case of leveling and tamping, where the percentage is 11%, so that these percentages have been added to the net times to give the actual times. In the Tables 55 and 56 at the end of the chapter the actual times are given so as to include the necessary percentage for rest and delays.

It may be noticed that the total time of mixing when changed to time per cubic yard does not agree with the total time as given in Table 55. Items (1a) and (1b) in Table 54 are based on a bottomless box for a measure while Item (1) in Table 55 is the average time of several different methods of measuring.

ARRANGEMENT OF MIXING GANG

One use which may be made of unit times such as are given in Table 54 is in the arrangement of a gang, so that the men work to the best advantage, that is, the operations of the different men fit together so as to avoid waste time of one man waiting for another to complete his work.

The operations of hand-mixing can be fitted to almost any number of men because the operations are so small as to be readily divided among them. Gang (5) on page 280, where there are 14 or 15 men in addition to the men wheeling and ramming, is as large a number of men as can be handled satisfactorily.

To illustrate an arrangement of a gang which may be adjusted by combining the unit times, the mixing of 1:2:4 concrete with a gang of 4 men and again with a gang of 6 men is given as an example and worked out in detail in the following pages.

Gang of 4 Men Mixing. A gang of 4 or 6 men may be arranged so as to be busy practically all the time if they work according to the outline given in Examples 7 and 8. In each case, the times in the table are divided by the number of men performing the operation, so as to give the time per gang of this group; also, actual times are used in every case so that the individual times are really longer than would be obtained by timing the individual operations with a stop-watch, but, on the other hand, correspond to the times which may be maintained throughout the day.

Example 7: How many cubic yards of 1: 2: 4 concrete can a gang of 4 men mix in a day of 10 hours?

Solution: The operations taken from Table 54 are as follows:

Item (1) 2 men measuring stone in bottomless box .... $\frac{28.7}{2} = 14.4$ min.

Item (2) 2 other men measuring sand.......... $\frac{8.5}{2} = 4.2$ min.
Item (3) 2 men also getting and emptying cement .... $\frac{8.0}{2} = 4.0$ min.
Item (4) 2 men also mixing sand and cement.. $\frac{7.7}{2} = 3.8$ min.
Item (9) 2 men also on miscellaneous work .... 2.4 min.
} = 14.4 min.

4 men on miscellaneous work .... $\frac{9.3 - (2 \times 2.4)}{4} = 1.1$ min.

Item (5) 4 men together spreading cement and sand on stone.............................. $\frac{4.2}{4} = 1.0$ min.

Item (6) 4 men together wetting and mixing concrete (turning twice) .... $\frac{2}{3} \times \frac{30.4}{4} = 5.1$ min.

Item (6) 2 men mixing (3rd turn), $\frac{1}{3} \times \frac{30.4}{2}$ .... 5.1 min.
Item (7) 2 other men meanwhile shoveling concrete..... 5.1 min.
} = 5.1 min.

Item (7) 4 men finish shoveling concrete.......... $\frac{15.8 - (2 \times 5.1)}{4} = 1.4$ min.

Thus the total time including delays for the batch will be......... 28.1 min.

This gang should mix in 10 hours $\frac{600}{28.1} = 21.4$, or say, 22 batches. Since the concrete is in proportions 1:2:4, which averages 17.2 cubic feet per batch, 22 batches will make $\frac{22 \times 17.2}{27} = 14$ cubic yards of concrete, an ordinary output for 4 average men in 10 hours.

In addition to the mixers, there must also be sufficient men to level and tamp the concrete. In the present case, since 33.4 minutes are required per man for leveling and tamping and the total time of mixing per batch is 28.1 minutes, one man should be able to level and tamp. This man will be in addition to the 4 men in the mixing gang. One or more extra men, according to the distance carried, will be needed to transport the concrete to place.

Example 8: How long will it take a gang of 6 men to mix a 4-bag batch of 1:2:4 concrete and how many men will be required for leveling and tamping?

Solution: This gang will work most satisfactorily when it is divided into two sub-gangs, one of these sub-gangs made up of 4 men who handle the stone and mix the concrete, and the other sub-gang of 2 men who perform the operations relating to sand.

The operations of the 2 gangs are tabulated separately.

First Sub-Gang of 4 men:

			TIME PER GANG OF 4 MEN
Items (1a, 1b)	4 men fix measure, shovel stone to bottomless box, level and remove measure......	$\frac{18.8 + 6.9}{4} =$	6.4 min.
Item (5)	4 men spread sand and cement on stone......	$\frac{4.2}{4} =$	1.0 min.
Item (6)	4 men wet and mix concrete (2 turns)...	$\frac{2}{3} \times \frac{30.4}{4} =$	5.1 min.
Item (6)	2 men mix concrete (third turn)....	$\frac{1}{3} \times \frac{30.4}{2} = 5.1$	5.1 min.
Item (7)	2 men start shovel concrete.......	$= 5.1$	
Item (7)	4 men finish shovel concrete,.....	$\frac{15.8-(2\times 5.1)}{4} =$	1.4 min.
	Total time including delays of sub-gang per batch..................................		19.0 min.

Second Sub-Gang of 2 men:

			TIME PER GANG OF 2 MEN
Item (1c)	2 men wet gravel or stone	$\frac{3.0}{2} =$	1.5 min.
Item (2)	2 men fix and shovel sand into sand-measure and remove measure..................	$\frac{0.8 + 7.7}{2} =$	4.2 min.
Item (3)	2 men get, open, and empty cement.........................	$\frac{2.9 + 1.7 + 3.4}{2} =$	4.0 min.
Item (4)	2 men mix sand and cement................	$\frac{7.7}{2} =$	3.9 min.
Item (9)	2 men carry water and miscellaneous work ...	$\frac{9.3}{2} =$	4.7 min.
	Total time including delays of sub-gang per batch..................................		18.3

Hence time per 4-bag batch for 6 average men who also shovel concrete direct to place is 19 minutes.

For leveling and tamping, $\frac{33.4}{19} = 2$ men will be required.

Gangs of Other Size. The work for gangs with different numbers of men can be laid out in a similar fashion.

While it is often difficult to lay out the times so that each man or sub-gang will finish his or their work at the same time as the others, the lost time can be kept down to the smallest possible quantity. In practice, work is frequently arranged in a more or less haphazard fashion, so that some of the men work to poor advantage and either loaf between operations or else work very slowly. Such loafing or soldiering can be located by applying the principles outlined, and frequently when the times do not come out just right, the men who finish their operations first can be made to assist other men.

EXAMPLES

A number of examples illustrating different conditions have been given in various places throughout the chapter. To still further illustrate the use of Table 55, several more examples are presented in the following pages, which apply to some of the more complicated conditions relating to hand-mixed concrete frequently met with in practice, and for which the cost of concrete per cubic yard has to be estimated.

These examples illustrate how easily the tables may be used, and the small amount of labor required to make an estimate far more accurate than the usual method of guess.

To bring out the methods most clearly, and to illustrate the variation in costs due to different conditions, one definite set of operations is stated in Example 9, and in succeeding examples variations in costs are provided which may be due to a variety of local circumstances. All of these examples are based on proportions 1: 2: 5. For other proportions, similar methods of estimating are followed except that different columns are selected in Table 55.

Example 9: What is the cost of concrete, exclusive of materials, proportions 1 part packed Portland cement to 2 parts sand to 5 parts gravel, under the following conditions: sand and gravel are obtained at a bank 2 miles away and the gravel must be screened to remove sand; the cement is hauled ½ mile from railroad station to job; the cement and sand are mixed into mortar and spread on the gravel; the concrete is wheeled an average distance of 50 feet; labor is paid $1.75 per day of 9 hours?

Solution: From Table 55, the different items are obtained, for average men under ordinary conditions, as follows:

Item (42) Screening gravel by hand to remove sand................	$0.202
Item (31) Loading and hauling gravel 2 miles @ $0.387............	0.774
Item (35) Loading and hauling sand 2 miles @ $0.146.............	0.292
Item (37) Loading Portland cement in bags into wagons............	0.012
Item (38) Hauling Portland cement ½ mile @ $0.051...............	0.026
Item (39) Unloading Portland cement in bags.....................	0.009
Item (10) Labor mixing and placing..............................	0.527
Item (12) Add for sand and cement mixed into mortar.............	0.009
Items (22) and (23) Wheeling concrete 50 feet ($0.056+$0.009)....	0.065
Total cost of labor @ 10¢ per hour..........................	$1.916

Hence total cost of labor @ $\frac{\$1.75}{9}$ or 19.4¢ per hour is $\$1.916 \times \frac{19.4}{10} = \$3.73$ per cubic yard of concrete exclusive of cost of materials.

Example 10: What would be the total cost of the concrete in Example 9 if the cement cost $2.00 per barrel f.o.b. railroad station?

Solution: Assuming the gravel to contain 45% voids for a cubic yard of concrete, from Table 22, page 151, there would be required 1.39 barrels of cement. At $2.00 a barrel, the cost of the cement per cubic yard of concrete would be $\$2.00 \times 1.39 = \$2.78$. This added to the cost of labor gives $\$3.73 + \$2.78 = \$6.51$ as the total cost of the concrete per cubic yard provided the sand and gravel cost nothing at the bank.

Example 11: What would be the difference in the labor cost of concrete in Example 9 if the concrete was carried 14 feet to place on shovels instead of wheeled 50 feet?

Solution: The comparative cost per cubic yard is found as follows:

Items (22) and (23) Wheeling concrete 50 feet ($0.056+$0.009)....	$0.065
Item (18) Carry concrete on shovels 14 feet......................	0.080
Difference in cost @ 10¢ per hour..............................	$0.015

and, at $\frac{\$1.75}{9}$ or 19.4¢ per hour, $\$0.015 \times \frac{19.4}{10} = \$0.029$ per cubic yard. It would cost $0.029 more per cubic yard in Example 9 to carry concrete in shovels 14 feet than to wheel 50 feet in barrows.

Example 12: In Example 9, how much more would it cost if the concrete was hauled 200 feet in single carts instead of 50 feet in barrows?

Solution: The comparative cost is:

Items (26) and (27) Hauling concrete 200 feet in carts (\$0.092+ \$0.012)	\$0.104
Cost of wheeling 50 feet in barrows	0.065
Difference in cost @ 10¢ per hour	\$0.039

and, at 19.4¢ per hour, $\$0.039 \times \frac{19.4}{10} = \$0.076$ per cubic yard. It would cost \$0.076 more per cubic yard to haul concrete in carts 200 feet than in barrows 50 feet.

Example 13: What would be the additional cost per cubic yard if the concrete was mixed and laid very dry?

Solution: The extra labor tamping very dry concrete is

Item (19) Extra labor tamping very dry concrete at 10¢ per hour	\$0.109

and, at 19.4¢ per hour, the extra cost per cubic yard would be $\$0.109 \times \frac{19.4}{10} = \$0.212$.

Example 14: If part of the concrete in Example 9 is to be used in the construction of a culvert, what would be the extra cost per cubic yard of concrete for the part so used?

Solution: The extra cost of concrete, exclusive of forms is:

Item (20) Forming small invert by template	\$0.044
Item (21) Extra tamping in invert or arch	0.021
Extra cost per cubic yard of concrete in invert @ 10¢ per hour	\$0.065

and, at 19.4¢ per hour, $\$0.065 \times \frac{19.4}{10} = \$0.126$.

In the arch, the extra cost would be $\$0.021 \times \frac{19.4}{10} = \$0.041$ per cubic yard.

Example 15: What would be the cost of labor in Example 9 if quick men were employed and other conditions were favorable?.

Solution: Times and costs on concrete work where quick men are employed were found to be 70% of the average times and costs.

Therefore the cost of labor for quick men is $0.70 \times \$3.73 = \$2.61$ per cubic yard with labor at \$1.75 per day of 9 hours.

Example 16: What would be the total cost of concrete in Examples 9 and 10 with labor at \$1.50 per 10 hours instead of \$1.75 per 9 hours?

Solution: In Example 9, the cost of labor at \$1.00 per day of 10 hours is \$1.916 per cubic yard and at \$1.50 per day the cost would be $\$1.916 \times 1.50 = \$2.87$ per cubic yard for labor. The cost of materials would remain the same so that total cost of concrete in place would average $\$2.87 + \$2.78 = \$5.65$ per cubic yard.

Example 17: How much concrete (in proportions 1: 2: 5) should an average gang of 15 men mix, shovel to place, and tamp, per day of 9 hours?

Solution: From column (12), Table 55, the total time expressed as the time of one man for mixing and placing one cubic yard of concrete is 239.2 minutes and with a gang of 15 men the time per gang is $\frac{239.2}{15}$ or 15.9 minutes per cubic yard. In a day of 9 hours or 540 minutes the gang could mix and place $\frac{540}{15.9}$ or 34 cubic yards.

Example 18: How many of the gang in Example 17 are required for leveling and tamping?

Solution: From Table 55, Item (8), the time required for leveling and tamping is 53 minutes or $\frac{53}{239.2} = 22\%$ of the whole time. Hence 22% of the gang or 3 men working all the time and a fourth man working part of the time will be required to level and tamp.

Example 19: How many additional men would be required in Example 17 if the concrete was wheeled in barrows 75 feet?

Solution: From Table 55, Items (22) and (23) the time required to haul one cubic yard of concrete 75 feet is

Item (22) Concrete wheeled 25 feet	25.4 min.
Item (23) Wheeling 50 additional feet @ 3.9 per 25 feet	7.8 min.
Total time wheeling one cubic yard 75 feet	33.2 min.

and wheeling 34 cubic yards 75 feet is therefore 33.2×34 or 1128 minutes. The extra men required to do the wheeling in a 9-hour day would be $\frac{1128}{540}$ or 2 men working a little faster than usual.

TABLE 55. TIMES AND COSTS OF

Times and costs are per cubic yard of concrete in place. Costs include but do not include office expenses or profit.

Item	Unit Operation	Refer to Page Indicated	Unit Time Expressed as Time of One Man — Average Men	Unit Time Expressed as Time of One Man — Quick Men	Unit Cost Labor 10 Cts. Per Hour — Average Men	Unit Cost Labor 10 Cts. Per Hour — Quick Men	Unit Cost Labor 20 Cts. Per Hour — Average Men
	Proportions 1:2:3 also 1:2½:4, 1:3:5 Where Sand More Than Half the Stone		min.	min.	$	$	$
			Per Cubic Yard of Concrete in Place				
					@ 10c		20c
	Mixing and laying concrete (Sand and cement mixed dry and spread on stone or gravel)	(1)	(2)	(3)	(4)	(5)	(6)
(1)	Measuring and wetting stone (may include wheeling 25 ft. if measured in barrow)	291	45.4	31.8	0.100	0.070	0.201
(2)	Measuring sand (may include wheeling 25 ft. if measured in barrow)	291	15.4	10.8	0.034	0.024	0.068
(3)	Getting and emptying cement	292	14.5	10.2	0.032	0.023	0.064
(4)	Mixing sand and cement dry, turned 3 times	292	14.0	9.8	0.031	0.022	0.062
(5)	Spreading sand and cement on stone	292	7.6	5.3	0.017	0.012	0.034
(6)	Wetting and mixing concrete, turned 3 times	292	47.5	33.3	0.105	0.074	0.210
(7)	Shoveling concrete to place, or to barrows or buckets	293	25.0	17.5	0.055	0.039	0.110
(8)	Leveling and tamping	293	53.0	37.1	0.117	0.082	0.234
(9)	Miscellaneous work		14.5	10.2	0.032	0.022	0.064
(10)	Total labor, mixing and placing		236.9	166.0	0.523	0.368	1.047
(11)	If stone is dumped on top of sand and cement, deduct from Item (10)	293	3.8	2.7	0.008	0.006	0.017
(12)	If sand and cement is mixed into mortar and spread on stone add to Item (10)	293	12.2	8.5	0.027	0.190	0.055
(13)	If stone is dumped on top of paste deduct from Item (10)	293	9.3	6.5	0.021	0.014	0.041
(14)	For each additional time that dry sand and cement is turned, add		18.8	13.2	0.042	0.029	0.083

MIXING CONCRETE BY HAND (See pp. 282 and 291)

(See pp. 282 and 291)

allowance for foreman, plus 15% for superintendence, overhead charges, etc.,

Proportions 1:2:4 also 1:1½:3, 1:2½:5, 1:3:6 Where Sand Half the Stone					Proportions 1:2:5 also 1:1:3, 1:1½:4, 1:2½:6 Where Sand Less Than Half the Stone					Item
Unit Time Expressed as Time of One Man		Unit Cost Labor 10 Cts. Per Hour		Unit Cost Labor 20 Cts. Per Hour	Unit Time Expressed as Time of One Man		Unit Cost Labor 10 Cts. Per Hour		Unit Cost Labor 20 Cts. Per Hour	
Average Men	Quick Men	Average Men	Quick Men	Average Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	
min.	min.	$	$	$	min.	min.	$	$	$	
Per Cubic Yard of Concrete in Place					Per Cubic Yard of Concrete in Place					
		@10c		@20c			@10c		@20c	
(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	
52.2	36.5	0.115	0.081	0.231	57.8	40.5	0.128	0.089	0.255	(1)
13.2	9.2	0.029	0.020	0.058	11.7	8.2	0.026	0.018	0.052	(2)
12.5	8.8	0.028	0.019	0.055	11.1	7.8	0.025	0.017	0.049	(3)
12.0	8.4	0.027	0.019	0.053	10.7	7.5	0.024	0.017	0.047	(4)
6.6	4.6	0.015	0.010	0.029	5.8	4.1	0.013	0.009	0.026	(5)
47.7	33.4	0.105	0.074	0.211	48.4	33.9	0.107	0.075	0.214	(6)
25.0	17.5	0.055	0.039	0.110	25.0	17.5	0.055	0.039	0.110	(7)
53.0	37.1	0.117	0.082	0.234	53.0	37.1	0.117	0.082	0.234	(8)
14.5	10.2	0.032	0.022	0.064	14.7	10.4	0.032	0.023	0.065	(9)
236.7	165.7	0.523	0.366	1.045	239.2	167.0	0.527	0.369	1.052	(10)
3.3	2.3	0.007	0.005	0.015	2.9	2.0	0.006	0.004	0.013	(11)
8.0	5.6	0.018	0.012	0.035	3.9	2.7	0.009	0.006	0.017	(12)
8.0	5.6	0.018	0.012	0.035	5.4	3.8	0.012	0.008	0.024	(13)
16.2	11.3	0.036	0.025	0.072	14.3	10.0	0.032	0.022	0.063	(14)

TABLE 55. TIMES AND COSTS OF

Item	Unit Operation	Refer to Page Indicated	Proportions 1:2:3 also 1:2½:4, 1:3:5 Where Sand More Than Half the Stone — Unit Time Expressed as Time of One Man: Average Men	Unit Time Expressed as Time of One Man: Quick Men	Unit Cost Labor 10 Cts. Per Hour: Average Men	Unit Cost Labor 10 Cts. Per Hour: Quick Men	Unit Cost Labor 20 Cts. Per Hour: Average Men
			min.	min.	$	$	$
			Per Cubic Yard of Concrete in Place				
	Mixing and laying concrete—Continued				@ 10c		20c
		(1)	(2)	(3)	(4)	(5)	(6)
(15)	For each additional time that concrete is turned, add........		14.4	10.1	0.032	0.022	0.064
(16)	For each additional 25 ft. that stone is wheeled in barrows add	292	2.4	1.7	0.005	0.004	0.011
(17)	For each additional 25 ft. that sand is wheeled in barrows add	292	1.4	1.0	0.003	0.002	0.006
(18)	If concrete is carried on shovels about 14 ft., add............	293	36.3	25.4	0.080	0.056	0.160
(19)	Extra tamping if concrete is laid very dry......................	293	49.4	34.6	0.109	0.076	0.219
(20)	Forming small invert by templet	293	20.0	14.0	0.044	0.031	0.088
(21)	Extra tamping, in small invert or arch....	293	9.7	6.8	0.021	0.015	0.043
	Transporting concrete in barrows and carts						
(22)	Add if concrete of dry consistency is wheeled 25 ft...............	294	25.4	17.7	0.056	0.039	0.112
(23)	Wheeling dry concrete in barrows, each additional 25 ft.....	294	3.9	2.7	0.009	0.006	0.017
(24)	Add if very wet concrete is wheeled in ordinary barrows 25 ft..............................	294	34.4	24.1	0.076	0.053	0.152
(25)	Wheeling very wet concrete in barrows each additional 25 ft.	294	5.7	4.0	0.013	0.009	0.025
(26)	Add if concrete is hauled in single carts with horse 100 ft.....		41.5	29.0	0.092	0.064	0.183
(27)	Hauling in single carts, each additional 100 ft..................		5.6	3.9	0.012	0.009	0.025
	Handling broken stone or gravel by carts						
(28)	Loading double carts and hauling 100 ft. (4 men loading)........	236	57.2	40.0	0.126	0.088	0.253

MIXING CONCRETE BY HAND—Continued

Proportions 1:2:4 also 1:1½:3, 1:2½:5, 1:3:6 Where Sand Half the Stone					Proportions 1:2:5 also 1:1:3, 1:1½:4, 1:2½:6 Where Sand Less Than Half the Stone					
Unit Time Expressed as Time of One Man		Unit Cost Labor 10 Cts. Per Hour		Unit Cost Labor 20 Cts. Per Hour	Unit Time Expressed as Time of One Man		Unit Cost Labor 10 Cts. Per Hour		Unit Cost Labor 20 Cts. Per Hour	Item
Average Men	Quick Men	Average Men	Quick Men	Average Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	
min.	min.	$	$	$	min.	min.	$	$	$	
Per Cubic Yard of Concrete in Place					Per Cubic Yard of Concrete in Place					
		@ 10c		@ 20c			@ 10c		@ 20c	
(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	
14.5	10.2	0.032	0.023	0.064	14.7	10.3	0.033	0.023	0.066	(15)
2.7	1.9	0.006	0.004	0.012	3.2	2.2	0.007	0.005	0.014	(16)
1.2	0.8	0.003	0.002	0.005	1.2	0.8	0.003	0.002	0.005	(17)
36.3	25.4	0.080	0.056	0.160	36.3	25.4	0.080	0.056	0.160	(18)
49.4	34.6	0.109	0.076	0.219	49.4	34.6	0.109	0.076	0.219	(19)
20.0	14.0	0.044	0.031	0.088	20.0	14.0	0.044	0.031	0.088	(20)
9.7	6.8	0.021	0.015	0.043	9.7	6.8	0.021	0.015	0.043	(21)
25.4	17.7	0.056	0.039	0.112	25.4	17.7	0.056	0.039	0.112	(22)
3.9	2.7	0.009	0.006	0.017	3.9	2.7	0.009	0.006	0.017	(23)
34.4	24.1	0.076	0.053	0.152	34.4	24.1	0.076	0.053	0.152	(24)
5.7	4.0	0.013	0.009	0.025	5.7	4.0	0.013	0.009	0.025	(25)
41.5	29.0	0.092	0.064	0.183	41.5	29.0	0.092	0.064	0.183	(26)
5.6	3.9	0.012	0.009	0.025	5.6	3.9	0.012	0.009	0.025	(27)
66.2	46.3	0.146	0.102	0.293	73.7	51.7	0.163	0.114	0.326	(28)

TABLE 55. TIMES AND COSTS OF

Item	Unit Operation	Refer to Page Indicated	Proportions 1:2:3 also 1:2½:4, 1:3:5 Where Sand More Than Half the Stone — Unit Time Expressed as Time of One Man: Average Men	Unit Time Expressed as Time of One Man: Quick Men	Unit Cost Labor 10 Cts. Per Hour: Average Men	Unit Cost Labor 10 Cts. Per Hour: Quick Men	Unit Cost Labor 20 Cts. Per Hour: Average Men
			min.	min.	$	$	$
			Per Cubic Yard of Concrete in Place				
					@ 10c		20c
	Handling broken stone or gravel by carts—Continued	(1)	(2)	(3)	(4)	(5)	(6)
(29)	Loading double carts and hauling 100 ft. if teamster loads alone.	236	77.7	54.4	0.172	0.120	0.343
(30)	Hauling in carts each additional 100 ft. up to 1 mile............	236	1.7	1.2	0.004	0.003	0.008
(31)	Loading *and* hauling per mile if distance is more than 1 mile..	238	136.8	95.8	0.302	0.212	0.605
	Handling sand by carts						
(32)	Loading double carts and hauling 100 ft. (4 men loading)........	236	29.6	20.7	0.065	0.046	0.131
(33)	Loading and hauling 100 ft. if teamster loads alone..........	236	37.3	26.1	0.082	0.058	0.165
(34)	Hauling in double carts additional 100 ft. up to 1 mile.....	236	1.0	0.7	0.002	0.002	0.004
(35)	Loading *and* hauling per mile if distance is more than 1 mile..	238	86.7	60.7	0.192	0.134	0.383
	Handling cement						
(36)	Loading Portland Cement in barrels into wagons.............	251	3.4	2.4	0.008	0.005	0.015
(37)	Loading Portland Cement in bags into wagons..................	251	6.9	4.8	0.015	0.011	0.030
(38)	Hauling Portland Cement per mile.........................	251	29.9	20.9	0.066	0.046	0.132
(39)	Unloading bags or barrels of Portland Cement from wagons	251	5.2	3.6	0.011	0.008	0.023
	Screening sand and gravel						
(40)	Screening sand by hand to remove small stones............	298	20.0	14.0	0.044	0.031	0.088
(41)	Screening gravel by hand to remove coarse stones...........	298	40.0	28.0	0.088	0.062	0.176
(42)	Screening gravel by hand to separate sand.....................	298	71.2	49.7	0.157	0.109	0.313

MIXING CONCRETE BY HAND—Continued

Proportions 1:2:4 also 1:1½:3, 1:2½:5, 1:3:6 Where Sand Half the Stone					Proportions 1:2:5 also 1:1:3, 1:1½:4, 1:2½:6 Where Sand Less Than Half the Stone					
Unit Time Expressed as Time of One Man		Unit Cost Labor 10 Cts. Per Hour		Unit Cost Labor 20 Cts. Per Hour	Unit Time Expressed as Time of One Man		Unit Cost Labor 10 Cts. Per Hour		Unit Cost Labor 20 Cts. Per Hour	Item
Average Men	Quick Men	Average Men	Quick Men	Average Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	
min.	min.	$	$	$	min.	min.	$	$	$	
Per Cubic Yard of Concrete in Place					Per Cubic Yard of Concrete in Place					
		@ 10c		@ 20c			@ 10c		@ 20c	
(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	
89.9	62.9	0.199	0.139	0.397	99.2	69.4	0.220	0.153	0.438	(29)
1.9	1.3	0.004	0.003	0.008	2.2	1.5	0.005	0.003	0.010	(30)
158.4	110.9	0.350	0.245	0.700	175.0	122.5	0.387	0.271	0.774	(31)
25.6	17.9	0.057	0.040	0.113	22.6	158.0	0.050	0.035	0.100	(32)
32.2	22.5	0.071	0.050	0.142	28.5	20.0	0.063	0.044	0.126	(33)
0.9	0.6	0.002	0.013	0.004	0.8	0.6	0.002	0.001	0.004	(34)
74.8	52.4	0.165	0.116	0.331	66.0	46.2	0.146	0.102	0.292	(35)
3.0	2.1	0.007	0.005	0.013	2.6	1.8	0.006	0.004	0.012	(36)
6.0	4.2	0.013	0.009	0.026	5.3	3.7	0.012	0.008	0.023	(37)
25.9	18.1	0.057	0.040	0.115	22.9	16.0	0.051	0.035	0.101	(38)
4.6	3.2	0.010	0.007	0.020	4.0	2.8	0.009	0.006	0.018	(39)
17.2	12.0	0.038	0.027	0.076	15.3	10.7	0.034	0.024	0.067	(40)
46.1	32.3	0.102	0.071	0.203	51.5	36.0	0.114	0.079	0.226	(41)
82.5	57.5	0.181	0.127	0.362	91.9	64.1	0.202	0.141	0.404	(42)

TABLE 56. EXAMPLES OF LABOR COSTS OF HAND MIXING FOR SPECIAL CONDITIONS (See p. 319)

Proportions 1:2:4, 1:2½:5, or 1:3:6.

Values apply approximately also to other ordinary proportions. Wages of labor 20 cents per hour, with allowance included for foremen, superintendence, miscellaneous job expenses, and small tools.

Neither home-office expense nor profit are included in costs. Values are made up from Table 55, Column (11) (see p. 312); for cost of materials, see pages 165 to 172.

Case	Conditions	Item Numbers from Table 55	Labor Cost per cu. yd. of Concrete Wages @ 20¢ Per Hour
I	Mixing and placing concrete with no transporting	(10)	$1.05
II	Mixing and placing, when cement and sand are mixed into a mortar and spread on stone	(10) (12)	1.08
III	Mixing and placing when stone is dumped on top of sand and cement	(10) (11)	1.03
IV	Mixing and placing, including wheeling stone an additional 50 feet	(10) (16)	1.07
V	Mixing and placing, including wheeling sand an additional 50 feet	(10) (17)	1.05
VI	Mixing and placing, including wheeling sand and stone an additional 50 feet	(10) (16) (17)	1.08
VII	Mixing and placing, including screening gravel to separate the sand	(10) (42)	1.41
VIII	Mixing and placing, with sand and gravel both hauled 500 feet	(10) (28) (30) (32) (34)	1.50
IX	Mixing and placing, with sand and gravel both hauled 1¼ miles	(10) (31) (35)	2.33
X	Mixing and placing, with gravel screened to separate sand, and sand and gravel both hauled 500 feet	(10) (42) (28) (30) (32) (34)	1.86
XI	Mixing and placing, with gravel screened to separate sand, and sand and gravel both hauled 1¼ miles	(10) (42) (31) (35)	2.70
XII	Mixing and placing, with concrete carried on shovels about 14 feet	(10) (18)	1.21
XIII	Mixing and placing, with concrete wheeled 100 feet	(10) (22) (23)	1.21

Note: When distances differ from those in Table 55, the cost items are corrected accordingly; for example, in Case XIII, Item (23) is multiplied by 3 to provide for the additional 75 feet.

TABLE 56. EXAMPLES OF LABOR COSTS OF HAND MIXING FOR SPECIAL CONDITIONS—Continued

Case	Conditions	Items from Table 55	Labor Cost per cu. yd. of Concrete Wages @ 20¢ Per Hour
XIV	Mixing and placing, with very wet concrete wheeled 100 feet	(10) (24) (25)	$1.27
XV	Mixing and placing, with concrete hauled 300 feet in single carts	(10) (26) (27)	1.28
XVI	Mixing and placing, with gravel screened to separate sand and gravel; both hauled 500 feet; and very wet concrete wheeled 100 feet in barrows..........	(10) (42) (28) (30) (32) (34) (24) (25)	2.09
XVII	Mixing and placing, with gravel screened to separate sand; sand and gravel both hauled $1\frac{1}{4}$ miles; and very wet concrete wheeled 100 feet...............	(10) (42) (31) (35) (24) (25)	2.92
XVIII	Mixing and placing, with cement in bags loaded and hauled 5 miles; gravel screened to separate sand; sand and gravel both hauled $1\frac{1}{4}$ miles; and very wet concrete wheeled 100 feet	(10) (37) (38) (39) (42) (31) (35) (24) (25)	3.54

NOTE: When distances differ from those in Table 55, the cost items are corrected accordingly; for example, in Case XIV, Item (25) is multiplied by 3 to provide for the additional 75 feet.

Conditions not covered in the cases cited may be computed readily by selecting the proper items from Table 55.

EXAMPLES OF SPECIAL CONDITIONS OF HAND MIXING

Table 56 is presented in order to show in convenient form a series of costs for different conditions of concreting, for the man who wishes simply an approximate figure and does not care to go to the trouble of combining the various elements by the methods illustrated in the preceding tables.

Each value in this table represents a case of specially selected conditions, and by glancing down the columns one may frequently find a case which applies so nearly to the conditions of his own work that the value can be used directly or with a small estimated correction. Allowance must be made, of course, for a different wage rate per hour. The costs given are based, as stated, on a rate of 20 cents per hour.

Different proportions will also slightly affect the cost of the labor, as may be seen by reference to Table 55.

In Table 56, a brief description is given of the conditions of each case selected. This is followed by a column giving the items in Table 55 from which the costs are made up. A fuller description of the conditions may be found in each case under the separate items in Table 55.

Actual costs will always vary slightly from any estimate, no matter how carefully it is made, because of unforeseen conditions such as the effect of uneconomical conditions or of weather conditions upon the men, slight changes in the method of handling the materials and other uncertainties. If the actual cost of any job is found to be appreciably higher or lower than the estimate, when making up the estimate for the next job, handled by similar men, the tabular values may be corrected by the percentage by which the actual cost of the first job was found to disagree with the original estimate.

CHAPTER XII

MACHINERY PLANT FOR MIXING AND HANDLING CONCRETE

The remarkable development of concrete construction on a large scale, the demand for rapid prosecution of work, and the increasing observance of economy in all details, have made mechanical mixing a necessity. Not only is machine mixing usually cheaper than hand mixing, but it produces a more thorough and uniform product, and places less dependence upon the expertness of the workmen.

The present chapter is a general discussion of concrete machinery and plants, prepared so as to give the designer or estimator a comprehensive view of the subject. The information includes a description of different types of mixers (see p. 323); discussion of economical design (see p. 324); methods of handling raw materials and concrete (see p. 327); notes on the selection of mixers (see p. 330); a discussion of initial plant costs and running expenses (see p. 338); descriptions and illustrations of typical plants together with their approximate costs (see p. 342) approximate costs of materials and machinery, such as shovels, barrows, mixer engines, cableways, and belt conveyors (see p. 367); and references to descriptions of mixer plants in current literature (see p. 376).

Costs in detail of mixing by machinery and the items of the various mixer operations are taken up in the chapter which follows. With the aid of the material there given, the cost of operation under ordinary conditions can be estimated and the work can be laid out so as to realize the greatest economy. The excavating and crushing of rock for concrete are discussed in Chapter IX, page 174; handling and transporting materials, in Chapter X, page 217; and hand mixing of concrete in Chapter XI, page 270. These various chapters include discussions of interest in the design of plants.

Necessity for Careful Estimates. Although, in general, machinery should be employed for mixing concrete in preference to hand labor, local conditions must receive very careful consideration. While it pays to invest a large sum of money in machinery when laying a large quantity of concrete masonry, if for any reason but a small quantity—we will say not over 25 cubic yards—can be deposited in a day, or where frequent moving of machinery is necessary, the charges for the machinery may amount to so large an item of cost that hand labor is the cheaper plan. The type of plant to select for mixing concrete by machinery also depends, not only upon the arrangement of the work, but upon the quantity of concrete which must be deposited each day and upon the total number of cubic yards in the job. A certain plant may be operated at very small daily expense and yet be uneconomical because the job is not large enough to pay for the cost of installation of the plant and the depreciation and interest.

With the aid of the tables of cost of machine mixing at the end of the following chapter, different types of plants may be compared with each other and with the cost of hand mixing as discussed in the last chapter, and the cheaper method ascertained.

The process of mixing by machinery can be readily divided into unit operations, but local conditions so affect the necessary arrangement and design of a plant that it is not easy to select average conditions which will apply to the different jobs, and more independent treatment is necessary. The cost of the plant,—which must include interest on the investment, a replacement charge covering depreciation, and a charge for moving and setting up,—may be, and frequently is, the largest item of expense in the cost per cubic yard of the concrete. These machinery charges, then, must be taken separately from the cost of the labor and combined in accordance with the local requirements.

The number of men required for operating the machinery is apt to vary but little with the output. On the other hand, the gang handling the materials previous to mixing and the gang handling the concrete after it leaves the mechanical apparatus will vary with the amount of material passing through the machine in a given time, that is, with the output of the mixer. In order to get at the portion of the cost of mixing which is to be charged to the machinery, the items of cost referred to above—interest, depreciation, and changing location of apparatus—must be estimated by a comparison of data and added to the labor charge. The information on plants in the present chapter must therefore be used in connection with the labor costs presented in the chapter which follows. Tables 57 to 60, pages 371 to 374, present times and costs for this purpose.

CONCRETE MIXING MACHINES

The object to be attained in mixing concrete is to secure as great uniformity as possible in the mixture of cement, sand, stone, and water.

This is variously accomplished in different types of mixing machines by rotating the mixer and the material within; by throwing the material from one part of the machine to another; by cutting the mass again and again; or by a combination of these operations.

Methods of Mixing. The two general methods of mixing concrete by machine are (1) continuous mixing, where the materials are fed constantly and the concrete is discharged in a steady stream; and (2) batch mixing, where the mixer receives at one time a charge of, say, two, three or four bags of cement with their proportionate volume of sand and stone, and after mixing discharges the concrete in one mass.

Many mixing machines are adapted to either continuous or batch mixing and either method may be satisfactory, provided the materials are accurately proportioned. In continuous mixing, the measuring should also be continuous so that every part of the mass will have the same proportions.

Types of Mixing Machines.* Mixers may be classified in three general types: Rotating mixers, Paddle mixers, and Gravity mixers.

Rotating, or rotary, mixers, as they are usually termed, sometimes mix the materials by simply tumbling them in an oblong or cubical box, and in other cases by throwing them against deflectors, blades or plows.

The cubical box is one of the simplest forms of rotating mixers, and formerly was used largely on extensive concrete construction. This is now giving place to modified patterns of cylindrical, conical or cubical form, with improvements which produce more thorough mixing and in some cases permit the inspection of the material during mixing.

The rotary mixers, many of which contain deflectors, or blades to cut the concrete, are usually mounted by the manufacturers upon suitable frames, although in certain cases it is preferable to construct special timber framework, so that materials may be introduced and the concrete taken away more economically. The larger machines of this type are so constructed that the materials can be introduced into the charging hoppers from derrick buckets, carts, or barrows. A loading skip or tray is frequently arranged so that barrows may be dumped into it on the ground level and then it is lifted by the engine operating the mixer and dumped into the mixer.

The rotating of the drum in the mixers of ordinary type tumbles the material and also throws it against the mixing blades which cut and throw

*Illustrated in Taylor and Thompson's "Concrete, Plain and Reinforced," second edition, pp. 259 to 263.

it from side to side. Many of these machines can be dumped while running either by tilting them or their chutes.

Paddle mixers usually consist of a cylinder or trough in which one shaft or sometimes two shafts, carrying paddles, rotate. The material is fed at one end and cut apart and stirred by the paddles, and at the same time in continuous mixing is carried toward the other end and discharged there.

Of the paddle mixers, those adapted to mix a batch at a time can be depended upon more surely to produce good concrete than the continuous machine fed by shovels. With automatic measuring devices, however, it is possible to measure and feed the material uniformly and at the same time secure the maximum output of the machine.

In gravity mixers, the materials are charged at the top of the machine and discharged at the lower level, the mixing being accomplished by striking obstructions which mix them together in their descent through the machine.

Automatic Measurers.* Accurate measuring of cement and aggregates automatically is difficult because of the inaccuracy in measuring cement by volume and the different amount of moisture in the sand from day to day which affects the handling. Before accepting any type, it should be tested for accuracy under working conditions.

Proportioning Materials by Weight.* Not only cement, but also sand, stone, and other material, can be more accurately proportioned by weight than by volume, the difference in moisture on different days affecting the weight less than the volume. By the use of automatic weighing devices, which, by counter weights, close the gates to the bins, it should be possible to devise effective and economical weighing apparatus.

DESIGN OF CONCRETE PLANTS

The character of the plant to be selected for design, as stated in previous pages, must be governed by local conditions. The most important conditions to consider are: (a) the layout of the construction work, (b) the required output per day, and (c) the total quantity of concrete to be laid.

With reference to the layout of the construction work, (a), if a large mass of concrete is to be placed in a comparatively small area, such as in dam construction, it is generally economical to establish a fixed plant, to which the materials are supplied either by gravity or machinery,

*Several types of measurers and proportioning by weight are referred to in Taylor and Thompson's "Concrete, Plain and Reinforced," second edition, pp. 264 and 265.

and from which the concrete is conveyed to different parts of the work. On the other hand, if the mass of concrete is large, but is distributed over a considerable area, as in a large reservoir, or along a line, as in a sewer or conduit or retaining wall, machinery of a more portable character may be economical. For example, in building retaining walls for railways, where tracking is convenient, a fairly complete plant may be established on trucks or on flat cars to be moved from place to place.

In laying the concrete for the reservoir bottom at Jerome Park Reservoir, New York City, the construction plant as originally designed consisted of one or two central plants from which the concrete was conveyed to place. A thorough study of the conditions, which are described in detail on page 344, showed that a number of small mixers, which could be moved from place to place at small expense, were more economical, even disregarding plant cost, than the larger plant involving more machinery and longer transportation of concrete.

The required output per day, (b), affects the selection of the size of mixer and governs to a certain extent the amount of handling and conveying machinery which is economical. A small daily output will not pay for the interest and depreciation on an expensive plant. For these reasons hand mixing sometimes may be cheaper than machine mixing, especially on a structure like a small sewer where the speed is dependent upon the progress in trench excavation.

The total quantity of concrete to be laid in the entire job, (c), has an important bearing on the design of the plant, because the total cost of all portions of the plant that are not transportable to a subsequent job must be divided by the number of yards of concrete laid and figured as a portion of the cost per cubic yard of concrete. The different parts of the plant, such as the mixing and conveying machinery, which can be used afterwards, must be provided for in the cost account by a considerable depreciation and interest charge. This, as well as the expense of freight, setting up and moving machinery, and such general items, also must be figured into the cost per cubic yard of the concrete.

Because of the failure to include such items as these in government work and force accounts, and even by contractors themselves who do not keep accurate accounts of costs, the cost of machine mixing is frequently regarded as very low, only a few cents per cubic yard, when, as a matter of fact, the actual plant charges, which are just as real items as the wages paid, will bring the unit costs up to ordinary figures. Writers of descriptive articles frequently fail to include all these incidental charges in stating costs and so mislead the inexperienced estimator.

On page 338, the costs of these incidental items are taken up in some detail.

On all work of such magnitude as to make the use of a concrete machinery-mixing and handling plant expedient, it is of great importance in the matter of speed and economy to have the entire plant well designed and planned out to the best advantage. And this design must of necessity vary according to the nature of the work; the way in which raw materials can be brought to the plant; the natural features of the ground where the plant is to be located; the cost of materials delivered on the job for constructing the plant; the time in which the work must be completed; the amount of money there is in the job; and any special conditions that may exist in connection with the work. Even where the general features of the plant are practically the same for two different jobs, the details are usually more or less at variance. Therefore, it means careful and thorough study and efficient planning to effectively meet the conditions, so as to prevent waste of money and to decrease cost.

The design of the plant for handling the raw materials for concrete and for conveying the concrete to place usually has more to do with economy in mixing than the particular type of mixing machine. As there are plenty of good mixers, engines, and other machinery on the market, the particular make used is, in a measure, a matter of personal choice, or is determined by what can be economically had at any given location, either new or brought from some previous job.

The layout of the proposed plant should be sketched out, and the cost and expense of installation, as well of operation, estimated as accurately as possible so as to determine whether the volume of concrete to be laid is sufficient to warrant the construction and operating expense. The authors have seen expensive machinery, which could not be transported readily to another job, installed on a section of work where hand-mixing would have been actually more economical because of the small total volume of concrete and its distribution over a large area.

Usually the important points to plan for are what shall be used for handling the materials and the concrete: whether cableways; belt conveyors; elevators of various kinds; cars hauled by dinkies, by horses, or by hand on level tracks; cars hauled by cable on inclines; or derricks; whether trestles shall be built and to what extent; whether the mixers can be so located that raw material can be dumped direct to bins from standard gage cars; whether the mixing plant shall be mounted complete on trucks or cars; or whether some special combination of a part or all of these shall be used. The minimum amount of concrete that will make it advantageous to install a machinery-mixing and handling plant is variable, depending on the nature of the work and local conditions to such an extent that it must be carefully figured out for each. On some jobs, 500 cubic yards would be the minimum, while on others it might be 1500 cubic yards.

Several types of plants in common use are briefly described on pages 342 to 367 as illustrations of economical plant construction under different conditions. The approximate costs are also given.

Having selected the general type of plant, published descriptions of plants in successful operation will aid in designing details. On pages 376 to 380 are given references to various plants described in current literature, together with a brief outline of the character of the design and, when available, the output.

HANDLING RAW MATERIALS

Storage of Raw Materials. Large enough storage space must be provided for raw materials to have always on hand a sufficient supply to avoid shutdowns or running at partial capacity.

Every lift of materials, whether by machinery or hand-labor, costs money and wherever the contour of the ground is adapted to handling economically by gravity, it should be utilized. Storage bins located directly above the mixer may supply the mixer direct instead of using barrows, or may feed into a car on a level track, which dumps into the mixer. Belt conveyors frequently are economical.

Ordinarily, for a given output of concrete, the quantity of sand required is at least double the quantity of cement used, while the quantity of stone is apt to be about twice that of the sand. It follows then that if all the materials cannot be placed close to the mixer, it is most economical, as a rule, to arrange the layout so that the stone will be most accessible, and the sand next, while the cement may be farthest away. The sand, too, is more quickly loaded than stone so that a man can wheel sand from a greater distance in the same time.

The layout, however, may be affected by the arrangement of the gang supplying the mixer. For example, if one or more extra men are required for handling the cement from a distance, while the men supplying sand and stone can more than keep up with the mixer, the cement shed should be close at hand.

When the sand and stone are handled in wheelbarrows or hand carts, the mistake is frequently made of having the run or track above the level of the floor of the storage bin, so that either the sand and stone must be shoveled with a high lift or from the top of the pile. Either method requires more labor, and therefore more time, than when the shovel can be pushed in under the bottom of the pile on a smooth floor and the stone thrown into the vehicle with a low lift. On the other hand, a high lift may be necessary to avoid pushing a cart or barrow up an incline or to permit filling the wheelbarrow to the full capacity required by the proportions. In such cases, it may be economical to build a raised platform for the storage of the sand and stone, the cost of this being soon overbalanced by the saving in labor.

This general discussion illustrates the necessity for making a full study even of small details. Reference to pages 382 to 409 will show how this can be done in a practical way by studies of the times of the different operations.

Measuring Raw Materials. Cement is usually measured by counting the number of bags or barrels, so that no special attention need be paid to this except to carefully check the count of the bags to be sure that the full quantity of cement is used in every batch. Where possible, it is advisable that the quantity of concrete laid each day should be measured and compared with the count of the empty cement bags to see that the proper quantity of cement is being used per cubic yard of concrete.

It was formerly common practice in machine mixing to measure the sand and stone in barrels, bottomless boxes, or other measures on a platform close to the mixer and then shovel the materials into it. This has been largely superseded either by automatic measures or else by measurement in the barrows or other vehicles in which the materials are conveyed to the mixer. When measuring in the vehicle, that is, in the barrow or cart or car or bucket, special care is required to insure the exact quantity for each batch. If the unit quantities of sand or cement run too small, the contractor is losing money because he makes less concrete to a batch and therefore uses more cement to the cubic yard than is necessary. On the other hand, if the measures are overfilled, the concrete will be leaner than specified and the structure may be endangered or the surface may be rough or sandy.

To avoid inaccurate measurement with the ordinary contractor's wheelbarrow, barrows for handling concrete materials are now made of special shape and deep enough so that they can be roughly leveled off and accurate measurements obtained.

If the measure, whether it be a bucket, hopper, or vehicle, is not quite filled to give the proper quantity, the correct level should be marked distinctly on the sides, or better still, a gage should be provided which will drop down into the measure to designate the correct surface of the sand or stone.

The water for each batch of concrete should be measured. While every batch will not require the same quantity of water because of differences in weather conditions, wetness of the sand, or surplus water in the last batch of concrete placed, it is possible with a definite gage, to give a uniform quantity for each batch, or if desired, to vary the quantity of water as required. A float can be arranged to shut off the water automatically or to indicate the level on a gage. When making or purchasing a gage-box, one should be sure that it is large enough. A four-bag batch of 1:2:4 concrete may require from 2.4 to 3.7 cubic feet or from 18 to 28 gallons water according to the materials and the consistency.

Charging Raw Materials. So many methods of handling raw materials and charging the mixer are in successful use that it is impossible to recommend one in preference to others without considering the local conditions. With the simpler type of mixer, having a bucket or tray attachment which hoists and discharges into the hopper, wheelbarrows of the special measuring types referred to in a preceding paragraph are usually most convenient for filling the hoist bucket or tray. Barrows are also economical for charging a mixer with a fixed hopper when it can be placed in a pit below the level of the ground or on a comparatively low level easily reached by barrow runs.

Where barrows are used, it is essential that proper platforms and runways should be provided. Ample space should be allowed to dump and turn the barrows and the barrow men should be kept moving and not forced to wait on the platform while another man is coming up the run. Remember that a few minutes saved on a man's work per day foots up in the estimate to an amount sufficient to build convenient runs.

Considerable thought should be given, in designing even a small plant, to arrange the length of haul and the quantity per barrowload so as to use the smallest possible number of men for charging the mixer. But, on the other hand, it is better economy to have an extra man in the charging gang who does not work full time than to keep the mixer with its gang waiting for material.

If the sand and stone must be hauled from some distance, say, 350 feet, carts with horses or cars on a track will be more economical than barrows. Cars on a track are especially useful in a fixed plant, even for a short haul, where the sand, stone, and cement are dumped from elevated bins and the car can be pushed on a level or on a slight decline or hauled up an incline by cable so as to dump directly into the hopper or mixer.

Belting or other conveyors—bucket elevators if the lift is nearly vertical—are adapted for raising the material on an incline. Separate measurers have to be used in connection with this either before the material is dropped on to the belt or conveyor, or else in the hopper over the mixer.

Under some conditions, derricks with buckets are an economical apparatus for handling the raw materials, as, for example, where the sand or stone is raised from flat boats or barges to the mixer, or where the mixers must be on a considerable elevation above the sand and gravel and the plant is subject to occasional moves. Sometimes the same derrick can be used for handling both raw materials and concrete.

The unit times in Table 62, page 418, will afford assistance in designing a plant so that the operations of the different men and machinery will fit into each other and avoid lost time and extra men. The examples of such studies are given on pages 434 to 436.

The references given in pages 376 to 380, and the examples of plant construction on pages 342 to 367, will afford suggestions for charging materials under various conditions.

KIND AND TYPE OF MIXER

Different types of mixing machines and methods of mixing are described on pages 322 to 324.

The selection of the mixer should be based on the general prinicples outlined in connection with the design of the plant on pages 324 to 327. The criterion of a good mixer, so far as the quality of concrete is concerned, is that it shall turn out a concrete of homogenous composition and consistency with the aggregates, cement, and water thoroughly incorporated with one another.

The simplest form of mixing plant consists of a portable machine mixer with engine and boiler or with motor. These may be mounted on simple frames or purchased from the factory with a wheel base. A convenient size for such a machine is the ½ cubic yard capacity, adapted for mixing batches containing 2 bags of cement. The output from such a machine may vary from 3½ cubic yards per hour up to 9 cubic yards per hour, according to the method of supplying materials and taking away the concrete. Tables 63 and 64, pages 425 to 431 give definite information with reference to output under different conditions.

The small mixers as well as the large ones are equipped, if desired, with a tray or hopper in which the raw materials may be placed on the ground level and raised to the hopper opening into the mixer by the machinery which operates the mixer. This avoids the building of inclines and staging.

The economy of a mixer in operation depends upon various considerations, the relative importance of which from the cost standpoint may be studied by reference to the tables at the end of Chapter XIII. The points may be classified as follows:

First Cost. On a large job the first cost of the mixing machine is of subordinate importance to economical operation. The effect of the first cost of plant upon the cost of the concrete and, in fact, the cost per cubic yard which must be charged to the mixer, is obtained by methods outlined on page 338. Items of cost in the tables at the end of Chapter XIII are based on usual conditions as outlined on page 342.

Repairs. If a mixer breaks down while in use, the gang may have to lie idle until repairs are made. The importance of selecting a machine that is well recommended for durability by users is evident. If a machine is found to have weak parts, the trouble may be minimized by maintaining it in thorough repair outside of working hours and by keeping in stock those parts that are liable to prove defective.

The cost of repairs under ordinary conditions is referred to on page 340.

Output. The capacity of a mixing machine should be slightly greater than actually required on the work to avoid delaying the workmen. The difference in cost between different sizes is comparatively small and of slight consideration if the progress of the work can be quickened or if the labor cost can be lessened. On the other hand, it is useless to have a machine of very much larger capacity than is required for the work, especially if an extra man is necessary in its operation or if it must work to full capacity when running.

Power to Operate. This is usually a comparatively small item of cost, as is indicated on page 341. The largest part of the cost of making concrete is in the handling of the raw and finished material and if less power or even if no power is required on a certain machine, the labor must be carefully outlined to see that there is not a corresponding increase in labor cost in handling materials.

Men to Operate. A reduction in the number of men to operate a mixer is an important saving because the operating cost is a continuous one, frequently going on during shutdowns. An ordinary gang is outlined on page 396.

Methods of Charging and Discharging. Since the labor cost is a principal item in ordinary mixing, any apparatus which will lessen the number of men without an equivalent increase in machinery cost per cubic yard is of special value.

Inspection of the above points indicates the advisability of examining the principles of operation of any special machine so as to select the kind and type,—whether it be continuous or batch, or whether it be rotary, or paddle, or gravity,—best suited to the work in hand.

Different methods of operation may be compared by reference to the unit times given in Table 62, page 418 and discussed on pages 382 to 409.

CONVEYING CONCRETE

If the concrete is to be deposited above the level of the mixer or transported for a considerable distance, the conveying machinery may be a considerable part of the plant charge. Contractors' wheelbarrows, special wheelbarrows, two-wheel hand carts, cars on tracks, derricks, hoists, cableways, and gravity chutes are variously used. Only a few general prinicples of operation may be referred to here. References to literature are given on pages 376 to 380.

Barrows. Ordinary contractors' barrows, while useful in some cases for handling concrete of dry or plastic consistency, hold so small a quantity of wet, sloppy concrete that some other type of barrow is preferable. If two-wheeled barrows or hand carts like that shown in Fig. 19, page 221, are used, the run for them must be practically level and smooth, and wide enough to hold both wheels without danger of running off, while turnouts should be provided occasionally to avoid delay when an empty barrow meets a full one. With no turnouts, the empty barrow must be taken off the run and then replaced by two men.

In building construction where barrows of any sort are run over floor forms with slab steel in place, runs of plank spiked to substantial cleats, so as to raise the planking above the forms and carry it over the slab steel, should be provided. At turns or on continuous runs, any two adjacent sections must meet on a level or be lapped so that the drop is in the direction taken by the full barrow. A wedge-shaped piece also should be spiked in for the incline. This seems a simple requirement, and yet laborers, unless watched, are continually building runs the wrong way.

When using the large two-wheel barrows or carts, remember that the actual capacity of the barrow measured as the quantity of concrete deposited, is much smaller than the measured volume of the barrow. For

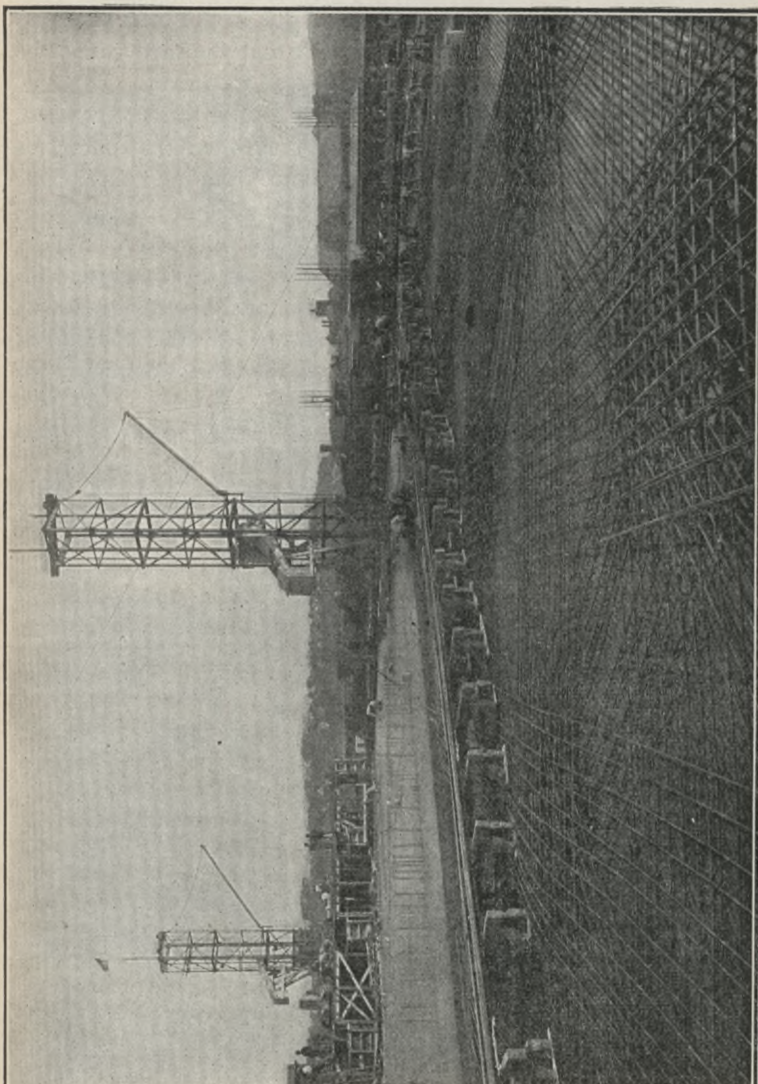


FIG. 23. Handling Concrete in Cars at Lowell, Mass. (See p. 334.)

example, a barrow or cart of 6 feet measured capacity does not hold, on the average, over 4 to $4\frac{1}{2}$ feet of very wet concrete such as is used in building construction. A part of this difference is due to the bulk of excess water and the rest of the difference to the fact that the carts cannot be filled full without slopping over or making the load too heavy.

Cars. Small dump cars holding from $\frac{1}{2}$ to 1 cubic yard of concrete and loading direct from mixer are frequently used where the concrete is distributed over quite an area or at some distance from the mixer plant. These cars run on light rails placed on plank runs. Figure 23, page 333, shows them loading from hopper and depositing concrete for a floor under construction by the Aberthaw Construction Co. In this case, the runs are supported by timber horses so constructed that they may be easily pulled out of the soft concrete. Turnouts must be provided at frequent intervals to avoid waiting. A nearer view on the same work is shown in Fig. 24 page 335.

Trains of flat cars, holding one or two buckets each and hauled by cable or by small locomotives, are used where the amount of concrete to be placed warrants the expense of such a plant. The buckets are filled directly from the mixers and are taken from the cars and dumped by derricks or cableways.

Hoists. In building or other elevated construction, the concrete is sometimes loaded into barrows and wheeled on to an elevator, then raised to the required level and wheeled to place. This is a much more expensive form of hoisting than the regular hoist bucket (see Fig. 24, p. 335), which takes the concrete direct from the mixer, raises it to the required level, and dumps it automatically into cars or into a hopper to be taken by barrows as required.

Considerable time of the plant is frequently wasted and the output restricted by dumping from the mixer or from the hoist bucket into barrows, instead of into a hopper large enough to hold at least a batch and a half from which the concrete may be drawn into barrows.

The loss of time is indicated by a comparison of the different groups of items in Tables 63 and 64, pages 425 to 431.

Derricks, as well as bucket hoists, are sometimes used in building or other elevated construction with fair success. In some cases, with a long boom, the bucket can be dumped directly into the forms, but, in general, building superintendents prefer to dump into a hopper to save the time placing and discharging the bucket at the exact point where the concrete is required. When dumping into a hopper, the engineman below can swing the boom so that no tag-man is required on the higher level. The common type of bucket hoist, such as is illustrated on page 335, is generally more economical than derricks for building construction. Times and costs with derrick work are discussed on page 402.

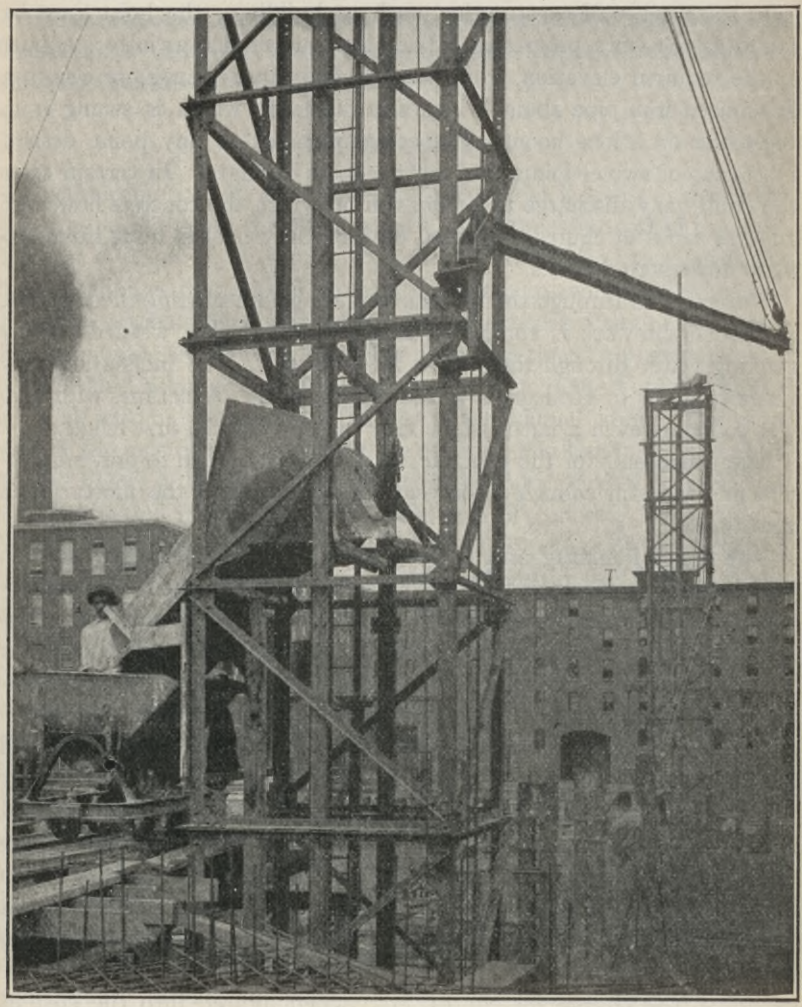


FIG. 24. Bucket Hoist for Handling Concrete at Lowell, Mass. (See p. 334.)

Chutes. Long chutes down which the concrete flows to place have been used successfully in bridge construction and have also been adopted in certain cases in building construction. The concrete is hoisted in a bucket running in a light framework to a high level, from whence chutes, the ends of which are movable, supply the concrete to the point desired. A plant of this kind is illustrated on page 362.

In some types of construction, such as buildings, the hoist must be raised as the work progresses. The hoist bucket dumps into a hopper at the required elevation, from which it flows to a trough, or else to a galvanized iron pipe about 7 inches in diameter, which is swung from the tower on a long boom. The concrete is fed to any point desired by means of swivel joints and short lengths of chute. In certain cases the chute may discharge to hoppers, from which the concrete flows into another series of chutes supported on secondary booms, hung from auxiliary towers or derricks.

Water is run through the troughs or pipes before starting the concrete, and when the work is completed they are thoroughly washed out by running water through them for a few minutes. The inclination may range from 20 to 45 degrees with the horizontal. Sometimes with very wet concrete, even a flatter slope may be used for the first length.

The consistency of the concrete must be thin enough to prevent clogging and yet stiff enough to prevent the separation of the mortar from the stone.

The cost of mixing and placing by chutes has been estimated on various jobs at from 15 cents to 50 cents per cubic yard. In considering the cost of this method of handling concrete, it must be recognized that the only practical difference between this and the other methods where the concrete is hoisted in towers, lies in the substitution of the pipes or troughs for barrows, cars or other vehicles.

In estimating the economy, the original cost of the chutes and auxiliary apparatus must be taken into account and a fair charge for depreciation and interest, as well as for installation, charged against the job upon which it is used. This item of plant charge must be combined with the labor of handling the apparatus, and then compared with the labor cost and charge for vehicles by other methods of transportation. The result for any particular case may depend upon the quantity of concrete to be deposited. With a plant of large capacity, the charge for chutes, etc., when figured into the cost of concrete may be a comparatively small item, while in other cases it may amount to more than the extra labor required by other methods of transporting. The construction of chutes is illustrated in Fig. 35, page 363.

Belt Conveyors. For fixed plants, belt conveyors are frequently economical. Approximate costs for different conditions are tabulated on page 373.

Cableways. Cableways with large buckets are frequently used in heavy construction, such as dams. An example of this is the Ashokan Reservoir for the New York Water Supply.* Approximate costs of cableways are tabulated on page 374.

COST OF PLANT

In estimating the cost per cubic yard of concrete, it is just as necessary to figure the charge for the plant expense as for the labor cost of the men. Even for a simple style of mixer, turning out 50 to 75 cubic yards per day, the charges that should be made for the plant will usually amount at least to 10 cents per cubic yard. Where expensive labor-saving machinery is used, the plant expense may be several times this rate, and may form, in fact, a large part of the total unit cost, being actually higher per cubic yard of concrete than the cost of the manual labor. The more efficient the machinery for making the concrete and handling the materials, the higher is apt to be the plant cost per cubic yard of concrete, the actual reduction in total cost per cubic yard of concrete being due to the reduced manual labor. In spite of the large effect of plant cost, it is frequently simply guessed at or widely underestimated. Data which fail to take this item into account are valueless.

The cost of placing concrete, as given in the tables at the end of Chapter XIII, includes the charge for plant, presented so as to be readily adapted to different conditions of ordinary simple work. Examples of costs of certain typical plants with descriptions and, in some cases, drawings of the plants are given on pages 342 to 367.

Certain general principles will be outlined here, indicating the special points which must be considered in estimating.

Unless the conditions are fully known, the quotations of costs of completed jobs are of little value as a basis for making new estimates. Even if the costs are given in full so as to include all the items, conditions on a new job usually make comparison difficult. On the other hand, plant costs that are carefully compiled may be of considerable value to an experienced contractor or engineer to aid him in making a rough estimate.

To obtain an accurate estimate, a design should be worked out in the rough for each new job so as to secure the one best adapted to the con-

*The Ashokan plant is described and illustrated on pages 357 to 360.

ditions. A plant designed especially to suit the local characteristics with a view to reducing the labor expense, in some cases, may not cost any more than a plant for which the labor item has not been carefully considered, but the labor cost will be much smaller. In other words, as the plant charge per cubic yard of concrete increases, the labor charge should decrease more rapidly. The most economical plant is that in which the sum of these two charges is a minimum. Neither can be neglected.

A great deal of money is lost by contractors by building the construction plant haphazard or according to the ideas of a foreman who has seen only a few jobs. A design, carefully prepared in the office, with the advice of a practical superintendent, will effect a large daily saving in wages of men and in plant expense.

ESTIMATING PLANT COSTS

Since concrete estimates are usually made in terms of the number of cubic yards of concrete in place, the plant cost may be best expressed in this unit.

First Cost of Plant. The costs of machine mixers with their accessories vary from time to time as prices change and designs are altered. It is always advisable to purchase a first-class machine, since loss in time of men during a shutdown quickly overbalances the saving in first cost of a machine of poor quality. Also, the saving in labor by mechanical devices may cut an important figure on a large job. In estimating the cost of a new plant, the prices for the mixers and for machinery may readily be obtained from the manufacturers. In general, however, the machinery which is purchased is of more or less value at the close of the job, so that, in determining the cost to charge to a cubic yard of concrete, it is frequently sufficiently accurate to use approximate general costs large enough to include contingencies, and carefully work these out into unit costs. The method of making such a computation is shown on page 342.

Table 57, page 371, gives approximate prices of apparatus and concrete machinery.

The small size of mixer suitable for a one-bag batch, such as would be supplied for the lowest price, is an uneconomical size to purchase. A 2-bag or a 3-bag batch mixer is most suitable for ordinary concrete construction, while a 4-bag is adapted to larger work. A still smaller size of mixer, adapted for very small batches of concrete, is made for such work as making up building blocks by hand, and other similar work. Continuous mixers range somewhat lower in price than batch mixers, although when provided with satisfactory measuring apparatus, the price may exceed that of the batch mixer.

Allowance must be made in figuring costs for wire rope, belting and for the various incidentals, such as measuring tanks, buckets, and miscellaneous tools. On a building construction job of concrete figured to cost say $75 000, from $100 to $200 may be estimated for small tools, including hammers, saws, bars, etc., for laborers' use in taking down forms and for incidental operation. In our cost tables, however, these small tools are figured for convenience into the cost of the form labor.

For an average estimate, the authors have selected, for use in the tables in Chapter XIII, a price of $1200 for a 2-bag mixer with engine and boiler, and $1800 for a 4-bag mixer with engine and boiler.

Where special machinery is required for handling the raw materials and transporting the concrete, the cost of the plant may run up to $5000, $10 000, or even considerably higher than this. Such expensive plants only pay where the quantity of concrete to be laid is large and the output per day is considerable, so that the costs can be distributed into a large quantity of concrete with a small resulting cost per cubic yard.

The cost of a single cableway may range from $3700 to $23 000, as outlined in Table 59, page 374. For covering an area of some width the towers must be movable. A line of derricks is frequently needed to take the material from the cable. Approximate costs of derricks are given in Table 60, page 374.

The approximate costs of belt conveyors are tabulated on page 373. The complete plant for the Parsippany Dike* with bins, materials, belt conveyors, mixers, and all appurtenances cost about $7000.

The costs of several plants are given on pages 342 to 367. For prices of other materials, reference should be made to Table 57, page 371.

Freight. The cost of the freight, which must be charged to the job, can be obtained from the railroad company in terms of 100 pounds, and the weight of the machinery usually found from the manufacturer's catalog. Under ordinary conditions, the cost of the freight on a concrete mixer with appurtenances should not exceed $20 to $40.

In many places, when near a large city, machinery can be hauled by a team, but the cost will usually run nearly as high as when it is shipped a longer distance by freight.

Installation and Moving. The installation of a plant must of course

*Illustrated in Taylor and Thompson's "Concrete, Plain and Reinforced," second edition, page 272.

be charged to the job. This includes the hauling from the freight station or from one job to another; the setting up of the mixer; the building of the platforms; and the setting up of any other machinery connected with the plant. Hauling may be estimated at $30 or, assuming that there must be a haul in each direction, $60 may be taken. The set-up of the simple mixing plant, without conveying machinery or special storage bins, may be estimated at from $75 to $150. These may be used as approximate figures to cover the cost of platform and runs in a fixed plant or the cost of 4 to 6 moves of portable machinery.

Depreciation and Repairs. Depreciation of a mixing and handling plant varies to such an extent both in the matter of machinery and handling equipment that only an approximate average can be mentioned. When operated nearly to its maximum capacity continuously and given average good care, mixing machinery will run, at practically maximum efficiency, for 3 to 5 seasons on an average. There are special instances where the work is so very severe that the machines do not run more than one to two seasons at satisfactory or economical efficiency. Engines, boilers, and hoist-engines should last longer than five seasons, although dependent on how they are used and the care taken of them: anywhere up to eight years would be a fair estimate. Cableways, derricks, dump cars, belt conveyors (excepting the belts) should be figured with the mixing machinery. Platforms, inclines, trestles, hoists, bins, chutes, sheds, etc., built of lumber cannot be used more than once ordinarily, and on many jobs, owing to the location or to the nature of the work, practically their whole cost must be charged to the first job. Depreciation and repairs may be taken together because, when repairs are well kept up, there is less depreciation. On a large job, lasting, say, three or four years, the entire plant may be used up, that is, the repairs and replacements may amount to as much as the salvage value of the plant at the end of the period. In such cases, the original cost should be charged to the job, dividing it by the number of cubic yards of concrete to be laid to determine the cost per cubic yard.

Second-hand machinery, while cheaper in the first place, is apt to be expensive in running, so that it is not usually economical to purchase.

For depreciation and repairs a fair rating under ordinary conditions is considered to be 25 per cent per year, in addition to the interest on the cost. Properly, the depreciation should be deducted year by year and the interest figured on the value after deducting the depreciation. Because of the uncertainty of this item, it is customary to figure the interest for each year on the first cost and the depreciation beside.

An illustration of depreciation in concrete mixing machinery is found in the records by the Aberthaw Construction Co.* Taking the average of four mixers in operations for about 4 years, the repairs and depreciation actually figured about 26 per cent per year.

Rental. Small contractors frequently rent the machinery necessary for the carrying out of their work. This rental takes the place of the item for depreciation and repairs and in addition includes an item for profit. The total rent divided by the total number of cubic yards of concrete laid gives the rent per cubic yard of concrete.

Assuming the life of machinery as four years, the rental charge with a fair allowance for profit and idle periods, should not be over 5% of original cost per month.†

Operating Days per Year. It is most convenient to compute the plant cost in the first place in terms of per day, then divide this by the average quantity laid per day. To do this, an estimate must be made of the number of working days in the year. Concrete work is apt to be more or less irregular. There is time lost during the winter and on small contracts a large amount of wasted time between jobs; consequently, to be on the safe side, it is fair to assume not over 100 days per year. In records of mixers owned by the Aberthaw Company, mentioned above, the average running time was 160 days per year, this being somewhat larger than the average which we have selected. A smaller concern, or one which does not make a specialty of concrete work, would be apt to have longer idle periods.

Tools. The cost of tools has been referred to incidentally under the general heading of the first cost of plant. In the table on page 367 are also given some approximate costs which may be used in estimates.

Fuel. The charge for fuel will vary of course to a certain degree with the output of concrete. For mixing, the authors have allowed $0.03 per cubic yard of concrete, and the same unit cost for hoisting or conveying short distances by machinery. This is based on coal at $4.00 per ton.

Plant Costs Reduced to Rate per Day. Taking the approximate average costs outlined above, the daily charge for a 2-bag mixer and a 4-bag mixer may be compiled as follows:

***Engineering News*, May 26, 1910, p. 619.

†This figure is suggested also for sewer machinery by Messrs. Metcalf & Eddy in their Report to the Boston Finance Commission, Vol. III, page 446.

Item	2-Bag Mixer	4-Bag Mixer
First cost mixer, engine and boiler	$1200	$1800
Freight	30	45
Total first cost	$1230	$1845
Annual depreciation (¼ total cost)	307	461
Interest on capital invested at 6 per cent	74	111
Hauling and setting up (once)	60	90
Moving 3 times	48	72
Annual charge for mixing plant	$489	$734
Daily charge (100 full days)	$4.89	$7.34

These items are exclusive of the labor of running the machinery or of the fuel for the plant.

With the suggestion above, it is comparatively easy to figure the plant costs, whatever may be the first cost of the machinery. The plant charge per cubic yard of concrete is determined by dividing the cost per day by the number of cubic yards made on the average throughout the length of the job. This in turn may be determined by dividing the estimated total length of time of construction in days by the total number of cubic yards to be laid.

It is to be understood that the values above given are principally to illustrate general methods and apply only to the most general conditions. They may be used in preliminary estimates of costs when the design of the plant is somewhat undetermined, but when actual conditions become known, corrections should be made in detail.

EXAMPLES OF CONCRETE PLANTS

Several concrete plants that have proved satisfactory in practical operation are briefly described below. These are given for the purpose of suggesting methods of plant design adapted to various conditions and also to furnish an approximate idea of costs of plant construction. Selections have been made of various types so as to cover as wide a range as possible. The descriptive matter in connection with each plant has been supplemented by personal knowledge or correspondence.

The costs which are given will afford suggestions to an engineer or contractor who wishes to obtain, for a preliminary estimate, a rough approximation of the cost of the plant. As the cost is divided into a large quantity of concrete, a figure which is not strictly accurate is frequently sufficiently exact for such a preliminary estimate.

STATIONARY BATCH MIXER

A satisfactory arrangement for a stationary batch mixer adaptable to various cases of actual construction is shown in Fig. 25, page 343.

The bin above the hopper is divided into two compartments for the sand and stone, and these are measured by feeding them to defin-

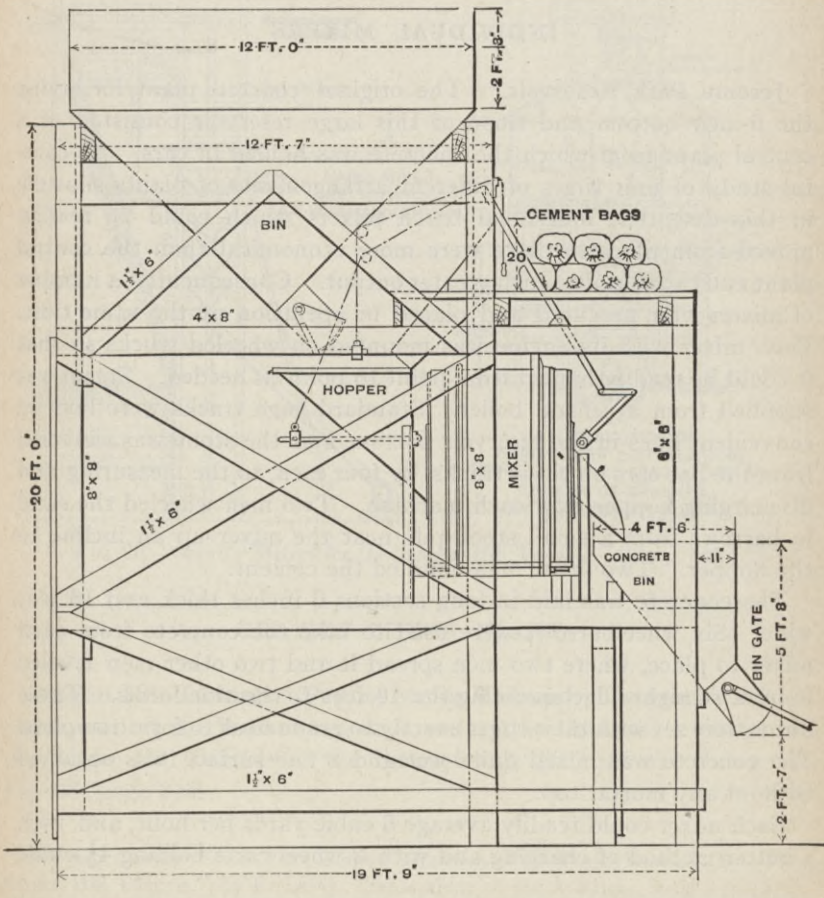


FIG. 25. Stationary Mixing Plant with a One Yard Rotary Mixer (See p. 343)

ite heights in the hopper, the cement being dumped into the chute in front. The output of such a plant is governed chiefly by the time required for the mixing and the arrangements for taking away the concrete. Average times under different conditions and the corresponding outputs can be obtained from Table 63, page 425. From this table it will be seen that under average conditions, such a mixer dumped at one operation can turn out, day in and day out, a batch every 2.6 minutes or 230 batches in 10 hours. The output under specially good conditions would be considerably larger than this, as indicated on page 397.

INDIVIDUAL MIXERS

Jerome Park Reservoir.* The original concrete plant for laying the 6-inch bottom and slope of this large reservoir consisted of a central plant from which the concrete was hauled in cars. A careful study of unit times of different arrangements of plants showed, in this case, that individual batch mixers which could be readily moved from place to place were more economical than the central plant and capable of a much greater output. Consequently, a number of mixers were procured and placed in operation at the same time. Each mixer with its engine was mounted on wheeled trucks so that it could be readily hauled from point to point as needed. Steam was supplied from a central boiler. Standard gage tracks were laid on convenient lines in the reservoir bottom and the stone was shoveled from the flat cars on these tracks, by four men, to the measuring and discharging hopper over each machine. Two men wheeled the sand in barrows from a small stock pile near the mixer up an incline to the hopper. Two other men handled the cement.

The concrete was laid in long sections 6 inches thick and 16 feet wide. Six wheelbarrows were used to take the concrete from each mixer to place, where two men spread it and two other men leveled it by a straight-edge spanning the 16 feet to the side forms. These forms were set with their edges exactly to grade so as to form templets. The concrete was mixed quite wet and a fine surface was obtained without any mortar top.

Each mixer could readily average 6 cubic yards per hour, and with a better method of charging and with 2-wheel carts holding $4\frac{1}{2}$ cubic

*See also *Engineering News*, September 21, 1905, p. 299.

feet of concrete, instead of the small wheelbarrows, the output could have been still further increased.

The first cost of a plant of this character can be figured from the information given at the end of this chapter and in the following chapter. This case depends upon the number and length of tracks laid, the number of mixers and engines, the size of boiler, the number of barrows, the amount of staging built, the amount of lumber used in runways, and so on.

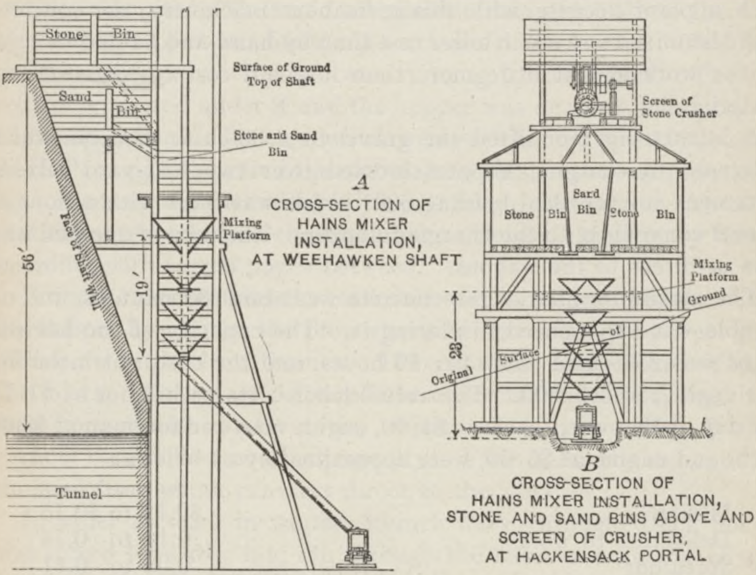


FIG. 26. Gravity Mixers for the Bergen Hill Tunnels. (See p. 345.)

GRAVITY MIXER PLANT

Bergen Hill Tunnels,* Pennsylvania Railroad. The gravity mixer plants used at the Weehawken shaft and at the Hackensack portal of the Bergen Hill Tunnels of the Pennsylvania Railroad are shown in Fig. 26, page 345.

*See paper on the "New York Tunnel Extension of the Pennsylvania R. R. The Bergen Hill Tunnels," by F. Lavis, Transactions of the American Society of Civil Engineers, Vol. LXVIII, 1910, p. 118.

CENTRAL PLANT

Laclede Gas Light Company.* In certain cases, such as city work, or on a large job where very small pieces of concrete are to be laid at scattered points, a stationary plant from which the concrete is hauled in carts may be economical. The economy of such a plant depends upon the quantity of concrete to be laid, which must be sufficient to keep the plant in fairly continuous operation. Local conditions should be carefully studied before selecting this type.

The Laclede Gas Light Company, at St. Louis, Mo., established such a plant because, with this permanent machinery, the concrete could be mixed at a much lower cost than by hand and hauled in carts to the work at but little more than it would cost to haul the dry materials.

A bucket elevator lifted the gravel to a 30-cubic yard bin which delivered to charging hoppers located over two half-yard mixers. A cement storage shed holding 500 barrels was built with a floor at a level convenient to the charging hopper. The mixers dumped into cars or direct to the wagons.

The maximum haul of the concrete was about 30 minutes, and no trouble was experienced in placing it. The capacity of the Laclede plant was 250 cubic yards per 10 hours, and the cost, not including the engine, was $2500. The actual labor costs with labor at $1.75 per day of 10 hours, teams at $4.00, engine man and foreman at $3.00 each, and engine at $5.00, were approximately as follows:

	Per Cubic Yard
Mixing	$0.12 to $0.15
Delivering to work	0.10 to 0.14
Spreading	0.08 to 0.11
	$0.30 to $0.40

These costs do not include the cost of material, or the interest and depreciation upon the plant.†

MIXER SUPPLIED BY CABLE HAULED CARS

Long Island Railway Power House.‡ This plant was built to handle 300 cubic yards of concrete per 10 hours, but with 60 men

*See *Engineering News*, March 10, 1904, p. 231.

†Personal correspondence with Mr. D. G. Fisher.

‡See *Engineering News*, May 31, 1906, p. 592, and *Engineering Record*, April 9, 1904, p. 454.

working it actually made and placed about double this amount, i.e., 600 cubic yards per day, or, on an average, about one cubic yard per minute.

As shown in the illustration, Fig. 27, a platform 30 feet in width and over 100 feet long was built at a height of about 18 feet above ground. Teams drove up an incline on to this and the stone and sand were dumped from the wagons on each side of the platform in piles 125 feet long. Under each of these piles a trench or tunnel is shown, in which ran cable cars which were filled by hand from the ends of the piles. To avoid all possible delay in loading the cars, a movable hopper was built on a track above the tunnel. This hopper was filled while the car was running to the mixer. The car, returning, passed under it and the hopper was dumped, filling the car at one operation. The cars, which were each hauled up an incline by a 25 H. P. engine, delivered the materials to bins, as shown in the drawing. Cement was delivered in bags through chutes from the upper platform and stored on the platform, as shown, closed in by double boarding with tarred paper between.

From the storage bins the materials were run down into the charging hopper by chutes, the proportions being regulated by steel gates sliding in angle iron frames. The charging hopper delivered to the mixer. The mixer delivered the concrete, mixed very wet, to a steel hopper with double gates, which in turn delivered to 2-wheel carts of 6 cubic feet nominal capacity. From these the concrete was dumped from plank runways direct to the work.

In order to work in winter, 18-inch flues, through which hot air was forced by a disc fan, ran through the bases of each pile of sand and stone for the full length.

MIXING PLANT CAR FOR RETAINING WALLS

Chicago Drainage Canal.* For the retaining walls of a part of the Drainage Canal, mixing plants were built on flat cars running on standard gage tracks, 12 feet apart on centers, along one side of the wall for its entire length. The center line of the nearest track was 10 feet from the face of the wall. Two standard flat cars were solidly united by heavy timber platforms, so as to form practically one very wide car. A timber framework built upon this platform supported 3 working floors. An engine, boiler, and one mixer were located on

*Plant is shown in *Engineering Record*, February 17, 1906, p. 190.

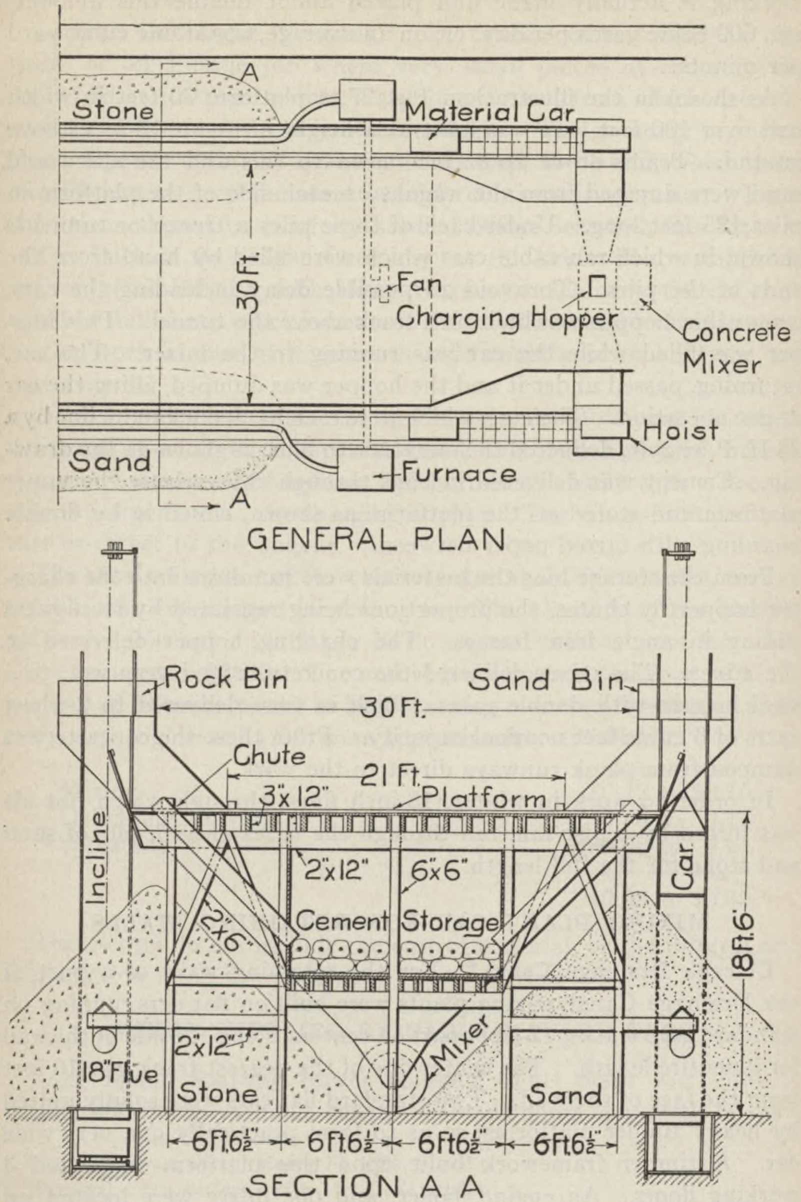


FIG. 27. Plan and Section of Mixing Plant, L. I. R. R. Power House (See p. 346).

the first floor and 2 mixers on the second floor, the machinery being all driven by line shafting and friction gearing.

A small derrick and hoisting engine on the third floor hoisted materials from a surface track alongside and dumped into three 15-cubic yard hoppers, two holding stone and the third divided in the middle for cement and screenings. This double hopper fed through a measuring hopper into a mixer on the first floor, where the cement and screenings were mixed dry* and then raised by two bucket elevators to measuring hoppers over two mixers on the second floor. The broken stone was drawn from the bins through mixing hoppers direct to these two mixers. These two mixers delivered the concrete to inclined bucket elevators which dumped it into a hopper on the middle line of the wall. From this hopper the concrete ran to place in 10-inch pipe chutes. The cost of both of these plants complete was about \$21 000.† The cost of the two plants divided by the total quantity of concrete laid gives a unit plant cost of \$0.21 per cubic yard. This, however, does not include the repairs, or fuel, or the cars and locomotive handling the materials.

Lawrenceville Bottoms.‡ A car plant was used also in the construction of a concrete trestle for the Big Four Railway, over the Lawrenceville Bottoms, near Lawrenceville, Ill., and illustrates a type of construction suited to fairly level ground. The plant is shown in Fig. 28, page 350.

Materials were unloaded from railway cars into small steel V-shaped cars which dumped directly to skips. These skips were hauled up an incline, as shown in the drawing, and delivered direct to the mixer. The boom skip cars, into which the mixer dumped, received the concrete and delivered it to steel dump cars running on the top of the viaduct. The part of the rear incline extending into the pit was hinged to fall back while moving and the boom was movable so as to provide for varying height and also for moving forward.

The labor cost mixing and placing concrete with this machine was \$1.20 per cubic yard, whereas the labor cost where the machine was not used averaged about \$2.00 per cubic yard.

*This preliminary mixing of the cement and sand is not generally considered necessary in machine mixed concrete. The same scheme of plant design could be used effectively without this feature.

†Personal correspondence with Mr. L. K. Sherman, Assistant Chief Engineer.

‡See *Engineering Record*, August 11, 1906, p. 155.

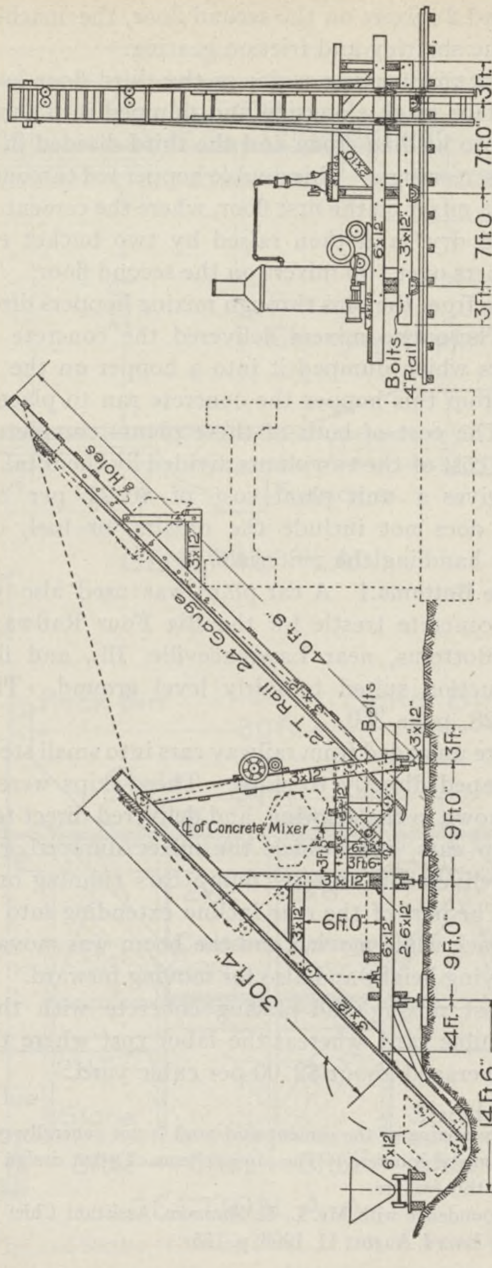


FIG. 28. Car Plant at Lawrenceville, Ill. (See p. 349)

An approximate estimate of cost is as follows:*

Three V-shaped feeding cars	$ 195
Two skip cars	160
20-H.P. hoisting engine	1150
Concrete mixer	950
Three V-shaped distributing cars	195
Crabs	100
Timber and labor, estimated	150
Total Cost of Plant	$2900

PLANT WITH DERRICK AND LIGHTERS

Buffalo Breakwater.† The plant which was used in the construction of the Buffalo Breakwater for making concrete blocks of 15 to 20 tons weight is shown in Fig. 29, page 352. This plant was built on a pier 32 feet wide by 280 feet long, located in the shallow water off shore at Stony Point. Three hundred 20-foot piles were driven and capped with 12 by 12-inch timbers, upon which a floor of $1\frac{3}{4}$-inch plank, planed and tongued-and-grooved, was laid. On this pier, near the middle of its length, was located a 4-foot cube mixer elevated on framing. Near the mixer was placed an engine and boiler for hoisting material from two 125-yard scows, alongside, where the materials were measured in proper proportions in buckets and then delivered to a hopper over the mixer.

The concrete was handled by cars running on two 20-inch gage tracks extending the length of the pier. These cars, running under the mixer, received their loads and delivered them in 6-inch layers to molds placed on either side of the tracks for their entire length. The molds were made of 2-inch lumber, planed and matched, with 6 by 8-inch framing. One side of each mold was formed by planking against the timbers which supported one side of the railway trestle. The other side and the ends were independent sections held together by iron rods. The floor of the pier formed the bottom of the mold.

*Personal correspondence with Mr. DeWitt V. Moore, Contractor.

†For further discussion of breakwater plants, see paper by Emile Low, Resident Engineer, Transactions American Society of Civil Engineers, Vol. LII, p. 73, 1904; and article by Major T. W. Symons, U. S. A., *Engineering News*, May 29, 1902, p. 429.

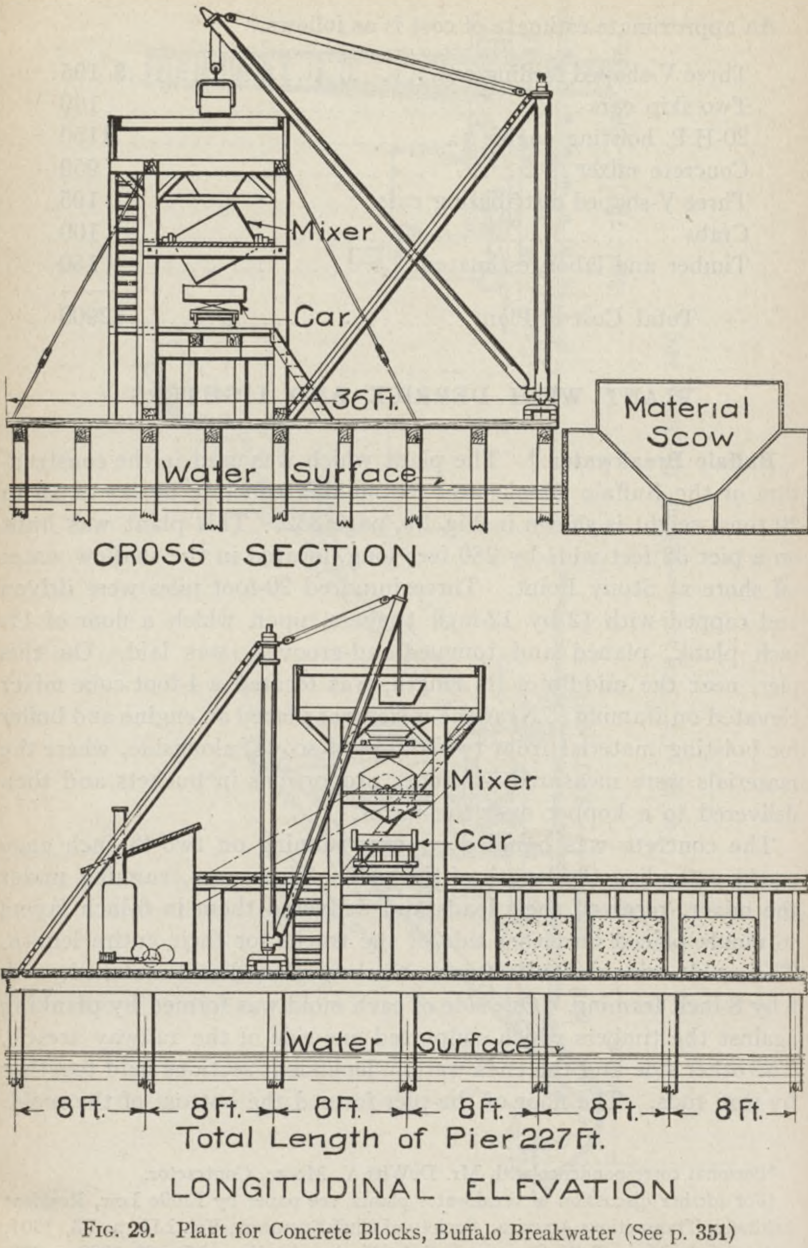


FIG. 29. Plant for Concrete Blocks, Buffalo Breakwater (See p. 351)

The cost of the plant was approximately as follows:*

300 piles in place	$ 3000
12 by 12-inch stringers	1800
2-inch flooring	1000
30 000 feet B. M. lumber for molds	1800
Concrete mixer	700
Derrick, framing for mixer, trestle on track, cars, engine, approximately	3000
	$11300
Add 10% for miscellaneous items	1130
Total Cost of Plant	$12430

FLOATING MIXER PLANT

Buffalo Breakwater.† A floating plant was used for monolithic concrete on the parapet and deck. An old schooner, 140 feet long and 27-foot beam, held a 5-foot cube mixer elevated on framing and run by a 9 by 12-inch horizontal engine. The mixer was placed well forward and two derricks were located amidships, one on either side. One derrick handled the materials from the scows alongside the mixer and the other took the concrete from the mixer. Each derrick had its own engine, and these with the mixer engine were run by steam from a single boiler. The concrete was delivered from the mixer to a skip placed on a small car, which was then run out far enough for the derrick to pick up the skip and swing it over the desired point in the breakwater. The cost of this plant was approximately as follows:‡

Schooner	$1000
Concrete mixer	700
Two derricks, two engines and one boiler	2000
Two scows	1000
Tug boat	4000
	$8700
Add 10% for miscellaneous materials	870
Total Cost of Plant	$9570

*Personal correspondence with Mr. Emile Low.

†See footnote, page 351.

‡Personal correspondence with Mr. Emile Low.

MIXERS FED BY BELT CONVEYORS

Corn Products Refinery Company Buildings.* A compact and efficient plant used at Argo, Ill., in the construction of several buildings, consisted of a number of units, each of which was made up by placing a rotary mixer on the middle of a 40-foot standard gage flat car. Above the car, high enough to clear the mixer, was a double bin for sand and stone, from which raw materials were run to a lower hopper in the required proportions, and then after the cement was added the charge was dumped into the mixer.

Cars holding the stone and sand were placed one at each end of the mixer car and the materials delivered to the bins by two belt-conveyors which extended on an incline out beyond the ends of the mixer car far enough to reach well into the material cars. The outer or receiving ends of the conveyors were supported by breast derricks placed at the ends of the mixer car platform, the stone and sand being shoveled into a small hopper which fed to the belt. The cement was elevated to the charging platform by a small hoist. The mixer delivered the concrete to steel cars which, in turn, dumped it to place or else into the bucket of a hoist which raised it to a hopper located on the floor where it was required. It was then carried to place by barrows.

With 16 men, not including those handling the concrete after it left the mixer, about 25 cubic yards per hour could be turned out continuously.

The approximate cost of each unit of the plant was as follows:†

Concrete mixer with engine and boiler	$ 765
Flat car, 40 by 90 feet	350
Steel charging hoppers	85
Shafting, conveyors, cement bag hoist, etc	573
Steam and water piping	45
Miscellaneous hardware	50
Norway pine timber	192
Labor, carpenter and millwright	395
Labor, steam fitters, etc	54
Engineering and supervision	100
Freights and incidentals	250
Total Cost of Plant	$2859

*See article by Mr. W. A. Hoyt, *Engineering News*, August 26, 1909, p. 212.

†Personal correspondence with Mr. W. A. Hoyt, Consulting Engineer.

New York Barge Canal.* Belt conveyors on a large scale, for handling both the materials and also the concrete after mixing, were used on one section of the New York Barge Canal.

The structures required about 100000 cubic yards of concrete and the plant maintained a continuous output of one cubic yard per minute when running at its maximum speed. The conveyors handling the concrete were over 800 feet in length, being made up of three sections, 80, 140, and 600 feet respectively.

Sand and stone were dumped from standard gage cars to hoppers from which belt conveyors carried them up to the bins over the Hains mixer. Through the middle of a 10000 barrel cement house ran a 20-inch belt conveyor which took the cement to the mixer. The concrete, as already stated, was carried from the mixer by a series of belts, each dumping on to the succeeding belt by a hopper so as to secure an even flow of material properly distributed over it. The speed of the belts was about 450 feet per minute. Traveling on the long conveyor trestle was a tripper on which the long belt ran at an angle of 20 degrees, feeding the concrete to another belt supported on a 45-foot boom, which swung from the tripper tower. This boom could be elevated to any level and swung over an arc of 200 degrees, so as to place the concrete at any point desired.

The concrete was deposited in the forms by spouts attached to the end of the boom and made so that they could swing easily and place the concrete in horizontal layers.

The method adopted in filling a section was to start in one corner and then move the tripper tower back and forth, swinging the boom through its arc and also swinging the spout. This formed a layer of any desired thickness over the whole section.

In handling the concrete on the belts it was necessary to mix it slightly drier than required on the work and the required wet consistency was obtained by piping water to the end of the boom conveyor, where it was added to the concrete. The tripper was shifted along by hand by means of a capstan and the boom was handled by hand winches.

Parsippany Dike, N. J.† Another belt conveyor plant which is described in "Concrete, Plain and Reinforced" cost complete, with bins, conveyors, mixers, etc., in the neighborhood of $7000.

*Plant is shown in *Engineering Record*, October 10, 1908, p. 416.

†For plan and brief description, see Taylor and Thompson's "Concrete, Plain and Reinforced," second edition, p. 273.

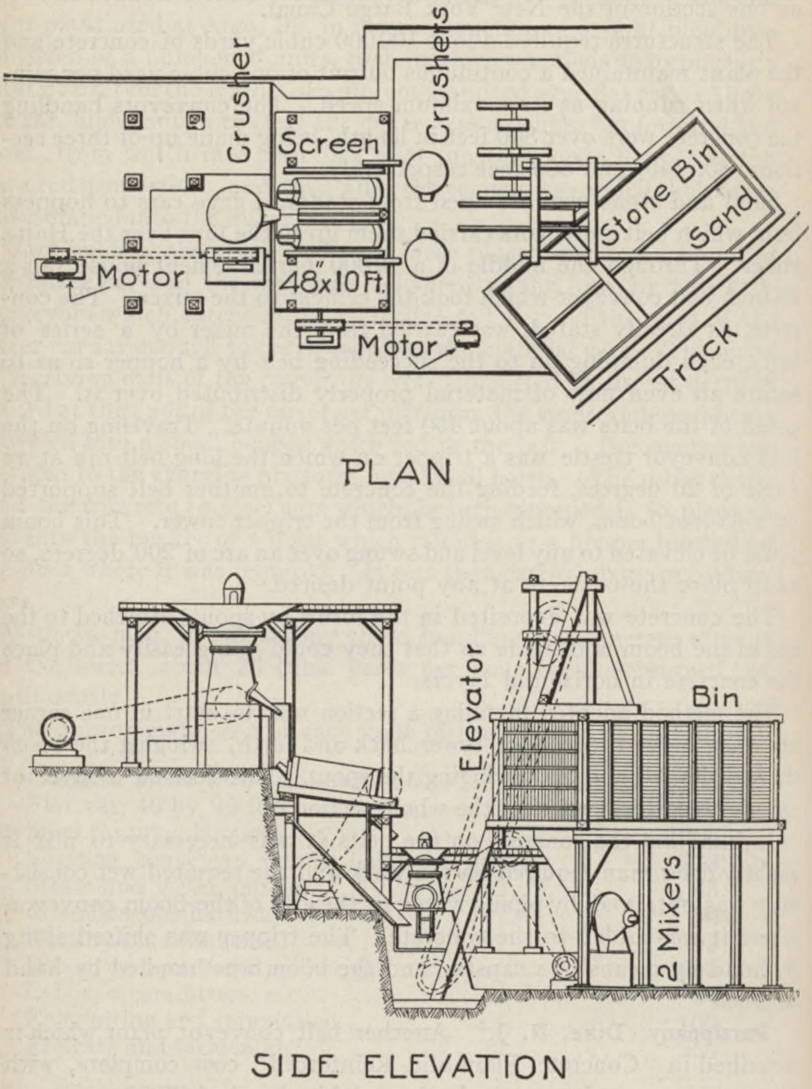


FIG. 30. Mixing Plant of Southern Power Co. (See p. 357.)

CONCRETE HANDLING BY CARS AND DERRICKS

Southern Power Company Dam, near Blacksburg, S. C.* The mixing and crushing plant used at the Ninety-Nine Islands Station on the Broad River is illustrated in Fig. 30, page 356.

Stone was brought from a quarry on three cableways to a No. 10 gyratory crusher that discharged either direct or through two No. 5 crushers, as desired, to a bucket elevator which carried the stone to bins over the mixer. Sand, which was received in dump cars, was handled by a derrick with a 2-yard clam shell bucket from the stock piles to the bins. The bins discharged to measuring hoppers over two 64-cubic foot cube mixers.

A track was laid near the upstream base of the dam and flat cars received the dump buckets from the mixer and carried them to a line of derricks which deposited the concrete where it was required.

To operate the crushers and mixing plant, 300 H. P. was used.

The cost of installing the plant complete was about $23 500.† This sum includes the cost, $18 000, of the machinery,—i.e., the crushers, screens, elevator, mixers, and motors,—as well as the cost of the bins and of the actual setting up of the machinery, and in addition to these items also includes the sum of $5000 for engine and bucket for sand, making a total of $23 500.

The average output was approximately 1100 cubic yards per day. This could have been increased to 1800 cubic yards per day or even to 2000, with the same plant, if the conditions had warranted it.

CONCRETE HANDLING BY CABLEWAYS

Ashokan Reservoir.‡ The plant at the Olive Bridge Dam for crushing and storing the materials and mixing the concrete is well arranged and efficient for a work of this magnitude. The dam contains about 500 000 cubic yards of concrete. The plant turns out 1000 cubic yards of concrete per day, this capacity being necessary in order to complete the job within the specified time.

An outline of the general design of the mixing and crushing plants is shown in Figs. 31 and 32, pages 358 and 359.

*See *Engineering Record*, April 2, 1910, p. 379.

†Personal correspondence with Mr. B. H. Hardaway, Contractor.

‡See *Engineering Record*, April 3, 1909, p. 380.

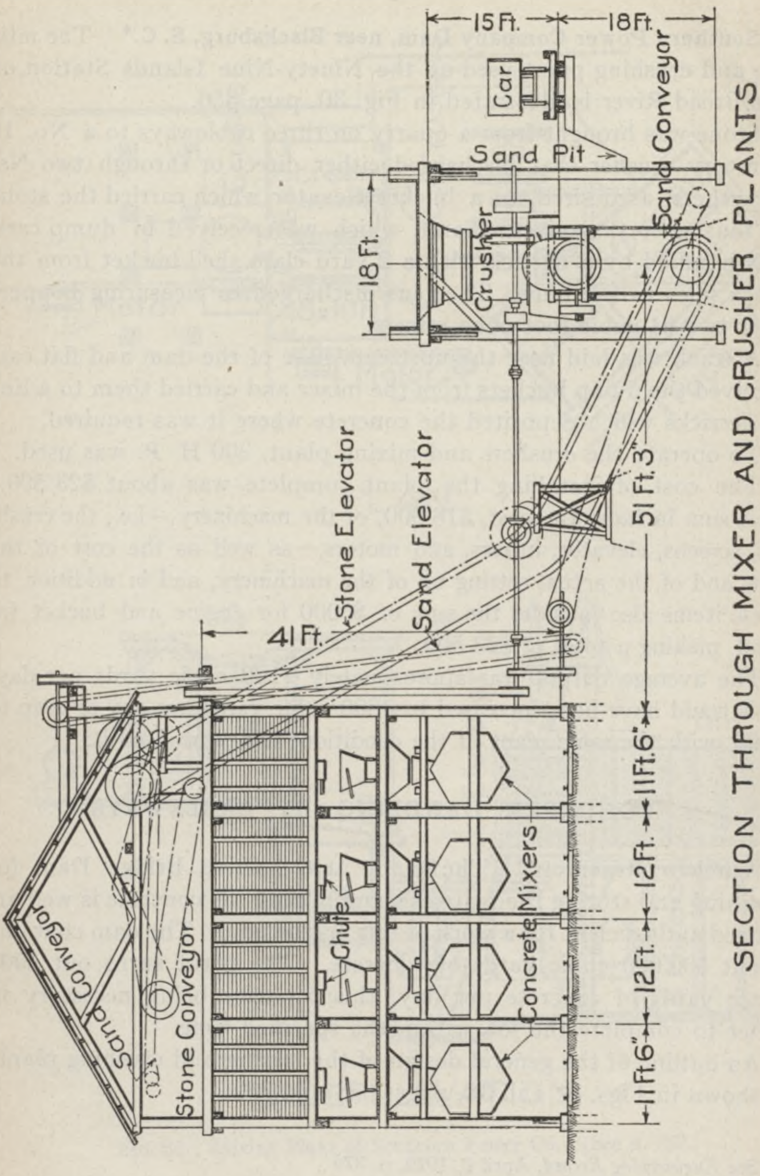


FIG. 31. Section through Mixer and Crusher Plant, Ashokan Reservoir, N. Y. (See p. 357.)

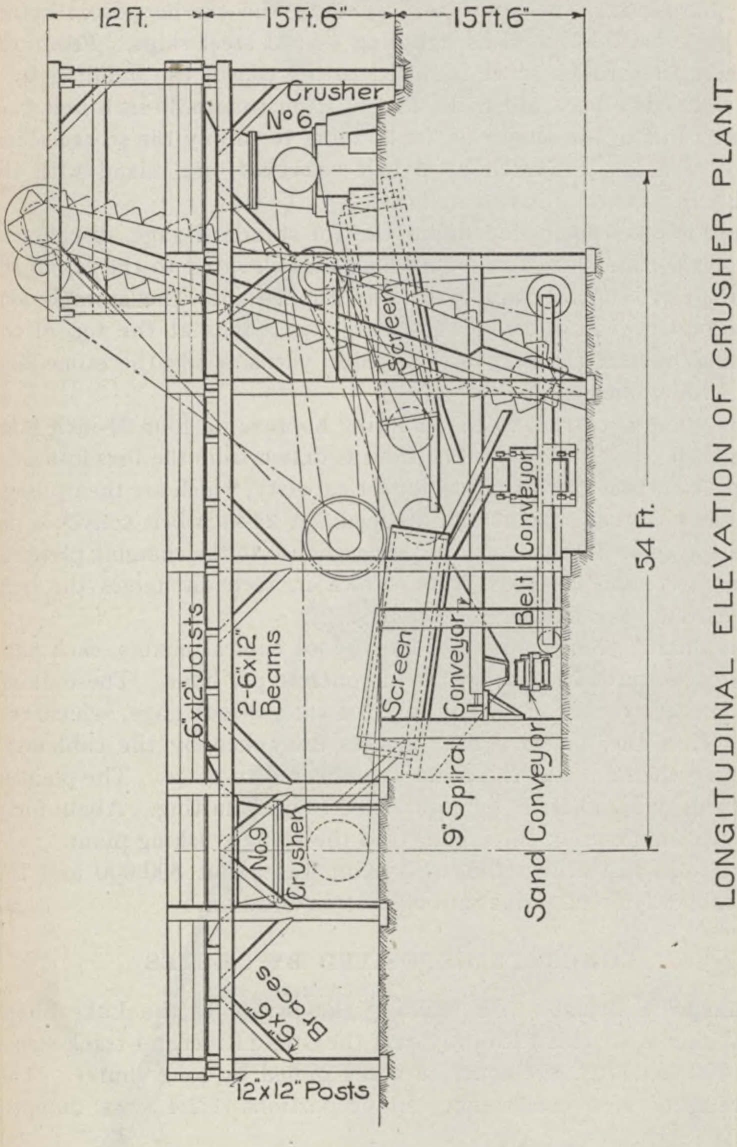


FIG. 32. Elevation of Crusher Plant, Ashokan Reservoir, N. Y. (See p. 357.)

In the lower story of the building, which contains the complete plant, are three stone crushers having a combined capacity of 200 tons per hour. The stone is hoisted to the crushers from standard gage cars by derricks handling 4-yard steel skips. From the crushers the broken stone is raised to the top of the building by a link belt conveyor, which discharges it on to two 30-inch belt conveyors running the length of the building to supply the storage bins. The screenings, delivered by a belt conveyor, are mixed with the sand which is also handled by a belt.

Sand is received in side dump cars of standard gage, discharging into a 500-cubic yard bin, from which it is elevated to the top of the building by bucket conveyors and dropped into the storage bins by secondary conveyors. These large sand bins at the top of the building have a capacity of 500 cubic yards, while the stone bins hold 1000 cubic yards.

The stone is carried to the charging hoppers on four 24-inch horizontal belt conveyors, while the sand is drawn from the bins into side-dump, A-bottom cars of 40 cubic feet capacity, which are then pushed over the charging hoppers and dumped. A 24-inch belt conveyor delivers the cement bags from the storage house to the charging platform or to a secondary belt conveyor, which in turn discharges the bags between any pair of charging hoppers.

The mixing plant consists of four 5-foot cubical mixers, each having a capacity of 75 cubic yards of concrete per hour. These dump into buckets carried on eight lines of cars, 3-foot gage, which run underneath the mixers. The buckets are taken by the cableways spanning the dam and the concrete delivered to place. The plant is operated by a 250 H. P. engine, belted to line shafting. About forty men are employed in the mixing and the stone crushing plant.

The total cost of installing this plant was about $90 000 and the four cableways cost about $16 000 each in addition.*

CONCRETE DEPOSITED BY CHUTES

Painesville Bridge.† In building the bridge of the Lake Shore and Michigan Southern Railway over the Grand River, a 4-track structure 400 feet long, the concrete was handled by long chutes. The concrete, of wet consistency, in proportions 1:2:4, was dumped

*Personal Correspondence with Mr. J. O. Winston, Contractor.

†See *Engineering Record,* May 1, 1909, p. 564.

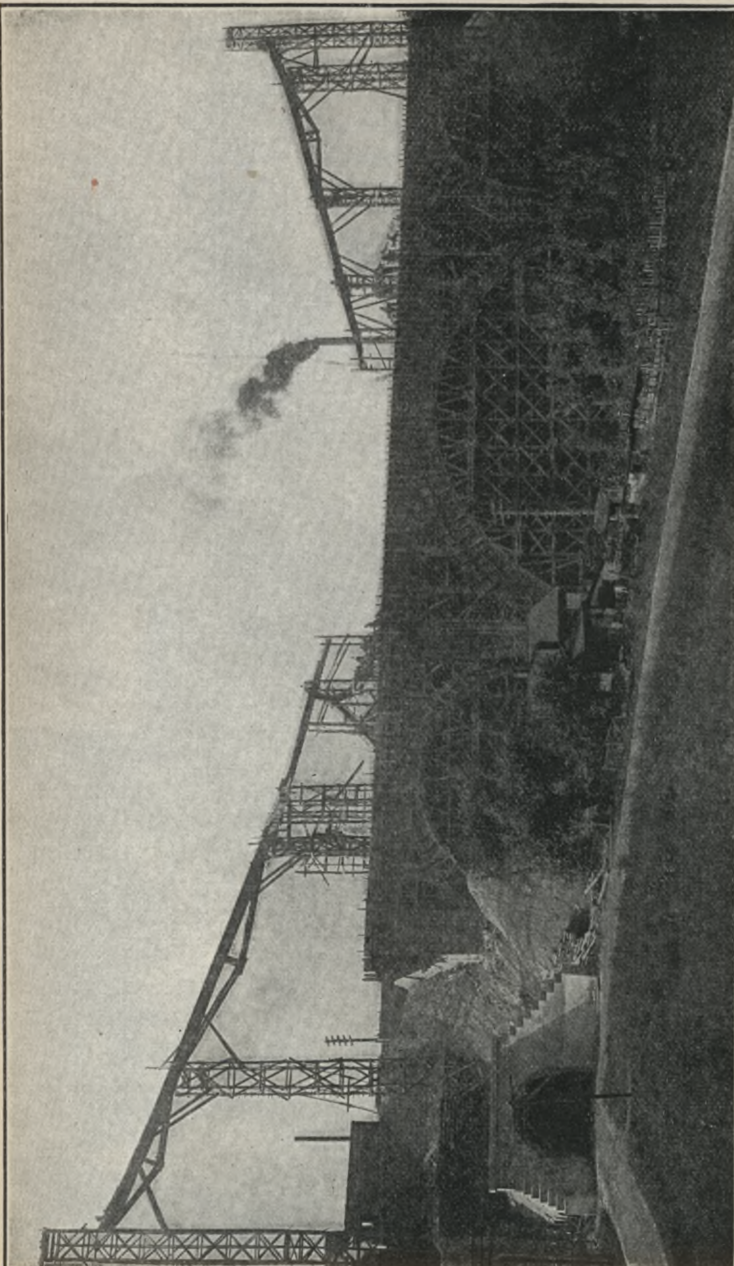


FIG. 33. Painesville Bridge under Construction. (See p. 360.)

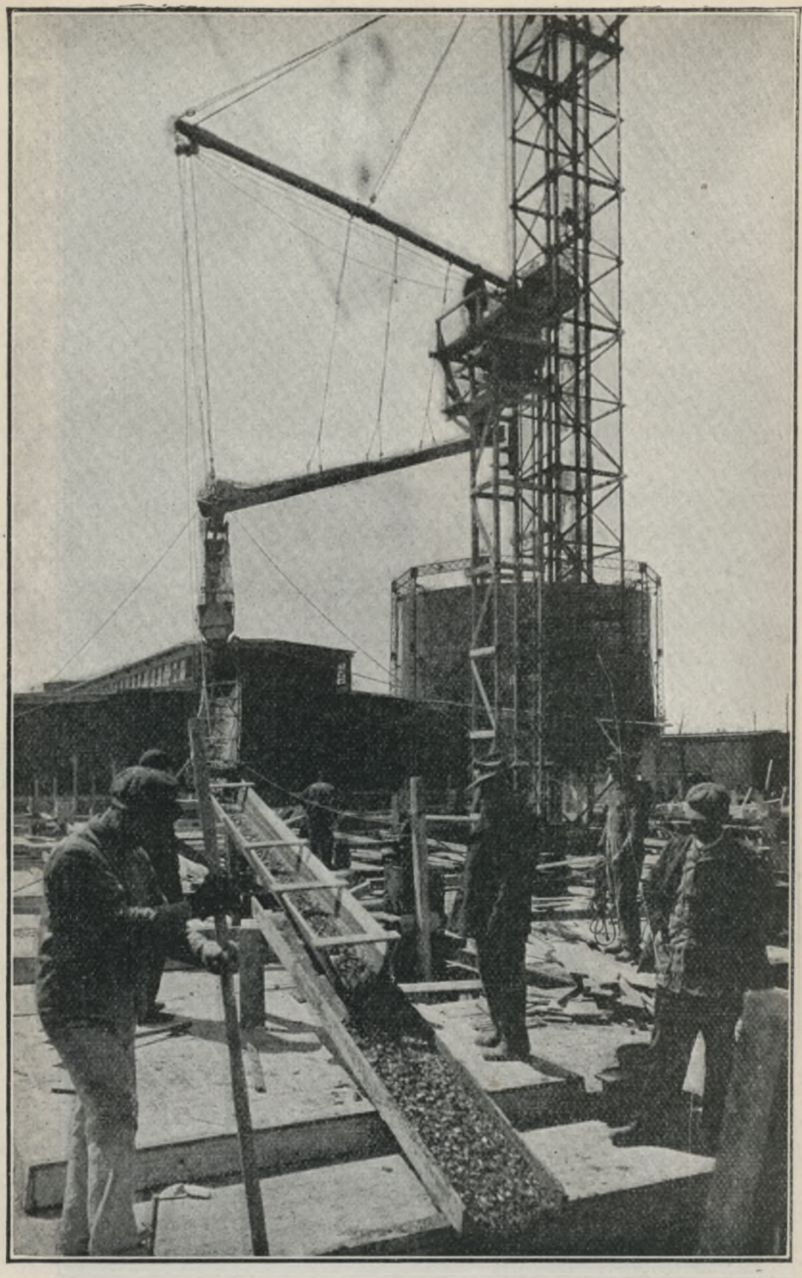


FIG. 34. Chuting Concrete at New Haven, Conn. (See p. 366.)

into the chutes from the mixing towers so fast that the flow was nearly continuous. By proper location of the chutes it was possible to allow the mixers to run continuously, close to their maximum capacity, and the concrete was satisfactorily placed. Stone and sand were shipped to the job in standard gage bottom dump cars, which unloaded

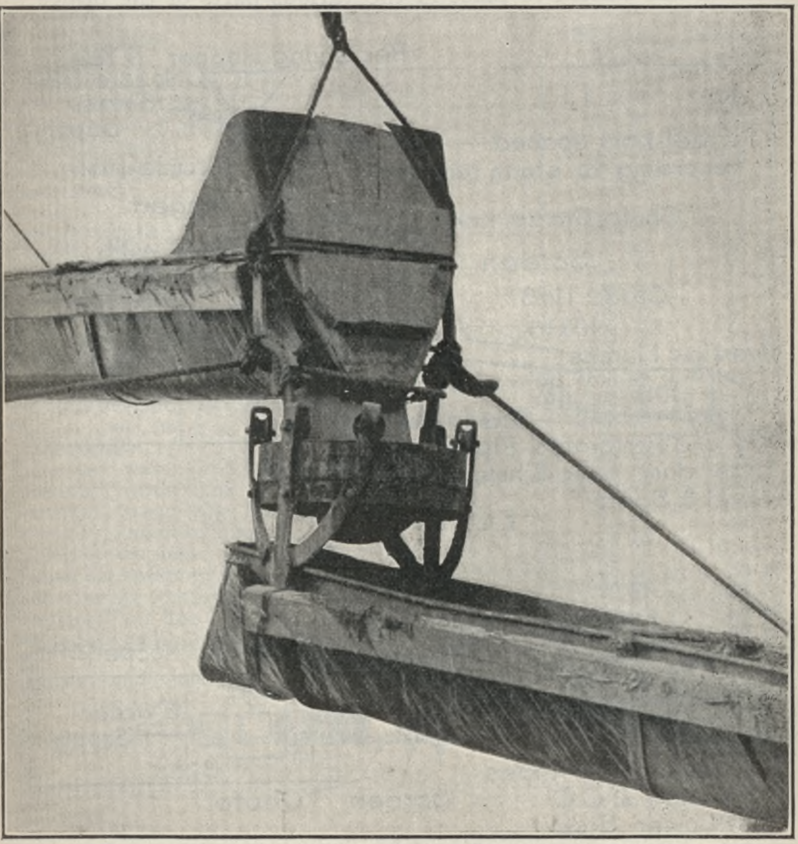


FIG. 35. Swivel Joint for Chute. (See p. 366.)

direct to the storage bins. These materials were then fed by gravity from the bins into small cars which dumped into a hopper above the mixer. The cement was brought on cars from the storage shed to the mixer in a similar manner.

A duplicate plant was provided at each end of the bridge. The concrete was hoisted in a one-yard bucket to the top of a frame work tower high enough to allow the concrete to be distributed through chutes to all parts of the bridge. The extreme length of flow was about 250 feet. The chutes were 24 by 24 inches in section, built of 2-inch lumber, planed one side. A continuous grade of one vertical to four horizontal was maintained for their full length. The concrete was carried to place in the various parts of the bridge by

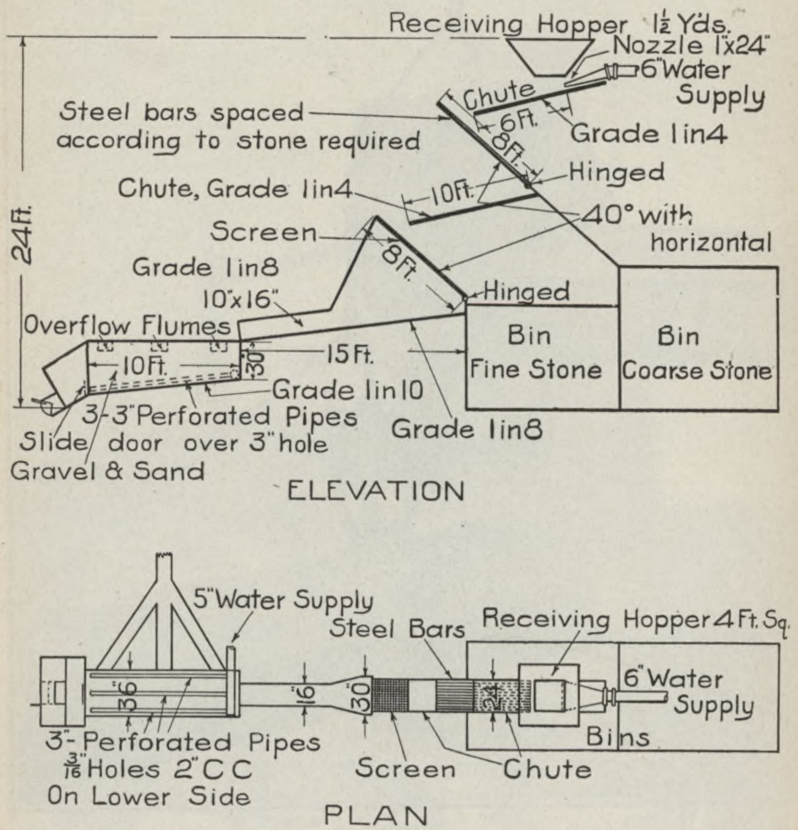


FIG. 36. Washing and Screening Plant. (See p. 367.)

vertical spouts and by lateral chutes running from the main troughs, which were on the axis of the structure. Secondary branches led from these laterals. The flow of concrete was diverted into the laterals and branches as required, by gates set against small cleats in the troughs. A view of the work is shown in Fig. 33, page 361.

The cost of the plant was as follows:*

COST OF PLANT FOR PAINESVILLE ARCH BRIDGE, ERIE DIVISION, NEW YORK CENTRAL LINES.

Plant	Material	Labor
Boarding houses	$476.40	$329.55
Tool house	70.88	35.00
Office (placing and repairs)	0.02	11.23
Cement house	312.41	205.95
Boiler house and sheds	276.30	353.75
Blacksmith shop	47.71	30.00
Material bins	1488.55	712.00
Water closet	22.34	16.00
Coal pit		11.62
Concrete chutes	1353.76	3103.25
Concrete elevator	574.83	963.46
Trestle for operation	1258.43	275.21
Material platforms	175.53	76.35
Temporary foot bridge	88.55	86.25
Temporary stairway	33.89	50.00
Removing temporary buildings		951.49
Placing pile driver scow and repairs	45.36	259.29
Tools and machinery (placing and repairs)	893.39	2153.58
Supplies (coal for engines and ice for employees)	2163.99	
Water supply	29.35	13.30
Temporary water pipe line	248.92	324.61
Temporary water tank	29.52	30.00
Temporary steam pipe line	257.91	223.82
Fitting up concrete mixer	50.78	198.52
Fitting up derricks	219.96	614.01
Placing air compressor	28.68	38.18
Shed over air compressor	29.87	33.75
Temporary air line	491.54	69.87
Temporary walk on old bridge	30.08	62.75
	$10698.95	$11231.89
Credit by material received from plant	2206.95	
	$8492.00	
Machinery depreciation	2125.00	
Total Cost of Plant	$10617.00	$11231.89

There was an average of about 200 men employed on the job. Italians were used as common labor and were paid 16¢ per hour.

Carpenters were paid from............22½¢ to 25¢ per hour
Chief foreman..........................35¢ per hour
Assistant foremen......................30¢ per hour

*Personal Correspondence with Mr. B. R. Leffler, Bridge Engineer.

The total cost of the bridge, including excavations, falsework, forms, arch centering, and all materials and labor, including work trains, is as follows:

TOTAL COST OF PAINSVILLE ARCH. BUILT 1908

	Labor	Material
Engineering and designing	$3 055.00	$25.00
Plant (including machinery depreciation)	11 231.00	10 617.00
Excavation	14 257.00	423.00
Cofferdams and timbering	16 919.00	15 649.00
Piling and centering	34 619.00	26 781.00
Forms	12 174.00	10 244.00
Concreting	16 700.00	85 058.00
Waterproofing top	185.00	480.00
Total cost of labor	$109 140.00	$149 277.00
Total cost of material	149 277.00	
Total cost of bridge	$258 417.00	

No freight charge on material or equipment was made as it was not the policy of the railroad to charge freight on Company material which originated on their line.

Each plant turned out a total of 12 575 cubic yards of concrete, making a total of 25 150 cubic yards. This gives a cost per cubic yard of $10.25.

Winchester Repeating Arms Company Building. In erecting one of the buildings of the Winchester Repeating Arms Co. at New Haven the concrete was raised in a bucket hoist of usual construction and dumped into a hopper from which it flowed to chutes about 11 inches wide by 11 inches deep. The plant for depositing the concrete is shown in Fig. 34, page 362, and the swivel joint designed by the builders, the Aberthaw Construction Co., is illustrated in Fig. 35, page 363.

The chute was made of No. 18 gage metal strengthened with $\frac{1}{4}$ by 1-inch bands about 3 feet on centers. The top chute was 30 feet long and the other two auxiliary chutes about 16 feet. The actual cost* of the 3 chutes was $216 or about $3.20 per linear foot, a somewhat lower price than can be counted on for an average.

The cost of erecting and removing amounted to about $150. Figured on a cubic yard basis, the total cost of the chute and the labor amounted to about 13 cents per cubic yard of concrete.

* Information by courtesy of the Aberthaw Construction Co.

PLANT FOR WASHING GRAVEL AND SAND.

A plant for screening gravel and washing gravel and sand is illustrated in Fig. 36, page 364. This is similar in design to plants that have proved satisfactory in practice.

TOOL COSTS

In the following pages are worked out some approximate costs, per cubic yard of concrete in place, of the tools and of the plant necessary for a mixer turning out about 150 cubic yards of concrete per day. These values are given simply as examples, showing the way in which costs can be figured for any special case.

The unit costs of the tools are taken from Table 57, page 371.

Both the raw materials and the concrete are wheeled 200 feet.

New sets of tools are figured for each 5000 cubic yards of concrete.

Case I. Both raw materials and concrete handled by wheelbarrows.

TOOLS:

20 wheelbarrows @ $4.00	$80.00
4 dozen shovels @ $8.00	32.00
½ dozen rammers @ $10.00	5.00
½ dozen spades @ $6.00	3.00
Total cost of tools for 5000 cubic yards of concrete	$120.00
Cost of tools per cubic yard of concrete is $\frac{\$120.00}{5000}$	$0.024

WHEELBARROW RUNS:

Lumber	Supports 2 × 4 inches × 3 feet	40 feet. B. M.
	Plank 2 inches × 2 feet × 100 feet	400 feet. B. M.
		440 feet B. M.
	@ $30 per M	$13.20
Labor		2.00
Total cost per 100 feet of runs		$15.20
Total cost per 400 feet of runs		$60.80

With new runs every 1000 cubic yards of concrete laid, cost of runs per cubic yard of concrete is $\frac{\$60.80}{1000}$ $0.061

Total cost of tools and runs per cubic yard of concrete in place = $0.024 + $0.061 . . . . $0.085

Case II. Raw materials handled by wheelbarrows and concrete by 2-wheel hand carts.

TOOLS:

10 wheelbarrows @ $4.00	$40.00
7 2-wheel hand carts @ $18.00	126.00
4 dozen shovels @ $8.00	32.00
½ dozen rammers @ $10.00	5.00
½ dozen spades @ $6.00	3.00
Total cost of tools for 5000 cubic yards of concrete	$206.00
Cost of tools per cubic yard of concrete is $\frac{\$206.00}{5000}$	$0.041

CART RUNS:

Lumber { 20 horses @ 16 feet	320 feet B. M.
{ Plank 2 inches × 3 feet × 100 feet	600 feet B. M.
	920 feet B. M.
@ $30.00 per M	$27.60
Labor @ $10.00 per M feet B. M.	9.20
Total cost per 100 feet of runs	$36.80
Total cost per 200 feet of runs	73.60
With new runs every 1000 cubic yards of concrete laid, cost of runs per cubic yard of concrete is $\frac{\$73.60}{1000}$	$0.074

TOTAL COST OF TOOLS AND RUNS:

Tools	$0.041
200 feet wheelbarrow runs (Case I)	0.030
200 feet 2-wheel hand cart runs	0.074
Total cost of tools and runs per cubic yard of concrete in place	$0.145

Case III. Raw materials handled by wheelbarrows and concrete by cars.

TOOLS:

10 wheelbarrows @ $4.00	$40.00
3 cars @ $75.00	225.00
4 dozen shovels @ $8 00	32.00
½ dozen rammers @ $10.00	5.00
½ dozen spades @ $6.00	3.00
Total cost of tools for 5000 cubic yards of concrete	$305.00
Cost of tools per cubic yard of concrete is $\frac{\$305.00}{5000}$	$0.061

TRESTLE AND TRACK:

Total cost of trestle and tracks complete, (see Table 57, p. 372) for 200 feet = \$440.00

With new trestle and tracks every 5000 cubic yards, cost of trestle and tracks per cubic yard of concrete in place is $\frac{\$440.00}{5000}$ \$0.088

TOTAL COST OF TOOLS, RUNS AND TRESTLE:

Tools	\$0.061
200 feet wheelbarrow runs (Case I)	0.030
200 feet trestle and tracks	0.088

Total cost of tools, runs, and trestle per cubic yard of concrete in place \$0.179

Case IV. Raw materials handled by cars and concrete by 2-wheel hand carts.

TOOLS:

3 cars @ \$75.00	\$225.00
7 2-wheel hand carts @ \$18.00	126.00
4 dozen shovels @ \$8.00	32.00
½ dozen rammers @ \$10.00	5.00
½ dozen spades @ \$6.00	3.00

Total cost of tools for 5000 cubic yards of concrete .. \$391.00

Cost of tools per cubic yard of concrete is $\frac{\$391.00}{5000}$ .. \$0.078

TOTAL COST OF TOOLS, RUNS AND TRACKS:

Tools	\$0.078
200 feet 2-wheel hand cart runs (Case II)	0.074
200 feet car tracks (Case III)	0.088

Total cost of tools, runs and track per cubic yard of concrete in place \$0.240

Case V. Raw materials and concrete handled by cars.

TOOLS:

6 cars @ \$75.00	\$450.00
4 dozen shovels @ \$8.00	32.00
½ dozen rammers @ \$10.00	5.00
½ dozen spades @ \$6.00	3.00

Total cost of tools for 5000 cubic yards of concrete .. \$490.00

Cost of tools per cubic yard of concrete in place is

$\frac{\$490.00}{5000}$ \$0.098

TOTAL COST OF TOOLS, TRACKS AND TRESTLE:

Tools	$0.098
400 feet trestle and tracks (Case III)	0.176
Total cost of tools, tracks and trestle per cubic yard of concrete in place	$0.274

MACHINERY COSTS

The cost of machinery and tools for a concrete plant can be obtained by correspondence with manufacturers and manufacturers' agents. The prices will vary with the weight of the machinery, the character of the workmanship, and the design. Frequently the most expensive machinery will be the cheapest in the end because of the lower cost of repairs and the saving in labor of operation. Prices of the same machines also vary from year to year and styles are occasionally changing, so that for accurate estimates prices must be obtained direct.

On the other hand, an engineer or a contractor frequently wishes to know the approximate cost of a lot of machinery, so as to make an advance estimate, while in other cases the quantity of concrete to be laid may be so large that it is not necessary to make an exact estimate of the plant, approximate figures being sufficient for the purpose. For such cases as these, Tables 57 to 61, pages 371 to 375, have been prepared. It must be definitely borne in mind, however, that these values are not to be considered absolute and exact and that for accurate estimates the prices must be obtained for the special case under consideration. The cost of freight, transportation charges, and installation are not included in the figures given and must be added to them when making an estimate.

TABLE 57. APPROXIMATE COST OF HANDLING AND MIXING MACHINERY (See p. 370)

I. Rotary Mixers Without Engines or Boilers

Capacity of Mixer*	Quantity of Material Before Mixing	Price
	cu. ft.	
One bag batch	5	$200
One bag batch	7	220
One bag batch†	10	290
Two bag batch	15	325
Three bag batch	20	400
Four bag batch	30	440
One yard	40	550
Two yards	80	975

*Based on 1:2:4 concrete
†Based on 1:3:6 concrete
Charging elevators or trays attached to mixer increase price $100 to $500.

II. Vertical Engines

Size	Price
5 H. P.	$125
10 H. P.	180
15 H. P.	225
20 H. P.	270
25 H. P.	320
35 H. P.	450

III. Vertical Tubular Boilers

Size	Price
5 H. P.	$ 90
10 H. P.	135
15 H. P.	175
20 H. P.	225
25 H. P.	300
35 H. P.	375
50 H. P.	500
75 H. P.	750

An electric motor costs somewhat less than an engine and boiler, perhaps 10 per cent or 15 per cent less.

IV. Hoisting Engines with Boiler, Double Cylinder and Double Drum

Size	Price
20 H. P.	$800
25 H. P.	900
35 H. P.	1100
40 H. P.	1200

V. Contractors' Dinkey Locomotives, 30-Inch or 36-Inch Gage

Size	Price
12 ton	$2800
16 to 18 ton	3500

VI. **4 ft. $8\frac{1}{2}$-inch Gage Single Track,** laid complete with new 55 lb. rails and new soft wood ties 6×8 inch...............$1.00 per linear foot.
Same track with second-hand rails and ties can be bought for $\frac{1}{3}$ to $\frac{1}{2}$ cost of track with new material.

VII. 4 ft. 8½-inch Gage Flat Cars (wooden)

40-foot Flat Cars.......................................$800

40-foot Flat Cars (second-hand)..........................$150 to $400

VIII. 24-inch Gage Double Track, laid complete with new

16-lb. rails, bolted and spiked......................$0.60 per linear foot

Split switches...$22.00

Turntables...$35.00

IX. 24-inch Gage Double Track and Trestle, complete with labor and materials:

Average height of bents 25 feet, posts 6 × 8 inch, stringers 6 × 8 inch, bracing 2 × 6 inch, ties 2 feet c. to c., 16-lb. rails, bolted construction...........$2.20 per linear foot

Same Trestle, cheaper construction, with round posts and 12-lb. rails.................................$1.75 per linear foot

X. Steel Dump Cars (roller bearings)

	Capacity	Price
	cu. ft.	
24-inch gage	18	$65
24-inch gage	27	75
36-inch gage	45	110

XI. Hoist Tower as shown in Fig. 24, page 335, complete, with bolted construction, and including friction hoist, dumping bucket of 30 cubic feet capacity, cable, sheave, and concrete hoppers at every other floor...........$70.00 per story

Hoist Tower without equipment...................$24.00 per story

XII. Hoist Buckets, 30 cubic feet capacity..............$75.00 each

XIII. 2-Wheel Hand Carts, Steel, 6 cubic feet capacity....$18.00 each

XIV. Wheelbarrows, Steel..............................$50.00 per doz.

Wheelbarrows, Wooden.................................$25.00 per doz.

XV. No. 2 Shovels.......................................$8.00 per doz.

XVI. Rammers..$10.00 per doz.

XVII. Picks...$7.00 per doz.

XVIII. Hoes...$6.50 per doz.

XIX. Spades..$6.00 per doz.

TABLE 58. APPROXIMATE COST OF BELT CONVEYORS*

(See p. 370)

Conveyors are supported on wooden trestles 15 feet high (Cost of trestle is included in cost of conveyor)

Length of Conveyor	Width of Belt	Proper Speed of Belt	Capacity per Hour in Cubic Yards		Conveyor Discharging at End or by Tripper	H. P. Required	Cost of Conveyor Erected
			Sand	Concrete			
ft.	in.	ft. per min.					
50	20	300	142	142	at end	1.30	$510.
50	20	300	142	142	by tripper	2.33	830.
50	30	350	376	376	at end	4.20	830.
50	30	350	376	376	by tripper	5.70	1220.
100	20	300	142	142	at end	2.47	880.
100	20	300	142	142	by tripper	3.47	1290.
100	30	350	376	376	at end	8.30	1410.
100	30	350	376	376	by tripper	9.90	1900.
200	20	300	142	142	at end	4.95	1630.
200	20	300	142	142	by tripper	6.05	2130.
200	30	350	376	376	at end	16.70	2630.
200	30	350	376	376	by tripper	18.20	3280.
300	20	300	142	142	at end	7.42	2350.
300	20	300	142	142	by tripper	8.52	2990.
300	30	350	376	376	at end	25.10	3820.
300	30	350	376	376	by tripper	26.60	4600.
400	20	300	142	142	at end	9.90	3090.
400	20	300	142	142	by tripper	11.00	3860.
400	30	350	376	376	at end	33.40	5280.
400	30	350	376	376	by tripper	35.00	6190.

Note—Cost of conveyor erected does not include cost of engine.

The costs in the above table are for first-class plants. Where this cost of plant is limited or the work to be done is only temporary a cheaper type of belt may be desirable.

*The authors are indebted to the Robins Conveying Belt Company, New York City, for the material in this table.

TABLE 59. APPROXIMATE COST OF CABLEWAYS

(See p. 370)

SIMPLE CABLEWAY

Span	Height of Towers	Diameter of Cable	Capacity of Skips	Capacity per hour at Average Haul	Size of Engine: Cylinder	Size of Engine: H.P.	Number of Engines	Number of Boilers	Cost Installed Complete
feet	*feet*	*inches*	*yards*	*yards*					
450	50	1½	1	30	Double 8¼″ x 10″	30	1	1	$3700
600	60	1¾	1	25	Double 9″ x 10″	40	1	1	4600
700	75	1¾	1	23	Double 9″ x 10″	40	1	1	4800
800	80	1¾	1	21	Double 9″ x 10″	40	1	1	5000
900	90	1¾	1	19	Double 9″ x 10″	40	1	1	5300
1000	95	2	1	17	Double 9″ x 10″	40	1	1	5800
1200	100	2¼	1	15	Double 9″ x 10″	40	1	1	6500
1200	100	2¼	2	30	Double 10″ x 12″	50	1	1	7600
1500	110	2½	2	24	Double 12″ x 12″	60	1	1	11000
2000	135	2¾	2	18	Double 12¼″ x 15″	75	1	1	15000

DUPLEX CABLEWAY

Two Cables 15 to 20 ft. c. to c. on double towers with an A-Frame tower at middle of span

Span	Height of Towers: End Towers	Height of Towers: A Frame Tower	Diameter of Cable	Capacity of Skips	Capacity per Hour at Average Haul	Size of Engines: Cylinder	Size of Engines: H. P.	Number of Engines	Number of Boilers	Cost Installed Complete
2000 ft.	130ft.	75ft.	2¼″	4 Skips each 2 yd.	140 yd. on all 4 parts of cableway	Double Reversible 10″ x 12″	50	4	2	$23000

TABLE 60. APPROXIMATE COST OF DERRICKS

(See p. 370)

Load	Mast	Boom	Price
Ton	Feet	Feet	
2	30	40	$400
3	60	55	500
5	71	60	800

The cost of a derrick varies with the kind and manner of rigging so that the costs given here are general. These prices include guys, falls, and everything necessary for hoisting except engine and boiler.

TABLE 61. HORSE POWER REQUIRED FOR MIXERS OF VARIOUS CAPACITIES

(See p. 370)

Capacity of Mixer*	H. P.
One-bag batch	4
Two-bag batch	6
Three-bag batch	8
Four-bag batch	12
One yard	20
2 yards	35

*Based on 1:2:4 concrete.

REFERENCE LIST OF CONCRETE MIXING AND HANDLING PLANTS

Structure and Location	Capacity and Type of Mixer	Method of Supplying Mixer	Method of Handling Concrete from Mixer to Place	Average Output Cubic Yards per Hour	Authority
Catskill Aqueduct, N. Y. Water Supply	1-yd Rotary	Bucket conveyors to bins to measuring hoppers	1-yd. bottom dump buckets on flat cars		Eng. Rec. Jan. 8, '10 p. 37
Bridge, Rocky River, Ohio, (25 000 cu. yd.)	Pug Mill	From storage piles by derricks to bins to measuring hopper	½ and ¾-yd. bottom dump buckets on flat cars to cableway		Eng. Rec. Jan. 1, '10 p. 4
Dam, U. M. R. Power Co., Montana (250 000 cu. yd.)	4, 1-yd. Rotaries	Cars to elevated bins to measuring hoppers	Buckets on flat cars to traveling derricks		Eng. Rec. Oct. 29, '10 p. 480
Subway, Chicago	18 cu. ft. Rotary	Bins below tracks hoisted to mixer	Chutes	30	Eng. Contr. Oct. 5, '10 p. 286
Rondout Tunnel, N. Y. Water Supply	1½-yard Cube	Aerial tramway to bins to steel measuring cars	1-yd. dump cars lowered down shafts		Eng. Rec. Sept. 17, '10 p. 312.
Car Plant, Detroit United Ry.	2-yd. Rotary	Dump cars and hoisted by scoop to charging hopper	Direct to place	18	Eng. Rec. Sept. 3, '10 p. 260.
Plant, Minnesota Steel Co., Duluth	1-yd. Cube	Belt conveyors to bins, measured and hoisted to mixer	1-yd. buckets on flat cars.	32	Eng. Rec. Nov. 1, '10 p. 515
Dry Dock, Toledo Ship Bldg. Co., (13 000 cu. yd.)	22 cu. ft. Rotary	Elevated bins stocked at night by crane	Side dump cars, run by gravity	30 to 35	Eng. Rec. Apr. 2, '10 p. 477
Lock, N. Y. Barge Canal	Gravity	From elevated bins by dump cars up incline to measuring hoppers	1½-yd. buckets on cars to cableway and derricks		Eng. Rec. Apr. 2, '10 p. 426
Factory Building, Chicago	1-yd. Rotary	Bucket conveyors to bins to hopper	Hoisted and delivered by chutes	30	Eng. Rec. Oct. 22, '10 p. 457
Traveling Plant, Catskill Aqueduct, N. Y. Water Supply	Gravity	Bucket elevator to bins to hopper	Buckets on overhead runway	20	Eng. Rec. Nov. 5, '10 p. 508
Retaining Wall, Chicago (plant on car)	½-yd. Rotary	From cars to wheelbarrow	Chute from car traveling parallel to wall	15	Eng. Contr. Sept. 28, '10 p. 264
Dam, N. Y. Barge Canal (85 000 cu. yd.)	Cube	From barge by derrick to bins	Buckets on cars to cableway		Eng. Contr. Sept. 21, '10 p. 242
Plant for Bridge Work, N. P. R. R., Mont	1-yd.	Cars to stock piles, then belt conveyor	Bottom dump car		Eng. Rec. Dec. 17, '10 p. 718

REFERENCE LIST OF CONCRETE MIXING AND HANDLING PLANTS.—Continued

Structure and Location	Capacity and Type of Mixer	Method of Supplying Mixer	Method of Handling Concrete from Mixer to Place	Average Output Cubic Yards per Hour	Authority
Irrigation Canal, California (plant on platform over canal)	10-cu. ft. Rotary	From stock piles by skip cars on incline to hopper	Chute	8	Eng. Rec. Sept.10,'10 p. 284
Dam, Salmon River Water Co., Idaho	2, 1-yd. Rotaries	Stock piles by belt conveyors to bins	1-yd. steel dump cars		Eng. Rec. Apr. 2, '10 p. 412
Car Plant, Met. St. Ry., Kansas City	12-cu. ft. Rotary	Elevator to hopper	Chute to place or to wheelbarrows		Eng. News Apr.28,'10 p. 505
Tunnel, Detroit River	3, 1-yd. Cubes	Barges alongside, to elevated bins on scow	Buckets to tremie tubes	90	Eng. News Mar.17,'10 p. 318
Dam, Bellows Falls, Vt.	21- cu. ft. Rotary	Wagons dumped to chutes discharging to elevated bins, washed in chute	Dump cars		Eng. Rec. Apr. 3, '09 p. 457
Dam,* Southern Power Co. (160 000 cu. yd.)	2, 1½-yd. Cubes	Cableways to elevated bins to hoppers	Buckets on flat cars to derricks with 80 and 100 ft. booms.		Eng. Rec. Apr. 2, '10 p. 379
Dam, Connecticut River Power Co.	2, 1-yd. Rotaries	Bucket conveyor to bins to hopper	Buckets on cars to derricks	28	Eng. Rec. Apr. 3, '09 p. 443
Bridge, Connecticut Ave. Washington	Gravity	Cars on incline to bins to hopper	Buckets on flat cars to derricks	20	Eng. Rec. Apr. 3, '09 p. 409
Sewerage Disposal Works, Baltimore	2, 1-yd. Rotaries	Bucket elevators to bins to hopper	Buckets on flat cars	40	Eng. Rec. Nov.13,'09 p. 545
Building, U. S. Printing Co., Norwood, Ohio	2 Rotaries	Steel dump cars from stock piles	Hoist and wheelbarrows	50	Eng. Contr. Apr.21,'09 p. 306
Bridge, Delaware River, D. L. & W. R. R.	Rotary		Duplex Cableways		Eng. Contr. June 30, '09 p. 527
Dam, Eastern Colorado Power Co. (140 000 cu. yd.)	4, 30-cu. ft. Rotaries	Standard gage cars to stone crusher thence to bins	Steel dump buckets on cars to cableway	70	Eng. Rec. Oct. 2,'09 p. 368
Hostetter Building, Pittsburg	½-yd. Rotary	Bins below street level to hopper	Wheelbarrows hoisted by elevator		Eng. Rec. Feb. 6, '09 p. 149
Grand River Bridge, †Painsville, Ohio. L. S. & M. S. Ry.	2, 1-yd Rotaries	Dump cars to bins to hopper	Chute from hoist towers		Eng. Rec. May 1, '09 p. 564

*See page 357.
†See page 360.

REFERENCE LIST OF CONCRETE MIXING AND HANDLING PLANTS—Continued

Structure and Location	Capacity and Type of Mixer	Method of Supplying Mixer	Method of Handling Concrete from Mixer to Place	Average Output Cubic Yards per Hour	Authority
Factory Building,* Argo, Ill.	Rotary	Belt conveyors to bins to hoppers	Dump cars and hoist buckets		Eng. News Aug. 26, '09 p. 216
Dam, †Ashokan Reservoir, N.Y. W. W. (560 000 cu. yd.	4, 2½ yd. Cubes	Inclined conveyor to bins to hoppers	Bottom dump buckets on flat cars to cableway	125	Eng. Rec. Apr. 3, '09 p. 380
Dam, Croton Falls, N. Y. W. W.	2, 1-yd. Gravities	Belt conveyor to elevated bins to hopper	Cableways	60	Eng. Rec. Dec. 12, '08 p. 677
Dam, Springfield, Mass. W. W.	1-yd. Cube	Cars by gravity from storage bins to hopper	Bottom dump buckets on flat cars to cableway		Eng. Rec. Dec. 12, '08 p. 656
Reservoir, Springfield, Mass W. W.	1-yd. Rotary	From stock piles at crushing plant by dump car on incline to hopper	Buckets on cars to cableway		Eng. Rec. Dec. 12, '08 p. 656
Sewer, Bronx Borough, N. Y.	Rotary	Derrick from storage piles to cars	Direct	10	Eng. Rec. Nov. 28, '08, p. 620
Breakwater, Milwaukee, Wis. (Scow Plant)	2-yd. Rotaries	Derrick from scows alongside to hopper	Derrick and dump buckets	25	Eng. Contr. Oct. 28, '08 p. 272
Tunnel, N.Y., N. H. & H. R.R., Providence, R. I.	½-yd. Rotary	Standard gage cars and hoist buckets. Skips on incline to hopper	Bucket and hoist	4	Eng. Rec. Nov. 7, '08 p. 514
Buffalo, N. Y. W. W. (Scow Plant)	1-yd. Cube	Derricks from scow alongside to hoppers	Bottom dump buckets and derrick		Eng. Rec. Oct. 10, '08 p. 400
Car Plant Track work, Chicago, Ill	½-yd. Rotary	Wheelbarrow to skips on elevator to mixer	Dumped direct	20	Eng. Rec. June 20, '08 p. 790
Dam, LaCross W. P. Co. Wis., (30 000 cu. yd)	3, 1-yd. Rotaries	By train to bins to hoppers	Buckets on push cars to derricks	45	Eng. Rec. May 30, '08 p. 685
Bridge Anchorage, Brooklyn. (100 000 cu. yd.)	Gravity	Bucket conveyor to bins to hopper		40	Eng. Contr. Mar. 18, '08 p. 163
Dam, Croton Falls, N. Y. W. W. (300 000 cu. yd.)	3 Gravities	Belt conveyor to cars on incline dumping to hoppers	Derricks to 2 cableways	100	Eng. Rec. Apr. 11, '08 p. 491
Dry Dock, Mare Island, Cal.	2½-yd. Rotaries	From storage pocket by cars on incline to hopper	Bottom dump buckets on flat cars to derricks	100	Eng. Rec. Apr. 4, '08 p. 432

* See page 354
† See page 357

REFERENCE LIST OF CONCRETE MIXING AND HANDLING PLANTS—Continued.

Structure and Location	Capacity and Type of Mixer	Method of Supplying Mixer	Method of Handling Concrete from Mixer to Place	Average Output Cubic Yards Per Hour	Authority
Reservoir, Mexico City W. W....	½-yd. Rotary	Hoist buckets to mixer	Push cars on revolving bridge		Eng. Rec. Mar.28,'08 p. 362
Dry Dock, Charleston Navy Yard, S. C....................	1-yd. Rotary	Belt conveyor to elevated bins to hopper	Dump buckets on cars to derricks	16	Eng. Rec. Feb. 1, '08 p. 120
Steel Plant, Jones & Laughlin Co., Pittsburgh. (215 000 cu. yd.)	2, 1-yd Rotaries	Standard gage cars to bins to hopper	Buckets on flat cars to derricks	40	Eng. News July 25, '07 p. 100
Locks,* N. Y. Barge Canal (100 000 cu. yd.)	Gravity	Belt conveyor to bins to hopper	Belt conveyors	55	Eng. Rec. Oct. 10,'08 p. 416
Street Paving, Mixing, and Spreading Machine...........	11-cu. ft. Cube	Hopper hauled up incline from the street	Wheeled dump bucket traveling on boom	115 sq. yd.	Eng. News Dec.12,'07 p. 645
Bridge Anchorage, N. Y. City	30-cu. ft.	Dump cars on incline to hoppers	Side dump cars to place	22	Eng. Rec. Dec.28,'07 p. 704
Dam, S. & I. Ry. Co. Washington........................	2 Rotaries	Gravel sluiced from bank. Sand hauled by tram cars to mixer	Skips on flat cars to derricks		Eng. Rec. July20,'07 p. 73
Track Elevation, Chicago......	30-cu. ft. Rotary	Derrick from gondola cars to hopper	1-yd dump cars	22	Eng. Rec. July13,'07 p. 32
Track Elevation, Chicago......	21-cu. ft.	From gondola cars by special dump car to hopper	Derrick handling ¾-yd. dump bucket		Eng. Rec. July 13,'07 p. 32
Tunnel Lining, J. F. L. Ext. So. Ry., Indiana..................	1½-yd. Cube	Derrick from cars to bucket elevators to bins to hopper	1½-yd dump cars		Eng. Rec. Oct. 12, '07 p. 393
Store Bldg. Chicago (125 000 cu. yd.)	2, 1½ yd. Rotaries	Bins fed by belt conveyors to hopper	Dump buckets handled by derricks		Eng. News July25,'07 p. 82
Manhattan Bridge Anchorage N. Y. City (100 000 cu. yd.) ..	1-yd. Cube	Charging cars taking supply from measuring cars to skip hoist	Bottom dump buckets on cars, to derricks		Eng.Contr. May 8, '07 p. 205
Trestle,† C. C. C. & St. L. R. R. Lawrenceville, Ind...........	Rotary	Dump cars to skip car on incline to hopper	Skip car on inclined boom		Eng. Rec. Aug.11,'06 p. 155
Piers, New Orleans Terminal Co., La.......................	¾-yd Rotary	Inclined belt conveyors to hoppers.	Chute direct	30	Eng. Rec. July28,'06 p. 89

*See page 355
†See page 349

REFERENCE LIST OF CONCRETE MIXING AND HANDLING PLANTS—Continued

Structure and Location	Capacity and Type of Mixer	Method of Supplying Mixer	Method of Handling Concrete from Mixer to Place	Average Output Cubic Yards per Hour	Authority
Sedimentation Basins, Pittsburgh, Pa., W. W.	2, 1¼-yd Rotaries	Cars on tramway dumping to bins to hopper	3-yard side dump cars	25	Eng. Rec Dec. 29, '06 p. 714
Filters, Pittsburgh Pa., W. W.	2, Gravities	Bins fed to inclined conveyors to hopper	1-yard bottom dump buckets on flat cars to cableways	80	Eng. Rec. Dec. 29, '06 p. 714
Piers, Manhattan Bridge, N. Y. City (100 000 cu. yd.)	Gravity	Bucket elevator to bins to hoppers	2-yard buckets on flat cars	60	Eng. Rec. Aug. 25, '06 p. 201
Elevated Ry., Phila.	Rotary	Bins over mixer supplied by derrick	Belt conveyors		Eng. Contr. Sept. 26, '06 p. 81
Gas Plant, Astoria, L. I.	2, 1-yd Rotaries	From storage bins by belt conveyor to hopper	Belt conveyor from mixer to cars		Eng. News Apr. 5, '06 p. 380
Drainage Canal,* Chicago	Pug Mill	By derrick to hoppers, through dry mixers to hoppers of wet mixers	Bucket elevators to place	30	Eng. Rec. Feb. 17, '06 p. 190
Central Plant,† St. Louis	2, ½-yd. Rotaries	Bucket elevator to bins to hoppers	By wagons	25	Eng. News Mar. 10, '04 p. 231
Jerome Park Reservoir,‡ N.Y. City	18, ½-yd. Rotaries	Stone shoveled from standard gage cars direct to hoppers. Sand delivered by wheelbarrows	Wheelbarrows	100	Eng. News Sept. 21, '05 p. 299
Power House,§ Penn N.Y. & L. I. R. R. (11 000 cu. yd.)	1-yd Rotary	Cars from storage piles to chutes to hopper	Wheelbarrows	50	Eng. Rec. Apr. 9, '04 p. 454
Breakwater,$ Buffalo	1½ yd. Cube	Derrick from scows to hopper	Dump cars		Eng. News May 29, '02 p. 429

*See page 347
†See page 346
‡See page 344
§See page 346
$See page 351

CHAPTER XIII

LABOR COSTS OF MACHINE MIXING

The last chapter was devoted to a description of concrete machinery and plants with a certain amount of miscellaneous information on plant costs. In the present chapter the various operations relating to mixing concrete by machinery are taken up and discussed very fully. The information given will enable a man to study and estimate the time and cost of concreting under the varying conditions that are liable to occur in ordinary practice.

As has been stated repeatedly in this book, the only way to reach accurate results in any estimate is to divide the work into its various operations, so as to provide for those that are variable or which apply only to the job under consideration. The careful analysis, covering a variety of conditions, is therefore given, not merely for the purpose of presenting facts about machine mixing, but as an illustration of methods that may be followed in investigations of a similar character.

The text of the chapter includes a general discussion of the tables and also of conditions not specifically covered in the tables.

The tables at the end of the chapter present information for any special case occurring in ordinary practice. This information includes:

Cost of machine mixing under specified conditions, Tables 69 and 70, pages 438 and 441.

Cost of machine mixing for given output per hour, Table 68, page 437.

Cost of mixer gang and machinery for mixing only, Tables 65 and 66, pages 432 and 433.

Times and Costs of handling the raw material and concrete, Table 67, page 434.

Average times and outputs under different conditions, Tables 63 and 64, pages 425 and 428.

These tables are made up by combining the times or costs of unit operations by methods described in preceding chapters. For the benefit of those who wish (1) either to go into methods employed in compiling the tables, or (2) to obtain information for making up similar schedules based on unit times, or (3) to study the design of a plant to reach the most economical plan of operation, these unit times are tabulated in full in Table 62, page 418.

In addition to these carefully itemized tables, a general table is presented for use in estimating a large job, where the cost of the plant has been determined approximately and the operating gang has been outlined. Costs based on plants of various capacities and different sized gangs are given in Table 71, page 444.

In general, the aim has been to treat most thoroughly the common operations and classes of work, rather than peculiar cases, the former comprising the greater part of the experience of an engineer or architect or contractor.

Although the more complicated mixing plants are not analyzed, much of the elementary data and unit times and costs presented will be of use when estimates for such plants are needed. The descriptions of some of these plants, on pages 342 to 367, also give approximate ideas of special plant costs and suggestions for designs under a variety of conditions.

STUDY OF UNIT OPERATIONS

The various operations in making and placing concrete have been studied in detail on actual work. They may be grouped as follows:

(1) Transporting raw materials.
(2) Conveying materials to mixing machine.
(3) Mixing and dumping.
(4) Conveying concrete to place.
(5) Placing concrete.

These have been divided into unit operations and their times given in Table 62, pages 418 to 424. The times are given as net and actual times for average men and as net times for quick men.

Net Times for average men represent the labor actually required to perform an operation in contract work under ordinary conditions with fair superintendence and no allowance for rest or delays.

Actual Times for average men represent the labor in contract work as above but include allowance for rest and delays. These values for average men are taken from 10 per cent to 50 per cent more than the net times, depending upon the operation. There is very little delay while actually pushing a barrow, so the actual times for these items are taken as 10 per cent more than the net times. For charging or discharging a mixer, there is greater chance for delays and the actual times are taken as 50 per cent more than the net times. In handling materials or concrete with a derrick or hoist or with pails or shovels, 30 per cent more than the net times is taken, while for handling concrete with barrows, carts or cars, 40 per cent more is taken.

Net times for quick men represent the labor actually required to perform an operation by quick working and experienced men under exceptionally good supervision although by the day and not by the piece. An allowance for rest and delays always must be added. When using the times in task or piece-work, they must be multiplied by a ratio determined for each case by actual time studies.

Times in Minutes and Hundredths of Minutes. It is convenient to express the times of operations in minutes and decimals of minutes instead of in minutes and seconds. In this way they can be conveniently added, subtracted, multiplied and divided. For timing operations, watches reading to minutes and decimals of a minute are quite generally used. These are described on page 96. The times are given in minutes per operation and never in operations per minute.

From a study of Table 62, any ordinary operation in concrete work can be analyzed and the proper gang organized for doing the work in the most economical manner, or an estimate can be made and the work planned on scientific lines.

ORGANIZATION OF GANG

To organize the work satisfactorily, so that one gang will fit into another, requires experience on the part of the foreman and rearrangement after the work has started. The great trouble is that the time for the different operations is not generally known, so that it is impossible to tell in advance how long, for example, it will take a man wheeling concrete to fill his barrow, wheel it to a certain distance, and dump it; and consequently the number of men to use cannot be properly determined in advance. It is in just such ways as these that the time studies, which are taken up in detail in the pages that follow, will be found of value to anyone who is trying to bring his work down to the lowest possible cost and to eliminate all unnecessary labor. Without such study even an experienced man may be misled by slow work on the part of the men or by their carrying small barrow-loads, so that he may authorize his sub-foreman to use one or perhaps two more men than are really necessary.

The times in Table 62, page 418, will be found convenient for such organization, and, where necessary, special time studies may be made, following out the same general principles that have been outlined in this volume.

TRANSPORTING RAW MATERIALS

The transporting of the materials for concrete is usually independent of the operation of mixing. The sand, stone, and cement are hauled or conveyed to bins, sheds or platforms near the work, ready for conveying to the mixer by separate apparatus or vehicles. For this reason the processes of handling and transporting materials are taken up separately in Chapter X, page 222, and reference should be made to that chapter for full information in regard to these items. In the present chapter, the more important operations of this class are referred to briefly and given in terms of a cubic yard of concrete instead of in terms of the quantity of the raw material itself. These various items are briefly described below.

Traveling. Items (1) to (3), page 418. The times of a man walking with a load and with a wheelbarrow and the time of a horse hauling a cart are useful for combination with other unit times. They are based on a large number of observations in connection with handling various materials.

The net times show the speed of walking and the actual times include rests and other delays that are apt to occur while the man or horse is traveling. A man walking either with or without a load is more apt to loiter than when pushing a wheelbarrow or driving a horse, so that his percentage of delay is larger. The actual time of a horse hauling a cart is given as 0.45 minutes per 100 feet. If he could maintain this speed throughout a 10-hour day he would travel $\frac{600 \times 100}{0.45} = 133\,000$ feet or about 25 miles. This, as stated on page 247, is a greater distance than horses under ordinary conditions can travel day after day, the average travel of a work horse being about 17 miles. In other words, an ordinary horse cannot travel continually without resting, any more than a man can walk continually throughout an entire day. The times given, however, can be used for all kinds of practical work except for long hauls, when the average daily haul must be used instead. Tables for hauling are given in Chapter X, pages 264 and 266.

Screening Sand and Gravel by Hand. Items (4) to (10), page 418. The times of screening sand and gravel have already been discussed on page 227 and page 298. On page 316 are tabulated the times and costs converted into terms of a cubic yard of concrete for convenient use in estimating. The method of combining the unit times for use with different materials is illustrated on page 228.

Hauling Sand and Gravel in Carts. Items (15) and (16), page 419. Hauling sand and gravel in carts together with the loading and the economical arrangement of gangs, is discussed on pages 232 to 250.

To use the times and costs in Tables 51, 52, and 53, pages 263 to 267, for estimating costs of concrete in place, note that the values must be multiplied by the quantity of each given material in a cubic yard of concrete. For convenient use in estimating concrete costs, some of the values are converted into terms of per cubic yard of concrete and given in Table 55, page 312. The tables are made up for two-horse carts or dumping wagons.* If extra large carts or carts with high side boards are used on paved or macadamized streets, the loads may run up to 2 or $2\frac{1}{2}$ cubic yards and the times and costs are reduced accordingly. (See p. 248.)

As stated on page 232, the times and costs of hauling sand and stone for concrete allow for the fact that the work is not apt to be so well systematized as in ordinary earth excavation, so that the times and costs of loading are somewhat larger.

As an illustration of the use of Table 53, page 266, if sand is hauled from bank 2 miles away and the teamster loads alone, the cost is $1.42 per cubic yard of sand or for 1:2:4 concrete $0.63 per cubic yard of concrete. Table 55, page 317, gives $0.66 per cubic yard of 1:2:4 concrete directly.

Hauling Cement in Wagons. Table 50, page 261. The loading and hauling of cement is discussed on page 251, and times and costs per cubic yard of concrete are given in Table 55, page 312. For other proportions than those given, the values may be taken from page 262 and converted into terms of a cubic yard of concrete.

Example 1: What will be the approximate cost per barrel, with labor at 20¢ per hour, for loading and hauling Portland cement in

* The average capacity of an ordinary double cart or dumping wagon is $29\frac{1}{2}$ cubic feet of sand or 27 cubic feet of gravel. Carts of larger size or with high side boards may contain $35\frac{1}{2}$ cubic feet of sand or $33\frac{1}{2}$ cubic feet of gravel. (See p. 234.)

bags 2 miles, unloading, carrying about 30 feet, and piling in store-house?

Solution: For this example, refer to Table 50, page 262, as follows:

Item		
(13)	Loading 4 bags into wagons....	$0.017
(14)	Hauling cement 2 miles @ $0.073............	0.146
(17)	Unloading cement and carrying about 30 ft....	0.013
(22)	Piling in store-house......................	0.016
	Total cost per barrel (4 bags) cement.............	$0.192

This cost includes an allowance for superintendence and overhead charges, but no profit.

Example 2: What will this cost amount to per cubic yard of 1 : 2 : 4 concrete?

Solution; From Table 22, page 151, we find an average of 1.57 barrels of cement per cubic yard of concrete. Hence, the cost will be $0.192 × 1.57 = $0.30 per cubic yard of concrete.

Example 3: What is the cost with labor at 20¢ per hour of unloading cement from cars to storehouse by the use of baggage trucks?

Solution: Turning again to Table 50, page 262, and using Items (20), (21) and (22), which are compiled for average distances and conditions, we have

Item		
(20)	Loading bags of cement on trucks.	$0.008
(21)	Hauling into storehouse (including return). .	0.016
(22)	Piling in storehouse........................	0.016
	Total cost per barrel (4 bags) cement	$0.040

Hauling Sand and Stone in Cars. Cars running on a track may be used for hauling the materials from a gravel bank or from a crusher to the stock pile or bin, and also in a large plant for measuring and conveying the materials to the mixer. The conditions are quite different in the two cases. (See p. 389).

These values are for working under good supervision. On a job like building construction, the times and costs for the preliminary handling of the raw materials should be increased, for estimates, by 50 per cent to allow for slow work and the delays that are incident to work done by the day under no direct supervision. On the other hand, by laying out the work in advance and paying high rates the time and cost can be reduced largely.

CONVEYING THE MATERIALS TO MIXER

Unless expensive machinery is employed, wheelbarrows are commonly used for wheeling the sand and stone to mixer, and by using barrows of definite measure, deep enough to be leveled off, the proper proportions of the materials are measured by counting the barrowloads.

In certain cases, small cars on tracks operated by a cable and hoisting engine may replace the barrows economically.

Other conditions require horses and carts, cars, derricks and buckets, clamshell dredges, endless belts, or other forms of conveyors (see pp. 329 and 330).

Wheeling Sand and Stone to the Mixer in Barrows. Items (17) to (34), page 419. Hauling sand and gravel in barrows is treated quite fully in the chapter on Handling Materials, page 241, also in the chapter on Hand Mixing, page 294, and the operations are analyzed there.

In Table 62 of Unit Operations, page 419, the times of barrow work are given in terms of per barrow and also, assuming definite barrow capacities, per cubic foot. The times per barrow are for use in arranging a gang and for timing men to see whether or not they are working to good advantage, and the times per cubic foot are more convenient to use in computations involving economy and cost.

It will be noticed that the allowance for delays and lost time is 50 per cent except in the wheeling. This appears large, but is due to the difficulty in arranging a gang of wheelers so as to work steadily when supplying a mixer, and also to the waits liable in mixing concrete. The percentage was determined by averaging a number of actual cases. If, however, the work is laid out by a thorough study of the times required for each operation and the gang is arranged to fit the particular case, an allowance of 30 per cent is ample, and the actual times may be altered accordingly.

The times are based on a wheeler loading his own barrow. This arrangement is most economical because if other men load there is apt to be considerable delay between barrows.

To charge the mixer without delay, the gang of wheelers must be so arranged that they can supply enough sand and stone for one batch of concrete without any wait for reloading. The number of barrows of sand and stone required per batch can be determined from the quantity of each material required, assuming an ordinary barrow to hold

3 cubic feet of sand and 2.7 cubic feet of stone or gravel for an average load. For convenience in computation, a barrow load of either sand or gravel is assumed in Table 62 of Unit Operations as 3.0 cubic feet.

It is possible on a good run where the men are not overworked to wheel 3.5 cubic feet to a barrow load. The times for this capacity of barrow may be obtained by altering the unit time filling barrow by the ratio of 3.5 to 3.0. The gang can then be arranged so that a certain number of men wheel the stone, another group wheel the sand, and a separate man or men dump the cement. This is done to avoid error in proportioning. At the same time, under ordinary conditions where the sand and stone are within about 50 feet of the mixer, the men can each load and wheel their barrows in a shorter time than is required to mix a batch of concrete, so that there is frequently a considerable amount of lost time. It is worth while, therefore, to make a careful study of the unit times to avoid as much of this loss of time as possible, even if it results in some other method of hauling than by wheelbarrow.

Lost Time Due to Slow Mixing. If the barrows are used to measure the sand and gravel, so that a definite number are required per batch, there may be considerable lost time for the barrow men if the stock pile is near and the mixer runs slow. This is illustrated in the following example.

Example 4: Suppose a mixer runs at the rate of 120 batches per day of 8 hours, the gravel pile is 100 feet from the mixer, and each gravel man wheels one barrow per batch, what will be the percentage of waiting of the barrow men in addition to that which may be ordinarily allowed?

Solution: The actual speed of the mixer averages 4 minutes per batch. From the sum of Items (26) to (30) we find the allowable actual time loading and wheeling one barrow 100 feet and return to be 3.04 minutes. Hence there is a wait of nearly one minute per batch or 32 per cent lost time in addition to the delays provided for in the table. The men wheeling sand to the same distance work in still quicker time so that their lost time is even greater.

Extra Men Shoveling. In order to keep up with the mixer, it may be ecomonical to reduce the time of loading barrows by having extra shovelers to help the wheelers load, or, in certain cases, especially where the run is elevated above the stock pile, to do all the shoveling. These extra men are most apt to be needed where the haul is a long one or where the mixer runs at a high rate of speed. If more than one man loads a barrow, the time of filling the barrow is decreased in proportion. Thus, with one man helping barrow man to load, the net time of filling a barrow with sand, Item (18), is $\frac{0.75}{2} = 0.37\frac{1}{2}$ minutes. The time per cubic foot, Item (23), is unchanged because each man loads only half the amount. The *total* time per cubic foot is increased, however, because of necessary waiting. This is illustrated in the following example.

Example 5: Suppose that a 4-bag mixer must run at the rate of $1\frac{3}{4}$ minutes per batch net time and the gravel pile is 100 feet from the mixer, what will be the arrangement of the gravel men?

Solution: For ordinary proportions having 18 to 19 cubic feet of gravel per batch, we may assume that $\frac{18\frac{1}{2}}{3+} = 6$ barrow men are required to measure and wheel the gravel. If each man loads his own barrow, Items (26) to (30), the net time willl be 2.28 minutes. If one man helps to load, the shoveling time is reduced to $\frac{1.05}{2} = 0.52$ minutes, and the time per round trip of each man is reduced to $2.28 - 0.52 = 1.76$ minutes, which corresponds to the $1\frac{3}{4}$ minutes time required by the example. Since the loading man requires 0.52 minutes per barrow, he can help load 3 barrows in 1.76 minutes, provided the barrow men can dump into a hopper without waiting for the mixer.

Times in Terms of Quantity of Materials Handled. While in Table 55, page 312, the times of wheeling sand and stone are given only in terms of per cubic yard of concrete, the tables in the present chapter give them also in terms of the quantity of material handled.

Hauling Sand and Stone to Mixer in Cars. Items (35) to (44) page 420. A car on a track may be economically employed for hauling sand and stone to mixer:

(1) In a large plant where the materials are stored in bins from which they can be dumped into cars.

(2) Where the materials can be shoveled from railroad flat cars into the measuring car.

(3) Where the mixer is above the level of the stock pile and car is hauled up by a cable.

If a large plant with bins and car transportation is contemplated, the items of plant cost must be carefully figured to see that the interest and depreciation does not more than overbalance the saving in daily expense.

The times of dumping from bin into car, Items (39) and (40), page 420, and from car into hopper, Item (44), page 420 are given for definite quantities of materials, but are so small that they can be used for cars of other capacities without appreciable error.

These times as well as that of pushing a car are given in terms of per gang, since the number of men to handle the cars depends upon local conditions. For this reason, as stated in the footnote, the times must be multiplied by the number of men performing the operation.

A large percentage, 50 per cent, is added to the net times for delays and waits, since it is difficult to arrange such operations to avoid considerable lost time.

The times shoveling materials from a platform up into measuring cars and from railroad cars into measuring cars are given in Items (35) to (38), page 420. In the first two items there is a higher throw while in the last two the horizontal distance between the two cars is sufficient to make the time nearly the same. As stated in a note, the times are the times of the men while they are actually shoveling. Instead of using the 50 per cent for delays, it is more accurate to use the net times and estimate from the other unit times for any given case the time which a man will have to wait between carloads, and then add 30 per cent to this sum for the incidental delays.

As in other shoveling items, the values are per man, that is, they are given as the time of one man. If two men work, the length of the operation will be one-half that given.

Item (42) gives the time per gang and Item (43) gives the time per man pushing a car 100 feet loaded and 100 feet empty. The values for these items are taken from time observations on a car holding 18 cubic feet and handled by two men. While Item (43) will vary with the size of load to some extent, the number of men pushing the car is nearly proportional to the load and the variation is not great. For example, if the car contained a much larger load of material, the time per man would still be practically the same, as 3 men would be required to push it.

Example 6: What will be the time per gang if two men fill car from bin with sand and stone for a 4-bag batch of concrete and push 25 feet to mixer?

Solution: Referring to page 420:

Item		
(39)	Dump batch sand into car	0.06 min.
(40)	Dump batch stone into car	0.15 min.
(41)	Get ready to start after each material is put in	0.62 min.
(42)	Push loaded car on track 25 feet and return @1.56 minutes per 100 feet	0.39 min.
(44)	Dump into mixer	0.07 min.
	Total time per batch	1.29 min.

The net time of feeding one batch of concrete is therefore 1.29 minutes, or the actual time, which may be expected to include delays, is $1.29 \times 1.50 = 1.94$ minutes.

This actual time may be used for figuring the cost of the plant unless the mixer is known to make a slower running time, while for figuring the cost of the men, the time should be multiplied by 2, since there are 2 men.

Example 7: What will be the time per batch per gang if five men shovel gravel and two men shovel sand from platform into car, while three other men push the cars on the track, three cars being in operation, one being loaded with sand while another is loaded with gravel, while the third is being pushed to mixer? Assume a 4-bag mixer requiring for 1:2:4 proportions $7\frac{1}{2}$ cubic feet of sand to 15 cubic feet of gravel.

Solution: The net time shoveling sand is 0.55 minutes per cubic foot, or $\frac{0.55 \times 7.5}{2} = 2.06$ minutes loading sand. The five gravel men load 15 cubic feet in $\frac{0.68 \times 15}{5} = 2.04$ minutes. The men, pushing the car 50 feet, dumping, and returning, require $\frac{1.56}{2} + 2(0.31) + 0.07 = 1.47$ minutes per car. Hence, they can keep the shovelers busy all the time. On the average, we consider 50 per cent lost time, so that unless the speed of the mixer is actually known to be less than 3 minutes per batch, we may assume the rate to be 2.06 minutes $+ 50\% = 3.1$ minutes per batch. If less, the men will work with a less delay so no increase of gang will be necessary till the time is reduced to 2.06 minutes.

Example 8: What will be the time to use in figuring labor costs in the last example?

Solution: The time may be obtained by multiplying the number of minutes found in the last example by the total number of men, which gives $3.1 \times 10 = 31$ minutes. If the present example is to be solved independently the result may be obtained as follows:

Item		
(35)	Shovel 7.5 cubic feet sand @ 0.83 minutes.	6.2 min.
(36)	Shovel 15 cubic feet gravel @ 1.02 minutes	15.3 min.
(41)	Three men get ready to start cars at sand and at gravel pile @ 0.46 minutes each	2.8 min.
(41)	Seven loading men wait while cars are started @ 0.46 minutes	3.2 min.
(43)	Push car 50 feet, $0.26 \times (15+7\frac{1}{2}) \times \frac{50}{100}$	2.9 min.
(44)	Dump car into hopper, 3 men @ 0.10 minutes.	0.3 min.
	Total time per batch	30.7 min.

This last result checks the former one where the work of each man was considered separately. The total time will be substantially the same if the time per car, Item (42) is used instead of the time per cubic foot, Item (43).

Handling Sand and Stone in Carts. No times are given for hauling sand and stone in carts direct to the mixer, but the times per trip can be estimated by inspection of the unit times of a similar nature to see when it will be economical to employ, instead of barrows or cars, a horse and cart or two horses with two carts or double carts. Special carts are required for convenient loading, dumping, and measuring of the materials.

Handling by Derrick. Items (45) to (55), page 420. A derrick frequently may be used to advantage for charging the mixer. Sometimes when the concrete is being placed in a large mass close to the mixer, the same derrick may carry the concrete to place provided it can operate fast enough to supply the mixer as well. If the derrick simply supplies the raw material to the mixer, two buckets are required, one to be filled while the other is being swung and dumped.

The gravel and sand may be placed in the same bucket either by having a vertical division, or by filling one of the materials up to a certain level and putting the other material on top. The cement may be emptied directly into the mixer or may be opened on the gravel platform and dumped on top of the other materials, provided there is room in the bucket.

An inspection of the unit operations (p. 420) shows that each round trip of a derrick is made up of several units independent of the quantity of material handled. Although the times of these units vary in a measure with the length of boom and speed of swing, for ordinary conditions the average values in the table may be used. If more accurate data are desired special stop-watch observations should be made. The time of loading varies with the number of men and with the character of the materials. In the table, Items (45) and (46) are based on the time of one man; for example, if there are three men filling, the net time to load a bucket holding 20 cubic feet of gravel will be, Item (46), $\frac{0.42\times 20}{3}=2.8$ minutes. Item (47), on the other hand, gives the time of changing buckets in terms of per bucket, so that with 3 men loading as above, the total net time filling bucket will be $2.8+0.50=3.3$ minutes per bucket. The time per cubic foot (based on the time of one man) will be $0.42+\frac{(0.50\times 3)}{20}=0.49$ minutes.

It is difficult to arrange the men so that the time shoveling just balances the speed of the bucket, and for this reason 50 per cent is added to the shoveling times for delays. On the other hand, the bucket is apt to be kept busy on such work so that 30 per cent is added to the bucket times.

If maximum capacity of the derrick is required, enough men must be provided to load one bucket while the other one is being swung and dumped.

The use of derricks for elevating concrete to place is referred to on page 402.

The quantity of material handled by a derrick can be determined from the unit times as illustrated in the following example.

Example 9: For what rate of mixing can a derrick under ordinary conditions furnish sand and stone, using a one yard bucket and swinging a full half circle, the proportions of the concrete being 1:2½:5, mixed in 4-bag batches?

Solution: It is assumed of course that two buckets are used, one being filled while the other is being swung to the mixer. For determining the time of a round trip, we may refer to Table of Unit Times on page 420.

A bucket, to hold the stone and sand for a batch of 1:2½:5 concrete, which with a unit measure of 3.8 cubic feet requires one barrel (4 bags) cement to 9½ cubic feet sand to 19 cubic feet of stone, must have a capacity of $28\frac{1}{2}$ cubic feet. A yard bucket slightly heaped should hold this volume.

The unit times per bucket load of the derrick are as follows:

Item	Operation	Net Time	Actual Time
		min.	*min.*
(48)	Hook full bucket	0.25	0.32
(49)	Hoist full bucket	0.21	0.27
(51)	Swing full bucket 180 degrees to hopper	0.73	0.94
(52)	Lower bucket	0.20	0.26
(53)	Place over hopper	0.32	0.42
(54)	Dump	0.19	0.24
(51)	Swing empty bucket 180 degrees to stock pile	0.73	0.94
(55)	Unhook	0.25	0.32
	Total time per batch	2.88	3.71

Since a bucket, in this case, carries materials for one batch of concrete, a batch of concrete can be made in $3\frac{3}{4}$ minutes on the average or $\frac{600}{3.75} = 160$ batches per day of 10 hours, which, with $1:2\frac{1}{2}:5$ concrete is equal to about 123 cubic yards, provided the mixer can handle this quantity and it can be taken care of after leaving the mixer.

Example 10: How many men will be required for filling the bucket to maintain the above rate of speed?

Solution: The method of solution depends upon whether the sand and gravel are shoveled into the bucket from opposite sides at the same time, a partition separating the 2 materials, or whether the gravel is filled in first and the sand on top, or whether the materials are shoveled into a hopper and dumped at one operation into the bucket. If we assume that the sand pile is on one side and the gravel pile on the other side of the bucket, we find, from Item (46) on page 420, that one man will load one cubic foot of gravel into a bucket in 0.42 minutes net; since 19 cubic feet of gravel are required, the net time for one man to shovel the gravel is, Item (46), $19 \times 0.42 = 7.98$ minutes. The allowable net time for filling the bucket is 2.88 minutes from which must be subtracted the time that the buckets are being changed, Item (47), or 0.50 minutes; therefore the net time allowable for shoveling is $2.88 - 0.50 = 2.38$ minutes, and the number of men required to shovel is $\frac{7.98}{2.38} = 3.4$ or 4 men. For sand, Item (45), one man will shovel $9\frac{1}{2}$ cubic feet into the bucket in 9.50×0.31 or 2.94

minutes, and the number of men required to shovel the sand in the given time is $\frac{2.94}{2.38} = 1.2$ or one man, as one of the men who is shoveling gravel can help the man with the sand during a part of his time. Therefore there would be 5 men required to fill the bucket as fast as it can be handled by the derrick.

Raising Gravel with Dredge. Sometimes for concrete for such work as piers, it is convenient to dump the gravel in the water near the site, and raise it with an orange-peel or rehandling dredge. The quantity handled varies with the size of the bucket and to a slight degree with the character of the material. For any given case the unit times may be determined by stop-watch observations on similar work.

In figuring the capacity of such a dredge, allowance must be made for occasional stops such as for moving the lighter containing the dredge, etc. If the gravel requires screening, the quantity of concrete made will depend upon the relative proportions of sand and coarse gravel in the original material and the amount which must be wasted to correctly proportion the concrete.

Transporting by Endless Conveyors. Bucket conveyors or elevators or endless belts are frequently adapted to plants of comparatively permanent character. The quantities to be handled vary so largely with different cases that each one must be studied separately. The number of men to operate must be determined and the machinery cost which must be charged to every cubic yard of concrete may be estimated by methods similar to those given on page 342.

CHARGING MIXERS

The various methods of conveying materials already described cover the item of charging the mixers, so far as the handling of the materials is concerned, except where the sand and stone must be shoveled into the mixer as a separate operation. When considering the work of the mixer gang, the charging time is the time of the mixer while being filled and may not correspond to the time of the charging gang.

Charging Continuous Mixers. Continuous mixers may be fed by shovels or with an automatic feed leading from hoppers. The hoppers may be charged by barrows or other apparatus similar to the batch mixers.

Handling Cement. Items (56) to (62) page 421. A few unit times are presented to be used in studying the work of the cement men who supply the mixer to see when extra men are required. The unit times are applied in a similar manner to that adopted in other cases. The handling of cement is discussed on page 251.

OPERATIONS OF A BATCH MIXER

When the mixer is of a larger capacity than required for the work, the output is governed by the rate at which the materials are fed to it. In discussing the times of mixing as applied to the machine itself, it is assumed that the gang is arranged so as to keep the mixer working at average capacity.

For handling the mixer, a gang consists usually of the following:

One engineman.
One man running mixer.
One cement man.
One man handling water.

If the cement is opened at a distance and conveyed to the mixer with the other materials, the cement man may be part of the transporting gang. If the concrete is dumped into barrows, a special man may be required to dump the mixer. If the sand and stone are dumped direct from bins, another laborer is required. Sometimes an independent fireman is required to run the boiler, although the engineman should be able to do this unless he also operates hoisting or other machinery which requires constant attention. On account of these variations, the tables are made up on the basis of one engineman and four laborers.

The operations of the mixing machine may be separated into charging, mixing and dumping.

The times of charging as applied to the gang supplying the mixer with materials have been discussed on page 387. When applied to the mixer times, however, the operations are different. For example, if the mixer is fed by barrows, the speed of charging is governed by the work of the barrow men, but only that part of their work which consists of dumping and turning their barrows.

Batch mixers of ordinary types are fed in various ways:

(1) By loading tray.
(2) By barrows.
(3) From hopper or car.
(4) By derrick.
(5) By other special machinery.

The time of charging a mixer is dependent upon the method and, since this is one of the principal items governing the output of a large mixer, several of the more common methods will be considered separately.

The time of dumping is dependent largely upon the manner of dumping,—whether the material is dumped all at once or into small vehicles, such as barrows, which require a wait between loads.

In the table of unit times, the operations that are dependent upon the quantity of material mixed, such as Items (63) to (67) and Items (75) to (79) are given in terms of per batch. The proportions assumed are 1:2½:5 concrete, but the unit times for other proportions will not ordinarily vary enough to warrant changes. The operations which involve the work of the mixing machinery, as stated in a footnote, must be multiplied by the number of men performing the operation. In these mixer items, the men to figure in this way are those belonging merely to the gang handling the machinery. The men transporting the raw materials or the concrete can be figured separately, from other unit times.

To the mixer items 50 per cent is added because observations have shown that, under average conditions, the delays of the mixing machinery through the day average this amount. In exceptional cases, where the estimator can be sure that the machinery will run smoothly, 30 per cent can be substituted.

The authors know of several instances where for a day's continuous run the machines mixed at the rate of a batch a minute, but this rate is very exceptional and does not give enough time to thoroughly mix the concrete.

Charging by Loading Tray. Items (63) to (68), page 421. When the materials are dumped into a tray or bucket that is elevated to the mixer by power, the time charging, as applied to the mixer, consists of the time raising the tray plus the time dumping the materials into the mixer.

For example, the net time to charge the materials for a 3-bag batch of concrete (which, with 1:2½:5 proportions, makes $\frac{3}{4} \times 20.8 = 15.6$ cubic feet of concrete) is, from Items (63) and (66), $0.21 + 0.33 = 0.54$ minutes per batch. This is the average net time required to charge the mixer under the conditions indicated.

Charging by Barrows. Items (69) to (73), page 421. The time charging a mixer with barrows as applied to the mixer itself consists of dumping each barrow and getting it out of the way. The time required illustrates the advantage of having a hopper above the mixer into which the batch can be charged at one time instead of the mixer being idle while the different barrows are being dumped.

The time charging the mixer is simply the time of dumping hopper into mixer and is represented for different sizes of batch in ordinary proportions by Items (64) to (67).

The time charging mixer with any given proportions is obtained by multiplying the above times by the proper quantities.

Example 11: If a batch of concrete consists of 2 bags cement, 2 wheelbarrow loads of sand, and 4 wheelbarrow loads of stone, what will be the net time of dumping this into a hopper or mixer?

Solution:

Item		
(73)	Dumping 2 bags cement	0.26 min.
(69), (70)	Dumping 2 barrows of sand and turning	0.30 min.
(71), (72)	Dumping 4 barrows stone and turning	0.72 min.
	Total time filling mixer	1.28 min.

or about $1\frac{1}{4}$ minutes. Under ordinary conditions, an allowance of 50 per cent for delays must be made when estimating the cost to provide for the delays waiting for mixer, etc., which are liable to occur.

Charging from Hopper or Bin. Items (64) to (68), page 421. The quickest method of charging a mixer is to have the materials ready, measured in a hopper above the mixer, and drop them in by opening the gate. The hopper may be provided with marks for measuring the sand and stone, and the material fed by gravity from bins above, or the sand and stone may be dumped into the hoppers from barrows, and measured either in the hopper or in the barrows.

The time charging the mixer is simply the time of dumping hopper into mixer and is represented for different sizes of batch in ordinary proportions by Items 64 to 68.

MIXING

A continuous mixer mixes while it is being charged, so that the time per batch for the machinery and the mixer men is determined by the time charging.

In a batch mixer, whatever the type, rotary, stationary, or gravity, the mixing is to a certain extent a separate operation, although the materials are really being mixed together from the time charging begins until the dumping is complete.

The time mixing in a rotary mixer averages about 0.70 minutes in addition to the charging, in some cases running as low as 0.35 minutes. There is some question as to whether this gives sufficient time to thoroughly mix the materials together. In such cases, when the mixer is charged in one operation and also dumped in a single operation, the total net time per batch may be one minute or less. Care must be taken therefore to see that the time is not reduced so low that the materials will not be thoroughly mixed together. A thorough mixing tends to produce a stronger concrete so that time saved by exceptionally quick work is doubtful economy.

Water is added while the charging or the mixing is in progress, that is, it is a part of the mixing item and is not separated from it.

DISCHARGING BATCH MIXER

With continuous mixers, the discharging is continuous, so that it need not be separated from the rest of the work except as it applies to the labor of conveying the concrete as described in succeeding paragraphs.

The operation of discharging a batch mixer consists of tipping the mixer or the spout, dumping (the time of which varies with the size of the batch), and tipping back the mixer or spout. If the mixer discharges without tipping, the tipping operations are omitted. The time of dumping, then, varies with the quantity mixed, so that the time may be expressed also in terms of per batch of different sizes, or, in terms of per cubic yard, as given in Item (80). Discharging into barrows or other vehicles of less capacity than the mixer delays the work because of the extra time changing barrows and tipping the mixer for each. Hence, for quickest work, batch mixers should be arranged to dump the entire batch at one operation. If the concrete is to be carried away by vehicles holding less than a batch, a hopper should be provided below the mixer so that the concrete can be dumped at one operation and then drawn into barrows while next batch is mixing.

In some mixers, the time of dumping is very much smaller than is given on page 422. In fact, it may be as low as 0.02 minutes for a one-bag batch, with an increase in time proportional to the quantity for larger batches. The time per cubic yard for dumping would then be 0.10 minutes instead of 0.46, a difference which should be taken into account when the particular mixer under consideration can be observed and timed.

Discharging into Barrows, and 2-Wheel Hand Carts. Items (82) and (83), page 422. The net times and the actual times, including delays, are given for discharging a rotary mixer into ordinary contractors' wheelbarrows and 2-wheel hand carts. Notice that the times apply to the work of the mixer and not to the barrows themselves. For the work of the barrow men, refer to Item (88) and the following items.

The ordinary contractors' wheelbarrows hold only about 1.3 cubic feet of wet concrete measured in place; while a large 2-wheel hand cart, such as a Ransome, although having an actual water measurement of 6 to 7 cubic feet, holds only about 4.5 cubic feet of wet concrete measured after placing. For barrows having other than the given capacities, the times are obtained by interpolation.

Dumping Full Batch. Items (75) to (81), page 422. The net time dumping a rotary mixer may be separated into the following items:

Item		
(75)	Tipping mixer or spout per batch	0.12 min.
(76)	Dumping into hopper, per one-bag batch	0.09 min.
(81)	Tipping mixer or spout to place	0.12 min.
	Total net time per one-bag batch	0.33 min.
(77)	Dumping 2-bag batch, total	0.42 min.
(78)	Dumping 3-bag batch, total	0.51 min.
(79)	Dumping 4-bag batch, total	0.60 min.

The two operations of tipping are independent of the quantity of concrete in the mixer. The second item, that of dumping, varies with the quantity in the mixer, as indicated above.

TRANSPORTING CONCRETE

Concrete is transported commonly by either wheelbarrows, 2-wheel hand carts, cars on a track, derricks and buckets, or hoists. Each of these may be studied in detail to estimate the time under different conditions. When special machinery, such as cables and endless conveyors, is used, the charge for machinery is determined as described on page 342, and the charge for men is based on the output of the machinery.

Hoisting Concrete in Vertical Hoists. Items (84) to (87), page 422. Bucket hoists, where a full batch of concrete is dumped directly from the mixer into a bucket and raised in a vertical frame such as is described on page 334, have replaced the older method of filling wheelbarrows below and raising them on a platform elevator. The hoist bucket should dump automatically into a hopper from which the concrete can be conveyed in cars or barrows or by chutes to the place required.

The plant cost, which is an important item in figuring the cost of the concrete, must be included as indicated on page 337.

A knowledge of the average times hoisting buckets in a frame hoist is useful simply as a check, to be sure that the hoist has a working capacity as great as that of the mixer since the bucket must be hoisted and dumped while a batch is being mixed.

The time of hoisting per foot varies somewhat with the height of hoist, the time per foot being a little larger with a low lift because of the slower speed at the beginning and end of the operation. Observations under different conditions, however, show that this difference is so small that it may be neglected and an average time taken as given in the table. The method of computing the capacity of a bucket hoist is best illustrated by an example.

Example 12: What will be the average time of a round trip of bucket raising concrete to a height of six stories, using a 2-bag mixer, proportions of concrete 1:2:4?

Solution: A 4-bag batch of 1:2:4 concrete averages 17.2 cubic feet and a 2-bag batch, 8.6 cubic feet. We have, therefore, the following tabulation:

Item		
(84)	Filling bucket................	$\frac{8.6}{27}\times 0.70 = 0.22$ min.
(85)	Hoisting bucket (assuming stories 12 ft. high)................	$12\times 6\times 0.008 = 0.58$ min.
(86)	Dumping bucket............	$\frac{8.6}{27}\times 0.66 = 0.21$ min.
(87)	Lowering bucket,..... ..	$12\times 6\times 0.003 = 0.22$ min.
	Total net time per 2-bag batch..............	1.23 min.

Actual time with allowance for ordinary delay is $1.23 \times 1.30 = 1.60$ minutes.

Example 13: What will be the output of the hoist if a 4-bag mixer is used?

Solution: Times are made up in a similar manner, using a full batch of 17.2 cubic feet.

Item		Min.
(84)	Filling bucket	$\frac{17.2}{27}\times 0.70=0.45$
(85)	Hoisting	$72\times 0.008=0.58$
(86)	Dumping	$\frac{17.2}{27}\times 0.66=0.42$
(87)	Lowering	$72\times 0.003=0.22$
	Total net time per batch	1.67

Actual time including allowance for delays is $1.67 \times 1.30=2.17$ minutes.

The capacity of the hoist will be $\frac{480}{2.17} = 221$ batches per day of 8 hours or $221 \times \frac{17.2}{27} = 141$ cubic yards of concrete.

Of course in order to maintain the speed in either example, the mixer must be operated to the capacity given and provision must be made for taking away the concrete. Under exceptionally good management, the net times of quick men may be used and, adding the same percentage of delay as for average men, the time of operation is reduced to 1.52 minutes, with a consequent increase in output to 201 cubic yards per day.

Handling Concrete with Derricks. Items (45) to (55), page 420. Derrick work for handling materials has been described on page 392. This applies to handling where the stockpile and the dumping platform have no very great difference in levels. The times given for the derrick work can be applied to the handling of the concrete as well as the raw materials; or if, as suggested, the supplying of the mixer and the taking away of the concrete is done by the same derrick, the time per derrick load may be readily computed by adding up the units for both sets of operations.

To work a derrick to its full capacity, at least two concrete buckets must be provided so that one may be filled while another is being swung and emptied. For this arrangement, it is convenient to have a short piece of track placed crosswise at the mouth of the mixer with a car running upon it large enough to hold the two buckets. The derrick places the empty bucket on the car and as soon as the other bucket is filled, the car is moved by hand so that the empty bucket comes under the mixer and the derrick takes away the full one. When the new bucket is full the car is pushed in the opposite direction.

If the bucket is hoisted, as in building construction, there are two additional operations of hoisting and lowering, besides the time swinging, which must be included in figuring the time.

For work of this character, the derrick either must be placed on one of the floors already constructed and raised from story to story, which cannot be done satisfactorily except in a steel frame building, or else placed on an elevated framework.

Derricks have been used in building construction for dumping directly into the floor forms instead of into a hopper from which the concrete is handled by barrows. The time lost in placing the bucket exactly where required is apt to overbalance the time of wheeling the concrete a short distance. Then, too, the derrick limit is too short to work effectively on a large building. An elevated derrick of this kind is not generally so economical as a bucket hoist. The only advantage is in its use for hoisting other materials, and this usually can be accomplished to better advantage by an independent hoist.

Wheeling Concrete in Barrows and 2-Wheel Hand Carts. Items (88) to (112), page 422. Concrete is handled in barrows either direct from the mixer or by filling them from a hopper into which the mixer or the hoist bucket dumps. The latter method, as described on page 399, is much more economical because the mixer does not have to wait to fill barrows. The barrows are also more quickly and evenly filled from a gate than from the mixer.

The time and cost of handling depends largely on the size of the barrow used. It is economical to use as large a barrow as can be handled conveniently by one man. If a 2-wheel hand cart is used, the run must be made wide enough for both wheels and turnouts provided so that the carts can pass each other. The unit times for two sizes of barrows are given but the same method can be employed for figuring the time and cost with barrows of other sizes. The ordinary contractor's barrow, although having an average capacity of about 3 cubic feet of sand, holds on the average only about 1.9 cubic feet of plastic concrete or 1.3 cubic feet of very wet concrete measured in place. The actual barrow measurement is more than this, since the water in very wet concrete has considerable bulk. (See p. 260).

A 2-wheel hand cart, such as a Ransome cart of 6 cubic feet capacity water measure, holds on the average about 4.5 cubic feet of very wet concrete measured in place. This provides for filling the concrete to within about 6 to 8 inches of the top, the remaining difference in measure being due to the excess water.

The operations of wheeling are given, therefore, in terms of an ordinary barrow holding 1.3 cubic feet of concrete, 2-wheel hand carts of 4.5 cubic feet capacity, and also in terms of per cubic yard of concrete when handled in each size of barrow. The times for barrows of other capacities can be obtained by interpolation. The simplest way to determine the capacity of a barrow of concrete is to count the number of barrows required to carry off a batch of concrete made with given quantities of materials. Knowing the number of bags of cement and the proportions, the quantity of concrete per batch can be obtained from Table 25, page 154.

Beginning with Item (88), page 422, the times for an ordinary barrow are represented by the first five items, (88) to (92). If the concrete is wheeled a distance of 100 feet, Item (90) must be doubled, thus giving a total net time of 1.46 minutes per round trip of barrow when it is filled from the mixer. If filled from hopper, Items (93) and (94) must be substituted for Items (88) and (89), and the time will be 0.08 minutes less or 1.38 minutes. The times also are given in terms of per cubic yard of concrete, including placing barrow, so that by adding together Items (96) to (99),—Item (95) may be used instead of (96),—the time is obtained directly in terms of per cubic yard of concrete.

The operations for 2-wheel hand carts are taken up in a similar manner, Items (100) to (112), page 423.

Dumping. The times of dumping, Items (91), (98), (104), and (111), pages 422 and 423 apply to places where the barrows or carts are easily dumped, such as beams and slabs. Dumping into columns is slightly more difficult, and requires about 25 per cent longer. To avoid confusion, however, this difference is not indicated in the table.

The time per cubic foot shoveling concrete from barrows is given in Item (137), page 424.

Example 14: What will be the average actual time and cost per cubic yard of concrete, filling 2-wheel hand carts from hopper, wheeling 100 feet, and dumping to beam and slab forms, with labor at 20 cents per hour?

Solution: The example may be solved either by finding from Items (102) to (107) the actual time per cart and multiplying by the number of cart loads per cubic yard; or by finding the time per cubic yard direct from Items (109) to (112). The times for both ways are given on page 405 in separate columns.

Item	Operation	Actual Time per Cart	Item	Actual Time per Cubic Yard
(106)	Place cart at hopper..........	0.11 min.	(109)	2.35 min.
(107)	Fill cart at hopper............	0.18 min.		
(102)	Turn ready to wheel..........	0.10 min.		
(104)	Dump into beams and slabs..	0.28 min.	(111)	1.68 min.
(105)	Turn empty cart..............	0.06 min.	(112)	0.34 min.
(103)	Wheel 100 feet round trip at 0.53 × 2 =	1.06 min.	(110)	6.33 min.
	Total time per cart..............	1.79 min.	per cu. yd.	10.70 min.

To compare the two totals, we may compute from the first the total time per cubic yard as $1.79 \times \frac{27}{4.5} = 10.74$ minutes. This checks substantially with the other time of 10.70 minutes, which was found directly in terms of per cubic yard.

To find the cost, multiply the time by the rate per minute, which, for 20 cents per hour, is \$0.0033; but to this rate must be added 15 per cent for foreman and 15 per cent extra for superintendence, overhead charges, etc., making a total rate per minute of \$0.00442. The cost per cubic yard of concrete, therefore, is 10.70 × \$0.00442 = \$0.047. This is for average conditions and does not include profit.

Example 15: What will be the cost of wheeling above that in last example if concrete is dumped direct from mixer?

Solution: The items are all the same except the second for which values in Item (101) are substituted:

Item	Operation	Actual Time per Cart	Time per Cubic Yard
(101)	Fill cart at mixer	0.22 min.	1.32 min.

Substituting these, gives a difference of +0.04 minutes per cart or 0.24 minutes per cubic yard, which at the rate of \$0.00442 per minute gives an extra cost of \$0.001 per cubic yard. The extra cost of the mixer and mixer gang will be much greater than this because the mixer must wait while the barrows are being changed.

Example 16: What will be the cost in Example 14 if ordinary wheelbarrows are used holding 1.3 cubic feet of very wet concrete?

Solution: Giving the different items, as in Example 14, both per cart and per cubic yard:

Item	Operation	Actual Time per Barrow	Item	Actual Time per Cubic Yard
(93)	Place barrows at hopper......	0.14 min.	(96)	4.65 min.
(94)	Fill barrow from hopper......	0.08 min.		
(91)	Dump........................	0.28 min.	(98)	5.88 min.
(92)	Turn empty barrow..........	0.08 min.	(99)	1.75 min.
(90)	Wheeling 100 feet including return @ 0.53 min..........	1.06 min.	(97)	22.00 min.
	Total time per barrow.......	1.64 min.	per cu. yd.	34.28 min.

From the column, where the total time per barrow is 1.64 minutes, the time per cubic yard is $1.64 \times \frac{27}{1.3} = 34.10$ minutes, which checks substantially with the time found directly.

To find the cost, multiply 34.28 minutes by the rate as found in Example 14, or $0.00442, which gives $0.151 as the cost per cubic yard. This cost includes the cost of foreman, superintendence, overhead charges, etc., but does not include profit or home-office expense.

Example 17: What will be the cost in the last example if the barrows are filled direct from the mixer?

Solution: Items are all the same except the first two, which from page 422, will be 0.34 minutes per barrow or 7.11 minutes per cubic yard instead of 0.22 minutes or 4.65 minutes respectively.

This is 0.12 minutes greater per barrow than the first two items in the last example or 2.46 minutes per cubic yard, and at $0.00442 per minute the cost is $0.011 greater per cubic yard of concrete.

Transporting Concrete in Carts with Horses. Horses and carts are seldom used for hauling concrete except in special cases, as for instance, in a central mixing plant where small masses of concrete are distributed over quite an area or in localities where it is impossible to establish a mixing plant on the work.* Again, for hauls over 300 or 400 feet, where roads are good but it is inconvenient to lay tracks, horses and carts are used frequently. On page 346, a description is given of a central plant from which concrete was hauled over a mile by teams. Under the conditions existing there, the work was carried on economically. But in the general run of concrete work it is either impossible or not economical to construct suitable roads.

Approximate times and costs are given in Table 55, page 312.

*In some of the "cut and cover" work of the Subway at Cambridge, Mass., carts were used efficiently.

Handling Concrete in Cars. Items (113) to (121), page 423. If the concrete is handled in cars running on a track, they should be of a capacity to hold an entire batch dumped direct from the mixer or from the hoist bucket. To avoid too frequent moves, extra men are generally required to assist in placing the concrete between the lines of track.

Two sets of times are given, Items (113) to (116) in terms of per car, that is, the time it takes the gang handling the car to perform each operation, and another set, Items (117) to (121), page 423, in terms of a cubic yard of concrete based on 2 men being required to operate a car holding an ordinary batch.

The net time for the round trip of a car hauling concrete to a distance of 100 feet, from Items (113) to (116), averages 2.24 minutes, or, allowing 40 per cent for lost time and delays, 3.13 minutes.

Item (121) is an approximate estimate of the extra time (expressed in terms of one man) for spreading a cubic yard of concrete when tracks are employed instead of the wheelbarrow runs that are more easily moved.

The time moving the track and placing the switches in position is a variable item governed by the length of haul and location of the dump. Track can generally be moved outside of the regular working hours, so as not to interfere with the output of the mixer.

Handling Concrete in Pails. Items (122) to (133), page 424. On a small job, or in placing a small quantity of concrete where the runs for power hoists are not available, it is sometimes convenient to carry the concrete in pails or to pass the pails from one man to another. Although this plan is more apt to be followed with hand mixed than with machine-mixed concrete, there are occasions on a job employing machine mixing where it seems to be the only practical method to follow.

The times handling concrete in pails are given in terms of per pail, Items (122) to (126), (130), and (131), page 424, and can be obtained so as to estimate the time required for any given condition and to determine the number of men needed; also, in terms of per cubic yard of concrete, Items (127) to (129), (132), and (133), page 424, which can be used differently for estimating the approximate costs per cubic yard. These latter items allow for the fact that the men who carry the buckets usually have to wait for the empty buckets to be returned to them.

On a small job the men may carry the concrete in pails to a hoist consisting of a rope running over a single block and operated by a man on the stage. One or more other men take the pails at the top and dump them into the wall. This character of work is covered in Items (122) to (129).

Another plan is to station men on stages, at different heights about 5 feet apart vertically, and pass the pails from one man to another. This class of work is covered in Items (130) to (133).

Example 18: Suppose the mixing board is located 100 feet from the wall and the concrete is hoisted 10 feet in pails by a rope and single block, how many men should be provided for the gang?

Solution: If the man who carries waits for his pail to be raised and an empty one to come down, his net time per round trip will be the sum of Items (123), (124), and (126), or 1.10 minutes. If three carrying men are provided, the man who fills pails will have to work at a speed of 0.37 minutes per pail instead of 0.47 minutes. The time of the hoisting man for each pail is represented by the sum of Items (124) and (126) or 0.18 minutes per pail, and he therefore will be idle $0.37 - 0.18 = 0.19$ minutes between each pail. One man can dump concrete, his time, Item (125), being 0.28 minutes, provided he does not have to walk more than $\frac{0.37 - 0.28}{0.0092} = 10$ ft. The entire gang then, provided the man filling pails works fast, will consist of six men.

Example 19: What will be the cost per cubic yard in this case for transporting the concrete?

Solution: The time per pail is 0.37 minutes net, or, adding 30 per cent for delays, is 0.48 minutes. Hence the time for the gang is $6 \times 0.48 = 2.88$ minutes per pail or $2.88 \times \frac{27}{0.3} = 259.2$ minutes per cubic yard. With labor at 20¢ per hour and allowing 15 per cent for foremen, this amounts to $259.2 \times \frac{\$0.20}{60} \times 1.15 = \$0.99$ per cubic yard. Allowing an additional 15 per cent for general superintendence and overhead charges, we have $1.15 per cubic yard for transporting the concrete in pails and dumping it. This does not include the mixing or tamping but simply the filling of pails and carrying and raising to place.

A similar result in time is obtained by adding Items (127) and (128), which gives the time per cubic yard directly as 282.0 minutes. The difference between this and the 259.2 minutes obtained by the other method is due to the fact that the gang is arranged more economically than usual. If, on the other hand, the man filling pails had worked at an average rate of 0.47 minutes, it would have increased the time to $259.2 \times \frac{0.47}{0.38} = 321$ minutes. Again, if the concrete on the stage had required a carry of 30 feet, 2 men would have been necessary there, and from Item (123) it is evident that there would have been a considerable loss of time which would have increased the cost. These differences in time and cost clearly show the necessity for an economical arrangement of the gang so that the men will all be busy as much of the time as possible.

Example 20: What will be the difference in net time between the method of hoisting 20 feet by single block hoist and passing up the concrete to the same height?

Solution: The first method is covered by Items (127) and (129), giving 166.5 minutes per cubic yard, while the second method is covered by Item (132), giving $2 \times 95.4 = 190.8$ minutes per cubic yard, a difference of 24.3 minutes in favor of the rope hoist for these particular conditions.

PLACING CONCRETE

Leveling and Tamping Concrete. Items (142) and (143), page 424. For leveling and tamping concrete of plastic or wet consistency, a man can be assumed to handle a definite number of cubic yards per day, this being about 11 cubic yards for plastic and 18 cubic yards for wet concrete.

For wet mixed concrete placed around reinforcement in narrow or shallow forms, the time and cost is best estimated from different observations of different gangs working under ordinary conditions. An average of a number of jobs of building construction gives the time, based on the total day's work of the gang, these being really gross, as 33 minutes per cubic yard. The variation under different conditions with different factors is much less than would be expected for such an item, ranging in the jobs observed from 22 minutes per cubic yard to 55 minutes per cubic yard.

In concrete building construction the number of men spading and ramming are apt to range from 3 to 8, according to the character of the work and the quantity of concrete mixed per day. Four may be called a usual number.

PERCENTAGES FOR REST AND DELAY

The percentages allowed for rest and delay will appear very high to those who are not accustomed to analysis of labor operations. For work laid out in a scientific manner these percentages may be reduced considerably, but they now apply to average conditions on ordinary contract work. It must be remembered that these percentages include not only the irregularities in the times of different batches but also allow for loss of time due to occasional stops and shutdowns.

TASK-WORK IN CONCRETING

The general principles that must be applied in the introduction of task-work or piece-work have been discussed on pages 75 to 106 and at other places in this book. So few construction jobs are properly organized, while fewer have even attempted the layout of tasks, or the introduction of piece-work, that it is impossible to present a full series of unit times that are exactly applicable to scientifically managed work. On the other hand, the net quick times given may be readily altered to suit special conditions and then used with smaller percentages for rest and delays than have been adopted for the average times. The percentages, or ratios, to be used must be obtained in every case by a thorough study of the work in all its details.

DESCRIPTION OF MACHINE MIXING TABLES

Table 62 has been fully described under the study of "unit times" in preceding pages. It is to be used where a study of the different operations is to be made or a gang is to be organized. The other tables have been made up by combining these unit times in a proper manner to give the desired results.

The average times in this table and those that follow, as has been already stated, apply to average men and average conditions. For example, the net times for average men represent an average of a large number of actual observations under ordinary working conditions. The values, as stated in a preceding paragraph, do not apply to exceptionally fast work by first-class men and scientifically organized methods. Exceptionally quick times for mixing machinery are referred to on page 399.

Tables 63 and 64 give the net, average, and quick times for mixing a 4-bag batch and a 2-bag batch of 1:2:4 and 1:2½:5 concrete.

Other proportions of mix may be closely estimated from these values. These times vary with the different conditions of loading and dumping. Nine different cases are analyzed, the times required per batch to mix are given and the output of the machine for each condition.

In Case I, where the mixer is charged by loading tray, the operation of mixing consists of four items. Two of these, "raise tray" and "mix and wet" are constant for all sizes of batch, while the other two items, "charge" and "dump mixer," vary with the quantity. The "loading tray" is simply a tray or bucket so rigged that it may be lowered and filled by wheelbarrows or other vehicles and then raised and dumped into the mixer. With this arrangement, very little time of either the loading or mixing gang is wasted.

In Case II, where the materials are each dumped separately into the mixer, the time of charging, and therefore of the whole operation, is much longer. Here, there is only one constant operation,—"mix and wet,"—all the others varying with the size of batch and the proportions of the concrete.

Where the materials are dumped directly from hopper to mixer and the concrete from mixer to hopper or car, as in Case III, the maximum output per day is obtained. Here both the times charging and dumping are as short as it is possible to make them for the gang assumed unless the design of the mixer permits quicker unit operations.

Where the materials are dumped from mixer to wheelbarrows, as in Case IV, the mixer must tip back after each load, wasting a great deal of time, so much, in fact, that the output per hour is only about one-third of what it is when the mixer dumps directly into hopper.

If the mixer is charged by barrows and dumps into barrows, Case V, the time required for the whole operation of mixing is nearly 4 times as much as is required by Case III, where the materials and concrete are handled as complete batches. Besides the extra time required for tipping back mixer after each barrow load is discharged, is the time required for each charging barrow to dump its load of sand or stone and then get out of the way for the next barrow.

Comparing Case VI, where the mixer is charged from hopper and discharged into barrows, with Case V, where the mixer is charged by barrows, it is evident that the manner of dumping the mixer has a greater influence on the total time of mixing than has the manner of charging.

In Case VII the mixer is charged by barrows and discharged into 2-wheel hand carts. Only about one-third the time is required to discharge the mixer into these carts that is required by wheelbarrows, because of their larger capacity.

The mixer in Case VIII is charged by the loading tray and discharged into 2-wheel hand carts, and in Case IX is charged from hopper. The total output is practically the same, since the charging item is such a small percentage of the whole time.

The following examples illustrate the different uses to which Tables 63 and 64 can be applied.

Example 21: What is the difference in time required to mix a 4-bag batch of 1:2½:5 concrete where the mixer is charged by barrows and discharges into barrows, and where it is charged by loading tray and dumps into hopper?

Solution: From Table 63, Case V, the actual time per gang of average men required to mix a batch of 1:2½:5 concrete, where the mixer is charged by barrows and dumped into barrows, is 10.03 minutes, and from Case I, where the mixer is charged by loading tray and dumps into hopper, the time required is only 2.93 minutes. It therefore takes 7.10 minutes longer in Case V than in Case I.

Example 22: How much smaller is the output per hour of 1:2:4 concrete for a 2-bag than for a 4-bag batch mixer, the mixer being charged by cars and dumped into 2-wheel hand carts?

Solution: From Table 64, Case IX, the output is 9.35 cubic yards per hour and from Table 63, Case IX, the output is 12.74 cubic yards per hour. The hourly output is 3.39 cubic yards greater for the 4-bag than for the 2-bag mixer.

Example 23: What is the difference in output per hour for a 4-bag batch mixer when mixing 1:2:4 and 1:2½:5 concrete, where mixer is charged by barrows and discharged into 2-wheel hand carts?

Solution: From Table 63, Case VII, the output for 1:2:4 concrete is 7.22 cubic yards per hour and for 1:2½:5 concrete 7.90 cubic yards or 0.68 cubic yards more per hour for 1:2½:5 concrete.

Tables 65 and 66 give the costs of mixing and of mixing machinery for average and for quick men per cubic yard of concrete under the different conditions assumed in Tables 63 and 64. The outputs per hour and the time per gang for these outputs are taken directly from Tables 63 and 64. The cost of fuel is based on a value of $4.00 per ton for coal, or $0.03 per cubic yard of concrete. This value is assumed the same for all outputs of all mixers. The cost of machinery, from an example on page 342, is taken at $7.34 per day for a 4-bag batch mixer and $4.89 per day for a 2-bag batch mixer, assuming 100 8-hour working days per year. The cost of machinery per day divided by the daily output gives the machinery cost per cubic yard. The items in the tables for machinery costs include the $0.03 per cubic yard for fuel.

The cost of labor is taken at 20 cents per hour and 15 per cent is added for the cost of the foreman and 15 per cent extra for general superintendence, overhead charges, etc.

The cost of machinery and fuel plus the labor cost gives the total cost of mixing per cubic yard of the concrete.

The uses for the Tables 65 and 66 are shown by the following examples.

Example 24: What would be the cost per cubic yard, including machinery charges, of mixing 1:2½:5 concrete when the 4-bag batch mixer is charged by cars and dumped into a hopper?

Solution: From Table 65, Case III, the cost of mixing per cubic yard of concrete for average men is $0.18 and for quick men $0.13. This does not include supplying materials to mixer or hauling or placing the concrete.

Example 25: How much greater would be the cost in Example 24 if the concrete was mixed in a 2-bag batch mixer?

Solution: From Table 66, Case III, the cost of mixing in the 2-bag batch mixer per cubic yard of concrete for average men is $0.23 and for quick men $0.17. Hence, for average men the cost per cubic yard is $0.05 greater, and for quick men $0.04 greater where mixed in a 2-bag batch mixer than where mixed in a 4-bag batch mixer.

Example 26: How much cheaper is it to mix 1:2½:5 concrete than 1:2:4, when the 4-bag batch mixer is charged by barrows and dumps into 2-wheel hand carts?

Solution: From Table 65, Case VII, the total cost per cubic yard for average men of mixing 1:2½:5 concrete is $0.35 and for 1:2:4 concrete is $0.38, a difference of 3 cents per cubic yard.

Table 67 gives the times and costs per cubic yard of 1:2½:5 concrete of handling raw materials and concrete. The times are given as times of one man. The table is made up by combining the proper items from Table 62 for the times and multiplying these times by the given rate per hour, 20 cents, plus 15 per cent allowance for foreman, and 15 per cent extra for general superintendence, overhead charges, etc. The table is divided into two parts, the handling of raw materials, and the handling of concrete. In the first part, Group I, the times and the costs for handling sand and gravel in cars for different ways of loading the materials are given. Group II gives the times and costs for handling sand and gravel or stone with a derrick, and Group III with wheelbarrows. Group IV gives the times and costs for handling cement in bags. In each case an extra item is given for an additional haul.

In the same table, Group V, the times and costs of handling concrete in cars of $\frac{3}{4}$ cubic yard (4-bag batch) capacity are given. Group VI gives the times and costs of handling concrete in 2-wheel hand carts for different conditions of filling and emptying the carts. The times and costs of handling concrete in ordinary barrows under different conditions of loading are given in Group VII. These times and costs are much larger than in Group VI where the concrete is handled by 2-wheel hand carts because of the extra time required to load. Group VIII gives the times and costs for handling the concrete with pails. In each of these groups, an item for additional haul or carry is given. Group IX gives the times and costs for leveling and tamping the concrete in place.

These groups of items may be combined to give the total cost of the concrete in place, exclusive of materials, plant cost, and mixing. The following examples show how this may be done.

Example 27: What is the actual time for average men, reduced to the time of one man, and what is the cost per cubic yard to handle the sand, gravel, and cement for a cubic yard of 1:2½:5 concrete? The sand is wheeled 50 feet in wheelbarrows, the gravel loaded from flat car into car and pushed 50 feet and the cement is carried 150 feet in bags.

Solution: The solution can best be made by tabulating the several groups.

From Table 67, page 434.

		Time	Cost
		min.	$
Group III	Sand wheeled 50 feet in wheelbarrows	8.31	$0.037
Group I	Gravel loaded from flat cars into car and pushed 25 feet	27.83	0.123
	Push car additional 25 feet	1.77	0.008
Group IV	Carry cement in bags 50 feet	7.38	0.033
	Carry cement additional 100 feet	8.00	0.036
	Total	53.29	$0.237

The actual time for average men to handle the raw materials is thus 53.29 minutes which, at the rate of 20 cents per hour plus allowances for foreman and for general superintendence, overhead charges, etc., gives a total cost of $0.237 per cubic yard of concrete, not including profit.

Example 28: What is the total cost per cubic yard of 1:2½:5 concrete, exclusive of materials and plant, for handling the raw materials and mixing and placing the concrete, when sand and stone are unloaded from flat cars into cars, pushed 100 feet, and dumped into mixer; cement is carried 50 feet in bags; concrete mixed in a 4-bag batch mixer and carried 100 feet from mixer to place by barrows?

Solution: The several groups are tabulated below.

		Cost
From Table 67, page 434.		
Group I	Sand unloaded from flat car and pushed 25 feet	$0.049
	Push car additional 75 feet	0.024
	Stone unloaded from flat car and pushed 25 feet	0.123
	Push car additional 75 feet	0.024
Group IV	Carry cement 50 feet in bags	0.033
Group VII	Wheel concrete 50 feet in ordinary barrows	0.114
	Wheel concrete additional 50 feet	0.048
Group IX	Level and tamp concrete	0.145
From Table 65, page 432		
Group VI	Mixing in 4-bag batch mixers	0.260
	Total cost of concrete per cubic yard, exclusive of materials and plant	$0.820

The total cost of the concrete per cubic yard in place is therefore $0.820. This does not include cost of materials or plant charges.

Table 68 gives the total costs per cubic yard of mixing and placing concrete for given outputs per hour with a 2-bag batch and a 4-bag batch mixer. It illustrates the high cost of running a plant with a small output. The sand and stone are wheeled 50 feet in barrows and dumped into a loading tray. The concrete is wheeled from a hopper 50 feet to place in barrows. The number of men for each operation required to handle the materials for a given output of concrete per hour are figured from the times of one man for the different operations as given in Table 67. The labor cost for each item is then figured and the plant costs for machinery taken from page 342 and for tools, runs, etc., from page 367. The sum of the labor, plant, and fuel costs is the total cost per cubic yard of the concrete in place, exclusive of cost of materials. The following example shows the use of this table.

Example 29: For a given output of 8 cubic yards of 1:2½:5 concrete per hour, is it cheaper to use a 2-bag batch or a 4-bag batch mixer?

Solution: The total cost per cubic yard of the concrete in place, exclusive of the cost of the materials themselves, for an output of 8 cubic yards per hour when mixed in a 2-bag batch mixer, is $0.77 and, when mixed in a 4-bag batch mixer, is $0.81. It is therefore $0.04 per cubic yard cheaper to use the smaller mixer.

Tables 69 and 70 give the total cost of labor and of plant per cubic yard of 1:2½:5 concrete in place for mixing and placing concrete under the specified conditions. They are practically a summary of the preceding tables. The outputs are taken as given in Tables 63 and 64, pages 425 and 428. The sand, gravel, and concrete are wheeled about 50 feet. Different conditions of wheeling, of charging and discharging mixer and of wheeling concrete are assumed. Under these different conditions, the costs of wheeling the raw materials and the concrete as well as the cost of placing are obtained from Table 67, page 434, and the costs of mixing from Tables 65 and 66, pages 432 and 433. The plant cost for the mixing machinery is given on page 342 and for the tools, runs, etc., on pages 367 to 370. A constant fuel cost for all outputs is taken at $0.03 per cubic yard. This is based on a cost of coal of $4.00 per ton. These tables are used in comparing the cost of concrete for different ways of handling the raw materials and the concrete.

The following example explains the way in which the tables may be used.

Example 30: Is it cheaper to handle the raw materials for a 4-bag batch of 1:2½:5 concrete by cars dumping directly into the mixer or by wheelbarrows dumping into a loading tray where the concrete is handled by barrows from a hopper?

Solution: From Table 69, where the mixer is fed by cars and discharges into a hopper from which ordinary wheelbarrows take the concrete, the cost of concrete per cubic yard in place is $0.62. Where the mixer is charged by loading tray into which the barrows are dumped and is discharged into hoppers and from hoppers to barrows, the cost is $0.66 per cubic yard of concrete in place. It is therefore $0.04 a yard cheaper, where the mixer has a loading tray to use cars than barrows, if the concrete is handled alike in both cases. The difference in cost is thus scarcely appreciable.

Table 71 gives the cost of concrete per cubic yard in place for different costs of plant, including installation, and different costs of labor per day. A yearly cost of one-quarter the initial value of the plant is taken and the number of working days a year assumed to be 100. The yearly cost of the plant divided by 100 times the daily capacity gives the plant cost per cubic yard. The cost of labor per day divided by the daily capacity of the plant gives the labor cost per cubic yard. The labor cost includes the cost of fuel.

The use of the table is shown by the following example.

Example 31: If the cost of plant is \$1000 and the daily cost of labor \$40 for an output of 100 cubic yards per day, what are the plant and labor costs per cubic yard?

Solution: From Table 71, the plant cost per cubic yard for an initial value of \$1000 is \$0.03 and the labor cost per cubic yard for a daily labor cost of \$40 is \$0.40, making a total cost of \$0.43 per cubic yard for a daily output of 100 cubic yards.

TABLE 62. TIMES OF UNIT OPERATIONS (See p. 384)

Unless otherwise stated, times are expressed as the time of one man, that is, they are to be used *direct* and *not* multiplied by the number of men in the gang.

NET TIMES apply to continuous work with no allowance for rest or other stops.

PER CENT DELAY includes rests, stops, and delays which occur throughout an average day's work.

ACTUAL TIMES include allowance for rests and delays. When computing costs, make allowance for superintendence, overhead charges, etc., (see p. 225).

AVERAGE MEN apply to the men and conditions on an ordinary contract job.

QUICK MEN apply to men working fast under exceptionally good contract conditions but not to piece-work.

When using net times of quick men in task or piece-work, a per cent must always be added for rest and delays. (See pp. 102 and 410)

All values given in this table are labor values and do not include machinery.

Proportions 1:2½:5 unless otherwise stated.

No.	Item	Reference Unit	Average Men			Quick Men
			Net Times min.	Per cent Delay	Actual Times min.	Net Times min.
	TRAVELING (See p. 384)					
1	Man walking with load or returning 100 feet		0.46	30	0.60	0.32
2	Man walking with wheelbarrow, each way 100 feet		0.48	10	0.53	0.33
3	Horse walking with cart, 100 feet		0.41	10	0.45	0.29
	SCREENING SAND AND GRAVEL BY HAND (See p. 385)					
4	Throwing gravelly sand to screen per cubic yard of unscreened sand (not including moving screen, etc.)	cu. yd.	18.9	30	24.6	13.2
5	*Screening sand to remove small stones per cubic yard of screened sand	cu. yd.	25.8	30	33.5	18.0
6	Throwing gravel to screen per cubic yard of unscreened gravel (not including moving screen, etc.)	cu. yd.	25.3	30	32.9	17.7
7	Shoveling away coarse stuff from screen and odd work (included in following item)	cu. yd.	21.5	30	28.0	15.1
8	Screening gravel to remove coarse stones per cu. yd. of screened gravel	cu. yd.	34.5	30	44.8	24.1
9	†Screening gravel to remove sand per cu. yd. of screened gravel	cu. yd.	72.2	30	93.8	50.5
10	Screening gravel to separate sizes (materials measured on both sides of screen)	cu. yd.	36.1	30	46.9	24.3

*Same as preceding item, except includes occasional moving of screen, shoveling away coarse stuff, etc.

†Time is based on measurement of gravel after screening. Gravel is taken as 50 per cent sand, hence if both sand and gravel are measured time would be one-half that given. See next item.

TABLE 62. TIMES OF UNIT OPERATIONS—Continued

(See important note on p. 418, also p. 382)

No.	Item	Reference Unit	Average Men: Net Times min.	Average Men: Per Cent Delay	Average Men: Actual Times min.	Quick Men: Net Times min.
	UNLOADING FLAT CARS					
11	*Shovel sand from open flat cars (no sides)	cu. ft.	0.18	30	0.23	0.12
12	*Shovel gravel or stone from open flat cars (no sides)	cu. ft.	0.27	30	0.35	0.19
13	*Shovel sand over sides of car to pile or bin	cu. ft.	0.48	30	0.62	0.33
14	*Shovel gravel or stone over sides of car to pile or bin	cu. ft.	0.69	30	0.90	0.48
	HAULING SAND AND GRAVEL (See p. 385)					
15	Haul sand and gravel from bank in carts (See table 52, p. 264)					
16	Haul sand and gravel from bank in barrows (See table 50, p. 261)					
	WHEELING SAND TO MIXER, PER BARROW† (See p. 387)					
17	Get ready to fill, etc.	barrow	0.15	50	0.22	0.11
18	Shovel sand to barrow	barrow	0.75	50	1.13	0.53
19	Wheel full barrow per 100 feet	barrow	0.46	10	0.51	0.32
20	Dump	barrow	0.10	50	0.15	0.07
21	Wheel empty barrow per 100 feet	barrow	0.50	10	0.55	0.35
	WHEELING SAND TO MIXER IN BARROW OF 3 CUBIC FEET CAPACITY PER CUBIC FOOT† (See p. 387)					
22	Get ready to fill, etc.	cu. ft.	0.05	50	0.07	0.04
23	Shovel sand to barrows	cu. ft.	0.25	50	0.38	0.16
24	Wheel per 100 feet including return.	cu. ft.	0.32	10	0.35	0.22
25	Dump	cu. ft.	0.03	50	0.04	0.02
	WHEELING GRAVEL OR STONE TO MIXER PER BARROW (See p. 387)					
26	Get ready to fill barrows, etc.	barrow	0.12	50	0.18	0.08
27	Shovel gravel or stone to barrows	barrow	1.05	50	1.58	0.74
28	Wheel full barrow per 100 feet	barrow	0.46	10	0.51	0.32
29	Dump	barrow	0.15	50	0.22	0.08
30	Wheel empty barrow per 100 feet	barrow	0.50	10	0.55	0.35

*Shoveling continuously under good supervision on a job like building construction. Increase by 50 per cent to allow for "soldiering," delays, etc.

†Based on wheeler loading his barrow. Extra loaders increase unit times because of necessary waits.

TABLE 62. TIMES OF UNIT OPERATIONS—Continued

(See important notes on p. 418, also p. 382)

No.	Item	Reference Unit	Average Men: Net Times, min.	Average Men: Per Cent Delay	Average Men: Actual Times, min.	Quick Men: Net Times, min.
	WHEELING GRAVEL OR STONE TO MIXER IN BARROW OF 3 CUBIC FEET CAPACITY, PER CUBIC FOOT (See p. 387)					
31	Get ready to fill, etc.	cu. ft.	0.05	50	0.08	0.03
32	Shovel gravel or stone to barrows	cu. ft.	0.35	50	0.52	0.24
33	Wheel per 100 feet including return.	cu. ft.	0.32	10	0.35	0.22
34	Dump	cu. ft.	0.04	50	0.06	0.03
	HAULING SAND AND STONE TO MIXER IN CARS ON TRACK (See p. 389)					
35	Shovel sand from platform up into car or cart	cu. ft.	0.55	50	0.83	0.38
36	Shovel gravel or stone from platform up into car or cart	cu. ft.	0.68	50	1.02	0.47
37	Shovel sand from flat car into car or cart below	cu. ft.	0.48	50	0.72	0.33
38	Shovel gravel or stone from flat car into car or cart below	cu. ft.	0.69	50	1.03	0.48
39	*Dump sand for 4-bag batch from bin above into measuring car	batch	0.06*	50	0.09*	0.04*
40	*Dump gravel or stone for 4-bag batch from bin above into measuring car	batch	0.15*	50	0.22*	0.11*
41	*Get ready to start car, etc.	car	0.31*	50	0.46*	0.22*
42	*Push car on track per 100 feet, including return	car	1.56*	50	2.34*	1.09*
43	Push car 100 ft., including return (in time of one man) (See p. 390)	cu. ft.	0.17	50	0.26	0.12
44	*Dump dry material for 4-bag batch from car to hopper or mixer†	cu. yd.	0.07*	50	0.10*	0.05*
	DERRICK WORK (See p. 392)					
45	Shovel sand to bucket	cu. ft.	0.31	50	0.46	0.22
46	Shovel gravel or stone to bucket	cu. ft.	0.42	50	0.63	0.29
47	*Time of shovelers while buckets are being changed	bucket	0.50*	50	0.75*	0.35*
48	*Hook bucket	bucket	0.25*	30	0.32*	0.17*
49	*Hoist bucket	bucket	0.21*	30	0.27*	0.15*
50	*Swing bucket 90 degrees one way	bucket	0.41*	30	0.53*	0.29*
51	*Swing bucket 180 degrees one way	bucket	0.73*	30	0.94*	0.51*
52	*Lower bucket	bucket	0.20*	30	0.26*	0.14*
53	*Place bucket (if necessary)	bucket	0.32*	30	0.42*	0.22*
54	*Dump	bucket	0.19*	30	0.24*	0.13*
55	*Unhook bucket	bucket	0.25*	30	0.32*	0.17*

*Multiply these times by number of men performing the operation.
†Sand and gravel or stone usually pushed in same car from bins to mixer.

TABLE 62. TIMES OF UNIT OPERATIONS—Continued

(See important note on p. 418, also p. 382)

No.	Item	Reference Unit	Average Men: Net Times min.	Average Men: Per Cent Delay	Average Men: Actual Times min.	Quick Men: Net Times min.
	HANDLING CEMENT (See p. 395)					
56	†Cut string on cement bag.........	bag	0.11†			
57	†Move bag about 2 feet.............	bag	0.08†			
58	Dump bag of cement into hopper..	bag	0.13	50	0.20	0.09
59	Lift bag of cement to shoulder....	bag	0.30	50	0.45	0.21
60	Carry bag of cement 100 feet including return........................	bag	1.18	30	1.53	0.83
61	Place bag of cement on pile........	bag	0.05	50	0.08	0.03
62	Unloading and handling cement (see Table 55, p. 316)............					
	CHARGING CONTINUOUS MIXER (See p. 395)					
	CHARGING GRAVITY MIXER (Operations vary with methods, and times may be selected from times of similar operations given in various parts of this table)					
	CHARGING BATCH MIXER BY LOADING TRAY OR HOPPER (See p. 397)					
63	*Raise tray........................	batch	0.21*	50	0.32*	0.15*
64	*Dump tray or hopper into mixer per one-bag batch....................	batch	0.11*	50	0.16*	0.08*
65	*Dump tray or hopper into mixer per 2-bag batch......................	batch	0.22*	50	0.33*	0.15*
66	*Dump tray or hopper into mixer per 3-bag batch......................	batch	0.33*	50	0.50*	0.23*
67	*Dump tray or hopper into mixer per 4-bag batch......................	batch	0.44*	50	0.66*	0.31*
68	*Dump tray or hopper into mixer per cubic yard........................	cu. yd.	0.57*	50	0.86*	0.40*
	CHARGING BATCH MIXER OR HOPPER BY BARROWS (See p. 397)					
69	*Dump barrow of sand..............	barrow	0.05*	50	0.08*	0.03*
70	*Turn barrow......................	barrow	0.10*	50	0.15*	0.07*
71	*Dump barrow of stone............	barrow	0.08*	50	0.12*	0.06*
72	*Turn barrow......................	barrow	0.10*	50	0.15*	0.07*
73	*Dump bag of cement..............	bag	0.13*	50	0.20*	0.09*
	MIXING IN BATCH MIXER (See p. 398)					
74	*Mix and wet......................	batch	0.70*	50	1.05*	0.49*
	MIXING IN CONTINUOUS MIXER (See p. 398) (Based on time of gang charging)					
	MIXING IN GRAVITY MIXER (See p. 398) (Based on time of gang charging)					

*Multiply these times by number of men performing the operation.
†Item not often used because done while mixing.

TABLE 62. TIMES OF UNIT OPERATIONS—Continued

(See important note on p. 418, also p. 382)

No.	Item	Reference Unit	Average Men: Net Times min.	Average Men: Per Cent Delay	Average Men: Actual Times min.	Quick Men: Net Times min.
	DISCHARGING BATCH MIXER (See p. 399 and for machinery costs, p. 342)					
75	*Tip mixer or spout	batch	0.12*	50	0.18*	0.08*
76	*Dump at one operation one-bag batch (5.2 cubic feet)	batch	0.09*	50	0.14*	0.06*
77	*Dump at one operation 2-bag batch (10.4 cubic feet)	batch	0.18*	50	0.27*	0.13*
78	*Dump at one operation 3-bag batch (15.6 cubic feet)	batch	0.27*	50	0.40*	0.19*
79	*Dump at one operation 4-bag batch (20.8 cubic feet)	batch	0.36*	50	0.54*	0.25*
80	*Dump at one operation per cu. yd.	cu. yd.	0.46*	50	0.69*	0.32*
81	*Tip back	batch	0.12*	50	0.18*	0.08*
82	*Discharge into barrows of 1.3 cubic feet capacity‡	cu. yd.	5.08*	50	7.62*	3.55*
83	*Discharge into 2-wheel hand carts of 4.5 cubic feet capacity‡	cu. yd.	1.46*	50	2.19*	1.02*
	HOISTING CONCRETE IN VERTICAL HOIST† (See p. 400) (Do not use in cost computations)					
84	*Fill bucket with concrete from mixer	cu. yd.	0.70*	30	0.91*	0.49*
85	*Hoist bucket per 10 feet of height	batch	0.08*	30	0.10*	0.06*
86	*Dump into hopper	cu. yd.	0.66*	30	0.86*	0.46*
87	*Lower bucket per 10 feet of height	batch	0.03*	30	0.04*	0.02*
	WHEELING CONCRETE IN BARROWS OF 1.3 CUBIC FEET CAPACITY‡ (See p. 403)					
88	Place barrow at mixer	barrow	0.16	40	0.23	0.11
89	Fill barrow of 1.3 cubic feet	barrow	0.08	40	0.11	0.06
90	Wheel 100 feet one way	barrow	0.48	10	0.53	0.34
91	Dump	barrow	0.20	40	0.28	0.14
92	Turn empty barrow	barrow	0.06	40	0.08	0.04
93	Place barrow under hopper (may be substituted for Item 88)	barrow	0.10	40	0.14	0.07
94	Fill barrow from hopper (may be substituted for Item 89)	barrow	0.06	40	0.08	0.04
95	Fill barrow from mixer, including placing	cu. yd.	5.08	40	7.11	3.55

*Multiply these times by number of men performing the operation.

†The different items come under mixer gang and need only be taken in account when they limit capacity of mixer.

‡Barrow capacities are based on average volume of wet concrete carried. Times include changing barrows and tipping mixer.

TABLE 62. TIMES OF UNIT OPERATIONS—Continued

(See important note on p. 418, also p. 382)

No.	Item	Reference Unit	Average Men: Net Times min.	Average Men: Per Cent Delay	Average Men: Actual Times min.	Quick Men: Net Times min.
96	Fill barrow from hopper, including placing	cu. yd.	3.32	40	4.65	2.32
97	Wheel per 100 feet including return	cu. yd.	20.00	10	22.00	14.00
98	Dump	cu. yd.	4.20	40	5.88	2.94
99	Turn empty barrow	cu. yd.	1.25	40	1.75	0.88
	WHEELING CONCRETE IN 2-WHEEL HAND CARTS OF 4.5 CUBIC FEET CAPACITY (See p. 403)					
100	Place cart at mixer	cart	0.08	40	0.11	0.06
101	Fill cart of 4.5 cubic feet	cart	0.16	40	0.22	0.11
102	Turn ready to wheel	cart	0.07	40	0.10	0.49
103	Wheel 100 feet one way	cart	0.48	10	0.53	0.34
104	Dump	cart	0.20	40	0.28	0.14
105	Turn empty cart	cart	0.04	40	0.06	0.03
106	Place cart under hopper (may be substituted for Item 100)	cart	0.08	40	0.11	0.06
107	Fill cart from hopper (may be substituted for Item 101)	cart	0.13	40	0.18	0.09
108	Fill cart from mixer, including placing and turning	cu. yd.	1.86	40	2.61	1.30
109	Fill cart from hopper, including placing and turning	cu. yd.	1.68	40	2.35	1.18
110	Wheel per 100 feet, including return.	cu. yd.	5.75	10	6.33	4.02
111	Dump	cu. yd.	1.20	40	1.68	0.84
112	Turn empty cart	cu. yd.	0.24	40	0.34	0.17
	HANDLING CONCRETE IN CARS ON TRACK, PER CAR (See p. 407)					
113	*Fill car from mixer (4-bag batch)	car	0.60*	40	0.84*	0.42*
114	*Get ready to start	car	0.31*	40	0.43*	0.22*
115	*Push car on track per 100 feet including return	car	0.78*	40	1.09*	0.55*
116	*Dump	car	0.55*	40	0.77*	0.39*
	HANDLING CONCRETE IN CARS HOLDING ONE 4-BAG BATCH, ON TRACK (See p. 407)					
117	Fill car	cu. yd.	1.80	40	2.52	1.26
118	Get ready to start	cu. yd.	0.93	40	1.31	0.65
119	Push car on track per 100 feet including return	cu. yd.	2.34	40	3.28	1.64
120	Dump	cu. yd.	1.65	40	2.31	1.15
121	Extra work placing concrete when cars are used				10.00	

*Multiply these times by number of men performing the operation.

TABLE 62. TIMES OF UNIT OPERATIONS—Continued

(See important note on p. 418, also p. 382)

No.	Item	Reference Unit	Average Men: Net Times min.	Average Men: Per Cent Delay	Average Men: Actual Times min.	Quick Men: Net Times min.
	HANDLING CONCRETE IN PAILS, PER PAIL (See p. 407)					
122	Fill pail	pail	0.47	30	0.61	0.33
123	Carry pail per 100 feet and return	pail	0.92	30	1.20	0.64
124	Hoist pail per 10-foot lift, actual time hoisting with single block	pail	0.13	30	0.17	0.09
125	Dump	pail	0.28	30	0.36	0.20
126	Lower pail per 10 feet	pail	0.05	30	0.07	0.04
	HANDLING CONCRETE IN 0.3 CU. FT. PAILS, PER CU. YD. (See p. 407)					
127	*Fill pails, hoist 10 feet and dump	cu. yd.	134.1	30	174.4	93.9
128	Carry pails 100 feet including return	cu. yd.	82.8	30	107.6	58.0
129	Hoist pails each additional 10 feet	cu. yd.	32.4	30	42.1	22.7
	LIFTING CONCRETE BY PASSING IN 0.3 CU. FT. PAILS FROM MAN TO MAN (See p. 407)					
130	Fill pail and pass 10 feet of height	pail	1.06	30	1.38	0.74
131	Carry pail 100 feet, including return	pail	0.92	30	1.20	0.64
132	Fill pails and pass 10 feet of height	cu. yd.	95.4	30	124.0	66.8
133	Carry pails 100 feet including return	cu. yd.	82.8	30	107.6	58.0
	SHOVELING CONCRETE					
134	Shovel to barrow from floor	cu. yd.	15.0	30	19.5	10.5
135	Shovel to carts or cars from floor	cu. yd.	20.6	30	26.8	14.4
136	Shovel to hole in floor from floor or tray	cu. yd.	24.9	30	32.4	17.4
137	Shovel to curtain wall from barrow or tray	cu. yd.	30.2	30	39.3	21.1
138	Hoe from hopper	cu. yd.	16.2	30	21.1	11.3
139	Change place of barrow	barrow	0.24	30	0.31	0.17
140	Change place of barrows, capacity 1.3 cubic feet	cu. yd.	5.0	30	6.5	3.50
141	Clean floor and change location, in filling curtain wall	cu. yd.	1.2	30	1.5	0.84
	PLACING CONCRETE (See p. 409)					
142	Level and tamp concrete, plastic consistency	cu. yd.	40.7	30	53.0	28.5
143	Level and tamp concrete, wet consistency	cu. yd.	25.4	30	33.0	17.8
144	Move section of run 11 feet in length	cu. yd.	2.20	30	2.86	1.5

* This includes time of man at hoist or 0.53 minutes per pail = 50.3 minutes per cubic yard.

TABLE 63. AVERAGE TIMES AND OUTPUTS PER BATCH OF CONCRETE FOR 4-BAG BATCH MIXERS (See p. 410)

Proportions 1:2:4, have 4 bags cement to 7.6 cu. ft. sand to 15.2 cu. ft. stone.
Proportions 1:2½:5, have 4 bags cement to 9.5 cu. ft. sand to 19 cu. ft. stone.
Other proportions of mix may be closely estimated from these values.

NET TIMES apply to continuous work with no allowance for rest or other stops.

ACTUAL TIMES include allowance for rest and delays. When computing costs, add allowance for superintendence, overhead charges, etc. (see p. 225).

AVERAGE MEN apply to the men and conditions on an ordinary contract job.

QUICK MEN apply to men working fast under exceptionally good contract conditions but not to piece-work.

The same per cent of delay has been used for average men and for quick men. For task-work, take net times of quick men from Table 62 and allow a per cent for delays, depending upon the conditions (see p. 410).

All values given in this table are labor values and do not include machinery.
Times are expressed as times per gang, i. e., as the time of the mixer.
Gang may consist of 4 laborers and 1 engineman.
When figuring costs take engineman equal two laborers.

Item Numbers from Table 62	Items from Table 62	1:2:4 Concrete			1:2½:5 Concrete		
		Net Times	Actual Times		Net Times	Actual Times	
		Average Men	Average Men	Quick Men	Average Men	Average Men	Quick Men
I CHARGE BY LOADING TRAY, DUMP INTO HOPPER OR CAR							
		min.	min.	min.	min.	min.	min.
63	Raise tray	0.21	0.32	0.22	0.21	0.32	0.22
67	Charge mixer	0.36	0.55	0.38	0.44	0.66	0.46
74	Mix and wet	0.70	1.05	0.74	0.70	1.05	0.74
75–79–81	Dump mixer	0.53	0.80	0.57	0.60	0.90	0.63
Time mixing one batch		1.80	2.72	1.91	1.95	2.93	2.05
Batches per hour			22.05	31.41		20.47	29.30
Quantity in cubic yards per hour			14.05	20.03		15.77	22.55
II CHARGE BY BARROWS, DUMP INTO HOPPER OR CAR							
73	Dump cement 4 bags	0.52	0.80	0.56	0.52	0.80	0.56
69–70	Dump sand 3 barrows	0.45	0.69	0.45	0.45	0.69	0.45
71–72	*Dump stone 5 barrows	0.90	1.35	0.90	1.08	1.62	1.08
74	Mix and wet	0.70	1.05	0.74	0.70	1.05	0.74
75–79–81	Dump mixer	0.53	0.80	0.57	0.60	0.90	0.63
Time mixing one batch		3.10	4.69	3.22	3.35	5.06	3.46
Batches per hour			12.79	18.63		11.85	17.30
Quantity in cubic yards per hour			8.15	11.86		9.13	13.32

*For 1:2½:5 mixture, use 6 barrows of stone.

TABLE 63. AVERAGE TIMES AND OUTPUTS PER 4-BAG BATCH OF CONCRETE—Continued

(See important note on p. 425, also p. 410.)

Item Numbers from Table 62	Items From Table 62	1:2:4 Concrete			1:2½:5 Concrete		
		Net Times	Actual Times		Net Times	Actual Times	
		Average Men	Average Men	Quick Men	Average Men	Average Men	Quick Men
III CHARGE FROM HOPPER. DUMP INTO HOPPER OR CAR							
		min.	min.	min.	min.	min.	min.
67	Dump hopper into mixer..	0.36	0.55	0.38	0.44	0.66	0.46
74	Mix and wet..............	0.70	1.05	0.74	0.70	1.05	0.74
75–79–81	Dump mixer..............	0.53	0.80	0.57	0.60	0.90	0.63
Time mixing one batch		1.59	2.40	1.69	1.74	2.61	1.83
Batches per hour			25.00	35.50		23.00	32.80
Quantity in cubic yards per hour			15.93	22.60		17.72	25.25
IV CHARGE BY LOADING TRAY. DISCHARGE INTO BARROWS							
63	Raise tray................	0.21	0.32	0.22	0.21	0.32	0.22
67	Charge mixer............	0.36	0.55	0.38	0.44	0.66	0.46
74	Mix and wet..............	0.70	1.05	0.74	0.70	1.05	0.74
82	Discharge batch into barrows....................	3.23	4.85	3.40	3.91	5.87	4.11
Time mixing one batch		4.50	6.77	4.74	5.26	7.90	5.53
Batches per hour			8.86	12.68		7.60	10.85
Quantity in cubic yards per hour			5.65	8.09		5.86	8.36
V CHARGE BY BARROWS. DISCHARGE INTO BARROWS							
73	Dump cement 4 bags......	0.52	0.80	0.56	0.52	0.80	0.56
69–70	Dump sand 3 barrows.....	0.45	0.69	0.45	0.45	0.69	0.45
71–72	*Dump stone 5 barrows....	0.90	1.35	0.90	1.08	1.62	1.08
74	Mix and wet..............	0.70	1.05	0.74	0.70	1.05	0.74
82	Discharge batch into barrows....................	3.23	4.85	3.40	3.91	5.87	4.11
Time mixing one batch		5.70	8.74	6.05	6.66	10.03	6.94
Batches per hour			6.87	9.92		5.98	8.65
Quantity in cubic yards per hour. ...			4.38	6.32		4.61	6.66

* For 1:2½:5 mixture, use 6 barrows of stone.

TABLE 63. AVERAGE TIMES AND OUTPUTS PER 4-BAG BATCH OF CONCRETE—Continued

(See important notes on p. 425, also p. 410)

Item Numbers from Table 62	Items From Table 62	1:2:4 Concrete			1:2½:5 Concrete		
		Net Times	Actual Times		Net Times	Actual Times	
		Average Men	Average Men	Quick Men	Average Men	Average Men	Quick Men
VI	**CHARGE FROM HOPPER. DISCHARGE INTO BARROWS**						
		min.	min.	min.	min.	min.	min.
67	Dump hopper into mixer..	0.36	0.55	0.38	0.44	0.66	0.46
74	Mix and wet..............	0.70	1.05	0.74	0.70	1.05	0.74
82	Discharge batch into barrows.....................	3.23	4.85	3.40	3.91	5.87	4.11
Time mixing one batch		4.29	6.45	4.52	5.05	7.58	5.31
Batches per hour			9.30	13.27		7.92	11.30
Quantity in cubic yards per hour			5.92	8.45		6.10	8.70
VII	**CHARGE BY BARROWS. DISCHARGE INTO 2-WHEEL HAND CARTS**						
73	Dump cement 4 bags......	0.52	0.80	0.56	0.52	0.80	0.56
69–70	Dump sand 3 barrows.....	0.45	0.69	0.45	0.45	0.69	0.45
71–72	*Dump stone 5 barrows....	0.90	1.35	0.90	1.08	1.62	1.08
74	Mix and wet..............	0.70	1.05	0.74	0.70	1.05	0.74
83	Discharge batch into 2-wheel hand carts.........	0.93	1.40	0.98	1.12	1.68	1.18
Time mixing one batch...............		3.50	5.29	3.63	3.87	5.84	4.01
Batches per hour.....................			11.34	16.52		10.27	14.96
Quantity in cubic yards per hour....			7.22	10.52		7.90	11.52
VIII	**CHARGE BY LOADING TRAY. DISCHARGE INTO 2-WHEEL HAND CARTS**						
63	Raise tray................	0.21	0.32	0.22	0.21	0.32	0.22
67	Charge mixer.............	0.36	0.55	0.38	0.44	0.66	0.46
74	Mix and wet..............	0.70	1.05	0.74	0.70	1.05	0.74
83	Discharge batch into 2-wheel hand carts.........	0.93	1.40	0.98	1.12	1.68	1.18
Time mixing one batch..............		2.20	3.32	2.32	2.47	3.71	2.60
Batches per hour.....................			18.07	25.85		16.16	23.09
Quantity in cubic yards per hour....			11.51	16.46		12.46	17.78

* For 1:2½:5 mixture, use 6 barrows of stone.

TABLE 63. AVERAGE TIMES AND OUTPUTS PER 4-BAG BATCH OF CONCRETE—Continued

(See important notes on p. 425, also p. 410)

Item Numbers from Table 62	Items From Table 62	1:2:4 Concrete			1:2½:5: Concrete		
		Net Times	Actual Times		Net Times	Actual Times	
		Average Men	Average Men	Quick Men	Average Men	Average Men	Quick Men
IX CHARGE FROM HOPPER. DISCHARGE INTO 2-WHEEL HAND CARTS							
		min.	min.	min.	min.	min.	min.
67	Dump hopper into mixer..	0.36	0.55	0.38	0.44	0.66	0.46
74	Mix and wet..............	0.70	1.05	0.74	0.70	1.05	0.74
83	Discharge batch into 2-wheel hand carts.........	0.93	1.40	0.98	1.12	1.68	1.18
Time mixing one batch...............		1.99	3.00	2.10	2.26	3.39	2.38
Batches per hour			20.00	28.55		17.70	25.20
Quantity in cubic yards per hour.....			12.74	18.19		13.63	19.42

TABLE 64. AVERAGE TIMES AND OUTPUTS PER 2-BAG BATCH OF CONCRETE FOR BATCH MIXER (See p. 410)

Proportions 1:2:4, have 2 bags cement to 3.8 cu. ft. sand to 7.6 cu. ft. stone.
Proportions 1:2½:5, have 2 bags cement to 4.75 cu. ft. sand to 9.5 cu. ft. stone.

(See important notes on p. 425)

Item Numbers from Table 62	Items From Table 62	1:2:4 Concrete			1:2½:5 Concrete		
		Net Times	Actual Times		Net Times	Actual Times	
		Average Men	Average Men	Quick Men	Average Men	Average Men	Quick Men
I CHARGE BY LOADING TRAY. DUMP INTO HOPPER OR CAR							
		min.	min.	min.	min.	min.	min.
63	Raise tray	0.21	0.32	0.22	0.21	0.32	0.22
65	Charge mixer.............	0.18	0.27	0.19	0.22	0.33	0.23
74	Mix and wet..............	0.70	1.05	0.74	0.70	1.05	0.74
75–77–81	Dump mixer...............	0.39	0.58	0.41	0.42	0.63	0.44
Time mixing one batch...............		1.48	2.22	1.56	1.55	2.33	1.63
Batches per hour......................			27.00	38.50		25.70	36.80
Quantity in cubic yards per hour....			8.60	12.25		9.87	14.20

TABLE 64. AVERAGE TIMES AND OUTPUTS PER 2-BAG BATCH OF CONCRETE—Continued

(See important notes on pp. 425 and 428, also p. 410)

Item Numbers from Table 62	Items From Table 62	1:2:4 Concrete			1:2½:5 Concrete		
		Net Times	Actual Times		Net Times	Actual Times	
		Average Men	Average Men	Quick Men	Average Men	Average Men	Quick Men
II CHARGE BY BARROWS. DUMP INTO HOPPER OR CAR							
73	Dump cement 2 bags......	0.26	0.40	0.28	0.26	0.40	0.28
69–70	Dump sand 2 barrows.....	0.30	0.46	0.30	0.30	0.46	0.30
71–72	Dump stone 3 barrows....	0.54	0.81	0.54	0.54	0.81	0.54
74	Mix and wet..............	0.70	1.05	0.74	0.70	1.05	0.74
75–77–81	Dump mixer..............	0.39	0.58	0.41	0.42	0.63	0.44
Time mixing one batch		2.19	3.30	2.27	2.22	3.35	2.30
Batches per hour			18.18	26.45		17.90	26.10
Quantity in cubic yards per hour			5.79	8.43		6.88	10.05
III CHARGE FROM HOPPER. DUMP INTO HOPPER OR CAR							
		min.	min.	min.	min.	min.	min.
65	Dump hopper into mixer..	0.18	0.27	0.19	0.22	0.33	0.23
74	Mix and wet..............	0.70	1.05	0.74	0.70	1.05	0.74
75–77–81	Dump mixer..............	0.39	0.58	0.41	0.42	0.63	0.44
Time mixing one batch		1.27	1.90	1.34	1.34	2.01	1.41
Batches per hour			31.60	44.80		29.85	42.55
Quantity in cubic yards per hour			10.10	14.26		11.50	16.39
IV CHARGE BY LOADING TRAY. DISCHARGE INTO BARROWS							
63	Raise tray................	0.21	0.32	0.22	0.21	0.32	0.22
65	Charge mixer.............	0.18	0.27	0.19	0.22	0.33	0.23
74	Mix and wet..............	0.70	1.05	0.74	0.70	1.05	0.74
82	Discharge batch into barrows..................	1.62	2.43	1.70	1.96	2.94	2.06
Time mixing one batch		2.71	4.07	2.85	3.09	4.64	3.25
Batches per hour			14.74	21.05		12.93	18.46
Quantity in cubic yards per hour			4.69	6.71		4.99	7.12

TABLE 64. AVERAGE TIMES AND OUTPUTS PER 2-BAG BATCH OF CONCRETE—Continued

(See important notes on pp. 425 and 428, also p. 410)

Item Numbers from Table 62	Items From Table 62	1:2:4 Concrete			1:2½:5 Concrete		
		Net Times	Actual Times		Net Times	Actual Times	
		Average Men	Average Men	Quick Men	Average Men	Average Men	Quick Men
V	CHARGE BY BARROWS. DISCHARGE INTO BARROWS						
73	Dump cement 2 bags......	0.26	0.40	0.28	0.26	0.40	0.28
69–70	Dump sand 2 barrows.....	0.30	0.46	0.30	0.30	0.46	0.30
71–72	Dump stone 3 barrows....	0.54	0.81	0.54	0.54	0.81	0.54
74	Mix and wet..............	0.70	1.05	0.74	0.70	1.05	0.74
82	Discharge batch into barrows....................	1.62	2.43	1.70	.96	2.94	2.06
	Time mixing one batch	3.42	5.15	3.56	3.76	5.66	3.92
	Batches per hour		11.65	16.85		10.60	15.30
	Quantity in cubic yards per hour...		3.71	5.36		4.09	5.90
VI	CHARGE FROM HOPPER. DISCHARGE INTO BARROWS						
		min.	min.	min.	min.	min.	min.
65	Dump hopper into mixer..	0.18	0.27	0.19	0.22	0.33	0.23
74	Mix and wet..............	0.70	1.05	0.74	0.70	1.05	0.74
82	Discharge batch into barrows	1.62	2.43	1.70	1.96	2.94	2.06
	Time mixing one batch	2.50	3.75	2.63	2.88	4.32	3.03
	Batches per hour		16.00	22.81		13.89	19.80
	Quantity in cubic yards per hour		5.10	7.27		5.35	7.63
VII	CHARGE BY BARROWS. DISCHARGE INTO 2-WHEEL HAND CARTS						
73	Dump cement 2 bags......	0.26	0.40	0.28	0.26	0.40	0.28
69–70	Dump sand 2 barrows.....	0.30	0.46	0.30	0.30	0.46	0.30
71–72	Dump stone 3 barrows....	0.54	0.81	0.54	0.54	0.81	0.54
74	Mix and wet..............	0.70	1.05	0.74	0.70	1.05	0.74
83	Discharge batch into 2-wheel hand carts.........	0.47	0.70	0.49	0.56	0.84	0.59
	Time mixing one batch	2.27	3.42	2.35	2.36	3.56	2.45
	Batches per hour		17.55	25.53		16.85	24.50
	Quantity in cubic yards per hour. ...		5.59	8.14		6.50	9.44

TABLE 64. AVERAGE TIMES AND OUTPUTS PER 2-BAG BATCH OF CONCRETE—Continued

(See important notes on pp. 425 and 428, also p. 410)

Item Numbers from Table 62	Items From Table 62	1:2:4 Concrete			1:2½:5 Concrete		
		Net Times	Actual Times		Net Times	Actual Times	
		Average Men	Average Men	Quick Men	Average Men	Average Men	Quick Men
VIII CHARGE BY LOADING TRAY. DISCHARGE INTO 2-WHEEL HAND CARTS							
63	Raise tray	0.21	0.32	0.22	0.21	0.32	0.22
65	Charge mixer	0.18	0.27	0.19	0.22	0.33	0.23
74	Mix and wet	0.70	1.05	0.74	0.70	1.05	0.74
83	Discharge batch into 2-wheel hand carts	0.47	0.70	0.49	0.56	0.84	0.59
Time mixing one batch		1.56	2.34	1.64	1.69	2.54	1.78
Batches per hour			25.63	36.60		23.61	33.70
Quantity in cubic yards per hour			8.14	11.65		9.10	12.98
IX CHARGE FROM HOPPER. DISCHARGE INTO 2-WHEEL HAND CARTS							
		min.	min.	min.	min.	min.	min.
65	Dump hopper into mixer	0.18	0.27	0.19	0.22	0.33	0.23
74	Mix and wet	0.70	1.05	0.74	0.70	1.05	0.74
83	Discharge batch into 2-wheel hand carts	0.47	0.70	0.49	0.56	0.84	0.59
Time mixing one batch		1.35	2.02	1.42	1.48	2.22	1.56
Batches per hour			29.70	42.25		27.02	38.45
Quantity in cubic yards per hour			9.35	13.45		10.40	14.81

TABLE 65. COST PER CUBIC YARD OF MIXING CONCRETE WITH 4-BAG BATCH MIXER (See p. 412)

Includes only cost of labor of mixer men and machinery charge.

Costs of labor include 15 per cent for foreman and 15 per cent extra for superintendence and overhead charges but do not include profits.

For times and costs of men supplying materials and transporting concrete, see Table 67, page 434. For other plant costs see page 342.

Based on a mixer gang of 4 laborers and 1 engineman.

Pay of engineman twice that of laborer.

Items	Charge by Loading Tray. Dump into Hopper or Car	Charge by Barrows. Dump into Hopper or Car	Charge from Hopper. Dump into Hopper or Car	Charge by Loading Tray. Dump into Barrows	Charge by Barrows. Dump into Barrows	Charge from Hopper. Dump into Barrows	Charge by Barrows. Dump into 2-Wheel Hand Carts	Charge by Loading Tray. Dump into 2-Wheel Hand Carts	Charge from Hopper. Dump into 2-Wheel Hand Carts
	I	II	III	IV	V	VI	VII	VIII	IX
1:2:4 CONCRETE									
Output per hour	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.
Average men	14.05	8.15	15.93	5.65	4.38	5.92	7.22	11.51	12.74
Quick men	20.03	11.86	22.60	8.09	6.32	8.45	10.52	16.46	18.19
Time per gang	min.	min.	min.	min.	min.	min.	min.	min.	min.
Average men	4.27	7.36	3.77	10.61	13.70	10.14	8.31	5.21	4.71
Quick men	2.99	5.05	2.65	7.42	9.50	7.10	5.70	3.64	3.30
Cost of fuel* and machinery	$	$	$	$	$	$	$	$	$
Average men	0.10	0.14	0.10	0.19	0.24	0.19	0.16	0.11	0.11
Quick men	0.08	0.11	0.08	0.14	0.18	0.14	0.12	0.09	0.09
Cost of labor at 20¢ per hr.									
Average men	0.11	0.19	0.10	0.28	0.36	0.27	0.22	0.14	0.12
Quick men	0.08	0.13	0.07	0.20	0.25	0.19	0.15	0.10	0.09
Total cost of mixing									
Average men	**0.21**	**0.33**	**0.20**	**0.47**	**0.60**	**0.46**	**0.38**	**0.25**	**0.23**
Quick men	0.16	0.24	0.15	0.34	0.43	0.33	0.27	0.19	0.18
1:2½:5 CONCRETE									
Output per hour	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.
Average men	15.77	9.13	17.72	5.86	4.61	6.10	7.90	12.46	13.63
Quick men	22.55	13.32	25.25	8.36	6.66	8.70	11.52	17.78	19.42
Time per gang	min.	min.	min.	min.	min.	min.	min.	min.	min.
Average men	3.81	6.57	3.39	10.23	13.01	9.85	7.60	4.81	4.40
Quick men	2.66	4.50	2.38	7.18	9.01	6.90	5.21	3.38	3.09
Cost of fuel* and machinery	$	$	$	$	$	$	$	$	$
Average men	0.09	0.13	0.09	0.19	0.23	0.18	0.15	0.10	0.10
Quick men	0.07	0.10	0.07	0.14	0.17	0.14	0.11	0.08	0.08
Cost of labor at 20¢ per hr.									
Average men	0.10	0.17	0.09	0.27	0.34	0.26	0.20	0.13	0.12
Quick men	0.07	0.12	0.06	0.19	0.24	0.18	0.14	0.09	0.08
Total cost of mixing									
Average men	**0.19**	**0.30**	**0.18**	**0.46**	**0.57**	**0.44**	**0.35**	**0.23**	**0.22**
Quick men	0.14	0.22	0.13	0.33	0.41	0.32	0.25	0.17	0.16

* Fuel is considered at a constant price of $0.03 per cubic yard of concrete.

TABLE 66. COST PER CUBIC YARD OF MIXING CONCRETE WITH 2-BAG BATCH MIXER (See p. 412)

Includes only cost of labor of mixer men and machinery charge.

Costs of labor include 15 per cent for foreman and 15 per cent extra for superintendence and overhead charges, but do not include profits. Labor 20¢ per hour.

For times and costs of men supplying materials and transporting concrete, see Table 67, page 434. For other plant costs see page 342.

Based on a mixer gang of 4 laborers and 1 engineman.

Pay of engineman twice that of laborer.

Items	Charge by Loading Tray. Dump into Hopper or Car	Charge by Barrows. Dump into Hopper or Car	Charge from Hopper. Dump into Hopper or Car	Charge by Loading Tray. Dump into Barrows	Charge by Barrows. Dump into Barrows	Charge from Hopper. Dump into Barrows	Charge by Barrows. Dump into 2-Wheel Hand Carts	Charge by Loading Tray. Dump into 2-Wheel Hand Carts	Charge from Hopper. Dump into 2-Wheel Hand Carts
	I	II	III	IV	V	VI	VII	VIII	IX
1:2:4 CONCRETE									
Output per hour	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.
Average men............	8.60	5.79	10.10	4.69	3.71	5.10	5.59	8.14	9.35
Quick men.............	12.25	8.43	14.26	6.71	5.36	7.27	8.14	11.65	13.45
Time per gang	min.	min.	min.	min.	min.	min.	min.	min.	min.
Average men............	6.98	10.36	5.94	12.79	16.17	11.76	10.73	7.35	6.42
Quick men.............	4.90	7.12	4.21	8.94	11.19	8.26	7.38	5.15	4.46
Cost of fuel* and machinery	$	$	$	$	$	$	$	$	$
Average men............	0.10	0.14	0.10	0.16	0.19	0.16	0.14	0.11	0.10
Quick men.............	0.08	0.10	0.08	0.12	0.14	0.12	0.11	0.08	0.08
Cost of labor at 20¢ per hr.									
Average men............	0.18	0.27	0.16	0.34	0.43	0.31	0.28	0.19	0.17
Quick men.............	0.13	0.19	0.11	0.24	0.30	0.22	0.20	0.14	0.12
Total cost of mixing									
Average men............	**0.28**	**0.41**	**0.26**	**0.50**	**0.62**	**0.47**	**0.42**	**0.30**	**0.27**
Quick men.............	0.21	0.29	0.19	0.36	0.44	0.34	0.31	0.22	0.20
1:2½:5 CONCRETE									
Output per hour	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.
Average men............	9.87	6.88	11.50	4.99	4.09	5.35	6.50	9.10	10.40
Quick men.............	14.20	10.05	16.39	7.12	5.90	7.63	9.44	12.98	14.81
Time per gang............	min.	min.	min.	min.	min.	min.	min.	min.	min.
Average men............	6.05	8.70	5.22	12.02	14.70	11.21	9.24	6.60	5.77
Quick men.............	4.23	5.97	3.66	8.43	10.16	7.86	6.36	4.62	4.05
Cost of fuel* and machinery	$	$	$	$	$	$	$	$	$
Average men............	0.09	0.12	0.09	0.15	0.18	0.15	0.12	0.10	0.09
Quick men.............	0.07	0.09	0.07	0.12	0.13	0.11	0.09	0.08	0.07
Cost of labor at 20¢ per hr.									
Average men............	0.16	0.23	0.14	0.32	0.39	0.30	0.24	0.17	0.15
Quick men.............	0.11	0.16	0.10	0.22	0.27	0.21	0.17	0.12	0.11
Total cost of mixing									
Average men............	**0.25**	**0.35**	**0.23**	**0.47**	**0.57**	**0.45**	**0.36**	**0.27**	**0.24**
Quick men.............	0.18	0.25	0.17	0.34	0.40	0.32	0.26	0.20	0.18

*Fuel is considered at a constant price of $0.03 per cubic yard of concrete.

TABLE 67. TIMES AND COSTS OF HANDLING RAW MATERIAL AND CONCRETE PER CUBIC YARD OF CONCRETE IN PLACE (See p. 413)

Based on material necessary for one cubic yard of 1:2½:5 Concrete; 5.2 bags of cement, 12.4 cubic feet of sand and 24.8 cubic feet of gravel or stone.

For other proportions, values may be corrected by ratio of quantities of each material per cubic yard.

All times and costs are per cubic yard of concrete in place not per cubic yard of raw materials. For time and costs per cubic yard of raw material see pages 261 to 267.

Costs of labor include 15 per cent for foreman and 15 per cent extra for superintendence and overhead charges, but do not include profit.

Labor 20¢ per hour.

Item Numbers from Table 62	Items from Table 62	Actual Time of One Man: Average Man	Actual Time of One Man: Quick Man	Cost of Labor 20¢ per Hour: Average Man	Cost of Labor 20¢ per Hour: Quick Man
I HANDLING SAND AND GRAVEL OR STONE WITH CARS OF ONE YARD CAPACITY ON TRACK					
		min.	min.	$	$
35–41–42–44	Load sand from platform, push 25 feet, dump and return......	12.49	8.75	$0.055	$0.039
36–41–42–44	Load gravel or stone from platform, push 25 feet, dump and return..........................	27.58	19.30	0.122	0.085
37–41–42–44	Load sand from flat car, push 25 feet, dump and return........	11.11	7.78	0.049	0.034
38–41–42–44	Load gravel or stone from flat car, push 25 feet, dump and return..	27.83	19.48	0.123	0.086
39–40–41–42–44	*Load sand and gravel or stone from bin, push 25 feet, dump and return.....................	6.12	4.29	0.027	0.019
42	Push car each additional 25 feet and return.....................	1.77	1.24	0.008	0.005
II HANDLING SAND AND GRAVEL OR STONE BY DERRICK WITH BUCKET† OF ONE YARD CAPACITY					
45 to 50, 52 to 55	Load bucket with sand, gravel or stone, hoist, swing 90° to place, lower, dump, and return.......	44.46	31.10	$0.196	$0.137

*Sand and gravel or stone are usually hauled from bins in same car.

†This bucket with a little heaping will hold necessary sand and gravel or stone for a 4-bag batch of 1:2½:5 concrete.

TABLE 67. TIMES AND COSTS OF HANDLING RAW MATERIAL AND CONCRETE PER CUBIC YARD OF CONCRETE IN PLACE—Continued.

See important notes page 434, also page 413

Item Numbers from Table 62	Items from Table 62	Actual Time of One Man		Cost of Labor 20¢ per Hour	
		Average Man	Quick Man	Average Man	Quick Man
III HANDLING SAND AND GRAVEL OR STONE WITH WHEELBARROWS* OF 3.0 CUBIC FEET CAPACITY					
		min.	min.	$	$
22 to 25	Load, wheel sand to mixer 50 feet distant, dump and return..	8.31	5.83	$0.037	$0.026
24	Wheel sand to mixer each additional 50 feet and return......	2.23	1.63	0.010	0.007
31 to 34	Load, wheel gravel or stone to mixer 50 feet distant, dump and return..........................	20.84	14.64	0.092	0.064
33	Wheel gravel or stone each additional 50 feet and return......	4.46	3.12	0.020	0.014
IV HANDLING CEMENT IN BAGS					
59–60–58	Carry cement 50 feet, dump and return..........................	7.38	5.17	$0.033	$0.023
60	Carry each additional 50 feet and return..........................	4.00	2.81	0.018	0.012
V HANDLING CONCRETE IN CARS OF ¾ CUBIC YARD CAPACITY ON TRACKS					
117 to 120	Fill car at mixer or hopper, push 50 feet, dump and return......	7.78	5.45	$0.034	$0.025
119	Push car each additional 50 feet and return....................	1.64	1.15	0.007	0.005
VI HANDLING CONCRETE IN 2-WHEEL HAND CARTS OF 4.5 CUBIC FEET CAPACITY					
108–110 to 112	Fill at mixer, wheel 50 feet, dump and return....................	7.78	5.45	$0.034	$0.025
109 to 112	Fill at hopper, wheel 50 feet, dump and return...............	7.53	5.27	0.033	0.023
110	Wheel each additional 50 feet and return....................	3.17	2.22	0.014	0.010

*Barrow times and costs assume that wheeler loads his own barrow. Values slightly increased if other men help load.

TABLE 67. TIMES AND COSTS OF HANDLING RAW MATERIAL AND CONCRETE PER CUBIC YARD OF CONCRETE IN PLACE—Continued

See important notes page 434, and also page 413

Item Numbers from Table 62	Items from Table 62	Actual Time of One Man		Cost of Labor 20¢ per Hour	
		Average Man	Quick Man	Average Man	Quick Man
VI HANDLING CONCRETE IN 2-WHEEL HAND CARTS OF 4.5 CUBIC FEET CAPACITY (Continued)					
		min.	min.	$	$
109 to 112–136	Fill at hopper, wheel 50 feet, dump, shovel into hole in floor and return	39.93	27.98	$0.176	$0.123
109–110–137–112	Fill at hopper, wheel 50 feet, shovel into curtain wall from barrow and return	45.15	31.60	0.199	0.139
VII HANDLING CONCRETE IN ORDINARY BARROWS* OF 1.3 CUBIC FEET CAPACITY					
95–97–98–99	Fill at mixer, wheel 50 feet, dump and return	25.74	18.00	$0.114	$0.080
96 to 99	Fill at hopper, wheel 50 feet, dump and return	23.28	16.28	0.103	0.072
97	Wheel each additional 50 feet and return	11.00	7.70	0.048	0.034
VIII HANDLING CONCRETE IN PAILS OF 0.3 CUBIC FEET CAPACITY					
122 to 126	Fill, carry 50 feet, hoist 12 feet, dump, lower, and return	172.80	121.50	$0.762	$0.535
129	Hoist and lower each additional 12 feet	31.30	21.90	0.138	0.097
IX PLACING CONCRETE					
143	Level, tamp, and wet concrete	33.00	23.10	$0.145	$0.102
	To be added when concrete is handled in cars	10.00	7.00	0.044	0.031

*Barrow times and costs assume that wheeler loads his own barrow. Values slightly increased if other men help load.

TABLE 68. APPROXIMATE AVERAGE COST OF MACHINE MIXING FOR GIVEN OUTPUTS PER HOUR OF BATCH MIXERS (See p. 415)

1:2½:5 CONCRETE

Gang so arranged that proper number of men to handle the materials in given time for given output is used.

Raw material hauled 50 feet by barrows, dumped in tray and concrete wheeled 50 feet in barrows from hopper.

Costs are based on actual times of average man. Costs include 15 per cent for foreman and 15 per cent extra for superintendence, overhead charges, etc., but do not include profit.

Labor at 20¢ per hour.

Items	2-Bag Batch Mixer			4-Bag Batch Mixer					
	Output in Cubic Yards Per Hour								
	4	6	8	4	6	8	10	12	14
	$	$	$	$	$	$	$	$	$
Wheel sand	0.04	0.04	0.03	0.04	0.04	0.03	0.03	0.04	0.03
Wheel stone	0.09	0.09	0.10	0.09	0.09	0.10	0.11	0.09	0.09
Mix and wet	0.40	0.26	0.20	0.40	0.26	0.20	0.16	0.13	0.11
Wheel concrete 50 feet	0.13	0.13	0.10	0.13	0.13	0.10	0.11	0.11	0.12
Level and tamp concrete	0.13	0.13	0.17	0.13	0.13	0.17	0.16	0.15	0.15
Total labor	0.79	0.65	0.60	0.79	0.65	0.60	0.57	0.52	0.50
Plant Cost—Machinery	0.15	0.10	0.08	0.23	0.15	0.12	0.09	0.08	0.07
Plant Cost—Tools, Runs, etc.	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Fuel	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Total cost per cu. yd.	1.03	0.84	0.77	1.11	0.89	0.81	0.75	0.69	0.66

TABLE 69. COST OF MACHINE MIXING WITH A 4-BAG BATCH MIXER PER CUBIC YARD OF CONCRETE IN PLACE (See p. 416)

PROPORTIONS 1:2½:5

Costs include wheeling material about 50 feet to mixer, charging mixer, mixing, machinery and plant charge, wheeling concrete, placing and tamping, also include 15 per cent for foreman and 15 per cent extra for superintendence, overhead charges, etc., but do not include profit.

Labor at 20¢ per hour.

MIXER CHARGED BY LOADING TRAY

Item	Concrete Discharged into Barrows		Concrete Discharged into 2-Wheel Hand Carts		Concrete Discharged into Cars or Hopper		Concrete Discharged into Hopper and Barrows		Concrete Discharged into Hopper and 2-Wheel Hand Carts	
	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men
	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.
Average output in continuous operation	5.9	8.4	12.5	17.8	15.8	22.6	15.8	22.6	15.8	22.6
	$	$	$	$	$	$	$	$	$	$
Wheel sand	0.04	0.03	0.04	0.03	0.04	0.03	0.04	0.03	0.04	0.03
Wheel gravel or stone	0.09	0.06	0.09	0.06	0.09	0.06	0.09	0.06	0.09	0.06
Mix and wet	0.27	0.19	0.13	0.09	0.10	0.07	0.10	0.07	0.10	0.07
Wheel concrete 50 ft.	0.11	0.08	0.03	0.02	0.03	0.02	0.10	0.07	0.03	0.02
Level and tamp concrete	0.15	0.10	0.15	0.10	0.19	0.13	0.15	0.10	0.15	0.10
Total cost of labor	0.66	0.46	0.44	0.30	0.45	0.31	0.48	0.33	0.41	0.28
Plant cost—Machinery*	0.16	0.11	0.07	0.05	0.06	0.04	0.06	0.04	0.06	0.04
Plant cost—Carts, tools, etc.†	0.09	0.09	0.15	0.15	0.18	0.18	0.09	0.09	0.15	0.15
Fuel‡	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Total cost per cubic yard	0.94	0.69	0.67	0.53	0.72	0.56	0.66	0.49	0.65	0.50
Wheel concrete 50 ft. additional	0.05	0.03	0.01	0.01	0.01	0.01	0.05	0.03	0.01	0.01

*Based on a yearly cost of $734 (see page 342).

†Based on a cost of tools, runs, etc., as given on pages 367 to 370.

‡Based on a cost of fuel of $0.03 per cubic yard of concrete.

Note.—Loading tray is filled by wheelbarrows.

TABLE 69. COST OF MACHINE MIXING WITH A 4-BAG BATCH MIXER PER CUBIC YARD OF CONCRETE IN PLACE—Continued (See p. 416)

PROPORTIONS 1:2½:5

Costs include wheeling material about 50 feet to mixer, charging mixer, mixing, machinery and plant charge, wheeling concrete, placing and tamping, also include 15 per cent for foreman and 15 per cent extra for superintendence, overhead charges, etc., but do not include profit.

Labor at 20¢ per hour.

Item	Concrete Discharged into Barrows		Concrete Discharged Into 2-Wheel Hand Carts		Concrete Discharged into Cars or Hopper		Concrete Discharged into Hopper and Barrows		Concrete Discharged into Hopper and 2-Wheel Hand Carts	
	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men
MIXER CHARGED BY BARROWS										
	cu. yd.	cu. yd.	cu. yd.	cu. yd.	cu. yd.	cu. yd.	cu. yd.	cu. yd.	cu. yd.	cu. yd.
Average output in continuous operation	4.6	6.7	7.9	11.5	9.1	13.3	9.1	13.3	9.1	13.3
	$	$	$	$	$	$	$	$	$	$
Wheel sand	0.04	0.03	0.04	0.03	0.04	0.03	0.04	0.03	0.04	0.03
Wheel gravel or stone	0.09	0.06	0.09	0.06	0.09	0.06	0.09	0.06	0.09	0.06
Mix and wet	0.34	0.24	0.20	0.14	0.17	0.12	0.17	0.12	0.17	0.12
Wheel concrete 50 ft.	0.11	0.08	0.03	0.02	0.03	0.02	0.10	0.07	0.03	0.02
Level and tamp concrete	0.15	0.10	0.15	0.10	0.19	0.13	0.15	0.10	0.15	0.10
Total cost of labor	0.73	0.51	0.51	0.35	0.52	0.36	0.55	0.38	0.48	0.33
Plant cost—Machinery*	0.20	0.14	0.12	0.08	0.10	0.07	0.10	0.07	0.10	0.07
Plant cost—Carts, tools, etc.†	0.09	0.09	0.15	0.15	0.18	0.18	0.09	0.09	0.15	0.15
Fuel‡	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Total cost per cubic yard	**1.05**	**0.77**	**0.81**	**0.61**	**0.83**	**0.64**	**0.77**	**0.57**	**0.76**	**0.58**
Wheel concrete 50 ft. additional	0.05	0.03	0.01	0.01	0.01	0.01	0.05	0.03	0.01	0.01

*Based on a yearly cost of $734 (see p. 342).

†Based on a cost of tools, runs, etc. as given on pages 367 to 370.

‡Based on a cost of fuel of $0.03 per cubic yard of concrete.

TABLE 69. COST OF MACHINE MIXING WITH A 4-BAG BATCH MIXER PER CUBIC YARD OF CONCRETE IN PLACE—Continued (See p. 416)

PROPORTIONS 1: $2\frac{1}{2}$: 5

Costs include wheeling material about 50 feet to mixer, charging mixer, mixing, machinery and plant charge, wheeling concrete, placing and tamping, also include 15 per cent for foreman and 15 per cent extra for superintendence, overhead charges, etc., but do not include profit.

Labor at 20¢ per hour.

MIXER CHARGED FROM HOPPER OR CAR

Item	Concrete Discharged into Barrows		Concrete Discharged into 2-Wheel Hand Carts		Concrete Discharged into Cars or Hopper		Concrete Discharged into Hopper and Barrows		Concrete Discharged into Hopper and 2-Wheel Hand Carts	
	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men
	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.
Average output in continuous operation	6.1	8.7	13.6	19.4	17.7	25.3	17.7	25.3	17.7	25.3
	$	$	$	$	$	$	$	$	$	$
Sand and gravel or stone hauled in cars.	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Mix and wet..........	0.26	0.18	0.12	0.08	0.09	0.06	0.09	0.06	0.09	0.06
Wheel concrete 50 ft.	0.11	0.08	0.03	0.02	0.03	0.02	0.10	0.07	0.03	0.02
Level and tamp concrete................	0.15	0.10	0.15	0.10	0.19	0.13	0.15	0.10	0.15	0.10
Total cost of labor.....	0.54	0.38	0.32	0.22	0.33	0.23	0.36	0.25	0.29	0.20
Plant cost—Machinery*................	0.15	0.11	0.07	0.05	0.05	0.04	0.05	0.04	0.05	0.04
Plant cost—Carts, tools†, etc...........	0.18	0.18	0.24	0.24	0.27	0.27	0.18	0.18	0.24	0.24
Fuel‡................	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Total cost per cubic yard................	0.90	0.70	0.66	0.54	0.68	0.57	0.62	0.50	0.61	0.51
Wheel concrete 50 ft. additional...........	0.05	0.03	0.01	0.01	0.01	0.01	0.05	0.03	0.01	0.01

* Based on a yearly cost of $734 (see p. 342).

† Based on a cost of tools, runs, etc., as given on pages 367 to 370.

‡ Based on a cost of fuel of $0.03 per cubic yard of concrete.

NOTE.—Hopper filled by cars.

TABLE 70. COST OF MACHINE MIXING WITH A 2-BAG BATCH MIXER PER CUBIC YARD OF CONCRETE IN PLACE (See p. 416)

PROPORTIONS 1:2½:5

Costs include wheeling material about 50 feet to mixer, charging mixer, mixing, machinery and plant charge, wheeling concrete, leveling and tamping, also include 15 per cent for foreman and 15 per cent extra for superintendence, overhead charges, etc., but do not include profit.

Labor 20¢ per hour.

MIXER CHARGED BY LOADING TRAY

Item	Concrete Discharged into Barrows		Concrete Discharged into 2-Wheel Hand Carts		Concrete Discharged into Cars or Hopper		Concrete Discharged into Hopper and Barrows		Concrete Discharged into Hopper and 2-Wheel Hand Carts	
	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men
	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.
Average output in continuous operation	5.0	7.1	9.1	13.0	9.9	14.2	9.9	14.2	9.9	14.2
	$	$	$	$	$	$	$	$	$	$
Wheel sand	0.04	0.03	0.04	0.03	0.04	0.03	0.04	0.03	0.04	0.03
Wheel gravel or stone	0.09	0.06	0.09	0.06	0.09	0.06	0.09	0.06	0.09	0.06
Mix and wet	0.32	0.22	0.17	0.12	0.16	0.11	0.16	0.11	0.16	0.11
Wheel concrete 50 ft.	0.11	0.08	0.03	0.02	0.03	0.02	0.10	0.07	0.03	0.02
Level and tamp concrete	0.15	0.10	0.15	0.10	0.19	0.13	0.15	0.10	0.15	0.10
Total cost of labor	0.71	0.49	0.48	0.33	0.51	0.35	0.54	0.37	0.47	0.32
Plant cost—Machinery*	0.12	0.09	0.07	0.05	0.06	0.04	0.06	0.04	0.06	0.04
Plant cost—Carts, tools, etc.†	0.09	0.09	0.15	0.15	0.18	0.18	0.09	0.09	0.15	0.15
Fuel‡	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Total cost per cubic yard	0.95	0.70	0.73	0.56	0.78	0.60	0.72	0.53	0.71	0.54
Wheel concrete 50 ft. additional	0.05	0.03	0.01	0.01	0.01	0.01	0.05	0.03	0.01	0.01

* Based on a yearly cost of $489 (see p. 342).

† Based on a cost of tools, runs, etc., as given on pages 367 to 370.

‡ Based on a cost of fuel of $0.03 per cubic yard of concrete.

NOTE.—Loading tray is filled by wheelbarrows.

TABLE 70. COST OF MACHINE MIXING WITH A 2-BAG BATCH MIXER PER CUBIC YARD OF CONCRETE IN PLACE—Continued (See p. 416)

PROPORTIONS 1:2½:5

Costs include wheeling material about 50 feet to mixer, charging mixer, mixing, machinery and plant charge, wheeling concrete, leveling and tamping, also include 15 per cent for foreman and 15 per cent extra for superintendence, overhead charges, etc., but do not include profit.

Labor 20¢ per hour.

MIXER CHARGED BY BARROWS

Item	Concrete Discharged into Barrows		Concrete Discharged into 2-Wheel Hand Carts		Concrete Discharged into Cars or Hopper		Concrete Discharged into Hopper and Barrows		Concrete Discharged into Hopper and 2-Wheel Hand Carts	
	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men
	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.
Average output in continuous operation	4.1	5.9	6.5	9.4	6.9	10.0	6.9	10.0	6.9	10.0
	$	$	$	$	$	$	$	$	$	$
Wheel sand	0.04	0.03	0.04	0.03	0.04	0.03	0.04	0.03	0.04	0.03
Wheel gravel or stone	0.09	0.06	0.09	0.06	0.09	0.06	0.09	0.06	0.09	0.06
Mix and wet	0.39	0.27	0.24	0.17	0.23	0.16	0.23	0.16	0.23	0.16
Wheel concrete 50 ft.	0.11	0.08	0.03	0.02	0.03	0.02	0.10	0.07	0.03	0.02
Level and tamp concrete	0.15	0.10	0.15	0.10	0.19	0.13	0.15	0.10	0.15	0.10
Total cost of labor	0.78	0.54	0.55	0.38	0.58	0.40	0.61	0.42	0.54	0.37
Plant cost—Machinery*	0.15	0.10	0.09	0.06	0.09	0.06	0.09	0.06	0.09	0.06
Plant cost—Carts, tools, etc.†	0.09	0.09	0.15	0.15	0.18	0.18	0.09	0.09	0.15	0 15
Fuel‡	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Total cost per cubic yard	1.05	0.76	0.82	0.62	0.88	0.67	0.82	0.60	0.81	0.61
Wheel Concrete 50 ft. additional	0.05	0.03	0.01	0.01	0.01	0.01	0.05	0.03	0.01	0.01

* Based on a yearly cost of $489 (see p. 342).

† Based on a cost of tools, runs, etc., as given on pages 367 to 370.

‡ Based on a cost of fuel of $0.03 per cubic yard of concrete.

TABLE 70. COST OF MACHINE MIXING WITH A 2-BAG BATCH MIXER PER CUBIC YARD OF CONCRETE IN PLACE—Continued (See p. 416)

PROPORTIONS 1:2½:5

Costs include wheeling material about 50 feet to mixer, charging mixer, mixing, machinery and plant charge, wheeling concrete, leveling and tamping, also include 15 per cent for foreman and 15 per cent extra for superintendence, overhead charges, etc., but do not include profit.

Labor 20¢ per hour.

MIXER CHARGED FROM HOPPER OR CAR

Item	Concrete Discharged into Barrows		Concrete Discharged into 2-Wheel Hand Carts		Concrete Discharged into Cars or Hopper		Concrete Discharged into Hopper and Barrows		Concrete Discharged into Hopper and 2-Wheel Hand Carts	
	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men	Average Men	Quick Men
	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.
Average output in continuous operation	5.4	7.6	10.40	14.8	11.50	16.40	11.50	16.40	11.50	16.40
	$	$	$	$	$	$	$	$	$	$
Sand and gravel or stone hauled in cars	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Mix and wet	0.30	0.21	0.15	0.11	0.14	0.10	0.14	0.10	0.14	0.10
Wheel concrete 50 ft.	0.11	0.08	0.03	0.02	0.03	0.02	0.10	0.07	0.03	0.02
Level and tamp concrete	0.15	0.10	0.15	0.10	0.19	0.13	0.15	0.10	0.15	0.10
Total cost of labor	0.58	0.41	0.35	0.25	0.38	0.27	0.41	0.29	0.34	0.24
Plant cost—Machinery*	0.11	0.08	0.06	0.04	0.05	0.04	0.05	0.04	0.05	0.04
Plant cost—Carts, tools, etc.†	0.18	0.18	0.24	0.24	0.27	0.27	0.18	0.18	0.24	0.24
Fuel‡	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Total cost	0.90	0.70	0.68	0.56	0.73	0.61	0.67	0.54	0.66	0.55
Wheel concrete 50 ft. additional	0.05	0.03	0.01	0.01	0.01	0.01	0.05	0.03	0.01	0.01

*Based on a yearly cost of $489 (see p. 342).

†Based on a cost of tools, runs, etc., as given on pages 367 to 370.

‡Based on a cost of fuel of $0.03 per cubic yard of concrete.

NOTE.—Hopper filled by cars.

TABLE 71. COST OF MIXING AND PLACING CONCRETE PER CUBIC YARD OF CONCRETE IN PLACE (See p. 417)

Based on given Cost of Plant and Cost of Labor per Day.
Cost of fuel is included in Cost of Labor.

Cost of Plant	Cost of Labor per Day	Normal Output per Day											
		25 Cubic Yards			50 Cubic Yards			75 Cubic Yards			100 Cubic Yards		
		Cost per Cubic Yard			Cost per Cubic Yard			Cost per Cubic Yard			Cost per Cubic Yard		
		Labor	Plant	Total	Labor	Plant	Total	Labor	Plant	Total	Labor	Plant	Total
$	$	$	$	$	$	$	$	$	$	$	$	$	$
500	20	0.80	0.05	0.85	0.40	0.03	0.43	0.27	0.02	0.29	0.20	0.01	0.21
	40	1.60	0.05	1.65	0.80	0.03	0.83	0.53	0.02	0.55	0.40	0.01	0.41
	60	2.40	0.05	2.45	1.20	0.03	1.23	0.80	0.02	0.82	0.60	0.01	0.61
	80	3.20	0.05	3.25	1.60	0.03	1.63	1.07	0.02	1.09	0.80	0.01	0.81
1000	20	0.80	0.10	0.90	0.40	0.05	0.45	0.27	0.03	0.30	0.20	0.03	0.23
	40	1.60	0.10	1.70	0.80	0.05	0.85	0.53	0.03	0.56	0.40	0.03	0.43
	60	2.40	0.10	2.50	1.20	0.05	1.25	0.80	0.03	0.83	0.60	0.03	0.63
	80	3.20	0.10	3.30	1.60	0.05	1.65	1.07	0.03	1.10	0.80	0.03	0.83
2000	20	0.80	0.20	1.00	0.40	0.10	0.50	0.27	0.07	0.34	0.20	0.05	0.25
	40	1.60	0.20	1.80	0.80	0.10	0.90	0.53	0.07	0.60	0.40	0.05	0.45
	60	2.40	0.20	2.60	1.20	0.10	2.30	0.80	0.07	0.87	0.60	0.05	0.65
	80	3.20	0.20	3.40	1.60	0.10	1.70	0.17	0.07	1.14	0.80	0.05	0.85
3000	40	1.60	0.30	1.90	0.80	0.15	0.95	0.53	0.10	0.63	0.40	0.08	0.48
	60	2.40	0.30	2.70	1.20	0.15	1.35	0.80	0.10	0.90	0.60	0.08	0.68
	80	3.20	0.30	3.50	1.60	0.15	1.75	1.07	0.10	1.17	0.80	0.08	0.88
	100	4.00	0.30	4.30	2.00	0.15	2.15	1.33	0.10	1.43	1.00	0.08	1.08
5000	40	1.60	0.50	2.10	0.80	0.25	1.05	0.53	0.17	0.70	0.40	0.13	0.53
	60	2.40	0.50	2.90	1.20	0.25	1.45	0.80	0.17	0.97	0.60	0.13	0.73
	80	3.20	0.50	3.70	1.60	0.25	1.85	1.07	0.17	1.24	0.80	0.13	0.93
	100	4.00	0.50	4.50	2.00	0.25	2.25	1.33	0.17	1.50	1.00	0.13	1.13
	150	6.00	0.50	6.50	3.00	0.25	3.25	2.00	0.17	2.17	1.50	0.13	1.63
	200	8.00	0.50	8.50	4.00	0.25	4.25	2.67	0.17	2.84	2.00	0.13	2.13
10000	60	2.40	1.00	3.40	1.20	0.50	1.70	0.80	0.33	1.13	0.60	0.25	0.85
	80	3.20	1.00	4.20	1.60	0.50	2.10	1.07	0.33	1.40	0.80	0.25	1.05
	100	4.00	1.00	5.00	2.00	0.50	2.50	1.33	0.33	1.66	1.00	0.25	1.25
	150	6.00	1.00	7.00	3.00	0.50	3.50	2.00	0.33	2.33	1.50	0.25	1.75
	200	8.00	1.00	9.00	4.00	0.50	4.50	2.67	0.33	3.00	2.00	0.25	2.25
	300	12.00	1.00	13.00	6.00	0.50	6.50	4.00	0.33	4.33	3.00	0.25	3.25
20000	80	3.20	2.00	5.20	1.60	1.00	2.60	1.07	0.67	1.74	0.80	0.50	1.30
	100	4.00	2.00	6.00	2.00	1.00	3.00	1.33	0.67	2.00	1.00	0.50	1.50
	150	6.00	2.00	8.00	3.00	1.00	4.00	2.00	0.67	2.67	1.50	0.50	2.00
	200	8.00	2.00	10.00	4.00	1.00	5.00	2.67	0.67	3.34	2.00	0.50	2.50
	300	12.00	2.00	14.00	6.00	1.00	7.00	4.00	0.67	4.67	3.00	0.50	3.50
	500	20.00	2.00	22.00	10.00	1.00	11.00	6.67	0.67	7.34	5.00	0.50	5.50

NOTE:—When interpolating between different values of "Cost of Plant" see that the same "Cost of Labor" is used.

Installation cost should be included in Cost of Plant.

TABLE 71. COST OF MIXING AND PLACING CONCRETE Continued (See p. 417)

Assumption: Plant runs 100 days* a year and costs per year† 25 per cent of its initial cost.

Normal Output per Day														
150 Cubic Yards			200 Cubic Yards			300 Cubic Yards			400 Cubic Yards			500 Cubic Yards		
Cost per Cubic Yard			Cost per Cubic Yard			Cost per Cubic Yard			Cost per Cubic Yard			Cost per Cubic Yard		
Labor	Plant	Total	Labor	Plant	Total	Labor	Plant	Total	Labor	Plant	Total	Labor	Plant	Total
$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
0.13	0.01	0.14	0.10	0.01	0.11	0.07	0.01	0.08	0.05	0.01	0.06	0.04	0.01	0.05
0.27	0.01	0.28	0.20	0.01	0.21	0.13	0.01	0.14	0.10	0.01	0.11	0.08	0.01	0.09
0.40	0.01	0.41	0.30	0.01	0.31	0.20	0.01	0.21	0.15	0.01	0.16	0.12	0.01	0.13
0.53	0.01	0.54	0.40	0.01	0.41	0.27	0.01	0.28	0.20	0.01	0.21	0.16	0.01	0.17
0.13	0.02	0.15	0.10	0.01	0.11	0.07	0.01	0.08	0.05	0.01	0.06	0.04	0.01	0.05
0.27	0.02	0.29	0.20	0.01	0.21	0.13	0 01	0.14	0.10	0.01	0.11	0.08	0.01	0.09
0.40	0.02	0.42	0.30	0.01	0.31	0.20	0.01	0.21	0.15	0.01	0.16	0.12	0.01	0.13
0.53	0.02	0.55	0.40	0.01	0.41	0.27	0.01	0.28	0.20	0.01	0.21	0.16	0.01	0.17
0.13	0.03	0.16	0.10	0.03	0.13	0.07	0.02	0.09	0.05	0.01	0.06	0.04	0.01	0.05
0.27	0.03	0.30	0.20	0.03	0.23	0.13	0.02	0.15	0.10	0.01	0.11	0.08	0.01	0.09
0.40	0.03	0.43	0.30	0.03	0.33	0.20	0.02	0.22	0.15	0.01	0.16	0.12	0.01	0.13
0.53	0.03	0.56	0.40	0.03	0.43	0.27	0.02	0.29	0.20	0.01	0.21	0.16	0.01	0.17
0.27	0.05	0.32	0.20	0.04	0.24	0.13	0.03	0.16	0.10	0.02	0.12	0.08	0.02	0.10
0.40	0.05	0.45	0.30	0.04	0.34	0.20	0.03	0.23	0.15	0.02	0.17	0.12	0.02	0.14
0.53	0.05	0.58	0.40	0.04	0.44	0.27	0.03	0.30	0.20	0.02	0.22	0.16	0.02	0 18
0.67	0.05	0.72	0.50	0.04	0.54	0.33	0.03	0.36	0.25	0.02	0.27	0.20	0.02	0.22
0.27	0.08	0.35	0.20	0.06	0.26	0.13	0.04	0.17	0.10	0.03	0.13	0.08	0.03	0.11
0.40	0.08	0.48	0.30	0.06	0.36	0.20	0.04	0.24	0.15	0.03	0.18	0.12	0.03	0.15
0.53	0.08	0.61	0.40	0.06	0.46	0.27	0.04	0.31	0.20	0.03	0.23	0.16	0.03	0.19
0.67	0.08	0.75	0.50	0.06	0.56	0.33	0.04	0.37	0.25	0.03	0.28	0.20	0.03	0.23
1.00	0.08	1.08	0.75	0.06	0.81	0.50	0.04	0.54	0.38	0.03	0.41	0.30	0.03	0.33
1.33	0.08	1.41	1.00	0.06	1.06	0.67	0.04	0.71	0.50	0.03	0.53	0.40	0.03	0.43
0.40	0.17	0.57	0.30	0.13	0.43	0.20	0.08	0.28	0.15	0.06	0.21	0.12	0.05	0.17
0.53	0.17	0.70	0.40	0.13	0.53	0.27	0.08	0.35	0.20	0.06	0.26	0.16	0.05	0.21
0.67	0.17	0.84	0.50	0.13	0.63	0.33	0.08	0.41	0.25	0.06	0.31	0.20	0.05	0.25
1.00	0.17	1.17	0.75	0.13	0.88	0.50	0.08	0.58	0.38	0.06	0.44	0.30	0.05	0.35
1.33	0.17	1.50	1.00	0.13	1.13	0.67	0.08	0.75	0.50	0.06	0.56	0.40	0.05	0.45
2.00	0.17	2.17	1.50	0.13	1.63	1.00	0.08	1.08	0.75	0.06	0.81	0.60	0.05	0.65
0.53	0.33	0.86	0.40	0.25	0.65	0.27	0.17	0.44	0.20	0.13	0.33	0.16	0.10	0.26
0.67	0.33	1.00	0.50	0.25	0.75	0.33	0.17	0.50	0.25	0.13	0.38	0.20	0.10	0.30
1.00	0.33	1.33	0.75	0.25	1.00	0.50	0.17	0.67	0.38	0.13	0.51	0.30	0.10	0.40
1.33	0.33	1.66	1.00	0.25	1.25	0.67	0.17	0.84	0.50	0.13	0.63	0.40	0.10	0.50
2.00	0.33	2.33	1.50	0.25	1.75	1.00	0.17	1.17	0.75	0.13	0.88	0.60	0.10	0.70
3.33	0.33	3.66	2.50	0.25	2.75	1.67	0.17	1.84	1.25	0.13	1.38	1.00	0.10	1.10

* If plant runs 150 days a year, plant cost per cubic yard will be reduced 33 per cent.

† If yearly cost of plant is taken at 20 per cent of its initial cost the plant cost per cubic yard will be reduced 20 per cent.

CHAPTER XIV

FORMS FOR MASS CONCRETE

The design of forms for mass concrete is governed so much by the character of the construction that only a general treatment can be given. The thickness of the mass; the length of wall surface; the height of wall surface; location above or below ground level; character of machinery, if available for handling; and many other conditions affect the design.

If the construction is small and especially if the lumber can be used afterwards in the permanent structure, it may be economical to cover the entire surface with common sheathing nailed to joists or studs that are suitably supported and braced. Frequently the studs in two opposite wall forms can be tied together so as to avoid timber bracing.* In other cases, light movable forms may be made. For such work as locks and dams, where forms are to be used many times and can be handled by machinery, heavier construction is needed to prevent racking. For high masses, such as dams, the forms may be anchored into the concrete and the anchors left in place.

A form suitable for a large mass like a dam is illustrated in Fig. 37, page 447. The form is sectional and may be from 3 to 5 feet in height and 10 to 15 feet in length. The rods and turnbuckles are left imbedded in the concrete. This at first appears extravagant, but the cost of these anchorages does not amount to more than 3 or 4 cents per square foot of wall surface and their use may avoid the cost of expensive bracing. The blocks separating the bolts from the form are removed before placing the next layer of concrete, so that only the bolt holes have to be filled after removing the form.

A number of other types of forms suitable for wall construction are illustrated in Chapter XVI. Further suggestions on form design for mass concrete may be obtained by consulting the various articles on the subject that are tabulated on page 448.

*Forms connected by wire ties are illustrated in Taylor and Thompson's "Concrete, Plain and Reinforced," second edition, p. 295.

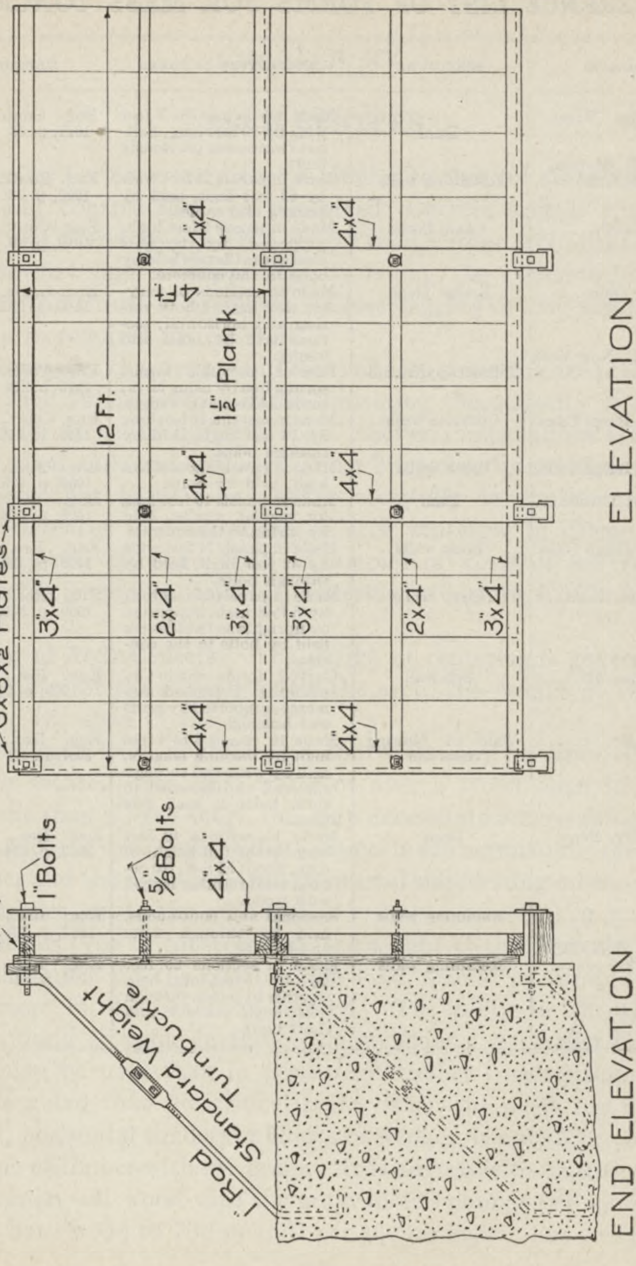


FIG. 37. Form for Mass Concrete. (See p. 446)

REFERENCE LIST OF FORMS FOR MASS CONCRETE

LOCATION	STRUCTURE	DESCRIPTION OF FORMS	REFERENCE
Androscoggin River, Maine	Dam	Made up in panels 3 feet wide by 10 feet long, bolted to buttresses previously built.	Eng. Contr., Jan. 4, 1911, p. 33.
Penn. R. R. Station, New York City	Retaining walls	Made in panels 24 feet wide by 62 feet high, held by bracing and cables.	Eng. Contr., Apr. 13, 1910, p. 328.
Panama Canal	Canal Locks	Made in panels 6 feet high, supported by uprights used as cantilevers held by bolts in the concrete.	Eng. Contr., July 27, 1910, p. 70.
Cleveland, Ohio	Bridge piers	Made in sections of varying size; lagging both vertical and horizontal; sections held by bolts and wiring.	Eng. Contr., Sept. 14, 1910, p. 222.
Penn. R. R., New York City	Tunnel approaches	Interior movable forms, sprung free by using keys, turnbuckles, and wedges.	Eng. Contr. Sept. 21, 1910, p. 244.
New York Barge Canal	Concrete walls	Made in sections 40 feet long by 16 feet high, held by through bolts.	Eng. Contr., Sept. 21, 1910, p. 246.
New York Barge Canal	Lock walls	Made in panels about 4 feet high, held by bolts.....	Eng. Rec., Apr. 3, 1909, p. 425.
Connecticut River	Dam	Made in panels 10 feet long by varying widths, held by wiring to the concrete.	Eng. Rec., Apr. 3, 1909, p. 445.
New York Barge Canal	Lock walls	Made in panels 27 feet wide by 32 feet high, held by through bolts.	Eng. Rec., Apr. 3, 1909, p. 430.
Chattanooga, Tenn.	Heavy walls	Made in panels 15 feet long by 5 feet high, supported by uprights as cantilevers held by bolts in the concrete.	Eng. Rec., Apr. 24, 1909, p. 540.
Fort Morgan, Ala.	Sea wall	Curved forms made by planking in trussed segments, supported by posts and bracing.	Eng. Rec., Apr. 24, 1909, p. 545.
St. Louis, Mo.	Walls of filtering reservoir	Made in panels 3 to 4 feet high by varying lengths, held by wires run through the wall and fastened to short bolts at each side form.	Eng. Rec., July 6, 1907, p. 16.
McCall Ferry, Penn.	Dam	Made in sections 40 feet long by the full height of dam, about 55 feet. Structural steel framing lagged with wood.	Eng. Rec., Sept. 21, 1907, p. 319.
C. B. & Q. R. R.	Retaining walls	Sectional and continuous, held by through bolts and bracing.	Eng. Rec., Mar. 9, 1907, p. 338.
N. Y. C. & H. R. R. R., New York	Retaining walls	Made in sections 20 feet high by 52 feet long, held together by ½-inch through rods with sockets and short bolts.	Eng. Rec., Jan. 6, 1906, p. 24.

CHAPTER XV

ARCH CENTERS

Centering for concrete arches is similar to that for stone arches in design and construction. A reinforced concrete arch is apt to be thinner and therefore lighter in weight than a stone arch, thus requiring somewhat lighter supports. By laying the concrete in rings, less eccentric thrust is produced. Close lagging or else sheet metal is of course required for concrete.

In the present chapter no unit costs of arch centering are presented, but on page 461 is given a curve indicating the quantity of lumber required for arches of different span. Several illustrations are given of both wood and steel centering and a brief description of a number of designs that have been used successfully in construction. A list of references to descriptions of arch centering in current literature is given on page 463. Examples of costs of several concrete arches including costs of centering are given in Chapter II, page 26.

Design of Arch Centers. The design of centering is governed by the character of the ground below the arch, the weight of the arch ring, and the span of the arch.

A clear span from abutment to abutment may be required if the bridge is located over deep water or over a street open to traffic. Unless the span is very short, this may necessitate a truss design. If, as is usually the case, intermediate supports are permissible, the design is simpler and the posts may run from mud sills, resting on the ground or upon piles, up to the arch ribs.

For either type of construction, the weight of the concrete, with a small allowance for the construction load, should be computed and the stresses in the centering figured. The tables in Chapter XX, will be found of value in these computations. A smaller factor of safety may be used than in permanent timber construction, but it must be noted that the critical point, when the posts rest upon, or support, horizontal timbers or blocks or wedges, is apt to be the bearing value of timber with the grain. It is advisable to limit the crushing stress on soft wood with the grain to 400 pounds per square inch and on hard wood to 700 pounds per square inch. For wedges, 300 pounds per square inch may well be the limit to provide for imperfect bearing. Wedges should be made of hard wood so that they can be driven without crushing. The centering must be braced thoroughly so as to keep its shape under the unequal loading during the laying of the concrete.*

CENTERS FOR ARCHES OF SHORT SPAN

The simplest centering, suitable for an arch of a few feet span, such as a small sewer or culvert, consists of ribs of a single board or plank

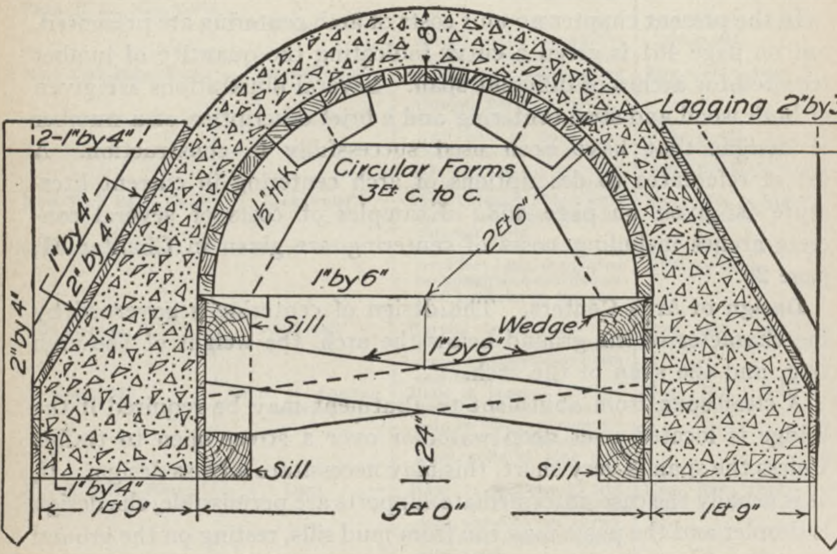


FIG. 38. Center for Arch of 5-Foot Span. (See p. 451)

sawed to the curve of the arch and spaced from 18 to 30 inches apart, according to the weight to be supported (see Table, page 610), and covered with narrow tongued-and-grooved boards or plank. For slightly longer spans, up to, say, 10 feet, the ribs may consist of

*Mr. Ira O. Baker, in "Masonry Construction" 10th Edition, 1909, p. 650, gives practical suggestions on the design of centering with a table of masonry pressures which also may be adapted to concrete construction. Mr. W. J. Douglas in *Engineering News*, December 20, 1906, p. 643, and January 24, 1907, p. 98, gives excellent suggestions for form construction and quotes specifications of the Piney Branch Bridge.

pieces of 2-inch plank—the number depending upon the width of the plank as well as the shape of the arch—lapped over each other, so as to break joints, and spiked solidly together. After spiking, the curve of the arch is marked on them and they are sawed to this line. Typical centers of 5-foot and 8-foot spans are shown in Figs. 38 and 39.*

For longer spans, even up to 30 feet, similar ribbed construction may be adopted, stiffened by one or three braces which run vertically and diagonally down to the center of a horizontal timber.

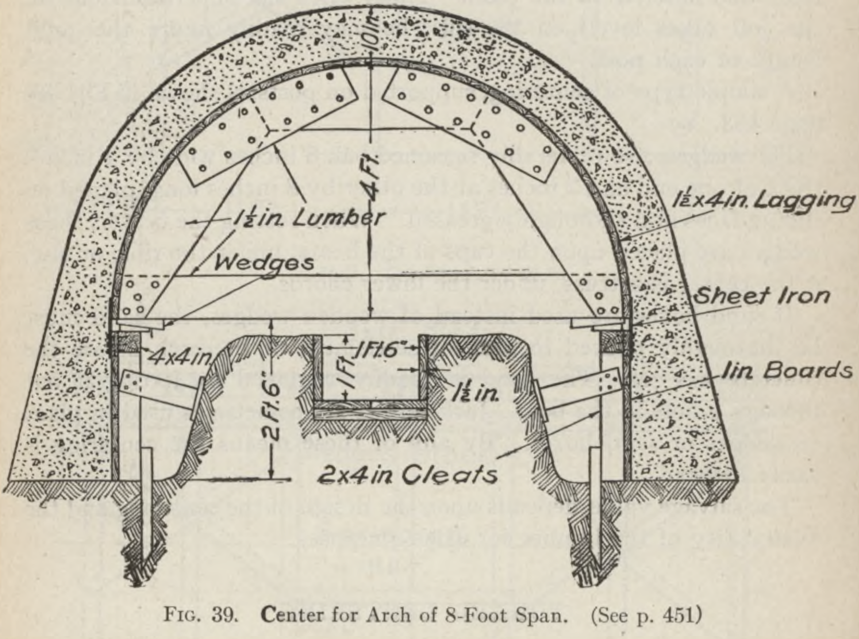


FIG. 39. Center for Arch of 8-Foot Span. (See p. 451)

These may span from abutment to abutment or else be supported by a post at the center.

CENTERS FOR ARCHES OF LONGER SPAN

In larger arches, the spacing of the posts is governed by the height and the weight of the arch and by the character of the ground underneath. If the posts are difficult to place or require pile supports,

*From "Concrete in Highway Construction," published by the Atlas Portland Cement Co.

it may be cheaper to use comparatively few posts and a more complicated truss. In general, where the arch is comparatively low and the span 30 feet or more, the cheapest plan is to frame the vertical posts into bents parallel to the center line of the arch and support the ribs upon wedges resting directly upon the caps of the bents.

When the posts run clear up to the ribs and are therefore of varying lengths, the distance from the under surface of the arch to the level of the springing line should be computed in the drafting room and entered on the plan. Then, when the superintendent on the job takes levels on the sills, he may readily figure the total length of each post.

A simple type of centering, supported on posts, is shown in Fig. 40, page 453.

For wedges, use preferably seasoned oak 8 inches wide by 4 inches thick at one end and 2 inches at the other by 8 inches long, planed on sliding faces and thoroughly greased. When setting the center, these wedges are placed upon the caps of the bents, under the ribs, or else, if the center is a truss, under the lower chords.

If sand boxes are used instead of wooden wedges, the sand must be thoroughly packed to prevent settlement of the arch before the concrete has set. The sand is readily removed by letting it out through a hole in the box. Jack screws are sometimes used in place of wedges or sand boxes. By any of these means the centering is easily lowered.

The salvage value depends upon the design of the centering and the availability of the lumber for other purposes.

TUNNEL CENTERING

Centering for concrete tunnel linings is designed for each special case according to the local conditions. Some of the notes given in connection with arch centers will be of interest in deciding upon the design and construction. Two illustrations of tunnel centering of well-designed types are described and illustrated below.

Tunnel Centering, Shawinigan Falls, Canada*. The centering is illustrated in Fig. 41, page 454. Angles 3 by 3 by ½-inch formed the ribs, which were stiffened by segments of 2-inch planks bolted to them. The frame-work consisted chiefly of 8-inch timber bracing,

*The work is described in *Engineering Record*, April 4, 1908, page 452.

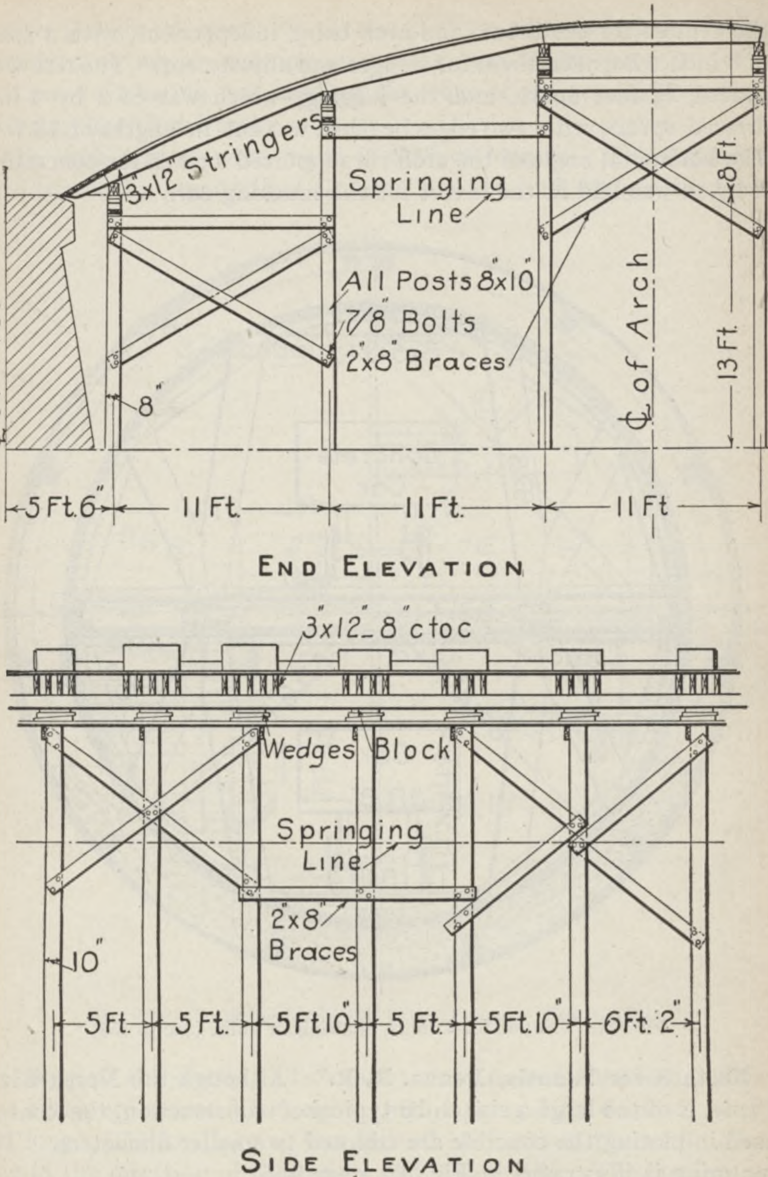


FIG. 40. Centering for Sandy Hill Arch Bridge, 60 Foot Span. (See p. 452)*

*Redrawn from paper on "Concrete Bridges Across Hudson River at Sandy Hill, New York," by William H. Burr, Transactions American Society of Civil Engineers, Vol. LIX, 1907, page 198.

the centers for the invert and arch being independent, with a space of 6 inches between them for wedges and adjustment. The ribs were spaced $2\frac{1}{2}$ feet apart, and the lagging, which was of 2 by 4-inch dressed spruce with two edges beveled, was cut in lengths of 13 feet. The horizontal angle of the arch rib supported a track for concreting. A track was laid in the invert for the mucking car.

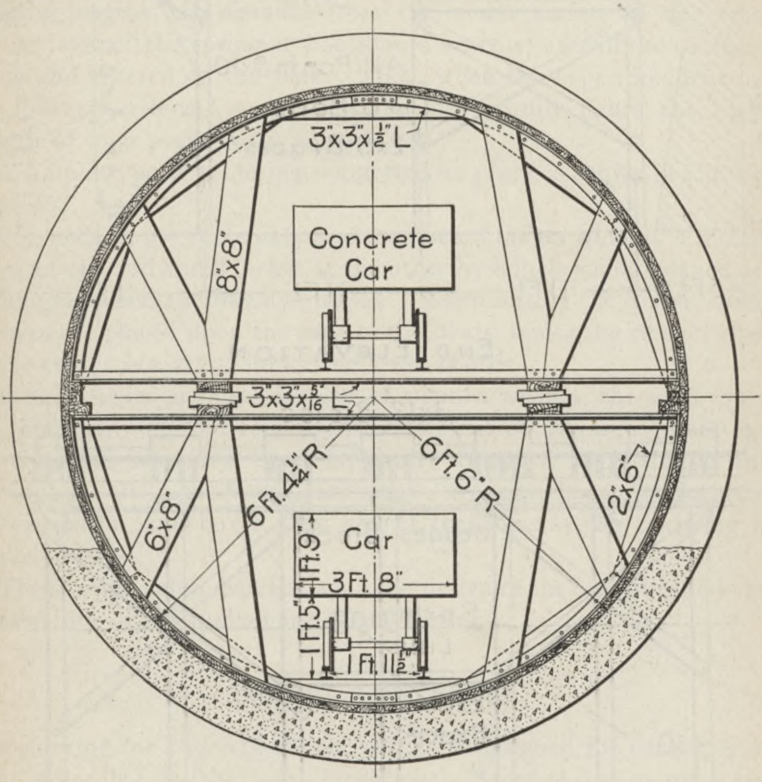


FIG. 41. Centers for Tunnel, Shawinigan Falls. (See p. 452)

North River Tunnels, Penna. R. R.* Although the North River tunnel is of too large a size to be typical of construction, the centers used in placing the concrete are adapted to smaller diameters. The centering is illustrated in Fig. 42, page 455.

*See paper by B. H. M. Hewett and W. L. Brown on "The New York Tunnel Extension of the Pennsylvania R. R.—The North River Tunnels," Transactions American Society Civil Engineers, Vol. LXVIII, 1910, page 280.

After placing the invert for the roadbed, an adjustable frame-work supported on wheels, running on a track, was placed upon it. Six-inch cross timbering was used on the sides of the tunnel below the springing line of the arch.

The arch centers were made in 20-foot lengths. The segments were braced by longitudinal timbers, blocked and wedged up from

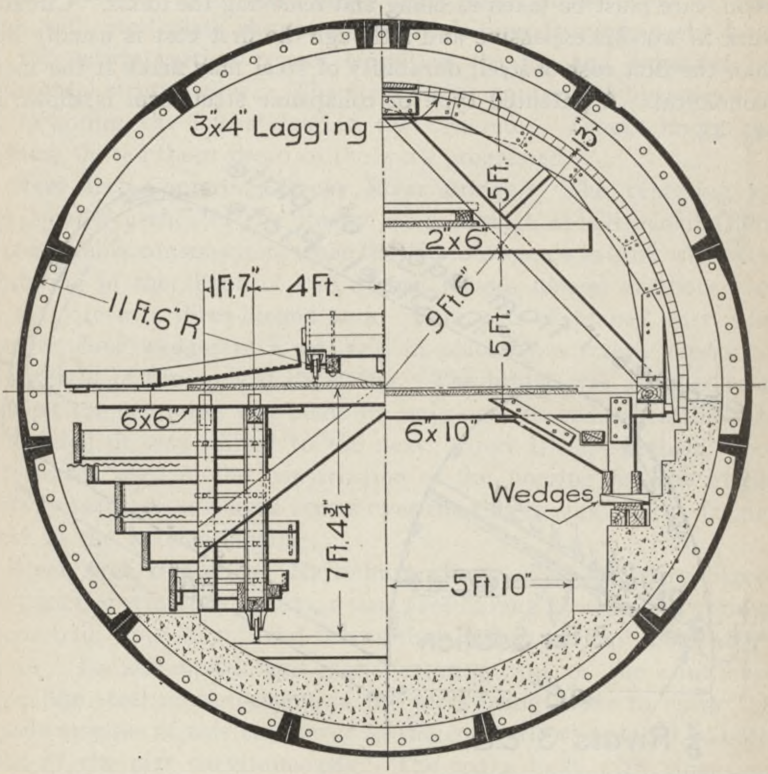


FIG. 42. Centering for North River Tunnel. (See p. 454)

the steps of the ducts. The centers were moved ahead on rollers. The ribs were spaced 5 feet apart, with lagging 3 by 4 inches by 10 feet long. The key lagging was formed of blocks of timber 6 inches long in the direction of the tunnel and 2 feet wide. The lagging on each side for a distance of 4 feet up from the springing line was framed so that it could be swung in a few inches to allow the centering to clear the concrete.

STEEL CENTERING

Steel centering for reinforced concrete has been used in many special instances with good results.

Steel is well adapted to arch forms because it can be bent to the required shapes, it is easily collapsed for removal, and can be used a great many times but as concrete adheres to it more readily than to wood, care must be taken in oiling and removing the forms. Circular work in wood is expensive and although the first cost is usually less than the first cost of steel, durability of steel may make it the more economical. A patented type of collapsible steel form is shown in Fig. 43.

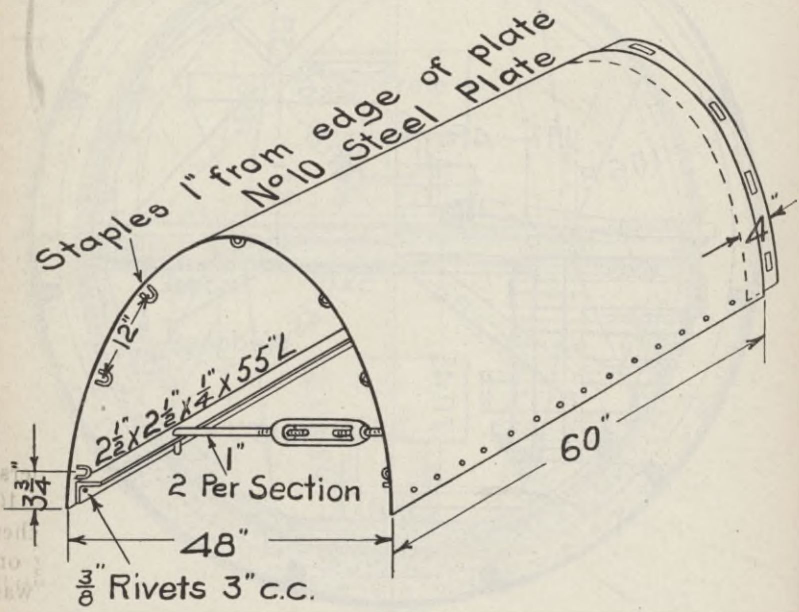


Fig. 43. Collapsible Steel Centering for a 4-foot Arch. (See p. 456)

Several typical structures are briefly described in the following pages and references to the original articles given in the foot-notes.

Steel Sewer Centering, St. Louis, Mo.* Steel centers were used for the large Harlem Creek sewers, some of which are 29 feet clear span by 19 feet high inside. The forms were made in 25-foot lengths and weighed about 15 tons. They were expanded to the full shape

*The work is illustrated in *Engineering News*, July 30, 1908, page 131.

or contracted to clear the concrete by screws connected to the inner framing. The section was shifted ahead on small wheels attached to the I-beams, which supported the centering, and running on rails fastened to timbers laid in the invert.

Steel Culvert Centering, Gatun Dam.* Culverts were here constructed up to 18 feet in diameter, of both horseshoe and circular shaped section. The steel forms were made in sections 12 feet long with steel plate sheathing and angle iron framing in the form of two nearly vertical trusses hinged at the top and separated by horizontal struts below. The struts were contracted by screws so as to spring the forms clear of the concrete. Trucks under the centers shifted them ahead as the work progressed.

Steel Arch Centering, Rocky River Bridge.† The centering for the smaller arches of the Rocky River Bridge at Cleveland, Ohio, was of timber construction, while the 280-foot span was built with steel centering in the shape of two arched trusses hinged at the crown so as to form a three-hinged arch. Four sets of planed cast steel wedges, four wedges to a set, held in place by a screw, supported the weight of the arch at its spring. The bridge was a ribbed arch so that the centering was made for only one rib and, when this was completed, it was shifted to the next. Steel I-beams, which were afterwards used in the construction of the flooring for the street railway track, were placed across over the ribs to support the framework of the wooden lagging.

Steel Arch Centering, Harrisburg, Pa.‡ The Mulberry Street Viaduct is a reinforced concrete structure having 23 arches of various spans built over 30 railroad tracks that had to be kept clear at all times. To accomplish this, the centering was of the cantilever type, the steel reinforcement of the piers being made to carry the tensile stresses of this cantilever as the concrete was placed on both sides of the pier simultaneously. The spans built with this construction were of 100 feet, each cantilever extending a little more than one-quarter of the span, thus making the space between the ends of the cantilevers a little less than 50 feet.

The steel cantilever forms were made of $\frac{5}{16}$-inch steel with 5-inch and 6-inch angles, the forms for each rib measuring 12 feet high at the piers and 4 feet high at the outer ends.

*The work is described in "*Engineeing Record*" October 30, 1909, page 484.

†The work is described in "*Concrete Engineering*," July, 1909, page 178.

‡The work is described in "*Engineering Record*," April 3, 1909, page 377.

Steel Arch Centering, Hopatcong Cut-Off, D. L. & W. R. R.* The bridge has 5 arches of 150-foot span and 2 of 120 feet. The larger arches were built with two steel centers which were moved ahead to build the other arches. The centers consisted of a number of trussed arch ribs placed together laterally. The arch rib connections were riveted except at the crown hinge. To lower the centering and clear the concrete, two of the struts near the crown were provided with specially devised right and left thread screws, by means of which they could be lengthened so as to spread the quadrilaterals of which they formed a part and thus separate the hinge.

Steel Centering for Concrete Water Tower, Westerly, R. I.† The standpipe at Westerly, R. I., is 40 feet inside diameter and 70 feet high with a capacity of 650 000 gallons. The walls are 14 inches thick.

The inside forms were of $\frac{1}{8}$-inch sheet steel 6 feet in height, while the outside forms were of the same steel in sections 3 feet in height by 6 feet long, 2 sets of these being used. Planed angles, 3 by 3 by $\frac{1}{4}$ inch, were riveted around the edge of each 3-foot section, with two intermediate verticals for stiffening. To release the inside form for raising it, the steel sheeting at one place overlapped 6 inches and the angle irons were provided with turnbuckles which made it possible to spring the entire circle of forms to a smaller diameter so that it could be raised at one operation. A steel staging, supported upon four 4 by 4-inch posts, was especially designed for the inside of the standpipe, to be raised as the work progressed.

UNIT TIMES ON ARCH CENTERS NOT GIVEN

It is possible to analyze the times of the carpenters and the costs of building arch centers in similar fashion to the plan followed in forms for building construction, Chapter XXII, but since the number of arches built each year is comparatively small, the subject is of less general interest, so that the costs are treated for the present only in a general way. However, the information given is intended to be full enough to provide for ordinary estimates.

Instead of determining unit times, rules are given, (1) for estimating quantity of lumber for arches of different span and rise, and (2) for estimating the cost of labor per 1000 feet B. M. of lumber.

*The work is described in "*Engineering News*," December 30, 1909, page 713.

†The work is described in "*Engineering and Contracting*," October 5, 1910, page 285.

QUANTITY OF LUMBER FOR CENTERS

A study of a large number of designs of arch centers shows that, on the average, there is a fairly definite relation between the rise and span of the arch and the quantity of lumber in the centering. It is possible therefore to estimate approximately in advance the quantity of lumber required for a given span and rise of arch, varying this by judgment for special conditions. Of course when ordering the lumber for centering, it is necessary to actually design the falsework, not only to obtain the exact quantity required but also the exact dimensions of the various pieces.

Curve of Quantity of Lumber for Centering. To find the best way of estimating the quantity of lumber for any given arch, the quantity of lumber actually used in the centers of a large number of arches has been figured and studied with a view to obtain some general rule. It is evident that as the span and rise of the arch increases, more lumber is needed per square foot of surface because a heavier weight is to be supported. After a number of trials, it was found that the quantity of lumber, when plotted in terms of the span plus the rise, took the form of a smooth curve. This curve is given, together with the points from which it is obtained, on page 461. It will be noticed that the curve runs down to as small a span as 3 feet.

The values in the curve are given per foot of width of arch. That is, having found the ordinate on the curve corresponding to the span plus rise of the arch in question, the value of the ordinate is multiplied by the width of the arch, *i.e*, by the length of barrel or crown line.

For a skew arch take the span as the center line on the skew. The use of the curve is illustrated in the following examples.

Example 1: What will be the approximate quantity of lumber for centering for an ordinary arch 30 feet wide, 40-foot span, and 10-foot rise?

Solution: Referring to the curve, page 461, we find directly that 380 feet B. M. of lumber will be needed per foot of width for an arch of 50-foot span plus rise. Since the curve allows for waste, this quantity may be used directly in figuring the cost of the lumber and we have $380 \times 30 = 11400$ feet B. M. for the total quantity of lumber required. Allowance should be made for salvage, which depends upon the design of the centering and the probable future use of the material.

Example 2: What will be the quantity of lumber per square foot of surface of soffit of arch of Example 1?

Solution: The length of the 3-centered curve of the soffit of an arch of 40-foot span and 10-foot rise is approximately $48\frac{1}{2}$ feet. Hence quantity of lumber per square foot of surface of soffit is the quantity from curve, 380, divided by this length, or 7.84 feet B. M.

Cost of Lumber for Centers. In figuring the approximate cost of lumber from the quantity obtained from the curve, as illustrated in the example just given, the price per thousand must include the cost of delivery of the lumber as well as the market rate. The price per thousand feet will differ with the size and finish, and any average price must be based on costs of the different parts, taking into consideration the relative quantity of each required.

COST OF LABOR BUILDING AND REMOVING FORMS

Examination of a large number of actual cost records shows that the most nearly constant unit to use for labor costs in the building of centers is the cost per thousand feet board measure of lumber. An inspection of the curve on page 461 illustrates the impossibility of basing costs on the surface area of the arch, because so much more material is required for long spans, in proportion to the area, than for short spans. The curve also shows that the area of road surface above the arch would be equally inaccurate.

On the other hand, figuring the cost per 1000 feet board measure of labor in a large number of actual cases, we find that the variation is no more than always must be expected in averages of this kind. Published unit costs frequently give the cost of labor at \$8.00 to \$10.00 per 1000 feet board measure for centering, but the authors have been unable to find authorization for this, except in one or two isolated cases where the conditions were abnormally simple.

Averaging a number of jobs, with spans ranging from 18 to 160 feet, it is found that the cost of labor does not vary in any definite degree with the span of the arch, but that the following figures will apply satisfactorily to ordinary cases and be sufficiently exact for estimates of cost.

With carpenter labor at 40¢ per hour, average labor cost is about \$25.00 per 1000 feet B. M. net, or \$30.00 including allowances for superintendence and overhead charges, but not including charges for home-office expenses or profit. The range in total cost, except

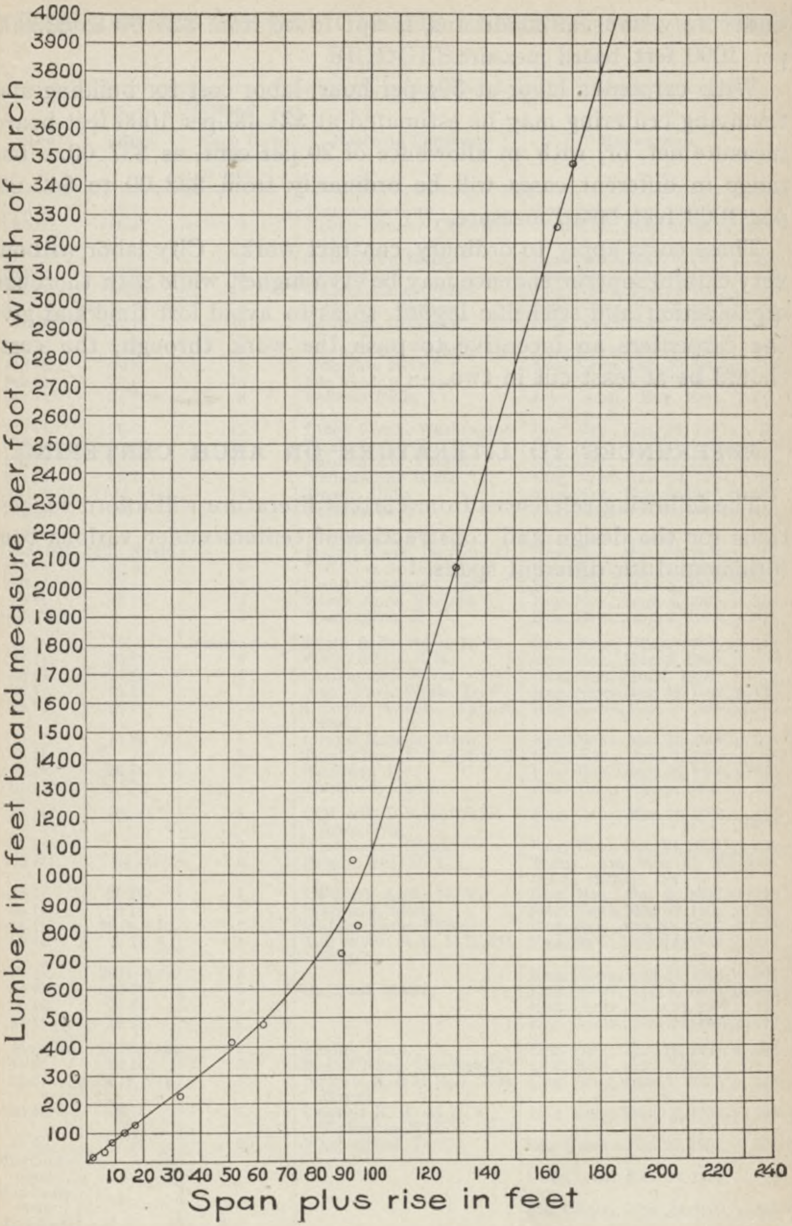


FIG. 44. Curve for Estimating Approximate Quantity of Lumber in Arch Centering

(See p. 459)

under very unusual conditions, is apt to be from $25.00 to $35.00 per 1000 feet board measure.

With carpenter labor at 50¢ per hour, labor cost for building and removing centering may be estimated at $31.00 per 1000 feet board measure net, or, with an allowance of 20 per cent, as $37.00. The range in different cases will be ordinarily from $32.00 to $42.00. per 1000 feet board measure.

These costs apply to ordinary contract work. City labor without very careful superintendence may be even higher, while with thorough organization and scientific layout, so as to avoid lost time and give the carpenters an incentive to push the work through, the costs should be at least cut in two.

REFERENCES TO LITERATURE ON ARCH CENTERING

The following references from current literature will afford suggestions for the design and construction of centers under various conditions and for different spans.

REFERENCES TO DESIGNS OF CENTERS FOR ARCH BRIDGES

Span	Rise	Number of Supports in Each Row in Length of Span	Name or Location	Reference
295 ft.	59 ft.		Plauen, Saxony	Eng. News, Jan. 28, 1904, p. 73
280 ft.	90 ft.	2	Rocky River, Cleveland, O.*	Con. Eng., July, 1909, p. 181
277 ft.		4	Luxemburg Bridge†	Eng. News, Mar. 5, 1903, p. 206
259 ft.	87 ft.	14	Switzerland	Eng. News. Aug. 5, 1909, p. 136
233 ft.	70 ft.	19	Walnut Lane, Phila.	Eng. News, Aug. 15, 1907, p. 168
211½ ft.	86 ft. 8½ in.	4	Kempten, Bavaria	Eng. News, May 2, 1907, p. 481
187½ ft.	32 ft.	16	Lautrach, Bavaria	Eng. News, May 2, 1907, p. 480
150 ft.	75 ft.	9	Conn. Ave., Washington	Eng. News, June 1, 1905, p. 575
150 ft.	40 ft.	2	Delaware River*	Eng. News, Dec. 30, 1909, p. 717
140 ft.	30 ft.	13	Big Muddy River	Eng. News, Nov. 12, 1903, p. 429
140 ft.	24 ft.	8	Bellows Falls, Vt.	Jour. Assn. Eng. Soc., July, 1901, p. 3
125 ft.	39 ft.	11	Piney Creek, Washington	Eng. Rec., Jan. 26, 1907, p. 89
125 ft.	39 ft.	13	Washington, D. C.	Eng. News, Apr. 19, 1906, p. 453
120 ft.	60 ft.	11	Paulins Kill Viaduct	Eng. Rec., Aug. 15, 1908, p. 193
120 ft.	15 ft.	3	Yellowstone River	Eng. News, Jan. 14, 1904, p. 27
106 ft. 8 in.	11 ft. 9 in.	9	Dover, Ohio	Eng. Rec., Feb. 9, 1907, p. 145
105 ft.	16½ ft.	11	Pelham, N. Y.	Eng. Rec., Oct. 31, 1908, p. 485
100 ft.		Cantilever	Harrisburg, Penn.	Eng. Rec., Apr. 3, 1909, p. 377
80, 90 & 100 ft.	14, 13, & 11 ft.		Miami River, Dayton, O.	Eng. Rec., Mar. 24, 1906, p. 387
100 ft.	40 ft.	6	C.C.C. & St.L.R.R.	Eng. Rec., Mar. 3, 1906, p. 2[illegible]8
100 ft.	32 ft.	9	Conococheague Creek	Eng. News, Apr. 8, 1909, p. 377
86 ft.	43 ft.	4	Santa Anna Viaduct	Eng. Rec., Sept. 9, 1905, p. 286
82 and 150 ft.		9	Washington, D. C.	Eng. Rec., June 2, 1906, p. 676
81 ft.	10½ ft.	Suspended	Elgin & Belvidere R. R.	Con. Eng., May, 1908, p. 119
80 ft.	30 ft.	6	C.C.C.&St.L.R.R.	Eng. Rec., Mar. 3, 1906, p. 238
80 ft.	30 ft.	2	Conemaugh River	Eng. Rec., Jan. 4, 1908, p. 10
80 ft.	15 ft.	7	Nat'l Park, Wash., D. C.	Eng. News, Aug. 14, 1902, p. 110
75 ft.	18 ft.	7	Charley Creek, Wabash, Ind.	Eng. News, Mar. 15, 1906, p. 290
75 ft.	14 ft.	7	Grand Rapids, Mich.	Eng. News. Mar. 22, 1906, p. 323
75 ft.		9	Rock Creek, C.B. & Q.R.R.	Eng. Rec., Jan. 2, 1904, p. 18
70 ft.	20 ft.	7	Southern Ry.	Eng. Rec., Sept. 22, 1906, p. 315
68 to 119 ft.			Hartford, Conn.	Eng. Rec., Mar. 3, 1906, p. 291
64 ft.	16½ ft.	5	C.M. & St.P.R.R., Watertown, Wis.	Eng. News, Mar. 26, 1903, p. 266
63 ft.		2	Neshaminy, Penn.	Eng. Rec., Oct. 13, 1906, p. 399
60 ft.	8½ ft.	6	Sandy Hill, N. Y.*	Trans. Am. Soc. C. E. Vol. LIX, 1907, p. 198
60 ft.	20 ft.	3	175th St. Arch, N. Y.	Eng. Rec., Oct. 5, 1907, p. 379
54 ft.	8 ft.	7	Plainwell, Mich.	Eng. News, May 12, 1904, p. 457
53 ft.	26 ft. 4 in.	2	Walnut Lane, Phila.	Eng. Rec., Aug. 31, 1907, p. 225
50 ft.	8 ft.	4	Mill River, N.Y.,N.H.&H. R.R.	Eng. Rec., Nov. 14, 1908, p. 558
50 ft.	20 ft. 5 in.	3		Eng. News, Aug. 23, 1906, p. 207
50 ft.	12 ft.	9	St. Paul, Minn.	Eng. News, Apr. 6, 1905, p. 352
50 ft.	20 ft.	2		Eng. Contr., Nov. 24, 1909, p. 442
50 ft.	20 ft.	3		Eng. Contr., Nov. 24, 1909, p. 442
46 ft. 2 in.	17 ft. 5 in.	2	Media, Penn.	Eng. Rec., Apr. 14, 1906, p. 484
44 ft.	22 ft.	3	Rocky River, Cleveland, O.	Con. Eng., July, 1909, p. 171
31 ft.	6 ft. 8 in.	3	N.Y.,N.H. & H.R.R., New Haven	Con. Eng., June 1, 1907, p. 249
30 ft.	9 ft.	5	Central R. R. of N. J., Vulcanite, N. J.	Eng. Rec., Sept. 9, 1905, p. 296
14 ft.	7 ft.	2	Washington, D. C.	Eng. Contr., May 22, 1907, p. 227
Miscellaneous				Eng. Contr., Feb. 24, 1909, p. 150
Miscellaneous				Eng. Contr., Nov. 24, 1909, p. 440
Miscellaneous				Eng. Contr., Dec. 1, 1909, p. 464

*Steel centering. †Steel tie rods used.

REFERENCES TO DESIGNS OF CENTERING FOR TUNNELS

Span	Shape	Location	Reference
56 ft.	Sides straight, top circular	Bergen Hill	Eng. Rec., Dec. 18, 1909, p. 688
30 ft.	Sides straight, roof circular	Pocahontas Tunnel, N. Y. C. & H. R. R. R.	Eng. Rec., Aug. 26, 1905, p. 245
27 ft.	Circular	Brooklyn Rapid Transit R.R.	Eng. Rec., May 12, 1906, p. 594
23 ft.	Circular	Selby Hill, St. Paul, Minn.	Eng. Rec., Sept. 21, 1907, p. 308
23 ft.	Side straight, top circular	Langsville, Ohio	Eng. News, Jan. 7, 1909, p. 11
19 ft.	Circular	North River, Penn. R.R.	Trans. Am. Soc. C. E., Vol. LXVIII, 1910, p. 280.
18 ft.	Circular	Kanawha & Mich. R.R.	Eng. News, Jan. 7, 1909, p. 12
18 ft.	Sides straight, top circular	Western Pacific Standards	Eng. Rec., Sept. 28, 1907, p.337
16 ft.	Sides sloping, top circular	Hodges Pass, Oregon Short Line	Eng. News, Dec. 6, 1906, p. 587
14½ ft.	Sides curved, top circular	Central Mass R.R.	Eng. Rec., Jan. 2, 1904, p. 6.
13 ft.	Circular	Shawinigan Falls	Eng. Rec., Apr. 4, 1908, p. 454
8 ft.	Circular*	Chicago Water Works	Eng. News, Oct. 22, 1908, p. 441

*Steel centering.

REFERENCES TO DESIGNS OF FORMS FOR SEWERS, CULVERTS AND CONDUITS

Span	Shape	Location	Remarks	Reference
25 ft.	Circular	Harlem Creek, St. Louis, Mo.	Steel sewer centering	Eng. News, July 30, 1908, p. 132
15 to 20 ft.	Groined	Reading, Penn.	Filter roof arches	Eng. News, Apr. 14, 1910, p. 424
4 to 20 ft.	Square	C.B. & Q.R.R.	Box culvert forms	Eng. Rec., Mar. 9, 1907, p. 338
18 ft.	Circular	Panama Canal	Steel culvert forms	Eng. Rec., Oct. 30, 1909, p. 484
13½ ft.	Circular	Brooklyn, N.Y.	Corrugated steel centering for sewer	Eng. News, Jan. 30, 1908, p. 116
8½ ft.	Oval	Jersey City Water Supply	Conduit forms	Eng. Rec., Jan. 16, 1904, p. 75
6 to 10 ft.	Oval and Circular	Torresdale Filters	Conduits and sewers	Eng. Rec., Feb. 13, 1904, p. 192
8½ ft.	Circular	Baltimore, Md.	Outfall sewer	Eng. Rec., Feb. 8, 1908, p. 164
8 ft.	Circular	New York, Ingleside	Steel invert forms for sewer	Eng. Rec., Nov. 9, 1907, p. 519
5 ft. 9 in.	Circular	New Orleans	Sewer forms	Eng. Rec., June 2, 1906, p. 679
5½ ft.	Circular	South Bend, Ind.	Sewer forms	Eng. Rec., June 16, 1906, p. 736
3½ ft.	Vertical sides, top circular	Salt Lake City Water Supply	Conduit form	Eng. Rec., Mar. 21, 1908, p. 353
1½ to 4 ft.	Circular		Small culvert forms	Eng. Contr., Dec. 16, 1908, p. 408

CHAPTER XVI

FORMS FOR REINFORCED CONCRETE

The variation in form costs and the difficulty in estimating them are apt to play havoc with estimates and determine the amount of profit, or frequently of loss, in the building of reinforced concrete structures. Other items of cost, such as the cost of the concrete materials and the labor of mixing and placing, may be separated easily and estimated as accurately as in any other class of construction.

The greatest trouble met with by the estimator is the lack of knowledge of what is a fair cost of the labor and especially of the comparative costs of different parts of the same work. It is the aim of this volume to treat the cost problem in such detail that the labor on different parts of the structure may be separated into units small enough to allow for the variations that are apt to occur under all ordinary conditions. At the same time the processes have been kept as simple as possible, the units combined for practical use, and a large number of tables provided, so that by the methods proposed the labor of making an accurate estimate is greatly reduced.

Unit times and costs are valuable not only for the making of estimates but also for use in the practical layout of the work so as to economize in labor cost. This phase of the question has been discussed in Chapters IV and V, pages 66 and 74. In form construction, especially in the making, it has been found possible, by methods such as we have described, and which have been adopted so successfully in shops operating under scientific management, to systematize the work and reduce the labor cost in a remarkable degree.

The treatment of cost of forms and economy in construction involves, for a comprehensive view, a discussion of many of the seemingly minor points in design and construction, as well as of the details of time and cost for doing the different parts of the work.

To satisfactorily consider the question of economy in form construction, it is therefore necessary to take up the following points:

(1) Materials for forms. (See p. 466)
(2) Steel versus wood for forms. (See p. 467)
(3) Economical thickness of form lumber. (See p. 469)

(4) Quantity of lumber required. (See p. 470)
(5) Old versus new lumber. (See p. 470)
(6) Number of times forms are used. (See p. 471)
(7) Design of forms. (See p. 474)
(8) Notes on economy of design of forms. (See p. 474)
(9) Tables to use in design. (See p. 475)
(10) Construction notes. (See p. 478)
(11) Organization of the construction gang. (See p. 478)
(12) Hoisting materials. (See p. 648)
(13) Removing forms. (See p. 483)
(14) Remaking forms. (See p. 484)
(15) Making up form sections. (See p. 485)
(16) Foundation forms. (See p. 488)
(17) Types of column form construction, with illustrations (See p. 488)
(18) Types of beam construction, with illustrations. (See p. 498)
(19) Types of girder construction, with illustrations. (See p. 504)
(20) Types of slab construction, with illustrations. (See p. 508)
(21) Types of wall construction, with illustrations. (See p. 517)
(22) Methods of measuring forms. (See p. 621)
(23) Allowance for various incidental and general expenses. (See p. 625)
(24) Home-office expense and profit (See p. 623.)
(25) Tables of quantities of lumber for forms. (See p. 618)
(26) Tables of times for performing different parts of the work. (See p. 658)
(27) Tables of times per member for labor. (See p. 630)
(28) Tables of costs per member for labor. (See p. 631)
(29) Tables of unit times. (See p. 664)
(30) Tables of over-all approximate costs. (See Chapter II)
(31) Methods of making up estimates. (See Chapter XXIII)

The times and costs of mixing and placing concrete are presented in Chapter XIII in a manner somewhat similar to our form treatment; the labor of placing steel and the quantities of steel for different designs are treated in Chapters XIX and XVIII respectively; approximate costs are scheduled in Chapter I; and cost data on actual jobs in Chapter II. Chapter XXIII summarizes the method of estimating and gives a form for practical use.

MATERIALS FOR FORMS

Forms must be so designed and built and the material used must be of a character that will produce surfaces and lines in the finished concrete that are even, smooth and true, without noticeable warps, irregularities, or lines of joints between different sections of the forms.

The most economical material is that which will produce this result with the smallest amount of manual labor in making and setting these forms, rather than the material of lowest first cost. The first cost, of course, must not be so excessive as to overbalance the saving in labor and material. As materials for form construction, wood, steel, cast iron, concrete, and brick, have been variously used.

Wood is most readily adapted to different designs, although it is expensive in construction and the waste is large. The treatment in this chapter is chiefly of wood forms.

Steel has been successfully used for conduits and is coming into use for other classes of concrete construction. (See p. 456.) The chief difficulties, as indicated in paragraphs which follow, lie in conforming to variations in design of the structure and in producing even surfaces.

Cast iron is expensive in first cost and costly to transport from place to place. In certain cases where it may be used repeatedly in buildings which are close together, it may be economical.

Concrete or mortar slabs sometimes have been made up in advance and then set in place to serve as forms. They are left in place permanently to make the finished surface of the structure.

Brick in the same way has been laid up for the faces of a column or wall and the interior filled with concrete. The brick, however, must be supported to resist the pressure of the concrete. The more common practice is to first build the concrete wall, using wood forms in the usual manner and then face the concrete with brick. Metal strips are attached to the form in such a way that they are cast in the concrete and when the form is removed they tear loose from it and serve as ties to bind in the brick face.

STEEL VERSUS WOOD FOR FORM CONSTRUCTION

Steel forms are very much more expensive than wood in the first cost, but can be used a larger number of times provided they can be adjusted to suit the variations in the design of the structure. When the structure is symmetrical throughout, as a conduit or tunnel, or where forms for certain parts, such as round columns, can be more readily shaped from steel than from wood and are repeated many times, the durability of steel may be a distinct advantage in reducing costs.

In ordinary work, such as building construction, the difficulty lies in adjusting the steel forms to different dimensions of members and to different buildings which vary even very slightly in design. If the steel is lapped to change the dimension, the joint is apt to show badly in the finished concrete surface. Furthermore, when the steel sheathing is made thin enough to be light in weight and of moderate cost, it dents and warps in handling, so that uneven concrete surfaces* are produced.

LUMBER FOR FORMS

The character of the work and the lumber markets generally determine the kind of lumber to use for forms. For very nice work where exceptionally smooth surfaces are required, as in moldings and other ornamental designs, white pine is the best material to use. For ordinary work, it is too expensive and too soft to be durable where forms are used over and over again. Spruce, Norway pine, and Southern pine are generally the most available. Short leaf pine makes excellent sheathing. Spruce, in sections where it is readily obtained, is perhaps the best material for studs, joists, and posts. Hemlock is too coarse grained for sheathing and is unsafe for supporting heavy framework. The hard woods are too expensive to work.

Lumber should be free from shakes and rot and as free as possible from knots. Knots will show on the finished surface of the concrete and of course will weaken lumber which is used for supporting forms.

Partly dry lumber is better than kiln dried, which will swell and bulge at the joints, and better than green lumber, which will shrink if not kept wet, so as to leak badly when the wet concrete is placed.

FINISH OF LUMBER

Even for rough work it is generally best to use lumber for sheathing that is dressed at least on one side and two edges to make the boards of uniform width so that they will fit together. Even if the appearance of the concrete is of no account, the smooth form surface will reduce the labor of removing and cleaning the forms.

It is still better to use lumber dressed on all four sides. The first cost is so little more that it will be over-balanced by the convenience in handling and working up and placing.

*Steel forms are discussed by W. L. Caldwell in Proceedings National Association of Cement Users, 1908, p. 286. Also by Frank B. Gilbreth in Journal American Society of Mechanical Engineers, May, 1910.

Tongue-and-grooved stock is most common for sheathing, although shiplap is used sometimes and beveled edge is preferred by many, especially with dry lumber, so that when it swells the edges will crush without warping. Beveled edge stuff is cheaper than tongue-and-grooved because with the latter there is $\frac{3}{4}$-inch waste in the width of every board or plank. On the other hand, for sheathing which is to be used over and over again, the tongue-and-grooved stock holds its place better and gives smoother surfaces.

The thickness of face boards should be absolutely uniform to prevent unevenness in the surface of the concrete.

THICKNESS OF LUMBER

The dimensions of posts, studs, and joists are governed by the strength and stiffness required. The tables in Chapter XX are arranged for assisting in the design of forms. The thickness of sheathing for walls and floor forms is also treated there.

ECONOMICAL THICKNESS OF SHEATHING FOR BUILDING CONSTRUCTION

Studies from the unit costs of the authors show that 1-inch lumber, that is, $\frac{7}{8}$-inch after dressing, averages for column forms about 16 per cent cheaper to make and about $7\frac{1}{2}$ per cent cheaper to erect the first time than $1\frac{1}{2}$-inch stock. The 1-inch ($\frac{7}{8}$-inch) is about 15 per cent cheaper to erect the first time than 2-inch. This lighter stock is easier to patch also than the heavier. On the other hand, 1-inch stock is not so durable and is more apt to break when removing the forms, so that thicker material is advisable in certain cases where it has to be used a large number of times.

As to cost of material, the thicker sheathing permits spacing of studs or joists further apart, but since the quantity of lumber in the studs or joists is apt to be governed by the strength required to resist the weight or pressure, the saving in material here is not enough to balance the excess cost of the thicker sheathing.

In general, therefore, 1-inch stock, ($\frac{7}{8}$-inch dressed) is recommended for slab forms and for sides of beams and girders. For the bottoms of beams and girders, 2-inch stock ($1\frac{7}{8}$ or $1\frac{3}{4}$-inch after dressing) should be used for ordinary work and $1\frac{1}{2}$-inch for narrow members. For columns $1\frac{1}{2}$-stock is recommended because of its greater durability.

If slab boards are not built in panels but are nailed on to joists at each resetting, 1-inch stock is too thin and $1\frac{1}{4}$ or $1\frac{1}{2}$-inch should be used instead. Also, if sheathing is used many times for floor slabs, say, more than six times, especially if the lumber is soft, $1\frac{1}{4}$-inch stock is preferable to 1-inch.

Salvage on the completion of the job is greater with thicker stuff, but not enough greater to balance the higher first cost and the more expensive handling, unless the builders have a structure practically identical in design which they are to put up immediately.

QUANTITY OF LUMBER FOR FORMS

Form lumber should be ordered by definite schedule made up from the design of forms, as discussed on page 475.

For estimating the cost of the structure, a common plan is to assume a certain thickness of lumber per square foot of form surface, using different thicknesses, which may vary from 2 to 5 inches, for different parts of the structure. This method of estimating is discussed in Chapter XXI, where also is given the description of tables made up by still more accurate methods, from which the quantities of lumber for different members may be taken directly.

USE OF OLD VERSUS NEW LUMBER

Since lumber for forms costs \$20.00 to \$30.00, or even more, per 1000 feet B. M., while labor on forms for building construction (see p. 8) averages \$15.00 to \$20.00, it would appear to be cheaper to spend considerable extra labor on old lumber than to use new. It is a general principle in ordinary carpentry work that old lumber should always be used where possible. In form building the conditions are somewhat different because the cost of taking apart small sections may actually count up to a larger sum per 1000 feet B. M. than the actual cost of the new lumber, while at the same time the cost of rebuilding it is also increased.

The cost of making over old forms, when the dimensions are near enough alike to avoid excessive work, has been found by observation to be about 90 per cent greater than making up the same forms from new lumber.

As a general rule, new lumber is advised for patching, especially where odds and ends from the saw mill are available.

It must not be understood from the above that the authors advise throwing away old stock that is in fairly good condition. On the other hand, where this old material has been used many times and is somewhat injured or in short lengths, its value is very small.

Where forms have to be taken apart and rebuilt or used for other purposes, very light nailing is of great advantage.

NUMBER OF TIMES TO USE FORMS

The cost of the form lumber, no matter what method of figuring is used, depends upon the number of times the forms are used. For example, in a one-story structure the whole cost of the lumber (less its salvage), as well as the entire cost of making, must be charged to the surface or volume of concrete in this one floor.

The following example illustrates the error in not taking into account the number of times the forms are used. Suppose the column form lumber at \$30.00 per thousand feet B. M. averages in first cost \$0.16 per square foot of surface, including sheathing, supports, and bracing (see p. 470). If used for a one-story structure, the lumber cost is therefore \$0.16 per square foot in addition to a labor cost of, say, \$0.045 for making and \$0.155 for erecting and removing, or a total of \$0.36. If the lumber, on the other hand, is used three times without alteration, the cost per square foot of surface is $\frac{1}{3}$ of \$0.16 = \$0.053 for the lumber plus $\frac{1}{3}$ of \$0.045 = \$0.015 for making, plus \$0.155 for erecting and removing, or \$0.22 for the total cost per square foot of surface as against \$0.36 for the one story building.

Notwithstanding this direct effect upon the cost, the number of times moving is frequently not considered at all in estimating even by those who are otherwise accurate in their methods.

The number of times that forms are used in building construction generally depends upon the size and height of the building, which limit the number of times to use, rather than on the actual wear upon the forms. In other words, forms are not generally worn out when discarded, and frequently the same lumber can be used in two large buildings, provided the two are substantially alike in design, although of course with a greater labor cost.

As a rough estimate of the life of forms in building construction before they are worn out, we may suggest: walls, 16 times; columns, beams and girders, 10 times; floor forms, 6 times, if of soft lumber like spruce, or 10 times if of Southern pine. These times apply to 1-inch stock.

Number of Sets of Forms in a Building. The number of sets of forms to make up for any building varies with the speed of construction required, weather conditions, and shape of building.

On an average $1\frac{1}{2}$ sets of forms is a fair allowance. With this number, erection on the floor above can begin while the concrete below is green, so that in good weather a story can be built in a week or ten days.

Some large building contractors have adopted the use of only one set of forms in a building, whether it be 2 stories or 10 stories high, with additional lumber for girder bottoms and supports that must be left in place.

A building of large floor area may be built in sections, setting up, say, one-half of a floor area at a time, so that forms for only about three-fourths of one floor are needed with the extra beam bottoms and posts. On the other hand, if the building is small in area and high, two sets of forms may be needed in order that the work may progress fast enough.

Sometimes because of low basements or heavy columns the basement forms cannot be remade economically for use on the floors above; in other buildings these forms cannot be removed because of heavy construction loads on the first floor which would exceed the capacity of the concrete alone. In such cases, they must be figured as an extra set.

The weather has a decided effect upon the time of form removal. In the cool weather of the spring and fall, even if there is no frost, concrete hardens slowly, so that the forms may need to remain for several weeks, or even until the building is completed, and then taken down very carefully. Concrete should never be allowed to freeze.

The above discussion illustrates the necessity of considering each individual building independently in estimating form lumber, instead of assuming for all an approximate price per square foot or per cubic yard of concrete.

In our treatment of average costs of buildings, page 40, definite selections are made for different conditions.

TIME TO REMOVE FORMS

The time that forms have to remain in place depends upon the character of the members, weather conditions, the span, if a beam or slab, and the relation of the dead to the live load.

Vertical members, such as walls thicker than 4 inches, or columns, will bear their own weight when quite green, while horizontal members, such as floors, must harden until the concrete can sustain the dead weight and the load during construction.

The weather conditions greatly affect the setting and hardening of concrete. Heat causes it to harden quickly while cold retards the hardening and therefore prevents early removal of forms. If, through accident, the concrete should be frozen, it will not begin to harden until it has thawed and then it may require several months to attain the strength usually reached in two or three weeks.

A long span beam or slab must be supported, in general, a longer time than a short one, chiefly because of the larger dead load. If the dead load, *i. e.*, the weight of the concrete, is heavy in comparison with the live load, *i.e.*, the load which the floor must bear later on, forms must be left a longer time, because the compression in the concrete is large even before the live load comes upon it.

Experienced builders have definite rules for the minimum time which the forms must be left in ordinary weather, and then these times are lengthened for poor weather conditions and special members according to judgment.

As a guide to practice, the following rules are suggested:*

Walls in mass work: One to 3 days, or until the concrete will bear pressure of the thumb without indentation.

Thin walls: In summer, 2 days; in cold weather, 5 days.

Columns: In summer, 2 days; in cold weather, 4 days, provided the girders are shored to prevent an appreciable weight reaching the columns.

Slabs up to 7-foot spans: In summer, 6 days; in cold weather, 2 weeks.

Beam and girder sides: In summer, 6 days; in cold weather, 2 weeks.

Beam and girder bottoms and long span slabs: In summer, 10 days or 2 weeks; in cold weather, 3 weeks to 1 month. Time to vary with the conditions.

Conduits: 2 or 3 days, provided there is not a heavy fill upon them.

Arches: If of small size, 1 week; large arches with heavy dead load, 1 month.

*See also paper on "Form Construction" by Sanford E. Thompson, in Bulletin No. 13, Association of American Portland Cement Manufacturers, and Proceedings National Association of Cement Users, Vol. 3, p. 64, 1907.

All these times are of course simply approximate, the exact time varying with the temperature and moisture of the air and the character of the construction. Even in summer, during a damp, cloudy period, wall forms sometimes cannot be removed inside of 5 days, and other members are delayed proportionally. Occasionally, too, batches of concrete will set abnormally slow, either because of slow setting cement or impurities in the sand, and the foreman and inspector must watch very carefully to see that the forms are not removed too soon. Trial with a pick may help to determine the right time. One large builder* requires that a 20-penny spike driven into the concrete must double up before it has penetrated one inch.

A plan which is being introduced on some of the best construction work is to take a sample of concrete from the mixer once or twice a day and allow it to set out-of-doors, under the same conditions as the construction work, until the date when the forms should be removed, then, before beginning to remove, find the actual strength of the concrete by crushing the blocks in a testing machine to see whether it is strong enough to carry the dead and the construction load.

DESIGN OF FORMS

On pages 488 to 524 the designs of forms for different members in a concrete building are discussed at length with suggestions as to economy. Sketches of typical designs are there given. Before presenting this discussion a number of important details relating to form construction will be taken up.

DESIGN OF FORMS BY FOREMEN

A practical foreman or superintendent is apt to see the points of advantage for cheap construction and quick removal, and his judgment is better than that of a draftsman of ordinary experience. However, the plan of leaving the design entirely to the discretion of the men on the job results in haphazard design, delays of the carpenters, and usually an excessive amount of lumber used. A careful practical man is bound to average farther on the safe side than is necessary, while occasionally he will make an error in judgment in a place where computation of strength is the only means of determining the proper spacing of supports.

*Mr. C. A. P. Turner.

It is absolutely wrong, therefore, on any important job, to leave the design to the foreman alone. On the other hand, it is just as bad to leave it to the draftsman of little or no practical experience.

FORMS SHOULD BE BUILT FROM PLANS

The forms are not a part of the permanent structure but this is no reason why so little attention should be paid to their design. As already stated, they constitute the most expensive part of the labor cost in reinforced concrete and time spent on plans in the drafting room is repaid over and over again by saving in the field, provided the plans are made up under the direction or with the assistance of the builder or superintendent so as to take advantage of his practical ability.

The thickness of lumber and the spacing of supports for the most economical design under different conditions, may be obtained directly from tables in Chapter XX.

FORM LUMBER CUT BY MILL SAW

Even on a comparatively small job a mill-saw run by power should always be provided. It will pay for itself in the saving of time of the carpenters.

In systematizing construction work, Mr. Thompson has found it usually the cheapest plan to make out a lumber schedule from the drawings so that the lumber will be ordered direct from the mill to exact widths and even foot lengths. By ordering the boards or planks in two or in three standard widths the number of sizes will not be excessive and the waste will be small. Before making up, the boards can be routed to the saw mill and cut to exact lengths. Either before or after making up, the odd boards can be ripped on the mill saw.

In certain cases where forms are of fairly uniform sizes, it may be cheapest to schedule all the pieces, ordering to the exact lengths and widths required. This plan has been followed by Mr. Herbert W. Goddard of the R. H. Howe Construction Co.

IMPORTANT DETAILS IN FORM DESIGN

Economy of labor, not only in making, but in removing the forms, remaking, and resetting depends upon the small details of design and construction. A few points, therefore, may be mentioned which conduce to cheapness in making up, erecting, and removing.

Design to Permit Removal in Definite Order. The most convenient and logical order of removal is (1) column sides, (2) joists, (3) girder sides, (4) beam sides, (5) slab bottoms, (6) girder and beam bottoms. Walls are often built independently of the rest of the building and forms may be removed whenever the concrete is hard enough.

Design Forms to be Easily Removed. The forms must be designed so as to be easily freed without damage to themselves or to the concrete.

Wall forms between pilasters are liable to bind if in one piece and some builders advise dividing them in the center. An objection to this middle joist, however, is the danger of its showing badly in the finished concrete.

Slab forms in a floor bay are preferably divided into 4 sections with joints at right angles so that they can be removed without binding.

Beam bottoms may rest on column sides, but should be made with a slight play so that swelling will not bind the beveled end.

Where a length of form cannot be prevented from binding, a narrow strip may be nailed across the end to be broken out with the aid of a crow bar when the forms are being removed.

Tapering Beams. If the beam form is to be taken down as a unit, it is advantageous to slightly taper the sides of the beam, making it narrower at the bottom. This also makes it easier to free the column forms which have to be taken down first.

Mill Widths of Boards. When fixing the exact dimensions of a concrete beam, they frequently may be arranged to fit mill widths of boards or planks or else a slight leeway in the dimensions may be allowed the builder. For example, instead of making a beam $9\frac{1}{2}$ inches in width, it will be cheaper to make it $9\frac{3}{4}$ inches wide so as to fit a 10-inch plank planed on its edges. In some sections of the country, widths do not run exact enough to make this plan worth considering.

Buying Lumber to Length and Width. Sometimes the design of the concrete, even to the length of the beams, may be made to conform to standard lengths and widths of lumber in the locality, thus saving expense and waste of cutting. The ordering of lumber in the mill to exact lengths and widths has been referred to on page 475.

Uniform Story Heights. Keep the story heights the same throughout the building where possible. In a wood frame building or even in a steel frame, there is little advantage in uniformity. In reinforced concrete work, however, cutting down or lengthening forms is very expensive.

Exterior Columns of Uniform Width. The appearance of a building is improved by running up exterior pilasters of uniform width, or, possibly, with a single change in width. This also results in a saving in the cost of column and wall forms. To save concrete, the thickness of the wall columns may be reduced coincidently with the change in the dimensions of interior columns.

Reducing Size of Columns. To avoid frequent changes in column sizes, the column reinforcement may be varied in successive stories. It is frequently cheaper to use the same size of columns on successive floors than to reduce the size. Mr. Leonard C. Wason* states that in one case the saving in concrete by reducing the size was $2.30 per column; on the other hand, the increase in form cost was $5.70 per column, entailing a loss of $3.40 per column. This reference is of interest because of its close agreement with results from tables in this book. Computing the average cost from these tables we find the loss to be $3.37 per column, thus checking almost exactly with Mr. Wason's figure.

A reduction in column size necessitates lengthening the beams and girders running into it as well as reducing the column forms.

Bevel Strips. The appearance of all members is improved by avoiding square corners. Triangular pieces, usually called V-strips or bevel strips, may be inserted in all corners, or the edges and ends of the sheathing lumber may be beveled. Triangular strips across the end of planks or boards prevent the end grain of the wood showing on the finished concrete. They also make form removal more easy.

Strength. Forms must be strong enough to bear the weight of the concrete and of the construction load which comes upon them. For floors, 75 pounds per square foot is sufficient to cover ordinary construction work, except storage piles of cement or sand, even where the concrete is handled in cars. In many cases, a still smaller construction load of 50 pounds is enough.

Vertical forms must be strong enough to resist the pressure of wet concrete.

The tables in Chapter XX give necessary dimensions for form lumber to resist definite weights and pressures.

Rigidity. While the rigidity of the forms must be left in a measure in the hands of the field superintendent, the plans for the forms should

*Proceedings, National Association of Cement Users, Vol. V, 1909, p. 38.

show the amount and dimensions of the bracing so that they will neither be omitted nor used in excess.

Smooth Walls vs. Pilasters. Long smooth walls are cheaper than pilaster construction but do not look so well. In a long wall it is difficult to make and keep the forms in perfect alignment.

CONSTRUCTION NOTES

However carefully the forms are designed, the chief points in economy lie with the constructor in the field, the organization of his men, and the methods he employs in making up, erecting, and removing the forms. A thoroughly organized job requires a planning department and an exact layout of the work in advance as described in Chapters IV and V.

Marking Sections of Forms. Whether made up at the saw mill where the lumber is purchased, the saw mill on the job, or by hand labor, the sections should be marked distinctly to designate their position in the building.

A system of marking by combination of letters and figures is convenient to save the labor of writing words.

Form Sections. The construction of forms is simplified by the necessity of dividing them into units or sections. For example, the side of a column is a column unit and this differs in construction from the beam unit or the slab unit. The work on each of these units is necessarily divided into making, handling, erecting, and removing, so that the work naturally divides itself into definite operations.

Having established a systematic layout, the next step will be to fix a time for performing each operation so that the men may be paid in accordance with the task which they accomplish. This will eventually result in an immense saving in cost of construction, and at the same time give higher wages to the carpenters and laborers. The tables in the chapters that follow are based on the results of time study although they apply to average conditions rather than task-work.

Organization of Men. The difference between a fair profit and an actual loss may easily lie between a good superintendent and a poor one. Whatever the ability of the superintendent, however, the speed and quality of the work are improved by insisting upon a definite organization, systematized so that each carpenter and each gang of laborers have definite work to do and jobs follow one another in definite order.

With this in view, the carpenters should be divided into small gangs, usually consisting of 1 or 2 men each.

Each gang should repeat the same work over and over. They may: lay out the work; make one kind of form unit repeatedly; set columns; brace columns; set posts; set girders; attach end of girders to columns; set beams; attach end of beams; and so on.

Different designs require different arrangements, but the various operations should be arranged in sequence so that one gang will follow directly upon another and yet not interfere with it. The times required by the different gangs should be as nearly equal as possible. Some parts of the work may require a gang of 2 men, other parts two gangs of 2 men each, while some operations can be performed most economically by a single carpenter. In some cases if one gang has harder work to do, it may be started considerably ahead of the gang on the next operation, so as not to interfere with it.

The principle is to get each man accustomed to and expert in his work, to give each man a definite thing to do, and finally to let each man feel that he must work steadily in order to keep up to the gang ahead of him or out of the way of the gang behind. In order to carry this out to the best advantage, Mr. Thompson has adopted in construction work a system similar to that used so successfully in scientific management in shop-work. The work of each man is planned in advance and the lumber and materials are routed to him so that no time need be wasted. This in itself has been found to effect a great saving in labor cost. The general principles of the plan are outlined in Chapter V.

Laborers' Work. Laborers should not make forms or set them up. They should carry and hoist all the materials, bring the sections per unit to the carpenters, provide the carpenters with bracing lumber, blocks and wedges, and do most of the work of form removal.

To do this, the laborers, like the carpenters, must be organized and under the supervision of one or more first-class bosses. On a small job much of such labor falls to the concrete gang. These men, unless watched every minute or given a definite task, will be apt to work simply to kill time, and will take three or four times longer than necessary on miscellaneous jobs like carrying form lumber. It has been found practicable to plan the work of the labor gang moving material in a manner similar to that employed with the carpenters.

Under ordinary management from 5 per cent to 10 per cent can be saved in labor cost of form construction by giving laborers the work outlined above. With scientific management the saving is still greater.

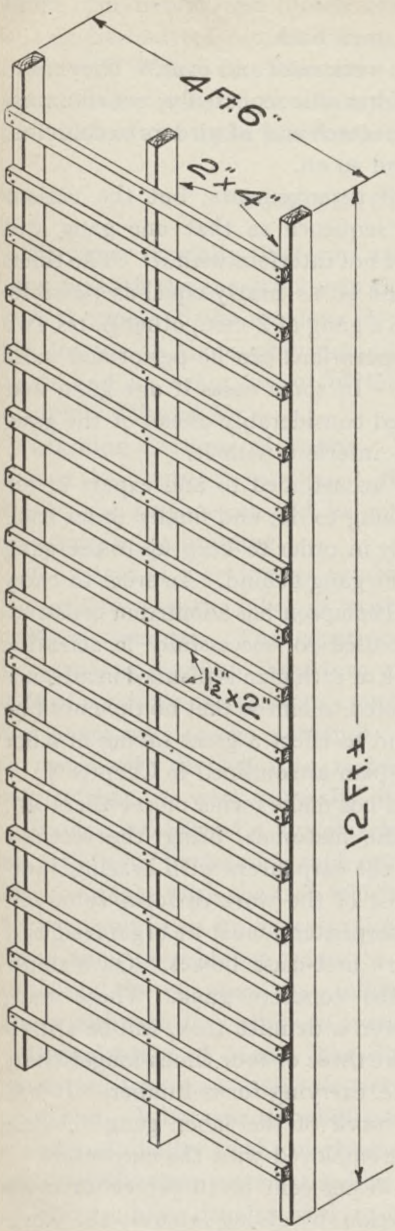


FIG. 45. Construction Ladder (See p. 480)

Mill Saw. If the total cost of the concrete on the job (labor and material) is over $20 000, a circular swing arm saw and a table saw on the job will be economical. For a large job a planer and a boring machine should be added. On small jobs the men who run the saw can work on other jobs when not busy. Proper operation of a saw mill means the layout of the work in advance according to definite plans and the careful marking and piling of the pieces sawed.

Raising Saw from Story to Story. If the saw is run by a motor, it can be raised from story to story so as to permit the remaking of the forms on each floor or every other floor as the case may be. This avoids the cost of lowering the forms to the ground and hoisting them again.

Staging. Men will do more work and do it easier with plenty of staging.

Sometimes it is economical to build a wide staging on the level of each floor to avoid extra travel and interference with the work.

Stairs should be built at an angle not steeper than 45 degrees. Staging and runs should be built with enough headroom to allow men to walk without stooping.

Ladders should have a slope of about 2 feet horizontal to 4 feet vertical. A construction ladder is shown in Fig. 45.

Making Up Forms. Plans, if provided, should be followed exactly or altered only with the approval of the builder before work on them is begun.

Sections to be used over and over must be securely nailed. On the other hand, all joints that are to be taken apart should have as few nails as possible. The sheathing of wall forms, for instance, if to be removed board by board, requires only enough nails to take out the wind of the boards and hold their own weight till the concrete is placed. Methods of making sections are discussed more in detail on page 485.

Accurate Measurements. One of the difficulties in form construction is in setting the forms level and true enough to line to avoid a lot of subsequent labor straightening and adjusting. This trouble is largely due to inaccuracies in making up the forms. If the widths of the column forms are exact and the beam forms are cut to exact length, the wall columns must come plumb and true. Accuracy in level is somewhat more difficult to obtain if the forms are set upon concrete which is not absolutely smooth, and, in such cases, they must be brought up to line and level by wedges.

Good vs. Poor Carpenters. In accuracy of workmanship the difference between the good and the poor carpenter is manifest. Cheap skilled labor is always expensive, and because form construction is necessarily somewhat rough and temporary, there is a tendency to think that any carpenter is good enough. Just the reverse of this is true because the poor man will take more time and material to construct the forms and then his work will require more labor after it is set. Of course it is possible to go too far to the other extreme, for example, a carpenter who is skilled simply in cabinet work will spend too much labor on parts that can be done merely with a saw and hatchet. Nicely planed joints are absurd on form construction.

Alignment of Forms. The columns must be laid out in a systematic manner. After marking their exact locations on the floor they must be set true and plumbed, the beams must be without wind and either level or with the required camber, and the slabs must be level and true. In some cases, especially in a large building, labor is saved by leveling up the forms with an engineer's leveling instrument.

If much time elapses between the erection of the forms and the concreting, the lines and levels should be checked to see that the forms have kept their shape.

The details of construction should receive careful attention. See that nuts are tight on the bolts; wedges securely driven and tacked with a nail if necessary; wire ties taut; bolts greased; and spacers between wall forms removed before concreting. Tie bolts should not be run through walls near corners because there is danger of cracking the concrete when they are drawn. Joints in forms should be tight enough to prevent leakage of cement, as any leakage will tend inevitably to form pockets of stone or coarse sand on the surface of the concrete.

Camber. When a load is placed upon any structural member like a beam, the stresses cause it to bend or deflect a little. In forms there is a slight movement, due to the adjustment of the wedges under load and the compressing of the wood, so that it is advisable to raise the beam forms slightly higher in the center than at the ends. A rough rule for this is to assume a deflection of the forms equal to $\frac{1}{4}$-inch in every 10 feet of length.

Bevel or V-strips. The putting in of bevel strips or triangular pieces has been referred to on page 477. When possible, fasten these to forms when making, instead of leaving it to the erection gang.

Wedges. Always drive wedges in pairs to give an even bearing, as shown in Fig. 49, page 493.

Forms Strong but not too Strong. A foreman will frequently say that to be on the safe side he will put in an extra set of posts or braces. This is proper if there is any doubt, but such things are really a matter of design, and the number of posts can be determined by figuring or by reference to tables such as are given in Chapter XX.

Forms should be well braced, but the braces should be designed to resist all tendency to slide and may be useless if put in without thought.

Nailing. Where the pressure of the concrete tends to tighten the joints or where the tightness is assured by clamps, nails may be only partly driven, which leaves the heads projecting so that they can be easily drawn.

A special form of double headed nail, designed for easy drawing, is now on the market.

Anchoring for Upward Pressure. Liquid or semi-liquid concrete will produce an upward pressure when pouring under horizontal or inclined forms. An example of this is in a flaring column footing. Such inclined forms must be fastened to prevent their lifting.

Straightening Forms when Pouring Concrete. Many builders detail one or two carpenters to see that forms are not thrown out of true as the concrete is being poured. This is good practice, but at the same time it must be impressed upon the carpenters that it is absolutely wrong to straighten forms after the concrete has begun to dry out or stiffen. Common sense should teach this and yet the authors have known good house carpenters to line up wall forms the day after the concrete was poured. Of course the concrete cracked so that it had to be removed.

Time Lost in Holding Forms. Much time is wasted unnecessarily in form construction by one carpenter holding a form while another nails or saws. On one job, for example, a job fairly well organized, 40 per cent of the total time of carpenters erecting a column form was occupied in holding the sections in position.

Oiling. Forms should usually be oiled before they are set in place, by laborers and not by carpenters. By using not a grease but an oil, like crude oil, which is a petroleum product, it will soak into the wood and the forms will not be too greasy to handle.

If the surface of the concrete is to be plastered, the forms must not be oiled but instead must be thoroughly soaked with water. Sometimes even oiled forms require wetting on hot days to prevent shrinkage. In freezing weather, forms should not be wet.

Cleaning Forms before Concreting. To remove shavings and dirt, clean-out holes must be left at the bottom of wall forms and column forms. For cleaning beam and slab forms, a steam hose or a fire hose may be economically used. This should be done by the concrete gang and not by carpenters.

Be sure to close these holes before concreting.

Hoisting Materials. Costs of hoisting materials with breast derricks are given in Table 155, page 648.

REMOVAL OF FORMS

The best gang for the removal of forms consists of enough laborers under a labor boss to just keep the carpenters busy either remaking or resetting the forms.

The forms should be set in the first place so that they can be taken down without the use of sledges or heavy bars, which are liable to break the forms and injure the concrete. Notes have been given already on methods of making that will facilitate the removal. Methods of removal are discussed more in detail on page 476.

Tools for Removing Forms. Special tools should be made up, so as to remove the forms quickly and with as little injury as possible. A bolt puller and a wrecking bar are illustrated in Fig. 46, page 484.

Cleaning Forms after Removal. Forms must be cleaned before rebuilding. Concrete which sticks to them can be removed most easily immediately after they are taken down.

If a section of forms has been badly oiled so that the concrete sticks once, a rough surface is left on the lumber and it is difficult to prevent sticking when the forms are used again.

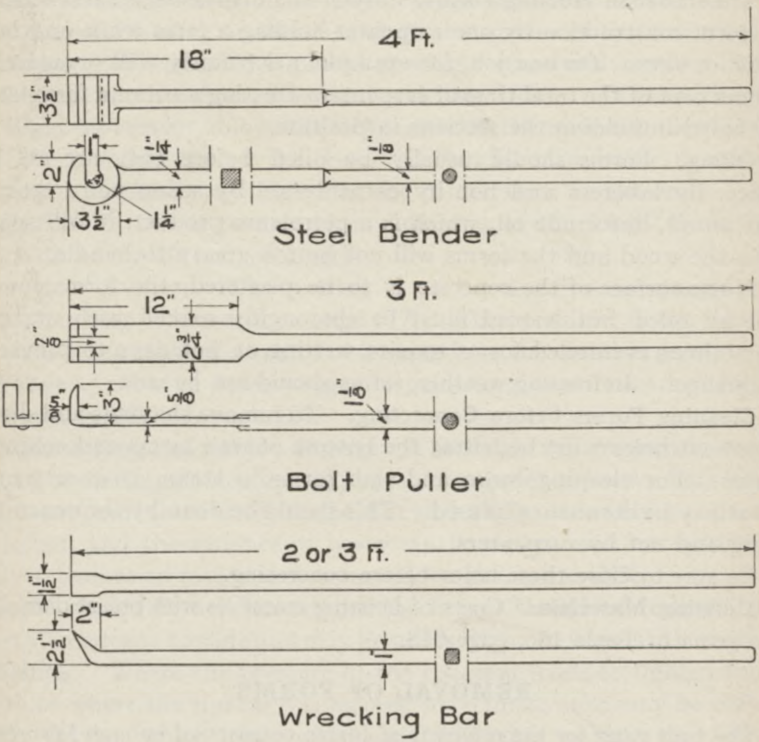


FIG. 46. Tools for Removing Forms and for Bending Steel. (See pp. 483 and 562).

REMAKING FORMS

The raising of the mill-saw from story to story has been referred to on page 480, and the use of old versus new lumber on page 470.

Remaking is one of the largest items of cost, and thus offers the greatest opportunity for waste of labor and material. The ease of remaking depends to a large extent upon the original design and upon the care in the first erection.

EFFECT OF DESIGN OF FORMS UPON THE LABOR COST

Economy in form construction depends in a large degree upon the design, and the labor of construction upon the type selected. In order to present times and costs of form construction that can be used without question, therefore, it is necessary to show very clearly the methods and details of design on which they are based. The values in the tables in Chapter XXII, are based on certain well-defined designs clearly shown on the following pages in drawings prepared by the authors. Minor changes in detail will not greatly affect the cost. The various sketches presented may be of considerable assistance to the designer of forms, since all of the drawings are based on actual construction work. By our methods of unit time-study it is possible, further, to indicate, in many cases, which is the most economical type; or to show that the difference between different types is so slight that a man may select that which best fits the job under consideration.

MAKING FORM SECTIONS ON BENCHES

The making up of sections of forms that are duplicated over and over again is essentially shop work, even though the work is done on the job. It is easier to systematize this work than to systematize the operations of erecting or removing.

The pieces should be cut to length on a mill-saw and made up on benches, the work being carefully laid out in advance.

The following scheme may be followed to good advantage:

(1) Design the section, indicating by a drawing or sketch the thickness, length, width, and number of boards or plank, the size of the cleats, the location of the cleats, the number and location of nails, and the size of nails.

(2) Number each section to correspond to number on plan; for example, beam sides may be designated as BS1, BS2, etc.

(3) Mark on the plan each piece of lumber in the section. The like pieces on different sections, that is, pieces of the same width, thickness and length, may have the same mark. In this way, when passing through the saw-mill, pieces that are cut alike can be sawed in one lot regardless of where they are located in the forms.

(4) Design in this way, either by sketches using carbon paper, or by regular drawings and blue prints, all the forms to be used on the job, except the comparatively few sections, like foundation forms in rough places, that cannot be laid out in advance.

(5) Take off schedule of all the lumber in these designs just as one would schedule steel, indicating the mark, the sections requiring each mark, the sizes, etc.

(6) Order lumber from mill either cut to exact widths and lengths, as per schedule, or else in such a way as to have as little waste as possible.

(7) Deliver lumber to yard piled so that any pieces can be readily found. Each pile should be distinctly marked.

(8) Saw the lumber to schedule, marking each.

(9) Pile by marks or deliver at once to bench where form sections are to be made up.

(10) Lay out each section on a bench, using the drawing or sketch as the Instruction Card. The bench is described below.

(11) Make all the like sections of forms at one time.

(12) Pile sections and deliver to proper location by laborers working under a labor boss. Use hand carts wherever possible for transportation.

This method of work means a system that cannot be handled by the office force generally employed on a construction job. A man is needed to plan the work and another man is needed to see that the lumber is properly marked and piled and "routed" to the place where it belongs. On a small job these two duties or functions may be given to a single man.

The extra cost of these men, even if the job is so large as to require a special department with several assistants, will be made up many times over by the saving in time of the carpenters who make up and erect the forms. Not only will the forms be made much cheaper, but they will be made accurately so that they will fit together in place and the labor of sawing and fitting in erection will be avoided. Furthermore, with a job organized in this way it is a comparatively simple matter to take time-studies on the workmen and lay out definite daily tasks for each man.

Work Benches. If a contractor or builder has considerable work in one locality, well constructed benches that may be carried from one job to another are economical. A style of bench that has proved satisfactory in practice is shown in Fig. 47, page 487.

In laying out a section, cleat holders are tacked across the bench so that the cleats may be dropped between them, the boards or planks are laid on top of them, then clamped and nailed. If the cleats are 1-inch thick and the section is to be used over and over again it must be turned over and the nails clinched.

For beam sides and column forms the cleats should be of such size

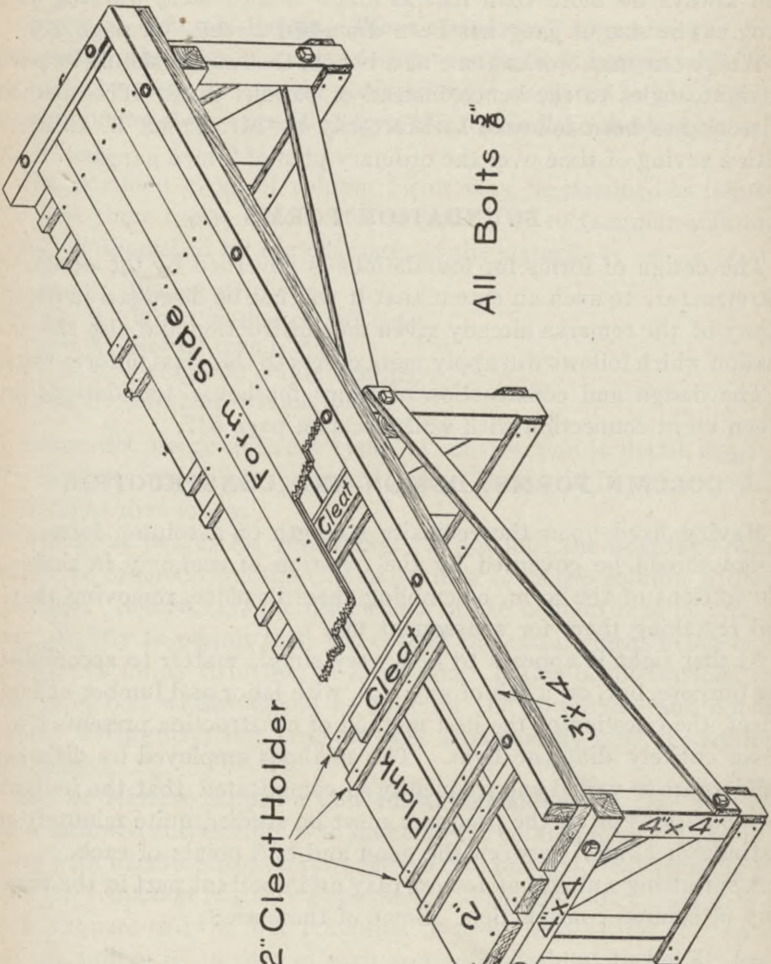


FIG. 47. Carpenter's Bench for Making Up Forms. (See p. 486.)

and so located as to serve as clamps when erecting the forms. Wherever possible, one carpenter should work at a bench. This is contrary to ordinary practice, but where the work is not too heavy, one man will always do more than half as much as two men, working as a gang. The size of gang has been discussed already on page 479.

Where one man works alone at a bench, the lumber should be piled at right angles to the bench instead of parallel to it. This method of work has been followed satisfactorily by Mr. Frank B. Gilbreth with a saving of time over the ordinary plan of 2-men gangs.

FOUNDATION FORMS

The design of forms for foundations is governed by the design of the structure to such an extent that it will not be discussed in detail. Many of the remarks already given on construction and also the discussion which follows will apply more or less to this class of form work.

The design and construction of forms for house foundations are taken up in connection with wall forms on page 517.

COLUMN FORMS: DESIGN AND CONSTRUCTION

Having fixed upon the requisite strength of a column form, the design should be governed by the question of economy in making the sections of the form, assembling them in place, removing them, and remaking them for subsequent use.

At first sight it appears to be a very simple matter to accomplish the purpose, but, on a job of any size, with labor and lumber at high prices, the question of the best method of construction presents itself in an entirely different light. The methods employed by different builders are so varied and frequently so complicated that the individual operations of all the processes must be studied quite minutely to distinguish clearly between the good and bad points of each.

A surprising number of factors play an important part in the economy of column construction. Some of these are:

(a) Kind of lumber.
(b) Thickness of lumber for sheathing, *i.e.*, whether 1, $1\frac{1}{4}$, $1\frac{1}{2}$ or 2-inch stock.
(c) Dressing, *i.e.*, whether square edge, tongue-and-grooved, shiplap, or bevel edge.
(d) Width of lumber for sheathing.
(e) Method of making forms.
(f) Kind of clamp to use.

(g) Number of clamps for each size of columns.
(h) Method of placing clamps.
(j) Method of erecting forms.
(k) Method of removing and transporting.

Types of Column Forms. When reinforced concrete was first introduced, the sides of column forms were made of horizontal boards set piece by piece, so that the concrete could be placed in thin layers. Now, columns always are filled from the top and the sheathing usually is vertical.

The common types of column forms may be classified as follows, the first three types, which refer to square or rectangular columns, being distinguished by the character of the clamps.

Type 1 Wedge strip type.
Type 2 Wood wedge clamp type.
Type 3 Bolted clamp type.
Type 4 Octagonal column forms.
Type 5 Circular column forms.

Before discussing different types of construction in detail, some of the elements which are common to all of them will be considered in paragraphs that follow.

Widths of Boards for Sheathing. If possible, the boards or plank should be ordered from the mill of a width to fit the column without splitting. Sometimes, the dimensions of the column may be altered very slightly to permit this, the cost of the extra widths being more than made up by reduction in form cost. If this is not feasible, the boards of odd widths should be split on the power saw and not by hand. Frequently, this is done most economically after the sections are cleated.

Use of Narrow Strips for Convenient Remaking. A plan that has been followed successfully is to make up the column form for the first story with narrow strips on the edges so that one strip may be removed for each reduction in size. For example, if the first story column is 30 inches square and the first reduction is to 28 inches, the next to 26 inches, and so on, a part of each section may be made up of strips 2 inches wide so that one strip can be taken off for each reduction. This is illustrated in Fig. 49, page 493.

Column Heads. The tops of the column forms that are intersected by beams may be made separate from the rest of the column so as to reduce the labor in adjusting different beam sizes. Construction for beam connections is illustrated in Fig. 48, page 491.

Bevel Strips. The corners of square columns should always be chamfered both for the sake of appearance and to prevent danger of breaking off sharp corners when removing forms. The triangular strips to form the bevels should be nailed on to two opposite sides of the column forms when they are made up.

Cleanout Holes. A cleanout hole must be cut in one side of every column. For convenience in replacing, this may be cut so as to come up to the middle of the first clamp. The piece of board cut off should be tacked to the column side so that it will be all ready to put back in place after the column is cleaned out and before the concrete is poured.

METHOD OF ERECTING COLUMN FORMS

The best method in erecting a column form is to nail three of the sides together before setting in place, and the fourth side afterward. If, as is sometimes done, each side is raised separately, one carpenter loses time holding the sides in place while another one nails them together. In some cases the four sides may be put together before raising but, if the reinforcement projects above the floor, extra laborers are needed to raise the form and then lower it over the reinforcement and also to place the new reinforcement from the floor above after the form is set.

The advantages of the 3-side method are therefore:

(a) Column reinforcement can be placed before the column form is set.
(b) Column reinforcement from story below can project up as high as desirable.
(c) Two carpenters can assemble and erect.
(d) One carpenter is not required to hold form while the other is nailing.

COLUMN FORMS WITH IRON CLAMP AND WEDGE STRIP. TYPE I.

This design of column is illustrated in Fig. 48, page 491.

Study of the time of the carpenter constructing this type indicates it to be one of the best and most economical methods of construction. It is quickly assembled, requires little nailing, and is easily removed.

The cleats, which are shown as 2 by 4 inches, may be placed on edge or flat, according to the strength required, and serve not

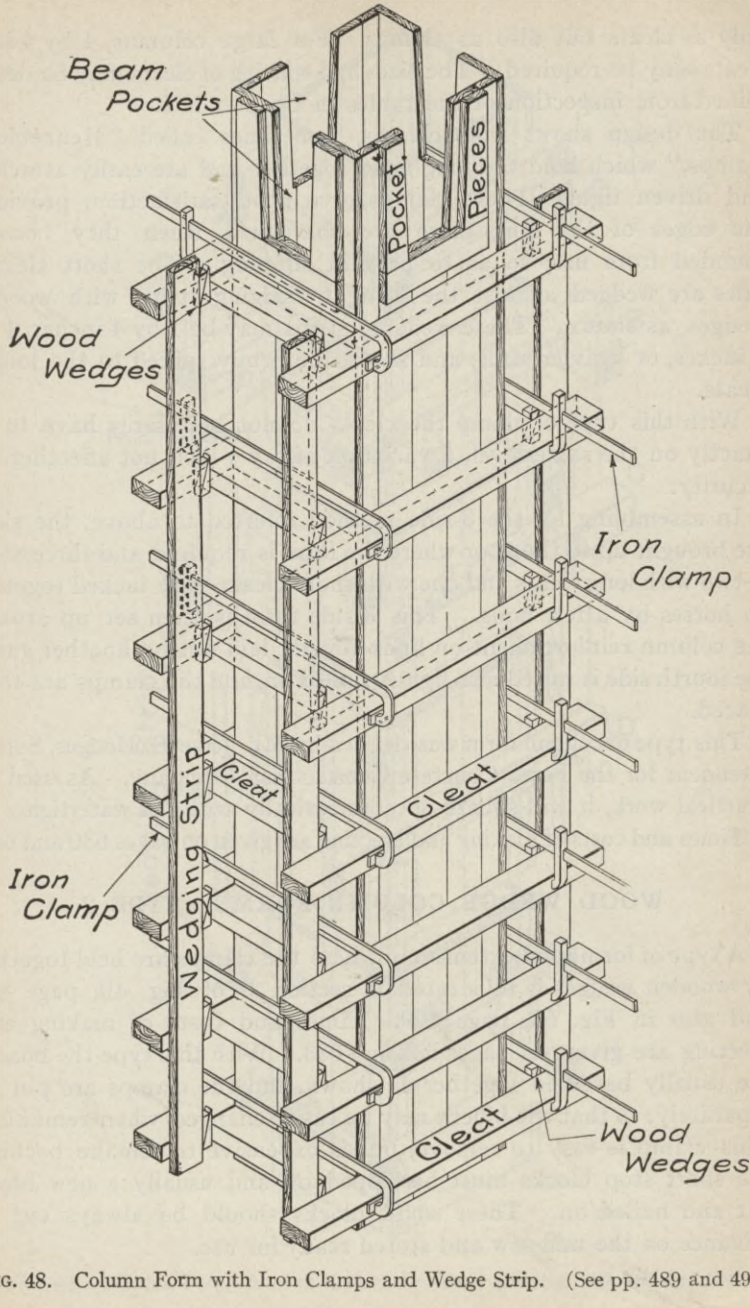


FIG. 48. Column Form with Iron Clamps and Wedge Strip. (See pp. 489 and 490.)

only as cleats but also as clamps. For large columns, 4 by 4 inch cleats may be required. The sizes and spacing of cleats may be determined from inspection of the tables in Chapter XX.

The design shows iron clamps, sometimes called "Hennebique clamps," which hold the long sides together and are easily attached and driven tight. These clamps give good satisfaction, provided the edges of the long piece are sharpened when they become rounded from use, so as to prevent slipping. The short cleated sides are wedged against the upright wedging strips with wooden wedges, as shown. These wedging strips may be 1 by 4 inches, 1 by 6 inches, or heavier stuff, and should be firmly spiked to the longer cleats.

With this type of clamp the cleats do not necessarily have to be exactly on the same level, a variation of say ½-inch not affecting the security.

In assembling by the 3-side method referred to above, the sides are brought up to the floor where the form is required and three sides —two with long cleats and one with short cleats—are tacked together on horses by a few nails. This 3-side form is then set up around the column reinforcement on lines already laid out by another gang, the fourth side is raised and lightly nailed on, and the clamps are then placed.

This type of column form was devised by Mr. Jesse E. Hodges, Superintendent for the Ferro Concrete Construction Company. As used on practical work, it will square up automatically true and watertight.

Times and costs of making and erecting are given on pages 630 and 631.

WOOD WEDGE COLUMN FORMS. TYPE 2

A type of form used extensively where the clamps are held together by wooden wedges is illustrated in section B of Fig. 49, page 493 and also in Fig. 53, page 499. Times and costs of making and erecting are given on pages 632 and 633. With this type the boards are usually battened together as shown, and the clamps are put on separately, so that the blocks may be easily changed when remaking. This clamp is easy to remove, but is expensive to remake because the short stop blocks must be ripped off and usually a new block cut and nailed on. These small blocks should be always cut in advance on the mill-saw and stored ready for use.

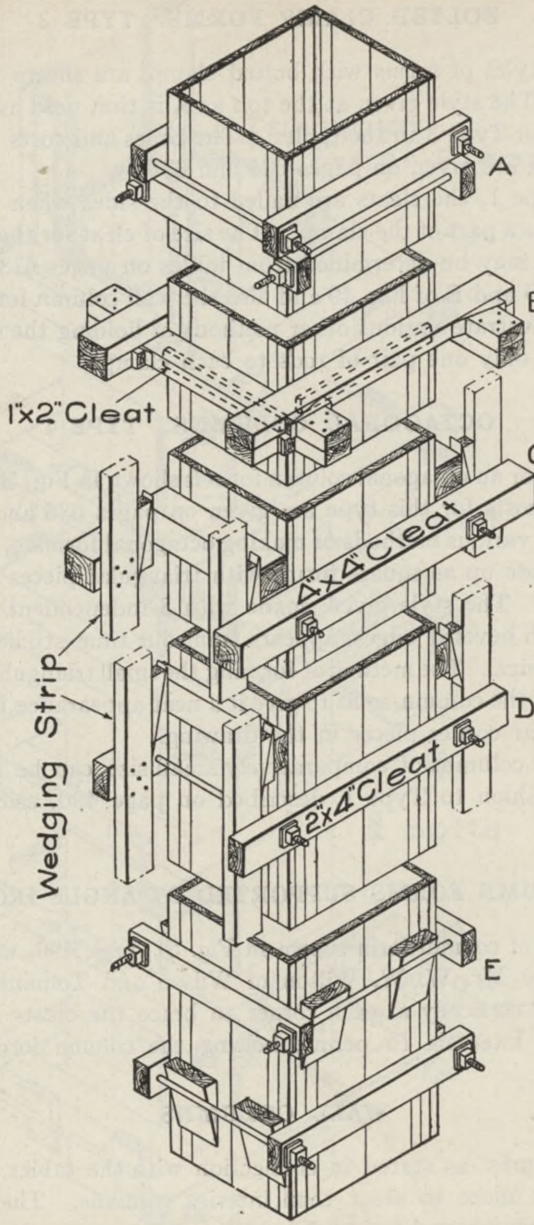


FIG. 49. Column Form showing Various Designs. (See pp. 489, 492 and 494.)

BOLTED CLAMP FORMS. TYPE 3

Several styles of forms with bolted clamps are shown in Fig. 49, page 493. The style given at the top as A is that used as the standard design for Type 3 in the tables. The times and costs of building and erecting are given on pages 634 and 635.

As in Type 1, the cleats are nailed to the sides when making, so that they are a part of the clamp. The size of cleat for the clamp and the spacing may be determined from tables on pages 613 to 615.

Sections D and E of Fig. 49 and also the wall column form, Fig. 52, page 497, illustrate various other methods of holding the sides of the form, using only one pair of rods to each clamp.

OCTAGONAL COLUMNS. TYPE 4

A design for an octagonal column form is shown in Fig. 50, page 495. Times and costs for this type are given on pages 636 and 637.

There are various methods of making octagonal forms. Sometimes they are made up as square forms with triangular pieces inserted in the corners. The style given, made with 8 independent sides, four of them with beveled edges, appears from our time studies to be the most economical. The method of forming the small triangular haunches at the top of the column, so as to give it a neat appearance, is shown by the triangular corner pieces in the drawing.

Octagonal columns of comparatively small size can be made up in a similar fashion to Type 1, described on page 490, using wedging strips.

COLUMN FORMS SUPPORTED BY ANGLE IRONS

The style of column form shown in Fig. 51, page 496, was designed and used by Mr. W. W. Wilson of Wilson and Tomlinson. Angle irons are set vertically at each corner to brace the cleats and drilled at frequent intervals to permit bolting the column form wherever needed.

WALL COLUMNS

Wall columns, as stated in connection with the tables, cost about 50 per cent more to erect than interior columns. They are more difficult to plumb and line and hold in place.

A good method of construction is shown in Fig. 52, page 497.

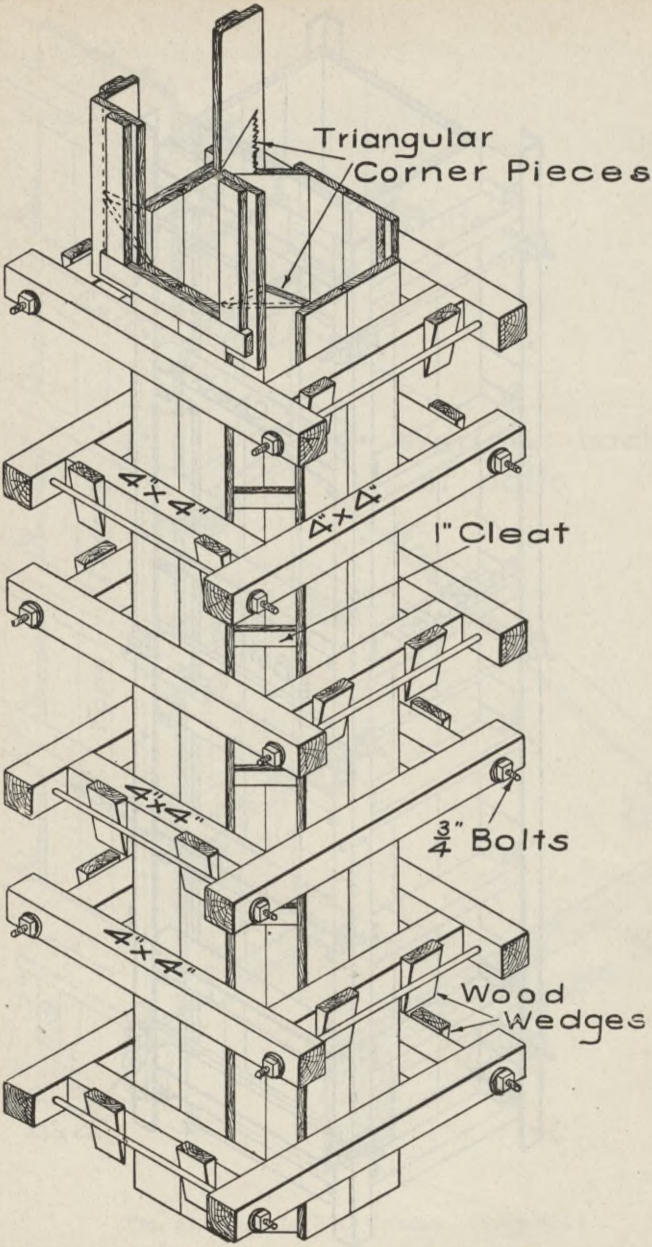


FIG. 50. Column Form for Octagonal Column. (See p. 494.)

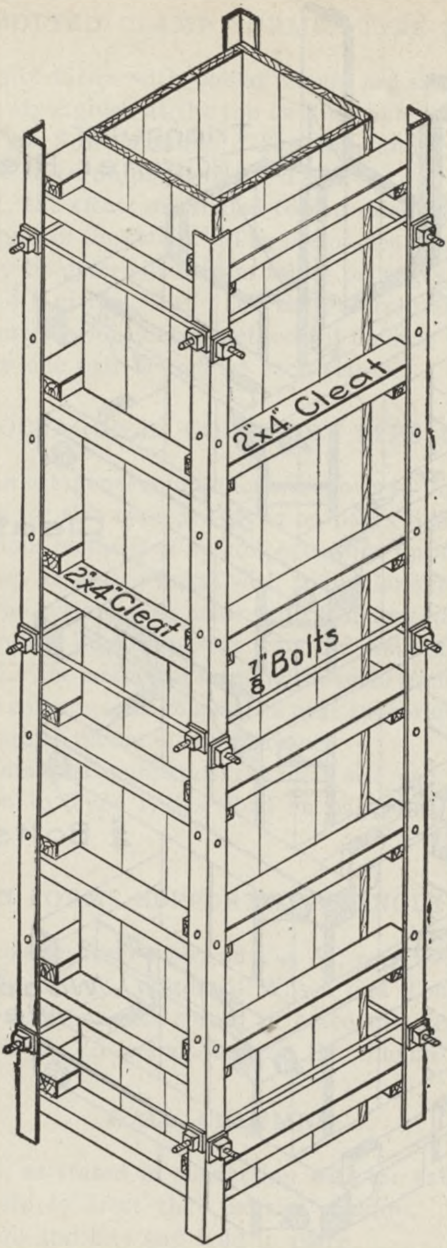


FIG. 51. Column Form with Angle Iron Verticals. (See p. 494.)

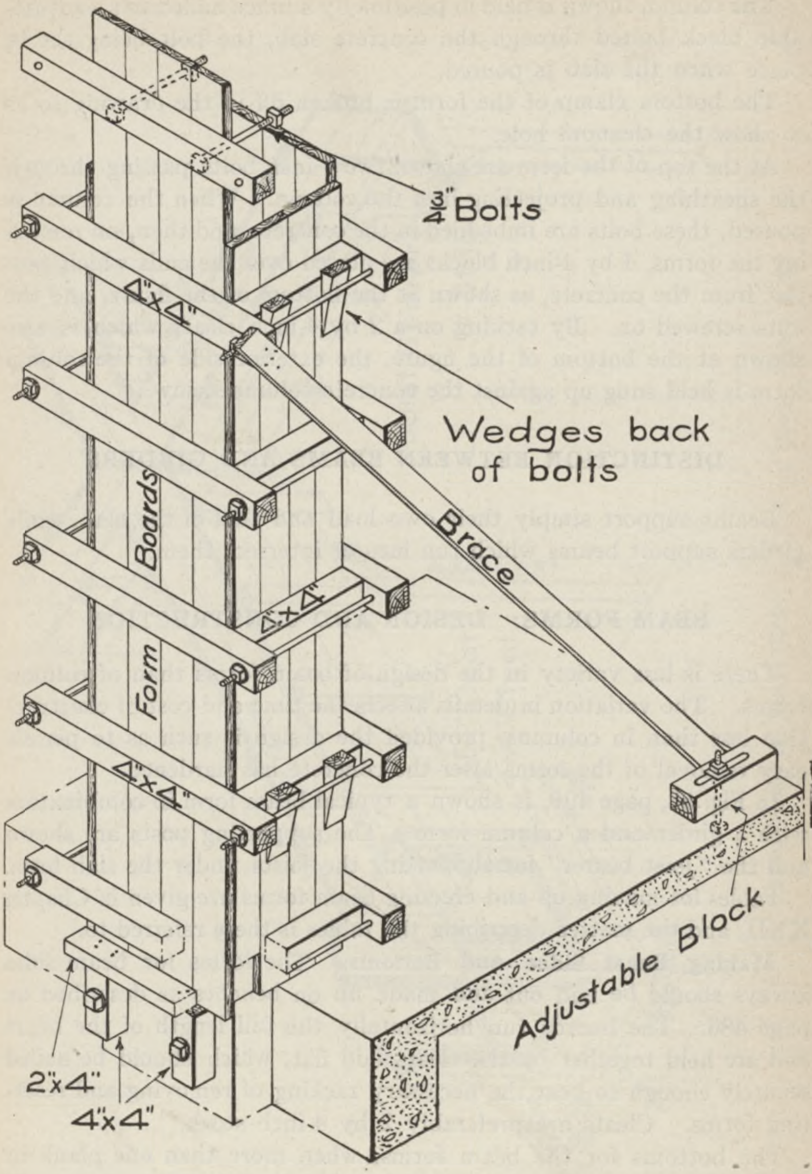


FIG. 52. Form for Wall Column. (See p. 494.)

The column shown is held in position by a brace nailed to an adjustable block bolted through the concrete slab, the bolt being set in place when the slab is poured.

The bottom clamp of the form is broken off in the drawing so as to show the cleanout hole.

At the top of the form are shown two ¾-inch bolts passing through the sheathing and projecting into the column. When the column is poured, these bolts are imbedded in the concrete, and then, on removing the forms, 4 by 4-inch blocks are placed over the ends which project from the concrete, as shown at the bottom of the figure, and the nuts screwed on. By tacking on a 2 by 4-inch cleat, which is also shown at the bottom of the figure, the exterior side of the column form is held snug up against the concrete column below.

DISTINCTION BETWEEN BEAMS AND GIRDERS

Beams support simply their own load and that of the slab, while girders support beams which run into or intersect them.

BEAM FORMS: DESIGN AND CONSTRUCTION

There is less variety in the design of beam forms than of column forms. The variation in details affects the time and cost of construction less than in columns, provided the design is such as to permit easy removal of the forms after the concrete has hardened.

In Fig. 53, page 499, is shown a typical beam form in combination with a girder and a column form. The supporting posts are shown and the "joist bearer" for supporting the joists under the slab form.

Tables for making up and erecting beam forms are given in Chapter XXII, and the matter describing the tables is there referred to.

Making Beam Sides and Bottoms. The forms for beam sides always should be laid out and made up on benches as described on page 486. The boards run horizontally the full length of the beam and are held together by the cleats laid flat, which should be nailed securely enough to bear the necessary racking of removing and resetting forms. Cleats are preferably 2 by 4-inch stock.

The bottoms for the beam forms, when more than one plank in width, should also be made up on benches in a similar manner. If a single plank forms the bottom, it should be cut to length on the millsaw, marked, and piled near the side sections.

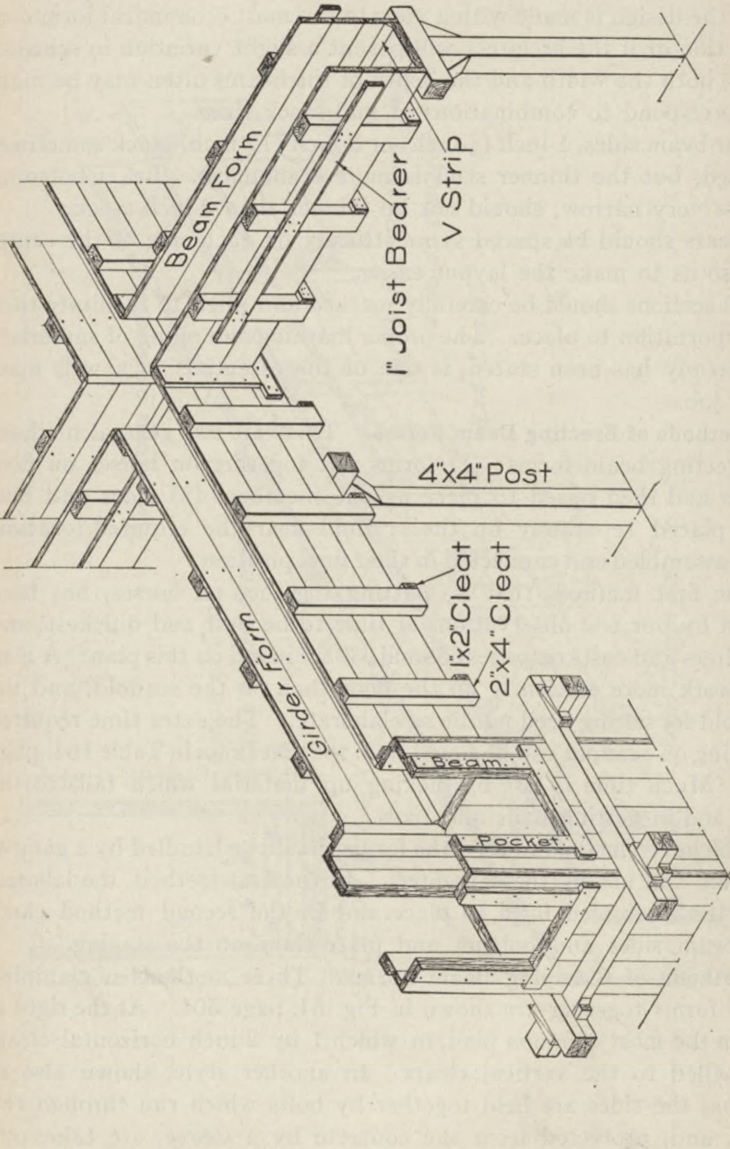


FIG. 53. Typical Forms for Beam, Girder, and Column Head. (See p. 498.)

The bottom plank should be the net width of the concrete beam while the sides should lap down over the edges of this bottom plank to permit their easy removal in advance of the bottom.

If the design is made with a view to the most economical form construction or if the architect will permit a slight variation in schedule sizes, both the width and the depth of the beams often may be made to correspond to combinations of mill stock sizes.

For beam sides, 1-inch ($\frac{7}{8}$-inch) or 2-inch ($1\frac{7}{8}$-inch) stock sometimes is used, but the thinner stuff is more economical. Beam bottoms, unless very narrow, should not be thinner than 2-inch stock.

Cleats should be spaced symmetrically on each side of the center line so as to make the layout easier.

All sections should be carefully marked and piled to facilitate their transportation to place. The proper marking and piling of materials, as already has been stated, is one of the essentials in a well managed job.

Methods of Erecting Beam Forms. There are two general methods of erecting beam forms: (1) forms put together on horses on floor below and then raised to place as one member; (2) sides and bottom placed separately on the scaffold near the required location, then assembled and connected in their final position.

The first method, that is, putting together on horses, has been found by our test observations of time to be best and quickest, and the times and costs on pages 638 and 639 are based on this plan. A man can work more efficiently on the floor than on the scaffold, and the scaffold for setting need not be so elaborate. The extra time required working on scaffold can be found from the unit times in Table 164, page 671. Much time is lost by picking up material which falls to the floor and in getting nails and tools.

Whichever method is used the forms should be handled by a gang of laborers and not by the carpenters. In the first method, the laborers raise the assembled form to place and in the second method carry the beam sides and bottom and place them on the staging.

Methods of Clamping Beam Forms. Three methods of clamping beam forms together are shown in Fig. 54, page 501. At the right is shown the most common plan, in which 1 by 2-inch horizontal cleats are nailed to the vertical cleats. In another style, shown also in section, the sides are held together by bolts which run through the form, and, protected from the concrete by a sleeve, are taken out when removing the forms. The holes may be filled with concrete

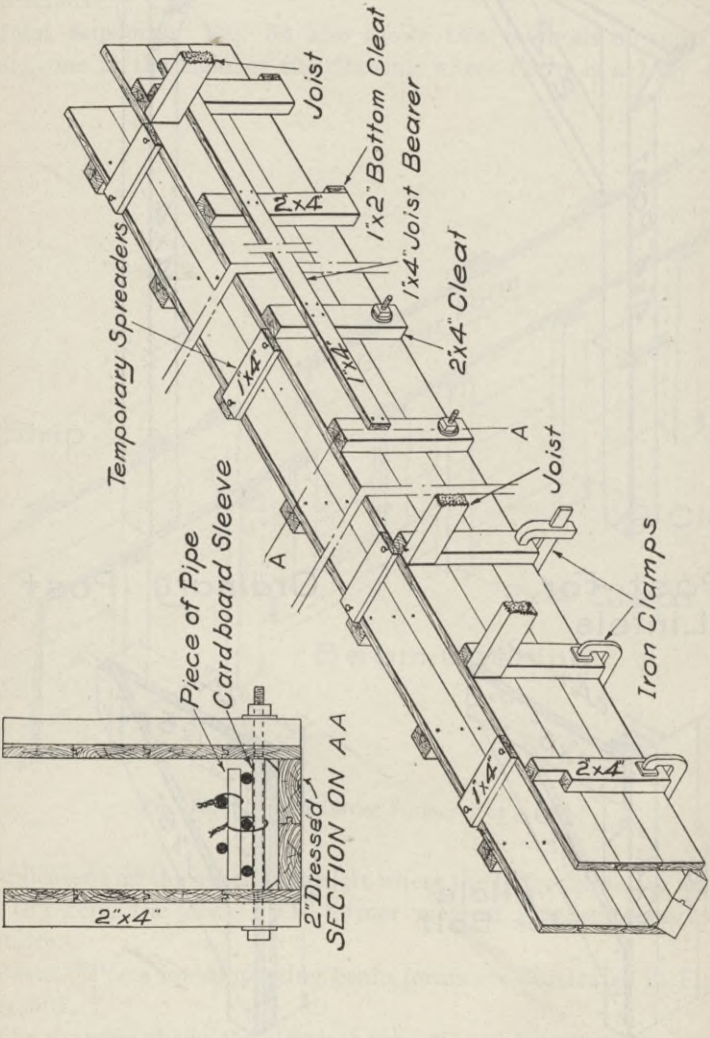


FIG. 54. Beam Form showing three Methods of Construction. (See p. 500.)

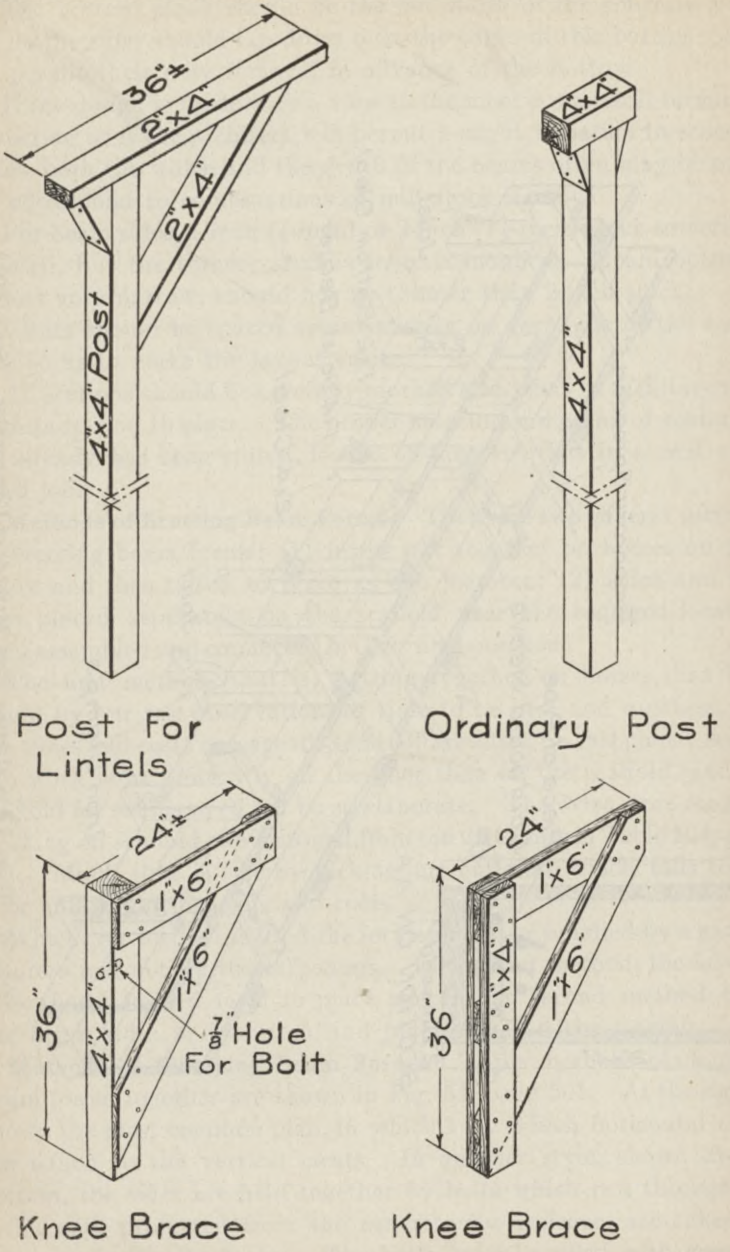


FIG. 55. Posts for Supporting Beams and Knee Braces. (See p. 503.)

or a permanent rod for hanger supports run through and cemented in. The sleeve provides a bearing for the reinforcing bars.

Another method, using iron clamps of the Hennebique type, is shown at the left of the drawing. This plan is the cheapest to erect and remove.

Joist Supports. Fig. 54 also shows two methods of supporting joists, one at the right of the drawing where there is a 1 by 4-inch

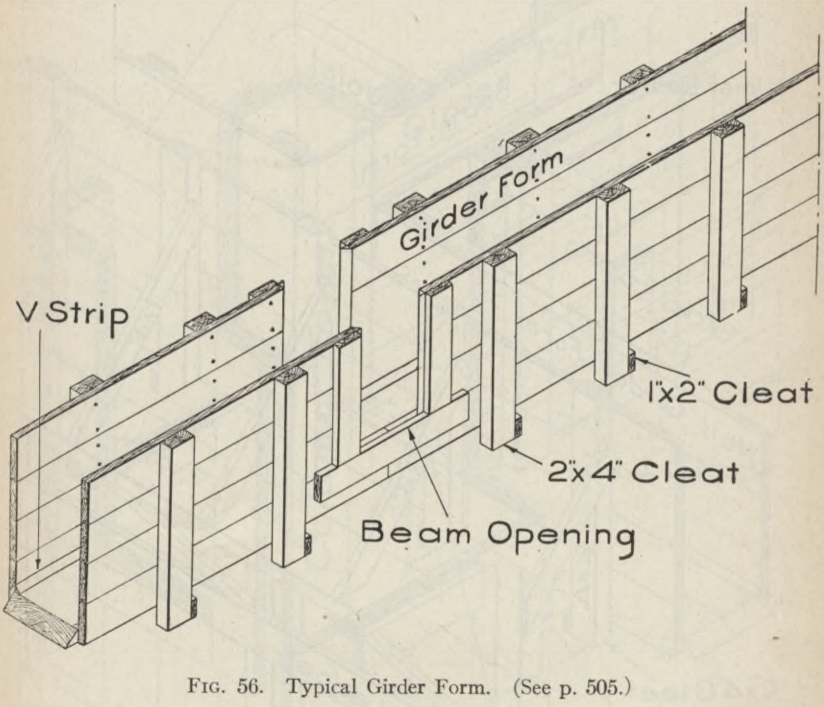


FIG. 56. Typical Girder Form. (See p. 505.)

joist bearer and the other at the left where the beam cleats are notched out to receive the joists. The former method represents more usual practice.

Posts. Posts for supporting beam forms are illustrated in Fig. 55, page 502.

The drawing shows the simplest type of post for ordinary construction and also a post for supporting a lintel. Detail designs of knee braces are shown in the lower part of the figure.

GIRDER FORMS: DESIGN AND CONSTRUCTION

The sides and bottoms of girder forms should be made up in advance, as in column and beam construction already described.

There are two general types of construction: (1) sides made the full length of the girder; (2) sides made in sections between beams.

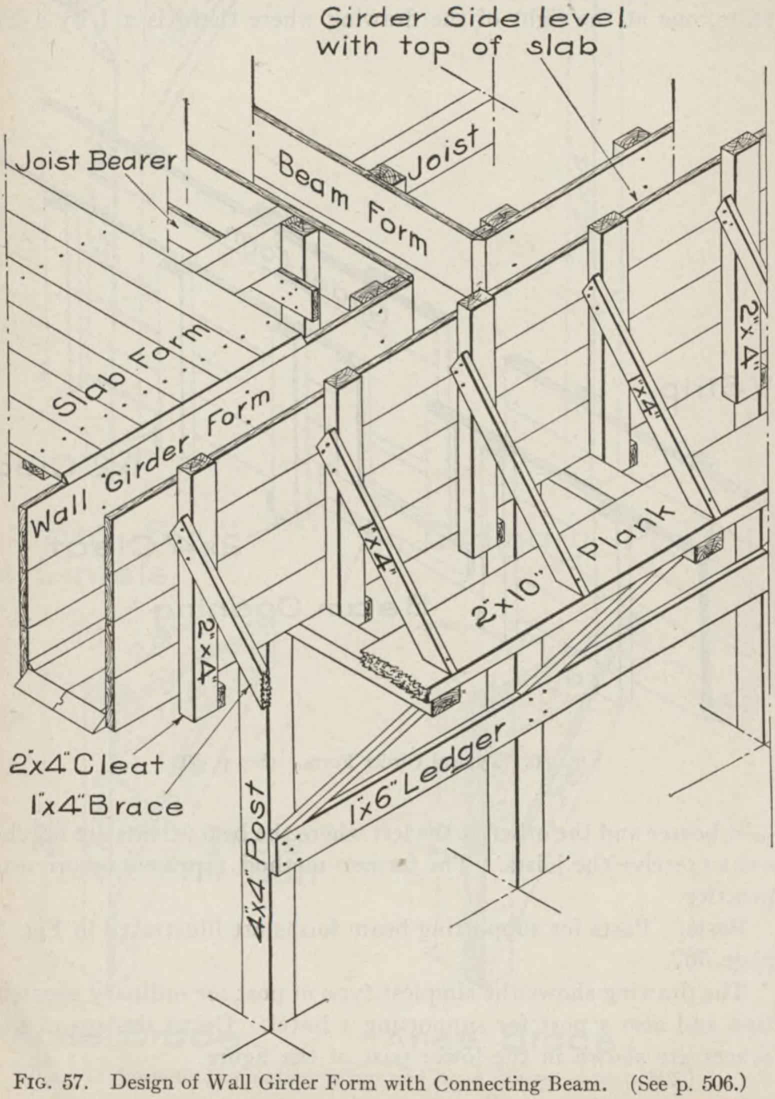


FIG. 57. Design of Wall Girder Form with Connecting Beam. (See p. 506.)

If the beams are the same depth as the girder, or only a little bit shallower, say 2 inches less, the first method should not be followed; otherwise it is cheapest to make the sides full length because there is less labor in placing. When the beams are shallower than the girders and the second method is used, a ledger strip may be placed the

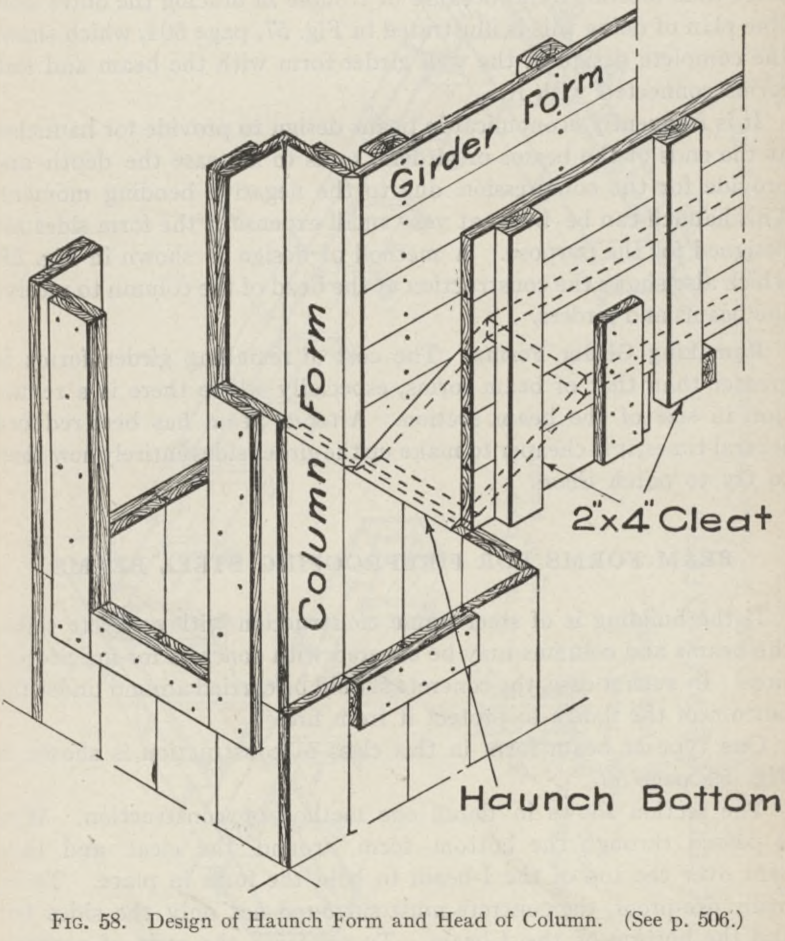


FIG. 58. Design of Haunch Form and Head of Column. (See p. 506.)

full length of the girder under the beam form and the sections between the beams placed above it.

Girder form construction is shown in Fig. 56, page 503, and times and costs of construction are given on pages 640 to 643.

Cutting Beam Pockets. The cost is about the same, it has been found by time study, whether the beam pockets are cut in the girder sides before or after the forms are erected. In some cases where the design of the floor system changes from story to story, the sides of the girders are remade for each floor and new pockets are cut.

Wall Girders. Wall girder or lintel forms are more difficult to erect than interior forms because of trouble in bracing the outer side. One plan of doing this is illustrated in Fig. 57, page 504, which shows the complete design of the wall girder form with the beam and slab forms connected with it.

It is frequently economical in beam design to provide for haunches at the ends of the beams or girders, so as to increase the depth and provide for the compression due to the negative bending moment. This haunch can be built at very small expense if the form sides are designed for the purpose. A method of design is shown in Fig. 58, which also shows the construction at the head of the column to receive the beams and girders.

Remaking Girder Forms. The cost of remaking girder forms is greater than that of beam forms, especially where there is a reduction in size of the beam section. After a beam has been reduced several times, it is cheaper to make up the girder sides entirely new than to try to patch them.

BEAM FORMS FOR FIREPROOFING STEEL BEAMS

If the building is of steel frame construction with concrete slabs, the beams and columns may be covered with concrete for fire protection. In such a case, the concrete should be carried around under the bottom of the flange to protect it from fire.

One type of beam form in this class of construction is shown in Fig. 59, page 507.

The section shows in detail one method of construction. Wire is passed through the bottom form around the cleat and then bent over the top of the I-beam to hold the form in place. To be really fire-proof, the concrete must surround not only the sides but also the bottom of the I-beam. To reinforce the strip of concrete under the lower flange of the I-beam, clips may be attached to the flange as shown in the figure. There are several patented designs of clips in the market.

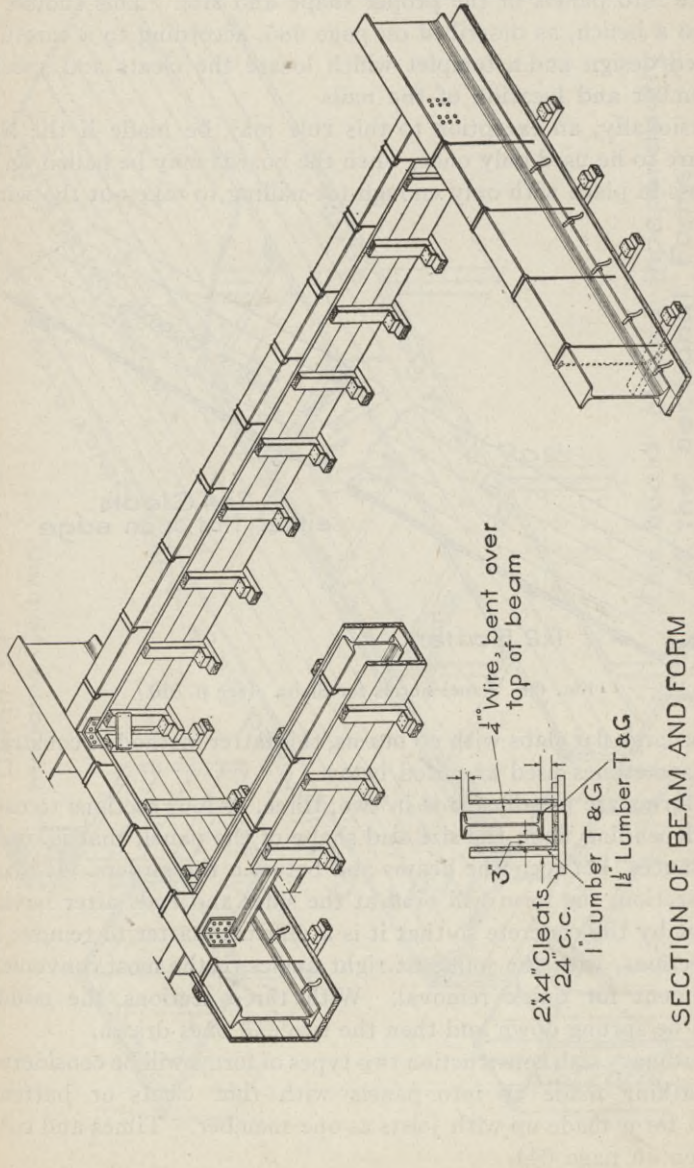


FIG. 59. Forms for Fireproofing Steel Beams. (See p. 506.)

SLAB FORMS: DESIGN AND CONSTRUCTION

Forms for slabs between beams and girders should be made up in advance into panels of the proper shape and size. This should be done on a bench, as described on page 485, according to a carefully prepared design and a templet which locate the cleats and specify the number and location of the nails.

Occasionally, an exception to this rule may be made if the slab forms are to be used only once, when the boards may be nailed on to the joists in place with only enough toe-nailing to take out the wind.

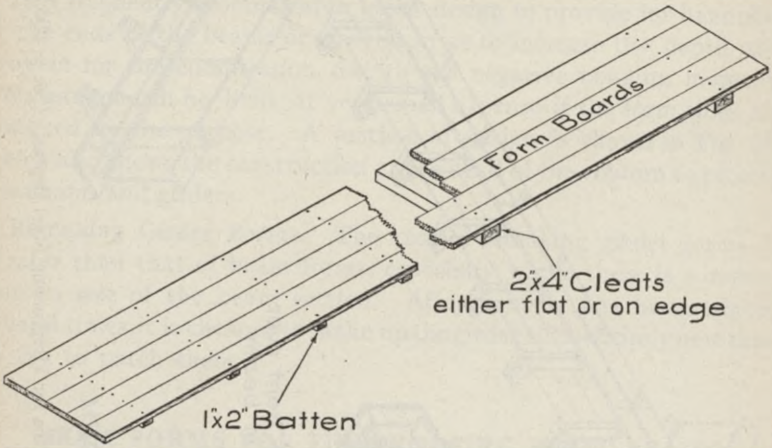


FIG. 60. Panel Forms for Slabs. (See p. 510.)

Also, for large flat slabs with no beams, this latter method of construction is sometimes used as noted below.

Slab forms are usually made in two, three, or four sections to each panel, depending upon the size and shape of the panel, that is, upon the distances between the beams and between the girders. If made in one section, the form will bind at the sides and ends after having been wet by the concrete so that it is a difficult matter to remove it. Four sections, with the joints at right angles, is the most convenient arrangement for quick removal. With three sections, the middle one can be sprung down and then the two end ones drawn.

For ordinary slab construction two types of forms will be considered: (1) sheathing made up into panels with thin cleats or battens: (2) slab form made up with joists as one member. Times and costs are given on page 644.

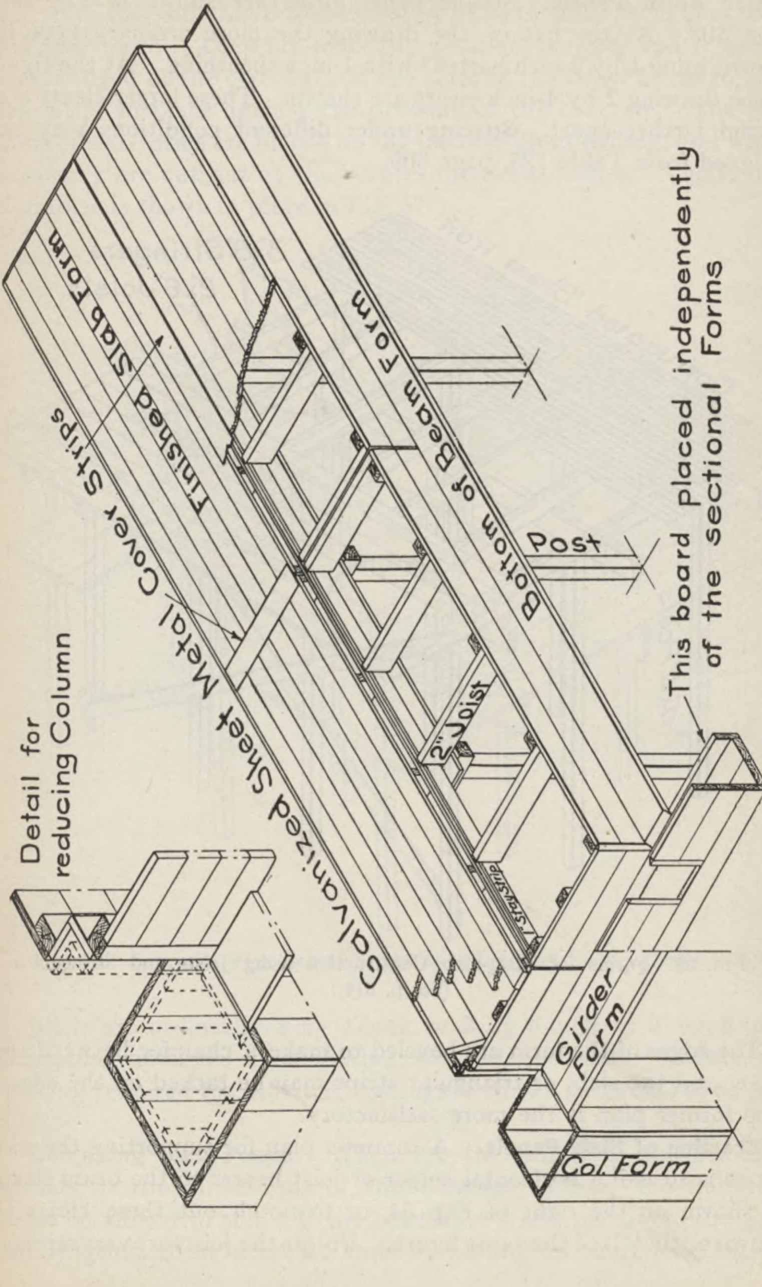


FIG. 61. Slab Form made up with Joists and Beam and Girder Sides. (See p. 512.)

Slab Form Panels. Simple panel forms are shown in Fig. 60, page 508. At the left of the drawing the more ordinary type is shown, using 1 by 2-inch battens with 1-inch sheathing. At the right of the drawing 2 by 4-inch cleats are shown. These larger cleats are spaced farther apart. Spacing under different conditions may be designed from Table 125, page 609.

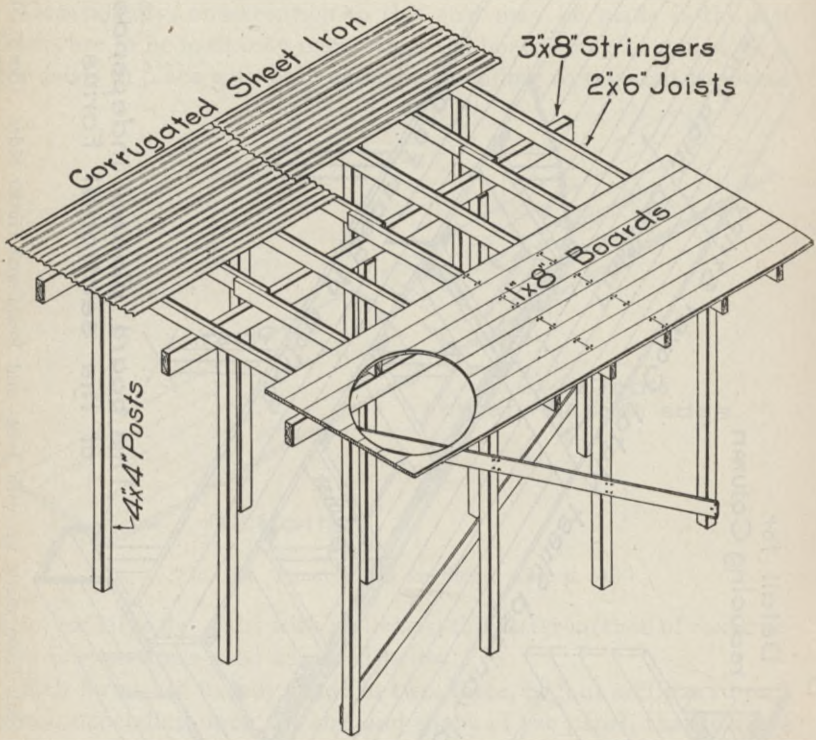


FIG. 62. Forms for Flat Slab Construction using Joists and Stringers. (See p. 514.)

The edges of the form are beveled to make a chamfer between the beam and the slab, or triangular strips may be tacked on the edges. The former plan is the more satisfactory.

Erection of Slab Panels. A common plan for supporting the slab forms is to nail a horizontal ledger or joist bearer to the beam cleats as shown on the right of Fig. 54, or to notch out these cleats as shown on the left of the same figure. Unless the joists are very straight andtrue, the ends have to be sized by hand to make them of exactly uniform depth. They are placed in position, leveled, and if necessary wedged at the ends against the sides of the beam forms to hold the latter in place against the pressure of the concrete. The sections of slab forms are placed on the joists without nailing, and where necessary are cut out at the corners for the columns. A part of a slab form is shown in place in Fig. 57.

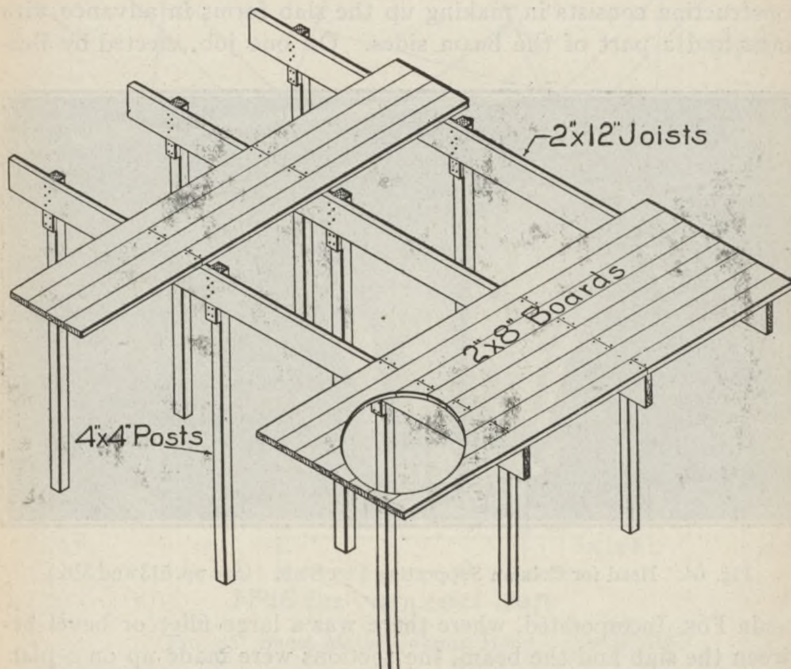


FIG. 63. Forms for Flat Slab Construction using Joists only. (See p. 514.)

Joists are ordinarily 2 by 4-inch, or 2 by 6-inch, or 2 by 8-inch, depending upon the span, spacing, and weight of slab. The size and spacing required for different loadings is shown in Table 126 on page 610.

Remaking Slab Forms. Whenever the widths of the beams or girders or the dimensions of the columns change, the slab form must be altered to suit. If the beams are made narrower, the joists are lengthened on alternate ends by nailing on short lengths. To avoid increasing the length or width of the sheathing, it is convenient to place a strip of zinc over the crack. If the space is too wide for this, a strip of wood must be cut to fill the central joint between the sections.

Whenever the columns are reduced in size, the panels must be cut back to beyond the first cleat and patched out to fit the new size of column.

Slab Forms Made Up with Joists. Another type of slab form construction consists in making up the slab forms in advance with joists and a part of the beam sides. On one job, erected by Ben-

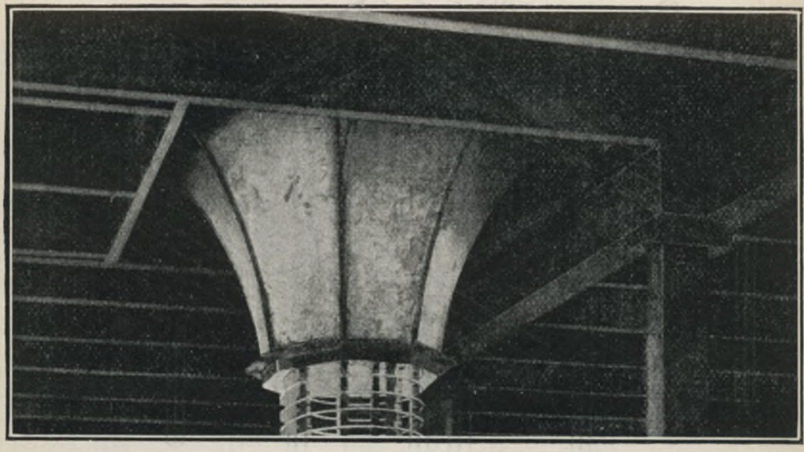


Fig. 64. Head for Column Supporting Flat Slab. (See pp. 513 and 516.)

jamin Fox, Incorporated, where there was a large fillet or bevel between the slab and the beam, the sections were made up on a platform on the ground. This was carefully marked out to show the dimensions and the locations of each piece, and the work was carried out by exact routine.

It is possible to go one step further and attach the entire sides of the beam and all but the bottom board of the girder sides to the joists and sheathing, as shown in Fig. 61 page 509. Each section is self-contained and supported by posts under the joists as shown. If the beams and girders are reduced in size, the metal strips which cover the joints are made wider. In the figure, a detail sketch is shown of the methods of enlarging the forms when the column is reduced in size.

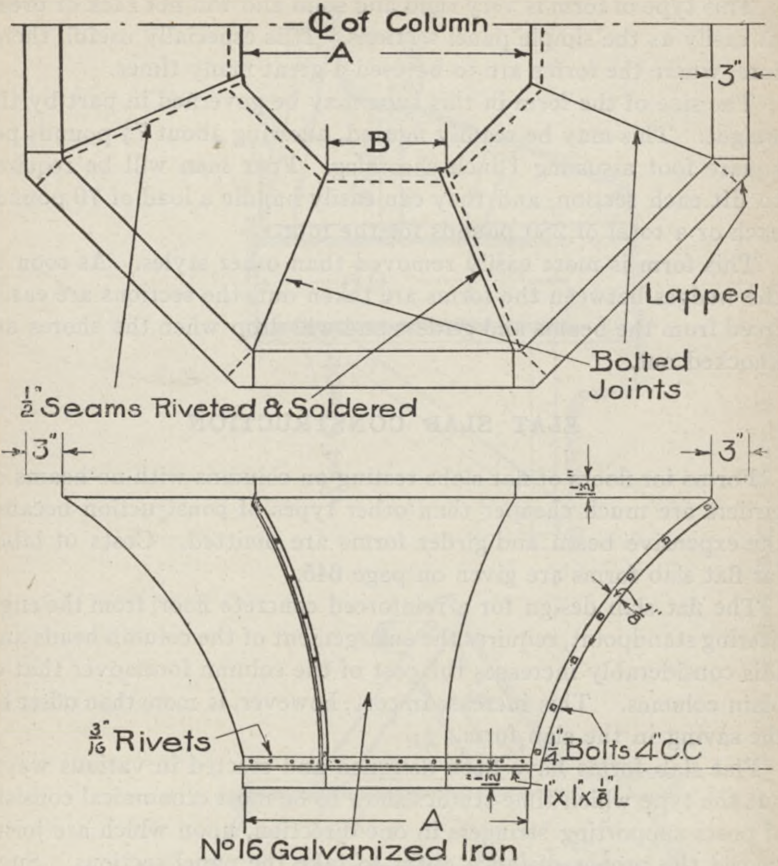


FIG. 65 Sheet Metal Column Head. (See p. 516.)

Dimensions of Cap used by Stone & Webster Engineering Corporation.

SIZE OF COLUMN	DIMENSION A	DIMENSION B
inches	inches	inches
14	$13\frac{3}{4}$	$5\frac{11}{16}$
16	$15\frac{3}{4}$	$6\frac{17}{32}$
18	$17\frac{3}{4}$	$7\frac{11}{32}$
20	$19\frac{3}{4}$	$8\frac{3}{16}$
22	$21\frac{3}{4}$	9
24	$23\frac{3}{4}$	$9\frac{27}{32}$
26	$25\frac{3}{4}$	$10\frac{21}{32}$
28	$27\frac{3}{4}$	$11\frac{1}{2}$

This type of form is very rigid and solid and will not rack or break as easily as the simple panel sections. It is especially useful, therefore, where the forms are to be used a great many times.

The size of the form in this type may be governed in part by the weight. This may be readily figured, allowing about 7½ pounds per square foot assuming 1-inch sheathing. Four men will be required to lift each section, and they can easily handle a load of 70 pounds each or a total of 280 pounds for the four.

This form is more easily removed than other styles. As soon as the wedges between the forms are taken out, the sections are easily freed from the beams and girders and will drop when the shores are knocked out.

FLAT SLAB CONSTRUCTION

Forms for floors of flat slabs resting on columns with no beams or girders are much cheaper than other types of construction because the expensive beam and girder forms are omitted. Costs of labor for flat slab forms are given on page 645.

The flat slab design for a reinforced concrete floor, from the engineering standpoint, requires the enlargement of the column heads and this considerably increases the cost of the column forms over that of plain columns. This increase in cost, however, is more than offset by the saving in the slab form.

Flat slab forms have been designed and erected in various ways, but the type which time-studies show to be most economical consists of posts supporting stringers in one direction, upon which are joists spaced the proper distance apart to take the panel sections. Such a design is shown in Fig. 62, page 510.

Another type of design where posts are nailed directly to the joists is shown in Fig. 63. In this construction the boards may be made into panels or lightly toe-nailed on to the joists.

Corrugated Metal Sheathing. Plain sheet steel for forms tends to warp and dent. To avoid this, corrugated metal has been successfully used for flat slab ceilings in warehouse construction, where the ceiling surface does not need to be absolutely smooth. The corrugated metal is stiffer, holds its shape better, and can be straightened after each removal by running it through rolls. The supporting construction is the same as for wooden sheathing, and the design shown either in Fig. 62 or Fig. 63 may be used.

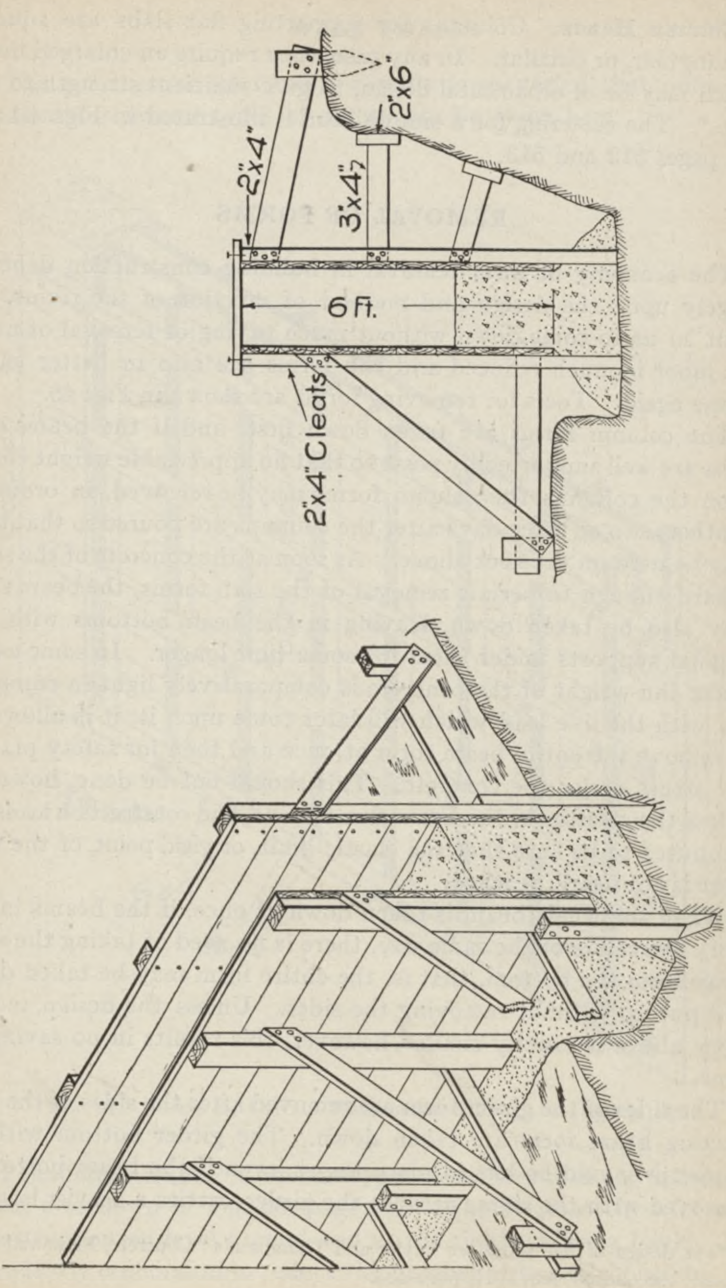


FIG. 66. Forms for Foundation Walls. (See p. 517.)

Column Heads. Columns for supporting flat slabs are square, rectangular, or circular. In any case, they require an enlarged head, which may be of ornamental design, to give sufficient strength to the slab.* The centering for a simple head is illustrated in Figs. 64 and 65, pages 512 and 513.

REMOVAL OF FORMS

The economy of form removal in building construction depends largely upon the design and method of erection of the forms. If built so as to come down without much prying or removal of nails, the labor is much reduced and the forms are also in better shape to use again. Tools for removing forms are shown in Fig. 46.

The column forms are taken down first, and if the beams and slabs are well supported by posts so that no appreciable weight comes upon the columns, the column forms may be removed, in ordinary weather, two or three days after the columns are poured so that they may be used on the floor above. As soon as the concrete of the slabs is hard enough to permit removal of the slab forms, the beam sides may also be taken down, leaving in the beam bottoms with the original supports under them for some time longer. In some cases, where the weight of the concrete is comparatively light in comparison with the live load which will later come upon it, it is allowable to remove the entire beam form at once and then for safety place a few struts under the concrete. This should not be done, however, unless the stresses in the beam due to dead and construction loads are computed to be sure that the elastic limit, or yield point, of the concrete is not nearly reached.

When the whole beam is taken down at once, if the beams in the story above are of the same size, there is no need of taking the sides away from the bottom, that is, the entire form may be taken down and put up without removing the sides. Unless the design on the story above is exactly similar, however, this results in no saving of time.

The sides of the girder form are removed after the sides of the connecting beam form are taken down. The girder bottom with its supports should be left in place longer, even if the beam bottom is removed with the sides, because the girder carries a heavier load.

*For design of flat slabs, see Taylor and Thompson's "Concrete, Plain and Reinforced," second edition, 1911, page 483.

WALL FORMS

The construction of forms for walls is so varied that only suggestions for several types of design can be given here.

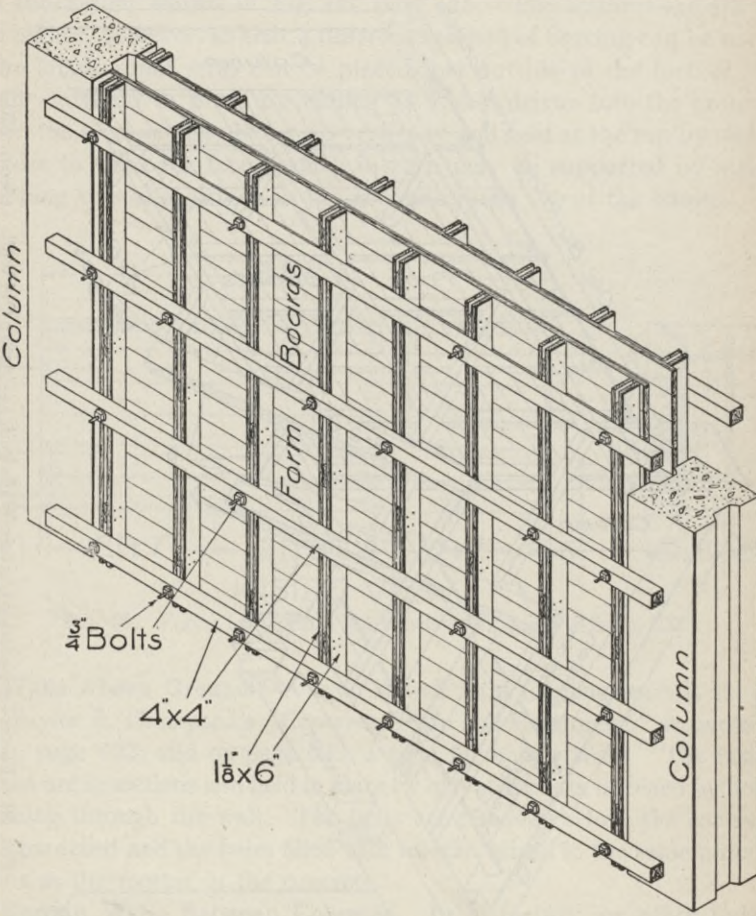


FIG. 67. Forms for Curtain Walls between Columns. (See p. 519.)

Foundation Walls. Common types of construction for foundation walls are shown in Fig. 66, page 515. The form at the left shows construction on level ground and at the right against a bank. It is frequently economical to reduce the number of braces shown, by put-

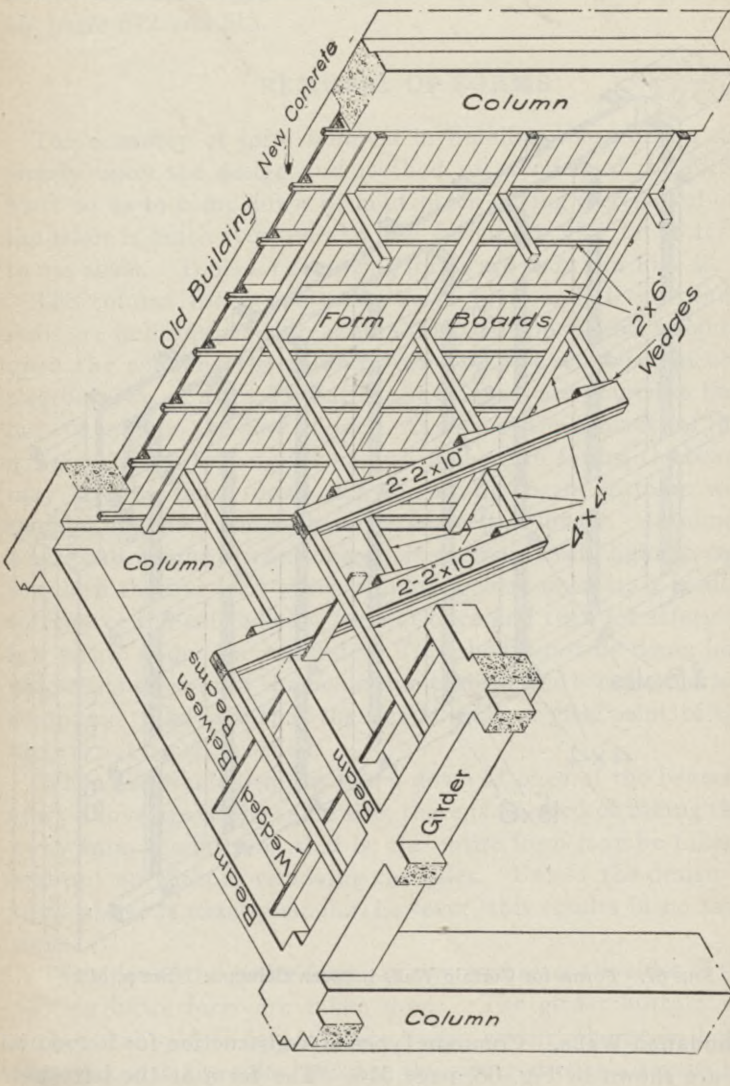


FIG. 68. Forms for Exterior Curtain Walls built against an Old Wall. (See p. 520.)

ting a longitudinal ranger near the tops of the studs, with only occasional braces down to the ground.

It is best to make up the sheathing for these wall forms on a bench as described on page 485.

Cellar Wall Forms. Forms for cellar walls may be built similarly to the design shown in Fig. 66, page 515. The sections are apt to be higher, however, so that a different method of bracing can be used. The longitudinal strip can be placed just outside of the face of the wall and held in place by nailing to stakes driven into the ground; then the sections may be set up vertically and held at the top by cleats across to the back form, which in turn may be supported by strips running to stakes driven in the ground on the top of the bank.

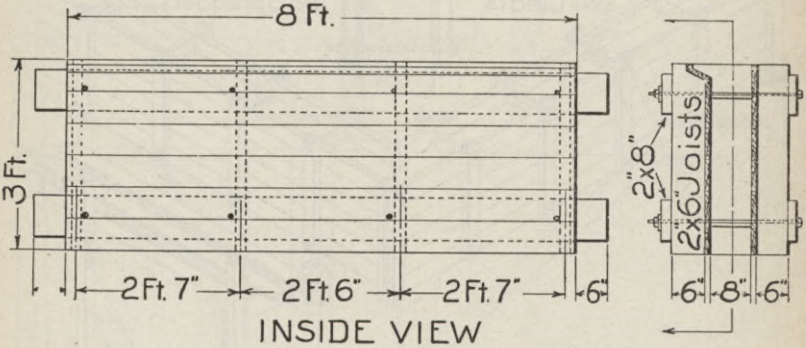


Fig. 69. Forms for Curtain Walls below Windows. (See p. 520.)

Walls Above Ground. A type of wall form for long walls is shown in Taylor & Thompson's "Concrete, Plain and Reinforced," second edition, page 622, and on page 623, a form for hollow walls. The inside forms are in sections and held in place by movable cleats fastened by bolts running through the wall. The bolts are removed before the concrete has hardened and the holes filled with mortar, mixed in the same proportions as the mortar in the concrete.

Curtain Walls Between Columns. In a factory or office building the columns are usually constructed first and the curtain walls put in afterwards. One type of design for wall forms is shown in Fig. 67, page 517.

In a blank wall built up against another wall as, for instance, where the new structure is built against an old one, there is no room for an outside form. In this case the inside form must be supported differently than where there is an outside form. A design for this class of work is shown in Fig. 68, page 518, and is used by Turner Construction Company. Although this form looks somewhat complicated, it is easy to construct and holds the forms securely. The forms supporting the floor and the floor slab itself are purposely omitted from the drawing.

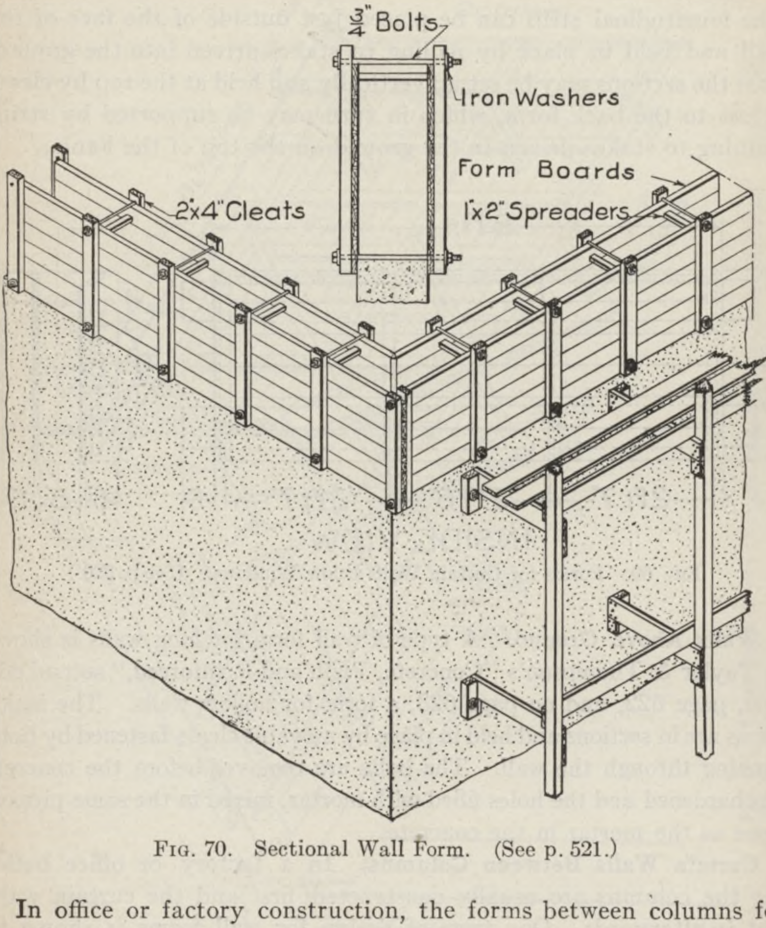


FIG. 70. Sectional Wall Form. (See p. 521.)

In office or factory construction, the forms between columns for molding the walls up to window level are used a great many times. They should be quite solidly constructed, therefore. A design is shown in Fig. 69. The forms on each side are connected with bolts which are afterwards withdrawn and the holes filled with concrete.

A very economical and much used type of wall form is shown in Fig. 70, page 520. This wall form is made in sections 3 feet high by 12 feet long and is bolted as shown. A form of this size is very easily handled by two carpenters. The bolt holes left in the wall can be utilized for attaching an outside scaffolding, as shown in Fig. 70, after which they can be very easily plugged up in the usual manner.

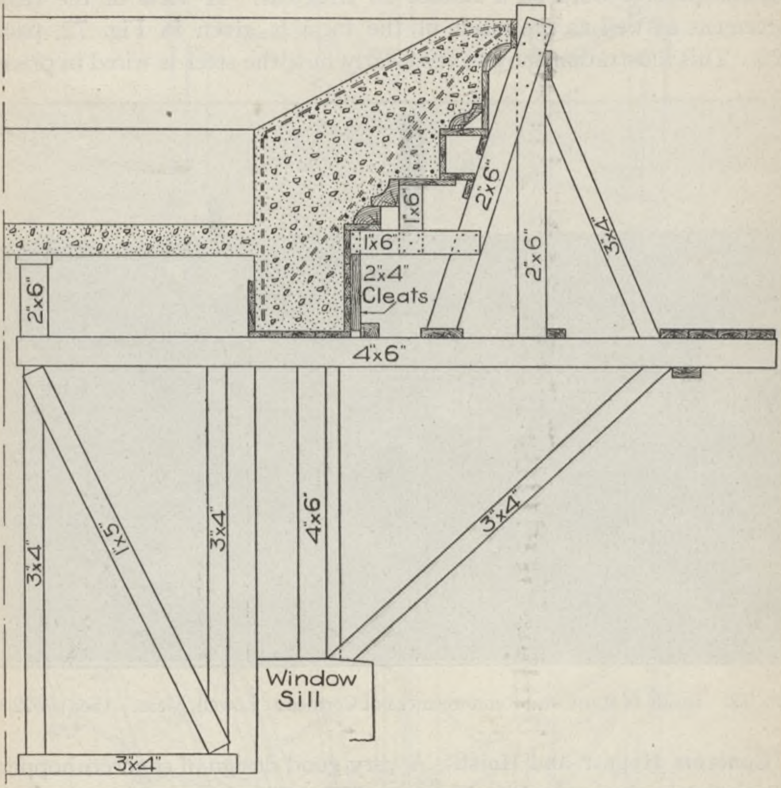


FIG. 71. Design of Overhanging Cornice used at Lowell, Mass. (See p. 522.)

Overhanging Cornice Forms. An overhanging cornice on a building is difficult to construct and costly, especially if the overhang is large. The extra expense is justifiable, however, on a building of six or more stories as it gives the structure a finished look and adds greatly to its appearance.

A form for a large overhanging cornice, somewhat similar to one designed by the Abertaw Construction Company for a twelve story warehouse, is shown in Fig. 71, page 521. The lumber used on the face of the cornice is molding such as can be readily obtained from a lumber yard although much more expensive than the ordinary lumber used for forms. For this reason, the forms should be handled carefully in placing and removing. The concrete also should be placed with care so that the surface of the cornice will require as little patching as possible. Patching is expensive work on a surface so irregular. A view of the reinforcement as well as the inside of the form is given in Fig. 72, page 522. This illustration shows very clearly how the steel is wired in place.

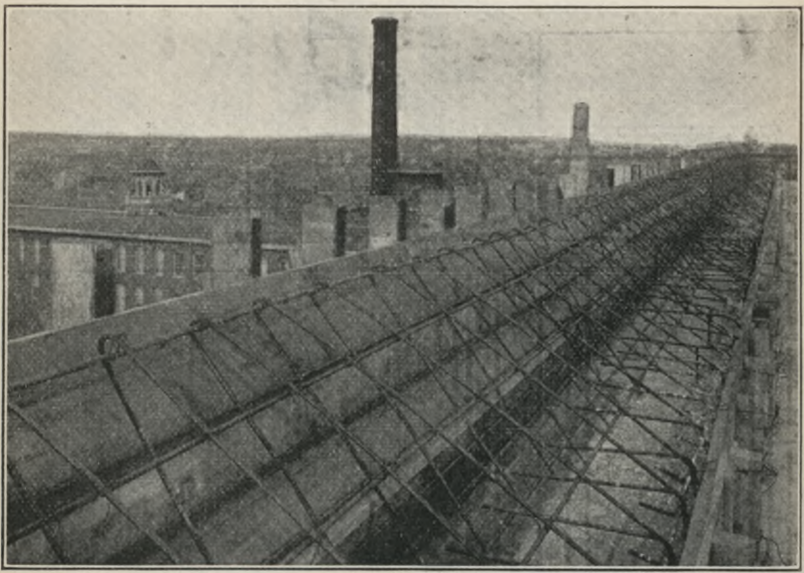


FIG. 72. Inside of Form and Reinforcement of Cornice at Lowell, Mass. (See p. 522.)

Concrete Hopper and Hoist. A very good design of concrete hopper and hoist is shown in Fig. 73, page 523. The hopper is made as a unit and is moved as such from floor to floor. The hoist is bolted at all joints and the pieces are made interchangeable as far as possible. A coat of paint always should be given the hoist to prevent the workmen from cutting up any piece belonging to it when it is dismembered.

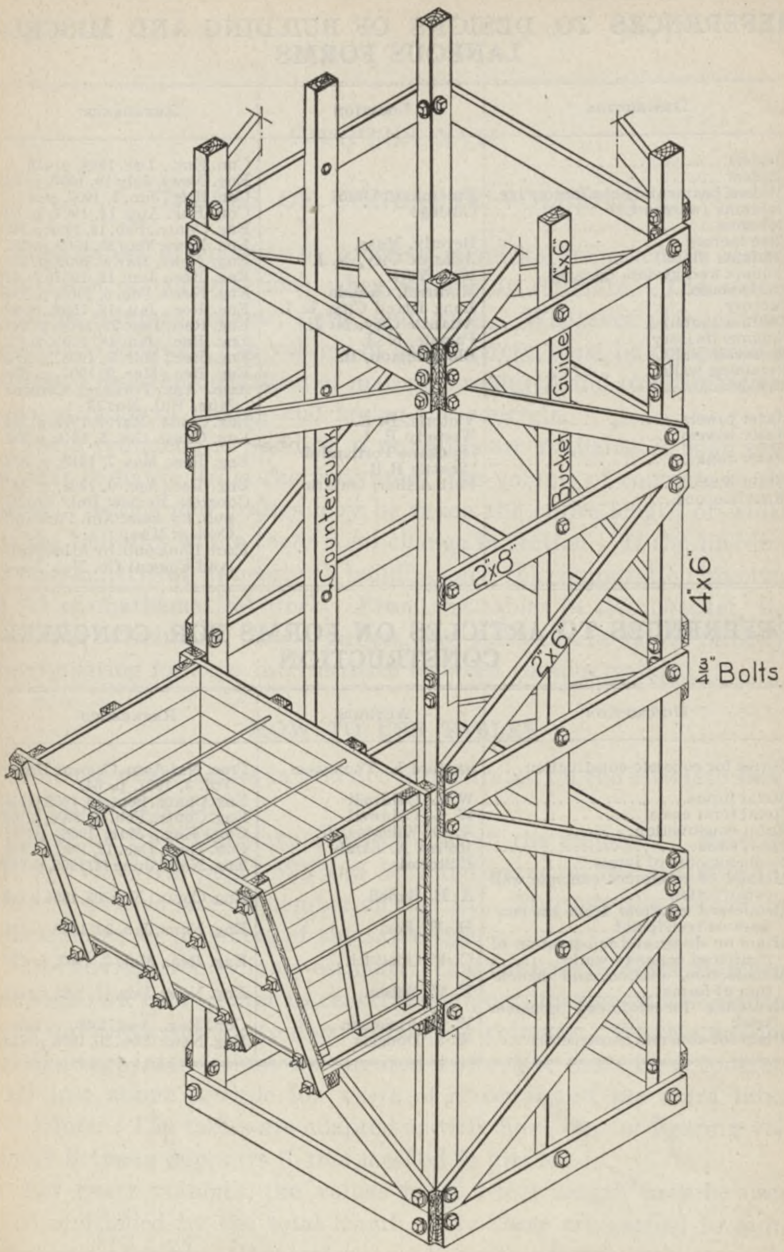


FIG. 73. Concrete Hopper and Hoist. (See p. 522.)

REFERENCES TO DESIGNS OF BUILDING AND MISCELLANEOUS FORMS

Description	Location	Reference
Girders		Con. Eng., Dec. 1908, p. 339
Girders		Eng. News, July 19, 1906, p. 80
Girders, beams and cols. (factory blg.)	Cincinnati, Ohio	Con. Eng., Jan. 1, 1907, p. 3
Columns (warehouse)	Chicago	Con. Eng. Aug. 15, 1907, p. 69
Columns		Eng. Contr., Feb. 19, 1908, p. 117
Shoe factory	Beverly, Mass.	Eng. News, May 25, 1905, p. 537
Columns (hotel)	Atlantic City, N. J.	Eng. News, Mar. 8, 1906, p. 251
Column and girders (garage)	New York	Eng. Rec., Jan. 12, 1907, p. 45
Stock house	Montreal, Canada	Eng. News, Feb. 6, 1908, p. 154
Factory	Long Island City, L. I.	Eng. Rec., Jan. 16, 1904, p. 69
Column (hotel)	Atlantic City, N. J.	Eng. Rec., Dec. 30, 1905, p. 744
Column (factory)	Passaic, N. J.	Eng. Rec., Jan. 18, 1908, p. 72
Reservoir walls	Bloomington, Il.	Eng. Rec., Mar. 3, 1906, p. 285
Retaining walls		Eng. Rec., Mar. 9, 1907, p. 339
Tanks		Assn. Am. Portland Cement Mfrs. Bul. No. 23
Water towers	Victoria, B. C.	Eng. Contr., Mar. 9, 1910, p. 224
Water towers	Westerly R. I.	Eng. Contr. Oct. 5, 1910, p. 284
Water tank	Spokane Portland & Seattle R.R.	Eng. Rec., May 7, 1910, p. 608
Grain bins	Port Arthur, Ontario	Eng. Rec., Apr. 9, 1904, p. 451
Miscellaneous		Concrete Review Bul. No. 21 pub. by Assn. Am. Portland Cement Mfrs.
		Farm Book pub. by Atlas Portland Cement Co, New York

REFERENCES TO ARTICLES ON FORMS FOR CONCRETE CONSTRUCTION

Description	Authors	Reference
Forms for concrete construction	Sanford E. Thompson	Proc. Nat. Assn. Cement Users, Vol. 3, 1907, p. 64.
Metal forms	W. L. Caldwell	Eng. Contr., Sept. 16, 1908, p. 174
Metal form costs	W. L. Caldwell	Eng. Contr., Feb. 10, 1909, p. 106
Form construction	A. D. Williams, Jr.	Con. Eng., Mar. 1908, p. 67
Form costs	Robert E. Lamb	Con. Eng., Dec. 12, 1907, p. 198
Reducing cost of forms	Editorial	Eng. News, June 14, 1906, p. 659
Method of reinforced concrete wall construction	A. E. Budell	Eng. Contr., Nov. 28, 1906, p. 162
Reinforced concrete from the contractors' standpoint	H. H. Fox	Eng. News, Jan. 30, 1908, p. 131
Hints on design and construction of reinforced concrete works	C. P. Goodrich	Eng. Rec., Mar. 2, 1907, p. 277
Manufacture, erection, and demolition of forms	F. W. Wilson	Eng. News, Dec. 17, 1908, p. 665
Centering for reinforced concrete work	W. P. Anderson	Con. Eng., Aug. 1909, p. 207
Hints for concrete constructors	W. J. Douglas	Eng. News, Dec. 20, 1906, p. 643

CHAPTER XVII

TABLES OF CONCRETE VOLUMES

The tables of volumes of concrete members are given to reduce the labor of computations when making an estimate. The values include columns, beams, slabs, and walls. Whatever plan of estimating is followed, the volume of the concrete must be computed in order to find the quantities of materials required and to estimate the cost of labor of mixing and laying the concrete.

For a symmetrical building, if no tables are available, it is an easy matter to figure, from the floor areas, the volume of concrete in the slabs. Beams and girders may be taken the entire length or width of the building where there is no change in section. If the building is unsymmetrical, as nearly all buildings are, the computation involves a lot of mathematical work. From the tables in this chapter, the volumes of columns, beams, girders, and slabs can be taken directly, interpolating for sizes intermediate between those scheduled.

HOW TO USE TABLES

The use of the tables in practice is illustrated on the estimate sheet in Chapter XXIII.

Take off from the plans a schedule of all the members. Refer to Tables 72 to 76, pages 526 and 533, and enter on the schedule the volume of each size of member on the list. Multiply the volume by the number of members of the same size.

It is advised, for ordinary estimates, that the lengths of the members be taken off from center to center of supports for beams and girders and from floor surface to floor surface for columns. By this method of figuring, intersections are figured twice, but this excess concrete will just about provide for waste of material and the extra labor on joints. The tables are adapted as well, however, for figuring volumes between supports if this method is preferred.

For exact volumes, the values for a 1-foot length may be used and multiplied by the total length, since these are carried to more decimals than the other columns. For all ordinary estimates, the numbers given in the tables, are sufficiently exact. The error, even for a single member, is not usually over 2% and in a structure of ordinary size the variations will average up so as to be inappreciable.

The tables will be found useful for small computations, such as the calculation of the volume of concrete in the base or wearing surface of a slab, as well as for taking off quantities in large reinforced concrete structures. Examples are given above some of the tables.

It is sometimes convenient to consider a beam or a girder as a single member extending the entire width or length of a building. For example if a beam 13 inches wide by 30 inches deep from top of 4-inch slab runs across a building 100 feet wide, we may multiply the volume in Table 76 for a 1-foot length or 2.35 cubic feet by 100, obtaining 235 cubic feet, or volume for a 25-foot length by 4, giving 236 cubic feet or substantially the same result.

TABLE 72] VOLUME OF CONCRETE PER 100 SQUARE FEET OF SLAB OR WALL

For slabs or walls thicker than schedule, select a slab one-half its thickness and double the volume.

Interpolate for intermediate thicknesses.

Example: What is the volume of a slab 50 feet square and 7½ inches thick?

Solution: The area of the slab is 2500 square feet. From the table, taking a value half way between the 7 and 8-inch thicknesses gives 62.5 cubic feet per 100 square feet of slab or, for 2500 square feet, 62.5×25=1563 cubic feet or 58 cubic yards.

Thickness in Inches	Volume of Concrete per 100 Square Feet		Thickness in Inches	Volume of Concrete per 100 Square Feet		Thickness in Inches	Volume of Concrete per 100 Square Feet	
	Cu. ft.	Cu. yd.		Cu. ft.	Cu. yd.		Cu. ft.	Cu. yd.
¼	2.1	0.08	7	58	2.16	24	200	7.41
½	4.2	0.15	8	67	2.47	26	217	8.02
¾	6.3	0.23	9	75	2.78	28	233	8.65
1	8.3	0.31	10	83	3.09	30	250	9.26
1½	12.5	0.46	12	100	3.71	36	300	11.11
2	16.7	0.62	14	117	4.33	42	350	12.96
3	25.0	0.93	16	133	4.94	48	400	14.82
4	33.3	1.23	18	150	5.56	60	500	18.52
5	41.7	1.54	20	167	6.18	72	600	22.22
6	50.0	1.85	22	183	6.79	84	700	25.92

TABLE 73] **[CONCRETE**

VOLUMES OF CONCRETE IN SQUARE COLUMNS

Quantities are figured for net lengths, but to allow for waste assume lengths as vertical distance between floor surfaces. **See page 525.**

For a column longer than scheduled, select a member one-half its length and double its volume. For volumes in cubic yards divide by 27.

Interpolate for intermediate areas or lengths.

Example: What is the volume of a 10 by 17-inch wall column, 13 feet long?

Solution: This has substantially the same area as a 13 by 13-inch column, hence take the volume as 15 cubic feet.

VOLUME IN CUBIC FEET

Dimension Inches	Area of Section Sq. In.	Length in Feet												
		1	6	8	9	10	11	12	13	14	15	16	18	20
6 × 6	36	0.25	1.5	2.0	2.2	2.5	2.7	3.0	3.3	3.5	3.7	4.0	4.5	5.0
7 × 7	49	0.34	2.0	2.7	3.1	3.4	3.7	4.1	4.4	4.8	5.1	5.5	6.1	6.8
8 × 8	64	0.45	2.7	3.6	4.0	4.5	4.9	5.4	5.8	6.3	6.7	7.2	8.1	9.0
9 × 9	81	0.56	3.3	4.5	5.0	5.6	6.1	6.7	7.3	7.8	8.4	8.9	10	11
10 × 10	100	0.70	4.2	5.6	6.3	7.0	7.7	8.4	9.1	9.8	10	11	13	14
11 × 11	121	0.84	5.0	6.7	7.6	8.4	9.3	10	11	12	13	13	15	17
12 × 12	144	1.00	6.0	8.0	9.0	10	11	12	13	14	15	16	18	20
13 × 13	169	1.18	7.0	9.4	11	12	13	14	15	16	18	19	21	24
14 × 14	196	1.36	8.1	11	12	14	15	16	18	19	20	22	25	27
15 × 15	225	1.56	9.4	13	14	16	17	19	20	22	23	25	28	31
16 × 16	256	1.78	11	14	16	18	20	21	23	25	27	28	32	36
17 × 17	289	2.00	12	16	18	20	22	24	26	28	30	32	36	40
18 × 18	324	2.25	14	18	20	23	25	27	29	32	34	36	41	45
19 × 19	361	2.50	15	20	23	25	28	30	33	35	38	40	45	50
20 × 20	400	2.78	17	22	25	28	31	33	36	39	42	44	50	56
21 × 21	441	3.06	18	25	28	31	34	37	40	43	46	49	55	61
22 × 22	484	3.36	20	27	30	34	37	40	44	47	50	54	61	67
23 × 23	529	3.67	22	29	33	37	40	44	48	51	55	59	66	74
24 × 24	576	4.00	24	32	36	40	44	48	52	56	60	64	72	80
25 × 25	625	4.34	26	35	39	43	48	52	56	61	65	69	78	87
26 × 26	676	4.69	28	38	42	47	52	56	61	66	70	75	85	94
27 × 27	729	5.06	30	41	46	51	56	61	66	71	76	81	91	101
28 × 28	784	5.45	33	44	49	54	60	65	71	76	82	87	98	109
29 × 29	841	5.85	35	47	53	58	64	70	76	82	88	93	105	117
30 × 30	900	6.25	38	50	56	63	69	75	81	88	94	100	112	125
31 × 31	961	6.67	40	53	60	67	73	80	87	93	100	107	120	134
32 × 32	1024	7.11	43	57	64	71	78	85	92	100	107	114	128	142
33 × 33	1089	7.56	45	61	68	76	83	91	98	106	113	121	136	151
34 × 34	1156	8.03	48	64	72	80	88	96	104	112	120	129	145	161
35 × 35	1225	8.51	51	68	77	85	94	102	111	119	128	136	153	170
36 × 36	1296	9.00	54	72	81	90	99	108	117	126	135	144	162	180
37 × 37	1369	9.50	57	76	86	95	105	114	124	133	143	152	171	190
38 × 38	1444	10.03	60	80	90	100	110	120	131	140	150	160	181	201
39 × 39	1521	10.56	63	85	95	106	116	127	137	148	158	169	190	211
40 × 40	1600	11.11	67	89	100	111	122	133	144	156	167	178	200	222

TABLE 74] VOLUMES OF CONCRETE IN OCTAGONAL COLUMNS [CONCRETE

Area of octagon is approximately 0.829 times the area of the enclosing square.

Quantities are figured for net lengths, but to allow for waste assume lengths as vertical distances between floor surfaces. See page 525.

For a column longer than scheduled, select a member one-half its length and double its volume.

Interpolate for intermediate areas or lengths.

Example: What is the volume of a 20-inch column, 24 feet long, extending through two floors?

Solution: The volume of a 20-inch column, 12 feet long, is 28 cubic feet, and multiplying this by 2, as the column is 24 feet long, gives 56 cubic feet as the required volume.

VOLUME IN CUBIC FEET

Diameter Inches	Area of Section Sq. In.	Length in Feet												
		1	6	8	9	10	11	12	13	14	15	16	18	20
6	30	0.21	1.3	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.4	3.8	4.2
7	41	0.28	1.7	2.3	2.5	2.8	3.1	3.4	3.7	4.0	4.2	4.5	5.1	5.6
8	53	0.36	2.1	2.9	3.2	3.6	4.0	4.3	4.7	5.0	5.4	5.7	6.5	7.2
9	67	0.46	2.7	3.7	4.1	4.6	5.1	5.6	6.0	6.4	6.9	7.4	8.3	9.2
10	83	0.58	3.4	4.6	5.2	5.8	6.4	6.9	7.5	8.1	8.7	9.3	10	12
11	100	0.69	4.1	5.6	6.2	6.9	7.6	8.3	9.0	9.7	10	11	13	14
12	119	0.83	5.0	6.6	7.4	8.3	9.1	10	11	12	12	13	15	17
13	140	0.97	5.8	7.8	8.7	9.7	11	12	13	14	15	16	18	19
14	162	1.13	6.8	9.0	10	11	12	14	15	16	17	18	20	23
15	187	1.30	7.8	10	12	13	14	16	17	18	19	21	23	26
16	212	1.47	8.8	12	13	15	16	18	19	21	22	24	27	30
17	240	1.66	10	13	15	17	18	20	22	23	25	27	30	33
18	269	1.87	11	15	17	19	21	22	24	26	28	30	34	37
19	299	2.08	12	17	19	21	23	25	27	29	31	33	37	42
20	332	2.30	14	19	21	23	25	28	30	32	35	37	41	46
21	366	2.54	15	20	23	25	28	31	33	36	38	41	46	51
22	401	2.79	16	22	25	28	31	34	36	39	41	45	50	56
23	439	3.05	18	24	27	30	33	37	40	43	46	49	55	61
24	478	3.31	20	27	30	33	37	40	43	47	50	53	60	66
25	518	3.60	22	29	32	36	40	43	47	50	54	58	65	72
26	560	3.89	23	31	35	39	43	47	51	54	58	62	70	78
27	604	4.20	25	34	38	42	46	50	55	59	63	67	76	84
28	650	4.51	27	36	41	45	50	54	59	63	68	72	81	90
29	697	4.84	29	39	44	48	53	58	63	68	73	77	87	97
30	746	5.18	31	41	47	52	57	62	67	73	78	83	93	104
31	797	5.53	33	44	50	55	61	66	72	78	83	88	100	111
32	849	5.90	35	47	53	59	65	71	77	83	89	94	106	118
33	903	6.27	38	50	56	63	69	75	82	88	94	100	113	125
34	958	6.66	40	53	60	67	73	80	87	94	100	107	120	133
35	1016	7.06	42	56	64	71	78	85	92	99	106	113	127	141
36	1074	7.46	45	60	67	75	82	90	97	104	112	119	134	149
37	1135	7.87	47	63	71	79	87	95	103	111	118	126	142	158
38	1197	8.31	50	67	75	83	91	100	108	116	125	133	150	166
39	1261	8.75	53	70	79	88	96	106	114	123	131	140	158	175
40	1326	9.21	55	74	83	92	101	111	120	129	138	147	166	185

TABLE 75] **VOLUMES OF CONCRETE IN ROUND COLUMNS** [CONCRETE

Quantities are figured for net lengths, but to allow for waste assume lengths as vertical distances between floor surfaces. See page 525.

For a column longer than scheduled, select a member one-half its length and double its volume. For volumes in cubic yards divide by 27.

Interpolate for intermediate areas or lengths.

Example: How many cubic yards of concrete in a 24-inch column, 15½ feet long?

Solution: From the table, taking the volume of a 24-inch column, 15½ feet long as half way between the 15 foot and 16 foot values, we have 48½ cubic feet or 1.8 cubic yards as the required volume.

VOLUME IN CUBIC FEET

Diameter Inches	Area of Section Sq. In.	Length in Feet												
		1	6	8	9	10	11	12	13	14	15	16	18	20
6	28	0.20	1.2	1.6	1.8	2.0	2.2	2.4	2.5	2.7	2.9	3.1	3.5	3.9
7	38	0.27	1.6	2.1	2.4	2.7	2.9	3.2	3.5	3.7	4.0	4.3	4.8	5.3
8	50	0.35	2.1	2.8	3.1	3.5	3.8	4.2	4.5	4.9	5.2	5.6	6.3	7.4
9	64	0.44	2.7	3.5	4.0	4.4	4.9	5.3	5.7	6.2	6.6	7.1	8.0	8.8
10	79	0.55	3.3	4.3	4.9	5.5	6.0	6.6	7.1	7.6	8.2	8.7	9.8	11
11	95	0.66	4.0	5.3	5.9	6.6	7.3	7.9	8.6	9.2	9.9	11	12	13
12	113	0.79	4.7	6.3	7.1	7.9	8.6	9.4	10	11	12	13	14	16
13	133	0.92	5.5	7.4	8.3	9.2	10	11	12	13	14	15	17	18
14	154	1.07	6.4	8.6	9.6	11	12	13	14	15	16	17	19	21
15	177	1.23	7.4	9.8	11	12	14	15	16	17	18	20	22	25
16	201	1.40	8.4	11	13	14	15	17	18	20	21	22	25	28
17	227	1.58	9.5	13	14	16	17	19	21	22	24	25	28	32
18	254	1.77	11	14	16	18	19	21	23	25	27	28	32	35
19	284	1.97	12	16	18	20	22	24	26	28	30	32	35	39
20	314	2.18	13	17	20	22	24	26	28	31	33	35	39	44
21	346	2.40	14	19	22	24	26	29	31	34	36	38	43	48
22	380	2.64	16	21	24	26	29	32	34	37	40	42	48	53
23	415	2.89	17	23	26	29	32	35	38	40	43	46	52	59
24	452	3.14	19	25	28	31	35	38	41	44	47	50	57	63
25	491	3.41	20	27	31	34	38	41	44	48	51	55	61	68
26	531	3.69	22	30	33	37	41	44	48	52	55	59	66	74
27	573	3.98	24	32	36	40	44	48	52	56	60	64	72	80
28	616	4.28	26	34	39	43	47	51	56	60	64	68	77	86
29	661	4.59	28	37	41	46	51	55	60	64	69	73	83	92
30	707	4.91	29	39	44	49	54	59	64	69	74	79	88	98
31	755	5.24	31	42	47	52	58	63	68	73	79	84	94	105
32	804	5.59	34	45	50	56	61	67	73	78	84	89	101	112
33	855	5.94	36	48	53	59	65	71	77	83	89	95	107	119
34	908	6.30	38	50	57	63	69	76	82	88	95	101	113	126
35	962	6.68	40	53	60	67	73	80	87	94	100	107	120	134
36	1018	7.07	42	57	64	71	78	85	92	99	106	113	127	141
37	1075	7.47	45	60	67	75	82	90	97	105	112	120	134	149
38	1134	7.88	47	63	71	79	87	95	102	110	118	126	142	158
39	1195	8.30	50	66	75	83	91	100	108	116	125	133	149	166
40	1257	8.73	52	70	79	87	96	105	113	122	131	140	157	175

TABLE 76] VOLUMES OF CONCRETE IN BEAMS AND GIRDERS [CONCRETE

Quantities are figured for net lengths, but to allow for waste assume length of beams as length from center to center of support. See page 525.

For a beam longer than scheduled, select a member one-half its length and double its volume.

Interpolate for intermediate areas and lengths.

VOLUME IN CUBIC FEET

Dimensions below Slab Inches	Area below Slab Sq. In.	LENGTH OF BEAM IN FEET														
		1	8	9	10	11	12	13	14	15	16	17	18	19	20	21
4 × 4	16	0.11	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.7	1.8					
4 × 8	32	0.22	1.8	2.0	2.2	2.4	2.6	2.9	3.1	3.3	3.5					
4 × 10	40	0.28	2.2	2.5	2.8	3.1	3.4	3.6	3.9	4.2	4.5	4.8				
4 × 12	48	0.33	2.6	3.0	3.3	3.6	4.0	4.3	4.6	5.0	5.3	5.6	5.9			
5 × 10	50	0.35	2.8	3.2	3.5	3.9	4.2	4.6	4.9	5.3	5.6	6.0	6.3	6.7		
5 × 12	60	0.42	3.4	3.8	4.2	4.6	5.0	5.5	5.9	6.3	6.7	7.1	7.6	8.0	8.4	
5 × 14	70	0.49	3.9	4.4	4.9	5.4	5.9	6.4	6.9	7.4	7.8	8.3	8.8	9.3	9.8	10
5 × 16	80	0.56	4.5	5.0	5.6	6.2	6.7	7.3	7.8	8.4	9.0	9.5	10	11	11	12
6 × 12	72	0.50	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10	11
6 × 14	84	0.58	4.6	5.2	5.8	6.4	7.0	7.5	8.1	8.7	9.3	9.9	10	11	12	12
6 × 16	96	0.67	5.4	6.0	6.7	7.4	8.0	8.7	9.4	10	11	11	12	13	13	14
6 × 18	108	0.75	6.0	6.8	7.5	8.3	9.0	9.8	11	11	12	13	14	14	15	16
7 × 14	98	0.68	5.4	6.1	6.8	7.5	8.2	8.8	9.5	10	11	12	12	13	14	14
7 × 16	112	0.78	6.2	7.0	7.8	8.6	9.4	10	11	12	12	13	14	15	16	16
7 × 18	126	0.88	7.0	7.9	8.8	9.7	11	11	12	13	14	15	16	17	18	18
7 × 20	140	0.97	7.8	8.7	9.7	11	12	13	14	15	16	16	17	18	19	20
8 × 14	112	0.78	6.2	7.0	7.8	8.6	9.4	10	11	12	12	13	14	15	16	16
8 × 16	128	0.89	7.1	8.0	8.9	9.8	11	12	12	13	14	15	16	17	18	19
8 × 18	144	1.00	8.0	9.0	10	11	12	13	14	15	16	17	18	19	20	21
8 × 20	160	1.11	8.9	10	11	12	13	14	16	17	18	19	20	21	22	23
8 × 22	176	1.22	9.8	11	12	13	15	16	17	18	20	21	22	23	24	26
8 × 24	192	1.33	11	12	13	15	16	17	19	20	21	23	24	25	27	28
8 × 26	208	1.44	12	13	14	16	17	19	20	22	23	24	26	27	29	30
9 × 16	144	1.00	8.0	9.0	10	11	12	13	14	15	16	17	18	19	20	21
9 × 18	162	1.13	9.0	10	11	12	14	15	16	17	18	19	20	21	23	24
9 × 20	180	1.25	10	11	13	14	15	16	18	19	20	21	23	24	25	26
9 × 22	198	1.38	11	12	14	15	17	18	19	21	22	23	25	26	28	29
9 × 24	216	1.50	12	14	15	17	18	20	21	23	24	26	27	29	30	32
9 × 26	234	1.63	13	15	16	18	20	21	23	24	26	28	29	31	33	34
9 × 28	252	1.75	14	16	18	19	21	23	25	26	28	30	32	33	35	37
10 × 18	180	1.25	10	11	13	14	15	16	18	19	20	21	23	24	25	26
10 × 20	200	1.39	11	13	14	15	17	18	19	21	22	24	25	26	28	29
10 × 22	220	1.53	12	14	15	17	18	20	21	23	24	26	28	29	31	32
10 × 24	240	1.67	13	15	17	18	20	22	23	25	27	28	30	32	33	35
10 × 26	260	1.81	14	16	18	20	22	24	25	27	29	31	33	34	36	38
10 × 28	280	1.94	16	17	19	21	23	25	27	29	31	33	35	37	39	41
10 × 30	300	2.08	17	19	21	23	25	27	29	31	33	35	37	39	42	44
11 × 20	220	1.53	12	14	15	17	18	20	21	23	24	26	28	29	31	32
11 × 22	242	1.68	13	15	17	18	20	22	24	25	27	29	30	32	34	35
11 × 24	264	1.83	15	16	18	20	22	24	26	27	29	31	33	35	37	38
11 × 26	286	1.99	16	18	20	22	24	26	28	30	32	34	36	38	40	42
11 × 28	308	2.14	17	19	21	24	26	28	30	32	34	36	39	41	43	45
11 × 30	330	2.29	18	20	23	25	27	30	32	34	37	39	41	44	46	48
11 × 32	352	2.44	20	22	24	27	29	32	34	37	39	41	44	46	49	51

TABLE 76] VOLUMES OF BEAMS—Continued [CONCRETE

Example: Find the volume of a beam $9\frac{1}{2}'' \times 26'' \times 18$ ft.-6″
Solution: From Table (by inspection)

Volume $9'' \times 26'' \times 18$ ft. = 29 cu. ft. Volume $9'' \times 26'' \times 19$ ft. = 31 cu. ft.
Volume $10'' \times 26'' \times 18$ ft. = 33 cu. ft. Volume $10'' \times 26'' \times 19$ ft. = 34 cu. ft.
Hence, $9\frac{1}{2}'' \times 26'' \times 18$ ft. = 31 cu. ft. Hence, $9\frac{1}{2}'' \times 26'' \times 19$ ft. = 33 cu. ft.
Therefore, volume = $9\frac{1}{2}'' \times 26'' \times 18$ ft.-6″ = 32 cu. ft.

VOLUME IN CUBIC FEET

Dimensions below Slab Inches	Area below Slab Sq. In.	Length of Beam in Feet														
		22	23	24	25	26	27	28	29	30	32	34	36	40	44	48
5 × 16	80	12														
6 × 12	72	11	12													
6 × 14	84	13	13	14												
6 × 16	96	15	15	16	17											
6 × 18	108	17	17	18	19	20										
7 × 14	98	15	16	16	17	18	18									
7 × 16	112	17	18	19	20	20	21	22								
7 × 18	126	19	20	21	22	23	24	24	25							
7 × 20	140	21	23	23	24	25	26	28	29	29						
8 × 14	112	17	18	19	20	20	21	22	23	23	24					
8 × 16	128	20	20	21	22	23	24	25	26	27	28	30				
8 × 18	144	22	23	24	25	26	27	28	29	30	32	34	36			
8 × 20	160	24	26	27	28	29	30	31	32	33	36	38	40	44		
8 × 22	176	27	28	29	31	32	33	34	35	37	40	42	44	49	54	
8 × 24	192	29	31	32	33	35	36	37	39	40	42	46	48	53	58	64
8 × 26	208	32	33	35	36	37	39	40	42	43	46	48	52	58	64	69
9 × 16	144	22	23	24	25	26	27	28	29	30	32	34	36	40	44	48
9 × 18	162	25	26	27	28	29	31	32	33	34	36	38	40	45	50	54
9 × 20	180	28	29	30	31	33	34	35	36	38	40	43	45	50	55	60
9 × 22	198	30	32	33	35	36	37	39	40	41	44	47	50	55	61	66
9 × 24	216	33	35	36	38	39	41	42	44	45	48	51	54	60	66	72
9 × 26	234	36	37	39	41	42	44	46	47	49	52	55	59	65	72	78
9 × 28	252	39	40	42	44	46	47	49	51	53	56	60	63	70	77	84
10 × 18	180	28	29	30	31	33	34	35	36	38	40	43	45	50	55	60
10 × 20	200	31	32	33	35	36	38	39	40	42	44	47	50	56	61	67
10 × 22	220	34	35	37	38	40	41	43	44	46	49	52	55	61	67	73
10 × 24	240	37	38	40	42	43	45	47	48	50	53	57	60	67	73	80
10 × 26	260	40	42	43	45	47	49	51	53	54	58	62	65	72	80	87
10 × 28	280	43	45	47	49	50	52	54	56	58	62	66	70	78	85	93
10 × 30	300	46	48	50	52	54	56	58	60	62	67	71	75	83	92	100
11 × 20	220	34	35	37	38	40	41	43	44	46	49	52	55	61	67	73
11 × 22	242	37	39	40	42	44	45	47	49	50	54	57	60	67	74	81
11 × 24	264	40	42	44	46	48	49	51	53	55	59	62	66	73	81	88
11 × 26	286	44	46	48	50	52	54	56	58	60	64	68	72	80	88	96
11 × 28	308	47	49	51	54	56	58	60	62	64	68	73	77	86	94	103
11 × 30	330	50	53	55	57	60	62	64	66	69	73	78	82	92	101	110
11 × 32	352	54	56	59	61	63	66	68	71	73	78	83	88	98	107	117

TABLE 76] VOLUMES OF CONCRETE IN BEAMS AND GIRDERS—Continued [CONCRETE

Quantities are figured for net lengths, but to allow for waste assume lengths of beams as length from center to center of support. See page 525.

For a beam longer than scheduled, select a member one-half its length and double its volume. For volumes in cubic yards divide by 27.

Interpolate for intermediate areas and lengths.

VOLUME IN CUBIC FEET

Dimensions below Slab Inches	Area below Slab Sq. In.	LENGTH OF BEAM IN FEET 1	8	9	10	11	12	13	14	15	16	17	18	19	20	21
12 × 22	264	1.83	15	16	18	20	23	24	26	27	29	31	33	35	37	38
12 × 24	288	2.00	16	18	20	22	24	26	28	30	32	34	36	38	40	42
12 × 26	312	2.17	17	20	22	24	26	28	30	33	35	37	39	41	43	46
12 × 28	336	2.33	19	21	23	26	28	30	33	35	37	40	42	44	47	49
12 × 30	360	2.50	20	23	25	28	30	33	35	38	40	43	45	48	50	53
12 × 32	384	2.67	21	24	27	29	32	35	37	40	43	45	48	51	53	56
12 × 34	408	2.83	23	25	28	31	34	37	40	43	45	48	51	54	57	59
13 × 26	338	2.35	19	21	24	26	28	31	33	35	38	40	42	45	47	49
13 × 28	364	2.53	20	23	25	28	30	33	35	38	41	43	46	48	51	53
13 × 30	390	2.71	22	24	27	30	33	35	38	41	43	46	49	52	54	57
13 × 32	416	2.89	23	26	29	32	35	38	41	43	46	49	52	55	58	61
13 × 34	442	3.07	25	28	31	34	37	40	43	46	49	52	55	58	61	64
13 × 36	468	3.25	26	29	32	36	39	42	46	49	52	55	59	62	65	68
13 × 38	494	3.42	27	31	34	38	41	45	48	51	55	58	62	65	69	72
14 × 28	392	2.72	22	24	27	30	33	35	38	41	44	46	49	52	54	57
14 × 30	420	2.92	23	26	29	32	35	38	41	44	47	50	53	55	58	61
14 × 32	448	3.11	25	28	31	34	37	40	44	47	50	53	56	59	62	65
14 × 34	476	3.31	26	30	33	36	40	43	46	50	53	56	60	63	66	70
14 × 36	504	3.50	28	32	35	39	42	46	49	53	56	60	63	67	70	74
14 × 38	532	3.69	30	33	37	41	44	48	52	55	59	63	66	70	74	77
14 × 40	560	3.89	31	35	39	43	47	51	54	58	62	66	70	74	78	82
15 × 30	450	3.13	25	28	31	34	38	41	44	47	50	53	56	59	63	66
15 × 32	480	3.33	27	30	33	37	40	43	47	50	53	57	60	63	67	70
15 × 34	510	3.54	28	32	35	39	42	46	50	53	57	60	64	67	71	74
15 × 36	540	3.75	30	34	38	41	45	49	53	56	60	64	68	71	75	79
15 × 38	570	3.96	32	36	40	44	48	51	55	59	63	67	71	75	79	83
15 × 40	600	4.16	33	38	42	46	50	54	58	63	67	71	75	79	83	88
15 × 42	630	4.38	35	39	44	48	53	57	61	66	70	74	79	83	88	92
16 × 32	512	3.56	28	32	36	39	43	46	50	53	57	60	64	68	71	75
16 × 34	544	3.78	30	34	38	42	45	49	53	57	60	64	68	72	76	79
16 × 36	576	4.00	32	36	40	44	48	52	56	60	64	68	72	76	80	84
16 × 38	608	4.22	34	38	42	46	51	55	59	63	68	72	76	80	84	89
16 × 40	640	4.44	36	40	44	49	53	58	62	67	71	75	80	84	89	93
16 × 42	672	4.67	37	42	47	51	56	61	65	70	75	79	84	89	93	98
16 × 46	736	5.11	41	46	51	56	61	66	72	77	82	87	92	97	102	107
18 × 36	648	4.50	36	41	45	50	54	59	63	68	72	77	81	86	90	95
18 × 40	720	5.00	40	45	50	55	60	65	70	75	80	85	90	95	100	105
18 × 44	792	5.50	44	50	55	61	66	72	77	83	88	94	99	105	110	116
18 × 48	864	6.00	48	54	60	66	72	78	84	90	96	102	108	114	120	126
20 × 30	600	4.17	33	38	42	46	50	54	58	63	67	71	75	79	83	88
20 × 40	800	5.55	44	50	56	61	67	72	78	83	89	95	100	106	111	117
20 × 50	1000	6.94	56	62	69	76	83	90	97	104	111	118	125	132	139	146
20 × 60	1200	8.34	67	75	83	92	100	108	117	125	133	142	150	158	167	175

TABLE 76] VOLUMES OF BEAMS—Continued [CONCRETE

Example: Find the exact volume of a 15 by 35-inch girder, 20 feet long.

Solution: The volume for one linear foot is $\frac{3.54 + 3.75}{2}$ = 3.645 cubic feet and for 20 feet is 72.9 cubic feet. Direct interpolation between 15 by 34 and 15 by 36 gives 73 cubic feet which is exact enough for practical purposes.

VOLUME IN CUBIC FEET

Dimensions below Slab Inches	Area below Slab Sq. In.	Length of Beam in Feet														
		22	23	24	25	26	27	28	29	30	32	34	36	40	44	48
12 × 22	264	40	42	44	46	48	49	51	53	55	59	62	66	73	81	88
12 × 24	288	44	46	48	50	52	54	56	58	60	64	68	72	80	88	96
12 × 26	312	48	50	52	54	56	59	61	63	65	69	74	78	87	95	104
12 × 28	336	51	54	56	58	61	63	65	68	70	75	79	84	93	103	112
12 × 30	360	55	58	60	63	65	68	70	73	75	80	85	90	100	110	120
12 × 32	384	59	61	64	67	69	72	75	77	80	85	91	96	107	117	128
12 × 34	408	62	65	68	71	74	76	79	82	85	91	96	102	113	125	136
13 × 26	338	52	54	56	59	61	63	66	68	70	75	80	85	94	103	113
13 × 28	364	56	58	61	63	66	68	71	73	76	81	86	91	101	111	121
13 × 30	390	60	62	65	68	70	73	76	79	81	87	92	98	108	119	130
13 × 32	416	64	66	69	72	75	78	81	84	87	92	98	104	116	127	139
13 × 34	442	68	71	74	77	80	83	86	89	92	98	104	111	123	135	147
13 × 36	468	72	75	78	81	85	88	91	94	98	104	111	117	130	143	156
13 × 38	494	75	79	82	86	89	92	96	99	103	110	117	123	137	151	165
14 × 28	392	60	63	65	68	71	73	76	79	82	87	92	98	109	120	131
14 × 30	420	64	67	70	73	76	79	82	85	88	93	99	105	117	128	140
14 × 32	448	68	72	75	78	81	84	87	90	93	100	106	112	124	137	149
14 × 34	476	73	76	79	83	86	89	93	96	99	106	113	119	132	146	159
14 × 36	504	77	81	84	88	91	95	98	102	105	112	119	126	140	154	168
14 × 38	532	81	85	89	92	96	100	103	107	111	118	125	133	148	162	177
14 × 40	560	86	89	92	97	101	105	109	113	117	124	132	140	155	171	185
15 × 30	450	69	72	75	78	81	84	88	91	94	100	106	113	125	138	150
15 × 32	480	73	77	80	83	87	89	93	96	100	107	113	120	133	147	160
15 × 34	510	78	81	85	89	92	96	99	103	106	113	120	127	142	156	170
15 × 36	540	83	86	90	94	98	102	105	109	113	120	128	135	150	165	180
15 × 38	570	87	91	95	99	103	107	111	115	119	127	135	143	158	174	190
15 × 40	600	92	96	100	104	108	112	117	121	125	133	142	150	167	183	200
15 × 42	630	96	101	105	110	114	118	123	126	131	140	149	157	175	193	210
16 × 32	512	78	82	85	89	93	97	100	104	107	114	121	128	142	157	171
16 × 34	544	83	87	91	95	98	102	106	110	113	121	129	136	152	166	182
16 × 36	576	88	92	96	100	104	108	112	116	120	128	136	144	160	176	192
16 × 38	608	93	97	101	106	110	114	118	122	127	135	143	152	169	186	203
16 × 40	640	98	102	107	111	115	119	124	128	133	142	151	160	178	195	213
16 × 42	672	103	107	112	117	121	126	131	136	140	149	159	168	187	206	224
16 × 46	736	112	118	123	128	133	138	143	148	153	164	174	184	204	225	245
18 × 36	648	99	104	108	113	117	122	126	130	135	144	153	162	180	198	216
18 × 40	720	110	115	120	125	130	135	140	145	150	160	170	180	200	220	240
18 × 44	792	121	127	132	138	143	149	154	160	165	176	187	198	220	242	264
18 × 48	864	132	138	144	150	156	162	168	174	180	192	204	216	240	264	288
20 × 30	600	92	96	100	104	108	112	117	121	125	133	142	150	167	183	200
20 × 40	800	122	128	133	139	144	150	156	161	167	178	189	200	222	245	267
20 × 50	1000	153	160	167	173	180	187	194	201	208	222	236	250	278	305	333
20 × 60	1200	183	192	200	208	217	225	233	241	250	267	283	300	333	367	400

CHAPTER XVIII

TABLES OF STEEL AREAS AND QUANTITIES

The tables in this chapter are prepared for two purposes:

(1) To assist in the design of reinforcement, and

(2) To give weights of steel for reinforced concrete members that will reduce the labor of computation in making up estimates.

For purposes of design, the areas of different combinations of steel are given in Tables 78 to 84. The values will aid the designer in selecting the sizes of steel bars, either round or square, that will best suit the requirements of his columns, beams, slabs, or walls.

For reducing the labor of computation, Tables 85 to 90 give directly the weights of steel for different combinations of sizes and for concrete members of different dimensions.

Table 78 gives areas, circumferences, and weights of steel bars.

Times and costs of labor are treated in the chapter which follows.

Weight of Steel Corresponding to Different Ratios. Table 77. Table 77 gives the weight of steel per cubic foot and also per cubic yard of concrete corresponding to different ratios, or percentages. For example, if a beam has a ratio of 0.008 (or 0.8%) steel, we find 3.9 pounds of steel per cubic foot of concrete. In using this table, the total quantity of concrete, and not the section above the steel, must be taken when figuring the ratio or percentage.

Area of Groups of Bars. Tables 79 and 80. Areas are given of groups of round and square bars from $\frac{1}{8}$-inch to 3 inches diameter. Thus, if a column requires 12 square inches of steel, we find from the table four 2-inch round bars or six $1\frac{5}{8}$-inch round bars, or four $1\frac{3}{4}$-inch square bars, and so on.

For weights of groups of bars of like size, see Tables 123 and 124.

Alternate Selection of Bars. Tables 81 to 84. Knowing the required area of section of steel in a beam, it is possible, from the tables, to select combinations of sizes that will best fit the case under consideration. For example, if a certain beam requires 2 square inches of steel, we find, from the table, one $1\frac{5}{8}$-inch round bar with an area of 2.07 square inches, or two $1\frac{1}{8}$-inch round bars with an area of 1.99 square inches, and so on.

Tables 83 and 84 provide means for selecting the sizes and spacing of bars in slabs or walls of various thicknesses and with various ratios or percentages of steel. Suppose, for example, that a 4-inch slab requires a ratio of 0.007 (0.7%) of steel, we find by reference to Table 83, alternate selections of $\frac{3}{8}$-inch diameter bars spaced 4.8 inches apart; or $\frac{1}{2}$-inch bars spaced 8.6 inches apart, and so on. It is frequently convenient to use the steel areas for one foot of width given in Column (4). In this case, Columns (1), (2), and (3) can be disregarded.

Weights of Column Steel. Tables 85 and 86. These tables and those which follow are for direct use in taking off steel quantities or checking estimates. Allowance is always made for lap so that the figures can be used without correction.

For example, if the plan calls for four $1\frac{1}{4}$-inch round bars with $\frac{3}{8}$-inch hoops, spaced 12 inches apart, in a column 13 feet high, take the weight of steel per column directly from Table 85, as 284 pounds.

Weights of Beam Reinforcement. Tables 87 and 88. Pages 556 to 559. The weights include allowance required under average conditions for extra steel in bends, for lap over supports, and for stirrups. The values therefore may be used directly in taking off steel quantities or checking estimates. The allowance of 20% for the lap over supports required for negative bending moment is based on a study of actual designs. Economical depths of beams* have been figured for each amount of steel to obtain the lengths of stirrups and the extra lengths required in bent bars. The number of stirrups required for average conditions, with the given quantity of straight and bent up tension bars, has been figured.† (See also pages 572 to 595.) As such computations can be only approximate, the same average depths are used for round and square bars.

To illustrate the use of the tables: If the design of a beam 20 feet long requires six $\frac{7}{8}$-inch round bars, find directly from Table 87, page 556, that 328 pounds of steel are needed. Economical total depth for T-beam will be about 26 inches, and twelve $\frac{3}{8}$-inch stirrups, six at each end, will satisfy average conditions.

The tables may be used for an approximate check of the design of beams. If number of stirrups is excessive, use larger steel and correspondingly fewer stirrups.

*Depths are obtained from Taylor & Thompson's "Concrete, Plain and Reinforced," second edition, pages 425 and 426, formulas (14) and (15) assuming $f_s = 16000$ and $b' = \frac{1}{2}d$.

†See "Concrete, Plain and Reinforced," second edition, pages 518b and 528.

BASE PRICE OF STEEL

In quotations on steel bars, it is customary to make a base price for bars $\frac{3}{4}$-inch or over in size and increase the price for smaller sizes by a fixed amount, as shown in table below. Thus if the base price of steel, f.o.b. Pittsburg, is $1.20 per hundredweight, the price of $\frac{3}{8}$-inch bars will be $1.20 + $0.25 = $1.45.

PRICES TO ADD TO BASE FOR STEEL OF SMALL SIZES

To the base price per hundredweight of steel, add the amount opposite the given size of bar.

Size of Bar, Inches	Extra Cost per Cwt. over Base Price	Size of Bar, Inches	Extra Cost per Cwt. over Base Price
$\frac{3}{4}$ to $3\frac{1}{16}$	Base	$\frac{9}{32}$	$0.40
$\frac{5}{8}$ to $\frac{11}{16}$	$0.05	$\frac{1}{4}$	0.50
$\frac{1}{2}$ to $\frac{9}{16}$	0.10	$\frac{15}{64}$	0.75
$\frac{7}{16}$	0.20	$\frac{7}{32}$	1 00
$\frac{3}{8}$	0.25	$\frac{3}{16}$	1.25
$\frac{5}{16}$	0.30		

TABLE 77. WEIGHTS OF STEEL PER CUBIC FOOT AND PER CUBIC YARD OF CONCRETE FOR GIVEN RATIOS OF REINFORCEMENT (See p. 534)

This table may be used where the volume of concrete has been figured and the approximate per cent of reinforcement is known.

Ratio of Steel to Concrete*	Weight of Steel in Pounds		Ratio of Steel to Concrete*	Weight of Steel in Pounds	
	Per cubic foot of concrete	Per cubic yard of concrete		Per cubic foot of concrete	Per cubic yard of concrete
0.0010	0.5	13	0.0100	4.9	132
0.0015	0.7	20	0.0105	5.1	139
0.0020	1.0	26	0.0110	5.4	145
0.0025	1.2	33	0.0115	5.6	152
0.0030	1.5	40	0.0120	5.9	159
0.0035	1.7	46	0.0125	6.1	165
0.0040	2.0	53	0.0130	6.4	172
0.0045	2.2	59	0.0140	6.9	185
0.0050	2.5	66	0.0150	7.3	197
0.0055	2.7	73	0.0160	7.8	210
0.0060	2.9	79	0.0170	8.3	224
0.0065	3.2	86	0.0180	8.8	238
0.0070	3.4	92	0.0190	9.3	251
0.0075	3.7	99	0.0200	9.8	264
0.0080	3.9	106	0.0225	11.0	297
0.0085	4.2	112	0.0250	12.2	329
0.0090	4.4	119	0.0275	13.5	364
0.0095	4.7	126	0.0300	14.7	397

*Percentages of steel are values in these columns multiplied by 100.

TABLE 78. AREAS, WEIGHTS, AND CIRCUMFERENCES OF SQUARE AND ROUND BARS

One cubic foot of steel weighs 490 lb.

Thickness or Diameter of Bar in Inches	Area of Square Bar in Square Inches	Area of Round Bar in Square Inches	Circumference of Round Bar in Inches	Weight of Square Bar One Foot Long	Weight of Round Bar One Foot Long	Thickness or Diameter of Bar in Inches	Area of Square Bar in Square Inches	Area of Round Bar in Square Inches	Circumference of Round Bar in Inches	Weight of Square Bar One Foot Long	Weight of Round Bar One Foot Long
0						2	4.000	3.142	6.283	13.60	10.68
1/16	0.004	0.003	0.196	0.013	0.010	2 1/16	4.254	3.341	6.480	14.46	11.36
1/8	0.016	0.012	0.393	0.053	0.042	2 1/8	4.516	3.547	6.676	15.35	12.06
3/16	0.035	0.028	0.589	0.119	0.094	2 3/16	4.785	3.758	6.872	16.27	12.78
1/4	0.063	0.049	0.785	0.212	0.167	2 1/4	5.063	3.976	7.069	17.22	13.52
5/16	0.098	0.077	0.982	0.333	0.261	2 5/16	5.348	4.200	7.265	18.19	14.28
3/8	0.141	0.110	1.178	0.478	0.375	2 3/8	5.641	4.430	7.461	19.18	15.07
7/16	0.191	0.150	1.374	0.651	0.511	2 7/16	5.941	4.666	7.658	20.20	15.86
1/2	0.250	0.196	1.571	0.850	0.667	2 1/2	6.250	4.909	7.854	21.25	16.69
9/16	0.316	0.249	1.767	1.076	0.845	2 9/16	6.566	5.157	8.050	22.33	17.53
5/8	0.391	0.307	1.964	1.328	1.043	2 5/8	6.891	5.412	8.247	23.43	18.40
11/16	0.473	0.371	2.160	1.608	1.262	2 11/16	7.223	5.673	8.443	24.56	19.29
3/4	0.563	0.442	2.356	1.913	1.502	2 3/4	7.563	5.940	8.639	25.00	20.20
13/16	0.660	0.519	2.553	2.245	1.763	2 13/16	7.910	6.213	8.836	26.90	21.12
7/8	0.766	0.601	2.749	2.603	2.044	2 7/8	8.266	6.492	9.032	28.10	22.07
15/16	0.879	0.690	2.945	2.989	2.347	2 15/16	8.629	6.777	9.228	29.34	23.04
1	1.000	0.785	3.142	3.400	2.670	3	9.000	7.069	9.425	30.60	24.03
1 1/16	1.129	0.887	3.338	3.838	3.014	3 1/16	9.379	7.366	9.621	31.89	25.04
1 1/8	1.266	0.994	3.534	4.303	3.379	3 1/8	9.766	7.670	9.818	33.20	26.08
1 3/16	1.410	1.108	3.731	4.795	3.766	3 3/16	10.160	7.980	10.014	34.55	27.13
1 1/4	1.563	1.227	3.927	5.312	4.173	3 1/4	10.563	8.296	10.210	35.92	28.20
1 5/16	1.723	1.353	4.123	5.857	4.600	3 5/16	10.973	8.618	10.407	37.31	29.30
1 3/8	1.891	1.485	4.320	6.428	5.049	3 3/8	11.391	8.946	10.603	38.73	30.42
1 7/16	2.066	1.623	4.516	7.026	5.518	3 7/16	11.816	9.281	10.799	40.18	31.56
1 1/2	2.250	1.767	4.712	7.650	6.008	3 1/2	12.250	9.621	10.996	41.65	32.71
1 9/16	2.441	1.918	4.909	8.301	6.520	3 9/16	12.691	9.968	11.192	43.14	33.90
1 5/8	2.641	2.074	5.105	8.978	7.051	3 5/8	13.141	10.321	11.388	44.68	35.09
1 11/16	2.848	2.237	5.301	9.682	7.604	3 11/16	13.598	10.680	11.585	46.24	36.31
1 3/4	3.063	2.405	5.498	10.41	8.178	3 3/4	14.063	11.045	11.781	47.82	37.56
1 13/16	3.285	2.580	5.694	11.17	8.773	3 13/16	14.535	11.416	11.977	49.42	38.81
1 7/8	3.516	2.761	5.891	11.95	9.388	3 7/8	15.016	11.793	12.174	51.05	40.10
1 15/16	3.754	2.948	6.087	12.76	10.020	3 15/16	15.504	12.177	12.370	52.71	41.40

TABLE 79] AREAS OF GROUPS OF ROUND BARS OF UNIFORM DIAMETER [STEEL

(See p. 534)

See Table 78 and Tables 85 to 90, pp. 554 to 561, and Table 123, p. 600, for weights of bars.

See Tables 81 and 83, for areas of combination of bars of different sizes.

AREAS OF ROUND BARS IN SQUARE INCHES

Diameter of Bar in Inches	Number of Bars														
	1	2	3	4	5	6	7	8	9	10	12	14	16	18	20
1/8	0.012	0.025	0.037	0.05	0.06	0.07	0.09	0.10	0.11	0.12	0.15	0.17	0.20	0.22	0.25
3/16	0.028	0.055	0.083	0.11	0.14	0.17	0.19	0.22	0.25	0.28	0.33	0.39	0.44	0.50	0.55
1/4	0.049	0.098	0.147	0.20	0.25	0.29	0.34	0.39	0.44	0.49	0.59	0.69	0.79	0.88	0.98
5/16	0.077	0.153	0.230	0.31	0.38	0.46	0.54	0.61	0.69	0.77	0.92	1.07	1.23	1.38	1.53
3/8	0.110	0.221	0.331	0.44	0.55	0.66	0.77	0.88	0.99	1.10	1.32	1.55	1.77	1.99	2.21
7/16	0.150	0.301	0.451	0.60	0.75	0.90	1.05	1.20	1.35	1.50	1.80	2.10	2.40	2.71	3.01
1/2	0.196	0.393	0.589	0.78	0.98	1.18	1.37	1.57	1.77	1.96	2.36	2.75	3.14	3.53	3.93
9/16	0.248	0.497	0.746	0.99	1.24	1.49	1.74	1.99	2.24	2.48	2.98	3.48	3.98	4.47	4.97
5/8	0.307	0.614	0.920	1.23	1.54	1.84	2.15	2.46	2.76	3.07	3.68	4.30	4.91	5.52	6.14
11/16	0.371	0.742	1.114	1.48	1.86	2.23	2.60	2.97	3.34	3.71	4.45	5.19	5.94	6.68	7.42
3/4	0.442	0.884	1.325	1.77	2.21	2.65	3.09	3.53	3.98	4.42	5.30	6.19	7.07	7.95	8.84
13/16	0.518	1.037	1.555	2.07	2.59	3.11	3.63	4.15	4.67	5.18	6.22	7.26	8.30	9.33	10.37
7/8	0.601	1.203	1.804	2.41	3.01	3.61	4.21	4.81	5.41	6.01	7.22	8.42	9.62	10.82	12.03
15/16	0.690	1.380	2.071	2.76	3.45	4.14	4.83	5.52	6.21	6.90	8.28	9.66	11.05	12.43	13.81
1	0.785	1.571	2.356	3.14	3.93	4.71	5.50	6.28	7.07	7.85	9.42	11.00	12.57	14.14	15.71
1/16	0.887	1.773	2.660	3.55	4.44	5.32	6.21	7.10	7.98	8.87	10.64	12.41	14.19	15.96	17.73
1/8	0.994	1.988	2.982	3.98	4.97	5.96	6.96	7.95	8.95	9.94	11.93	13.92	15.90	17.89	19.88
3/16	1.108	2.215	3.323	4.43	5.54	6.64	7.75	8.86	9.97	11.07	13.29	15.50	17.72	19.94	22.15
1/4	1.227	2.455	3.682	4.91	6.14	7.36	8.59	9.82	11.05	12.27	14.73	17.18	19.64	22.09	24.55
5/16	1.353	2.706	4.059	5.41	6.77	8.12	9.47	10.82	12.18	13.53	16.24	18.94	21.65	24.36	27.06
3/8	1.485	2.970	4.455	5.94	7.42	8.91	10.39	11.88	13.36	14.85	17.82	20.79	23.76	26.73	29.70
7/16	1.623	3.246	4.870	6.49	8.12	9.74	11.36	12.98	14.61	16.23	19.48	22.72	25.97	29.22	32.46
1/2	1.767	3.535	5.302	7.07	8.84	10.60	12.37	14.14	15.91	17.67	21.21	24.74	28.28	31.81	35.35
9/16	1.918	3.835	5.753	7.67	9.59	11.51	13.42	15.34	17.26	19.18	23.01	26.85	30.68	34.52	38.35
5/8	2.074	4.148	6.222	8.29	10.37	12.44	14.52	16.59	18.66	20.74	24.89	29.03	33.18	37.33	41.48
11/16	2.236	4.473	6.709	8.95	11.18	13.42	15.66	17.89	20.13	22.37	26.84	31.31	35.78	40.25	44.72
3/4	2.405	4.811	7.216	9.62	12.03	14.43	16.84	19.24	21.65	24.05	28.87	33.68	38.49	43.30	48.11
13/16	2.580	5.161	7.742	10.32	12.90	15.48	18.06	20.64	23.22	25.80	30.96	36.12	41.28	46.45	51.61
7/8	2.761	5.523	8.284	11.05	13.80	16.57	19.33	22.09	24.85	27.61	33.14	38.66	44.18	49.70	55.22
15/16	2.948	5.897	8.845	11.79	14.74	17.69	20.64	23.59	26.54	29.48	35.38	41.28	47.18	53.07	58.97
2	3.142	6.284	9.425	12.57	15.71	18.85	21.99	25.13	28.27	31.42	37.70	43.98	50.27	56.55	62.84
1/8	3.547	7.094	10.640	14.18	17.73	21.28	24.83	28.37	31.92	35.47	42.56	49.65	56.75	63.84	70.94
1/4	3.976	7.953	11.930	15.91	19.88	23.86	27.83	31.81	35.79	39.76	47.72	55.67	63.62	71.58	79.53
3/8	4.430	8.861	13.290	17.72	22.15	26.58	31.01	35.44	39.87	44.30	53.17	62.03	70.90	79.75	88.61
1/2	4.909	9.817	14.726	19.63	24.54	29.45	34.36	39.27	44.18	49.09	58.90	68.72	78.54	88.36	98.17
5/8	5.412	10.823	16.235	21.65	27.06	32.47	37.88	43.29	48.70	54.12	64.94	75.76	86.59	97.41	
3/4	5.940	11.878	17.818	23.76	29.70	35.63	41.57	47.51	53.46	59.39	71.27	83.14	95.03		
7/8	6.492	12.980	19.475	25.96	32.46	38.95	45.44	51.93	58.42	64.92	77.90	90.88			
3	7.069	14.139	21.210	28.28	35.35	42.41	49.48	56.55	63.62	70.69	84.83	98.96			

TABLE 80] **AREAS OF GROUPS OF SQUARE BARS OF UNIFORM SIZE** **[STEEL**

(See p. 534)

See Table 78 and Tables 85 to 90, pp. 554 to 561, and Table 124, p. 602, for weights of bars.

See Tables 82 and 84, for areas of combination of bars of different sizes.

AREAS OF SQUARE BARS IN SQUARE INCHES

Size of Bar in Inches.	Number of Bars														
	1	2	3	4	5	6	7	8	9	10	12	14	16	18	20
1/8	0.016	0.031	0.047	0.06	0.08	0.10	0.11	0.13	0.14	0.16	0.19	0.22	0.26	0.29	0.32
3/16	0.035	0.070	0.106	0.14	0.18	0.21	0.25	0.28	0.32	0.35	0.42	0.49	0.56	0.63	0.70
1/4	0.062	0.125	0.188	0.25	0.31	0.38	0.44	0.50	0.56	0.62	0.75	0.88	1.00	1.12	1.25
5/16	0.098	0.195	0.293	0.39	0.49	0.59	0.68	0.78	0.88	0.98	1.17	1.37	1.56	1.76	1.95
3/8	0.141	0.281	0.422	0.56	0.70	0.85	0.98	1.12	1.27	1.41	1.69	1.97	2.25	2.53	2.81
7/16	0.191	0.383	0.574	0.77	0.96	1.15	1.34	1.53	1.72	1.91	2.30	2.68	3.06	3.45	3.83
1/2	0.250	0.500	0.750	1.00	1.25	1.50	1.75	2.00	2.25	2.50	3.00	3.50	4.00	4.50	5.00
9/16	0.316	0.633	0.949	1.27	1.58	1.90	2.22	2.53	2.85	3.16	3.80	4.43	5.06	5.70	6.33
5/8	0.391	0.781	1.172	1.56	1.95	2.34	2.73	3.12	3.52	3.91	4.69	5.47	6.25	7.03	7.81
11/16	0.473	0.945	1.418	1.89	2.36	2.84	3.31	3.78	4.25	4.73	5.67	6.62	7.56	8.51	9.45
3/4	0.562	1.125	1.688	2.25	2.81	3.38	3.94	4.50	5.06	5.62	6.75	7.87	9.00	10.12	11.25
13/16	0.660	1.320	1.981	2.64	3.30	3.96	4.62	5.28	5.94	6.60	7.92	9.24	10.56	11.88	13.20
7/8	0.766	1.531	2.297	3.06	3.83	4.59	5.36	6.12	6.89	7.66	9.19	10.72	12.25	13.78	15.31
15/16	0.879	1.758	2.637	3.52	4.40	5.27	6.15	7.03	7.91	8.79	10.55	12.30	14.06	15.82	17.58
1	1.000	2.000	3.000	4.00	5.00	6.00	7.00	8.00	9.00	10.00	12.00	14.00	16.00	18.00	20.00
1/16	1.129	2.258	3.387	4.52	5.64	6.77	7.90	9.03	10.16	11.29	13.55	15.80	18.06	20.32	22.58
1/8	1.266	2.531	3.797	5.06	6.33	7.59	8.86	10.13	11.39	12.66	15.19	17.72	20.25	22.78	25.31
3/16	1.410	2.821	4.232	5.64	7.05	8.46	9.87	11.28	12.69	14.10	16.92	19.75	22.57	25.39	28.21
1/4	1.562	3.125	4.688	6.25	7.81	9.38	10.94	12.50	14.06	15.63	18.75	21.88	25.00	28.13	31.25
5/16	1.723	3.445	5.168	6.89	8.61	10.34	12.06	13.78	15.50	17.23	20.67	24.12	27.56	31.01	34.45
3/8	1.891	3.781	5.672	7.56	9.45	11.34	13.23	15.12	17.02	18.91	22.69	26.47	30.25	34.03	37.81
7/16	2.066	4.133	6.200	8.27	10.33	12.40	14.46	16.53	18.60	20.67	24.80	28.93	33.06	37.20	41.33
1/2	2.250	4.500	6.750	9.00	11.25	13.50	15.75	18.00	20.25	22.50	27.00	31.50	36.00	40.50	45.00
9/16	2.441	4.883	7.324	9.77	12.21	14.65	17.09	19.53	21.97	24.42	29.30	34.18	39.06	43.95	48.83
5/8	2.641	5.281	7.922	10.56	13.20	15.84	18.48	21.13	23.77	26.40	31.69	36.97	42.25	47.53	52.81
11/16	2.848	5.695	8.543	11.39	14.24	17.08	19.93	22.78	25.63	28.48	34.17	39.87	45.56	51.26	56.95
3/4	3.062	6.125	9.188	12.25	15.31	18.38	21.44	24.50	27.56	30.63	36.75	42.88	49.00	55.12	61.24
13/16	3.285	6.571	9.856	13.14	16.43	19.71	23.00	26.28	29.57	32.85	39.43	46.00	52.57	59.14	65.71
7/8	3.516	7.032	10.548	14.06	17.58	21.09	24.61	28.12	31.64	35.16	42.19	49.22	56.25	63.28	70.31
15/16	3.754	7.508	11.260	15.01	18.77	22.52	26.28	30.03	33.78	37.54	45.05	52.56	60.06	67.56	75.08
2	4.000	8.000	12.000	16.00	20.00	24.00	28.00	32.00	36.00	40.00	48.00	56.00	64.00	72.00	80.00
1/8	4.516	9.031	13.549	18.06	22.58	27.09	31.61	36.12	40.64	45.16	54.19	63.22	72.25	81.28	90.31
1/4	5.062	10.126	15.190	20.25	25.32	30.38	35.44	40.50	45.57	50.62	60.76	70.88	81.01	91.14	
3/8	5.641	11.280	16.925	22.56	28.21	33.85	39.49	45.13	50.77	56.41	67.69	78.97	90.25		
1/2	6.250	12.500	18.750	25.00	31.25	37.50	43.75	50.00	56.25	62.50	75.00	87.50			
5/8	6.891	13.780	20.670	27.56	34.46	41.35	48.24	55.12	62.02	68.91	82.70	96.48			
3/4	7.562	15.125	22.690	30.25	37.82	45.38	52.94	60.50	68.06	75.63	90.75				
7/8	8.266	16.530	24.800	33.06	41.33	49.59	57.86	66.12	74.39	82.65	99.18				
3	9.000	18.000	27.000	36.00	45.00	54.00	63.00	72.00	81.00	90.00					

TABLE 81] ALTERNATIVE SELECTIONS OF ROUND BARS FOR REINFORCED BEAMS AND COLUMNS (See p. 534) [STEEL

See Table 123, p. 600

Required Area Steel sq. in.	Single Bars		Two Bars		Three Round Bars		Four Round Bars	
	Diameter inches	Actual Area square inches	Diameter inches	Actual Area square inches	Diameters inches	Actual Area square inches	Diameters inches	Actual Area square inches
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
0.10	one 3/8	0.11	two 1/4	0.10	two 1/4 and one 1/8	0.11	four 3/16	0.11
0.15	one 7/16	0.15	two 5/16	0.15	three 1/4	0.15		
0.20	one 1/2	0.20	two 3/8	0.22	three 5/16	0.23	four 1/4	0.20
0.25	one 9/16	0.25			two 3/8 and one 1/4	0.27		
0.30	one 5/8	0.31	two 7/16	0.30	two 3/8 and one 5/16	0.30	four 5/16	0.31
0.35	one 11/16	0.37			three 3/8	0.33		
0.40			two 1/2	0.39	two 7/16 and one 3/8	0.41		
0.45	one 3/4	0.44			three 7/16	0.45	four 3/8	0.44
0.50	one 13/16	0.52	two 9/16	0.50	two 1/2 and one 3/8	0.50		
0.55					two 1/2 and one 7/16	0.54		
0.60	one 7/8	0.60	two 5/8	0.61	three 1/2	0.59	four 7/16	0.60
0.65					two 9/16 and one 7/16	0.65		
0.70	one 15/16	0.69			two 1/2 and one 5/8	0.70		
0.75			two 11/16	0.74	three 9/16	0.75		
0.80	one 1	0.79			two 5/8 and one 1/2	0.81	four 1/2	0.78
0.85					two 5/8 and one 9/16	0.86		
0.90	one 1 1/16	0.89	two 3/4	0.88	three 5/8	0.92		
0.95					two 11/16 and one 1/2	0.94		
1.00	one 1 1/8	0.99			two 11/16 and one 9/16	0.99	four 9/16	0.99
1.05			two 13/16	1.04	two 5/8 and one 3/4	1.06	two 5/8 and two 1/2	1.01
1.10	one 1 3/16	1.11			three 11/16	1.11	three 5/8 and one 1/2	1.12
1.15					two 3/4 and one 9/16	1.13		
1.20	one 1 1/4	1.23	two [illegible]	1.20	two 3/4 and one 5/8	1.19	four 5/8	1.23
1.25					two 3/4 and one 11/16	1.26	two 3/4 and two 1/2	1.28
1.30					three 3/4	1.32		
1.35	one 1 5/16	1.35			two 13/16 and one 5/8	1.34		
1.40			two 15/16	1.38	two 7/8 and one 1/2	1.40		
1.45					two 7/8 and one 9/16	1.45	two 13/16 and two 1/2	1.43
1.50	one 1 3/8	1.48			two 7/8 and one 5/8	1.51	four 11/16	1.48
1.55			two 1	1.57	three 13/16	1.56	two 13/16 and two 9/16	1.53
1.60	one 1 7/16	1.62			two 7/8 and one 11/16	1.57	two 7/8 and two 1/2	1.60
1.65					two 7/8 and one 3/4	1.64	three 3/4 and one 5/8	1.63
1.70					two 15/16 and one 5/8	1.69	two 7/8 and two 9/16	1.70
1.75	one 1 1/2	1.77	two 1 1/16	1.77	two 7/8 and one 13/16	1.72	four 3/4	1.77
1.80					three 7/8	1.80	three 3/4 and one 13/16	1.84
1.85					two 1 and one 5/8	1.88	two 15/16 and two 9/16	1.88
1.90	one 1 9/16	1.92			two 15/16 and one 13/16	1.90	two 13/16 and two 3/4	1.92
1.95					two 1 and one 11/16	1.94	two 1 and two 1/2	1.96
2.00			two 1 1/8	1.99	two 1 and one 3/4	2.01	two 15/16 and two 5/8	1.99
2.05	one 1 5/8	2.07			three 15/16	2.07	four 13/16	2.07
2.10					two 1 and one 13/16	2.09	two 7/8 and two 3/4	2.09
2.15					two 1 and one 7/8	2.17	two 15/16 and two 11/16	2.12
2.20			two 1 3/16	2.22	two 1 1/16 and one 3/4	2.22	two 1 and two 5/8	2.18
2.25	one 1 11/16	2.24			two 1 and one 15/16	2.26	two 15/16 and two 3/4	2.26
2.30					two 1/16 and one 13/16	2.29	two 1 and two 11/16	2.31
2.35					three 1	2.36	two 1 1/16 and two 5/8	2.39
2.40	one 1 3/4	2.41			two 1 1/16 and one 7/8	2.37	four 7/8	2.40
2.45			two 1 1/4	2.45	two 1 1/16 and one 15/16	2.46	two 1 and two 3/4	2.45
2.50	one 1 13/16	2..58	two 1 1/4	2..45	two 1 1/8 and one 13/16	2.51	three 7/8 and one 15/16	2..49

TABLE 81] ALTERNATIVE SELECTIONS OF ROUND BARS—Continued [STEEL

Rule—Having found area of cross section of steel in beam or column, select from table the number and sizes of bars to suit conditions. If steel area exceeds limit of column (1) divide area by two and double number of bars.

Required Area Steel sq. in.	Five Round Bars		Six Round Bars	
	Diameters inches	Actual Area square inches	Diameters inches	Actual Area square inches
(1)	(10)	(11)	(12)	(13)
0.10				
0.15	five 3/16	0.14		
0.20				
0.25	five 1/4	0.25		
0.30				
0.35			six 1/4	0.29
0.40	five 5/16	0.38		
0.45			six 5/16	0.46
0.50				
0.55	five 3/8	0.55		
0.60				
0.65			six 3/8	0.66
0.70				
0.75	five 7/16	0.75		
0.80				
0.85				
0.90			six 7/16	0.90
0.95				
1.00	five 1/2	0.98		
1.05				
1.10				
1.15			six 1/2	1.18
1.20	three 1/2 and two 5/8	1.20		
1.25	five 9/16	1.24	three 5/8 and three 3/8	1.25
1.30	three 5/8 and two 1/2	1.31	five 1/2 and one 5/8	1.29
1.35	three 9/16 and two 5/8	1.36		
1.40	four 1/2 and one 7/8	1.39	four 1/2 and two 5/8	1.40
1.45	three 1/2 and two 3/4	1.47	five 9/16 and one 1/2	1.44
1.50	three 11/16 and two 1/2	1.51	three 5/8 and three 1/2	1.51
1.55	five 5/8	1.53	four 1/2 and two 11/16	1.53
1.60	three 9/16 and two 3/4	1.63	four 9/16 and two 5/8	1.61
1.65	four 5/8 and one 3/4	1.67	four 1/2 and two 3/4	1.67
1.70	three 3/4 and two 1/2	1.72	four 5/8 and two 9/16	1.72
1.75	three 9/16 and two 13/16	1.78	five 5/8 and one 1/2	1.73
1.80	three 5/8 and two 3/4	1.80	five 5/8 and one 9/16	1.78
1.85	four 5/8 and one 7/8	1.83	six 5/8	1.84
1.90	four 11/16 and one 3/4	1.93	three 3/4 and three 1/2	1.91
1.95	three 3/4 and two 5/8	1.94	five 5/8 and one 3/4	1.98
2.00	four 3/4 and one 1/2	1.96	three 9/16 and three 3/4	2.07
2.05	three 3/4 and two 11/16	2.07		
2.10	four 3/4 and one 5/8	2.07	four 5/8 and two 3/4	2.11
2.15	three 11/16 and two 13/16	2.15	four 3/4 and two 1/2	2.16
2.20	five 3/4	2.21	six 11/16	2.23
2.25	four 3/4 and one 13/16	2.29	three 5/8 and three 3/4	2.25
2.30	three 11/16 and two 7/8	2.32	five 11/16 and one 3/4	2.30
2.35	four 3/4 and one 7/8	2.37	four 11/16 and two 3/4	2.37
2.40	three 7/8 and two 5/8	2.42	three 7/8 and three 1/2	2.39
2.45	three 13/16 and two 3/4	2.44	four 5/8 and two 7/8	2.43
2.50	three 3/4 andtwo 7/8	2.53	five 3/4 and one 5/8	2.52

TABLE 81] ALTERNATIVE SELECTIONS OF ROUND BARS FOR REINFORCED BEAMS AND COLUMNS—Continued [STEEL

Required Area Steel sq. in.	Single Bars		Two Bars		Three Round Bars		Four Round Bars	
	Diameter inches	Actual Area sq. in.	Diameter inches	Actual Area sq. in.	Diameters inches	Actual Area sq. in.	Diameters inches	Actual Area sq. in.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
2.55					two $1\frac{1}{16}$ and one 1	2.56	two $\frac{15}{16}$ and two $\frac{7}{8}$	2.58
2.60	one $1\frac{13}{16}$	2.58			two $1\frac{1}{8}$ and one $\frac{7}{8}$	2.59	two $\frac{13}{16}$ and two 1	2.61
2.65					three $1\frac{1}{16}$	2.66	two $\frac{3}{4}$ and two $1\frac{1}{16}$	2.66
2.70			two $1\frac{5}{16}$	2.71	two $1\frac{3}{16}$ and one $\frac{13}{16}$	2.73		
2.75	one $1\frac{7}{8}$	2.76			two $1\frac{1}{8}$ and one 1	2.77	four $\frac{15}{16}$	2.76
2.80					two $1\frac{3}{16}$ and one $\frac{7}{8}$	2.82	two $1\frac{1}{16}$ and two $\frac{13}{16}$	2.81
2.85					two $1\frac{1}{8}$ and one $1\frac{1}{16}$	2.88	two $1\frac{1}{8}$ and two $\frac{3}{4}$	2.87
2.90					two $1\frac{1}{4}$ and one $\frac{3}{4}$	2.90	three 1 and one $\frac{13}{16}$	2.87
2.95	one $1\frac{15}{16}$	2.95	two $1\frac{3}{8}$	2.97	three $1\frac{1}{8}$	2.98	three 1 and one $\frac{7}{8}$	2.96
3.00							two $1\frac{1}{4}$ and two $\frac{5}{8}$	3.07
3.10	one 2	3.14			two $1\frac{3}{16}$ and one $1\frac{1}{16}$	3.10	four 1	3.14
3.20			two $1\frac{7}{16}$	3.25	two $1\frac{1}{8}$ and one $1\frac{1}{4}$	3.22	two $1\frac{1}{8}$ and two $\frac{7}{8}$	3.19
3.30	one $2\frac{1}{16}$	3.34			two $1\frac{1}{4}$ and one 1	3.24	two $1\frac{1}{4}$ and two $\frac{3}{4}$	3.34
3.40					two $1\frac{1}{4}$ and one $1\frac{1}{8}$	3.45	two $1\frac{3}{16}$ and two $\frac{7}{8}$	3.42
3.50	one $2\frac{1}{8}$	3.55	two $1\frac{1}{2}$	3.53	two $1\frac{1}{4}$ and one $1\frac{3}{16}$	3.56	four $1\frac{1}{16}$	3.55
3.60					three $1\frac{1}{4}$	3.68	two $1\frac{1}{4}$ and two $\frac{7}{8}$	3.66
3.70	one $2\frac{3}{16}$	3.76			two $1\frac{3}{8}$ and one 1	3.76	two $1\frac{1}{8}$ and two $1\frac{1}{16}$	3.76
3.80			two $1\frac{9}{16}$	3.84	two $1\frac{3}{8}$ and one $1\frac{1}{16}$	3.86	two $1\frac{3}{16}$ and two 1	3.79
3.90							four $1\frac{1}{8}$	3.98
4.00	one $2\frac{1}{4}$	3.98			two $1\frac{3}{8}$ and one $1\frac{1}{8}$	3.96	two $1\frac{1}{4}$ and two 1	4.02
4.1			two $1\frac{5}{8}$	4.15	three $1\frac{5}{16}$	4.06	three 1 and one $1\frac{1}{2}$	4.12
4.2	one $2\frac{5}{16}$	4.20			two $1\frac{1}{4}$ and one $1\frac{1}{2}$	4.22	three $1\frac{1}{8}$ and one $1\frac{1}{4}$	4.21
4.3					two $1\frac{3}{8}$ and one $1\frac{5}{16}$	4.32	three $1\frac{1}{8}$ and one $1\frac{5}{16}$	4.34
4.4	one $2\frac{3}{8}$	4.43			three $1\frac{3}{8}$	4.46	four $1\frac{3}{16}$	4.43
4.5			two $1\frac{11}{16}$	4.47	two $1\frac{5}{16}$ and one $1\frac{1}{2}$	4.48	two $1\frac{3}{8}$ and two 1	4.54
4.6					two $1\frac{3}{8}$ and one $1\frac{7}{16}$	4.59	three $1\frac{1}{4}$ and one $1\frac{1}{16}$	4.57
4.7	one $2\frac{7}{16}$	4.67			two $1\frac{3}{8}$ and one $1\frac{1}{2}$	4.73	three $1\frac{1}{4}$ and one $1\frac{1}{8}$	4.68
4.8			two $1\frac{3}{4}$	4.81	two $1\frac{1}{2}$ and one $1\frac{1}{4}$	4.76	three $1\frac{1}{4}$ and one $1\frac{3}{16}$	4.78
4.9	one $2\frac{1}{2}$	4.91			three $1\frac{7}{16}$	4.88	four $1\frac{1}{4}$	4.91
5.0					two $1\frac{1}{2}$ and one $1\frac{3}{8}$	5.01	two $1\frac{1}{8}$ and two $1\frac{3}{8}$	4.96
5.1					two $1\frac{5}{8}$ and one $1\frac{1}{8}$	5.14	three $1\frac{1}{4}$ and one $1\frac{3}{8}$	5.17
5.2	one $2\frac{9}{16}$	5.16	two $1\frac{13}{16}$	5.16	two $1\frac{1}{2}$ and one $1\frac{7}{16}$	5.16	three $1\frac{3}{8}$ and one 1	5.24
5.3					three $1\frac{1}{2}$	5.30	three $1\frac{5}{16}$ and one $1\frac{1}{4}$	5.29
5.4	one $2\frac{5}{8}$	5.41			two $1\frac{3}{4}$ and one $\frac{7}{8}$	5.41	two $1\frac{3}{8}$ and two $1\frac{1}{4}$	5.42
5.5			two $1\frac{7}{8}$	5.52	two $1\frac{1}{2}$ and one $1\frac{9}{16}$	5.45	three $1\frac{1}{4}$ and one $1\frac{1}{2}$	5.45
5.6					two $1\frac{5}{8}$ and one $1\frac{3}{8}$	5.63	three $1\frac{3}{8}$ and one $1\frac{3}{16}$	5.56
5.7	one $2\frac{11}{16}$	5.67			three $1\frac{9}{16}$	5.75	three $1\frac{3}{8}$ and one $1\frac{1}{4}$	5.68
5.8					two $1\frac{3}{4}$ and one $1\frac{1}{8}$	5.80	three $1\frac{5}{16}$ and one $1\frac{1}{2}$	5.83
5.9	one $2\frac{3}{4}$	5.94	two $1\frac{15}{16}$	5.90	two $1\frac{9}{16}$ and one $1\frac{5}{8}$	5.91	four $1\frac{3}{8}$	5.94
6.0					two $1\frac{3}{4}$ and one $1\frac{1}{4}$	6.04	three $1\frac{3}{8}$ and $1\frac{7}{16}$	6.08
6.2	one $2\frac{13}{16}$	6.21	two 2	6.28	three $1\frac{5}{8}$	6.22	three $1\frac{3}{8}$ and one $1\frac{1}{2}$	6.22
6.4	one $2\frac{7}{8}$	6.49			two $1\frac{5}{8}$ and one $1\frac{11}{16}$	6.38	three $1\frac{7}{16}$ and one $1\frac{3}{8}$	6.35
6.6			two $2\frac{1}{16}$	6.68	two $1\frac{11}{16}$ and one $1\frac{5}{8}$	6.55	three $1\frac{7}{16}$ and one $1\frac{1}{2}$	6.64
6.8	one $2\frac{15}{16}$	6.78					three $1\frac{1}{2}$ and one $1\frac{3}{8}$	6.79
7.0	one 3	7.07	two $2\frac{1}{8}$	7.09	two $1\frac{3}{4}$ and one $1\frac{11}{16}$	7.05	four $1\frac{1}{2}$	7.07
7.2					three $1\frac{3}{4}$	7.21	three $1\frac{3}{8}$ and one $1\frac{7}{8}$	7.21
7.4	one $3\frac{1}{16}$	7.37			two $1\frac{3}{4}$ and one $1\frac{13}{16}$	7.39	three $1\frac{1}{2}$ and one $1\frac{5}{8}$	7.37
7.6	one $3\frac{1}{8}$	7.67	two $2\frac{3}{16}$	7.52	two $1\frac{3}{4}$ and one $1\frac{7}{8}$	7.57	two $1\frac{5}{8}$ and two $1\frac{1}{2}$	7.67
7.8					three $1\frac{13}{16}$	7.74	three $1\frac{9}{16}$ and one $1\frac{5}{8}$	7.82
8.0	one $3\frac{3}{16}$	7.98	two $2\frac{1}{4}$	7.95	two $1\frac{3}{4}$ and one 2	7.95	three $1\frac{5}{8}$ and one $1\frac{1}{2}$	7.99

TABLE 81] ALTERNATIVE SELECTIONS OF ROUND [STEEL BARS—Continued

Required Area Steel sq. in.	Five Round Bars		Six Round Bars		Eight Round Bars	
	Diameters inches	Actual Area sq. in.	Diameters inches	Actual Area sq. in.	Diameters inches	Actual Area sq. in.
(1)	(10)	(11)	(12)	(13)	(14)	(15)
2.55	three $\frac{3}{4}$ and two $\frac{7}{8}$	2.53	four $\frac{3}{4}$ and two $\frac{11}{16}$	2.51		
2.60	five $\frac{13}{16}$	2.59				
2.65	three $\frac{7}{8}$ and two $\frac{3}{4}$	2.69	six $\frac{3}{4}$	2.65		
2.70			three $\frac{7}{8}$ and three $\frac{5}{8}$	2.72		
2.75	three $\frac{13}{16}$ and two $\frac{7}{8}$	2.76				
2.80			four $\frac{5}{8}$ and two 1	2.80		
2.85	four $\frac{7}{8}$ and one $\frac{3}{4}$	2.85	five $\frac{3}{4}$ and one $\frac{7}{8}$	2.81		
2.90	three $\frac{3}{4}$ and two 1	2.90	three $\frac{7}{8}$ and three $\frac{11}{16}$	2.92		
2.95	three $\frac{13}{16}$ and two $\frac{15}{16}$	2.94	four $\frac{3}{4}$ and two $\frac{7}{8}$	2.97		
3.00	five $\frac{7}{8}$	3.01	four $\frac{7}{8}$ and two $\frac{5}{8}$	3.02		
3.10	three $\frac{15}{16}$ and two $\frac{13}{16}$	3.11	six $\frac{13}{16}$	3.11		
3.20	four $\frac{7}{8}$ and one 1	3.20				
3.30	three $\frac{15}{16}$ and two $\frac{7}{8}$	3.27	four $\frac{7}{8}$ and two $\frac{3}{4}$	3.29		
3.40	three $\frac{7}{8}$ and two 1	3.38	five $\frac{7}{8}$ and one $\frac{3}{4}$	3.45		
3.50	three $\frac{13}{16}$ and two $1\frac{1}{8}$	3.54	three 1 and three $\frac{11}{16}$	3.47		
3.60	four $\frac{7}{8}$ and one $1\frac{1}{4}$	3.64	six $\frac{7}{8}$	3.61		
3.70	three $\frac{15}{16}$ and two $1\frac{1}{16}$	3.74	five $\frac{3}{4}$ and one $1\frac{3}{8}$	3.70		
3.80	three $\frac{7}{8}$ and two $1\frac{1}{8}$	3.79	five $\frac{7}{8}$ and one 1	3.80		
3.90	five 1	3.93	three $\frac{7}{8}$ and three $\frac{15}{16}$	3.88		
4.00	three $1\frac{1}{8}$ and two $\frac{13}{16}$	4.02	four $\frac{7}{8}$ and two 1	3.98		
4.1	three 1 and two $1\frac{1}{16}$	4.13	six $\frac{15}{16}$	4.14	eight $\frac{13}{16}$	4.14
4.2	three $1\frac{1}{8}$ and two $\frac{7}{8}$	4.18	five $\frac{7}{8}$ and one $1\frac{1}{4}$	4.24	four $\frac{7}{8}$ and four $\frac{3}{4}$	4.16
4.3	three $\frac{7}{8}$ and two $1\frac{1}{4}$	4.26	four 1 and two $\frac{7}{8}$	4.34	five $\frac{7}{8}$ and three $\frac{3}{4}$	4.33
4.4	five $1\frac{1}{16}$	4.43	three $\frac{15}{16}$ and three 1	4.43	five $\frac{13}{16}$ and three $\frac{7}{8}$	4.39
4.5	four $1\frac{1}{8}$ and one $\frac{7}{8}$	4.57	five 1 and one $\frac{7}{8}$	4.53	six $\frac{7}{8}$ and two $\frac{3}{4}$	4.49
4.6	four 1 and one $1\frac{3}{8}$	4.62	five 1 and one $\frac{15}{16}$	4.62	seven $\frac{7}{8}$ and one $\frac{3}{4}$	4.65
4.7	four $1\frac{1}{8}$ and one 1	4.76	six 1	4.71	seven $\frac{7}{8}$ and one $\frac{13}{16}$	4.73
4.8	three $\frac{7}{8}$ and two $1\frac{3}{8}$	4.77	three $1\frac{1}{8}$ and three $\frac{7}{8}$	4.78	eight $\frac{7}{8}$	4.80
4.9	four $1\frac{1}{8}$ and one $1\frac{1}{16}$	4.86	five 1 and one $1\frac{1}{8}$	4.92	four 1 and four $\frac{3}{4}$	4.90
5.0	five $1\frac{1}{8}$	4.97	three 1 and three $1\frac{1}{16}$	5.01	seven $\frac{7}{8}$ and one 1	4.99
5.1	four $1\frac{1}{8}$ and one $1\frac{3}{16}$	5.08	five 1 and one $1\frac{1}{4}$	5.15	six $\frac{7}{8}$ and two 1	5.17
5.2	four $1\frac{1}{8}$ and one $1\frac{1}{4}$	5.20	five $1\frac{1}{16}$ and one 1	5.22	five 1 and three $\frac{3}{4}$	5.25
5.3	three $1\frac{3}{16}$ and two $1\frac{1}{8}$	5.31	six $1\frac{1}{16}$	5.32	seven $\frac{7}{8}$ and one $1\frac{3}{16}$	5.31
5.4	three $1\frac{1}{8}$ and two $1\frac{1}{4}$	5.44	five $1\frac{1}{16}$ and one $1\frac{1}{8}$	5.43	five $\frac{7}{8}$ and three 1	5.36
5.5	five $1\frac{3}{16}$	5.54	two 1 and four $1\frac{1}{8}$	5.55	four 1 and four $\frac{7}{8}$	5.54
5.6	four $1\frac{1}{4}$ and one $\frac{15}{16}$	5.60	four 1 and two $1\frac{1}{4}$	5.60	six 1 and two $\frac{3}{4}$	5.59
5.7	four $1\frac{1}{4}$ and one 1	5.70	four $1\frac{1}{8}$ and two $1\frac{1}{16}$	5.75	five 1 and three $\frac{7}{8}$	5.73
5.8	four $1\frac{1}{4}$ and one $1\frac{1}{16}$	5.79	five $1\frac{1}{8}$ and one 1	5.76	seven 1 and one $\frac{11}{16}$	5.87
5.9	four $1\frac{1}{4}$ and one $1\frac{1}{8}$	5.90			six 1 and two $\frac{7}{8}$	5.91
6.0	three $1\frac{3}{8}$ and two 1	6.02	six $1\frac{1}{8}$	5.96	seven 1 and one $\frac{7}{8}$	6.09
6.2	four $1\frac{1}{4}$ and one $1\frac{5}{16}$	6.26	four $1\frac{1}{8}$ and two $1\frac{3}{16}$	6.19	eight 1	6.28
6.4	three $1\frac{3}{8}$ and two $1\frac{1}{8}$	6.44	four $1\frac{1}{8}$ and two $1\frac{1}{4}$	6.43	seven 1 and one $1\frac{1}{8}$	6.48
6.6	three $1\frac{1}{4}$ and two $1\frac{3}{8}$	6.65	six $1\frac{3}{16}$	6.64	six 1 and two $1\frac{1}{8}$	6.70
6.8	five $1\frac{5}{16}$	6.77	five $1\frac{3}{16}$ and one $1\frac{1}{4}$	6.76	six $1\frac{1}{16}$ and two 1	6.89
7.0	three $1\frac{5}{16}$ and two $1\frac{3}{8}$	7.03	three $1\frac{1}{4}$ and three $1\frac{3}{16}$	7.00	eight $1\frac{1}{16}$	7.08
7.2	three $1\frac{1}{4}$ and two $1\frac{1}{2}$	7.22	five $1\frac{1}{4}$ and one $1\frac{3}{16}$	7.24	seven $1\frac{1}{16}$ and one $1\frac{1}{8}$	7.20
7.4	five $1\frac{3}{8}$	7.42	six $1\frac{1}{4}$	7.36	five $1\frac{1}{16}$ and three $1\frac{1}{8}$	7.41
7.6	three $1\frac{1}{2}$ and two $1\frac{1}{4}$	7.76	five $1\frac{1}{4}$ and one $1\frac{3}{8}$	7.62	five $1\frac{1}{8}$ and three $1\frac{1}{16}$	7.62
7.8	three $1\frac{7}{16}$ and two $1\frac{3}{8}$	7.83	four $1\frac{5}{16}$ and two $1\frac{1}{4}$	7.86	seven $1\frac{1}{8}$ and one $1\frac{1}{16}$	7.85
8.0	three $1\frac{3}{8}$ and two $1\frac{1}{2}$	7.98	three $1\frac{1}{2}$ and three $1\frac{1}{16}$	7.93	eight $1\frac{1}{8}$	7.95

TABLE 82] ALTERNATIVE SELECTIONS OF SQUARE [STEEL BARS FOR REINFORCED BEAMS AND COLUMNS (See p. 534)

See Table 124, p. 602

Required Area Steel sq. in.	Single Bars		Two Bars		Three Square Bars		Four Square Bars	
	Size in.	Actual Area sq. in.	Size in.	Actual Area sq. in.	Sizes inches	Actual Area sq. in.	Sizes inches	Actual Area sq. in.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
0.10	one $\frac{5}{16}$	0.10	two $\frac{1}{4}$	0.13	three $\frac{3}{16}$	0.11		
0.15	one $\frac{3}{8}$	0.14			two $\frac{1}{4}$ and one $\frac{3}{16}$	0.16	four $\frac{3}{16}$	0.14
0.20	one $\frac{7}{16}$	0.19	two $\frac{5}{16}$	0.20	three $\frac{1}{4}$	0.19		
0.25	one $\frac{1}{2}$	0.25			two $\frac{5}{16}$ and one $\frac{1}{4}$	0.26	four $\frac{1}{4}$	0.25
0.30	one $\frac{9}{16}$	0.32	two $\frac{3}{8}$	0.28	three $\frac{5}{16}$	0.29		
0.35					two $\frac{3}{8}$ and one $\frac{1}{4}$	0.34		
0.40	one $\frac{5}{8}$	0.39	two $\frac{7}{16}$	0.38	three $\frac{3}{8}$	0.42	four $\frac{5}{16}$	0.39
0.45	one $\frac{11}{16}$	0.47			two $\frac{7}{16}$ and one $\frac{1}{4}$	0.44		
0.50			two $\frac{1}{2}$	0.50	two $\frac{7}{16}$ and one $\frac{3}{8}$	0.52		
0.55	one $\frac{3}{4}$	0.56			three $\frac{7}{16}$	0.57	four $\frac{3}{8}$	0.56
0.60					two $\frac{1}{2}$ and one $\frac{5}{16}$	0.60		
0.65	one $\frac{13}{16}$	0.66	two $\frac{9}{16}$	0.63	two $\frac{1}{2}$ and one $\frac{3}{8}$	0.64		
0.70					two $\frac{1}{2}$ and one $\frac{7}{16}$	0.69		
0.75	one $\frac{7}{8}$	0.77			three $\frac{1}{2}$	0.75	four $\frac{7}{16}$	0.77
0.80			two $\frac{5}{8}$	0.78	two $\frac{1}{2}$ and one $\frac{9}{16}$	0.82		
0.85					two $\frac{9}{16}$ and one $\frac{1}{2}$	0.88		
0.90	one $\frac{15}{16}$	0.88			two $\frac{5}{8}$ and one $\frac{3}{8}$	0.92		
0.95			two $\frac{11}{16}$	0.95	three $\frac{9}{16}$	0.95		
1.00	one 1	1.00			two $\frac{5}{8}$ and one $\frac{1}{2}$	1.03	four $\frac{1}{2}$	1.00
1.05					two $\frac{5}{8}$ and one $\frac{1}{2}$	1.03		
1.10			two $\frac{3}{4}$	1.13	two $\frac{5}{8}$ and one $\frac{9}{16}$	1.10		
1.15	one $1\frac{1}{16}$	1.13			three $\frac{5}{8}$	1.17		
1.20					two $\frac{11}{16}$ and one $\frac{1}{2}$	1.20		
1.25	one $1\frac{1}{8}$	1.27			two $\frac{11}{16}$ and one $\frac{9}{16}$	1.26	four $\frac{9}{16}$	1.27
1.30			two $\frac{13}{16}$	1.32	two $\frac{11}{16}$ and one $\frac{5}{8}$	1.34	two $\frac{5}{8}$ and two $\frac{1}{2}$	1.28
1.35					two $\frac{3}{4}$ and one $\frac{1}{2}$	1.38	two $\frac{11}{16}$ and two $\frac{7}{16}$	1.33
1.40	one $1\frac{3}{16}$	1.41			three $\frac{11}{16}$	1.42	three $\frac{5}{8}$ and one $\frac{1}{2}$	1.42
1.45					two $\frac{3}{4}$ and one $\frac{9}{16}$	1.44	two $\frac{11}{16}$ and two $\frac{1}{2}$	1.44
1.50					two $\frac{3}{4}$ and one $\frac{5}{8}$	1.52	two $\frac{3}{4}$ and two $\frac{7}{16}$	1.51
1.55	one $1\frac{1}{4}$	1.56	two $\frac{7}{8}$	1.53	two $\frac{13}{16}$ and one $\frac{1}{2}$	1.57	four $\frac{5}{8}$	1.56
1.60					two $\frac{3}{4}$ and one $\frac{11}{16}$	1.60	two $\frac{3}{4}$ and two $\frac{1}{2}$	1.62
1.65					two $\frac{13}{16}$ and two $\frac{9}{16}$	1.64	three $\frac{5}{8}$ and one $\frac{11}{16}$	1.64
1.70	one $1\frac{5}{16}$	1.72			three $\frac{3}{4}$	1.69	two $\frac{13}{16}$ and two $\frac{7}{16}$	1.70
1.75			two $\frac{15}{16}$	1.76	two $\frac{7}{8}$ and one $\frac{1}{2}$	1.78	two $\frac{3}{4}$ and two $\frac{9}{16}$	1.76
1.80					two $\frac{7}{8}$ and one $\frac{1}{2}$	1.78	three $\frac{11}{16}$ and one $\frac{5}{8}$	1.81
1.85					two $\frac{7}{8}$ and one $\frac{9}{16}$	1.85	two $\frac{13}{16}$ and two $\frac{1}{2}$	1.82
1.90	one $1\frac{3}{8}$	1.89			two $\frac{7}{8}$ and one $\frac{5}{8}$	1.92	four $\frac{11}{16}$	1.89
1.95					three $\frac{13}{16}$	1.98	two $\frac{13}{16}$ and two $\frac{9}{16}$	1.95
2.00			two 1	2.00	three $\frac{13}{16}$	1.98	two $\frac{7}{8}$ and two $\frac{1}{2}$	2.03
2.05	one $1\frac{7}{16}$	2.07			two $\frac{15}{16}$ and one $\frac{9}{16}$	2.07	three $\frac{3}{4}$ and one $\frac{5}{8}$	2.08
2.10					two $\frac{7}{8}$ and one $\frac{3}{4}$	2.09	two $\frac{13}{16}$ and two $\frac{5}{8}$	2.10
2.15					two $\frac{15}{16}$ and one $\frac{5}{8}$	2.15	three $\frac{3}{4}$ and one $\frac{11}{16}$	2.16
2.20					two $\frac{7}{8}$ and one $\frac{13}{16}$	2.19	three $\frac{11}{16}$ and one $\frac{7}{8}$	2.18
2.25	one $1\frac{1}{2}$	2.25	two $1\frac{1}{16}$	2.26	two $\frac{15}{16}$ and one $\frac{11}{16}$	2.23	four $\frac{3}{4}$	2.25
2.30					three $\frac{7}{8}$	2.30	two $\frac{7}{8}$ and two $\frac{5}{8}$	2.31
2.35					two $\frac{15}{16}$ and one $\frac{3}{4}$	2.31	three $\frac{3}{4}$ and one $\frac{13}{16}$	2.35
2.40					two 1 and one $\frac{5}{8}$	2.39	two $\frac{9}{16}$ and two $\frac{15}{16}$	2.39
2.45	one $1\frac{9}{16}$	2.44			two 1 and one $\frac{11}{16}$	2.47	three $\frac{3}{4}$ and one $\frac{7}{8}$	2.45
2.50					two $\frac{15}{16}$ and one $\frac{7}{8}$	2.52	two $\frac{11}{16}$ and two $\frac{7}{8}$	2.48

TABLE 82] ALTERNATIVE SELECTIONS OF SQUARE BARS—Continued [STEEL

Rule—Having found area of cross section of steel in beam or column, select from table the number and sizes of bars to suit conditions. If steel area exceeds limit of column (1) divide area by two and double number of bars.

Required Area Steel sq. in.	Five Square Bars		Six Square Bars	
	Sizes inches	Actual Area square inches	Sizes inches	Actual Area square inches
(1)	(10)	(11)	(12)	(13)
0.10				
0.15	five $\frac{3}{16}$	0.18		
0.20			six $\frac{3}{16}$	0.21
0.25				
0.30	five $\frac{1}{4}$	0.31		
0.35			six $\frac{1}{4}$	0.38
0.40				
0.45				
0.50	five $\frac{5}{16}$	0.49		
0.55				
0.60			six $\frac{5}{16}$	0.59
0.65				
0.70	five $\frac{3}{8}$	0.70		
0.75				
0.80				
0.85			six $\frac{3}{8}$	0.84
0.90				
0.95	five $\frac{7}{16}$	0.96		
1.00				
1.05				
1.10				
1.15			six $\frac{7}{16}$	1.15
1.20	three $\frac{3}{8}$ and two $\frac{5}{8}$	1.20		
1.25	five $\frac{1}{2}$	1.25	four $\frac{7}{16}$ and two $\frac{1}{2}$	1.27
1.30	three $\frac{9}{16}$ add two $\frac{7}{16}$	1.33	four $\frac{1}{2}$ and two $\frac{3}{8}$	1.28
1.35	three $\frac{1}{2}$ and two $\frac{9}{16}$	1.38	four $\frac{3}{8}$ and two $\frac{5}{8}$	1.34
1.40	four $\frac{1}{2}$ and one $\frac{3}{8}$	1.39	five $\frac{1}{2}$ and one $\frac{3}{8}$	1.39
1.45	three $\frac{5}{8}$ and two $\frac{3}{8}$	1.45	five $\frac{1}{2}$ and one $\frac{7}{16}$	1.44
1.50	four $\frac{9}{16}$ and one $\frac{1}{2}$	1.52	six $\frac{1}{2}$	1.50
1.55	three $\frac{1}{2}$ and two $\frac{5}{8}$	1.53	four $\frac{7}{16}$ and two $\frac{5}{8}$	1.55
1.60	five $\frac{9}{16}$	1.58	three $\frac{3}{8}$ and three $\frac{5}{8}$	1.59
1.65	three $\frac{5}{8}$ and two $\frac{1}{2}$	1.67	five $\frac{1}{2}$ and one $\frac{5}{8}$	1.64
1.70	four $\frac{5}{8}$ and one $\frac{3}{8}$	1.70	four $\frac{7}{16}$ and two $\frac{11}{16}$	1.71
1.75	three $\frac{9}{16}$ and two $\frac{5}{8}$	1.73	four $\frac{1}{2}$ and two $\frac{5}{8}$	1.78
1.80	four $\frac{5}{8}$ and one $\frac{1}{2}$	1.81	five $\frac{1}{2}$ and one $\frac{3}{4}$	1.81
1.85	three $\frac{1}{2}$ and two $\frac{3}{4}$	1.88		
1.90	three $\frac{11}{16}$ and two $\frac{1}{2}$	1.92	six $\frac{9}{16}$	1.90
1.95	five $\frac{5}{8}$	1.95	three $\frac{5}{8}$ and three $\frac{1}{2}$	1.92
2.00	three $\frac{3}{4}$ and two $\frac{3}{8}$	1.97	five $\frac{1}{2}$ and one $\frac{7}{8}$	2.02
2.05	three $\frac{11}{16}$ and two $\frac{9}{16}$	2.05	four $\frac{5}{8}$ and two $\frac{1}{2}$	2.06
2.10	four $\frac{5}{8}$ and one $\frac{3}{4}$	2.12	three $\frac{9}{16}$ and three $\frac{5}{8}$	2.12
2.15	three $\frac{3}{4}$ and two $\frac{1}{2}$	2.19	four $\frac{1}{2}$ and two $\frac{3}{4}$	2.13
2.20	three $\frac{11}{16}$ and two $\frac{5}{8}$	2.20	five $\frac{5}{8}$ and one $\frac{1}{2}$	2.20
2.25	three $\frac{1}{2}$ and two $\frac{7}{8}$	2.28	five $\frac{5}{8}$ and one $\frac{9}{16}$	2.27
2.30	three $\frac{5}{8}$ and two $\frac{3}{4}$	2.30		
2.35	four $\frac{5}{8}$ and one $\frac{7}{8}$	2.33	six $\frac{5}{8}$	2.34
2.40			five $\frac{5}{8}$ and one $\frac{11}{16}$	2.43
2.45	three $\frac{3}{4}$ and two $\frac{5}{8}$	2.47	three $\frac{1}{2}$ and three $\frac{3}{4}$	2.44
2.50	four $\frac{3}{4}$ and one $\frac{1}{2}$	2.50	five $\frac{5}{8}$ and one $\frac{3}{4}$	2.52

TABLE 82] ALTERNATIVE SELECTIONS OF SQUARE [STEEL BARS FOR REINFORCED BEAMS AND COLUMNS—Continued

Required Area Steel sq. in.	Single Bars		Two Bars		Three Square Bars		Four Square Bars	
	Size inches	Actual Area square inches	Size inches	Actual Area square inches	Sizes inches	Actual Area square inches	Sizes inches	Actual Area square inches
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
2.55			two $1\frac{1}{8}$	2.53	two 1 and one $\frac{3}{4}$	2.56	two $\frac{15}{16}$ and two $\frac{5}{8}$	2.54
2.60					three $\frac{15}{16}$	2.64	two 1 and two $\frac{9}{16}$	2.63
2.65	one $1\frac{5}{8}$	2.64					four $\frac{13}{16}$	2.64
2.70					two 1 and one $\frac{13}{16}$	2.66	two $\frac{15}{16}$ and two $\frac{11}{16}$	2.70
2.75					two 1 and one $\frac{7}{8}$	2.77	two 1 and two $\frac{5}{8}$	2.78
2.80			two $1\frac{3}{16}$	2.82	two $1\frac{1}{16}$ and one $\frac{3}{4}$	2.82		
2.85	one $1\frac{11}{16}$	2.85			two 1 and one $\frac{15}{16}$	2.88	two $\frac{7}{8}$ and two $\frac{13}{16}$	2.85
2.90					two $1\frac{1}{16}$ and one $\frac{13}{16}$	2.92	two $\frac{15}{16}$ and two $\frac{3}{4}$	2.88
2.95					two $1\frac{1}{8}$ and one $\frac{5}{8}$	2.92	two 1 and two $\frac{11}{16}$	2.94
3.00	one $1\frac{3}{4}$	3.06			three 1	3.00	four $\frac{7}{8}$	3.06
3.10			two $1\frac{1}{4}$	2.13	two $\frac{7}{8}$ and one $1\frac{1}{4}$	3.09	two 1 and two $\frac{3}{4}$	3.12
3.20					two $1\frac{1}{8}$ and one $\frac{13}{16}$	3.19	two $\frac{15}{16}$ and two $\frac{7}{8}$	3.29
3.30	one $1\frac{13}{16}$	3.29			two $1\frac{1}{8}$ and one $\frac{7}{8}$	3.30	two $1\frac{1}{8}$ and two $\frac{5}{8}$	3.31
3.40			two $1\frac{5}{16}$	3.45	two $1\frac{1}{8}$ and one $\frac{15}{16}$	3.41		
3.50	one $1\frac{7}{8}$	3.52			two $1\frac{1}{8}$ and one 1	3.53	two 1 and two $\frac{7}{8}$	3.53
3.60					two $1\frac{1}{8}$ and one $1\frac{1}{16}$	3.66	two $1\frac{1}{8}$ and two $\frac{3}{4}$	3.66
3.70	one $1\frac{15}{16}$	3.75			three $1\frac{1}{8}$	3.80	three 1 and one $\frac{7}{8}$	3.77
3.80			two $1\frac{3}{8}$	3.78	two $1\frac{3}{16}$ and one 1	3.82	two $1\frac{1}{16}$ and two $\frac{7}{8}$	3.79
3.90					two $1\frac{1}{4}$ and one $\frac{7}{8}$	3.90	two $1\frac{1}{4}$ and two $\frac{5}{8}$	3.91
4.00	one 2	4.00			two $1\frac{1}{4}$ and one $\frac{15}{16}$	4.01	four 1	4.00
4.1			two $1\frac{7}{16}$	4.13	two $1\frac{1}{8}$ and one $1\frac{1}{4}$	4.09	three 1 and one $1\frac{1}{16}$	4.13
4.2	one $2\frac{1}{16}$	4.25			three $1\frac{3}{16}$	4.23	three $1\frac{1}{16}$ and one $\frac{7}{8}$	4.16
4.3							three 1 and one $1\frac{1}{8}$	4.27
4.4					two $1\frac{1}{4}$ and one $1\frac{1}{8}$	4.40	three 1 and one $1\frac{3}{16}$	4.41
4.5	one $2\frac{1}{8}$	4.52	two $1\frac{1}{2}$	4.50	two $1\frac{1}{4}$ and one $1\frac{3}{16}$	4.54	four $1\frac{1}{16}$	4.52
4.6							three $1\frac{1}{8}$ and one $\frac{7}{8}$	4.56
4.7					three $1\frac{1}{4}$	4.69	two $1\frac{1}{4}$ and two $\frac{7}{8}$	4.66
4.8	one $2\frac{3}{16}$	4.79			two $1\frac{1}{4}$ and one $1\frac{5}{16}$	4.85	three $1\frac{1}{8}$ and one 1	4.80
4.9			two $1\frac{9}{16}$	4.88			three $1\frac{1}{8}$ and one $1\frac{1}{16}$	4.93
5.0					two $1\frac{1}{4}$ and one $1\frac{3}{8}$	5.02		
5.1	one $2\frac{1}{4}$	5.06					four $1\frac{1}{8}$	5.06
5.2					three $1\frac{5}{16}$	5.17	three $1\frac{1}{8}$ and one $1\frac{3}{16}$	5.21
5.3	one $2\frac{5}{16}$	5.35	two $1\frac{5}{8}$	5.28	two $1\frac{3}{8}$ and one $1\frac{1}{4}$	5.34		
5.4							three $1\frac{1}{8}$ and one $1\frac{1}{4}$	5.36
5.5					two $1\frac{3}{8}$ and one $1\frac{5}{16}$	5.50	three $1\frac{1}{8}$ and one $1\frac{5}{16}$	5.52
5.6	one $2\frac{3}{8}$	5.64					four $1\frac{3}{16}$	5.64
5.7			two $1\frac{11}{16}$	5.70	three $1\frac{3}{8}$	5.67	three $1\frac{1}{4}$ and one 1	5.69
5.8							three $1\frac{1}{4}$ and one $1\frac{1}{16}$	5.82
5.9	one $2\frac{7}{16}$	5.94					three $1\frac{1}{4}$ and one $1\frac{1}{8}$	5.95
6.0					two $1\frac{3}{8}$ and one $1\frac{1}{2}$	6.03	two $1\frac{1}{2}$ and two $\frac{7}{8}$	6.03
6.2	one $2\frac{1}{2}$	6.25	two $1\frac{3}{4}$	6.13	three $1\frac{7}{16}$	6.20	four $1\frac{1}{4}$	6.25
6.4					two $1\frac{1}{2}$ amd one $1\frac{3}{8}$	6.39	three $1\frac{1}{4}$ and one $1\frac{5}{16}$	6.41
6.6	one $2\frac{9}{16}$	6.57					three $1\frac{1}{4}$ and one $1\frac{3}{8}$	6.58
6.8	one $2\frac{5}{8}$	6.89	two $1\frac{13}{16}$	6.57	three $1\frac{1}{2}$	6.75	four $1\frac{5}{16}$	6.89
7.0			two $1\frac{7}{8}$	7.03			three $1\frac{3}{8}$ and one $1\frac{1}{8}$	6.93
7.2	one $2\frac{11}{16}$	7.22			two $1\frac{1}{2}$ and one $1\frac{5}{8}$	7.14	three $1\frac{3}{8}$ and one $1\frac{1}{4}$	7.23
7.4					three $1\frac{9}{16}$	7.32	three $1\frac{3}{8}$ and one $1\frac{5}{16}$	7.39
7.6	one $2\frac{3}{4}$	7.56	two $1\frac{15}{16}$	7.51	two $1\frac{5}{8}$ and one $1\frac{1}{2}$	7.53	four $1\frac{3}{8}$	7.56
7.8							three $1\frac{1}{2}$ and one 1	7.75
8.0	one $2\frac{13}{16}$	7.91	two 2	8.00	three $1\frac{5}{8}$	7.92	three $1\frac{3}{8}$ amd one $1\frac{1}{2}$	7.92

TABLE 82] ALTERNATIVE SELECTIONS OF SQUARE [STEEL BARS—Continued

Required Area Steel sq. in.	Five Square Bars		Six Square Bars		Eight Square Bars	
	Sizes inches	Actual Area sq. in.	Sizes inches	Actual Area sq. in.	Sizes inches	Actual Area sq. in.
(1)	(10)	(11)	(12)	(13)	(14)	(15)
2.55	three $\frac{7}{8}$ and two $\frac{3}{8}$	2.58	four $\frac{1}{2}$ and two $\frac{7}{8}$	2.53		
2.60			three $\frac{11}{16}$ and three $\frac{5}{8}$	2.59		
2.65	four $\frac{3}{4}$ and one $\frac{5}{8}$	2.64				
2.70	three $\frac{5}{8}$ and two $\frac{7}{8}$	2.70	four $\frac{5}{8}$ and two $\frac{3}{4}$	2.69		
2.75	three $\frac{11}{16}$ and two $\frac{13}{16}$	2.74	four $\frac{3}{4}$ and two $\frac{1}{2}$	2.75		
2.80	five $\frac{3}{4}$	2.81				
2.85			three $\frac{3}{4}$ and three $\frac{5}{8}$	2.86		
2.90	four $\frac{3}{4}$ and one $\frac{13}{16}$	2.91	four $\frac{3}{4}$ and two $\frac{9}{16}$	2.88		
2.95	three $\frac{13}{16}$ and two $\frac{11}{16}$	2.93				
3.00	four $\frac{3}{4}$ and one $\frac{7}{8}$	3.02	five $\frac{3}{4}$ and one $\frac{1}{2}$	3.06		
3.10	three $\frac{7}{8}$ and two $\frac{5}{8}$	3.08	four $\frac{5}{8}$ and two $\frac{7}{8}$	3.09		
3.20	two $\frac{7}{8}$ and three $\frac{3}{4}$	3.22	five $\frac{3}{4}$ and one $\frac{5}{8}$	3.20		
3.30	four $\frac{3}{4}$ and one 1	3.25	three $\frac{15}{16}$ and three $\frac{3}{4}$	4.32		
3.40	three $\frac{7}{8}$ and two $\frac{3}{4}$	3.42	six $\frac{3}{4}$	3.38		
3.50			three $\frac{7}{8}$ and three $\frac{5}{8}$	3.47		
3.60	four $\frac{7}{8}$ and one $\frac{3}{4}$	3.62	three $\frac{3}{4}$ and three $\frac{13}{16}$	3.67		
3.70	three $\frac{3}{4}$ and two 1	3.68	four $\frac{3}{4}$ and two $\frac{7}{8}$	3.78		
3.80	five $\frac{7}{8}$	3.82	five $\frac{3}{4}$ and one 1	3.81		
3.90	three $\frac{11}{16}$ and two $1\frac{1}{8}$	3.95	six $\frac{13}{16}$	3.96		
4.00			three $\frac{7}{8}$ and three $\frac{3}{4}$	3.99		
4.1	three 1 and two $\frac{3}{4}$	4.13	four $\frac{7}{8}$ and two $\frac{3}{4}$	4.18	six $\frac{3}{4}$ and two $\frac{5}{8}$	4.15
4.2	four $\frac{7}{8}$ and one $1\frac{1}{16}$	4.19	five $\frac{7}{8}$ and one $\frac{5}{8}$	4.22	five $\frac{3}{4}$ and three $\frac{11}{16}$	4.23
4.3	four $\frac{7}{8}$ and one $1\frac{1}{8}$	4.32	five $\frac{7}{8}$ and one $\frac{11}{16}$	4.30	seven $\frac{3}{4}$ and one $\frac{5}{8}$	4.32
4.4	five $\frac{15}{16}$	4.39	five $\frac{7}{8}$ and one $\frac{3}{4}$	4.39	seven $\frac{3}{4}$ and one $\frac{11}{16}$	4.41
4.5	three 1 and two $\frac{7}{8}$	4.53	five $\frac{7}{8}$ and one $\frac{13}{16}$	4.49	eight $\frac{3}{4}$	4.50
4.6	four $\frac{7}{8}$ and one $1\frac{1}{4}$	4.62	six $\frac{7}{8}$	4.60	seven $\frac{3}{4}$ and one $\frac{13}{16}$	4.60
4.7	four 1 and one $\frac{13}{16}$	4.66	five $\frac{7}{8}$ and one $\frac{15}{16}$	4.70	seven $\frac{3}{4}$ and one $\frac{7}{8}$	4.70
4.8	four 1 and one $\frac{7}{8}$	4.77	four $\frac{7}{8}$ and two $\frac{15}{16}$	4.82	seven $\frac{3}{4}$ and one $\frac{15}{16}$	4.81
4.9	four 1 and one $\frac{15}{16}$	4.88	three $\frac{7}{8}$ and three $\frac{15}{16}$	4.93	six $\frac{3}{4}$ and two $\frac{7}{8}$	4.90
5.0	five 1	5.00	four $\frac{7}{8}$ and two 1	5.06	seven $\frac{3}{4}$ and one $1\frac{1}{16}$	5.06
5.1	four 1 and one $1\frac{1}{16}$	5.12	four 1 and two $\frac{3}{4}$	5.13	five $\frac{3}{4}$ and three $\frac{7}{8}$	5.11
5.2			five $\frac{15}{16}$ and one $\frac{7}{8}$	5.16	seven $\frac{3}{4}$ and one $1\frac{1}{8}$	5.20
5.3	four 1 and one $1\frac{1}{8}$	5.27	six $\frac{15}{16}$	5.27	four $\frac{7}{8}$ and four $\frac{3}{4}$	5.31
5.4			five $\frac{15}{16}$ and one 1	5.39	six $\frac{3}{4}$ and two 1	5.37
5.5	three 1 and two $1\frac{1}{8}$	5.53	four 1 and two $\frac{7}{8}$	5.53	five $\frac{7}{8}$ and three $\frac{3}{4}$	5.51
5.6	five $1\frac{1}{16}$	5.64	five 1 and one $\frac{3}{4}$	5.57	four $\frac{5}{8}$ and four 1	5.56
5.7			five 1 and one $\frac{13}{16}$	5.66	six $\frac{7}{8}$ and two $\frac{3}{4}$	5.71
5.8	three $1\frac{1}{8}$ and two 1	5,80	five 1 and one $\frac{7}{8}$	5.77	five $\frac{3}{4}$ and three 1	5.81
5.9			five 1 and one $\frac{15}{16}$	5.88	six $\frac{3}{4}$ and two $1\frac{1}{8}$	5.90
6.0	four $1\frac{1}{8}$ and one 1	6.06	six 1	6.00	seven $\frac{7}{8}$ and one $\frac{3}{4}$	5.93
6.2			four $1\frac{1}{8}$ and two $\frac{3}{4}$	6.19	eight $\frac{7}{8}$	6.13
6.4	five $1\frac{1}{8}$	6.33	three 1 and three $1\frac{1}{16}$	6.38	seven $\frac{7}{8}$ and one 1	6.36
6.6	four $1\frac{1}{8}$ and one $1\frac{1}{4}$	6.62	four 1 and two $1\frac{1}{8}$	6.53	six $\frac{7}{8}$ and two 1	6.59
6.8			six $1\frac{1}{16}$	6.78	five $\frac{7}{8}$ and three 1	6.83
7.0	five $1\frac{3}{16}$	7.05	four $1\frac{1}{8}$ and two 1	7.06	eight $\frac{15}{16}$	7.02
7.2	four $1\frac{1}{4}$ and one 1	7.25	three $1\frac{1}{8}$ and three $1\frac{1}{16}$	7.18	four 1 and four $\frac{7}{8}$	7.06
7.4			five $1\frac{1}{8}$ and one 1	7.33	five $\frac{15}{16}$ and three 1	7.39
7.6	four $1\frac{1}{4}$ and one $1\frac{1}{8}$	7.52	six $1\frac{1}{8}$	7.60	seven 1 and one $\frac{3}{4}$	7.56
7.8	five $1\frac{1}{4}$	7.82	five $1\frac{1}{8}$ and one $1\frac{1}{4}$	7.88	seven 1 and one $\frac{7}{8}$	7.77
8.0			three $1\frac{1}{8}$ and three $1\frac{3}{16}$	8.03	eight 1	8.00

TABLE 83] ALTERNATIVE SELECTIONS OF ROUND BARS FOR REINFORCED SLABS [STEEL

(See p. 535)

See Table 90, p. 561

Ratio of Cross Section of Steel to Slab above Steel	Total Depth of Slab	Depth to Center of Steel	Steel Area in a Section of Slab One Foot Wide	Spacing of Round Steel Bars in Inches — Diameter of Round Bars in Inches														
	inches	inches	sq. in.	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1
0.002	2½	1¾	0.042	3.5	7.9	14.0												
	3	2¼	0.054	2.7	6.1	10.9	17.0											
	3½	2¾	0.066	2.2	5.0	8.9	13.9											
	4	3¼	0.078	...	4.2	7.6	11.8	17.0										
	4½	3½	0.084	....	3.9	7.0	10.9	15.8										
	5	4	0.096	....	3.4	6.1	9.6	13.8	18.8									
	5½	4½	0.108	....	3.1	5.5	8.5	12.2	16.7	21.9								
	6	5	0.120	....	2.8	4.9	7.7	11.0	15.0	19.6								
	6½	5½	0.132	....	2.5	4.5	7.0	10.0	13.6	17.9	22.6							
	7	6	0.144	....	2.3	4.1	6.4	9.2	12.5	16.4	20.7							
	7½	6½	0.156	....	2.1	3.8	5.9	8.5	11.5	15.1	19.1	23.6						
	8	7	0.168	....	....	3.5	5.5	7.9	10.7	14.0	17.7	21.9						
	9	8	0.192	....	....	3.1	4.8	6.9	9.4	12.3	15.5	19.2	23.2	27.6	32.4			
	10	9	0.216	....	....	2.7	4.3	6.1	8.3	10.9	13.8	17.0	20.6	24.5	28.8			
0.004	2½	1¾	0.084	1.8	3.9	7.0	10.9											
	3	2¼	0.108	1.4	3.1	5.5	8.5	12.3	16.7									
	3½	2¾	0.132	....	2.5	4.5	7.0	10.0	13.7	17.8								
	4	3¼	0.156	....	2.1	3.8	5.9	8.5	11.6	15.0								
	4½	3½	0.168	....	....	3.5	5.5	7.9	10.7	14.0	17.7							
	5	4	0.192	....	....	3.1	4.8	6.9	9.4	12.3	15.5	19.2						
	5½	4½	0.216	....	....	....	4.3	6.1	8.3	10.9	13.8	17.0	20.6	24.5				
	6	5	0.240	....	....	....	3.8	5.5	7.5	9.8	12.4	15.3	18.5	22.1				
	6½	5½	0.264	....	....	....	3.5	5.0	6.8	8.9	11.3	13.9	16.9	20.1				
	7	6	0.288	....	....	....	3.2	4.6	6.3	8.2	10.3	12.8	15.0	18.4	21.6			
	7½	6½	0.312	....	....	....	2.9	4.2	5.8	7.6	9.6	11.8	14.3	17.0	19.9			
	8	7	0.336	....	....	....	....	3.9	5.4	7.0	8.9	10.9	13.3	15.8	18.5	21.5		
	9	8	0.384	....	....	....	2.4	3.4	4.7	6.1	7.8	9.6	11.6	13.8	16.2			
	10	9	0.432	....	....	....	2.1	3.1	4.2	5.5	6.9	8.5	10.3	12.3	14.4			
0.005	2½	1¾	0.105	1.4	3.2	5.6	8.8	12.6	17.1	22.5								
	3	2¼	0.135	1.1	2.4	4.4	6.8	9.8	13.3	17.5								
	3½	2¾	0.165	....	2.0	3.6	5.6	8.0	10.9	14.3	18.1							
	4	3¼	0.195	....	1.7	3.0	4.7	6.8	9.2	12.1	15.3	18.9						
	4½	3½	0.210	....	1.6	2.8	4.4	6.3	8.6	11.2	14.2	17.5	21.2					
	5	4	0.240	....	....	....	3.8	5.5	7.5	9.8	12.4	15.3	18.5	22.1				
	5½	4½	0.270	....	....	....	3.4	4.9	6.7	8.7	11.0	13.6	16.5	19.6	23.0			
	6	5	0.300	....	....	....	3.1	4.4	6.0	7.9	9.9	12.3	14.8	17.7	20.7	24.1		
	6½	5½	0.330	....	....	....	2.8	4.0	5.4	7.2	9.0	11.2	13.5	16.1	18.8	21.9	25.1	
	7	6	0.360	....	....	....	2.6	3.7	5.0	6.6	8.3	10.2	12.4	14.7	17.3	20.1	23.0	26.2
	7½	6½	0.390	....	....	....	2.4	3.4	4.6	6.0	7.6	9.4	11.4	13.6	16.0	18.5	21.2	24.2
	8	7	0.420	....	....	....	2.2	3.1	4.3	5.6	7.1	8.8	10.6	12.6	14.8	17.2	19.7	22.4

TABLE 83] ALTERNATIVE SELECTIONS OF ROUND BARS FOR REINFORCED SLABS—Continued [STEEL

Rule—Knowing either ratio of steel or area, select from table the diameter and spacing of bars for slab of given thickness.

Ratio of Cross Section of Steel to Slab Above Steel.	Total Depth of Slab	Depth to Center of Steel	Steel Area in a Section of Slab One Foot Wide	Spacing of Round Steel Bars in Inches — Diameter of Round Bars in Inches														
	inches	inches	sq. in.	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1
0.005	9	8	0.480	....	....	....	1.9	2.8	3.8	4.9	6.2	7.7	9.3	11.0	13.0	15.0	17.2	19.6
	10	9	0.540	....	....	....	1.7	2.4	3.3	4.4	5.5	6.8	8.3	9.8	11.5	13.4	15.3	17.4
0.006	2½	1¾	0.126	1.2	2.6	4.7	7.3	10.5	14.3									
	3	2¼	0.162	....	2.0	3.6	5.7	8.2	11.1	14.5								
	3½	2¾	0.198	....	....	3.0	4.6	6.7	9.1	11.9	15.1							
	4	3¼	0.234	....	....	2.5	3.9	5.7	7.7	10.0	12.7	15.7						
	4½	3½	0.252	....	....	....	3.6	5.3	7.2	9.3	11.8	14.6	17.7					
	5	4	0.288	....	....	....	3.2	4.6	6.3	8.2	10.3	12.8	15.5	18.4				
	5½	4½	0.324	....	....	....	2.8	4.1	5.6	7.3	9.2	11.4	13.7	16.4	19.2	22.3		
	6	5	0.360	....	....	....	....	3.7	5.0	6.5	8.3	10.2	12.4	14.7	17.3	20.0		
	6½	5½	0.396	....	....	....	....	3.3	4.6	6.0	7.5	9.3	11.2	13.4	15.7	18.2		
	7	6	0.432	....	....	....	....	3.1	4.2	5.5	6.9	8.5	10.3	12.3	14.4	16.7	19.2	21.8
	7½	6½	0.468	....	....	....	....	2.8	3.8	5.0	6.4	7.9	9.5	11.3	13.3	15.4	17.7	20.1
	8	7	0.504	....	....	....	....	....	3.6	4.7	5.9	7.3	8.8	10.5	12.3	14.3	16.4	18.7
	9	8	0.576	....	....	....	....	....	3.1	4.1	5.2	6.4	7.7	9.2	10.8	12.5	14.4	16.4
	10	9	0.648	....	....	....	....	....	2.8	3.6	4.6	5.7	6.9	8.2	9.6	11.1	12.8	14.5
0.007	2½	1¾	0.147	....	....	4.0	6.3	9.0	12.2									
	3	2¼	0.189	....	....	3.1	4.9	7.0	9.5	12.5	15.8							
	3½	2¾	0.231	....	....	2.6	4.0	5.7	7.8	10.2	12.9	15.9	19.3					
	4	3¼	0.273	....	....	2.2	3.4	4.8	6.6	8.6	10.9	13.5	16.3	19.4	22.8			
	4½	3½	0.294	....	....	....	3.1	4.5	6.1	8.0	10.1	12.5	15.1	18.0	21.2			
	5	4	0.336	....	....	....	2.7	3.9	5.4	7.0	8.9	11.0	13.2	15.8	18.5	21.5		
	5½	4½	0.378	....	....	....	2.4	3.5	4.8	6.2	7.9	9.7	11.8	14.0	16.5	19.1	21.9	
	6	5	0.420	....	....	....	....	3.1	4.3	5.6	7.1	8.8	10.6	12.6	14.8	17.2	19.7	22.4
	6½	5½	0.462	....	....	....	....	2.9	3.9	5.1	6.4	8.0	9.6	11.5	13.5	15.6	17.9	20.4
	7	6	0.504	....	....	....	....	....	3.6	4.7	5.9	7.3	8.8	10.5	12.3	14.3	16.4	18.7
	7½	6½	0.546	....	....	....	....	....	3.3	4.3	5.5	6.7	8.2	9.7	11.4	13.2	15.2	17.3
	8	7	0.588	....	....	....	....	....	3.1	4.0	5.1	6.3	7.6	9.0	10.6	12.3	14.1	16.0
	9	8	0.672	....	....	....	....	....	2.7	3.5	4.4	5.5	6.6	7.9	9.3	10.7	12.3	14.0
	10	9	0.756	....	....	....	....	....	2.4	3.1	3.9	4.9	5.9	7.0	8.2	9.6	11.0	12.5
0.008	2½	1¾	0.168	....	2.0	3.5	5.5	7.9	10.7									
	3	2¼	0.216	....	....	2.7	4.3	6.1	8.4	10.9	13.8							
	3½	2¾	0.264	....	....	2.2	3.5	5.0	6.8	8.9	11.3	13.9	16.9					
	4	3¼	0.312	....	....	....	2.9	4.2	5.8	7.6	9.6	11.8	14.3	17.0				
	4½	3½	0.336	....	....	....	....	3.9	5.4	7.0	8.9	10.9	13.2	15.8	18.5			
	5	4	0.384	....	....	....	....	3.4	4.7	6.1	7.8	9.6	11.6	13.8	16.2	18.8		
	5½	4½	0.432	....	....	....	....	3.1	4.2	5.5	6.9	8.5	10.3	12.3	14.4	16.7	19.2	21.8
	6	5	0.480	....	....	....	....	2.8	3.8	4.9	6.2	7.7	9.3	11.0	13.0	15.0	17.3	19.6
	6½	5½	0.528	....	....	....	....	2.5	3.4	4.5	5.6	7.0	8.4	10.0	11.8	13.7	15.7	17.8

TABLE 83] ALTERNATIVE SELECTIONS OF ROUND [STEEL BARS FOR REINFORCED SLABS—Continued

See p. 535

Ratio of Cross Section of Steel to Slab above Steel	Total Depth of Slab	Depth to Center of Steel	Steel Area in a Section of Slab one foot wide	Spacing of Round Steel Bars in Inches — Diameter of Round Bars in Inches														
	inches	inches	sq. in.	⅛	3/16	¼	5/16	⅜	7/16	½	9/16	⅝	11/16	¾	13/16	⅞	15/16	1
0.008	7	6	0.576	...	...	...	...	...	3.1	4.1	5.2	6.4	7.7	9.2	10.8	12.5	14.4	16.4
	7½	6½	0.624	...	...	...	...	...	2.9	3.8	4.8	5.9	7.1	8.5	10.0	11 6	13.3	15.1
	8	7	0.672	...	...	...	...	...	...	3.5	4.4	5.5	6.6	7.9	9.3	10.7	12.3	14.0
	9	8	0.768	...	...	...	...	...	...	3.1	3.9	4.8	5.8	6.9	8.1	9.4	10.8	12.3
	10	9	0.864	...	...	...	...	...	...	2.7	3.4	4.3	5.2	6.1	7.2	8.4	9.6	10.9
0.009	2½	1¾	0.189	...	1.8	3.1	4.9	7.0	9.5	12.5	15.8							
	3	2¼	0.243	...	1.4	2.4	3.8	5.4	7.4	9.7	12.3	15.1						
	3½	2¾	0.297	...	1.1	2.0	3.1	4.4	6.1	8.0	10.0	12.4	15.0	17.8				
	4	3¼	0.351	...	0.9	1.7	2.6	3.8	5.1	6.7	8.5	10.5	12.7	15.1	17.7			
	4½	3½	0.378	...	0.9	1.6	2.4	3.5	4.8	6.2	7.9	9.7	11.8	14.0	16.5			
	5	4	0.432	...	...	...	2.1	3.1	4.2	5.5	6.9	8.5	10.3	12.3	14.4	16.7		
	5½	4½	0.486	...	...	...	...	2.7	3.7	4.9	6.1	7.6	9.2	10.9	12.8	14.9	17.0	19.4
	6	5	0.540	...	...	...	...	2.4	3.3	4.4	5.5	6.8	8.2	9.8	11.5	13.4	15.3	17.4
	6½	5½	0.594	...	...	...	...	2.2	3.0	4.0	5.0	6.2	7.5	8.9	10.5	12.2	13.9	15.9
	7	6	0.648	...	...	...	...	...	...	3.6	4.6	5.7	6.9	8.2	9.6	11.1	12.8	14.5
	7½	6½	0.702	...	...	...	...	...	...	3.4	4.2	5.2	6.3	7.6	8.9	10.3	11.8	13.4
	8	7	0.756	...	...	...	...	...	...	3.1	3.9	4.9	5.9	7.0	8.2	9.6	11.0	12.5
	9	8	0.864	...	...	...	...	...	...	2.7	3.4	4.3	5.2	6.1	7.2	8.4	9.6	10.9
	10	9	0.972	...	...	...	...	...	...	2.4	3.1	3.8	4.6	5.4	6.4	7.4	8.5	9.7
0.010	2½	1¾	0.210	...	...	2.8	4.4	6.3	8.6	11.2								
	3	2¼	0.270	...	...	2.2	3.4	4.9	6.7	8.7	11.0	13.6						
	3½	2¾	0.330	...	...	...	2.8	4.0	5.5	7.1	9.0	11.1	13.5	16.1				
	4	3¼	0.390	...	...	...	...	3.4	4.6	6.0	7.6	9.4	11.4	13.6	15.9			
	4½	3½	0.420	...	...	...	...	3.1	4.3	5.6	7.1	8.8	10.6	12.6	14.8	17.2		
	5	4	0.480	...	...	...	...	...	3.8	4.9	6.2	•7.7	9.3	11.0	13.0	15.0	17.3	
	5½	4½	0.540	...	...	...	...	...	...	4.4	5.5	6.8	8.2	9.8	11.5	13.4	15.3	17.4
	6	5	0.600	...	...	...	...	...	...	3.9	5.0	6.1	7.4	8.8	10.4	12.0	13.8	15.7
	6½	5½	0.660	...	...	...	...	...	...	3.6	4.5	5.6	6.7	8.0	9.4	10.9	12.5	14.3
	7	6	0.720	...	...	...	...	...	...	3.3	4.1	5.1	6.2	7.4	8.6	10.0	11.5	13.1
	7½	6½	0.780	...	...	...	...	...	...	3.0	3.8	4.7	5.7	6.8	8.0	9.3	10.6	12 1
	8	7	0.840	...	...	...	...	...	...	...	3.5	4.4	5.3	6.3	7.4	8.(	9.9	11.2
	9	8	0.96C	...	...	...	...	...	...	2.5	3.1	3.8	4.6	5.5	6.5	7.5	8.6	9.8
	10	9	1.080	...	...	...	...	...	...	2.2	2.8	3.4	4.1	4.9	5.8	6.7	7.7	8.7

TABLE 84] ALTERNATIVE SELECTIONS OF SQUARE [STEEL BARS FOR REINFORCED SLABS

(See p. 535)

See Table 90, p. 561

Ratio of Cross Section of Steel to Slab above Steel	Total Depth of Slab	Depth to Center of Steel	Steel Area in a Section of Slab One Foot Wide	Spacing of Square Steel Bars in Inches — Size of Square Bars in Inches														
	inches	inches	sq. in.	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1
	2½	1¾	0.042	4.5	10.1													
	3	2¼	0.054	3.5	7.8	13.9												
	3½	2¾	0.066	2.8	6.4	11.4	17.8											
	4	3¼	0.078	2.4	5.4	9.6	15.0											
	4½	3½	0.084	2.2	5.0	8.9	13.9	20.1										
	5	4	0.096	1.9	4.4	7.8	12.2	17.6										
0.002	5½	4½	0.108	....	3.9	6.9	10.8	15.6	21.3									
	6	5	0.120	....	3.5	6.3	9.8	14.1	19.1									
	6½	5½	0.132	....	3.2	5.7	8.9	12.8	17.4	22.7								
	7	6	0.144	....	2.9	5.2	8.1	11.7	15.9	20.8								
	7½	6½	0.156	....	2.7	4.8	7.5	10.8	14.7	19.2	24.4							
	8	7	0.168	....	2.5	4.5	7.0	10.0	13.7	17.8	22.5							
	9	8	0.192	....	2.2	3.9	6.1	8.8	12.0	15.6	19.8	24.4	29.5					
	10	9	0.216	....	2.0	3.5	5.4	7.8	10.6	13.9	17.6	21.7	26.2	31.2				
	2½	1¾	0.084	2.2	5.0	8.9	13.9											
	3	2¼	0.108	1.7	3.9	6.9	10.8	15.6										
	3½	2¾	0.132	....	3.2	5.7	8.9	12.8	17.4									
	4	3¼	0.156	....	2.7	4.8	7.5	10.8	14.7	19.2								
	4½	3½	0.168	....	2.5	4.5	7.0	10.0	13.7	17.8								
	5	4	0.192	....	2.2	3.9	6.1	8.8	12.0	15.6	19.7							
0.004	5½	4½	0.216	....	2.0	3.5	5.4	7.8	10.6	13.9	17.6	21.7	26.3					
	6	5	0.240	....	....	3.1	4.9	7.0	9.6	12.5	15.8	19.5	23.6					
	6½	5½	0.264	....	....	2.8	4.4	6.4	8.7	11.4	14.4	17.8	21.5	25.6				
	7	6	0.288	....	....	2.6	4.1	5.9	8.0	10.4	13.2	16.3	19.7	23.4				
	7½	6½	0.312	....	....	2.4	3.8	5.4	7.4	9.6	12.2	15.0	18.2	21.6				
	8	7	0.336	....	....	....	3.5	5.0	6.8	8.9	11.3	13.9	16.9	20.1	23.6			
	9	8	0.384	....	....	....	3.0	4.4	6.0	7.8	9.9	12.2	14.8	17.6	20.6	23.9	27.5	31.2
	10	9	0.432	....	....	....	2.7	3.9	5.3	6.9	8.8	10.9	13.1	15.6	18.3	21.3		
	2½	1¾	0.105	1.8	4.0	7.1	11.1	16.1										
	3	2¼	0.135	1.4	3.1	5.6	8.7	12.5	17.0									
	3½	2¾	0.165	....	2.6	4.5	7.1	10.2	13.9	18.2								
	4	3¼	0.195	....	2.2	3.8	6.0	8.7	11.8	15.4	19.5	24.0						
	4½	3½	0.210	....	2.0	3.6	5.6	8.0	11.0	14.3	18.1	22.3	27.0					
0.005	5	4	0.240	....	1.8	3.1	4.9	7.0	9.6	12.5	15.8	19.5	23.6	28.1				
	5½	4½	0.270	....	....	....	4.3	6.3	8.5	11.1	14.1	17.4	21.0	25.0	29.3	34.0	39.1	
	6	5	0.300	....	....	....	3.9	5.6	7.7	10.0	12.7	15.6	18.9	22.5	26.4	30.6		
	6½	5½	0.330	....	....	....	3.6	5.1	7.0	9.1	11.5	14.2	17.2	20.5	24.0	27.9		
	7	6	0.360	....	....	....	3.3	4.7	6.4	8.3	10.5	13.0	15.8	18.8	22.0	25.5	29.2	
	7½	6½	0.390	....	....	....	3.0	4.3	5.9	7.7	9.7	12.0	14.5	17.3	20.3	23.6	27.1	30.8
	8	7	0.420	....	....	....	2.8	4.0	5.5	7.1	9.1	11.2	13.5	16.1	18.9	21.9	25.1	28.6

TABLE 84] ALTERNATIVE SELECTIONS OF SQUARE [STEEL BARS FOR REINFORCED SLABS—Continued

(See p. 535)

Ratio of Cross Section of Steel to Slab above Steel	Total Depth of Slab	Depth to Center of Steel	Steel Area in a Section of Slab one Foot Wide	Spacing of Square Steel Bars in Inches — Size of Square Bars in Inches														
	inches	inches	sq. in.	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1
0.005	9	8	0.480	....	....	....	2.4	3.5	4.8	6.3	7.9	9.8	11.8	14.1	16.5	19.1	22.0	25.0
	10	9	0.540	....	....	....	2.2	3.1	4.3	5.6	7.0	8.7	10.5	12.5	14.7	17.0	19.5	22.2
0.006	2½	1¾	0.126	1.5	3.3	6.0	9.3	13.4										
	3	2¼	0.162	....	2.6	4.6	7.2	10.4	14.2									
	3½	2¾	0.198	....	2.1	3.8	5.9	8.5	11.6	15.1								
	4	3¼	0.234	....	....	3.2	5.0	7.2	9.8	12.8	16.2	20.0						
	4½	3½	0.252	....	....	3.0	4.6	6.7	9.1	11.9	15.1	18.6						
	5	4	0.288	....	....	2.6	4.1	5.9	8.0	10.4	13.2	16.3	19.7					
	5½	4½	0.324	....	....	....	3.6	5.2	7.1	9.3	11.7	14.5	17.5	20.8	24.4			
	6	5	0.360	....	....	....	3.3	4.7	6.4	8.3	10.5	13.0	15.7	18.7	22.0			
	6½	5½	0.396	....	....	....	3.0	4.3	5.8	7.6	9.6	11.8	14.3	17.0	20.0			
	7	6	0.432	....	....	....	....	3.9	5.3	6.9	8.8	10.8	13.1	15.6	18.3	21.3		
	7½	6½	0.468	....	....	....	....	3.6	4.9	6.4	8.1	10.0	12.1	14.4	16.9	19.6	22.5	
	8	7	0.504	....	....	....	....	3.3	4.6	6.0	7.5	9.3	11.2	13.4	15.7	18.2	20.9	
	9	8	0.576	....	....	....	....	2.9	4.0	5.2	6.6	8.1	9.8	11.7	13.8	16.0	18.3	20.8
	10	9	0.648	....	....	....	....	2.6	3.6	4.6	5.9	7.2	8.8	10.4	12.2	14.2	16.3	18.5
0.007	2½	1¾	0 147	1.3	2.9	5.1	8.0	11.5										
	3	2¼	0.189	....	2.2	4.0	6.2	8.9	12.2									
	3½	2¾	0.231	....	1.8	3.2	5.0	7.3	10.0	13.0								
	4	3¼	0.273	....	....	2.8	4.3	6.2	8.4	11.0	13.9	17.2						
	4½	3½	0.294	....	....	2.6	4.0	5.8	7.8	10.2	12.9	16.0	19.3					
	5	4	0.336	....	....	2.2	3.5	5.0	6.8	8.9	11.3	14.0	16.9					
	5½	4½	0.378	....	....	....	3.1	4.5	6.1	7.9	10.1	12.4	15.0	17.9	21.0			
	6	5	0.420	....	....	....	2.8	4.0	5.5	7.1	9.0	11.2	13.5	16.1	18.9	21.9		
	6½	5½	0.462	....	....	....	....	3.7	5.0	6.5	8.2	10.2	12.3	14.6	17.1	19.9		
	7	6	0.504	....	....	....	....	3.4	4.6	6.0	7.5	9.3	11.2	13.4	15.7	18.2	20.9	23.8
	7½	6½	0.546	....	....	....	....	3.1	4.2	5.5	7.0	8.6	10.4	12.4	14.5	16.8	19.3	22.0
	8	7	0.588	....	....	....	....	2.9	3.9	5.1	6.5	8.0	9.6	11.5	13.5	15.6	17.9	20.4
	9	8	0.672	....	....	....	....	2.5	3.4	4.5	5.6	7.0	8.4	10.0	11.8	13.7	15.7	17.9
	10	9	0.756	....	....	....	....	2.2	3.0	4.0	5.0	6.2	7.5	8.9	10.5	12.2	14.0	15.9
0.008	2½	1¾	0.168	....	2.5	4.5	7.0	10.0										
	3	2¼	0.216	....	2.0	3.5	5.4	7.8	10.6	13.9								
	3½	2¾	0.264	....	....	2.8	4.4	6.4	8.7	11.4	14.4	17.7						
	4	3¼	0.312	....	....	....	3.8	5.4	7.4	9.6	12.2	15.0	18.2					
	4½	3½	0.336	....	....	....	3.5	5.0	6.8	8.9	11.3	13.9	16.9	20.1				
	5	4	0.384	....	....	....	3.1	4.4	6.0	7.8	9.9	12.2	14.8	17.6	20.6			
	5½	4½	0.432	....	....	....	....	3.9	5.3	6.9	8.8	10.9	13.1	15.6	18.3	21.3		
	6	5	0.480	....	....	....	....	3.5	4.8	6.2	7.9	9.8	11.8	14.1	16.5	19.1		
	6½	5½	0.528	....	....	....	....	3.2	4.4	5.7	7.2	8.9	10.7	12.8	15.0	17.4	20.0	

TABLE 84] ALTERNATIVE SELECTIONS OF SQUARE [STEEL BARS FOR REINFORCED SLABS—Continued (See p. 535)

Rule—Knowing either ratio of steel or area, select from table the diameter and spacing of bars for slab of given thickness.

Ratio of Cross Section of Steel to Slab above Steel	Total Depth of Slab	Depth to Center of Steel	Steel Area in a Section of Slab One Foot Wide	Spacing of Square Steel Bars in Inches — Size of Square Bars in Inches														
	inches	inches	sq. in.	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1
	7	6	0.576	....	....	....	....	2.9	4.0	5.2	6.6	8.1	9.8	11.7	13.8	15.9	18.3	20.8
	7½	6½	0.624	....	....	....	....	2.7	3.7	4.8	6.1	7.5	9.1	10.8	12.7	14.7	16.9	19.2
0.008	8	7	0.672	....	....	....	....	....	3.4	4.5	5.6	7.0	8.4	10.0	11.8	13.7	15.7	17.9
	9	8	0.768	....	....	....	....	....	3.0	3.9	5.0	6.1	7.4	8.8	10.3	12.0	13.7	15.6
	10	9	0.864	....	....	....	....	....	2.7	3.5	4.4	5.4	6.6	7.8	9.2	10.6	12.2	13.9
	2½	1¾	0.189	....	2.2	4.0	6.2	8.9	12.2									
	3	2¼	0.243	....	1.7	3.1	4.8	7.0	9.5	12.3	15.6							
	2½	2¾	0.297	....	....	2.5	3.9	5.7	7.7	10.1	12.8	15.8						
	4	3¼	0.351	....	....	....	3.3	4.8	6.6	8.6	10.8	13.4	16.2					
	4½	3½	0.378	....	....	....	3.1	4.5	6.1	7.9	10.1	12.4	15.0	17.9	21.0			
	5	4	0.432	....	....	....	2.7	3.9	5.3	6.9	8.8	10.9	13.1	15.6	18.3	21.3		
0.009	5½	4½	0.486	....	....	....	....	3.5	4.7	6.2	7.8	9.6	11.7	13.9	16.3	18.9	21.7	
	6	5	0.540	....	....	....	....	3.1	4.3	5.6	7.0	8.7	10.5	12.5	14.7	17.0	19.5	
	6½	5½	0.594	....	....	....	....	2.8	3.9	5.0	6.4	7.9	9.5	11.4	13.3	15.5	17.8	
	7	6	0.648	....	....	....	....	2.6	3.6	4.6	5.9	7.2	8.8	10.4	12.2	14.2	16.3	18.5
	7½	6½	0.702	....	....	....	....	2.4	3.3	4.3	5.4	6.7	8.1	9.6	11.3	13.1	15.0	17.1
	8	7	0.756	....	....	....	....	2.2	3.0	4.0	5.0	6.2	7.5	8.9	10.5	12.2	14.0	15.9
	9	8	0.864	....	....	....	....	2.0	2.7	3.5	4.4	5.4	6.6	7.8	9.2	10.6	12.2	13.9
	10	9	0.972	....	....	....	....	1.7	2.4	3.1	3.9	4.8	5.8	6.9	8.2	9.5	10.9	12.3
	2½	1¾	0.210	....	2.0	3.6	5.6	8.0	10.9	14.3								
	3	2¼	0.270	....	....	2.8	4.3	6.2	8.5	11.1	14.1							
	3½	2¾	0.330	....	....	2.3	3.5	5.1	7.0	9.1	11.5	14.2						
	4	3¼	0.390	....	....	....	3.0	4.3	5.9	7.7	9.7	12.0	14.5	17.3				
	4½	3½	0.420	....	....	....	2.8	4.0	5.5	7.1	9.0	11.2	13.5	16.1				
	5	4	0.480	....	....	....	....	3.5	4.8	6.2	7.9	9.8	11.8	14.1	16.5	19.1		
0.010	5½	4½	0.540	....	....	....	....	....	4.3	5.6	7.0	8.7	10.5	12.5	14.7	17.0	19.5	22.2
	6	5	0.600	....	....	....	....	....	3.8	5.0	6.3	7.8	9.5	11.2	13.2	15.3	17.6	20.0
	6½	5½	0.660	....	....	....	....	....	3.5	4.6	5.8	7.1	8.6	10.2	12.0	13.9	16.0	18.2
	7	6	0.720	....	....	....	....	....	3.2	4.2	5.3	6.5	7.9	9.4	11.0	12.7	14.6	16.7
	7½	6½	0.780	....	....	....	....	....	3.0	3.8	4.9	6.0	7.3	8.7	10.2	11.8	13.5	15.4
	8	7	0.840	....	....	....	....	....	....	3.6	4.5	5.6	6.7	8.0	9.4	10.9	12.5	14.3
	9	8	0.960	....	....	....	....	....	....	3.1	4.0	4.9	5.9	7.0	8.2	9.6	11.0	12.5
	10	9	1.080	....	....	....	....	....	....	2.8	3.5	4.3	5.2	6.2	7.3	8.5	9.8	11.1

TABLE 85] WEIGHTS OF COLUMN REINFORCEMENT [STEEL ROUND BARS

For Times and Costs see pp. 570 and 571 *For use of table see p. 535*

10% allowance has been made for lapping or pipe sleeves. Hoops are spaced 12 inches apart.

Number and Size of Bars in Column	Size of Steel in Hoops in Inches	Weights of Round Bars in Pounds per Column — Heights of Columns in Feet: 1	6	8	9	10	11	12	13	14	15	16	18	20
4–$\frac{1}{2}$″ Bars	$\frac{3}{16}$	3.8	23	32	34	38	42	45	49	53	57	61	68	76
	$\frac{1}{4}$	4.5	27	36	41	45	50	54	59	63	68	72	81	90
4–$\frac{3}{4}$″ Bars	$\frac{3}{16}$	7.4	45	60	67	74	82	89	97	104	112	119	134	149
	$\frac{1}{4}$	8.2	49	65	74	82	90	98	106	114	123	131	147	164
	$\frac{5}{16}$	9.0	54	72	81	90	99	108	117	126	135	144	162	180
4–$\frac{7}{8}$″ Bars	$\frac{1}{4}$	10.5	63	84	95	105	116	126	137	147	158	168	189	210
	$\frac{5}{16}$	11.4	68	91	103	114	125	137	148	160	171	182	205	228
	$\frac{3}{8}$	12.4	75	99	112	124	137	149	162	174	187	199	224	248
4–1″ Bars	$\frac{1}{4}$	13.3	80	107	120	133	147	160	173	187	200	213	240	266
	$\frac{5}{16}$	14.1	85	113	127	141	155	169	183	198	212	226	254	282
	$\frac{3}{8}$	15.2	91	122	137	152	167	183	198	213	228	244	274	304
4–1$\frac{1}{8}$″ Bars	$\frac{5}{16}$	17.4	105	139	157	174	192	209	227	244	262	279	314	348
	$\frac{3}{8}$	18.6	111	149	167	186	204	223	241	260	278	297	334	372
	$\frac{1}{2}$	21.2	127	169	191	212	233	254	275	296	318	339	381	422
4–1$\frac{1}{4}$″ Bars	$\frac{5}{16}$	20.7	124	166	187	207	228	249	269	290	311	332	373	414
	$\frac{3}{8}$	21.8	131	175	197	218	240	262	284	306	328	349	393	437
	$\frac{1}{2}$	24.5	147	196	221	245	270	294	319	343	368	392	441	490
4–1$\frac{1}{2}$″ Bars	$\frac{5}{16}$	28.8	173	231	260	288	317	346	375	404	433	461	519	577
	$\frac{3}{8}$	29.9	180	239	269	299	329	359	389	419	449	479	539	599
	$\frac{1}{2}$	32.6	195	260	293	326	358	391	423	456	488	521	586	657
8–$\frac{1}{2}$″ Bars	$\frac{3}{16}$	6.7	40	54	61	67	74	81	87	94	101	108	121	134
	$\frac{1}{4}$	7.4	45	60	67	74	82	89	97	104	112	119	134	149
8–$\frac{3}{4}$″ Bars	$\frac{3}{16}$	14.1	85	113	127	141	155	169	183	197	211	225	253	281
	$\frac{1}{4}$	14.8	89	118	133	148	163	177	192	207	222	236	266	296
	$\frac{5}{16}$	15.6	93	125	140	156	171	187	202	218	233	250	280	311
8–$\frac{7}{8}$″ Bars	$\frac{1}{4}$	19.5	117	156	175	195	214	233	253	272	292	311	350	389
	$\frac{5}{16}$	20.3	122	163	183	203	224	244	264	285	305	325	366	407
	$\frac{3}{8}$	21.2	127	169	191	212	233	254	275	296	318	339	381	423
8–1″ Bars	$\frac{1}{4}$	25.1	150	201	226	251	276	301	326	351	376	401	451	501
	$\frac{5}{16}$	25.8	155	207	233	258	284	310	336	362	388	413	465	517
	$\frac{3}{8}$	26.9	162	216	243	269	296	323	350	377	404	431	485	539
8–1$\frac{1}{8}$″ Bars	$\frac{5}{16}$	32.5	195	260	293	325	358	390	423	455	488	520	585	650
	$\frac{3}{8}$	33.6	201	269	302	336	369	403	436	470	503	537	604	672
	$\frac{1}{2}$	36.2	217	290	326	362	398	435	471	507	543	580	652	724
8–1$\frac{1}{4}$″ Bars	$\frac{5}{16}$	39.1	234	313	352	391	430	469	508	547	586	625	703	782
	$\frac{3}{8}$	40.2	241	321	362	402	442	482	522	562	602	643	723	804
	$\frac{1}{2}$	42.8	257	343	386	428	471	514	557	600	643	685	771	857

TABLE 86] WEIGHTS OF COLUMN REINFORCEMENT [STEEL SQUARE BARS

For Times and Costs see pp. 570 and 571 *For use of table see p. 535*

10% allowance has been made for lapping or pipe sleeves. Hoops are spaced 12 inches apart.

Number and Size of Bars in Column	Size of Steel in Hoops in Inches	Weights of Square Bars in Pounds per Column												
		Heights of Columns in Feet												
		1	6	8	9	10	11	12	13	14	15	16	18	20
4–½″ Bars	3/16	4.8	29	39	44	48	53	58	63	68	72	77	87	97
	¼	5.7	34	45	51	57	62	68	74	79	85	91	102	112
4–¾″ Bars	3/16	9.5	57	76	86	95	105	114	124	133	143	152	171	190
	¼	10.3	62	83	93	103	114	124	134	145	155	165	186	207
	5/16	11.5	69	92	103	115	126	138	149	160	172	183	206	229
4–⅞″ Bars	¼	13.4	80	107	121	134	147	161	174	187	201	214	241	268
	5/16	14.5	87	116	131	145	160	174	190	203	218	232	261	290
	⅜	15.8	95	127	142	158	174	190	206	222	237	253	285	317
4–1″ Bars	¼	16.9	101	135	152	169	186	203	220	236	253	270	304	338
	5/16	17.9	108	144	161	179	197	215	233	251	269	287	323	359
	⅜	19.4	116	155	175	194	213	233	252	271	291	310	349	388
4–1⅛″ Bars	5/16	22.2	133	177	200	222	244	266	288	310	333	355	399	444
	⅜	23.6	141	188	212	236	259	283	306	330	353	377	424	471
	½	27.0	162	216	243	270	297	323	350	377	404	431	485	539
4–1¼″ Bars	5/16	26.4	158	211	238	264	290	317	343	369	396	422	475	528
	⅜	27.7	166	222	250	277	305	333	360	388	416	444	499	554
	½	31.1	187	249	280	311	342	373	404	436	467	498	560	622
4–1½″ Bars	5/16	36.7	220	293	330	367	403	440	477	513	550	587	660	733
	⅜	38.1	228	305	343	381	419	457	495	533	570	608	685	761
	½	41.4	249	332	373	414	456	497	539	580	622	663	746	828
8–½″ Bars	3/16	8.6	51	69	77	86	94	103	111	120	128	137	154	171
	¼	9.4	56	75	85	94	103	113	122	132	141	150	169	188
8–¾″ Bars	3/16	17.9	107	143	161	179	197	215	233	251	268	286	322	358
	¼	18.7	112	150	169	187	206	225	243	262	281	300	337	374
	5/16	19.8	119	159	179	198	218	238	258	278	298	317	357	396
8–⅞″ Bars	¼	24.8	149	199	224	248	273	298	323	348	373	397	447	497
	5/16	25.9	155	207	233	259	285	311	337	363	388	414	466	518
	⅜	27.2	163	218	245	272	299	327	354	381	408	436	490	544
8–1″ Bars	¼	31.8	191	255	287	318	350	382	414	446	478	509	573	637
	5/16	32.9	198	264	297	329	362	395	428	461	494	527	593	659
	⅜	34.3	206	275	309	343	378	412	446	481	515	549	618	687
8–1⅛″ Bars	5/16	41.3	248	331	372	413	455	496	537	579	620	661	744	827
	⅜	42.7	256	342	384	427	470	513	555	598	641	684	769	854
	½	46.1	277	369	415	461	507	553	599	646	692	738	830	922
8–1¼″ Bars	5/16	49.7	298	398	448	497	547	597	646	696	746	796	895	994
	⅜	51.1	307	409	460	511	562	614	665	716	767	818	920	1022
	½	55.0	327	436	491	545	600	654	709	763	818	872	981	1090

ROUND BARS

For Times and Costs see Chapter XIX. *For use of table see p. 535.*

Weights include: extra steel required for bends in half the bars; allowance of 20% for lapping over supports; and weight of stirrups.

Total Number of Bars per Beam	Weight of Steel per Beam in Pounds — Length of Beam in Feet											Approximate Depth of Beam	Length of Each Stirrup Bar	Total Number of U-Stirrups
	8	10	12	14	16	18	20	22	24	26	30	in.	in.	
½-Inch Round Steel Bars—¼-Inch Stirrups														
1*	13	15	17	20	21							7	15	4
2†	18	21	25	28	31	35	38	42	46	49	57	9	20	6
3	22	27	32	36	41	45	50	55	60	65	75	11	24	6
4	28	35	42	48	55	61	68	74	81	87	100	12	28	6
5	37	45	53	61	69	77	85	93	101	109	125	14	30	8
6	43	53	63	73	82	92	102	112	121	131	150	15	34	8
7	53	64	75	87	98	110	121	132	143	155	177	17	38	12
8	62	75	88	101	113	126	139	152	165	171	203	18	40	16
9	72	86	99	114	128	143	157	172	187	193	229	19	47	16
10	81	97	111	127	144	159	175	192	208	215	255	20	49	20
¾-Inch Round Steel Bars—¼-Inch Stirrups														
1*	28	33	38	43	48	53	58	63	68	73	83	10	23	8
2†	40	48	56	64	71	79	87	95	103	111	127	14	30	8
3	51	62	73	84	94	105	116	127	138	148	170	16	35	14
4	68	83	98	112	127	141	156	170	185	199	228	18	40	14
5	88	106	125	142	161	178	196	214	233	251	287	20	45	20
6	108	129	151	172	194	215	237	259	281	302	346	22	50	20
7	130	155	180	205	231	256	281	306	332	357	408	24	55	28
8	150	179	208	237	265	294	323	352	381	409	467	25	57	34
9	170	203	235	268	299	333	364	396	427	461	526	27	69	34
10	190	227	262	300	333	372	405	440	473	513	586	29	72	40
⅞-Inch Round Steel Bars—⅜-Inch Stirrups														
1*	31	39	46	52	59	65	72	80	87	93	107	11	24	4
2†	50	63	74	84	95	105	116	128	139	149	170	15	34	4
3	71	86	101	116	130	145	160	175	189	204	233	18	42	8
4	96	116	136	155	175	194	214	234	254	273	313	21	48	8
5	125	150	175	199	224	248	273	297	322	346	395	24	54	12
6	153	182	211	240	270	299	328	357	387	416	475	26	60	12
7	183	217	251	285	320	354	388	422	457	491	560	28	65	16
8	212	251	290	329	369	407	447	486	525	565	643	29	67	16
9	240	284	327	372	417	462	504	548	592	637	720	31	78	20
10	267	317	364	415	465	510	561	610	659	709	796	34	82	24

*Allows for an additional bar over supports, length ⅖ of span.
†Allows for two additional bars over support, length ⅖ of span.

—Continued

ROUND BARS

Weights include: extra steel required for bends in half the bars; allowance of 20% for lapping over supports; and weight of stirrups.

Total Number of Bars per Beam	Weight of Steel per Beam in Pounds — Length of Beam in Feet											Approximate Depth of Beam	Length of Each Stirrup Bar	Total Number of U-Stirrups
	8	10	12	14	16	18	20	22	24	26	30	in.	in.	
1-Inch Round Steel Bars—$\frac{3}{8}$-Inch Stirrups														
1*	42	50	59	68	77	87	95	105	113	123	141	13	28	6
2†	71	84	98	112	127	141	155	169	183	198	226	17	39	6
3	99	118	137	156	176	195	214	233	252	272	310	21	48	12
4	132	158	184	210	235	261	287	313	338	364	415	24	56	12
5	169	201	233	265	297	329	361	394	425	458	522	27	62	16
6	205	243	281	320	358	397	435	474	512	551	628	29	68	16
7	247	292	337	382	426	471	516	561	606	651	741	31	72	22
8	295	346	397	448	500	551	602	653	704	756	858	33	80	22
9	342	392	449	505	565	622	679	737	794	853	968	36	89	28
10	387	438	501	562	630	693	756	821	884	950	1078	38	94	32
$1\frac{1}{8}$-Inch Round Steel Bars—$\frac{1}{2}$-Inch Stirrups														
1*	50	61	72	83	94	106	117	129	140	152	174	14	31	4
2†	89	107	124	142	161	178	195	213	231	249	285	19	44	4
3	128	152	176	200	225	249	273	297	322	346	395	24	54	8
4	170	203	236	268	301	333	366	398	431	463	528	27	63	8
5	225	265	305	346	386	427	467	508	548	589	670	30	70	12
6	270	319	368	416	465	514	562	611	659	708	805	33	76	12
7	327	384	441	498	554	611	668	725	782	838	952	35	83	16
8	385	450	515	580	644	709	774	839	904	970	1100	37	88	20
9	436	510	583	656	728	810	874	947	1020	1094	1241	40	99	20
10	487	570	651	732	812	907	974	1055	1136	1218	1382	42	109	24
$1\frac{1}{4}$-Inch Round Steel Bars—$\frac{1}{2}$-Inch Stirrups														
1*	61	76	90	104	118	132	146	160	181	188	216	16	35	6
2†	112	134	156	178	200	222	244	266	292	310	354	22	50	6
3	162	192	222	252	282	312	342	372	402	432	492	26	60	10
4	215	255	295	335	376	416	456	496	536	576	656	29	68	10
5	281	331	381	431	481	531	581	631	681	731	831	33	77	14
6	350	400	470	530	590	650	701	770	830	890	1010	36	85	14
7	419	489	559	629	700	770	840	910	980	1050	1190	39	92	20
8	489	569	649	729	809	889	969	1049	1129	1210	1370	40	98	24
9	554	640	734	824	914	1004	1094	1184	1274	1366	1546	45	110	24
10	619	711	819	919	1019	1119	1219	1319	1419	1522	1722	47	116	30

*Allows for an additional bar over supports, length $\frac{2}{5}$ of span.
†Allows for two additional bars over supports, length $\frac{2}{5}$ of span.

SQUARE BARS

For Times and Costs see Chapter XIX *For use of table see p. 535*

Weights include: extra steel required for bends in half the bars; allowance of 20% for lapping over supports; and weight of stirrups.

Total Number of Bars per Beam	Weight of Steel per Beam in Pounds — Length of Beam in Feet: 8	10	12	14	16	18	20	22	24	26	30	Approximate Depth of Beam in.	Length of Each Stirrup Bar in.	Total Number of U-Stirrups
½-Inch Square Steel Bars—¼-Inch Stirrups														
1*	16	19	22	25	27	30	33	36	39	42	48	7	15	4
2†	22	27	31	36	40	44	49	53	58	63	72	9	20	4
3	28	34	40	46	52	58	64	70	76	83	95	11	24	6
4	37	45	53	61	70	78	86	94	102	111	127	12	28	6
5	47	57	67	77	88	98	108	118	128	139	159	14	30	8
6	56	68	80	93	105	118	130	142	154	167	191	15	34	8
7	68	82	96	111	125	140	154	168	182	197	225	17	38	12
8	80	96	112	128	145	161	177	193	210	226	259	18	40	16
9	92	110	127	146	164	183	201	220	240	247	293	19	47	16
10	104	124	142	163	184	204	224	246	266	275	327	20	49	20
¾-Inch Square Steel Bars—¼-Inch Stirrups														
1*	36	42	48	55	61	68	74	80	87	93	106	10	23	8
2†	51	61	71	81	91	101	111	121	132	141	162	14	30	8
3	65	79	93	107	120	134	148	162	176	189	217	16	35	14
4	88	106	124	143	161	180	198	216	235	253	290	18	40	14
5	112	136	160	182	206	228	251	274	298	321	367	20	45	20
6	136	164	192	219	247	274	302	330	357	385	440	22	50	20
7	165	197	229	261	294	326	358	390	422	455	519	24	55	28
8	191	228	265	301	338	374	411	448	485	521	595	25	57	34
9	218	260	301	343	383	426	466	507	547	590	675	27	69	34
10	243	291	335	384	426	476	518	563	605	656	750	29	72	40
⅞-Inch Square Steel Bars—⅜-Inch Stirrups														
1*	40	49	58	66	75	83	92	101	110	118	136	11	24	4
2†	66	80	94	107	121	134	148	162	176	189	217	15	34	4
3	91	110	129	148	166	185	204	223	241	260	297	18	42	8
4	123	148	173	198	223	248	273	298	323	348	398	21	48	8
5	160	191	222	253	285	316	347	378	409	441	503	24	54	12
6	194	231	268	306	343	381	418	455	493	530	605	26	60	12
7	232	276	320	363	407	450	494	538	582	625	713	28	65	16
8	280	320	370	420	469	519	569	619	669	719	819	29	67	16
9	307	364	419	476	534	591	644	702	758	815	921	31	78	20
10	342	408	466	531	595	652	719	780	844	908	1020	34	82	24

*Allows for an additional bar over supports, length ⅖ of span.
†Allows for two additional bars over supports, length ⅖ of span.

—Continued

SQUARE BARS

Weights include: extra steel required for bends in half the bars; allowance of 20% for lapping over supports; and weight of stirrups.

Total Number of Bars per Beam	Weight of Steel per Beam in Pounds — Length of Beam in Feet											Approximate Depth of Beam	Length of Each Stirrup Bar	Total Number of U-Stirrups
	8	10	12	14	16	18	20	22	24	26	30	in.	in.	
1-Inch Square Steel Bars—$\frac{3}{8}$-Inch Stirrups														
1*	53	64	75	87	98	110	121	133	144	156	179	13	28	6
2†	89	107	125	143	161	180	197	215	233	201	287	17	39	6
3	125	150	175	199	224	249	273	297	322	346	395	21	48	12
4	168	201	234	267	299	332	365	398	430	463	528	24	56	12
5	216	256	298	339	380	421	462	504	544	586	665	27	62	16
6	260	309	358	407	456	505	554	603	652	701	799	29	68	16
7	315	372	429	486	543	600	657	714	771	829	943	31	72	22
8	375	440	505	571	636	702	767	832	897	963	1093	33	80	22
9	438	502	574	646	723	799	870	943	1016	1093	1240	36	89	28
10	496	560	642	719	806	887	968	1051	1132	1215	1380	38	94	32
$1\frac{1}{8}$-Inch Square Steel Bars—$\frac{1}{2}$-Inch Stirrups														
1*	63	77	91	106	120	135	149	164	178	193	222	14	31	4
2†	113	135	158	181	203	226	249	272	294	317	363	19	44	4
3	162	193	224	255	286	317	348	379	410	441	503	24	54	8
4	218	259	300	342	383	425	466	507	548	590	672	27	63	8
5	285	337	389	440	492	543	595	647	698	750	853	30	70	12
6	344	406	468	530	592	654	716	778	840	901	1025	33	76	12
7	417	489	561	633	706	779	850	922	995	1067	1212	35	83	16
8	490	573	656	738	821	903	986	1069	1152	1234	1400	37	88	20
9	558	653	746	840	932	1038	1118	1213	1305	1400	1588	40	99	20
10	623	730	833	937	1040	1161	1246	1350	1455	1559	1770	42	109	24
$1\frac{1}{4}$-Inch Square Steel Bars—$\frac{1}{2}$-Inch Stirrups														
1*	78	96	114	132	150	168	186	204	230	239	275	16	35	6
2†	142	170	198	226	255	283	311	339	371	395	451	22	50	6
3	206	244	282	320	359	397	435	473	511	550	626	26	60	10
4	274	325	376	427	478	529	580	631	682	733	835	29	68	10
5	357	421	485	549	612	676	740	804	867	931	1058	33	77	14
6	432	509	586	662	739	815	892	968	1045	1121	1274	36	85	14
7	534	623	712	801	891	980	1069	1158	1247	1337	1515	39	92	20
8	622	724	826	928	1030	1132	1234	1336	1438	1540	1744	40	98	24
9	709	819	940	1054	1170	1285	1400	1515	1630	1749	1980	45	110	24
10	792	910	1049	1176	1305	1432	1560	1687	1815	1948	2205	47	116	30

*Allows for an additional bar over supports, length $\frac{2}{5}$ of span.
†Allows for two additional bars over supports, length $\frac{2}{5}$ of span.

For Times and Costs see Chapter XIX *For use of table see p. 561*

10% Allowance has been made for lapping.

HORIZONTAL AND VERTICAL BARS SPACED EQUALLY

Thickness of Wall	$\frac{1}{4}$-Inch Bars			$\frac{3}{8}$-Inch Bars			$\frac{1}{2}$-Inch Bars			$\frac{5}{8}$-Inch Bars			$\frac{3}{4}$-Inch Bars		
	Spacing Each Way	Ratio of Cross Section of Steel to Wall in One Direction	Weight per 100 Sq. Ft. of Surface	Spacing Each Way	Ratio of Cross Section of Steel to Wall in One Direction	Weight per 100 Sq. Ft. of Surface	Spacing Each Way	Ratio of Cross Section of Steel to Wall in One Direction	Weight per 100 Sq. Ft. of Surface	Spacing Each Way	Ratio of Cross Section of Steel to Wall in One Direction	Weight per 100 Sq. Ft. of Surface	Spacing Each Way	Ratio of Cross Section of Steel to Wall in One Direction	Weight per 100 Sq. Ft. of Surface
in.	in.	p*	lb.	in.	p*	lb.	in.	p*	lb.	in.	p*	lb.	in.	p*	lb.
Square Bars.															
	12	0.0013	47	24	0.0015	52	24	0.0026	93	36	0.0027	97			
4	8	0.0020	70	12	0.0029	105	12	0.0052	186	24	0.0041	146			
	6	0.0026	93	8	0.0044	157	8	0.0078	280	12	0.0081	292			
	4	0.0039	140	6	0.0058	209	6	0.0104	373	8	0.0122	438			
	12	0.0009	47	24	0.0010	52	24	0.0017	93	36	0.0018	97			
6	8	0.0013	70	12	0.0020	105	12	0.0035	186	24	0.0027	146			
	6	0.0017	93	8	0.0029	157	8	0.0052	280	12	0.0054	292			
	4	0.0026	140	6	0.0039	209	6	0.0069	373	8	0.0081	438			
	12	0.0007	47	24	0.0007	52	24	0.0013	93	24	0.0020	146	36	0.0020	140
8	8	0.0010	70	12	0.0015	105	12	0.0026	186	12	0.0041	292	24	0.0029	210
	6	0.0013	93	8	0.0022	157	8	0.0039	280	8	0.0061	438	12	0.0059	420
	4	0.0020	140	6	0.0029	209	6	0.0052	373	6	0.0081	584	8	0.0088	630
				24	0.0006	52	24	0.0010	93	24	0.0016	146	36	0.0016	140
10				12	0.0012	105	12	0.0021	186	12	0.0033	292	24	0.0023	210
				8	0.0017	157	8	0.0031	280	8	0.0049	438	12	0.0047	420
				6	0.0023	209	6	0.0042	373	6	0.0065	584	8	0.0070	630
				24	0.0005	52	24	0.0009	93	24	0.0014	146	36	0.0013	140
12				12	0.0010	105	12	0.0017	186	12	0.0027	292	24	0.0020	210
				8	0.0015	157	8	0.0026	280	8	0.0041	438	12	0.0039	420
				6	0.0019	209	6	0.0035	373	6	0.0054	584	8	0.0059	630
Round Bars.															
	12	0.0010	37	24	0.0012	41	24	0.0020	74	36	0.0021	76			
4	8	0.0015	56	12	0.0023	81	12	0.0041	147	24	0.0032	114			
	6	0.0020	75	8	0.0034	122	8	0.0061	221	12	0.0064	229			
	4	0.0031	112	6	0.0046	163	6	0.0082	295	8	0.0096	343			
	12	0.0007	37	24	0.0008	41	24	0.0014	74	36	0.0014	76			
6	8	0.0010	56	12	0.0015	81	12	0.0027	147	24	0.0021	114			
	6	0.0014	75	8	0.0023	122	8	0.0040	221	12	0.0042	229			
	4	0.0020	112	6	0.0031	163	6	0.0054	295	8	0.0064	343			
	12	0.0005	37	24	0.0006	41	24	0.0010	74	24	0.0016	114	36	0.0015	110
8	8	0.0008	56	12	0.0011	81	12	0.0020	147	12	0.0032	229	24	0.0023	165
	6	0.0010	75	8	0.0017	122	8	0.0031	221	8	0.0048	343	12	0.0046	330
	4	0.0015	112	6	0.0023	163	6	0.0041	295	6	0.0064	458	8	0.0069	495
				24	0.0005	41	24	0.0008	74	24	0.0013	114	36	0.0012	110
10				12	0.0009	81	12	0.0016	147	12	0.0026	229	24	0.0018	165
				8	0.0014	122	8	0.0024	221	8	0.0038	343	12	0.0037	330
				6	0.0018	163	6	0.0033	295	6	0.0051	458	8	0.0055	495
				24	0.0004	41	24	0.0007	74	24	0.0011	114	36	0.0010	110
12				12	0.0008	81	12	0.0014	147	12	0.0021	229	24	0.0015	165
				8	0.0011	122	8	0.0020	221	8	0.0032	343	12	0.0031	330
				6	0.0015	163	6	0.0027	295	6	0.0042	458	8	0.0046	495

*Percentages of steel are values in this column multiplied by 100.

TABLE 90] WEIGHTS OF SLAB REINFORCEMENT [STEEL

For Times and Costs see Chapter XIX. *For use of table see p. 561.*

10% Allowance has been made for lapping.

$\frac{3}{8}$-inch bars, 24 inches apart included in weights for transverse steel.

No. of Panels per Bay	Size of Bars in Inches													
	$\frac{1}{4}''$	$\frac{3}{8}''$	$\frac{7}{16}''$	$\frac{1}{2}''$	$\frac{9}{16}''$	$\frac{5}{8}''$	$\frac{3}{4}''$	$\frac{1}{4}''$	$\frac{3}{8}''$	$\frac{7}{16}''$	$\frac{1}{2}''$	$\frac{9}{16}''$	$\frac{5}{8}''$	$\frac{3}{4}''$
Weight of Square Bars in Pounds per 100 Square Feet of Slab														
	Bars 4" C. to C. One Way							Bars 6" C. to C. One Way						
1	101	198	259	328	410	496	698	78	143	182	229	288	345	488
2	105	206	268	341	425	518	731	81	150	190	239	296	361	507
3	108	211	278	354	444	540	764	83	154	199	251	311	376	529
	Bars 8" C. to C. One Way							Bars 12" C. to C. One Way						
1	66	115	148	184	226	272	377	54	88	110	135	164	196	270
2	67	118	152	189	232	280	392	55	91	114	140	170	203	280
3	69	123	157	196	241	291	407	56	94	118	145	176	212	293
Weight of Round Bars in Pounds per 100 Square Feet of Slab														
	Bars 4" C. to C. One Way							Bars 6" C. to C. One Way						
1	88	160	210	266	327	396	561	68	117	151	189	232	275	390
2	91	165	217	275	341	412	582	71	121	156	196	241	288	404
3	93	171	225	286	355	428	605	73	125	163	204	251	300	420
	Bars 8" C. to C. One Way							Bars 12" C. to C. One Way						
1	58	95	121	150	181	218	296	50	75	92	112	135	160	218
2	60	98	125	155	189	225	312	51	77	96	117	141	165	227
3	61	100	129	160	195	233	324	52	79	99	121	146	171	235

Note—Weights increase with number of panels per bay because of extra bends.

Weights of Wall Reinforcement. Table 89. This table gives weights of steel for different thicknesses of walls and the spacing of bars of different sizes for various ratios, or percentages, of reinforcement. For example, an 8-inch wall, having $\frac{3}{8}$-inch square bars spaced 12 inches apart each way will require 106 pounds of steel per square foot of wall surface. The ratio of steel in this case will be 0.0015 (0.15%).

Weights of Slab Reinforcement. Table 90. Weights per 100 square feet of floor surface are given for different spacings and diameters of bars. The quantity of steel increases slightly with the number of bends. To prevent shrinkage cracks, transverse reinforcement is usually provided and, to approximate average conditions, allowance is made therefore for $\frac{3}{8}$-inch bars spaced 24 inches apart.

CHAPTER XIX

TABLES OF TIMES AND COSTS BENDING AND PLACING STEEL

The labor of bending and placing reinforcement is considered most often in terms of the cost per pound or per ton of steel. Although, as indicated below, a lump price per pound is sometimes best to use, it is ordinarily inaccurate because the labor varies so greatly with the size of the bar, the amount of bending required, the number of stirrups or hoops, and other conditions governed by the design.

The tables presented in this chapter give the times and costs of bending and placing steel of various sizes under the different conditions occurring in ordinary practice. The values given for average men are based upon average conditions and those given for quick men are based on very good men working hard under exceptionally competent supervision, but not by the piece or task.

METHODS AND TOOLS USED IN BENDING AND PLACING STEEL REINFORCEMENT

The methods employed in bending reinforcing bars and the types of machines used vary according to the diameter and length of the bars. Personal preference of the steel foreman seems to play a more important part in this department of construction work than in any of the others for this is generally left entirely to his discretion. A type of machine used for bending heavy bars and for short bends is shown in Fig. 74, page 563.

Some foremen prefer to bend all reinforcing bars by using a heavy pipe slipped on over the bar and making the bends either around heavy bars placed in the table, as shown on the left end of table in Fig. 75, page 564, or by using angles as shown in the right end of the same table.

A tool for bending slab reinforcing bars in place on the floor is shown in Fig. 46, page 484.

Reinforcing bars can generally be bought to exact length but on every job more or less cutting must be done by hand. A useful machine for cutting bars by hand is illustrated in Fig. 76, page 565.

ESTIMATING APPROXIMATE COST OF LABOR PER POUND OF STEEL

Frequently when an estimate is wanted at once, time is too limited to make detail computations of labor costs.

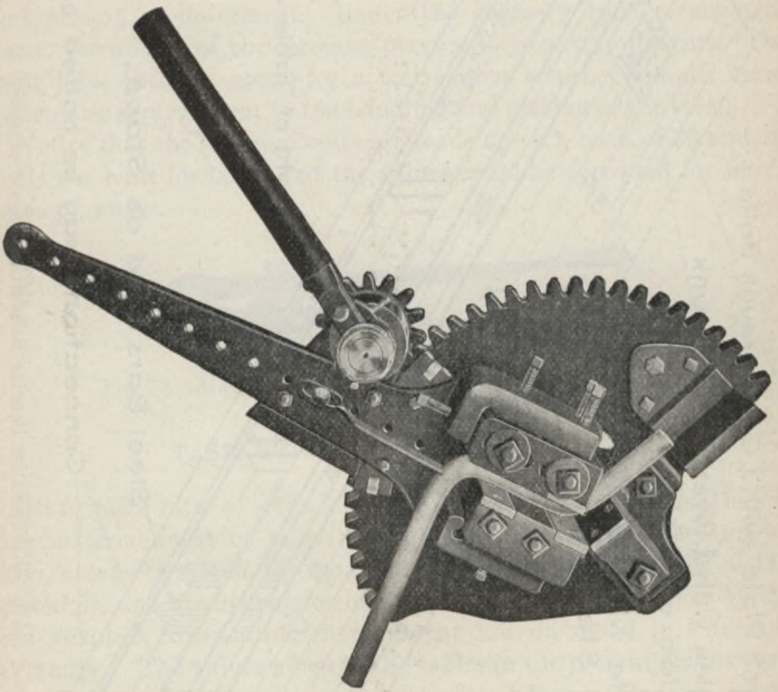


FIG. 74. Machine for Bending Reinforcing Bars (See p. 562)

In such cases, an approximate price per pound or per ton must be chosen and reference may be made to Table 6 in Chapter I. Though this table gives a range in prices, it covers only a portion of the field of reinforced concrete design so that, to make even a fair guess, records of costs are necessary on other structures of substantially the same design. Careful allowances must then be made by judgment for differences in conditions and also in rates of wages.

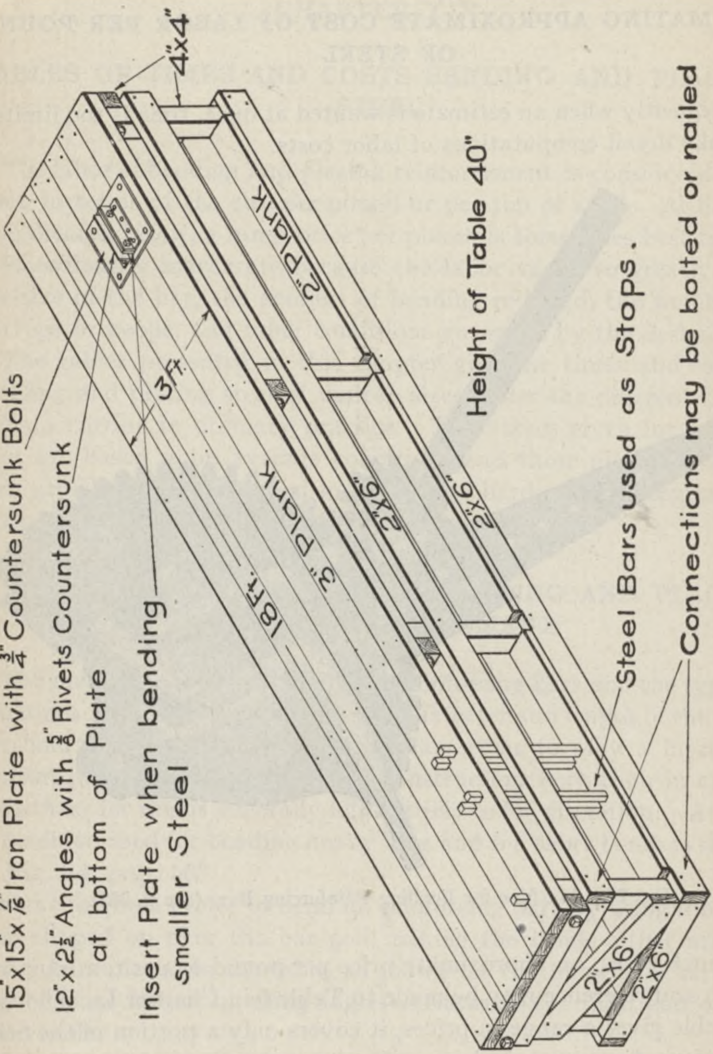


FIG. 75. Table for Bending Reinforcing Bars (See p. 562)

WAGES OF STEEL WORKERS

The wages of workmen bending and placing reinforcement vary more than on almost any other kind of construction work. The rate that must be paid per day on any given job should therefore be found out in advance. Sometimes structural steel men are employed and sometimes laborers although the so-called skilled workman may not accomplish any more work in a day than the lower priced man after he is well broken in. Carpenters also make good men for bending and placing reinforcement. Under the ordinary type of management, the ability of the foreman plays a large part in the cost. On most jobs, there is room for a tremendous advance toward more systematic arrangement in the handling and placing of the steel.

Notice that the tables of costs are made up on a basis of 30 and 10 cents per hour for labor and the values must be corrected for other rates of wages.

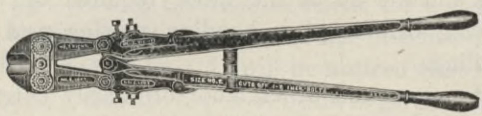


FIG. 76. Machine for Cutting Reinforcing Bars (See p. 563)

TASK-WORK. TIMES AND COSTS

To fix piece-rates or set tasks for steel workers, the methods of handling material must be taken into account and time studies made. Also, a definite system for the layout of the work, the routing of the materials, and the instruction of the men must be introduced. Methods adapted to scientific management are discussed in Chapters IV and V. The values given in the tables in the present chapter are valuable when fixing tasks, for comparing different kinds of work, and checking the ratios of one kind of work to another.

HOW TO USE TABLES OF BENDING AND PLACING STEEL

To use the tables of labor of reinforcement, the quantities of steel in the structure should be taken off in a manner similar to that shown in the estimate sheet on folding page 693. Having made out the schedule, the times or the costs, whichever are required, are taken for each member directly from the tables in the present chapter.

"Times of Labor" are given usually on left hand pages and "Costs of Labor" on right hand pages. For ordinary estimates, where the conditions correspond substantially to those outlined on page 562, the values in the cost tables are recommended. Even if the percentages for overhead charges, etc., are different from those assumed, the cost tables can be used by multiplying the values by a definite ratio to fit the case under consideration. Where special conditions must be taken into account, the tables of times should be used and the results reduced to costs, introducing the proper allowances as indicated below.

TABLES OF LABOR ON REINFORCEMENT

Times and costs per member for bending and placing steel under average conditions met with in ordinary practice are given in Tables 91 to 122. The times and the costs have been figured for square bars but will apply with sufficient accuracy to round bars of the given diameter.

The values include all of the labor required on ordinary jobs, such as carrying bars to piles, bending, placing, and the incidental work of handling.

The steel foreman and other labor ordinarily entered in the job time book are included in both times and costs. The times and costs also include due allowance for the rests and unavoidable delays occurring throughout the day.

The costs (but not the times) include an allowance of 15% for superintendence, overhead charges, etc., made up as follows:

Superintendence and job office expenses	9%
Contingencies chargeable to labor	3%
Liability insurance on employees and public	3%
Total	15%

The costs (but not the times) also include an additional 15% that has been added to allow for the excessive delays that usually occur in placing reinforcement through lack of proper supervision and organization. If the jobs are well managed, this may be deducted from the cost, or else the time values may be used without this extra allowance. The times therefore apply to fairly well organized but not scientifically managed work.

If the builders are inexperienced add 50% to allow for delays and inefficient work.

TO USE TABLES REFER TO FOLDING PAGE AS INDICATED

Column Reinforcement, Tables 91 to 94. The times and costs are given per member, so that, knowing the number of columns, their length, and the reinforcing bars in each, the labor can be figured at once.

Tables are given for two conditions, (1) where the steel is made up on horses and then placed as a unit and (2) where the bars are assembled in place, that is, set up individually and wired together there.

Beam and Girder Reinforcement, Tables 95 to 118. Pages 572 to 595. As in columns, there are two methods of assembling and placing beam and girder reinforcement. The first method, in which the steel is assembled on horses, wired, and then placed as a single unit, is preferred by many people to the second method, that of assembling the steel in place. The times and costs are given in the tables for both of these methods. The times or costs of labor for assembling and placing the reinforcement for a beam or girder of given length and specified number and size of tension bars can be taken directly from the tables. It will be noticed that for each layout of tension bars, a definite depth of beam is given and the corresponding necessary length and number of stirrups. The approximate depths of T-beams have been figured for an area of steel half way between the areas of round bars and square bars of the given size and number. The methods of computing the depths of beams and the stirrups are referred to on page 535.

Slab Reinforcement, Tables 119 to 121. The labor on slab reinforcement varies so much with the number of bends in the bars that several groups are given, each applying to a special condition. The column spacing provides for panels from 10 feet square to 30 feet square. One panel per bay means that there is a single square or oblong panel, corresponding to the column spacing, and surrounded by beams and girders. In this type, the slab bars have two double bends, i.e., four single bends. With two panels per bay, the bars have eight single bends and with three panels per bay they have twelve single bends.

Wall Reinforcement, Table 122. Page 599. The use of this table is evident from inspection.

Carrying Steel, Tables 123 and 124. A great deal of time is wasted by workmen in carrying small loads of steel bars. To indicate how large a load can be readily carried by an average man working by the day, the number of bars per load, their weight, and the number of men to carry each load are given. This is based on a load of not more than 60 pounds per man. First-class men working by the piece or task can exceed this, running up to say, 80 pounds per man.

These tables are convenient also for showing the weights of bars of different sizes and lengths.

Basis of Tables. The steel tables are figured upon the following basis, which is in accordance with the practice of the best contractors. For some of the conditions, see also folding page 605.

Column Reinforcement:

Hoop spacing, 12-inch centers.

Ten per cent extra allowed for lapping of bars or, in case sleeves are used, to cover the cost of the sleeves.

Beam Reinforcement:

Twenty per cent extra allowed for lapping of bars. This provides for lapping one-half of the bent bars one-fifth of the span at each end so as to give as much steel over the supports as in the middle, which is good design.

For length of stirrups, the ratio of depth of beam plus slab is taken as $2\frac{1}{2}$ times the width of the beam.

Slab Reinforcement:

Ten per cent extra allowed for lapping of bars.

Transverse steel, $\frac{3}{8}$-inch bars 2 feet apart, or $\frac{1}{2}$-inch bars 3 feet apart.

Wire every third bar to transverse steel, if the spacing is 2 feet or wire every other bar if the spacing is 3 feet.

Wall Reinforcement:

Ten per cent extra allowed for lapping of bars or waste due to cutting.

Wire every connection between horizontal and vertical bars.

EXAMPLES OF USE OF TABLES BENDING AND PLACING STEEL

The use of the tables is shown in the form of estimate, folding page 693, and is illustrated by the following examples.

Column Steel. *Example 1:* What is the average cost with labor at 25 cents per hour, of bending and placing, in a 24-inch column, 12 feet long, four 1-inch bars having $\frac{5}{16}$-inch hoops, 12 inches center to center, the bars being assembled on horses then placed?

Solution: From Table 92, page 570, the cost of bending and placing the reinforcement at 10 cents per hour is \$0.261 and at 25 cents per hour is therefore 2.5 × \$0.261 = \$0.653.

Example 2: What would be the average cost of labor in Example 1 in a well organized, but not scientifically managed, job where the allowance for superintendence, overhead charges, etc. is taken as 10%, this value having been found on a previous job under similar conditions, instead of 15% as used in Table 92?

Solution: At 25 cents per hour, the rate of labor per minute is \$0.00417. Add 10% for superintendence, overhead charges, etc., and we have \$0.00459 per minute. Find total time from Table 91 as 118 minutes and obtain total cost per column of \$0.542.

This could have been found directly from the cost in Example 1 by first taking away 15% from the cost there given, to allow for the well managed work (see p. 566), and then taking a ratio of 1.10 to 1.15 to change from the 15% to the 10% overhead charges. We would then have $\$0.653 \div 1.15 \times \frac{1.10}{1.15} = \$0.543$, which checks with the result obtained from Time Table 91.

Beam Steel. *Example 3:* For twelve beams, 20 feet long between centers of columns, what is the cost, for average men with wages at 30 cents per hour, of bending and placing reinforcement consisting of two $\frac{7}{8}$-inch straight bars, and two $\frac{7}{8}$-inch bars bent and lapped over girder or column at each end, where the reinforcement including stirrups is assembled on horses, then placed?

Solution: From Table 100, page 577, the cost of labor for one beam with above reinforcement is \$0.744 and for twelve beams is \$0.744 × 12 = \$8.928.

Example 4: For ordinary design based on the Joint Committee recommendations, how many $\frac{3}{8}$-inch stirrups will be required in each beam in Example 3?

Solution: From Table 100, page 577, the number of $\frac{3}{8}$-inch stirrups is given as 8.

Example 5: If $\frac{7}{16}$-inch stirrups are used in Example 3, how many will be required and how spaced?

Solution: The number of stirrups is inversely proportional to their cross sections, hence the number required will be $\frac{0.14 \times 8}{0.19} =$ 6 or 3 at each end. The spacing is determined from Table 9b in Taylor and Thompson's "Concrete Plain and Reinforced," second

(Continued on page 604)

BEFORE USING THESE TABLES, OPEN FOLDING PAGE 605

TABLE 91] LABOR ON COLUMN REINFORCEMENT [TIMES

ASSEMBLED ON HORSES, THEN PLACED

For Costs see table below *See p. 566*

Size of Bars	Size of Hoops* 12 Inches c. to c.	Time in Minutes per Column											
		Average Men						Quick Men					
		4 Bars			8 Bars			4 Bars			8 Bars		
in.	in.	6 ft. min.	12 ft. min.	18 ft. min.	6 ft. min.	12 ft. min.	18 ft. min.	6 ft. min.	12 ft. min.	18 ft. min.	6 ft. min.	12 ft. min.	18 ft. min.
$\frac{1}{2}$	$\frac{3}{16}$	45	79	120	71	125	186	30	53	80	47	83	124
$\frac{3}{4}$	$\frac{1}{4}$	49	95	140	79	149	220	33	63	93	53	99	147
$\frac{7}{8}$	$\frac{5}{16}$	59	109	160	91	173	249	39	73	107	61	115	166
1	$\frac{5}{16}$	62	118	180	100	188	276	41	79	120	67	125	184
$1\frac{1}{8}$	$\frac{3}{8}$	68	129	194	110	208	306	45	86	129	73	139	204
$1\frac{1}{4}$	$\frac{3}{8}$	73	139	208	120	228	336	49	93	139	80	152	224
$1\frac{3}{8}$	$\frac{3}{8}$	79	151	224	132	251	369	53	101	149	88	167	246
$1\frac{1}{2}$	$\frac{3}{8}$	84	163	240	144	273	401	56	109	160	96	182	267

TABLE 92] LABOR ON COLUMN REINFORCEMENT [COSTS

ASSEMBLED ON HORSES, THEN PLACED

Size of Bars	Size of Hoops* 12 Inches c. to c.	Cost in Dollars per Column											
		Average Men						Quick Men					
		4 Bars			8 Bars			4 Bars			8 Bars		
in.	in.	6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $
LABOR AT 30¢ PER HOUR													
$\frac{1}{2}$	$\frac{3}{16}$	0.297	0.525	0.795	0.468	0.828	1.233	0.198	0.351	0.528	0.315	0.549	0.822
$\frac{3}{4}$	$\frac{1}{4}$	0.327	0.627	0.927	0.525	0.984	1.458	0.219	0.417	0.615	0.351	0.657	0.975
$\frac{7}{8}$	$\frac{5}{16}$	0.390	0.723	1.062	0.603	1.146	1.650	0.258	0.486	0.708	0.405	0.762	1.101
1	$\frac{5}{16}$	0.411	0.783	1.194	0.663	1.245	1.827	0.270	0.525	0.795	0.444	0.828	1.221
$1\frac{1}{8}$	$\frac{3}{8}$	0.450	0.855	1.284	0.726	1.380	2.028	0.297	0.570	0.855	0.486	0.951	1.353
$1\frac{1}{4}$	$\frac{3}{8}$	0.486	0.921	1.380	0.795	1.509	2.226	0.327	0.615	0.921	0.528	1.005	1.482
$1\frac{3}{8}$	$\frac{3}{8}$	0.525	1.002	1.482	0.873	1.662	2.445	0.351	0.663	0.987	0.495	1.134	1.629
$1\frac{1}{2}$	$\frac{3}{8}$	0.558	1.080	1.590	0.954	1.809	2.655	0.369	0.723	1.062	0.636	1.206	1.770
LABOR AT 10¢ PER HOUR													
$\frac{1}{2}$	$\frac{3}{16}$	0.099	0.175	0.265	0.156	0.276	0.411	0.066	0.117	0.176	0.105	0.183	0.274
$\frac{3}{4}$	$\frac{1}{4}$	0.109	0.209	0.309	0.175	0.328	0.486	0.073	0.139	0.205	0.117	0.219	0.328
$\frac{7}{8}$	$\frac{5}{16}$	0.130	0.241	0.354	0.201	0.382	0.550	0.086	0.162	0.236	0.135	0.254	0.367
1	$\frac{5}{16}$	0.137	0.261	0.398	0.221	0.415	0.609	0.090	0.175	0.265	0.148	0.276	0.407
$1\frac{1}{8}$	$\frac{3}{8}$	0.150	0.285	0.428	0.242	0.460	0.676	0.099	0.190	0.285	0.162	0.317	0.451
$1\frac{1}{4}$	$\frac{3}{8}$	0.162	0.307	0.460	0.265	0.503	0.742	0.109	0.205	0.307	0.176	0.335	0.494
$1\frac{3}{8}$	$\frac{3}{8}$	0.175	0.334	0.494	0.291	0.554	0.815	0.117	0.221	0.329	0.195	0.378	0.543
$1\frac{1}{2}$	$\frac{3}{8}$	0.186	0.360	0.530	0.318	0.603	0.885	0.123	0.241	0.354	0.212	0.402	0.590

*If hoops are $\frac{1}{16}''$ smaller. deduct 5% from times and costs; if $\frac{1}{16}''$ larger, add 5%.

BEFORE USING THESE TABLES, OPEN FOLDING PAGE 605

TABLE 93] LABOR ON COLUMN REINFORCEMENT [TIMES

ASSEMBLED IN PLACE

For Costs see table below *See p. 566*

Size of Bars	Size of Hoops* 12 Inches c. to c.	Time in Minutes per Column											
		Average Men						Quick Men					
		4 Bars			8 Bars			4 Bars			8 Bars		
in.	in.	6 ft. min.	12 ft. min.	18 ft. min.	6 ft. min.	12 ft. min.	18 ft. min.	6 ft. min.	12 ft. min.	18 ft. min.	6 ft. min.	12 ft. min.	18 ft. min.
$\frac{1}{2}$	$\frac{3}{16}$	55	103	154	82	150	220	37	69	103	55	100	147
$\frac{3}{4}$	$\frac{1}{4}$	62	117	173	94	175	257	41	78	115	63	117	171
$\frac{7}{8}$	$\frac{5}{16}$	70	132	196	103	196	289	47	88	131	69	131	193
1	$\frac{5}{16}$	72	138	206	110	208	307	48	92	137	73	139	205
$1\frac{1}{8}$	$\frac{3}{8}$	78	150	223	119	227	336	52	100	149	79	151	224
$1\frac{1}{4}$	$\frac{3}{8}$	84	161	240	127	245	365	56	107	160	85	163	243
$1\frac{3}{8}$	$\frac{3}{8}$	88	170	254	138	263	393	59	113	169	92	175	262
$1\frac{1}{2}$	$\frac{3}{8}$	92	179	267	149	280	420	61	119	178	99	187	280

TABLE 94] LABOR ON COLUMN REINFORCEMENT [COSTS

ASSEMBLED IN PLACE

Size of Bars	Size of Hoops* 12 Inches c. to c.	Cost in Dollars per Column											
		Average Men						Quick Men					
		4 Bars			8 Bars			4 Bars			8 Bars		
in.	in.	6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $
LABOR AT 30¢ PER HOUR													
$\frac{1}{2}$	$\frac{3}{16}$	0.366	0.684	1.020	0.543	0.996	1.458	0.246	0.459	0.684	0.366	0.663	0.975
$\frac{3}{4}$	$\frac{1}{4}$	0.411	0.777	1.155	0.624	1.151	1.704	0.273	0.516	0.762	0.417	0.777	1.134
$\frac{7}{8}$	$\frac{5}{16}$	0.465	0.876	1.299	0.684	1.299	1.914	0.312	0.585	0.870	0.459	0.867	1.281
1	$\frac{5}{16}$	0.477	0.915	1.365	0.729	1.380	2.034	0.318	0.612	0.918	0.483	0.921	1.359
$1\frac{1}{8}$	$\frac{3}{8}$	0.516	0.993	1.476	0.789	1.506	2.126	0.345	0.662	0.987	0.525	1.002	1.485
$1\frac{1}{4}$	$\frac{3}{8}$	0.558	1.068	1.590	0.843	1.626	2.418	0.372	0.711	1.062	0.564	1.080	1.611
$1\frac{3}{8}$	$\frac{3}{8}$	0.585	1.128	1.653	0.915	1.743	2.604	0.390	0.750	1.119	0.609	1.161	1.737
$1\frac{1}{2}$	$\frac{3}{8}$	0.609	1.188	1.770	0.987	1.854	2.781	0.405	0.789	1.179	0.657	1.236	1.857
LABOR AT 10¢ PER HOUR													
$\frac{1}{2}$	$\frac{3}{16}$	0.122	0.228	0.340	0.181	0.332	0.486	0.082	0.153	0.228	0.122	0.221	0.325
$\frac{3}{4}$	$\frac{1}{4}$	0.137	0.259	0.385	0.208	0.387	0.568	0.091	0.172	0.254	0.139	0.259	0.378
$\frac{7}{8}$	$\frac{5}{16}$	0.155	0.292	0.433	0.228	0.433	0.638	0.104	0.195	0.290	0.153	0.289	0.427
1	$\frac{5}{16}$	0.159	0.305	0.455	0.243	0.460	0.678	0.106	0.204	0.306	0.161	0.307	0.453
$1\frac{1}{8}$	$\frac{3}{8}$	0.172	0.331	0.492	0.263	0.502	0.742	0.115	0.221	0.329	0.175	0.334	0.495
$1\frac{1}{4}$	$\frac{3}{8}$	0.186	0.356	0.530	0.281	0.542	0.806	0.124	0.237	0.354	0.188	0.360	0.537
$1\frac{3}{8}$	$\frac{3}{8}$	0.195	0.376	0.551	0.305	0.581	0.868	0.130	0.250	0.373	0.203	0.387	0.579
$1\frac{1}{2}$	$\frac{3}{8}$	0.203	0.396	0.590	0.329	0.618	0.927	0.135	0.263	0.393	0.219	0.412	0.619

*If hoops are $\frac{1}{16}''$ smaller, deduct 5% from times and costs; if $\frac{1}{16}''$ larger, add 5%.

TABLE 95] LABOR ON BEAM REINFORCEMENT [TIMES
ASSEMBLED ON HORSES, THEN PLACED

For Costs see opposite page *See p. 566*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

Times based on average workmen and well organized work. They include delays occurring throughout the day (see p. 566).

For ordinary work add 15% to times; with inexperienced builders add 50%.

Column spacings of 10 ft., 20 ft. and 30 ft. are from center to center of columns.

Times include allowance for foremen, sub-foremen, etc. (see p. 566) but do not include superintendence, contingencies, liability insurance, profit, or home-office expense.

Costs on opposite page include all allowances except profit and home-office expense.

½-Inch Steel Bars—¼-Inch Stirrups

Number of Bars per Beam				Time in Minutes per Beam						Approximate Depth of Beam	Length of Each Stirrup Bar	Total Number of U-Stirrups
				Average Men			Quick Men					
				Column Spacing c.c.			Column Spacing c.c.					
Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	10 ft. min.	20 ft. min.	30 ft. min.	10 ft. min.	20 ft. min.	30 ft. min.	in.	in.	
3	2	1		37	54	60	25	36	40	11	24	6
3	1	2		35	46	54	23	31	36	11	24	4
3	1	1	1	35	41	42	23	27	28	11	24	4
4	2	2		47	61	70	31	41	47	12	28	6
4	2	1	1	47	60	68	31	40	45	12	28	6
5	3	2		60	77	86	40	52	57	14	30	8
5	2	3		55	74	85	37	49	57	14	30	6
5	2	2	1	55	73	84	37	49	56	14	30	6
6	3	3		68	90	102	45	60	68	15	34	8
6	3	2	1	67	89	101	45	59	67	15	34	8
6	2	3	1	63	85	97	42	57	65	15	34	6
7	4	3		86	101	125	57	67	83	17	38	12
7	4	2	1	86	100	124	57	73	83	17	38	12
7	2	3	2	72	98	112	48	65	75	17	38	6
8	5	3		105	132	149	70	88	99	18	40	16
8	4	4		95	121	140	63	81	93	18	40	12
8	4	2	2	94	113	137	63	75	91	18	40	12
9	5	4		116	144	160	77	96	107	19	47	16
9	5	2	2	114	142	157	76	95	105	19	47	16
9	4	4	1	105	133	151	70	89	101	19	47	12
10	6	2	2	132	161	180	88	107	120	20	49	20
10	5	3	2	120	150	167	80	100	111	20	49	16
10	4	5	1	116	144	166	77	96	111	20	49	12

TABLE 96] LABOR ON BEAM REINFORCEMENT [COSTS
ASSEMBLED ON HORSES, THEN PLACED

For Times see opposite page *See pp. 566 and 572*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

$\frac{1}{2}$-Inch Steel Bars—$\frac{1}{4}$-Inch Stirrups.

Number of Bars per Beam: Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	Cost in Dollars per Beam: Average Men, Column Spacing c.c. 10 ft. $	20 ft. $	30 ft. $	Quick Men, Column Spacing c.c. 10 ft. $	20 ft. $	30 ft. $	Approximate Depth of Beam in.	Length of Each Stirrup Bar in.	Total Number of U-Stirrups
LABOR AT 30¢ PER HOUR												
3	2	1		0.246	0.357	0.396	0.165	0.237	0.264	11	24	6
3	1	2		0.201	0.303	0.357	0.135	0.201	0.237	11	24	4
4	2	2		0.309	0.396	0.456	0.207	0.264	0.303	12	28	6
5	3	2		0.441	0.510	0.567	0.294	0.339	0.378	14	30	8
6	3	3		0.450	0.594	0.672	0.300	0.396	0.447	15	34	8
7	4	3		0.570	0.669	0.828	0.381	0.447	0.552	17	38	12
8	5	3		0.678	0.870	0.984	0.453	0.579	0.654	18	40	16
8	4	4		0.621	0.774	0.912	0.414	0.516	0.609	18	40	12
9	5	4		0.759	0.945	1.044	0.504	0.630	0.696	19	47	16
10	6	2	2	0.870	1.062	1.188	0.579	0.718	0.792	20	49	20
10	5	3	2	0.792	0.990	1.104	0.528	0.660	0.735	20	49	16
LABOR AT 10¢ PER HOUR												
3	2	1		0.082	0.119	0.132	0.055	0.079	0.088	11	24	6
3	1	2		0.067	0.101	0.119	0.045	0.067	0.079	11	24	4
3	1	1	1	0.067	0.091	0.092	0.045	0.061	0.061	11	24	4
4	2	2		0.103	0.132	0.152	0.069	0.088	0.101	12	28	6
5	3	2		0.147	0.170	0.189	0.098	0.113	0.126	14	30	8
5	2	3		0.121	0.163	0.186	0.081	0.109	0.124	14	30	6
6	3	3		0.150	0.198	0.224	0.100	0.132	0.149	15	34	8
6	2	3	1	0.138	0.187	0.214	0.092	0.125	0.142	15	34	6
7	4	3		0.190	0.223	0.276	0.127	0.149	0.184	17	38	12
7	2	3	2	0.159	0.216	0.247	0.106	0.144	0.165	17	38	6
8	5	3		0.226	0.290	0.328	0.151	0.193	0.218	18	40	16
8	4	4		0.207	0.258	0.304	0.138	0.172	0.203	18	40	12
9	5	4		0.253	0.315	0.348	0.168	0.210	0.232	19	47	16
9	4	4	1	0.231	0.293	0.332	0.154	0.195	0.221	19	47	12
10	6	2	2	0.290	0.354	0.396	0.193	0.236	0.264	20	49	20
10	5	3	2	0.264	0.330	0.368	0.176	0.220	0.245	20	49	16
10	4	5	1	0.255	0.317	0.365	0.170	0.211	0.243	20	49	12

TABLE 97] LABOR ON BEAM REINFORCEMENT [TIMES

ASSEMBLED ON HORSES, THEN PLACED

For Costs see opposite page *See p. 566*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

Times based on average workmen and well organized work. They include delays occurring throughout the day (see p. 566).

For ordinary work add 15% to times, with inexperienced builders add 50%.

Column spacings of 10 ft., 20 ft. and 30 ft. are from center to center of columns.

Times include allowance for foremen, sub-foremen, etc. (see p. 566) but do not include superintendence, contingencies, liability insurance, profit, or home-office expense.

Costs on opposite page include all allowances except profit and home-office expense.

$\frac{3}{4}$-Inch Steel Bars—$\frac{1}{4}$-Inch Stirrups

Number of Bars per Beam				Time in Minutes per Beam						Approximate Depth of Beam	Length of Each Stirrup Bar	Total Number of U-Stirrups
				Average Men			Quick Men					
				Column Spacing c.c.			Column Spacing c.c.					
Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	10 ft. min.	20 ft. min.	30 ft. min.	10 ft. min.	20 ft. min.	30 ft. min.	in.	in.	
3	2	1		75	97	107	50	65	71	16	35	14
3	1	2		62	78	94	41	52	63	16	35	8
3	1	1	1	59	77	94	39	51	63	16	35	8
4	2	2		90	112	132	60	75	88	18	40	14
4	2	1	1	88	110	131	59	73	87	18	40	14
5	3	2		116	145	170	77	97	113	20	45	20
5	2	3		103	131	157	69	87	105	20	45	14
5	2	2	1	102	130	155	68	87	103	20	45	14
6	3	3		131	166	198	87	111	132	22	50	20
6	3	2	1	130	163	196	87	108	131	22	50	20
6	2	3	1	119	149	182	79	99	121	22	50	14
7	4	3		166	205	242	111	137	161	24	55	28
7	4	2	1	165	203	240	110	137	160	24	55	28
7	2	3	2	127	168	207	85	112	138	24	55	14
8	5	3		195	239	280	130	159	187	25	57	34
8	4	4		180	225	268	120	150	179	25	57	28
8	4	2	2	178	221	253	119	147	169	25	57	28
9	5	4		204	253	299	136	169	199	27	69	34
9	5	2	2	202	250	295	135	167	197	27	69	34
9	4	4	1	188	239	287	125	159	191	27	69	28
10	6	2	2	230	284	333	153	189	222	29	72	40
10	5	3	2	215	268	320	143	179	214	29	72	34
10	4	5	1	202	260	312	135	173	208	29	72	28

TABLE 98] LABOR ON BEAM REINFORCEMENT [COSTS

ASSEMBLED ON HORSES, THEN PLACED

For Times see opposite page *See pp. 556 and 574*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

$\frac{3}{4}$-Inch Steel Bars—$\frac{1}{4}$-Inch Stirrups

Number of Bars per Beam				Cost in Dollars per Beam						Approximate Depth of Beam	Length of Each Stirrup Bar	Total Number of U-Stirrups
				Average Men			Quick Men					
				Column Spacing c.c.			Column Spacing c.c.					
Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $	in.	in.	
LABOR AT 30¢ PER HOUR												
3	2	1		0.495	0.642	0.705	0.330	0.429	0.468	16	35	14
3	1	2		0.408	0.516	0.621	0.273	0.445	0.414	16	35	8
4	2	2		0.594	0.738	0.870	0.396	0.492	0.579	18	40	14
5	3	2		0.765	0.960	1.125	0.510	0.639	0.750	20	45	20
6	3	3		0.864	1.095	1.311	0.576	0.729	0.876	22	50	20
7	4	3		1.098	1.356	1.599	0.732	0.906	1.062	24	55	28
8	5	3		1.290	1.581	1.851	0.858	1.056	1.236	25	57	34
8	4	4		1.188	1.485	1.770	0.792	0.990	1.182	25	57	28
9	5	4		1.350	1.671	1.974	0.900	1.116	1.341	27	69	34
10	6	2	2	1.521	1.875	2.199	1.014	1.251	1.464	29	72	40
10	5	3	2	1.422	1.770	2.115	0.948	1.179	1.410	29	72	34
LABOR AT 10¢ PER HOUR												
3	2	1		0.165	0.214	0.235	0.110	0.143	0.156	16	35	14
3	1	2		0.136	0.172	0.207	0.091	0.115	0.138	16	35	8
3	1	1	1	0.130	0.169	0.207	0.087	0.113	0.138	16	35	8
4	2	2		0.198	0.246	0.290	0.132	0.164	0.193	18	40	14
5	3	2		0.255	0.320	0.375	0.170	0.213	0.250	20	45	20
5	2	3		0.226	0.288	0.345	0.151	0.192	0.230	20	45	14
6	3	3		0.288	0.365	0.437	0.192	0.243	0.292	22	50	20
6	2	3	1	0.262	0.328	0.400	0.175	0.218	0.266	22	50	14
7	4	3		0.366	0.452	0.533	0.244	0.302	0.354	24	55	28
7	2	3	2	0.280	0.370	0.456	0.187	0.247	0.304	24	55	14
8	5	3		0.430	0.527	0.617	0.286	0.352	0.412	25	57	34
8	4	4		0.396	0.495	0.590	0.264	0.330	0.394	25	57	28
9	5	4		0.450	0.557	0.658	0.300	0.372	0.437	27	69	34
9	4	4	1	0.414	0.527	0.632	0.276	0.352	0.422	27	69	28
10	6	2	2	0.507	0.625	0.733	0.338	0.417	0.488	29	72	40
10	5	3	2	0.474	0.590	0.705	0.316	0.393	0.470	29	72	34
10	4	5	1	0.445	0.573	0.687	0.297	0.382	0.457	29	72	28

TABLE 99] LABOR ON BEAM REINFORCEMENT [TIMES

ASSEMBLED ON HORSES, THEN PLACED

For Costs see opposite page *See p. 566*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

Times based on average workmen and well organized work. They include delays occurring throughout the day (see p. 566).

For ordinary work add 15% to times, with inexperienced builders add 50%.

Column spacings of 10 ft., 20 ft. and 30 ft. are from center to center of columns.

Times include allowance for foremen, sub-foremen, etc. (see p. 566) but do not include superintendence, contingencies, liability insurance, profit, or home-office expense.

Costs on opposite page include all allowances except profit and home-office expense.

$\frac{7}{8}$-Inch Steel Bars—$\frac{3}{8}$-Inch Stirrups

Number of Bars per Beam				Time in Minutes per Beam						Approximate Depth of Beam	Length of Each Stirrup Bar	Total Number of U-Stirrups
				Average Men			Quick Men					
				Column Spacing c.c.			Column Spacing c.c.					
Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	10 ft. min.	20 ft. min.	30 ft. min.	10 ft. min.	20 ft. min.	30 ft. min.	in.	in.	
3	2	1		65	89	109	43	59	73	18	42	8
3	1	2		56	80	103	37	53	69	18	42	4
3	1	1	1	54	78	100	36	52	67	18	42	4
4	2	2		81	113	142	54	75	95	21	48	8
4	2	1	1	79	110	135	53	73	90	21	48	8
5	3	2		105	145	181	70	97	121	24	54	12
5	2	3		97	138	175	65	92	117	24	54	8
5	2	2	1	96	137	172	64	91	115	24	54	8
6	3	3		122	170	215	81	113	143	26	60	12
6	3	2	1	121	168	212	80	112	141	26	60	12
6	2	3	1	102	161	206	68	107	137	26	60	8
7	4	3		149	203	254	99	135	170	28	65	16
7	4	2	1	146	200	252	97	133	168	28	65	16
7	2	3	2	127	183	236	85	122	157	28	65	8
8	5	3		173	235	294	115	156	196	29	67	20
8	4	4		170	228	288	113	152	192	29	67	16
8	4	2	2	165	224	284	110	149	190	29	67	16
9	5	4		183	252	316	122	168	211	31	78	20
9	5	2	2	181	248	312	121	165	208	31	78	20
9	4	4	1	173	243	309	115	162	206	31	78	16
10	6	2	2	204	280	351	136	188	234	34	82	24
10	5	3	2	197	274	346	131	183	231	34	82	20
10	4	5	1	188	259	341	125	173	227	34	82	16

TABLE 100] LABOR ON BEAM REINFORCEMENT [COSTS

ASSEMBLED ON HORSES, THEN PLACED

For Times see opposite page *See pp. 566 and 576*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

$\frac{7}{8}$-Inch Steel Bars—$\frac{3}{8}$-Inch Stirrups

Number of Bars per Beam				Cost in Dollars per Beam						Approximate Depth of Beam	Length of Each Stirrup Bar	Total Number of U-Stirrups
				Average Men			Quick Men					
				Column Spacing c.c.			Column Spacing c.c.					
Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $	in.	in.	
LABOR AT 30¢ PER HOUR												
3	2	1		0.429	0.588	0.720	0.285	0.393	0.480	18	42	8
3	1	2		0.369	0.528	0.678	0.246	0.351	0.453	18	42	4
4	2	2		0.534	0.744	0.939	0.357	0.495	0.627	21	48	8
5	3	2		0.693	0.960	1.194	0.462	0.639	0.798	24	54	12
6	3	3		0.804	1.110	1.401	0.537	0.738	0.936	26	60	12
7	4	3		0.984	1.341	1.680	0.657	0.894	1.119	28	65	16
8	5	3		1.140	1.551	1.941	0.762	1.035	1.296	29	67	20
8	4	4		1.122	1.509	1.902	0.737	1.014	1.266	29	67	16
9	5	4		1.209	1.665	2.085	0.804	1.110	1.389	31	78	20
10	6	2	2	1.347	1.848	2.316	0.897	1.236	1.545	34	82	24
10	5	3	2	1.305	1.812	2.286	0.870	1.206	1.521	34	82	20
LABOR AT 10¢ PER HOUR												
3	2	1		0.143	0.196	0.240	0.095	0.131	0.160	18	42	8
3	1	2		0.123	0.176	0.226	0.082	0.117	0.151	18	42	4
3	1	1	1	0.119	0.172	0.220	0.079	0.115	0.147	18	42	4
4	2	2		0.178	0.248	0.313	0.119	0.165	0.209	21	48	8
5	3	2		0.231	0.320	0.398	0.154	0.213	0.266	24	54	12
5	2	3		0.213	0.304	0.385	0.142	0.203	0.256	24	54	8
6	3	3		0.268	0.370	0.467	0.179	0.246	0.312	26	60	12
6	2	3	1	0.225	0.354	0.453	0.150	0.236	0.304	26	60	8
7	4	3		0.328	0.447	0.560	0.219	0.298	0.373	28	65	16
7	2	3	2	0.280	0.402	0.520	0.187	0.268	0.346	28	65	8
8	5	3		0.380	0.517	0.647	0.254	0.345	0.432	29	67	20
8	4	4		0.374	0.503	0.634	0.249	0.338	0.422	29	67	16
9	5	4		0.403	0.555	0.695	0.268	0.370	0.463	31	78	20
9	4	4	1	0.380	0.535	0.680	0.253	0.356	0.453	31	78	16
10	6	2	2	0.449	0.616	0.772	0.299	0.412	0.515	34	82	24
10	5	3	2	0.435	0.604	0.762	0.290	0.402	0.507	34	82	20
10	4	5	1	0.414	0.575	0.750	0.276	0.382	0.500	34	82	16

TABLE 101] LABOR ON BEAM REINFORCEMENT [TIMES

ASSEMBLED ON HORSES, THEN PLACED

For Costs see opposite page *See p. 566*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

Times based on average workmen and well organized work. They include delays occurring throughout the day (see p. 566).

For ordinary work add 15% to times, with inexperienced builders add 50%.

Column spacings of 10 ft., 20 ft. and 30 ft. are from center to center of columns.

Times include allowance for foremen, sub-foremen, etc. (see p. 566), but do not include superintendence, contingencies, liability insurance, profit, or home-office expense.

Costs on opposite page include all allowances except profit and home-office expense.

1-Inch Steel Bars—$\frac{3}{8}$-Inch Stirrups

Number of Bars per Beam				Time in Minutes per Beam								Approximate Depth of Beam	Length of Each Stirrup Bar	Total Number of U-Stirrups
				Average Men				Quick Men						
				Column Spacing c.c.				Column Spacing c.c.						
Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	10 ft. min.	20 ft. min.	30 ft. min.	40 ft. min.	10 ft. min.	20 ft. min.	30 ft. min.	40 ft. min.	in.	in.	
3	2	1		89	118	148		59	79	99		21	48	12
3	1	2		74	108	138		49	72	92		21	48	6
3	1	1	1	72	103	133		48	69	89		21	48	6
4	2	2		109	151	191		73	101	127		24	56	12
4	2	1	1	108	147	186		72	88	124		24	56	12
5	3	2		138	188	238		92	125	159		27	62	16
5	2	3		134	169	235		89	113	157		27	62	12
5	2	2	1	128	163	230		85	109	153		27	62	12
6	3	3		160	222	281		117	148	187		29	68	16
6	3	2	1	156	218	276		104	145	184		29	68	16
6	2	3	1	151	212	274		101	141	183		29	68	12
7	4	3		195	267	335		130	178	223		31	72	22
7	4	2	1	192	262	330		128	175	220		31	72	22
7	2	3	2	168	240	310		112	160	207		31	72	12
8	5	3		232	312	390	420	155	208	260	280	33	80	28
8	4	4		217	300	380	412	145	200	253	275	33	80	22
8	4	2	2	211	290	368	405	141	193	245	270	33	80	22
9	5	4		234	324	410	490	156	216	274	327	36	89	28
9	5	2	2	230	316	402	484	153	211	268	323	36	89	28
9	4	4	1	220	311	398	478	147	207	266	318	36	89	22
10	6	2	2	268	360	454	545	179	240	303	363	38	94	32
10	5	3	2	253	341	445	536	169	227	297	358	38	94	28
10	4	5	1	241	343	442	532	160	228	295	355	38	94	22

TABLE 102] LABOR ON BEAM REINFORCEMENT [COSTS

ASSEMBLED ON HORSES, THEN PLACED

For Times see opposite page *See pp. 566 and 578*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

1-Inch Steel Bars—$\frac{3}{8}$-Inch Stirrups

Number of Bars per Beam				Cost in Dollars per Beam								Approximate Depth of Beam	Length of Each Stirrup Bar	Total Number of U-Stirrups
				Average Men				Quick Men						
				Column Spacing c.c.				Column Spacing c.c.						
Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	10 ft.	20 ft.	30 ft.	40 ft.	10 ft.	20 ft.	30 ft.	40 ft.			
				$	$	$	$	$	$	$	$	in.	in.	
LABOR AT 30¢ PER HOUR														
3	2	1		0.588	0.780	0.978		0.393	0.522	0.654		21	48	12
3	1	2		0.489	0.714	0.912		0.327	0.477	0.609		21	48	6
4	2	2		0.720	0.996	1.260		0.480	0.666	0.840		24	56	12
5	3	2		0.912	1.239	1.572		0.609	0.825	1.047		27	62	16
6	3	3		1.056	1.470	1.854		0.705	0.981	1.236		29	68	16
7	4	3		1.290	1.761	2.208		0.861	1.176	1.476		31	72	22
8	5	3		1.530	2.058	2.580	2.775	1.020	1.371	1.719	1.851	33	80	28
8	4	4		1.431	1.980	2.490	2.730	0.954	1.320	1.665	1.821	33	80	22
9	5	4		1.545	2.136	2.712	3.240	1.032	1.425	1.809	2.160	36	89	28
10	6	2	2	1.770	2.376	3.000	3.600	1.179	1.584	2.001	2.400	38	94	32
10	5	3	2	1.671	2.316	2.940	3.540	1.116	1.545	1.962	2.355	38	94	28
LABOR AT 10¢ PER HOUR														
3	2	1		0.196	0.260	0.326		0.131	0.174	0.218		21	48	12
3	1	2		0.163	0.238	0.304		0.109	0.159	0.203		21	48	6
3	1	1	1	0.158	0.226	0.292		0.105	0.151	0.195		21	48	6
4	2	2		0.240	0.332	0.420		0.160	0.222	0.280		24	56	12
5	3	2		0.304	0.413	0.524		0.203	0.275	0.349		27	62	16
5	2	3		0.294	0.372	0.517		0.196	0.248	0.345		27	62	12
6	3	3		0.352	0.490	0.618		0.235	0.327	0.412		29	68	16
6	2	3	1	0.332	0.466	0.603		0.222	0.312	0.403		29	68	12
7	4	3		0.430	0.587	0.736		0.287	0.392	0.492		31	72	22
7	2	3		0.370	0.527	0.682		0.248	0.352	0.455		31	72	12
8	5	3		0.510	0.686	0.860	0.925	0.340	0.457	0.573	0.617	33	80	28
8	4	4		0.477	0.660	0.830	0.910	0.318	0.440	0.555	0.607	33	80	22
9	5	4		0.515	0.712	0.904	1.080	0.344	0.475	0.603	0.720	36	89	28
9	4	4	1	0.485	0.685	0.875	1.050	0.324	0.457	0.585	0.700	36	89	22
10	6	2	2	0.590	0.792	1.000	1.200	0.393	0.528	0.667	0.800	38	94	32
10	5	3	2	0.557	0.772	0.980	1.180	0.372	0.515	0.654	0.785	38	94	28
10	4	5	1	0.530	0.755	0.975	1.170	0.354	0.503	0.650	0.780	38	94	22

TABLE 103] LABOR ON BEAM REINFORCEMENT [TIMES

ASSEMBLED ON HORSES, THEN PLACED

For Costs see opposite page *See p. 566*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

Times based on average workmen and well organized work. They include delays occurring throughout the day (see p. 566).

For ordinary work add 15% to times, with inexperienced builders add 50%.

Column spacings of 10 ft., 20 ft. and 30 ft. are from center to center of columns.

Times include allowance for foremen, sub-foremen, etc. (see p. 566) but do not include superintendence, contingencies, liability insurance, profit, or home-office expense.

Costs on opposite page include all allowances except profit and home-office expense.

$1\frac{1}{8}$-Inch Steel Bars—$\frac{1}{2}$-Inch Stirrups

Number of Bars per Beam				Time in Minutes per Beam								Approximate Depth of Beam	Length of Each Stirrup Bar	Total Number of U-Stirrups
				Average Men				Quick Men						
				Column Spacing c.c.				Column Spacing c.c.						
Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	10 ft. min.	20 ft. min.	30 ft. min.	40 ft. min.	10 ft. min.	20 ft. min.	30 ft. min.	40 ft. min.	in.	in.	
3	2	1		89	126	163		59	84	109		24	54	8
3	1	2		84	121	161		56	81	107		24	54	4
3	1	1	1	81	116	154		54	77	103		24	54	4
4	2	2		116	166	216		77	111	144		27	63	8
4	2	1	1	113	161	210		75	107	140		27	63	8
5	3	2		150	211	274		100	141	183		30	70	12
5	2	3		144	206	270		96	137	180		30	70	8
5	2	2	1	141	202	264		94	135	176		30	70	8
6	3	3		178	252	328		119	168	219		33	76	12
6	3	2	1	174	248	322		116	165	215		33	76	12
6	2	3	1	167	244	318		111	163	212		33	76	8
7	4	3		213	297	385		142	198	257		35	83	16
7	4	2	1	209	293	380		139	195	254		35	83	16
7	2	3	2	192	278	366		128	185	244		35	83	8
8	5	3		246	344	442	470	164	230	295	314	37	88	20
8	4	4		241	338	440	468	161	226	293	313	37	88	16
8	4	2	2	232	329	428	456	155	219	286	305	37	88	16
9	5	4		262	368	470	580	175	246	314	387	40	99	20
9	5	2	2	256	361	462	569	171	241	308	379	40	99	20
9	4	4	1	253	361	460	565	169	241	307	377	40	99	16
10	6	2	2	290	405	520	636	194	270	346	424	42	104	24
10	5	3	2	282	398	518	635	188	266	346	423	42	104	20
10	4	5	1	278	396	517	634	185	264	345	422	42	104	16

TABLE 104] LABOR ON BEAM REINFORCEMENT **[COSTS**

ASSEMBLED ON HORSES, THEN PLACED

For Times see opposite page *See pp. 566 and 580*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

$1\frac{1}{8}$-Inch Steel Bars—$\frac{1}{2}$-Inch Stirrups

Number of Bars per Beam				Cost in Dollars per Beam								Approximate Depth of Beam	Length of Each Stirrup Bar	Total Number of U-Stirrups
				Average Men				Quick Men						
				Column Spacing c.c.				Column Spacing c.c.						
Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	10 ft. $	20 ft. $	30 ft. $	40 ft. $	10 ft. $	20 ft. $	30 ft. $	40 ft. $	in.	in.	
LABOR AT 30¢ PER HOUR														
3	2	1		0.588	0.831	1.074		0.393	0.555	0.717		24	54	8
3	1	2		0.555	0.798	1.062		0.369	0.531	0.708		24	54	4
4	2	2		0.765	1.098	1.425		0.510	0.732	0.951		27	63	8
5	3	2		0.990	1.395	1.806		0.660	0.930	1.206		30	70	12
6	3	3		1.176	1.665	2.166		0.786	1.110	1.449		33	76	12
7	4	3		1.410	1.956	2.550		0.942	1.320	1.701		35	83	16
8	5	3		1.626	2.268	2.925	3.096	1.086	1.515	1.950	2.070	37	88	20
8	4	4		1.590	2.235	2.910	3.090	1.062	1.491	1.938	2.064	37	88	16
9	5	4		1.728	2.430	3.096	3.825	1.152	1.620	2.070	2.550	40	99	20
10	6	2	2	1.920	2.670	3.435	4.200	1.281	1.782	2.289	2.802	42	104	24
10	5	3	2	1.860	2.625	3.420	4.185	1.242	1.749	2.280	2.796	42	104	20
LABOR AT 10¢ PER HOUR														
3	2	1		0.196	0.277	0.358		0.131	0.185	0.239		24	54	8
3	1	2		0.185	0.266	0.354		0.123	0.177	0.236		24	54	4
3	1	1	1	0.178	0.255	0.338		0.119	0.170	0.225		24	54	4
4	2	2		0.255	0.366	0.475		0.170	0.244	0.317		27	63	8
5	3	2		0.330	0.465	0.602		0.220	0.310	0.402		30	70	12
5	2	3		0.317	0.453	0.595		0.212	0.302	0.397		30	70	8
6	3	3		0.392	0.555	0.722		0.262	0.370	0.483		33	76	12
6	2	3	1	0.367	0.537	0.700		0.245	0.358	0.467		33	76	8
7	4	3		0.470	0.652	0.850		0.314	0.440	0.567		35	83	16
7	2	3	2	0.423	0.612	0.805		0.282	0.408	0.537		35	83	8
8	5	3		0.542	0.756	0.975	1.032	0.362	0.505	0.650	0.690	37	88	20
8	4	4		0.530	0.745	0.970	1.030	0.354	0.497	0.646	0.688	37	88	16
9	5	4		0.576	0.810	1.032	1.275	0.384	0.540	0.690	0.850	40	99	20
9	4	4	1	0.557	0.795	1.010	1.241	0.372	0.530	0.672	0.830	40	99	16
10	6	2	2	0.640	0.890	1.145	1.400	0.427	0.594	0.763	0.934	42	104	24
10	5	3	2	0.620	0.875	1.140	1.395	0.414	0.583	0.760	0.932	42	104	20
10	4	5	1	0.612	0.870	1.138	1.390	0.408	0.580	0.756	0.930	42	104	16

TABLE 105] LABOR ON BEAM REINFORCEMENT [TIMES

ASSEMBLED ON HORSES, THEN PLACED

For Costs see opposite page *See p. 566*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

Times based on average workmen and well organized work. They include delays occurring throughout the day (see p. 566).

For ordinary work add 15% to times, with inexperienced builders add 50%.

Column spacings of 10 ft., 20 ft. and 30 ft. are from center to center of columns.

Times include allowance for foremen, sub-foremen, etc., (see p. 566), but do not include superintendence, contingencies, liability insurance, profit, or home-office expense.

Costs on opposite page include all allowances except profit and home-office expense.

$1\frac{1}{4}$-Inch Steel Bars—$\frac{1}{2}$-Inch Stirrups

Number of Bars per Beam				Time in Minutes per Beam								Approximate Depth of Beam	Length of Each Stirrup Bar	Total Number of U-Stirrups
				Average Men				Quick Men						
				Column Spacing c.c.				Column Spacing c.c.						
Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	10 ft. min.	20 ft. min.	30 ft. min.	40 ft. min.	10 ft. min.	20 ft. min.	30 ft. min.	40 ft. min.	in.	in.	
3	2	1		109	154	197		73	103	131		26	60	10
3	1	2		104	151	197		69	101	131		26	60	6
3	1	1	1	100	147	192		67	98	128		26	60	6
4	2	2		140	202	262		93	135	175		29	68	10
4	2	1	1	136	197	260		91	131	173		29	68	10
5	3	2		178	254	328		119	169	219		33	77	14
5	2	3		173	252	327		115	168	218		33	77	10
5	2	2	1	169	246	321		113	164	214		33	77	10
6	3	3		211	304	393		141	203	262		36	85	14
6	3	2	1	206	298	387		137	199	258		36	85	14
6	2	3	1	202	297	387		135	198	258		36	85	10
7	4	3		258	365	468		172	243	312		39	92	20
7	4	2	1	253	359	462		169	239	308		39	92	20
7	2	3	2	233	341	445		155	227	297		39	92	10
8	5	3		297	417	535	569	198	278	356	379	40	98	24
8	4	4		284	413	535	567	190	275	356	378	40	98	20
8	4	2	2	280	403	522	552	187	268	348	368	40	98	20
9	5	4		313	445	575	707	209	297	384	472	45	110	24
9	5	2	2	306	437	570	706	204	292	380	471	45	110	24
9	4	4	1	304	437	565	693	203	292	377	465	45	110	20
10	6	2	2	350	497	640	785	233	332	427	523	47	116	30
10	5	3	2	338	487	632	778	225	324	422	517	47	116	24
10	4	5	1	334	485	626	772	223	323	408	515	47	116	20

TABLE 106] LABOR ON BEAM REINFORCEMENT [COSTS

ASSEMBLED ON HORSES, THEN PLACED

For Times see opposite page *See pp. 566 and 582*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

$1\frac{1}{4}$-Inch Steel Bars—$\frac{1}{2}$-Inch Stirrups

Number of Bars per Beam				Cost in Dollars per Beam								Approximate Depth of Beam	Length of Each Stirrup Bar	Total Number of U-Stirrups
				Average Men				Quick Men						
				Column Spacing c.c.				Column Spacing c.c.						
Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	10 ft. $	20 ft. $	30 ft. $	40 ft. $	10 ft. $	20 ft. $	30 ft. $	40 ft. $	in.	in.	
LABOR AT 30¢ PER HOUR														
3	2	1		0.720	1.020	1.302		0.480	0.678	0.867		26	60	10
3	1	2		0.690	0.996	1.302		0.459	0.666	0.867		26	60	6
4	2	2		0.924	1.335	1.728		0.618	0.788	1.152		29	68	10
5	3	2		1.176	1.680	2.166		0.786	1.119	1.446		33	77	14
6	3	3		1.395	1.965	2.595		0.930	1.311	1.710		36	85	14
7	4	3		1.701	2.400	3.090		1.134	1.599	2.061		39	92	20
8	5	3		1.956	2.760	3.540	3.750	1.305	1.836	2.361	2.505	40	98	24
8	4	4		1.875	2.730	3.540	3.735	1.236	1.808	2.361	2.490	40	98	20
9	5	4		2.070	2.940	3.795	4.665	1.380	1.962	2.526	3.105	45	110	24
10	6	2	2	2.310	3.270	4.230	5.190	1.539	2.178	2.820	3.465	47	116	30
10	5	3	2	2.235	3.210	4.170	5.130	1.485	2.145	2.775	3.420	47	116	24
LABOR AT 10¢ PER HOUR														
3	2	1		0.240	0.340	0.434		0.160	0.226	0.289		26	60	10
3	1	2		0.230	0.332	0.434		0.153	0.222	0.289		26	60	6
3	1	1	1	0.220	0.323	0.422		0.147	0.215	0.282		26	60	6
4	2	2		0.308	0.445	0.576		0.206	0.296	0.384		29	68	10
5	3	2		0.392	0.560	0.722		0.262	0.373	0.482		33	77	14
5	2	3		0.380	0.555	0.720		0.253	0.370	0.480		33	77	10
6	3	3		0.465	0.655	0.865		0.310	0.437	0.570		36	85	14
6	2	3	1	0.445	0.654	0.854		0.296	0.436	0.568		36	85	10
7	4	3		0.567	0.800	1.030		0.378	0.533	0.687		39	92	20
7	2	3	2	0.512	0.750	0.980		0.342	0.500	0.655		39	92	10
8	5	3		0.652	0.920	1.180	1.250	0.435	0.612	0.787	0.835	40	98	24
8	4	4		0.625	0.910	1.180	1.245	0.412	0.606	0.787	0.830	40	98	20
9	5	4		0.690	0.980	1.265	1.555	0.460	0.654	0.842	1.035	45	110	24
9	4	4	1	0.670	0.960	1.240	1.520	0.446	0.640	0.826	1.015	45	110	20
10	6	2	2	0.770	1.090	1.410	1.730	0.513	0.726	0.940	1.155	47	116	30
10	5	3	2	0.745	1.070	1.390	1.710	0.495	0.715	0.925	1.140	47	116	24
10	4	5	1	0.735	1.068	1.380	1.700	0.490	0.712	0.920	1.135	47	116	20

TABLE 107] LABOR ON BEAM REINFORCEMENT [TIMES

ASSEMBLED IN PLACE

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

For Costs see opposite page *See p. 566*

½-Inch Steel Bars—¼-Inch Stirrups

Number of Bars per Beam				Time in Minutes per Beam						Approximate Depth of Beam	Length of Each Stirrup Bar	Total Number of U-Stirrups
				Average Men			Quick Men					
				Column Spacing c.c.			Column Spacing c.c.					
Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	10 ft. min.	20 ft. min.	30 ft. min.	10 ft. min.	20 ft. min.	30 ft. min.	in.	in.	
1	1*			19	22	24	13	15	16	7	15	4
2	2†			31	37	38	21	25	25	9	20	6
2	1	1		26	31	36	17	21	24	9	20	4
3	2	1		36	52	58	24	35	39	11	24	6
3	1	2		33	45	52	22	30	35	11	24	4
3	1	1	1	33	39	41	22	26	27	11	24	4
4	2	2		46	56	67	31	37	45	12	28	6
4	2	1	1	46	55	65	31	37	43	12	28	6
5	3	2		58	70	83	39	47	55	14	30	8
5	2	3		53	67	82	35	45	55	14	30	6
5	2	2	1	53	66	81	35	44	54	14	30	6
6	3	3		66	82	98	44	55	65	15	34	8
6	3	2	1	65	81	97	43	54	65	15	34	8
6	2	3	1	61	78	93	41	52	62	15	34	6
7	4	3		83	92	120	55	61	80	17	38	12
7	4	2	1	83	91	119	55	60	79	17	38	12
7	2	3	2	70	89	107	47	59	71	17	38	6
8	5	3		102	120	143	68	80	95	18	40	16
8	4	4		92	110	134	61	73	89	18	40	12
8	4	2	2	91	103	131	61	69	87	18	40	12
9	5	4		113	131	153	75	87	102	19	47	16
9	5	2	2	110	129	151	73	86	101	19	47	16
9	4	4	1	102	121	145	68	81	97	19	47	12
10	6	2	2	128	146	173	85	97	115	20	49	20
10	5	3	2	116	136	160	77	91	107	20	49	16
10	4	5	1	113	131	159	75	87	106	20	49	12

* 1 additional bar over support, length ⅗ of span.
† 2 additional bars over support, length ⅗ of span.

ASSEMBLED IN PLACE

For Times see opposite page *See pp. 566 and 584*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

$\frac{1}{2}$-Inch Steel Bars—$\frac{1}{4}$-Inch Stirrups.

Number of Bars per Beam: Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	Cost in Dollars per Beam — Average Men — Column Spacing c.c. 10 ft. $	20 ft. $	30 ft. $	Quick Men — Column Spacing c.c. 10 ft. $	20 ft. $	30 ft. $	Approximate Depth of Beam in.	Length of Each Stirrup Bar in.	Total Number of U-Stirrups
				LABOR AT 30¢ PER HOUR								
1	1*			0.126	0.144	0.159	0.084	0.096	0.105	7	15	4
2	2†			0.204	0.243	0.252	0.135	0.162	0.168	9	20	6
3	2	1		0.237	0.342	0.384	0.159	0.228	0.255	11	24	6
4	2	2		0.303	0.369	0.441	0.201	0.246	0.294	12	28	6
5	3	2		0.384	0.462	0.546	0.255	0.309	0.363	14	30	8
6	3	3		0.435	0.540	0.648	0.288	0.360	0.432	15	34	8
7	4	3		0.549	0.606	0.792	0.366	0.405	0.528	17	38	12
8	5	3		0.672	0.792	0.945	0.447	0.528	0.630	18	40	16
9	5	4		0.750	0.864	1.011	0.501	0.576	0.675	19	47	16
10	6	2	2	0.846	0.966	1.143	0.564	0.642	0.762	20	49	20
				LABOR AT 10¢ PER HOUR								
1	1*			0.042	0.048	0.053	0.028	0.032	0.035	7	15	4
2	2†			0.068	0.081	0.084	0.045	0.054	0.056	9	20	6
2	1	1		0.057	0.068	0.079	0.038	0.045	0.053	9	20	4
3	2	1		0.079	0.114	0.128	0.053	0.076	0.085	11	24	6
3	1	2		0.073	0.099	0.114	0.049	0.066	0.076	11	24	4
3	1	1	1	0.073	0.086	0.090	0.049	0.057	0.060	11	24	4
4	2	2		0.101	0.123	0.147	0.067	0.082	0.098	12	28	6
5	3	2		0.128	0.154	0.182	0.085	0.103	0.121	14	30	8
5	2	3		0.117	0.148	0.180	0.078	0.099	0.120	14	30	6
6	3	3		0.145	0.180	0.216	0.096	0.120	0.144	15	34	8
6	2	3	1	0.134	0.172	0.205	0.089	0.115	0.137	15	34	6
7	4	3		0.183	0.202	0.264	0.122	0.135	0.176	17	38	12
7	2	3	2	0.154	0.196	0.236	0.103	0.131	0.157	17	38	6
8	5	3		0.224	0.264	0.315	0.149	0.176	0.210	18	40	16
8	4	4		0.203	0.242	0.295	0.135	0.161	0.196	18	40	12
9	5	4		0.250	0.288	0.337	0.167	0.192	0.225	19	47	16
9	4	4	1	0.225	0.266	0.320	0.150	0.177	0.214	19	47	12
10	6	2	2	0.282	0.322	0.381	0.188	0.214	0.254	20	49	20
10	5	3	2	0.256	0.300	0.352	0.171	0.200	0.234	20	49	16
10	4	5	1	0.248	0.288	0.350	0.165	0.192	0.233	20	49	12

* 1 additional bar over support, length $\frac{2}{5}$ of span.
† 2 additional bars over support, length $\frac{2}{5}$ of span.

TABLE 109] LABOR ON BEAM REINFORCEMENT [TIMES

ASSEMBLED IN PLACE

For Costs see opposite page *See p. 566*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

$\frac{3}{4}$-Inch Steel Bars—$\frac{1}{4}$-Inch Stirrups

Number of Bars per Beam				Time in Minutes per Beam						Approximate Depth of Beam	Length of Each Stirrup Bar	Total Number of U-Stirrups
				Average Men			Quick Men					
				Column Spacing c.c			Column Spacing c.c.					
Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	10 ft. min.	20 ft. min.	30 ft. min.	10 ft. min.	20 ft. min.	30 ft. min.	in.	in.	
1	1*			28	33	38	19	22	25	10	23	8
2	2†			50	48	70	33	32	47	14	30	14
2	1	1		39	45	53	26	30	35	14	30	8
3	2	1		71	92	102	47	61	68	16	35	14
3	1	2		59	74	89	39	49	59	16	35	8
3	1	1	1	56	73	89	37	49	59	16	35	8
4	2	2		85	105	125	57	70	83	18	40	14
4	2	1	1	83	103	124	55	69	83	18	40	14
5	3	2		108	136	161	72	91	107	20	45	20
5	2	3		96	123	149	64	82	99	20	45	14
5	2	2	1	95	122	147	63	81	98	20	45	14
6	3	3		122	156	188	81	104	125	22	50	20
6	3	2	1	121	153	186	81	102	124	22	50	20
6	2	3	1	110	140	173	73	93	115	22	50	14
7	4	3		154	192	230	103	128	153	24	55	28
7	4	2	1	154	191	228	103	127	152	24	55	28
7	2	3	2	118	158	197	79	105	131	24	55	14
8	5	3		181	224	268	121	149	179	25	57	34
8	4	4		167	211	254	111	141	170	25	57	28
8	4	2	2	165	207	240	110	138	160	25	57	28
9	5	4		190	238	284	127	159	189	27	69	34
9	5	2	2	188	235	280	125	157	187	27	69	34
9	4	4	1	175	225	272	117	150	181	27	69	28
10	6	2	2	214	267	316	143	178	210	29	72	40
10	5	3	2	200	252	304	133	168	202	29	72	34
10	4	5	1	188	244	296	125	163	197	29	72	28

* 1 additional bar over support, length $\frac{2}{5}$ of span.
† 2 additional bars over support, length $\frac{2}{5}$ of span.

ASSEMBLED IN PLACE

For Times see opposite page *See pp. 566 and 586*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

$\frac{3}{4}$-Inch Steel Bars—$\frac{1}{4}$-Inch Stirrups

Number of Bars per Beam				Cost in Dollars per Beam						Approximate Depth of Beam	Length of Each Stirrup Bar	Total Number of U-Stirrups
				Average Men			Quick Men					
				Column Spacing c.c.			Column Spacing c.c.					
Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $	in.	in.	
LABOR AT 30¢ PER HOUR												
1	1*			0.186	0.219	0.252	0.123	0.147	0.168	10	23	8
2	2†			0.330	0.315	0.462	0.219	0.210	0.309	14	30	14
3	2	1		0.468	0.606	0.672	0.312	0.405	0.447	16	35	14
4	2	2		0.561	0.693	0.828	0.375	0.462	0.542	18	40	14
5	3	2		0.714	0.900	1.062	0.477	0.600	0.708	20	45	20
6	3	3		0.804	1.032	1.242	0.537	0.690	0.828	22	50	20
7	4	3		1.020	1.266	1.518	0.681	0.846	1.014	24	55	28
8	5	3		1.194	1.482	1.770	0.798	0.990	1.179	25	57	34
9	5	4		1.260	1.566	1.875	0.840	1.044	1.251	27	69	34
10	6	2	2	1.410	1.761	2.085	0.942	1.176	1.395	29	72	40
LABOR AT 10¢ PER HOUR												
1	1*			0.062	0.073	0.084	0.041	0.049	0.056	10	23	8
2	2†			0.110	0.105	0.154	0.073	0.070	0.103	14	30	14
2	1	1		0.086	0.099	0.117	0.057	0.066	0.078	14	30	8
3	2	1		0.156	0.202	0.224	0.104	0.135	0.149	16	35	14
3	1	2		0.130	0.163	0.196	0.087	0.109	0.131	16	35	8
3	1	1	1	0.123	0.160	0.196	0.082	0.107	0.131	16	35	8
4	2	2		0.187	0.231	0.276	0.125	0.154	0.184	18	40	14
5	3	2		0.238	0.300	0.354	0.159	0.200	0.236	20	45	20
5	2	3		0.211	0.270	0.328	0.140	0.180	0.219	20	45	14
6	3	3		0.268	0.344	0.414	0.179	0.230	0.276	22	50	20
6	2	3	1	0.242	0.308	0.381	0.161	0.206	0.254	22	50	14
7	4	3		0.340	0.422	0.506	0.227	0.282	0.338	24	55	28
7	2	3	2	0.260	0.348	0.434	0.173	0.232	0.290	24	55	14
8	5	3		0.398	0.494	0.590	0.266	0.330	0.393	25	57	34
8	4	4		0.368	0.465	0.560	0.245	0.310	0.374	25	57	28
9	5	4		0.420	0.522	0.625	0.280	0.348	0.417	27	69	34
9	4	4	1	0.385	0.495	0.600	0.257	0.330	0.400	27	69	28
10	6	2	2	0.470	0.587	0.695	0.314	0.392	0.465	29	72	40
10	5	3	2	0.440	0.555	0.665	0.293	0.370	0.443	29	72	34
10	4	5	1	0.414	0.537	0.652	0.276	0.358	0.435	29	72	28

*1 additional bar over support, length $\frac{2}{5}$ of span.
†2 additional bars over support, length $\frac{2}{5}$ of span.

TABLE 111] LABOR ON BEAM REINFORCEMENT [TIMES

ASSEMBLED IN PLACE

For Costs see opposite page *See p. 566*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

$\frac{7}{8}$-Inch Steel Bars—$\frac{3}{8}$-Inch Stirrups

Number of Bars per Beam: Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	Time in Minutes per Beam — Average Men — Column Spacing c.c. 10 ft. min.	20 ft. min.	30 ft. min.	Quick Men — Column Spacing c.c. 10 ft. min.	20 ft. min.	30 ft. min.	Approximate Depth of Beam in.	Length of Each Stirrup Bar in.	Total Number of U-Stirrups
1	1*			20	26	34	13	17	23	11	24	4
2	2†			40	53	69	27	35	46	15	34	8
2	1	1		32	43	55	21	29	37	15	34	4
3	2	1		61	83	102	41	57	68	18	42	8
3	1	2		53	75	97	35	50	65	18	42	4
3	1	1	1	51	73	94	34	49	63	18	42	4
4	2	2		74	104	132	49	69	88	21	48	8
4	2	1	1	72	101	125	48	68	83	21	48	8
5	3	2		95	134	168	63	89	112	24	54	12
5	2	3		88	127	163	59	85	109	24	54	8
5	2	2	1	87	126	160	58	84	107	24	54	8
6	3	3		111	156	200	74	104	133	26	60	12
6	3	2	1	110	155	197	73	103	131	26	60	12
6	2	3	1	93	148	191	62	99	127	26	60	8
7	4	3		138	189	238	92	126	159	28	65	16
7	4	2	1	135	186	236	90	124	157	28	65	16
7	2	3	2	117	171	221	78	114	147	28	65	8
8	5	3		163	221	276	109	147	184	29	67	20
8	4	4		160	216	270	107	144	180	29	67	16
8	4	2	2	155	210	266	103	140	177	29	67	16
9	5	4		172	237	297	115	158	198	31	78	20
9	5	2	2	170	233	294	113	155	196	31	78	20
9	4	4	1	162	228	290	108	152	193	31	78	16
10	6	2	2	192	263	330	128	175	220	34	82	24
10	5	3	2	185	257	325	123	171	216	34	82	20
10	4	5	1	177	243	320	118	162	213	34	82	16

* 1 additional bar over support, length $\frac{2}{5}$ of span.
† 2 additional bars over support, length $\frac{2}{5}$ of span.

ASSEMBLED IN PLACE

For Times see opposite page *See pp. 566 and 588*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

$\frac{7}{8}$-Inch Steel Bars—$\frac{3}{8}$-Inch Stirrups

Number of Bars per Beam				Cost in Dollars per Beam						Approximate Depth of Beam	Length of Each Stirrup Bar	Total Number of U-Stirrups
				Average Men			Quick Men					
				Column Spacing c.c.			Column Spacing c.c.					
Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $	in.	in.	
LABOR AT 30¢ PER HOUR												
1	1*			0.132	0.171	0.225	0.087	0.114	0.150	11	24	4
2	2†			0.264	0.351	0.456	0.177	0.231	0.306	15	34	8
3	2	1		0.402	0.549	0.672	0.267	0.366	0.447	18	42	8
4	2	2		0.489	0.690	0.870	0.324	0.459	0.579	21	48	8
5	3	2		0.627	0.888	1.110	0.420	0.591	0.738	24	54	12
6	3	3		0.732	1.029	1.320	0.489	0.687	0.882	26	60	12
7	4	3		0.912	1.248	1.572	0.609	0.834	1.050	28	65	16
8	5	3		1.077	1.461	1.821	0.717	0.978	1.218	29	67	20
9	5	4		1.137	1.566	1.959	0.759	1.044	1.305	31	78	20
10	6	2	2	1.269	1.740	2.178	0.846	1.161	1.455	34	82	24
LABOR AT 10¢ PER HOUR												
1	1*			0.044	0.057	0.075	0.029	0.038	0.050	11	24	4
2	2†			0.088	0.117	0.152	0.059	0.077	0.102	15	34	8
2	1	1		0.070	0.095	0.121	0.047	0.063	0.080	15	34	4
3	2	1		0.134	0.183	0.224	0.089	0.122	0.149	18	42	8
3	1	2		0.117	0.165	0.214	0.078	0.110	0.143	18	42	4
3	1	1	1	0.112	0.161	0.206	0.075	0.107	0.138	18	42	4
4	2	2		0.163	0.230	0.290	0.108	0.153	0.193	21	48	8
5	3	2		0.209	0.296	0.370	0.140	0.197	0.246	24	54	12
5	2	3		0.194	0.280	0.359	0.129	0.187	0.239	24	54	8
6	3	3		0.244	0.343	0.440	0.163	0.229	0.294	26	60	12
6	2	3	1	0.204	0.326	0.420	0.136	0.218	0.280	26	60	8
7	4	3		0.304	0.416	0.524	0.203	0.278	0.350	28	65	16
7	2	3	2	0.258	0.376	0.487	0.172	0.251	0.325	28	65	8
8	5	3		0.359	0.487	0.607	0.239	0.326	0.406	29	67	20
8	4	4		0.352	0.476	0.595	0.235	0.318	0.397	29	67	16
9	5	4		0.379	0.522	0.653	0.253	0.348	0.435	31	78	20
9	4	4	1	0.357	0.503	0.640	0.238	0.335	0.427	31	78	16
10	6	2	2	0.423	0.580	0.726	0.282	0.387	0.485	34	82	24
10	5	3	2	0.407	0.566	0.715	0.272	0.378	0.477	34	82	20
10	4	5	1	0.390	0.535	0.705	0.260	0.357	0.470	34	82	16

* 1 additional bar over support, length $\frac{2}{5}$ of span.

† 2 additional bars over support, length $\frac{2}{5}$ of span.

TABLE 113] LABOR ON BEAM REINFORCEMENT [TIMES

ASSEMBLED IN PLACE

For Costs see opposite page *See p. 566*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

1-Inch Steel Bars—$\frac{3}{8}$-Inch Stirrups

Number of Bars per Beam				Time in Minutes per Beam								Approximate Depth of Beam	Length of Each Stirrup Bar	Total Number of U-Stirrups
				Average Men				Quick Men						
				Column Spacing c.c.				Column Spacing c.c.						
Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	10 ft. min.	20 ft. min.	30 ft. min.	40 ft. min.	10 ft. min.	20 ft. min.	30 ft. min.	40 ft. min.	in.	in.	
1	1*			28	35	45		19	23	30		13	28	6
2	2†			55	71	90		37	47	60		17	39	12
2	1	1		40	56	69		27	37	46		17	39	6
3	2	1		83	109	136		55	73	91		21	48	12
3	1	2		69	100	126		46	67	85		21	48	6
3	1	1	1	67	95	122		45	63	81		21	48	6
4	2	2		99	137	172		66	91	115		24	56	12
4	2	1	1	98	133	167		65	89	111		24	56	12
5	3	2		125	170	214		83	103	143		27	62	16
5	2	3		122	153	210		81	102	140		27	62	12
5	2	2	1	116	147	207		77	98	138		27	62	12
6	3	3		145	201	253		97	134	169		29	68	16
6	3	2	1	142	197	248		95	131	165		29	68	16
6	2	3	1	137	192	246		91	128	164		29	68	12
7	4	3		179	244	305		119	163	203		31	72	22
7	4	2	1	177	240	300		118	160	200		31	72	22
7	2	3	2	155	220	282		103	147	188		31	72	12
8	5	3		216	288	358	384	144	193	239	256	33	80	28
8	4	4		201	277	350	377	134	185	234	251	33	80	22
8	4	2	2	196	268	338	370	131	179	226	247	33	80	22
9	5	4		217	299	378	448	145	199	252	299	36	89	28
9	5	2	2	214	292	370	442	143	195	246	295	36	89	28
9	4	4	1	204	288	366	437	136	192	237	292	36	89	22
10	6	2	2	249	340	417	498	166	226	275	332	38	94	32
10	5	3	2	235	333	410	490	157	222	274	327	38	94	28
10	4	5	1	224	317	407	486	150	211	272	324	38	94	22

* 1 additional bar over support, length $\frac{2}{5}$ of span.
† 2 additional bars over support, length $\frac{2}{5}$ of span.

ASSEMBLED IN PLACE

For Times see opposite page *See pp. 566 and 590*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

1-Inch Steel Bars—$\frac{3}{8}$-Inch Stirrups

Number of Bars per Beam				Cost in Dollars per Beam								Approximate Depth of Beam	Length of Each Stirrup Bar	Total Number of U-Stirrups
				Average Men				Quick Men						
				Column Spacing c.c.				Column Spacing c.c.						
Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	10 ft. $	20 ft. $	30 ft. $	40 ft. $	10 ft. $	20 ft. $	30 ft. $	40 ft. $	in.	in.	
LABOR AT 30¢ PER HOUR														
1	1*			0.186	0.231	0.297		0.126	0.153	0.198		13	28	6
2	2†			0.363	0.468	0.594		0.243	0.312	0.396		17	39	12
3	2	1		0.546	0.720	0.900		0.363	0.480	0.600		21	48	12
4	2	2		0.654	0.906	1.134		0.435	0.603	0.756		24	56	12
5	3	2		0.825	1.122	1.410		0.549	0.747	0.942		27	62	16
6	3	3		0.960	1.326	1.671		0.642	0.885	1.116		29	68	16
7	4	3		1.182	1.611	2.016		0.789	1.074	1.344		31	72	22
8	5	3		1.425	1.902	2.361	2.535	0.951	1.266	1.575	1.689	33	80	28
9	5	4		1.431	2.071	2.490	2.955	0.942	1.350	1.659	1.971	36	89	28
10	6	2	2	1.644	2.250	2.760	3.285	1.098	1.500	1.839	2.190	38	94	32
LABOR AT 10¢ PER HOUR														
1	1*			0.062	0.077	0.099		0.042	0.051	0.066		13	28	6
2	2†			0.121	0.156	0.198		0.081	0.104	0.132		17	39	12
2	1	1		0.088	0.123	0.152		0.059	0.082	0.102		17	39	6
3	2	1		0.182	0.240	0.300		0.121	0.160	0.200		21	48	12
3	1	2		0.152	0.220	0.278		0.102	0.147	0.185		21	48	6
3	1	1	1	0.147	0.209	0.268		0.098	0.139	0.179		21	48	6
4	2	2		0.218	0.302	0.378		0.145	0.201	0.252		24	56	12
5	3	2		0.275	0.374	0.470		0.183	0.249	0.314		27	62	16
5	2	3		0.269	0.336	0.462		0.179	0.224	0.308		27	62	12
6	3	3		0.320	0.442	0.557		0.214	0.295	0.372		29	68	16
6	2	3	1	0.304	0.423	0.540		0.203	0.282	0.360		29	68	12
7	4	3		0.394	0.537	0.672		0.263	0.358	0.448		31	72	22
7	2	3	2	0.340	0.485	0.620		0.227	0.323	0.413		31	72	12
8	5	3		0.475	0.634	0.787	0.845	0.317	0.422	0.525	0.563	33	80	28
8	4	4		0.442	0.610	0.770	0.830	0.295	0.407	0.513	0.553	33	80	22
9	5	4		0.477	0.657	0.830	0.985	0.314	0.450	0.553	0.657	36	89	28
9	4	4	1	0.450	0.634	0.805	0.960	0.300	0.422	0.537	0.640	36	89	22
10	6	2	2	0.548	0.750	0.920	1.095	0.366	0.500	0.613	0.730	38	94	32
10	5	3	2	0.517	0.732	0.902	1.080	0.345	0.488	0.602	0.720	38	94	28
10	4	5	1	0.493	0.697	0.895	1.070	0.328	0.465	0.597	0.714	38	94	22

*1 additional bar over support, length $\frac{2}{5}$ of span.
†2 additional bars over support, length $\frac{2}{5}$ of span.

TABLE 115] LABOR ON BEAM REINFORCEMENT [TIMES

ASSEMBLED IN PLACE

For Costs see opposite page *See p. 566*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

$1\frac{1}{8}$-Inch Steel Bars—$\frac{1}{2}$-Inch Stirrups

Number of Bars per Beam				Time in Minutes per Beam								Approximate Depth of Beam	Length of Each Stirrup Bar	Total Number of U-Stirrups
				Average Men				Quick Men						
				Column Spacing c.c				Column Spacing o.c.						
Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	10 ft. min.	20 ft. min.	30 ft. min.	40 ft. min.	10 ft. min.	20 ft. min.	30 ft. min.	40 ft. min.	in.	in.	
1	1*			25	32	43		17	21	39		14	31	4
2	2†			51	70	91		34	47	61		19	44	8
2	1	1		43	61	78		29	41	52		19	44	4
3	2	1		82	115	147		55	77	98		24	54	8
3	1	2		77	110	145		51	73	97		24	54	4
3	1	1	1	74	105	138		49	70	92		24	54	4
4	2	2		104	148	190		69	99	127		27	63	8
4	2	1	1	102	143	185		68	95	123		27	63	8
5	3	2		135	188	242		90	125	161		30	70	12
5	2	3		130	183	238		87	122	159		30	70	8
5	2	2	1	127	180	232		85	120	155		30	70	8
6	3	3		160	224	288		107	149	192		33	76	12
6	3	2	1	157	221	284		105	147	189		33	76	12
6	2	3	1	150	217	280		100	145	187		33	76	8
7	4	3		194	269	345		129	179	230		35	83	16
7	4	2	1	190	265	340		127	177	227		35	83	16
7	2	3	2	174	252	328		116	168	218		35	83	8
8	5	3		227	316	403	423	151	211	268	282	37	88	20
8	4	4		222	311	400	421	148	208	266	281	37	88	16
8	4	2	2	214	303	390	412	143	202	260	275	37	88	16
9	5	4		242	338	427	522	161	226	285	348	40	99	20
9	5	2	2	236	332	420	517	157	221	280	342	40	99	20
9	4	4	1	234	332	418	510	156	221	278	340	40	99	16
10	6	2	2	268	372	474	573	179	248	316	383	42	104	24
10	5	3	2	261	366	472	572	174	244	314	381	42	104	20
10	4	5	1	257	360	470	570	171	240	314	380	42	104	16

* 1 additional bar over support, length $\frac{2}{5}$ of span.

† 2 additional bars over support, length $\frac{2}{5}$ of span.

ASSEMBLED IN PLACE

For Times see opposite page *See pp. 566 and 592*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

$1\frac{1}{8}$-Inch Steel Bars—$\frac{1}{2}$-Inch Stirrups

Number of Bars per Beam: Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	Cost in Dollars per Beam, Average Men, Column Spacing c.c. 10 ft. $	20 ft. $	30 ft. $	40 ft. $	Quick Men, Column Spacing c.c. 10 ft. $	20 ft. $	30 ft. $	40 ft. $	Approximate Depth of Beam In.	Length of Each Stirrup Bar In.	Total Number of U-Stirrups
LABOR AT 30¢ PER HOUR														
1	1*			0.165	0.210	0.285		0.111	0.141	0.189		14	31	4
2	2†			0.336	0.462	0.600		0.225	0.309	0.399		19	44	8
3	2	1		0.540	0.759	0.972		0.360	0.504	0.645		24	54	8
4	2	2		0.687	0.978	1.254		0.459	0.651	0.834		27	63	8
5	3	2		0.791	1.239	1.596		0.594	0.828	1.065		30	70	12
6	3	3		1.056	1.479	1.902		0.705	0.984	1.269		33	76	12
7	4	3		1.281	1.776	2.280		0.858	1.182	1.521		35	83	16
8	5	3		1.500	2.085	2.670	2.790	0.999	1.386	1.779	1.860	37	88	20
9	5	4		1.596	2.232	2.820	3.450	1.065	1.485	1.890	2.295	40	99	20
10	6	2	2	1.770	2.460	3.123	3.780	1.182	1.641	2.085	2.520	42	104	24
LABOR AT 10¢ PER HOUR														
1	1*			0.055	0.070	0.095		0.037	0.047	0.063		14	31	4
2	2†			0.112	0.154	0.200		0.075	0.103	0.133		19	44	8
2	1	1		0.095	0.105	0.172		0.063	0.070	0.115		19	44	4
3	2	1		0.180	0.253	0.324		0.120	0.168	0.215		24	54	8
3	1	2		0.170	0.242	0.320		0.113	0.161	0.214		24	54	4
3	1	1	1	0.163	0.231	0.304		0.109	0.154	0.203		24	54	4
4	2	2		0.229	0.326	0.418		0.153	0.217	0.278		27	63	8
5	3	2		0.297	0.413	0.532		0.198	0.276	0.355		30	70	12
5	2	3		0.286	0.400	0.524		0.191	0.266	0.348		30	70	8
6	3	3		0.352	0.493	0.634		0.235	0.328	0.423		33	76	12
6	2	3	1	0.330	0.477	0.615		0.220	0.318	0.410		33	76	8
7	4	3		0.427	0.592	0.760		0.286	0.394	0.507		35	83	16
7	2	3	2	0.383	0.555	0.722		0.255	0.370	0.482		35	83	8
8	5	3		0.500	0.695	0.890	0.930	0.333	0.462	0.593	0.620	37	88	20
8	4	4		0.490	0.685	0.880	0.928	0.326	0.457	0.586	0.618	37	88	16
9	5	4		0.532	0.744	0.940	1.150	0.355	0.495	0.630	0.765	40	99	20
9	4	4	1	0.515	0.730	0.920	1.120	0.343	0.487	0.614	0.745	40	99	16
10	6	2	2	0.590	0.820	1.041	1.260	0.394	0.547	0.695	0.840	42	104	24
10	5	3	2	0.575	0.805	1.040	1.258	0.383	0.537	0.694	0.839	42	104	20
10	4	5	1	0.565	0.791	1.035	1.253	0.377	0.528	0.690	0.833	42	104	16

*1 additional bar over support, length $\frac{2}{5}$ of span.
†2 additional bars over support, length $\frac{2}{5}$ of span.

TABLE 117] LABOR ON BEAM REINFORCEMENT [TIMES ASSEMBLED IN PLACE

For Costs see opposite page *See p. 566*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

$1\frac{1}{4}$-Inch Steel Bars—$\frac{1}{2}$-Inch Stirrups

Number of Bars Per Beam				Time in Minutes per Beam								Approximate Depth of Beam	Length of Each Stirrup Bar	Total Number of U-Stirrups
				Average Men				Quick Men						
				Column Spacing c.c.				Column Spacing c.c.						
Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	10 ft. min.	20 ft. min.	30 ft. min.	40 ft. min.	10 ft. min.	20 ft. min.	30 ft. min.	40 ft. min.	in.	in.	
1	1*			34	46	59		23	31	39		16	35	6
2	2†			61	87	112		41	58	75		22	50	10
2	1	1		55	76	98		37	51	65		22	50	6
3	2	1		99	138	175		66	92	117		26	60	10
3	1	2		95	136	175		63	91	117		26	60	6
3	1	1	1	90	132	171		60	88	114		26	60	6
4	2	2		126	178	225		84	119	150		29	68	10
4	2	1	1	122	173	223		81	115	149		29	68	10
5	3	2		160	224	282		107	149	188		33	77	14
5	2	3		155	222	281		103	148	187		33	77	10
5	2	2	1	152	216	276		101	144	184		33	77	10
6	3	3		190	267	338		126	178	226		36	85	14
6	3	2	1	185	262	327		123	175	218		36	85	14
6	2	3	1	182	261	326		121	174	216		36	85	10
7	4	3		235	328	412		156	219	275		39	92	20
7	4	2	1	230	323	408		153	215	272		39	92	20
7	2	3	2	212	307	394		141	205	262		39	92	10
8	5	3		273	382	487	515	182	255	326	344	40	98	24
8	4	4		261	378	487	513	174	252	326	342	40	98	20
8	4	2	2	258	368	475	500	172	246	317	333	40	98	20
9	5	4		288	407	524	640	192	272	349	428	45	110	24
9	5	2	2	281	400	519	639	187	267	346	427	45	110	24
9	4	4	1	280	400	515	626	187	267	344	417	45	110	20
10	6	2	2	322	455	582	710	214	304	388	470	47	116	30
10	5	3	2	310	446	575	705	207	298	384	473	47	116	24
10	4	5	1	306	443	570	700	204	295	380	467	47	116	20

* 1 additional bar over support, length $\frac{2}{5}$ of span.
† 2 additional bars over support, length $\frac{2}{5}$ of span.

LABOR ON BEAM REINFORCEMENT ASSEMBLED IN PLACE

For Times see opposite page *See pp. 566 and 594*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

$1\frac{1}{4}$-Inch Steel Bars—$\frac{1}{2}$-Inch Stirrups

Number of Bars per Beam				Cost in Dollars per Beam								Approximate Depth of Beam	Length of Each Stirrup Bar	Total Number of U-Stirrups
				Average Men				Quick Men						
				Column Spacing c.c.				Column Spacing c.c.						
Total No. Bars	Straight Bars	Bars with 4 Bends	Bars with 2 Bends	10 ft.	20 ft.	30 ft.	40 ft.	10 ft.	20 ft.	30 ft.	40 ft.			
				$	$	$	$	$	$	$	$	In.	In.	
LABOR AT 30¢ PER HOUR														
1	1*			0.225	0.303	0.390		0.150	0.201	0.261		16	35	6
2	2†			0.402	0.576	0.738		0.267	0.384	0.492		22	50	10
3	2	1		0.654	0.912	1.155		0.435	0.609	0.768		26	60	10
4	2	2		0.834	1.176	1.485		0.556	0.786	0.990		29	68	10
5	3	2		1.056	1.479	1.860		0.702	0.984	1.239		33	77	14
6	3	3		1.254	1.761	2.235		0.834	1.176	1.471		36	85	14
7	4	3		1.551	2.166	2.730		1.035	1.446	1.821		39	92	20
8	5	3		1.800	2.520	3.210	3.393	1.200	1.680	2.145	2.265	40	98	24
9	5	4		1.902	2.685	3.450	4.230	1.266	1.791	2.295	2.820	45	110	24
10	6	2	2	2.130	3.000	3.840	4.680	1.419	2.001	2.562	3.120	47	116	30
LABOR AT 10¢ PER HOUR														
1	1*			0.075	0.101	0.130		0.050	0.067	0.087		16	35	6
2	2†			0.134	0.192	0.246		0.089	0.128	0.164		22	50	10
2	1	1		0.121	0.167	0.216		0.081	0.101	0.144		22	50	6
3	2	1		0.218	0.304	0.385		0.145	0.203	0.256		26	60	10
3	1	2		0.209	0.300	0.385		0.139	0.200	0.256		26	60	6
3	1	1	1	0.198	0.291	0.377		0.132	0.194	0.251		26	60	6
4	2	2		0.278	0.392	0.495		0.186	0.262	0.330		29	68	10
5	3	2		0.352	0.493	0.620		0.234	0.328	0.413		33	77	14
5	2	3		0.341	0.489	0.619		0.227	0.326	0.412		33	77	10
6	3	3		0.418	0.587	0.745		0.278	0.392	0.497		36	85	14
6	2	3	1	0.400	0.575	0.725		0.266	0.384	0.483		36	85	10
7	4	3		0.517	0.722	0.910		0.345	0.482	0.607		39	92	20
7	2	3	2	0.467	0.675	0.867		0.312	0.450	0.578		39	92	10
8	5	3		0.600	0.840	1.070	1.131	0.400	0.560	0.715	0.755	40	98	24
8	4	4		0.575	0.832	1.070	1.125	0.384	0.555	0.715	0.750	40	98	20
9	5	4		0.634	0.895	1.150	1.410	0.422	0.597	0.765	0.940	45	110	24
9	4	4	1	0.616	0.880	1.130	1.380	0.412	0.587	0.753	0.920	45	110	20
10	6	2	2	0.710	1.000	1.280	1.560	0.473	0.667	0.854	1.040	47	116	30
10	5	3	2	0.681	0.985	1.265	1.550	0.455	0.657	0.843	1.035	47	116	24
10	4	5	1	0.674	0.975	1.250	1.540	0.448	0.650	0.835	1.030	47	116	20

*1 additional bar over support, length $\frac{2}{5}$ of span.

†2 additional bars over support, length $\frac{2}{5}$ of span.

TABLE 119] LABOR ON SLAB REINFORCEMENT [TIMES

For Costs see opposite page *See page 567*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

Tables based on average men—for quick men take ⅔ of values given below.

Column spacing is to be taken in the direction in which the slab reinforcement runs.

1 Panel per Bay means that slab is the full span given under Column Spacing.

2 Panels per Bay means that there is one intermediate beam, so that the span of slab is one-half the Column Spacing.

3 Panels per Bay means that there are two intermediate beams, so that the span of slab is one-third the Column Spacing.

Column Spacing	TIME IN MINUTES PER 100 SQUARE FEET														
	1 Panel per Bay					2 Panels per Bay					3 Panels per Bay				
	Bars 4″ c.c.—4 Bends per Bay					Bars 4″ c.c.—8 Bends per Bay					Bars 4″ c.c.—12 Bends per Bay				
ft.	¼ in. min.	⅜ in. min.	½ in. min.	⅝ in. min.	¾ in. min.	¼ in. min.	⅜ in. min.	½ in. min.	⅝ in. min.	¾ in. min.	¼ in. min.	⅜ in. min.	½ in. min.	⅝ in. min.	¾ in. min.
10	114	136	158	197	246	164	197	217	260	326	215	242	269	327	406
15	98	119	141	178	223	133	160	182	222	279	169	193	220	268	330
20	87	107	129	165	207	113	135	158	197	247	138	160	187	229	287
30	78	97	119	153	192	94	116	128	175	221	121	133	159	198	248
	Bars 6″ c.c.—4 Bends per Bay					Bars 6″ c.c.—8 Bends per Bay					Bars 6″ c.c.—12 Bends per Bay				
10	75	94	109	132	167	108	129	148	176	220	142	167	186	216	275
15	65	83	98	119	151	86	109	125	150	188	112	135	152	180	228
20	58	76	90	110	140	72	95	110	133	167	92	113	130	156	196
30	53	66	81	103	131	64	79	93	118	149	75	90	107	133	169
	Bars 8″ c.c.—4 Bends per Bay					Bars 8″ c.c.—8 Bends per Bay					Bars 8″ c.c.—12 Bends per Bay				
10	59	70	80	101	126	102	116	132	154	194	110	122	140	167	206
15	51	62	72	91	114	82	93	107	128	162	87	97	114	137	171
20	45	56	66	84	105	68	78	92	111	140	72	81	96	117	147
30	41	51	61	79	98	56	65	78	97	122	59	66	84	101	127
	Bars 12″ c.c.—4 Bends per Bay					Bars 12″ c.c.—8 Bends per Bay					Bars 12″ c.c.—12 Bends per Bay				
10	40	47	56	68	86	56	66	74	90	114	74	84	93	110	140
15	35	42	49	63	79	46	55	63	77	98	59	67	76	92	117
20	32	38	45	59	74	39	47	55	68	87	49	56	65	80	101
30	28	35	42	54	68	33	41	49	61	77	40	47	55	69	87

TABLE 120] LABOR ON SLAB REINFORCEMENT [COSTS

LABOR AT 30¢ PER HOUR

For Times, see page 596 *For 10¢ rate see page 598*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 606

Column spacing is to be taken in the direction in which the slab reinforcement runs.

1 Panel per Bay means that slab is the full span given under Column Spacing.

2 Panels per Bay means that there is one intermediate beam, so that the span of slab is one-half the Column Spacing.

3 Panels per Bay means that there are two intermediate beams, so that the span of slab is one-third the Column Spacing.

Column Spacing	Cost in Dollars per 100 Square Feet														
	1 Panel per Bay					2 Panels per Bay					3 Panels per Bay				
	Bars 4″ c.c.—4 Bends per Bay					Bars 4″ c.c.—8 Bends per Bay					Bars 4″ c.c.—12 Bends per Bay				
ft.	¼ in. $	⅜ in. $	½ in. $	⅝ in. $	¾ in. $	¼ in. $	⅜ in. $	½ in. $	⅝ in. $	¾ in. $	¼ in. $	⅜ in. $	½ in. $	⅝ in. $	¾ in. $
10	0.75	0.90	1.05	1.30	1.62	1.08	1.30	1.43	1.72	2.16	1.41	1.60	1.78	2.16	2.68
15	0.65	0.79	0.94	1.18	1.48	0.89	1.05	1.21	1.47	1.85	1.11	1.27	1.45	1.79	2.23
20	0.57	0.71	0.86	1.09	1.37	0.75	0.89	1.05	1.30	1.64	0.92	1.06	1.24	1.52	1.90
30	0.52	0.64	0.79	1.02	1.27	0.62	0.77	0.85	1.16	1.46	0.80	0.88	1.05	1.31	1.64
	Bars 6″ c.c.—4 Bends per Bay					Bars 6″ c.c.—8 Bends per Bay					Bars 6″ c.c.—12 Bends per Bay				
10	0.49	0.62	0.72	0.87	1.11	0.72	0.85	0.98	1.16	1.45	0.94	1.10	1.22	1.42	1.81
15	0.44	0.55	0.65	0.79	1.01	0.57	0.72	0.83	1.00	1.25	0.75	0.90	1.01	1.19	1.50
20	0.39	0.50	0.60	0.73	0.93	0.48	0.63	0.73	0.88	1.10	0.61	0.75	0.86	1.03	1.29
30	0.35	0.44	0.53	0.68	0.86	0.42	0.52	0.62	0.78	0.99	0.49	0.59	0.70	0.88	1.12
	Bars 8″ c.c.—4 Bends per Bay					Bars 8″ c.c.—8 Bends per Bay					Bars 8″ c.c.—12 Bends per Bay				
10	0.39	0.46	0.53	0.67	0.82	0.67	0.76	0.87	1.02	1.28	0.73	0.80	0.92	1.10	1.36
15	0.34	0.41	0.48	0.61	0.75	0.54	0.62	0.71	0.86	1.08	0.56	0.65	0.76	0.92	1.13
20	0.30	0.37	0.44	0.56	0.70	0.45	0.52	0.60	0.74	0.93	0.48	0.54	0.64	0.77	0.97
30	0.27	0.33	0.40	0.52	0.65	0.37	0.43	0.51	0.64	0.81	0.39	0.44	0.56	0.67	0.84
	Bars 12″ c.c.—4 Bends per Bay					Bars 12″ c.c.—8 Bends per Bay					Bars 12″ c.c.—12 Bends per Bay				
10	0.26	0.31	0.37	0.45	0.56	0.37	0.43	0.49	0.59	0.75	0.49	0.55	0.61	0.73	0.93
15	0.23	0.28	0.33	0.42	0.53	0.31	0.36	0.42	0.51	0.65	0.40	0.45	0.51	0.61	0.77
20	0.21	0.25	0.30	0.39	0.50	0.26	0.31	0.37	0.45	0.57	0.32	0.37	0.43	0.53	0.66
30	0.18	0.23	0.28	0.36	0.45	0.22	0.27	0.32	0.40	0.51	0.26	0.31	0.36	0.45	0.57

TABLE 121] LABOR ON SLAB REINFORCEMENT [COSTS

LABOR AT 10¢ PER HOUR

For Times see page 596 *For 30¢ rate see page 597*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

Column spacing is to be taken in the direction in which the slab reinforcement runs.

1 Panel per Bay means that slab is the full span given under Column Spacing.

2 Panels per Bay means that there is one intermediate beam, so that the span of slab is one-half the Column Spacing.

3 Panels per Bay means that there are two intermediate beams, so that the span of slab is one-third the Column Spacing.

Column Spacing	Cost in Dollars per 100 Square Feet														
	1 Panel per Bay					2 Panels per Bay					3 Panels per Bay				
	Bars 4″ c.c.—4 Bends per Bay					Bars 4″ c.c.—8 Bends per Bay					Bars 4″ c.c.—12 Bends per Bay				
ft.	$\frac{1}{4}$ in. $	$\frac{3}{8}$ in. $	$\frac{1}{2}$ in. $	$\frac{5}{8}$ in. $	$\frac{3}{4}$ in. $	$\frac{1}{4}$ in. $	$\frac{3}{8}$ in. $	$\frac{1}{2}$ in. $	$\frac{5}{8}$ in. $	$\frac{3}{4}$ in. $	$\frac{1}{4}$ in. $	$\frac{3}{8}$ in. $	$\frac{1}{2}$ in. $	$\frac{5}{8}$ in. $	$\frac{3}{4}$ in. $
10	0.25	0.30	0.35	0.43	0.54	0.36	0.43	0.48	0.58	0.72	0.47	0.54	0.59	0.72	0.89
15	0.22	0.26	0.31	0.39	0.49	0.30	0.35	0.40	0.49	0.62	0.37	0.42	0.48	0.60	0.74
20	0.19	0.24	0.29	0.36	0.46	0.25	0.29	0.35	0.43	0.55	0.31	0.35	0.41	0.51	0.63
30	0.17	0.21	0.26	0.34	0.42	0.21	0.26	0.28	0.39	0.50	0.27	0.29	0.35	0.44	0.55
	Bars 6″ c.c.—4 Bends per Bay					Bars 6″ c.c.—8 Bends per Bay					Bars 6″ c.c.—12 Bends per Bay				
10	0.17	0.20	0.24	0.29	0.37	0.24	0.28	0.33	0.39	0.48	0.31	0.36	0.41	0.47	0.60
15	0.15	0.18	0.22	0.26	0.34	0.19	0.24	0.28	0.33	0.42	0.25	0.30	0.34	0.40	0.50
20	0.13	0.17	0.20	0.24	0.31	0.16	0.21	0.25	0.29	0.37	0.20	0.25	0.29	0.34	0.43
30	0.12	0.15	0.18	0.23	0.29	0.14	0.17	0.21	0.26	0.33	0.16	0.20	0.23	0.29	0.37
	Bars 8″ c.c.—4 Bends per Bay					Bars 8″ c.c.—8 Bends per Bay					Bars 8″ c.c.—12 Bends per Bay				
10	0.13	0.15	0.17	0.22	0.27	0.22	0.25	0.29	0.34	0.43	0.24	0.27	0.31	0.37	0.46
15	0.11	0.14	0.16	0.20	0.25	0.18	0.21	0.24	0.29	0.36	0.19	0.22	0.25	0.31	0.38
20	0.10	0.12	0.15	0.19	0.23	0.15	0.17	0.20	0.25	0.31	0.16	0.18	0.21	0.26	0.32
30	0.09	0.11	0.13	0.17	0.22	0.12	0.14	0.17	0.21	0.27	0.13	0.15	0.19	0.22	0.28
	Bars 12″ c.c.—4 Bends per Bay					Bars 12″ c.c.—8 Bends per Bay					Bars 12″ c.c.—12 Bends per Bay				
10	0.09	0.10	0.12	0.15	0.19	0.12	0.14	0.16	0.20	0.25	0.16	0.18	0.20	0.24	0.31
15	0.08	0.09	0.11	0.14	0.18	0.10	0.12	0.14	0.17	0.22	0.13	0.15	0.17	0.20	0.26
20	0.07	0.08	0.10	0.13	0.16	0.09	0.10	0.12	0.15	0.19	0.11	0.12	0.14	0.18	0.22
30	0.06	0.08	0.09	0.12	0.15	0.07	0.09	0.11	0.13	0.17	0.09	0.10	0.12	0.15	0.19

TABLE 122] LABOR ON WALL REINFORCEMENT

See p. 567

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 605

Spacing Each Way	Time in Minutes per 100 Square Feet Surface Area					Cost in Dollars per 100 Square Feet Surface Area, 10¢ per Hour					Cost in Dollars per 100 Square Feet Surface Area, 30¢ per Hour				
	¼-Inch Bars	⅜-Inch Bars	½-Inch Bars	⅝-Inch Bars	¾-Inch Bars	¼-Inch Bars	⅜-Inch Bars	½-Inch Bars	⅝-Inch Bars	¾-Inch Bars	¼-Inch Bars	⅜-Inch Bars	½-Inch Bars	⅝-Inch Bars	¾-Inch Bars
in.	min.	min.	min.	min.	min.	$	$	$	$	$	$	$	$	$	$
36	—	—	—	30	36	—	—	—	0.07	0.08	—	—	—	0.20	0.24
24	—	36	42	48	54	—	0.08	0.09	0.11	0.12	—	0.24	0.27	0.32	0.36
12	84	96	102	114	132	0.18	0.22	0.23	0.25	0.29	0.55	0.64	0.67	0.75	0.87
8	168	180	198	216	240	0.37	0.40	0.43	0.47	0.53	1.11	1.19	1.30	1.42	1.58
6	276	294	318	336	—	0.61	0.65	0.70	0.74	—	1.82	1.94	2.10	2.22	—
4	576	—	—	—	—	1.26	—	—	—	—	3.79	—	—	—	—

For weights and percentages of steel in wall reinforcement, see Table 89.

IF STEEL IS CUT AT PLACE OF ERECTION

Time to be Added per Cut			Cost to be Added per Cut, 10¢ per Hour			Cost to be Added per Cut, 30¢ per Hour		
Size of Steel			Size of Steel			Size of Steel		
¼ Inch	⅜ Inch	½ Inch	¼ Inch	⅜ Inch	½ Inch	¼ Inch	⅜ Inch	½ Inch
min.	min.	min.	$	$	$	$	$	$
0.48	1.02	1.62	0.0010	0.0022	0.0035	0.0032	0.0067	0.0107

TIME AND COST OF WIRING ALL CONNECTIONS INCLUDED IN ABOVE TABLE

Time in Minutes per 100 Square Feet of Surface Area						Cost in Dollars per 100 Square Feet of Surface Area, 10¢ per Hour						Cost in Dollars per 100 Square Feet of Surface Area, 30¢ per Hour					
Spacing Each Way						Spacing Each Way						Spacing Each Way					
36 Inch	24 Inch	12 Inch	8 Inch	6 Inch	4 Inch	36 Inch	24 Inch	12 Inch	8 Inch	6 Inch	4 Inch	36 Inch	24 Inch	12 Inch	8 Inch	6 Inch	4 Inch
min.	min.	min.	min.	min.	min.	$	$	$	$	$	$	$	$	$	$	$	$
6.0	13.2	52.8	120.	212.	474.	0.013	0.029	0.116	0.264	0.466	1.042	0.039	0.087	0.348	0.792	1.398	3.126

If all connections are not wired, deduct the proper percentage of these values from totals given in table.

Example: What is the time per 100 square feet of surface area for ¼″ bars spaced 8″ each way, only one half of the bars being wired.

Solution: Since only one half of the bars are wired, we have from above times of wiring one half of 120 or 60 minutes. Time per 100 square feet, therefore, is 168 − 60 = 108 minutes or 1.8 hours.

WEIGHTS OF ROUND BARS AND NUMBER CARRIED PER LOAD (See p. 567)

An average man carries not over 60 pounds. For first-class men working under task and bonus, increase weights by about $\frac{1}{3}$.

Size Inches		Length of Bars in Feet																	
		1	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	40
$\frac{1}{8}$	W't. per Bar.	0.04	0.25	0.34	0.42	0.50	0.59	0.67	0.76	0.84	0.92	1.00	1.09	1.17	1.26	1.34	1.43	1.51	1.68
	Bars per load		200	175	145	120	100	180	160	140	195	180	165	150	140	130	125	120	115
	Men per load		1	1	1	1	1	2	2	2	3	3	3	3	3	3	3	3	3
$\frac{3}{16}$	W't. per Bar.	0.09	0.56	0.75	0.94	1.13	1.32	1.50	1.69	1.88	2.06	2.26	2.44	2.63	2.82	3.00	3.20	3.38	3.76
	Bars per load		100	80	60	50	45	80	70	60	90	80	75	65	63	60	55	50	45
	Men per load		1	1	1	1	1	2	2	2	3	3	3	3	3	3	3	3	3
$\frac{1}{4}$	W't. per Bar.	0.17	1.00	1.34	1.67	2.00	2.34	2.67	3.00	3.34	3.67	4.00	4.34	4.67	5.01	5.34	5.68	6.01	6.67
	Bars per load		50	40	30	25	21	36	33	30	27	25	25	33	30	28	26	25	22
	Men per load		1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	3	3
$\frac{5}{16}$	W't. per Bar.	0.26	1.57	2.09	2.61	3.13	3.65	4.18	4.70	5.22	5.74	6.26	6.78	7.31	7.83	8.35	8.87	9.40	10.4
	Bars per load		38	28	23	19	16	29	25	23	21	19	18	16	15	21	20	19	17
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3
$\frac{3}{8}$	W't. per Bar.	0.37	2.25	3.00	3.75	4.50	5.25	6.00	6.75	7.50	8.25	9.00	9.75	10.5	11.2	12.0	12.7	13.5	15.0
	Bars per load		25	20	16	13	11	20	18	16	14	13	12	11	11	15	14	13	12
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3
$\frac{7}{16}$	W't. per Bar.	0.51	3.07	4.09	5.11	6.13	7.15	8.18	9.20	10.2	11.2	12.3	13.3	14.3	15.3	16.3	17.4	18.4	20.4
	Bars per load		19	15	12	11	8	15	13	12	11	10	9	8	8	11	10	10	9
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3
$\frac{1}{2}$	W't. per Bar.	0.67	4.00	5.34	6.67	8.00	9.34	10.6	12.0	13.3	14.6	16.0	17.3	18.7	20.0	21.3	22.7	24.0	26.6
	Bars per load		15	12	10	8	7	12	10	9	9	8	7	7	6	9	8	8	7
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3
$\frac{9}{16}$	W't. per Bar.	0.84	5.07	6.76	8.45	10.1	11.8	13.5	15.2	16.9	18.6	20.3	22.0	23.7	25.3	27.0	28.7	30.4	33.8
	Bars per load		12	9	8	6	5	9	8	7	6	6	5	5	5	7	6	6	5
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3
$\frac{5}{8}$	W't. per Bar.	1.04	6.26	8.34	10.4	12.5	14.6	15.7	18.8	20.9	22.9	25.0	27.1	29.2	31.3	33.4	35.5	37.5	41.6
	Bars per load		10	8	6	5	4	7	6	6	5	5	4	4	4	5	5	4	4
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3
$\frac{11}{16}$	W't. per Bar.	1.26	7.57	10.1	12.6	15.1	17.7	20.1	22.7	25.2	27.8	30.3	32.8	35.3	37.8	40.4	42.9	45.4	50.4
	Bars per load		9	6	5	4	3	6	5	5	4	4	4	3	3	5	4	4	4
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3
$\frac{3}{4}$	W't. per Bar.	1.50	9.00	12.0	15.0	18.0	21.0	24.0	27.0	30.0	33.0	36.0	39.0	42.0	45.0	48.0	51.0	54.0	60.0
	Bars per load		7	5	4	3	3	5	4	4	4	3	3	3	3	4	4	3	3
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3
$\frac{13}{16}$	W't. per Bar.	1.76	10.6	14.1	17.6	21.1	24.7	28.2	31.7	35.3	38.8	42.3	45.8	49.4	52.9	56.4	59.9	63.5	70.4
	Bars per load		6	4	4	3	2	4	4	4	3	3	3	2	2	3	3	3	3
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3
$\frac{7}{8}$	W't. per Bar.	2.04	12.3	16.4	20.4	24.5	28.6	32.7	36.8	40.8	45.0	49.0	53.1	57.2	61.3	65.4	69.5	73.6	81.6
	Bars per load		5	4	3	2	2	4	4	3	3	2	2	2	2	3	3	2	2
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3
$\frac{15}{16}$	W't. per Bar.	2.35	14.1	18.8	23.5	28.1	32.9	37.5	42.2	46.9	51.6	56.3	61.0	65.7	70.4	75.1	79.8	84.5	94.0
	Bars per load		4	3	2	2	2	3	3	3	2	2	2	2	2	2	2	2	2
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3

TABLE 123] **[CARRYING STEEL**

WEIGHTS OF ROUND BARS AND NUMBER CARRIED PER LOAD—Continued

(See p. 567)

An average man carries not over 60 pounds. For first-class men working under task and bonus, increase weights by about $\frac{1}{3}$.

Size Inches		Length of Bars in Feet																	
		1	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	40
1	W't. per Bar.	2.67	16.0	21.4	26.7	32.0	37.4	42.7	48.0	53.4	58.7	64.0	69.4	74.7	80.1	85.4	90.8	96.1	106
	Bars per load		4	3	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3
$1\frac{1}{8}$	W't. per Bar.	3.38	20.3	27.0	33.8	40.5	47.3	54.0	60.8	67.6	74.3	81.1	87.8	94.6	101	108	115	121	135
	Bars per load		3	2	2	1	1	2	2	2	1	1	1	1	2	2	2	2	2
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	3	3	4	4	4
$1\frac{1}{4}$	W't. per Bar.	4.17	25.0	33.4	41.7	50.0	58.4	66.8	75.1	83.5	91.8	100	108	117	125	133	142	150	167
	Bars per load		2	2	1	1	1	2	2	2	2	2	1	1	1	1	1	1	1
	Men per load		1	1	1	1	1	2	3	3	3	3	2	2	2	3	3	3	3
$1\frac{3}{8}$	W't. per Bar.	5.05	30.3	40.4	50.5	60.6	70.7	80.8	90.9	101	111	121	131	141	151	161	172	182	202
	Bars per load		2	1	1	1	1	2	2	2	1	1	1	1	1	1	1	1	1
	Men per load		1	1	1	1	1	3	3	3	2	2	2	2	3	3	3	3	3
$1\frac{1}{2}$	W't. per Bar.	6.00	36.0	48.0	60.0	72.1	84.1	96.1	108	120	132	144	156	168	180	192	204	216	240
	Bars per load		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Men per load		1	1	1	2	2	2	2	2	2	3	3	3	3	3	3	4	4
$1\frac{5}{8}$	W't. per Bar.	7.05	42.3	56.4	70.5	84.6	98.7	113	127	141	155	169	183	197	211	226	240	254	282
	Bars per load		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Men per load		1	1	1	2	2	2	2	2	3	3	3	3	4	4	4	4	5
$1\frac{3}{4}$	W't. per Bar.	8.18	49.0	65.4	81.8	98.2	115	131	147	164	180	197	213	229	246	262	279	295	327
	Bars per load		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Men per load		1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	6
$1\frac{7}{8}$	W't. per Bar.	9.39	56.3	75.1	93.9	113	131	150	169	188	207	225	244	263	282	301	319	338	376
	Bars per load		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Men per load		1	2	2	2	2	3	3	3	3	4	4	4	5	5	5	6	6
2	W't. per Bar.	10.7	64.2	85.6	107	128	150	171	193	214	235	257	278	299	321	342	364	385	428
	Bars per load		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Men per load		1	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7
$2\frac{1}{8}$	W't. per Bar.	12.0	72.0	96.0	120	144	168	192	216	240	264	288	312	336	360	384	408	432	480
	Bars per load		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Men per load		2	2	2	3	3	3	4	4	4	5	5	6	6	6	7	7	8
$2\frac{1}{4}$	W't. per Bar.	13.5	81.0	108	135	162	189	216	243	270	297	324	351	378	405	432	459	486	540
	Bars per load		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Men per load		2	2	2	3	3	4	4	5	5	5	6	6	7	7	8	8	9
$2\frac{3}{8}$	W't. per Bar.	15.0	90.0	120	150	180	210	240	270	300	330	360	390	420	450	480	510	540	600
	Bars per load		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Men per load		2	2	3	3	3	4	5	5	6	6	7	7	7	8	8	9	10
$2\frac{1}{2}$	W't. per Bar.	16.7	100	133	167	200	233	267	300	333	367	400	433	467	500	533	567	600	667
	Bars per load		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Men per load		2	2	3	3	4	5	5	6	6	7	7	8	8	9	10	10	11

TABLE 124]

WEIGHTS OF SQUARE BARS AND NUMBER CARRIED PER LOAD (See p. 567)

[CARRYING STEEL

An average man carries not over 60 pounds. For first-class men working under task and bonus, increase weights by about ⅓.

Size Inches		Length of Bars in Feet																	
		1	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	40
⅛	W't. per Bar	0.05	0.31	0.42	0.53	0.64	0.74	0.85	0.95	1.06	1.17	1.27	1.38	1.48	1.59	1.69	1.80	1.91	2.00
	Bars per load		200	142	112	95	80	140	127	115	155	142	130	120	114	106	100	95	90
	Men per load		1	1	1	1	1	2	2	2	3	3	3	3	3	3	3	3	3
3/16	W't. per Bar	0.12	0.71	0.95	1.19	1.43	1.67	1.90	2.14	2.38	2.62	2.86	3.09	3.33	3.57	3.81	4.05	4.28	4.80
	Bars per load		85	62	50	42	35	62	55	50	72	66	60	54	50	46	45	41	37
	Men per load		1	1	1	1	1	2	2	2	3	3	3	3	3	3	3	3	3
¼	W't. per Bar	0.21	1.27	1.70	2.12	2.54	2.97	3.39	3.82	4.24	4.66	5.09	5.51	5.94	6.36	6.78	7.21	7.63	8.40
	Bars per load		60	45	30	25	20	35	32	28	25	20	32	30	28	26	25	23	21
	Men per load		1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	3	3
5/16	W't. per Bar	0.33	2.00	2.66	3.33	4.00	4.66	5.33	5.99	6.66	7.33	7.99	8.65	9.32	9.99	10.6	11.3	12.0	13.2
	Bars per load		30	22	18	15	13	22	20	18	16	15	14	13	12	17	16	15	14
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3
⅜	W't. per Bar	0.48	2.87	3.82	4.78	5.74	6.69	7.65	8.60	9.56	10.5	11.5	12.4	13.4	14.3	15.3	16.2	17.2	19.2
	Bars per load		20	16	13	11	9	16	14	13	12	11	10	9	8	12	11	10	9
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3
7/16	W't. per Bar	0.65	3.91	5.21	6.51	7.81	9.11	10.4	11.7	13.0	14.3	15.6	16.9	18.2	19.5	20.8	22.1	23.4	26.0
	Bars per load		15	11	9	8	6	11	10	9	8	8	7	7	6	9	8	8	7
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3
½	W't. per Bar	0.85	5.10	6.80	8.50	10.2	11.9	13.6	15.3	17.0	18.7	20.4	22.1	23.8	25.5	27.2	28.9	30.6	34.0
	Bars per load		11	9	7	6	5	9	8	7	6	6	5	5	5	7	6	6	5
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3
9/16	W't. per Bar	1.07	6.46	8.61	10.7	12.9	15.0	17.2	19.3	21.5	23.6	25.8	27.9	30.1	32.3	34.4	36.6	38.7	42.8
	Bars per load		9	7	6	5	4	7	6	6	5	5	4	4	4	5	5	5	4
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3
⅝	W't. per Bar	1.33	7.97	10.6	13.3	15.9	18.6	21.3	23.9	26.6	29.2	31.9	34.6	37.2	39.8	42.5	45.1	47.8	53.2
	Bars per load		7	6	5	4	3	6	5	5	4	4	3	3	3	4	4	4	3
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3
11/16	W't. per Bar	1.61	9.65	12.8	16.1	19.3	22.5	25.7	28.9	32.2	35.4	38.6	41.8	45.0	48.2	51.4	54.7	57.9	64.4
	Bars per load		6	5	4	3	3	5	4	4	4	3	3	3	2	3	3	3	3
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3
¾	W't. per Bar	1.91	11.5	15.3	19.1	22.9	26.8	30.6	34.4	38.3	42.0	45.9	49.7	53.6	57.4	61.2	65.0	68.9	76.4
	Bars per load		5	4	3	3	2	4	4	3	3	2	2	2	2	3	3	2	2
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3
13/16	W't. per Bar	2.24	13.5	17.9	22.4	26.9	31.4	35.9	40.4	44.9	49.4	53.9	58.4	62.9	67.3	71.8	76.3	80.8	89.6
	Bars per load		5	3	3	2	2	4	3	3	2	2	2	2	2	2	2	2	2
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3
⅞	W't. per Bar	2.60	15.6	20.8	26.0	31.2	36.4	41.6	46.8	52.0	57.3	62.5	67.7	72.9	78.0	83.3	88.5	93.7	104
	Bars per load		4	3	2	2	2	3	3	2	2	2	2	1	1	2	2	2	2
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3
15/16	W't. per Bar	2.99	17.9	23.9	29.9	35.9	41.8	47.8	53.8	59.8	65.8	71.7	77.7	83.7	89.7	95.6	101	107	120
	Bars per load		3	3	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2
	Men per load		1	1	1	1	1	2	2	2	2	3	3	3	3	3	3	3	4

TABLE 124] **WEIGHTS OF SQUARE BARS AND NUMBER CARRIED PER LOAD—Continued** [CARRYING STEEL

(See p. 567)

An average man carries not over 60 pounds. For first-class men working under task and bonus, increase weights by about $\frac{1}{3}$.

Size Inches		Length of Bars in Feet 1	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	40
1	W't. per Bar	3.40	20.4	27.2	34.0	40.8	47.6	54.4	61.2	68.0	74.8	81.6	88.4	95.2	102	108	115	122	136
	Bars per load		3	2	2	1	1	2	2	2	1	2	2	2	2	1	1	1	1
	Men per load		1	1	1	1	1	2	2	2	2	3	3	3	3	3	3	3	3
$1\frac{1}{8}$	W't. per Bar	4.30	25.8	34.4	43.0	51.6	60.2	68.8	77.4	86.0	94.7	103	111	120	129	137	146	155	172
	Bars per load		2	2	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1
	Men per load		1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3
$1\frac{1}{4}$	W't. per Bar	5.31	31.9	42.5	53.1	63.7	74.4	85.0	95.6	106	116	127	138	148	159	169	180	191	212
	Bars per load		2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Men per load		1	1	1	1	2	2	2	2	2	2	3	3	3	3	3	3	3
$1\frac{3}{8}$	W't. per Bar	6.43	38.6	51.4	64.3	77.1	90.0	102	115	128	141	154	167	180	192	205	218	231	257
	Bars per load		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Men per load		1	1	1	2	2	2	2	2	3	3	3	3	3	4	4	4	4
$1\frac{1}{2}$	W't. per Bar	7.65	45.9	61.2	76.5	91.8	107	122	137	153	168	183	199	214	229	244	260	275	306
	Bars per load		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Men per load		1	1	2	2	2	2	2	3	3	3	4	4	4	4	4	4	5
$1\frac{5}{8}$	W't. per Bar	8.98	53.9	71.8	89.8	107	125	143	161	179	197	215	233	251	269	287	305	323	359
	Bars per load		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Men per load		1	2	2	2	2	3	3	3	3	4	4	4	5	5	5	5	6
$1\frac{3}{4}$	W't. per Bar	10.4	62.4	83.2	104	125	145	166	187	208	229	249	270	291	312	333	353	374	416
	Bars per load		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Men per load		1	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7
$1\frac{7}{8}$	W't. per Bar	11.9	71.7	95.6	119	143	167	191	215	239	263	286	310	334	358	382	406	430	476
	Bars per load		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Men per load		2	2	2	3	3	3	4	4	4	5	5	6	6	6	7	7	8
2	W't. per Bar	13.6	81.6	108	136	163	190	217	244	272	299	326	353	380	408	435	462	489	544
	Bars per load		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Men per load		2	2	2	3	3	4	4	5	5	5	6	6	7	7	7	8	9
$2\frac{1}{8}$	W't. per Bar	15.3	92.1	123	153	184	215	246	276	307	338	368	399	430	460	491	522	553	612
	Bars per load		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Men per load		2	2	3	3	4	4	5	5	6	6	7	7	7	8	9	9	10
$2\frac{1}{4}$	W't. per Bar	17.2	103	138	172	207	241	276	310	244	379	413	448	482	517	551	585	620	688
	Bars per load		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Men per load		2	2	3	3	4	5	5	6	6	7	7	8	8	9	9	10	11
$2\frac{3}{8}$	W't. per Bar	19.2	115	153	192	230	269	307	345	384	422	460	499	537	575	614	652	690	768
	Bars per load		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Men per load		2	3	3	4	4	5	6	6	7	8	8	9	9	10	11	11	12
$2\frac{1}{2}$	W't. per Bar	21.2	127	170	212	255	297	341	383	426	467	511	553	596	638	681	723	765	848
	Bars per load		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Men per load		2	3	4	4	5	6	7	7	8	8	9	10	10	11	12	12	14

(Continued from page 569)

edition, page 518b. From the formula and table there given, we find the distance of 3 stirrups from the supports at each end to be 0.5 feet, 1.5 feet, and 3.1 feet, respectively.

Example 6: What is the difference in cost with labor at 30 cents per hour between assembling the reinforcement for the beams in Example 3 in place and assembling on horses and then placing?

Solution: From Table 112, page 589, the cost of assembling the reinforcement in place per beam is \$0.690 and for twelve beams is 12 × \$0.690 = \$8.280 or \$0.65 cheaper than assembling on horses and then placing as given in Example 3.

Slab Steel. *Example 7:* What would be the cost under average conditions of bending and placing $\frac{3}{8}$-inch round slab steel, spaced 8 inches apart with occasional cross reinforcement, and properly bent up over supports, in a floor 60 feet wide by 100 feet long, divided into bays 20 feet square, each bay having two intersecting beams?

Solution: Referring to Table 120, we find directly \$0.54 per 100 square feet of slab.

EXPLANATION FOR USE OF STEEL TABLES, PAGES 570 TO 603

Use Cost Tables ordinarily.

Use Time Tables only when estimator is thoroughly familiar with make-up of tables (see page 566).

Use columns marked "Average Men" ordinarily. Use "Quick Men" columns only where labor is exceptionally efficient.

The lengths of beams are the distances between centers of columns. For intermediate lengths, interpolate.

Tables apply to either round or square bars.

COST TABLES

Costs are given in "Dollars per Member."

Select cost per member corresponding to size and number or spacing of bars and length or area of member.

Use either 30¢ or 10¢ values and correct for actual wages paid. If wages are unknown use 30¢ values.

Costs are based on *average workmen* and *ordinary construction* and include handling, carrying, bending, and placing steel.

With inexperienced builders, increase costs by one-third.

Costs are figured from Times by adding 15% for ordinary construction and 15% extra for superintendence, contingencies, etc., as explained on page 566, but they do not include profit or home-office expenses.

TIME TABLES

Times are given in "Minutes per Member."

Select time per member corresponding to size and number or spacing of bars and length or area of member.

Multiply by average wage rate per minute.

Add proper per cent for superintendence, contingencies, etc. (15% used in Cost Tables, see p. 566).

Add 15% more unless work is exceptionally well managed, or—Add 50% (instead of 15%) if work is done by inexperienced builders.

Times are based on *average workmen* and *well organized* construction and include handling, carrying, bending, and placing steel. They also include delays occurring throughout the day and an allowance for foreman, sub-foremen, etc., but no allowance for superintendence, contingencies, etc., or for profit and home-office expenses. (See p. 566.)

EXPLANATION OF USE OF STEEL TABLES OF TIMES AND COSTS

CHAPTER XX

TABLES FOR DESIGNING FORMS

Many details of form design can be planned only by judgment and experience but the dimensions and spacing of supports for beams, slabs, and walls should be computed in order that the smallest necessary amount of lumber may be used.

The tables on the following pages have been carefully computed not merely from a theoretical standpoint but in accordance with the best practice in form design and construction. They are arranged (1) so that a designer can get at once, without computation, the exact dimensions and spacing of all centering and (2) so that the construction foreman or superintendent can decide how to place his centering, using the minimum amount of lumber, in case plans are not sent him from the office. Few construction men without long experience are able to vary the centering in the most economical manner with different column spacings, floor loads, etc., and in order to be on the safe side may use perhaps twice the lumber actually necessary. The extra cost of placing this also is a large item.

General principles of design are discussed in Chapter XVI and illustrations of different kinds and types of forms are shown there in drawings prepared by the authors.

Basis of Tables of Strength of Lumber. The values in Tables 125, 126 and 128, pages 609 to 611, are limited either by a fibre stress of 1200 pounds per square inch, a shearing stress of 100 pounds per square inch, or by a deflection of $\frac{1}{8}$ inch, the smallest of the three values being always selected. Tables 125, 126 and 128 are figured for $M=\frac{Wl}{10}$ for the moment, $H=\frac{3V}{2bd}$ for the shear, and $d=\frac{3}{384}\,\frac{Wl^3}{E\,I}$ for the deflection. The coefficient in the last formula is taken as an average between the values for the deflection of a beam with ends simply supported and a continuous beam. Table 126 has been figured for the sheathing continuous, partly continuous, and simply supported.

In Table 129, Spacing of Posts, the loads per linear foot of beam were figured using a depth of beam below slab of twice the width; 350 pounds per square inch was taken as the allowable fibre stress for 3 $\times$ 4-inch posts and 450 pounds for 4 $\times$ 4-inch posts.

The spacing of clamps in Figs. 77 to 79 is for the following conditions: Columns assumed to be filled rapidly with concrete exerting hydrostatic pressure; unit fiber stresses in clamps, 2400 lb. per sq. in., in sheathing, 1800 lb.; maximum deflection in clamps, $\frac{1}{4}$ inch, in sheathing, $\frac{1}{8}$ inch.

Pressure of Concrete. The pressure of concrete against column forms, used in making up the tables in this chapter, is the pressure of a liquid weighing 150 pounds per cubic foot. Tests and experience show that this pressure is actually exerted.

In mass work forms are filled slowly and the pressure is relieved by the stiffening of the concrete. The time of stiffening varies somewhat with the consistency, rate of setting of the cement, and character of the sand, but principally with the rate of filling and prevailing temperature. Tests by Major F. R. Shunk* on the pressure of wet mass concrete, see Table 127, although somewhat larger than the results of other tests, are on the safe side and avoid danger of breakage or the necessity of extra bracing.

EXAMPLES OF USE OF TABLES

Example 1: What is the correct spacing of 2 × 6-inch joists with a length of 6 feet to support forms for a 3-inch slab?

Solution: From Table 125, we find the spacing to be 28 inches.

Example 2: What spacing of studs is necessary for a wall form with $1\frac{1}{2}$-inch sheathing simply supported where the rate of filling the form is 4 vertical feet per hour?

Solution: Assuming the temperature of the concrete to be 60°, from Table 127 we find the pressure to be 980 pounds per square foot. From Table 126, we find the required spacing of studs to be 23 inches.

Example 3: What is the spacing of form stringers for an 8-inch flat slab and construction live load of 100 pounds per square foot?

Solution: From Table 126, we find the maximum spacing of joists, assuming the $1\frac{1}{2}$-inch sheathing to be continuous, is 40 inches. The load per linear foot of joists is a dead load of 100 pounds plus a live load of 100 pounds per square foot or 200 pounds times $3\frac{1}{3}$ or 667 pounds. From Table 128 by interpolation we find the necessary spacing of stringers for 2 × 6-inch joists to be 29 inches.

* *Engineering News*, September 9, 1909, page 288.

Example 4: What spacing of 4 × 4-inch posts is necessary to support the forms for 12 × 25-inch beams 8 feet c. c. with a 6-inch slab?

Solution: In Table 129, the spacing for the posts is given as $4\frac{3}{4}$ feet.

Example 5: How many 2 × 4-inch clamps on edge are necessary for a 30-inch square column, 12 feet high, with $1\frac{1}{2}$-inch sheathing?

Solution: Fig. 78, page 614, Column (g) shows 11 clamps as necessary.

Example 6: If in Example 5 the clamps were 3 × 4-inch, how many would be necessary?

Solution: Fig. 78, page 614, Column (j) gives 7 as the proper number of clamps.

Example 7: If in Example 5 the column was octagonal, how many 4 × 6-inch clamps would be necessary?

Solution: The necessary number of clamps is given as 6 in Fig. 77, page 613, Column (k).

TABLE 125] SPACING OF JOISTS IN SLAB FORMS [JOISTS FOR DIFFERENT SPANS

(See p. 607)

Joists are designed to support concrete slab, plus construction load of 75 lb. per sq. ft.

Limiting unit fibre and shearing stresses in joists 1200 and 100 lb. per sq. in. respectively. Deflection $\frac{1}{8}$ in.

Spacing of joists must never exceed, for 2″ plank, 50″; $1\frac{1}{2}$″ plank, 40″; 1″ board, 30″.

DISTANCE APART ON CENTERS OF JOISTS IN INCHES.

Dimensions of Joists	Spacing of 4 Foot Joists				Spacing of 6 Foot Joists				Spacing of 8 Foot Joists				Spacing of 10 Foot Joists			
	Thickness of Slab				Thickness of Slab				Thickness of Slab				Thickness of Slab			
Inches	3 in.	6 in.	9 in.	12 in.	3 in.	6 in.	9 in.	12 in.	3 in.	6 in.	9 in.	12 in.	3 in.	6 in.	9 in.	12 in.
2× 4	28	21	17	14	10											
2× 6	.....	.....	26	21	28	21	17	14								
2× 8	.....	.....	.....	.....	.....	28	23	19	25	20	16	13				
2×10	.....	.....	.....	.....	.....	.....	.....	.....	.....	36	21	18	21	16	13	
2×12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	21	35	26	20	17
3× 6	.....	.....	.....	.....	.....	32	26	22	16	12	10					
3× 8	.....	.....	.....	.....	.....	.....	.....	28	39	29	23	19	16	12		
3×10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	32	27	32	24	19	16
3×12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	39	30	25
4× 6	.....	.....	.....	.....	.....	.....	34	28	22	16	13					
4× 8	.....	.....	.....	.....	.....	.....	.....	.....	.....	39	31	26	22	16	13	
4×10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	42	31	25	21
4×12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	41	34

TABLE 126] SPACING OF WALL STUDS OR FLOOR JOISTS FOR DIFFERENT PRESSURES [STUDS OR JOISTS

(See p. 607)

Limiting unit fibre and shearing stresses in sheathing, 1200 and 100 lb. per sq. in. respectively. Deflection $\frac{1}{8}$ in.

DISTANCE APART ON CENTERS OF STUDS OR JOISTS IN INCHES.

Pressure in Pounds per Square Foot	Spacing of Joists or Struts if Sheathing is Continuous — Thickness of Sheathing			Spacing of Joists or Struts if Sheathing is Partly Continuous — Thickness of Sheathing			Spacing of Joists or Struts if Sheathing is Simply Supported — Thickness of Sheathing		
	1 in.	$1\frac{1}{2}$ in.	2 in.	1 in.	$1\frac{1}{2}$ in.	2 in.	1 in.	$1\frac{1}{2}$ in.	2 in.
100	30	40	50	30	40	50	30	40	50
200	30	40	50	30	40	50	28	39	48
300	30	40	50	30	40	50	26	35	43
400	29	40	50	27	38	47	24	32	40
500	27	40	50	24	36	45	22	31	39
600	25	38	50	22	33	44	20	29	36
700	22	33	44	20	30	41	18	27	35
800	21	32	42	19	28	38	17	26	34
900	20	29	39	18	27	36	16	24	32
1000	19	28	37	17	26	34	15	23	30
1100	17	26	36	16	25	33	14	22	29
1200	16	24	34	15	23	31	14	21	28
1300	15	22	33	15	22	29	13	20	26
1400	14	21	31	14	21	28	13	19	25
1500	13	19	30	13	19	28	12	18	25
1600	12	18	29	12	18	27	12	18	24
1700	11	17	28	11	17	26	11	17	23
1800	11	16	28	11	16	25	11	16	22
1900	10	15	27	10	15	25	10	15	22
2000	10	14	26	10	14	24	10	14	21

TABLE 127] PRESSURE OF MASS CONCRETE ON FORMS* [PRESSURE ON FORMS

PRESSURE IN POUNDS PER SQUARE FOOT

Rate of Filling Vertical Feet per Hour	Temperature				
	80°	70°	60°	50°	40°
2	530	560	600	680	790
3	690	720	810	920	1080
4	820	870	980	1130	1340
5	930	990	1120	1310	1570
6	1020	1090	1250	1480	1780
7	1090	1170	1350	1620	1970
8	1130	1240	1440	1740	

*Maj. Francis R. Shunk, U. S. A., *Engineering Record*, Jan. 15, 1910, p. 71.

TABLE 128] **[STRINGERS**

SPACING OF STRINGERS SUPPORTING WALL STUDS OR FLOOR JOISTS FOR DIFFERENT LOADS OR PRESSURES (See p. 607)

Load per linear foot of stud or joist equals pressure per square foot times distance apart of studs or joists.

Limiting unit fibre and shearing stresses in studs or joists, 1200 and 100 lb. per sq. in. respectively. Deflection $\frac{1}{8}$ in.

SPACING OF STRINGERS IN INCHES.

Dimensions of Stud or Joist	Load in Pounds per Linear Foot of Stud or Joist													
	200	400	600	800	1000	1200	1400	1600	1800	2000	2500	3000	3500	4000
Inches	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
2× 4 (Flat)	42	31	21	16	13	11	9	8						
2× 4 (Edge)	60	32	21	16	13	11	9	8	7	6				
2× 6	76	48	32	24	19	16	14	12	11	10	8			
2× 8	100	64	43	32	26	21	18	16	14	13	10	8		
2×10	120	80	53	40	32	27	23	20	18	16	13	11	9	8
3× 4	66	48	32	24	19	16	14	12	11	10	8			
3× 6	90	72	48	36	29	24	21	18	16	14	11	10	8	
3× 8	112	94	64	48	38	32	27	24	21	19	15	13	11	10
3×10	132	110	80	60	48	40	34	30	27	24	19	16	14	12
4× 4	71	60	43	32	26	21	18	16	14	13	10	8		
4× 6	97	81	64	48	38	32	27	24	21	19	15	13	11	10
4× 8	120	100	85	64	51	43	36	32	28	26	20	17	15	13
4×10	142	120	106	80	64	53	46	40	36	32	26	21	18	16
6× 6	108	76	62	54	48	44	40	36	32	29	23	19	16	14
6× 8	130	112	100	94	77	64	56	48	43	38	31	26	22	19
6×10	158	130	120	110	96	80	69	60	53	48	38	32	27	24
8× 8	142	120	108	100	95	85	73	64	57	51	41	34	29	26
8×10	170	142	128	120	112	106	92	80	71	64	52	42	36	32

WHEN TO USE TABLES 125, 126, 128 AND 129

For joists supporting slab forms between beams and girders — use Table 125.
See Figs. 54, 57, pp. 501, 504.

For joists supporting sheathing for flat slab construction — use Table 126.
See Figs. 62, 63, pp. 510, 511.

For vertical wall studs supporting sheathing — use Table 126.
See Figs. 67, 68, pp. 517, 518.

For stringers supporting joists — use Table 128.
See Fig. 62, p. 510.

For stringers supporting vertical wall studs — use Table 128.
See Figs. 67, 68, pp. 517, 518.

For posts supporting beams, girders, and flat slabs — useTable 129.
See Figs. 57, 62, pp. 504, 510.

SPACING OF POSTS FOR CONCRETE FLOOR CENTERING (See p. 608)

Unit stresses: 350 lb. per sq. in. in 3 x 4-in. posts, 450 lb. per sq. in. in 4 x 4-in. posts.

Posts support beam and slab, and construction live load of 75 lb. per sq. ft.

Spacings of posts under beams or girders limited to 5 feet unless stringers are used. If extra line of posts is placed under slabs between beams take slab spans as if an extra beam were placed between the actual beams.

Area of Section of Concrete Beam or Girder Below Slab	Thickness of Slab	Load per Linear Foot of Concrete Beam (Weight of Concrete plus Construction Live Load)				Spacing of Posts under Beams or Girders for Different Slab Spans							
						3 x 4 in. posts				4 x 4 in. posts			
		Span of Slab				Span of Slab				Span of Slab			
sq. in.	in.	4 ft.	8 ft.	12 ft.	16 ft.	4 ft.	8 ft.	12 ft.	16 ft.	4 ft.	8 ft.	12 ft.	16 ft.
		lb. pr. ft.	lb. pr. ft.	lb. pr. ft.	lb. pr. ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
	0	150	150	150	150								
100	3	550	1000	1450	1850	7¾	4¼	3	2¼	13	7¼	5	4
	6	700	1300	1900	2500	6	3¼	2¼	1¾	10¼	5½	3¾	3
	0	210	210	210	210								
150	3	600	1050	1500	1960	7	4	2¾	2¼	12	7	4¾	3¾
	6	750	1350	1950	2550	5½	3	2¼	1¾	9½	5¼	3¾	2¾
	0	270	270	270	270								
	3	660	1100	1560	2010	6½	3¾	2¾	2¼	11	6½	4½	3¾
200	6	810	1410	2010	2610	5¼	3	2	1¾	9	5	3½	2¾
	9	960	1700	2450	3200	4⅓	2½	1¾	1½	7½	4¼	3	2¼
	6	910	1510	2110	2710	4½	2¾	2	1½	8	4¾	3½	2¾
300	9	1060	1810	2550	3300	4	2¼	1½	1¼	6¾	4	2¾	2¼
	12	1210	2110	3010	3910	3½	2	1¼	1	6	3½	2½	1¾
	6	1120	1720	2320	2920	3¾	2½	1¾	1½	6½	4¼	3	2½
500	9	1270	2020	2760	3510	3¼	2	1½	1¼	5½	3½	2½	2
	12	1420	2320	3220	4120	3	1¾	1¼	1	5	3	2¼	1¾
	6	1640	2240	2840	3440	2½	2	1½	1¼	4½	3¼	2½	2
1000	9	1790	2540	3280	4030	2¼	1½	1¼	1	4	2¾	2¼	1¾
	12	1940	2840	3720	4640	2	1¼	1		3¾	2½	2	1½

SPACING OF POSTS FOR FLAT SLABS

Thickness of Slab	Spacing of Stringers									
	2 ft.		4 ft.		6 ft.		8 ft.		10 ft.	
	Size and Spacing of Posts along Stringers in Feet									
	3 x 4	4 x 4	3 x 4	4 x 4	3 x 4	4 x 4	3 x 4	4 x 4	3 x 4	4 x 4
in.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
3	18¼*	31*	9	15½*	6	10½	4½	7¾	3½	6¼
6	13	24*	7	12	4½	8	3½	6	2¾	4¾
9	10	17*	5	8½	3¼	5¾	2½	4¼	2	3½
12	9¼	16*	4½	8	3	5¼	2¼	4	1¾	3¼

* In practice, spacings of posts should be limited by strength of stringers.

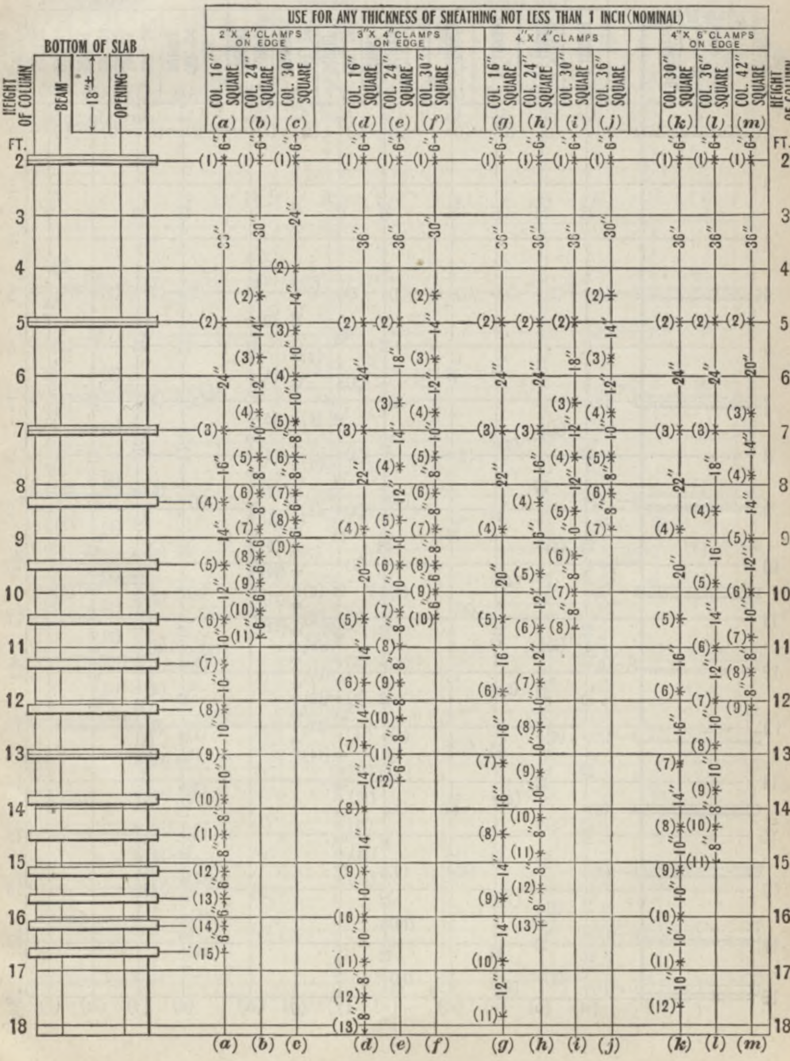
COLUMN FORMS

For spacings of clamps for square or rectangular columns see pp. 614–15.

Column sheathing 1 inch thick (nominal). Use of thicker sheathing does not decrease number of clamps used except for unusually short columns. Use of $1\frac{1}{4}$-inch lumber (nominal) is advised where forms are to be used more than twice.

Maximum unit fibre stresses: clamps, 2400 pounds; sheathing, 1800 pounds.

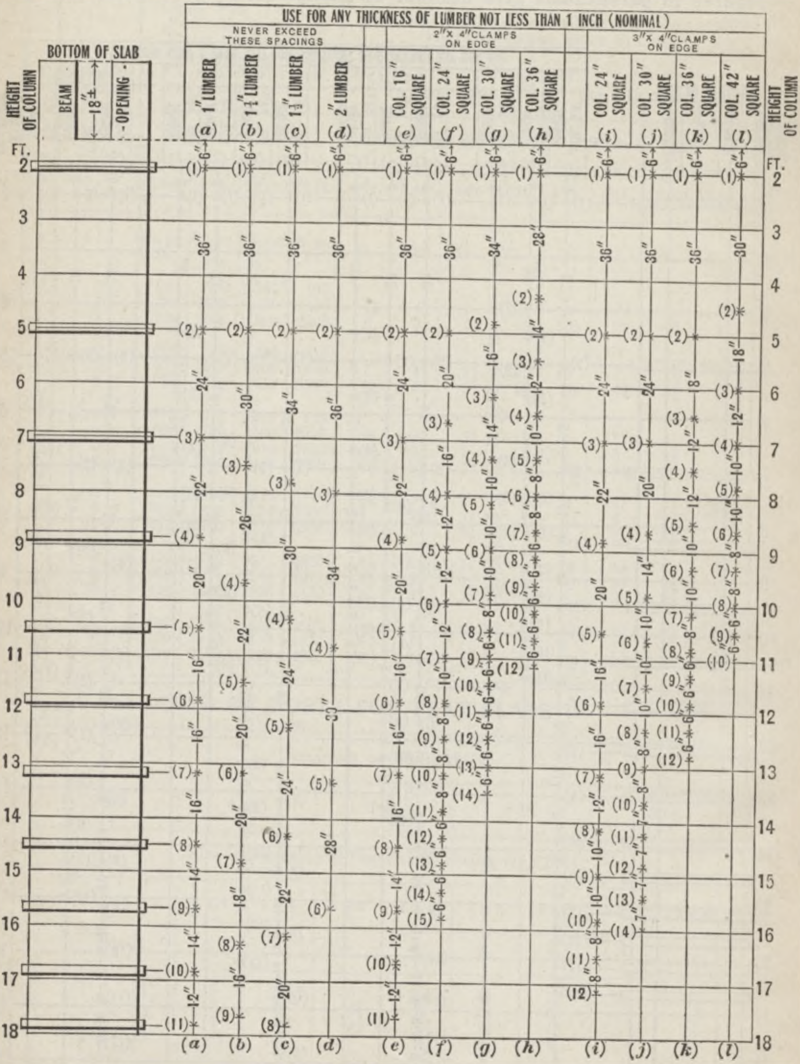
Figures in parenthesis give number of clamps for heights of column up to 18 feet.



SPACING OF CLAMPS FOR SQUARE OR RECTANGULAR COLUMN FORMS

For spacings for octagonal columns see page 613.

Column sheathing 1 inch thick (nominal). Use of thicker sheathing does not decrease number of clamps used except for unusually short columns. Use of $1\frac{1}{4}$-inch lumber (nominal) is advised where forms are to be used more than twice.

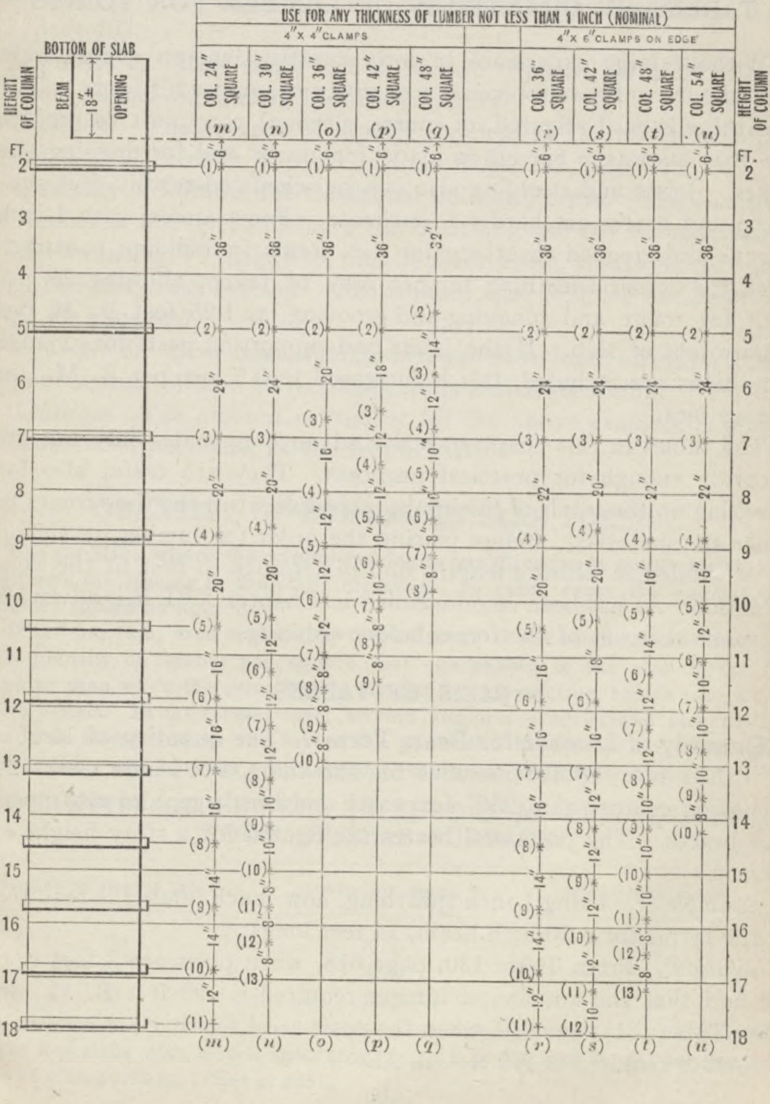


FIGS. 78-79] SPACING OF CLAMPS FOR SQUARE OR RECTANGULAR COLUMN FORMS—*Continued* [CLAMPS

For rectangular columns use spacings corresponding to large size of rectangle.

Maximum unit fibre stresses: clamps, 2400 pounds; sheathing, 1800 pounds.

Figures in parenthesis give number of clamps for heights of column up to 18 feet.



CHAPTER XXI

TABLES OF QUANTITIES OF LUMBER FOR FORMS

Without large experience in form construction, an estimator is almost sure to figure too small a quantity of lumber for forms. The sheathing is easily figured, of course, although care must be used to see that allowance enough is made for waste and for dressing the edges. Joists and studding also can be scheduled readily, but supports and braces are harder to estimate. For example, with 1-inch tongue-and-grooved sheathing for slab forms in building construction, the actual sheathing lumber may be taken, allowing 25 per cent for waste and tonguing-and-grooving, as 1.25 feet B. M. per square foot of slab. If the joists and supporting posts for average conditions are included, this is increased to 3.5 feet per B. M. per square foot.

The tables in this chapter are for advance estimates only, but are accurate enough for practical purposes. They are useful also for checking up the totals of the lumber schedule when the time comes to order the material. Before placing the order for lumber, it should be scheduled in definite lengths and dimensions to best fit the construction. As has been recommended in Chapter XVI, it is advisable to make sketches of the forms before ordering.

BASIS OF TABLES

Quantity of Lumber for Beam Forms. The quantity of lumber in Tables 130 and 131 includes the sheathing, 2 × 4-inch cleats 24 inches on centers, plus 25% for waste and breakage, and also posts and braces. The posts and braces are figured for a story height of 12 feet.

Example 1: Using 1-inch sheathing, how much lumber is required in the forms for a 20-inch beam, 14 feet long?

Solution: From Table 130, page 618, when posts are 3 feet c. c. we find that the amount of lumber required is 193 feet B. M., or, from Table 131, page 619, when the posts are 4 feet c. c., the amount of lumber required is 170 feet B. M.

Quantity of Lumber for Square Column Forms. The quantity of umber given in Table 132, page 620, includes the sheathing and the clamps spaced as shown in Fig. 77, page 613, plus 25% for waste, breakage, etc., and also includes a certain amount for cross bracing varying from 15 to 60 feet B. M. per column according to the height and spacing of the columns. The clamps are taken as shown in Fig. 49, page 493.

Example 2: How many feet B. M. are required per 16 × 16-inch column 12 feet high, using 1½-inch sheathing?

Solution: The amount of lumber required in the above example is taken as 239 feet B. M. directly from Table 132, page 620.

Quantity of Lumber for Octagonal Column Forms. The quantity of lumber in Table 133 includes the sheathing and the clamps spaced as shown in Fig. 79, page 615, plus 25% for waste, breakage, etc., and also includes cross bracing. The column was designed as shown in Fig. 50, page 495.

Example 3: How much lumber is required to build forms for a 20-inch octagonal column 16 feet long, using 2-inch sheathing?

Solution: The amount of lumber for the above example is given in Table 133, page 620, as 493 feet B. M.

QUANTITY OF LUMBER IN SLAB FORMS

Use for slabs where the column spacing in one direction is not greater than 1½ times the spacing in the other direction. In other cases the amount of lumber should be figured.

If the bay (i.e., area enclosed by four columns) is not subdivided by beams, the quantity of lumber per square foot chargeable to the slab forms is greater than when the same bay is divided by intersecting beams into 2 or more panels. In the former case, all the supports are charged directly to the slab forms and in the latter, the posts and braces for the beam and girder sides and bottoms are charged to the beam and girder forms.

QUANTITY OF LUMBER IN FEET B. M. PER SQUARE FOOT OF SLAB SURFACE

Number of Panels per Bay	1-inch Sheathing	1¼-inch Sheathing
1	3.50	3.85
2	3.00	3.30
3	2.50	2.75

For flat slabs with 1-inch sheathing, use 4.1 to 4.4 feet B. M. per square foot of slab surface. (See p. 645)

QUANTITY OF LUMBER FOR BEAM FORMS

(Including posts and braces)

Cleats, 2 × 4 inch on 24-inch centers.
Calculations are based on a 12 ft. story height.
25% added to lumber for waste.
For intermediate lengths take quantities midway.
If lengths are in feet and inches, take nearest foot length.

POSTS 4 × 4 INCH, 3 FEET C. TO C.

Depth of Beam Below Slab in.	Quantity of Lumber in Ft. B. M. per Beam Form												
	8*	10*	12*	14*	16*	18*	20*	22*	24*	26*	28*	30*	32*
1-inch Sheathing													
6	73	91	108	126	144	163	181	199	217	235	252	271	290
8	79	98	117	136	155	176	196	215	234	253	271	292	313
10	83	104	124	146	167	188	209	230	250	271	291	312	333
12	89	111	133	155	177	200	223	245	266	288	310	333	356
14	95	119	142	165	187	212	236	260	283	306	329	354	378
16	100	125	149	174	199	224	249	274	299	324	349	374	399
18	106	132	157	184	210	237	264	290	315	341	367	394	421
20	111	139	166	193	220	249	277	305	332	359	386	415	443
24	122	152	182	212	242	273	304	334	364	394	424	455	486
28	133	166	199	232	265	298	331	364	397	430	463	497	530
30	138	172	206	241	275	310	345	379	413	446	477	515	552
1½-inch Sheathing													
6	77	96	114	133	152	172	191	210	229	248	266	286	306
8	84	105	125	146	166	188	209	230	250	270	290	312	334
10	90	112	134	157	180	203	226	248	270	292	314	337	360
12	97	121	145	169	193	218	243	268	293	316	338	363	388
14	105	131	156	181	206	233	259	286	311	337	362	389	415
16	111	138	165	193	220	248	276	304	331	359	386	414	442
18	118	147	175	205	234	264	294	323	351	380	409	439	469
20	125	156	186	217	247	279	311	342	372	403	433	465	497
24	138	172	206	240	274	309	344	378	412	446	480	515	550
28	151	189	226	264	302	340	378	416	453	491	528	566	604
30	158	197	236	276	315	355	395	434	473	510	547	590	632
2-inch Sheathing													
6	81	101	120	140	160	181	201	221	241	261	280	301	322
8	89	111	133	155	176	199	222	244	265	287	309	332	355
10	97	121	144	169	193	218	243	267	290	314	337	362	387
12	105	131	157	183	209	236	263	289	314	340	366	393	420
14	114	142	170	198	225	254	283	311	339	367	395	424	453
16	122	152	181	211	241	272	303	333	363	393	423	454	485
18	130	162	193	226	258	291	324	356	387	419	451	484	517
20	138	172	206	240	274	309	344	378	412	446	480	515	550
24	154	192	230	268	306	345	384	422	460	498	536	575	614
28	170	212	254	297	339	382	424	467	509	552	594	637	679
30	178	222	266	311	355	400	445	489	533	575	617	665	712

*Length of beam in feet center to center of columns.

QUANTITY OF LUMBER FOR BEAM FORMS

(Including posts and braces)

Cleats, 2 × 4-inch on 24-inch centers.
Calculations are based on a 12 ft. story height.
25% added to lumber for waste.
For intermediate lengths take quantities midway.
If lengths are in feet and inches, take nearest foot length.

POSTS 4 × 4 INCH, 4 FEET C. TO C.

Depth of Beam Below Slab in.	QUANTITY OF LUMBER IN FT. B. M. PER BEAM FORM												
	8*	10*	12*	14*	16*	18*	20*	22*	24*	26*	28*	30*	32*
1-inch Sheathing													
6	59	74	88	103	118	133	147	162	177	192	206	221	236
8	65	81	97	113	129	146	162	178	194	210	225	242	259
10	69	87	104	123	141	158	175	193	210	228	245	262	279
12	75	94	113	132	151	170	189	208	226	245	264	283	302
14	81	102	122	142	161	182	202	223	243	263	283	304	324
16	86	108	129	151	173	194	215	237	259	281	303	324	345
18	92	115	137	161	184	206	230	253	275	298	321	344	367
20	97	122	146	170	194	219	243	268	292	316	340	370	399
24	108	135	162	189	216	243	270	297	324	351	378	405	432
28	119	149	179	209	239	261	293	322	357	382	407	442	476
30	124	155	186	218	249	280	311	342	373	402	431	465	498
1½-inch Sheathing													
6	63	79	94	110	126	142	157	173	189	205	220	236	252
8	70	88	105	123	140	158	175	196	216	230	244	262	280
10	76	95	114	134	154	173	192	211	230	249	268	287	306
12	83	104	125	146	167	188	209	230	250	271	292	313	334
14	91	114	136	158	180	203	225	248	271	294	316	339	361
16	97	121	145	170	194	218	242	267	291	316	340	364	388
18	104	130	155	182	208	234	260	286	311	337	363	389	415
20	111	139	166	194	221	249	277	305	332	360	387	415	443
24	124	155	186	217	248	279	310	341	372	401	430	463	496
28	137	172	206	241	276	310	344	379	413	448	482	516	550
30	144	180	216	253	289	325	361	397	433	467	501	540	578
2-inch Sheathing													
6	67	84	100	117	134	151	167	184	201	218	234	251	268
8	75	94	113	132	150	169	188	207	225	244	263	282	301
10	83	104	124	146	167	188	209	230	250	271	291	312	333
12	91	114	137	160	183	206	229	252	274	297	320	343	366
14	100	125	150	175	199	224	249	274	299	324	349	374	399
16	108	135	161	188	215	242	269	296	323	350	377	404	431
18	116	145	173	203	232	261	290	319	347	376	405	434	463
20	124	155	186	217	248	279	310	341	372	403	434	465	496
24	140	175	210	245	280	315	350	385	420	455	490	525	560
28	156	195	234	274	313	352	390	430	469	509	548	587	625
30	164	205	246	288	329	370	411	452	493	532	571	615	658

*Length of beam in feet center to center of columns.

SQUARE COLUMN FORMS (Fig. 49., p. 493)

Column clamps included, spacing of clamps shown in Fig. 77, p. 613.
Cross bracing between posts included.
25% has been added for waste, breakage, etc.
In figuring "Quantity of Lumber," sheathing is taken as thickness before planing.

Size of Column	Quantity of Lumber in Ft. B.M. per Column Form																				
	6 Ft.*			8 Ft.*			10 Ft.*			12 Ft.*			14 Ft.*			16 Ft.*			18 Ft.*		
in.	1″†	1½″†	2″†	1″†	1½″†	2″†	1″†	1½″†	2″†	1″†	1½″†	2″†	1″†	1½″†	2″†	1″†	1½″†	2″†	1″†	1½″†	2″†
8 × 8	70	84	87	89	106	115	133	144	157	152	167	185	181	190	213	241	243	270	270	277	309
10 × 10	76	92	100	97	118	129	144	159	176	165	185	207	197	210	239	259	267	300	291	304	343
12 × 12	83	102	109	106	130	144	156	174	195	179	203	230	214	232	265	279	291	331	314	332	378
14 × 14	89	110	120	115	142	153	167	188	213	192	221	252	229	252	291	297	315	360	334	359	412
16 × 16	96	120	131	124	154	174	179	204	232	206	239	275	246	274	318	316	339	391	356	387	447
18 × 18	102	128	142	132	166	188	190	218	250	219	257	297	261	294	344	334	363	420	377	414	481
20 × 20	109	138	153	141	178	204	201	234	269	233	275	320	278	316	371	354	387	451	399	442	516
22 × 22	115	146	164	150	190	218	212	248	288	246	293	342	294	336	397	372	411	480	420	469	550
24 × 24	122	156	175	158	202	233	224	264	307	260	311	365	311	358	423	392	435	512	443	497	585
26 × 26	128	164	186	167	214	247	235	278	325	273	329	387	326	378	449	410	459	541	463	524	619
28 × 28	135	174	197	176	226	263	247	294	344	287	347	410	343	400	476	429	480	572	485	552	654
30 × 30	141	182	208	184	238	277	258	308	362	300	365	432	358	420	502	453	507	601	505	579	689
32 × 32	148	192	236	193	250	310	269	324	398	331	400	472	392	459	546	484	565	666	545	607	757
34 × 34	154	200	247	201	262	325	280	338	417	347	418	495	409	480	572	503	590	697	567	657	792
36 × 36	161	210	259	210	274	340	292	354	437	359	437	518	426	502	599	525	615	729	608	698	828

TABLE 133] QUANTITY OF LUMBER FOR [LUMBER

OCTAGONAL COLUMN FORMS (Fig. 50, p. 495)

4 × 4-inch column clamps‡ included, spacing of clamps shown in Fig. 79, p. 615.
Cross bracing between posts included.
25% has been added for waste, breakage, etc.
In figuring "Quantity of Lumber," sheathing is taken as thickness before planing.

Size	Quantity of Lumber in Ft. B. M. per Column Form †																				
Diam. Side	6 Ft.*			8 Ft.*			10 Ft.*			12 Ft.*			14 Ft.*			16 Ft.*			18 Ft.*		
in. in.	1″	1½″	2″	1″	1½″	2″	1″	1½″	2″	1″	1½″	2″	1″	1½″	2″	1″	1½″	2″	1″	1½″	2″
8–3⅜	71	87	107	89	111	127	133	151	176	151	175	204	177	199	234	239	257	300			
12–5	85	107	132	107	137	159	159	185	214	180	214	252	213	242	289	283	310	364			
16–6⅝	98	125	155	127	162	189	183	217	255	210	253	300	249	294	346	325	362	428	480	525	624
18–7½	106	137	167	137	176	202	196	234	274	226	273	325	267	312	374	346	388	461	509	560	668
20–8⅝	114	146	181	145	188	221	208	250	294	241	292	348	285	335	401	367	413	493	540	594	707
22–9⅛	122	156	193	156	203	239	221	267	315	256	311	379	304	358	431	388	442	528	566	624	744
24–10	128	165	204	165	215	253	234	282	333	271	331	395	321	380	458	408	465	557	593	658	786
26–10¾	135	176	218	175	228	269	247	298	368	287	352	434	340	418	517	431	523	636	619	688	823
28–11⅝	141	185	229	183	240	284	260	314	389	300	370	460	358	440	545	451	549	669	647	721	864
30–12½	165	194	242	213	255	300	298	331	410	409	439	509	494	504	590	588	609	736	742	755	907
32–13⅜	173	204	255	223	267	333	312	363	446	428	460	533	517	529	621	607	637	770	774	790	950
34–14	181	215	267	234	280	349	327	381	469	448	482	560	540	556	652	632	668	807	803	818	984
36–15	188	224	278	243	293	365	340	397	490	466	503	584	563	579	681	651	695	841	834	851	1028
38–15¾	196	234	292	254	305	381	355	416	512	487	526	611	587	600	713	686	723	877	864	881	1066
40–16⅝	203	242	303	263	317	397	369	432	533	506	546	637	610	631	740	715	754	914	894	914	1107

*Height of column from top of floor to underside of slab.
†Thickness of sheathing after planing runs from ⅛″ to ¼″ less than value here given.
‡On columns over 10 ft. in length and 30″ diam., 4″×6″ clamps are used.

CHAPTER XXII

TABLES ON TIMES AND COSTS OF LABOR ON FORMS

The tables in this chapter have been prepared by the authors for computing the times and costs of labor on forms for reinforced concrete construction. The cost of materials is not included. Contrary to the usual way of stating costs, allowance has been made not only for the delays that are apt to occur during construction, but also for all the various overhead charges that are incident to such work, except central or home office expense. Profit is not included.

To reduce the labor of computation as much as possible, the times and costs are given in terms of per member, that is, per column form, per beam form, and so on. The estimator thus has only to schedule his members and take the costs direct from the table.

The ordinary methods of estimating forms make no distinction between the unit costs of forms for members of different sizes, nor do they allow for the effect upon the cost of the number of times the forms are used. The usual plan is to figure the cost of the forms in a structure in terms of the total volume of concrete or else in terms of per square foot of surface in contact. The errors incident to both of these methods may be readily illustrated. Suppose, for example, that the forms are figured in terms of the volume of concrete. A uniform cost of forms per cubic foot of concrete will give for a 24-inch column form a cost four times as large as for a 12-inch form. If the forms, on the other hand, are figured in terms of surface area, the 24-inch column form will be assumed to cost twice as much as the 12-inch form. Yet the actual labor cost of making a 24-inch column form is only about 40% greater than that of making a 12-inch column form of the same length. In erecting, the difference is even less.

The number of times the forms are used affects the cost to a large degree. If used only once, the entire cost of the materials and labor must be charged to that part of the structure. If used several times, only a portion of the cost of the materials and of the making should be charged to that part and the remainder distributed, according to the number of times used, to the rest of the structure.

Every contractor knows that re-making forms to reduce or increase their size is expensive, but very few have even an approximate idea of what the actual difference in cost really is between re-using a form of the same size and remaking to a different size. A practical illustration of this difference is given on page 477. Variations in costs due to various causes may be determined by comparison of the values in the tables in this chapter.

Only wooden forms are treated in the tables. Steel forms, which are adapted to certain types of construction, are discussed briefly on page 456. The tables apply, however, not simply to building construction, but to other classes of reinforced construction as well.

BASIS OF TABLES

The tables are the results of studies, covering a period of several years, of the times and costs of making and erecting forms in actual reinforced concrete construction. The plan adopted has been similar to that employed so successfully by Mr. Taylor in the fixing of tasks in scientific management operations in industrial establishments. Time-studies of all the small units or elements in each piece of work were made on a large number of jobs, by methods described in Chapter IV. These unit times, which are given on pages 662 to 677, were then recombined, with due allowance for the delays and lost time occurring in construction work under the ordinary types of management; and the results were thoroughly checked by comparison with overall times. Several of the best contractors in the country* were consulted on many of the individual features and the final results were compared with actual cost records from the private cost sheets of contractors.

If the cost in the tables differ from personal records on previous similar jobs, the labor totals may be multiplied by a ratio based on this difference.

ARRANGEMENT OF TABLES OF MAKING AND ERECTING FORMS

The tables are arranged in three groups:

(1) Times and costs for estimates (See pages 630 to 647).

(2) Times of certain definite operations (See pages 655 to 661).

(3) Unit times (See pages 662 to 677).

*See Preface.

Estimates. Tables 134 to 154, pages 630 to 647. The tables for estimating the cost of labor on forms are arranged so that the average costs can be figured directly for the different members, such as (1) columns, (2) beams, (3) girders, (4) slabs, and (5) walls.

Two sets of estimating tables are given; one in times of labor in hours per member; and the other in costs of labor in dollars per member. The cost tables should always be used unless the estimator knows from his own data that the percentages for overhead charges are different from those given on page 653. In most cases the times are given on the left-hand page and the costs on the right. Neither the times nor costs can be used for setting tasks, since they include not only the carpenter labor but also the sawing of lumber on the mill-saw, laborers' work carrying and handling material, and foremen's time. The laborers' and the foremen's time is converted into carpenters' time; the value of a laborer, for example, being considered as half that of a carpenter. The times and costs also include an allowance for the rests and delays occurring throughout the day. The costs, but not the times, include also allowance for overhead charges as outlined below, but do *not* include home-office expense or profit. In figuring the costs, 10% has been added to the values in the tables of times, so as to apply more nearly to ordinary conditions, the times being based on work under ordinary management but fairly well handled, whereas the costs are for the general run of such work. The percentages allowed in both cases are tabulated on page 625.

Average Men and Conditions. As has been stated elsewhere, the values in the tables are based on average men working under the ordinary type of management. For exceptionally quick men working by the day under excellent superintendence, 30% may be deducted from the costs, or 20% from the times. For task-work under scientific management, a still further reduction should be made, as indicated on page 628.

Wages per Hour. Variation in the wages of carpenters is so great in different localities that a uniform rate of 50 cents per hour has been used in the tables as a fair average. The values are easily converted to any other rate per hour. For example, for a rate of 40 cents, deduct one-fifth from the cost; for 35 cents, divide by 10, by pointing off one decimal, and multiply by 7. A slide rule is convenient for converting to any other rate.

Column Headings. The column headings in the tables of time and of cost are identical. The general operations are similar for the different kinds of members, being classified as follows: Make forms for different story heights; Place and remove forms first time; Place and remove forms after first time (same size column); Remake, place, and remove forms.

Each of these headings is subdivided for columns of 6, 12, and 18-foot story heights respectively. Values for intermediate heights may be found by interpolation.

The items for making forms include the unloading of the lumber, sawing on a mill-saw, and making up, besides the labor of handling during these operations. The times or costs for making must be selected only for members for which new forms are to be made; for example, in a five-story building requiring one and one-half sets of forms, the values from this group are used only for one and one-half stories.

The values for placing and removing forms first time apply only to the same section of the building considered in making forms.

The placing and removing of forms after the first time, with no remaking, apply to the portion of the structure where the forms can be re-used without change.

The final group, remaking, placing, and removing, apply to portions of the structure where old forms are used and must be made over. The time and cost of remaking vary greatly under different conditions, but the values are figured to cover average conditions.

The sizes of columns given in the first column of the table range from 8 by 8-inch to 36 by 36-inch. For labor on ordinary rectangular columns, select the column corresponding to the largest dimension of the rectangle.

Values are given for 1-inch and 2-inch lumber, nominal thicknesses; for example, 1-inch lumber after planing is $\frac{7}{8}$-inch thick and 2-inch stock is $1\frac{7}{8}$-inch, or sometimes $1\frac{3}{4}$-inch. The times or costs of labor on $1\frac{1}{4}$-inch or $1\frac{1}{2}$-inch stock may be obtained by taking values part way between the 1-inch and 2-inch.

Folding Page. To allow space for full notes describing the way to use the tables, folding page 653 is given, which should be opened every time any of the tables are used.

Effect of Design. Each table refers to a page where a drawing is given showing the design upon which the times and costs are based.

Mill-Saw. The values of making forms assume that there is a mill-saw on the job so that there will be practically no hand sawing. In case no mill-saw is used, add 50% to the time or cost of making up.

Laborers' Work. In making up the tables, it is assumed that the carrying of the lumber is done chiefly by laborers. Actual experience proves that about 5% of the total labor cost is saved, in such work as the making and erecting of forms in reinforced concrete building construction, by utilizing laborers for carrying. By relieving the carpenters of all handling, a still further saving is effected.

Allowance for Miscellaneous Items and General Expense. The overhead charges in any construction job cut a very large figure in the total cost and a neglect of these items, or a too small allowance, is one of the most frequent causes of low estimates by both the engineer and the contractor.

The tables of times include allowances for foremen's time and other items included in the regular payroll, as shown in the tabulation below.

Items	Per cent to Add to Unit Times	
	Making Forms	Erecting Forms
	%	%
Foreman and sub-foreman	7.5	7.5
Sharpening tools and similar work	4.0	4.0
Saw-mill man's time on miscellaneous work	3.0	1.0
Making benches, templets, etc.	10.0	1.0
Odd staging and similar work		1.0
Contingencies such as delays due to weather conditions	2.5	2.5
	27.0	17.0

The tables of costs include the following allowances *in addition* to those in the time tables:

Contingencies occurring on ordinary form construction that is not handled by contractors with large experience	15.0%
Deduct for work done by laborers, such as carrying, etc.	5.0%
Total	10.0%
And also an extra allowance for:	
Superintendence and miscellaneous items	9.0%
Contingencies chargeable to labor but not estimated as part of pay roll	2.5%
Odd tools, etc., not carried to next job	0.5%
Liability insurance on employees and the public	3.0%
Total	15.0%

ESTIMATES FOR FORMS FOR I-BEAM CONSTRUCTION

Tables on pages 646 and 647 give times and costs for labor on beam forms in steel frame buildings, since the cost of this work is quite different from ordinary reinforced concrete.

The values are based on the assumption that the depth of the form is one inch greater than the depth of the I-beam. Slight variations from this design will not appreciably affect the times or costs.

CARRYING LUMBER

Table 156, page 655, is convenient for determining the number of pieces of lumber that one or two men should carry as a load under ordinary conditions and also gives the number of feet board measure in single pieces of lumber of different dimensions and length. A laborer or carpenter will frequently carry only one stick of lumber when he can just as well handle two or more.

The values, as stated, are based on a load per man not exceeding 70 pounds. An exceptionally good man may carry larger loads than are given, running up, say, to 80 pounds, with an occasional load as high as 90 pounds; but where these heavier loads are required, the men should be given a special incentive, such as a bonus, for the extra hard work.

From the table, a foreman can tell at once how many boards or plank an average man should carry, and whether it is more economical for one man or two men to handle lumber of certain dimensions. The foreman also can estimate with this aid how long it should take laborers to carry lumber to a definite distance. In making such an estimate, it may be assumed that a man will walk one way on an average, with due allowance for rest, 100 feet in 0.6 minutes. On an average, also, 0.6 minutes may be allowed for picking up a load of lumber and throwing it down on a pile.

TABLES OF TIMES OF DIFFERENT OPERATIONS

Tables 157 to 160, pages 658 to 661, will enable a superintendent or foreman to determine the approximate length of time it should take the carpenters to perform a definite piece of work, such as making up the side of a form or erecting a form. From these tables, also, the foreman can estimate how much work the men should do in a day.

The tables give the times of making and assembling forms for the principal members of a building, such as the time of making each of 4 types of column forms, times of making beam and girder forms and of assembling and erecting column, beam, and girder forms. Definite times like these cannot be given without making accurate assumptions as to the methods employed in handling the materials and the exact design of the forms. The tables refer to places where these details are described in full.

The tables, as stated in a preceding paragraph, are based on work that is well managed, since under careless management the sequence of operations for the carpenters and the amount of handling they must do are indefinite. Under scientific management where the lumber is brought to the carpenters and they have nothing to do but follow instructions given in writing or by drawings, with no unnecessary loss of time incident to looking up the foreman for directions, still quicker times can be made.

The times, then, apply to average or quick men working by the day, and not by piece-work or task-work. They include an allowance for delays occurring throughout the day. Thus the time for an average man to make a single section of form ought to be smaller than that given in the table, but the total number of sections made in one day, or in, say, several hours, should correspond with the times there given. In setting forms, a 50-foot carry is allowed by the carpenters. Under scientific management this carry can be much reduced.

SAWING LUMBER

Table 161, page 662, gives average and quick time per cut for different kinds of mill and hand sawing. The times include all necessary operations of handling incident to both kinds of work. The time per cut is given in every case, and must be multiplied by the number of cuts as indicated.

UNIT TIMES

The basis of all of the principal times and costs in this book is unit time study, as is discussed in Chapters IV and V. To obtain accurate times, it is necessary to find out, by the aid of a stop-watch, how long it takes to perform the individual elements or unit operations involved in the larger piece of work. The unit times, used in making up the tables of form construction in this chapter, are given in Tables 162 to 166, pages 664 to 676. The times in these tables differ from the times given in the other tables in this book in that they are net, that is, they include no allowance for rest or for delays occurring throughout the day. A description of each item is given in the second column of the tables. To indicate the kind of work to which the times apply, so that the right ones may be selected, the kind of member is designated by a letter; for example, Item (12) may be used (provided the boards are ripped by hand) either for columns, C, beams, B, girders, G, or slabs, S. Item (1) is apt to occur in the three types of columns designated, also in beams, girders, slabs, and walls. Item (3) applies to Type II of beams and Type II of girders, as well as to columns and slabs. If no letter is given, the item should not be included when figuring the kinds of members designated at the top of the column.

In the tables of assembling and erecting, the corresponding columns refer to the drawing showing details of the construction and also give the type to which the units apply.

The column headed "Unit" indicates the value that must be used for mutiplying the times. For example, where the unit is "Corner," the selected time must be multiplied by the number of corners; where the unit is "Cleat," the time must be multiplied by the number of cleats in the member; and so on.

Times are given for 1-inch, $1\frac{1}{2}$-inch, and 2-inch lumber, and are based both on average men and quick men.

The values given may be applied to task-work by selecting the proper items under quick men, omitting the units that in scientifically managed work are unnecessary, and adding a percentage to provide for the necessary delays and lost time that occur even in the best handled work.

The use of the tables is best illustrated by the examples on page 648. These show the method of making up total times from the unit times.

TASK-WORK IN FORM CONSTRUCTION

To introduce task-work in the making or erecting of forms, it is necessary to provide some definite system for handling materials and for keeping track of the work that is being accomplished. Methods that have proved satisfactory in practice are described in Chapter XVI.

The time of accomplishing a certain piece of work depends so largely upon the details of design and the manner in which the workman is supplied with materials that it seems impossible to give values of times and costs that will be exact enough to use in paying the men, even though we can give values that are accurate enough for estimates. To set tasks on any class of work, it is therefore advisable that the methods described in Chapter V be adopted, and that the fundamental characteristics of each piece of work be studied. In connection with this study, the tables of unit times already referred to will be found extremely useful and will provide much valuable data for comparison with actual observations, and also for filling in times that cannot be taken conveniently by a stopwatch.

To give an idea of what has been accomplished in form making by adopting methods of systematic planning, routing the materials to the carpenters, and then giving them a definite task to perform, we would say that costs of making form sections have been actually reduced as much as 50%. Comparing times for making up sections of forms by task-work under scientific management with times of average carpenters on the same work, there should be a reduction of about 65% in the time for performing the work. The reduction in cost will not be proportional because the overhead charges are increased by the cost of the labor of planning out the work in advance, the making out of the route sheets, and the recording of the tasks accomplished. Taking these into consideration, the reduction in cost should be from 30 to 60%.

TABLE 134] LABOR ON COLUMN FORMS **[TIMES**

TYPE 1.—IRON CLAMPS—Fig. 48, p. 491

For costs see opposite page *See pp. 614, 623 and 648*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 653

Size of Column	Time in Hours per Column											
	Make Forms* for Different Story Heights			Place and Remove Forms 1st Time†			Place and Remove Forms After 1st Time (Same size col.)			Remake, Place and Remove Forms		
	6 ft. hr.	12 ft. hr.	18 ft. hr.	6 ft. hr.	12 ft. hr.	18 ft. hr.	6 ft. hr.	12 ft. hr.	18 ft. hr.	6 ft. hr.	12 ft. hr.	18 ft. hr.
1-inch Lumber (Nominal)												
8″ × 8″	1.1	1.8	2.8	5.6	7.4	9.6	4.7	6.0	8.0	6.4	8.8	11.7
10″ × 10″	1.2	1.9	2.9	5.7	7.7	9.9	4.8	6.1	8.2	6.5	8.9	11.9
12″ × 12″	1.2	2.0	3.1	5.9	8.0	10.4	5.0	6.3	8.5	6.7	9.2	12.2
14″ × 14″	1.3	2.2	3.3	6.2	8.3	10.7	5.2	6.6	8.9	6.9	9.5	12.6
16″ × 16″	1.4	2.3	3.5	6.3	8.6	11.1	5.4	7.0	9.3	7.1	9.7	12.9
18″ × 18″	1.5	2.4	3.8	6.6	8.9	11.6	5.7	7.2	9.7	7.3	10.0	13.3
20″ × 20″	1.5	2.6	4.0	6.8	9.2	11.9	5.9	7.5	10.1	7.5	10.3	13.7
22″ × 22″	1.6	2.7	4.2	7.1	9.5	12.3	6.1	7.8	10.5	7.7	10.6	14.1
24″ × 24″	1.7	2.9	4.4	7.4	9.8	12.8	6.4	8.1	10.9	7.9	10.8	14.5
26″ × 26″	1.9	3.1	4.8	7.7	10.2	13.4	6.6	8.5	11.3	8.3	11.3	15.0
28″ × 28″	2.1	3.5	5.3	8.1	11.0	14.4	7.0	8.9	11.9	8.6	11.8	15.6
30″ × 30″	2.2	3.7	5.6	8.4	11.1	14.6	7.2	9.2	12.3	8.8	12.1	16.0
32″ × 32″	2.3	3.8	5.8	8.6	11.6	14.9	7.4	9.5	12.7	9.0	12.3	16.4
34″ × 34″	2.4	4.0	6.1	8.9	11.9	15.3	7.6	9.7	13.0	9.2	12.6	16.7
36″ × 36″	2.5	4.1	6.3	9.0	12.0	15.8	7.9	10.0	13.5	9.4	12.9	17.1
2-inch Lumber (Nominal)												
8″ × 8″	1.4	2.4	3.7	6.3	8.6	11.1	5.7	7.3	9.8	8.3	11.3	15.1
10″ × 10″	1.5	2.5	3.9	6.6	8.9	11.6	6.0	7.5	10.0	8.5	11.6	15.4
12″ × 12″	1.6	2.7	4.1	6.9	9.2	12.0	6.1	7.7	10.3	8.7	11.9	15.8
14″ × 14″	1.7	2.9	4.4	7.1	9.6	12.5	6.4	8.1	10.8	8.9	12.3	16.3
16″ × 16″	1.8	3.1	4.7	7.4	9.9	12.9	6.6	8.5	11.3	9.2	12.6	16.8
18″ × 18″	2.0	3.2	5.0	7.7	10.2	13.4	6.9	8.8	11.8	9.5	13.0	17.3
20″ × 20″	2.0	3.4	5.2	8.0	10.7	13.8	7.2	9.2	12.3	9.8	13.4	17.8
22″ × 22″	2.2	3.6	5.5	8.3	11.0	14.3	7.5	9.5	12.8	10.0	13.8	18.3
24″ × 24″	2.3	3.8	5.8	8.6	11.4	14.9	7.7	9.9	13.3	10.3	14.1	18.8
26″ × 26″	2.5	4.1	6.3	8.9	11.9	15.5	8.1	10.3	13.9	10.7	14.7	19.5
28″ × 28″	2.7	4.6	7.0	9.5	12.6	16.4	8.5	10.8	14.5	11.2	15.3	20.3
30″ × 30″	2.9	4.8	7.3	9.6	12.9	16.8	8.8	11.2	15.0	11.4	15.7	20.8
32″ × 32″	3.0	5.0	7.7	9.9	13.4	17.3	9.1	11.5	15.5	11.7	16.0	21.3
34″ × 34″	3.1	5.2	8.0	10.2	13.7	17.9	9.3	11.8	15.9	11.9	16.4	21.8
36″ × 36″	3.3	5.4	8.3	10.5	14.0	18.2	9.6	12.1	16.4	12.2	16.7	22.2

*If old form lumber is used add 90% to "Make Forms."
†Values increased 50% as labor is generally inefficient on first set up.

TABLE 135] **LABOR ON COLUMN FORMS** [COSTS

TYPE 1.—IRON CLAMPS—Fig. 48, p. 491

For times see opposite page *See pp. 614, 623 and 648*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 653

Size of Column	Cost in Dollars per Column											
	Make Forms for Different Story Heights*			Place and Remove Forms 1st Time†			Place and Remove Forms After 1st Time (Same size col.)			Remake, Place and Remove Forms		
	6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $
1-inch Lumber (Nominal)												
8″ × 8″	0.70	1.16	1.76	3.50	4.68	6.09	2.96	3.77	5.06	4.05	5.53	7.37
10″ × 10″	0.74	1.21	1.86	3.62	4.83	6.29	3.05	3.89	5.21	4.12	5.64	7.51
12″ × 12″	0.77	1.29	1.98	3.74	5.01	6.53	3.14	4.01	5.37	4.22	5.79	7.70
14″ × 14″	0.81	1.37	2.11	3.89	5.19	6.77	3.29	4.20	5.63	4.37	5.98	7.95
16″ × 16″	0.87	1.46	2.24	4.04	5.45	7.04	3.44	4.40	5.86	4.49	6.16	8.18
18″ × 18″	0.92	1.54	2.37	4.19	5.61	7.29	3.59	4.57	6.11	4.62	6.34	8.42
20″ × 20″	0.97	1.64	2.50	4.31	5.79	7.53	3.74	4.75	6.38	4.77	6.51	8.66
22″ × 22″	1.03	1.71	2.64	4.49	6.00	7.82	3.88	4.94	6.62	4.90	6.70	8.92
24″ × 24″	1.08	1.80	2.75	4.64	6.20	8.06	4.03	5.14	6.88	5.02	6.86	9.14
26″ × 26″	1.19	1.98	3.02	4.83	6.50	8.45	4.20	5.36	7.18	5.22	7.16	9.51
28″ × 28″	1.32	2.19	3.36	5.13	6.89	9.11	4.40	5.61	7.52	5.44	7.44	9.89
30″ × 30″	1.38	2.31	3.53	5.28	7.07	9.20	4.54	5.79	7.77	5.56	7.62	10.14
32″ × 32″	1.44	2.39	3.66	5.42	7.28	9.44	4.69	5.98	8.03	5.70	7.81	10.36
34″ × 34″	1.50	2.50	3.82	5.55	7.49	9.71	4.81	6.14	8.21	5.81	7.95	10.58
36″ × 36″	1.56	2.61	3.98	5.70	7.64	9.93	4.98	6.33	8.51	5.95	8.14	10.80
2-inch Lumber (Nominal)												
8″ × 8″	0.91	1.52	2.33	4.04	5.45	7.07	3.61	4.60	6.18	5.24	7.18	9.56
10″ × 10″	0.96	1.60	2.45	4.17	5.61	7.28	3.79	4.74	6.33	5.36	7.34	9.74
12″ × 12″	1.03	1.70	2.61	4.34	5.84	7.55	3.85	4.90	6.53	5.49	7.52	9.99
14″ × 14″	1.08	1.82	2.78	4.50	6.06	7.83	4.03	5.14	6.85	5.65	7.77	10.32
16″ × 16″	1.16	1.93	2.95	4.67	6.27	8.18	4.20	5.36	7.15	5.83	7.99	10.63
18″ × 18″	1.24	2.04	3.14	4.83	6.50	8.46	4.38	5.56	7.44	6.01	8.25	10.95
20″ × 20″	1.29	2.16	3.29	5.00	6.72	8.75	4.54	5.82	7.77	6.18	8.47	11.25
22″ × 22″	1.36	2.27	3.46	5.19	6.96	9.03	4.74	6.02	8.09	6.34	8.70	11.54
24″ × 24″	1.42	2.39	3.63	5.36	7.20	9.38	4.90	6.25	8.40	6.51	8.92	11.88
26″ × 26″	1.56	2.61	3.98	5.58	7.53	9.80	5.12	6.53	8.77	6.78	9.30	12.33
28″ × 28″	1.72	2.90	4.41	5.93	8.00	10.32	5.37	6.84	9.14	7.06	9.66	12.84
30″ × 30″	1.82	3.04	4.63	6.11	8.19	10.65	5.55	7.06	9.47	7.22	9.92	13.17
32″ × 32″	1.90	3.16	4.85	6.39	8.45	10.95	5.73	7.30	9.81	7.41	10.14	13.47
34″ × 34″	1.98	3.30	5.04	6.44	8.66	11.25	5.87	7.49	10.03	7.55	10.36	13.76
36″ × 36″	2.06	3.44	5.25	6.60	8.87	11.51	6.07	7.66	10.36	7.73	10.58	14.06

* If old form lumber is used add 90% to "Make Forms."
† Values increased 50% as labor is generally inefficient on first set up.

TABLE 136] LABOR ON COLUMN FORMS [TIMES

TYPE 2.—WOOD WEDGE CLAMPS—Fig. 49B, p. 493

For costs see opposite page *See pp. 614, 623 and 648*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 653

Size of Column	TIME IN HOURS PER COLUMN											
	Make Forms for Different Story Heights*			Place and Remove Forms 1st Time†			Place and Remove Forms After 1st Time (Same size col.)			Remake, Place and Remove Forms		
	6 ft. hr.	12 ft. hr.	18 ft. hr.	6 ft. hr.	12 ft. hr.	18 ft. hr.	6 ft. hr.	12 ft. hr.	18 ft. hr.	6 ft. hr.	12 ft. hr.	18 ft. hr.
1-inch Lumber (Nominal)												
8″ × 8″	2.0	3.3	4.9	7.1	9.5	12.2	6.0	7.5	10.1	8.1	11.1	14.8
10″ × 10″	2.1	3.4	5.2	7.2	9.6	12.6	6.1	7.8	10.4	8.3	11.3	15.1
12″ × 12″	2.2	3.6	5.5	7.5	10.1	13.1	6.3	8.0	10.8	8.5	11.6	15.5
14″ × 14″	2.3	3.9	5.9	7.8	10.5	13.5	6.6	8.4	11.3	8.7	12.0	15.9
16″ × 16″	2.4	4.1	6.2	8.1	11.0	14.1	6.9	8.8	11.8	9.0	12.3	16.4
18″ × 18″	2.6	4.4	6.6	8.4	11.3	14.7	7.2	9.2	12.3	9.3	12.7	16.9
20″ × 20″	2.8	4.6	7.0	8.7	11.7	15.2	7.5	9.5	12.8	9.6	13.1	17.4
22″ × 22″	2.9	4.8	7.4	9.0	12.0	15.6	7.8	9.9	13.3	9.8	13.4	17.9
24″ × 24″	3.1	5.0	7.7	9.3	12.5	16.2	8.1	10.3	13.8	10.1	13.8	18.3
26″ × 26″	3.3	5.5	8.4	9.8	13.1	17.0	8.4	10.7	14.4	10.5	14.4	19.1
28″ × 28″	3.7	6.1	9.3	10.2	13.8	18.0	8.9	11.3	15.1	10.9	14.9	19.9
30″ × 30″	3.9	6.4	9.8	10.5	14.3	18.5	9.1	11.6	15.6	11.2	15.3	20.5
32″ × 32″	4.1	6.7	10.2	11.0	14.6	19.1	9.4	12.0	16.1	11.4	15.6	20.7
34″ × 34″	4.2	7.0	10.7	11.3	15.0	19.5	9.7	12.4	16.6	11.7	16.0	21.2
36″ × 36″	4.4	7.3	11.1	11.6	15.5	20.1	10.1	12.7	17.2	12.0	16.4	21.8
2-inch Lumber (Nominal)												
8″ × 8″	2.5	4.3	6.5	8.1	11.0	14.1	7.2	9.2	12.4	10.5	14.4	19.2
10″ × 10″	2.7	4.5	6.8	8.4	11.3	14.6	7.6	9.5	12.7	10.7	14.7	19.6
12″ × 12″	2.9	4.8	7.2	8.7	11.7	15.2	7.8	9.8	13.1	11.2	15.1	20.0
14″ × 14″	3.0	5.1	7.8	9.0	12.2	15.8	8.1	10.3	13.8	11.3	15.6	20.7
16″ × 16″	3.3	5.4	8.2	9.3	12.6	16.4	8.4	10.7	14.4	11.7	16.1	21.3
18″ × 18″	3.4	5.7	8.8	9.8	13.1	17.0	8.8	11.2	15.0	12.1	16.5	22.0
20″ × 20″	3.6	6.0	9.2	10.1	13.5	17.6	9.1	11.7	15.6	12.4	17.0	22.6
22″ × 22″	3.8	6.3	9.7	10.4	14.0	18.2	9.5	12.1	16.2	12.7	17.4	23.2
24″ × 24″	4.0	6.7	10.2	10.8	14.4	18.9	10.1	12.6	16.8	13.1	17.9	23.8
26″ × 26″	4.4	7.3	11.1	11.3	15.1	19.7	10.3	13.1	17.6	13.6	18.6	24.8
28″ × 28″	4.9	8.1	12.4	12.0	15.9	20.5	10.8	13.7	18.4	14.2	19.4	25.8
30″ × 30″	5.1	8.5	13.0	12.3	16.5	21.0	11.2	14.1	19.0	14.7	19.9	26.4
32″ × 32″	5.3	8.9	13.5	12.6	17.0	21.6	11.5	14.6	19.8	14.9	20.3	27.1
34″ × 34″	5.5	9.1	13.9	12.9	17.4	22.2	12.0	15.1	20.5	15.2	20.5	27.6
36″ × 36″	5.7	9.5	14.5	13.4	17.9	23.0	12.3	15.6	21.2	15.5	21.3	28.3

* If old form lumber is used add 90% to "Make Forms."
† Values increased 50% as labor is generally inefficient on first set up.

TABLE 137] LABOR ON COLUMN FORMS [COSTS

TYPE 2.—WOOD WEDGE CLAMPS—Fig. 49B, p. 493

For times see opposite page *See pp. 614, 623 and 648*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 653

Size of Column	COST IN DOLLARS PER COLUMN											
	Make Forms for Different Story Heights*			Place and Remove Forms 1st time†			Place and Remove Forms After 1st time (Same size col.)			Remake, Place and Remove Forms		
	6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $
1-inch Lumber (Nominal)												
8″ × 8″	1.24	2.07	3.12	4.43	5.94	7.71	3.77	4.77	6.42	5.13	7.00	9.35
10″ × 10″	1.30	2.17	3.30	4.55	6.11	7.97	3.86	4.92	6.59	5.23	7.16	9.55
12″ × 12″	1.37	2.29	3.49	4.76	6.36	8.27	3.97	5.08	6.82	5.35	7.33	9.78
14″ × 14″	1.45	2.45	3.73	4.94	6.63	8.58	4.18	5.33	7.13	5.53	7.57	10.09
16″ × 16″	1.54	2.61	3.93	5.13	6.79	8.91	4.38	5.57	7.46	5.71	7.81	10.36
18″ × 18″	1.64	2.75	4.17	5.36	7.13	9.24	4.55	5.81	7.78	5.87	8.03	10.68
20″ × 20″	1.75	2.91	4.41	5.48	7.37	9.57	4.75	6.03	8.08	6.09	8.27	11.00
22″ × 22″	1.83	3.03	4.66	5.69	7.62	9.86	4.91	6.25	8.42	6.20	8.50	11.31
24″ × 24″	1.94	3.18	4.88	5.87	7.86	10.25	5.12	6.51	8.72	6.36	8.72	11.60
26″ × 26″	2.11	3.49	5.32	6.14	8.24	10.71	5.33	6.79	9.10	6.64	9.08	12.07
28″ × 28″	2.35	3.87	5.92	6.50	8.72	11.36	5.60	7.14	9.55	6.90	9.42	12.57
30″ × 30″	2.49	4.07	6.23	6.68	8.97	11.67	5.74	7.36	9.84	7.07	9.66	12.85
32″ × 32″	2.57	4.24	6.46	6.89	9.24	12.02	5.97	7.60	10.19	7.23	9.88	13.15
34″ × 34″	2.68	4.42	6.74	7.08	9.50	12.36	6.16	7.84	10.52	7.39	10.10	13.43
36″ × 36″	2.80	4.62	7.04	7.28	9.76	12.69	6.36	8.09	10.85	7.58	10.36	13.77
2-inch Lumber (Nominal)												
8″ × 8″	1.60	2.70	4.08	5.13	6.89	8.97	4.57	5.83	7.84	6.66	9.10	12.14
10″ × 10″	1.70	2.84	4.31	5.30	7.13	9.21	4.81	5.99	8.03	6.79	9.31	12.40
12″ × 12″	1.82	3.02	4.57	5.48	7.48	9.57	4.94	6.20	8.29	7.10	9.52	12.67
14″ × 14″	1.90	3.20	4.90	5.72	7.68	9.96	5.12	6.50	8.72	7.16	9.84	13.08
16″ × 16″	2.05	3.38	5.20	5.91	7.97	10.35	5.33	6.79	9.08	7.41	10.15	13.48
18″ × 18″	2.17	3.59	5.55	6.14	8.24	10.74	5.55	7.07	9.46	7.64	10.42	13.81
20″ × 20″	2.28	3.78	5.82	6.35	8.54	11.12	5.77	7.38	9.87	7.84	10.75	14.28
22″ × 22″	2.39	4.01	6.12	6.59	8.85	11.48	5.99	7.64	10.27	8.05	11.03	14.67
24″ × 24″	2.51	4.21	6.42	6.81	9.14	11.91	6.36	7.94	10.64	8.27	11.35	15.08
26″ × 26″	2.75	4.58	7.02	7.13	9.48	12.41	6.51	8.29	11.12	8.60	11.79	15.67
28″ × 28″	3.07	5.12	7.81	7.55	10.10	12.94	6.82	8.70	11.63	8.97	12.27	16.32
30″ × 30″	3.22	5.37	8.22	7.76	10.41	13.25	7.05	8.90	12.02	9.32	12.56	16.69
32″ × 32″	3.36	5.61	8.56	7.97	10.71	13.68	7.30	9.24	12.54	9.40	12.87	17.11
34″ × 34″	3.44	5.75	8.78	8.19	11.03	14.09	7.57	9.57	12.99	9.58	13.13	17.46
36″ × 36″	3.60	6.01	9.18	8.43	11.34	14.48	7.81	9.86	13.40	9.83	13.50	17.90

* If old form lumber is used add 90% to "Make Forms."
† Values increased 50% as labor is generally inefficient on first set up.

TABLE 138] **LABOR ON COLUMN FORMS** [TIMES

TYPE 3.—BOLTED CLAMPS—Fig. 49A, p. 493

For costs see opposite page *See pp. 613, 623 and 648*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 653

Size of Column	Time in Hours per Column											
	Make Forms for Different Story Heights*			Place and Remove Forms 1st Time†			Place and Remove Forms After 1st Time (Same size col.)			Remake, Place and Remove Forms		
	6 ft. hr.	12 ft. hr.	18 ft. hr.	6 ft. hr.	12 ft. hr.	18 ft. hr.	6 ft. hr.	12 ft. hr.	18 ft. hr.	6 ft. hr.	12 ft. hr.	18 ft. hr.
1-inch Lumber (Nominal)												
8″ × 8″	1.5	2.5	3.8	7.1	9.5	12.2	6.0	7.5	10.1	8.1	11.1	14.8
10″ × 10″	1.6	2.6	4.0	7.2	9.6	12.6	6.1	7.8	10.4	8.3	11.3	15.1
12″ × 12″	1.7	2.8	4.2	7.5	10.1	13.1	6.3	8.0	10.8	8.5	11.6	15.5
14″ × 14″	1.8	3.0	4.5	7.8	10.5	13.5	6.6	8.4	11.3	8.7	12.0	15.9
16″ × 16″	1.9	3.2	4.6	8.1	11.0	14.1	6.9	8.8	11.8	9.0	12.3	16.4
18″ × 18″	2.0	3.3	5.1	8.4	11.3	14.7	7.2	9.2	12.3	9.3	12.7	16.9
20″ × 20″	2.1	3.5	5.4	8.7	11.7	15.2	7.5	9.5	12.8	9.6	13.1	17.4
22″ × 22″	2.2	3.7	5.7	9.0	12.0	15.6	7.8	9.9	13.3	9.8	13.4	17.9
24″ × 24″	2.3	4.0	5.9	9.3	12.5	16.2	8.1	10.3	13.8	10.1	13.8	18.3
26″ × 26″	2.5	4.2	6.5	9.8	13.1	17.0	8.4	10.7	14.4	10.5	14.4	19.1
28″ × 28″	2.8	4.7	7.2	10.2	13.8	18.0	8.9	11.3	15.1	10.9	14.9	19.9
30″ × 30″	3.0	4.9	7.6	10.5	14.3	18.5	9.1	11.6	15.6	11.2	15.3	20.5
32″ × 32″	3.1	5.2	7.9	11.0	14.6	19.1	9.4	12.0	16.1	11.4	15.6	20.7
34″ × 34″	3.2	5.4	8.0	11.3	15.0	19.5	9.7	12.4	16.6	11.7	16.0	21.2
36″ × 36″	3.4	5.6	8.3	11.6	15.5	20.1	10.1	12.7	17.2	12.0	16.4	21.8
2-inch Lumber (Nominal)												
8″ × 8″	2.0	3.3	5.0	8.1	11.0	14.1	7.2	9.2	12.4	10.5	14.4	19.2
10″ × 10″	2.1	3.4	5.3	8.4	11.3	14.6	7.6	9.5	12.7	10.7	14.7	19.6
12″ × 12″	2.2	3.7	5.5	8.7	11.7	15.2	7.8	9.8	13.1	11.2	15.1	20.0
14″ × 14″	2.3	3.9	6.0	9.0	12.2	15.8	8.1	10.3	13.8	11.3	15.6	20.7
16″ × 16″	2.5	4.1	6.3	9.3	12.6	16.4	8.4	10.7	14.4	11.7	16.1	21.3
18″ × 18″	2.7	4.4	6.8	9.8	13.1	17.0	8.8	11.2	15.0	12.1	16.5	22.0
20″ × 20″	2.8	4.6	7.1	10.1	13.5	17.6	9.1	11.7	15.6	12.4	17.0	22.6
22″ × 22″	2.9	4.9	7.4	10.4	14.0	18.2	9.5	12.1	16.2	12.7	17.4	23.2
24″ × 24″	3.1	5.1	7.8	10.8	14.4	18.9	10.1	12.6	16.8	13.1	17.9	23.8
26″ × 26″	3.4	5.6	8.5	11.3	15.6	19.7	10.3	13.1	17.6	13.6	18.6	24.8
28″ × 28″	3.7	6.2	9.5	12.0	15.9	20.7	10.8	13.7	18.4	14.2	19.4	25.8
30″ × 30″	3.9	6.5	10.0	12.3	16.5	21.5	11.2	14.1	19.0	14.7	19.9	26.4
32″ × 32″	4.1	6.8	10.4	12.6	17.0	21.6	11.5	14.6	19.8	14.9	20.3	27.1
34″ × 34″	4.2	7.0	10.6	12.9	17.4	22.2	12.0	15.1	20.5	15.2	20.5	27.6
36″ × 36″	4.4	7.3	11.1	13.4	17.9	23.0	12.3	15.6	21.2	15.5	21.3	28.3

* If old form lumber is used add 90 % to "Make Forms."
† Values increased 50% as labor is generally inefficient on first set up.

TABLE 139]

LABOR ON COLUMN FORMS

[COSTS

TYPE 3—BOLTED CLAMPS—Fig. 49A, p. 493

For times see opposite page *See pp. 613, 623 and 648*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 653

Size of Column	Cost in Dollars per Column											
	Make Forms for Different Story Heights*			Place and Remove Forms 1st Time†			Place and Remove Forms After 1st Time (Same size col.)			Remake, Place and Remove Forms		
	6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $
1-inch Lumber (Nominal)												
8″ × 8″	0.96	1.58	2.39	4.43	5.94	7.71	3.77	4.77	6.42	5.13	7.00	9.35
10″ × 10″	0.99	1.64	2.53	4.55	6.11	7.97	3.86	4.92	6.59	5.23	7.16	9.55
12″ × 12″	1.04	1.75	2.67	4.76	6.36	8.27	3.97	5.08	6.82	5.35	7.33	9.78
14″ × 14″	1.11	1.87	2.82	4.94	6.63	8.58	4.18	5.33	7.13	5.53	7.57	10.09
16″ × 16″	1.19	1.99	2.91	5.13	6.95	8.91	4.38	5.57	7.46	5.71	7.81	10.36
18″ × 18″	1.25	2.09	3.22	5.36	7.13	9.24	4.55	5.81	7.78	5.87	8.03	10.68
20″ × 20″	1.33	2.21	3.38	5.48	7.37	9.57	4.75	6.03	8.08	6.09	8.27	11.00
22″ × 22″	1.41	2.33	3.58	5.69	7.62	9.86	4.91	6.25	8.42	6.20	8.50	11.31
24″ × 24″	1.48	2.53	3.75	5.87	7.86	10.25	5.12	6.51	8.72	6.36	8.72	11.60
26″ × 26″	1.60	2.67	4.09	6.14	8.24	10.71	5.33	6.79	9.10	6.64	9.08	12.07
28″ × 28″	1.79	2.98	4.56	6.50	8.72	11.36	5.60	7.14	9.55	6.90	9.42	12.55
30″ × 30″	1.88	3.12	4.80	6.68	8.97	11.67	5.74	7.36	9.84	7.07	9.66	12.87
32″ × 32″	1.95	3.25	4.98	6.89	9.24	12.02	5.97	7.60	10.19	7.23	9.88	13.15
34″ × 34″	2.04	3.40	5.04	7.08	9.50	12.36	6.16	7.84	10.52	7.39	10.10	13.43
36″ × 36″	2.13	3.56	5.28	7.28	9.76	12.69	6.36	8.09	10.85	7 58	10 36	13 77
2-inch Lumber (Nominal)												
8″ × 8″	1 24	2.07	3.16	5.13	6.89	8.97	4.57	5.83	7.84	6.66	9.10	12.14
10″ × 10″	1.30	2.17	3.32	5.30	7.13	9.21	4.81	5.99	8.03	6.79	9.31	12.40
12″ × 12″	1.41	2.31	3.48	5.48	7.48	9.57	4.94	6.20	8.29	7.10	9.52	12.67
14″ × 14″	1.48	2.46	3.77	5.72	7.68	9.96	5.12	6.50	8.72	7.16	9.84	13.08
16″ × 16″	1.58	2.61	4.00	5.91	7.97	10.35	5.33	6.79	9.08	7.41	10.15	13.48
18″ × 18″	1.67	2.78	4.27	6.14	8.24	10.74	5.55	7.07	9.46	7.64	10.42	13.81
20″ × 20″	1.75	2.91	4.46	6.35	8.54	11.12	5.77	7.38	9.87	7.84	10.75	14.28
22″ × 22″	1.83	3.08	4.68	6.59	8.85	11.48	5.99	7.64	10.27	8.05	11.03	14.67
24″ × 24″	1.94	3.24	4.92	6.81	9.14	11.91	6.36	7.94	10.64	8.27	11.35	15.08
26″ × 26″	2.12	3.53	5.40	7.13	9.87	12.41	6.51	8.29	11.12	8.60	11.79	15.67
28″ × 28″	2.35	3.93	5.99	7.55	10.10	13.13	6.82	8.70	11.63	8.97	12.27	16.32
30″ × 30″	2.46	4.12	6.30	7.76	10.41	13.52	7.05	8.90	12.02	9.32	12.56	16.69
32″ × 32″	2.58	4.32	6.57	7.97	10.71	13.68	7.30	9.24	12.54	9.40	12.87	17.11
34″ × 34″	2.64	4.42	6.72	8.19	11.03	14.09	7.57	9.57	12.99	9.58	13.13	17.46
36″ × 36″	2.77	4.62	7.03	8.43	11.34	14.48	7.81	9.86	13.40	9.83	13.50	17.90

* If old form lumber is used add 90% to "Make Forms."

† Values increased 50% as labor is generally inefficient on first set up.

TABLE 140] LABOR ON COLUMN FORMS [TIMES

TYPE 4—OCTAGONAL FORMS—Fig. 50, p. 495

For costs see opposite page *See pp. 615, 623 and 648*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 653

Diameter of Column	Area of Column in Sq. In.	Time in Hours per Column											
		Make Forms for Different Story Heights*			Place and Remove Forms 1st Time†			Place and Remove Forms After 1st Time (Same size col.)			Remake, Place and Remove Forms		
		6 ft. hr.	12 ft. hr.	18 ft. hr.	6 ft. hr.	12 ft. hr.	18 ft. hr.	6 ft. hr.	12 ft. hr.	18 ft. hr.	6 ft. hr.	12 ft. hr.	18 ft. hr.
1-inch Lumber (Nominal)													
8″	53	2.0	3.5	5.2	7.7	10.2	13.5	6.2	8.1	10.5	7.7	11.0	14.5
10″	83	2.0	3.5	5.2	8.0	10.5	13.7	6.5	8.5	11.0	8.0	11.4	15.0
12″	119	2.1	3.6	5.3	8.3	10.8	14.4	6.8	8.8	11.5	8.3	11.8	15.6
14″	162	2.1	3.7	5.5	8.4	11.3	14.9	7.1	9.2	11.7	8.6	12.1	16.0
16″	212	2.2	3.9	5.7	8.7	11.6	15.5	7.3	9.5	12.3	8.8	12.4	16.5
18″	269	2.3	4.0	5.9	9.0	11.9	15.9	7.5	9.8	12.8	9.0	12.8	17.0
20″	332	2.4	4.2	6.2	9.3	12.3	16.2	7.9	10.2	13.3	9.4	13.3	17.7
22″	401	2.5	4.4	6.4	9.5	12.6	16.8	8.1	10.6	13.7	9.5	13.5	17.9
24″	478	2.6	4.6	6.7	9.8	12.9	17.3	8.4	10.9	14.2	9.7	13.8	18.2
26″	560	2.7	4.8	7.0	10.1	13.2	17.6	8.6	11.2	14.6	10.1	14.3	18.8
28″	650	2.8	5.0	7.3	10.4	13.7	18.2	8.8	11.5	15.0	10.3	14.6	19.3
30″	746	2.9	5.1	7.6	10.5	14.0	18.5	9.2	11.9	15.5	10.5	15.0	19.8
32″	849	3.0	5.3	7.9	10.8	14.3	18.9	9.4	12.3	16.0	10.8	15.4	20.4
34″	958	3.2	5.5	8.1	11.1	14.6	19.7	9.8	12.6	16.4	11.1	15.8	20.8
36″	1074	3.3	5.7	8.4	11.3	15.0	19.8	10.0	13.0	16.9	11.4	16.1	21.3
2-inch Lumber (Nominal)													
8″	53	2.5	4.3	6.4	8.7	11.6	15.3	7.3	9.5	12.4	9.3	13.3	17.5
10″	83	2.5	4.4	6.5	9.0	11.9	15.5	7.7	10.0	13.0	9.7	13.7	18.1
12″	119	2.6	4.5	6.6	9.3	12.3	16.4	8.0	10.4	13.5	10.1	14.3	18.8
14″	162	2.6	4.6	6.8	9.6	12.8	16.8	8.4	10.8	13.8	10.4	14.7	19.4
16″	212	2.7	4.8	7.1	9.9	13.1	17.4	8.6	11.2	14.5	10.6	15.0	20.0
18″	269	2.9	5.0	7.3	10.2	13.5	17.9	8.8	11.5	15.1	10.9	15.5	20.5
20″	332	3.0	5.2	7.7	10.5	13.8	18.3	9.3	12.1	15.7	11.3	16.1	21.4
22″	401	3.1	5.4	7.9	10.8	14.3	18.9	9.6	12.5	16.2	11.5	16.4	21.6
24″	478	3.2	5.7	8.3	11.1	14.6	19.5	9.9	12.9	16.8	11.8	16.7	22.0
26″	560	3.4	5.9	8.7	11.3	15.0	19.8	10.1	13.2	17.2	12.2	17.3	22.8
28″	650	3.5	6.1	9.0	11.6	15.3	20.4	10.4	13.6	17.7	12.5	17.7	23.4
30″	746	3.6	6.3	9.4	11.9	15.8	20.9	10.8	14.1	18.3	12.8	18.2	24.0
32″	849	3.8	6.6	9.7	12.2	16.2	21.5	11.1	14.5	18.8	13.0	18.6	24.0
34″	958	3.9	6.9	10.1	12.5	16.4	22.2	11.6	14.9	19.3	13.5	19.1	25.2
36″	1074	4.0	7.1	10.4	12.8	17.0	22.4	11.8	15.3	19.9	13.8	19.5	25.8

* If old form lumber is used add 90% to "Make Forms."
† Values increased 50% as labor is generally inefficient on first set up.

TABLE 141] **LABOR ON COLUMN FORMS** **[COSTS**

TYPE 4.—OCTAGONAL FORMS—Fig. 50, p. 495

For times see opposite page *See pp. 615, 623 and 648*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 653

Diameter of Column	Area of Column in Sq. In.	Cost in Dollars per Column: Make Forms for Different Story Heights*			Place and Remove Forms 1st Time†			Place and Remove Forms After 1st Time (Same size col.)			Remake, Place and Remove Forms		
		6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $	6 ft. $	12 ft. $	18 ft. $
1-inch Lumber (Nominal)													
8″	53	1.26	2.21	3.25	4.86	6.44	8.57	3.92	5.11	6.64	4.88	6.93	9.14
10″	83	1.27	2.24	3.29	5.03	6.66	8.64	4.11	5.35	6.96	5.06	7.19	9.48
12″	119	1.30	2.29	3.37	5.18	6.86	9.12	4.29	5.59	7.27	5.25	7.45	9.84
14″	162	1.34	2.35	3.46	5.34	7.10	9.44	4.51	5.79	7.40	5.42	7.67	10.14
16″	212	1.39	2.45	3.60	5.52	7.32	9.75	4.59	5.98	7.77	5.55	7.87	10.43
18″	269	1.45	2.54	3.72	5.69	7.53	9.99	4.77	6.22	8.08	5.72	8.12	10.73
20″	332	1.52	2.66	3.91	5.84	7.72	10.28	4.97	6.48	8.42	5.93	8.41	11.17
22″	401	1.57	2.77	4.04	6.00	7.97	10.58	5.14	6.70	8.70	6.03	8.55	11.30
24″	478	1.64	2.89	4.25	6.17	8.18	10.88	5.31	6.92	8.99	6.15	8.73	11.51
26″	560	1.71	3.00	4.41	6.33	8.39	11.10	5.44	7.09	9.21	6.36	9.03	11.91
28″	650	1.79	3.13	4.59	6.51	8.61	11.43	5.59	7.27	9.46	6.52	9.25	12.21
30″	746	1.85	3.24	4.82	6.66	8.82	11.66	5.80	7.55	9.80	6.67	9.49	12.54
32″	849	1.92	3.37	4.96	6.83	9.05	11.99	5.96	7.77	10.10	6.82	9.75	12.88
34″	958	2.01	3.50	5.14	6.98	9.24	12.44	6.20	7.99	10.37	7.03	9.97	13.17
36″	1074	2.05	3.61	5.31	7.16	9.47	12.54	6.32	8.22	10.66	7.20	10.21	13.47
2-inch Lumber (Nominal)													
8″	53	1.56	2.74	4.03	5.49	7.28	9.68	4.63	6.02	7.83	5.91	8.39	11.06
10″	83	1.58	2.77	4.08	5.69	7.53	9.77	4.85	6.31	8.21	6.13	8.69	11.47
12″	119	1.62	2.84	4.18	5.85	7.76	10.22	5.06	6.59	8.57	6.36	9.01	11.91
14″	162	1.67	2.92	4.30	6.05	8.01	10.67	5.33	6.84	8.73	6.56	9.29	12.26
16″	212	1.72	3.03	4.46	6.24	8.27	11.01	5.42	7.05	9.17	6.72	9.52	12.62
18″	269	1.80	3.15	4.64	6.42	8.51	11.30	5.59	7.33	9.54	6.92	9.82	12.99
20″	332	1.88	3.30	4.85	6.60	8.75	11.61	5.88	7.64	9.94	7.17	10.18	13.52
22″	401	1.95	3.43	5.01	6.78	8.99	11.96	6.07	7.90	10.26	7.30	10.35	13.68
24″	478	2.04	3.59	5.27	6.98	9.24	12.29	6.26	8.16	10.61	7.44	10.57	13.93
26″	560	2.12	3.71	5.47	7.16	9.47	12.54	6.42	8.36	10.87	7.70	10.92	14.41
28″	650	2.21	3.88	5.69	7.35	9.72	12.92	6.59	8.58	11.17	7.89	11.20	14.78
30″	746	2.29	3.98	5.91	7.53	9.98	13.19	6.84	8.91	11.57	8.07	11.49	15.18
32″	849	2.38	4.18	6.15	7.71	10.23	13.55	7.04	9.17	11.91	8.24	11.79	15.20
34″	958	2.49	4.34	6.37	7.88	10.35	14.06	7.32	9.44	12.23	8.51	12.07	15.94
36″	1074	2.54	4.48	6.58	8.09	10.70	14.18	7.46	9.69	12.58	8.71	12.30	16.30

* If old form lumber is used add 90% to "Make Forms.

† Values increased 50% as labor is generally inefficient on first set up.

TABLE 142] LABOR ON BEAM FORMS **[TIMES**

BEAM FORMS—Figs. 53 and 54, pp. 499 and 501

For costs see opposite page. *See pp. 623 and 648*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 653

Size of Beam Below Slab	Time in Hours per Beam											
	Make Forms for Different Column Spacing*			Place and Remove Forms 1st Time†			Place and Remove Forms After 1st Time (Same size beam)			Remake, Place and Remove Forms		
	10 ft. hr.	20 ft. hr.	30 ft. hr.	10 ft. hr.	20 ft. hr.	30 ft. hr.	10 ft. hr.	20 ft. hr.	30 ft. hr.	10 ft. hr.	20 ft. hr.	30 ft. hr.
1-inch Lumber (Nominal)												
3″ × 6″	1.0	1.3	2.3	2.3	3.6	5.3	2.0	2.9	4.2	2.8	4.1	5.7
4″ × 8″	1.1	1.5	2.5	2.4	3.9	5.7	2.1	3.1	4.7	3.1	4.4	6.2
5″ × 10″	1.1	1.6	2.7	2.6	4.1	6.2	2.2	3.4	5.1	3.4	4.8	6.8
6″ × 12″	1.2	1.7	2.9	2.7	4.4	6.5	2.3	3.7	5.5	3.6	5.1	7.2
7″ × 14″	1.2	1.9	3.0	2.7	4.5	6.9	2.4	3.9	5.8	3.8	5.4	7.6
8″ × 16″	1.3	2.0	3.2	2.9	4.8	7.2	2.5	4.1	6.2	4.0	5.8	8.1
9″ × 18″	1.3	2.2	3.4	3.0	5.0	7.5	2.5	4.3	6.5	4.1	6.0	8.5
10″ × 20″	1.4	2.3	3.6	3.0	5.1	7.7	2.6	4.5	6.8	4.2	6.3	8.9
11″ × 22″	1.5	2.7	4.2	3.0	5.3	8.0	2.7	4.7	7.1	4.4	6.6	9.3
12″ × 24″	1.6	2.8	4.4	3.2	5.4	8.1	2.8	4.9	7.3	4.5	6.8	9.6
13″ × 26″	1.7	2.9	4.5	3.2	5.6	8.3	2.9	5.0	7.6	4.7	7.0	10.0
14″ × 28″	1.7	3.0	4.7	3.2	5.6	8.6	2.9	5.2	7.9	4.8	7.3	10.3
15″ × 30″	1.8	3.1	4.9	3.3	5.7	8.7	3.0	5.3	8.1	4.9	7.4	10.6
16″ × 32″	1.8	3.2	5.0	3.3	5.9	8.9	3.0	5.5	8.3	5.0	7.6	10.9
2-inch Lumber (Nominal)												
3″ × 6″	1.1	1.5	2.7	2.7	4.2	6.2	2.4	3.5	5.1	3.5	5.1	7.1
4″ × 8″	1.2	1.7	2.9	2.9	4.5	6.6	2.5	3.7	5.6	3.9	5.5	7.8
5″ × 10″	1.3	1.8	3.1	3.0	4.8	7.2	2.6	4.1	6.1	4.2	6.0	8.4
6″ × 12″	1.3	2.0	3.3	3.0	5.1	7.7	2.7	4.4	6.6	4.5	6.4	9.0
7″ × 14″	1.4	2.1	3.5	3.2	5.4	8.0	2.8	4.7	7.0	4.7	6.8	9.6
8″ × 16″	1.4	2.3	3.7	3.3	5.6	8.4	3.0	5.0	7.5	5.0	7.2	10.1
9″ × 18″	1.5	2.5	3.9	3.5	5.9	8.7	3.1	5.2	7.9	5.1	7.5	10.6
10″ × 20″	1.5	2.6	4.1	3.6	6.0	9.0	3.2	5.5	8.2	5.3	7.9	11.1
11″ × 22″	1.8	3.1	4.9	3.6	6.2	9.3	3.2	5.6	8.6	5.5	8.2	11.6
12″ × 24″	1.8	3.2	5.0	3.8	6.3	9.6	3.4	5.9	8.9	5.6	8.5	12.0
13″ × 26″	1.9	3.3	5.3	3.8	6.5	9.8	3.5	6.1	9.2	5.8	8.8	12.4
14″ × 28″	1.9	3.4	5.4	3.8	6.6	10.1	3.5	6.2	9.5	6.0	9.1	12.8
15″ × 30″	2.0	3.5	5.6	3.9	6.8	10.4	3.6	6.4	9.7	6.1	9.3	13.3
16″ × 32″	2.1	3.6	5.7	3.9	6.9	10.5	3.7	6.6	10.0	6.2	9.6	13.6

* If old form lumber is used add 90% to "Make Forms."

† Values increased 50% as labor is generally inefficient on first set up.

TABLE 143] **LABOR ON BEAM FORMS** [COSTS

BEAM FORMS—Figs. 53 and 54, pp. 499 and 501

For times see opposite page *See pp. 623 and 648*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 653

Size of Beam Below Slab	Cost in Dollars per Beam											
	Make Forms for Different Column Spacing*			Place and Remove Forms 1st Time†			Place and Remove Forms After 1st Time (Same size beam)			Remake, Place and Remove Forms		
	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $
1-inch Lumber (Nominal)												
3″ × 6″	0.63	0.85	1.45	1.44	2.28	3.30	1.24	1.81	2.69	1.80	2.57	3.59
4″ × 8″	0.67	0.92	1.58	1.52	2.42	3.59	1.32	1.97	2.95	1.98	2.79	3.94
5″ × 10″	0.69	1.01	1.70	1.59	2.58	3.86	1.38	2.13	3.20	2.13	3.01	4.27
6″ × 12″	0.73	1.09	1.82	1.67	2.75	4.08	1.43	2.31	3.46	2.27	3.23	4.55
7″ × 14″	0.75	1.19	1.92	1.74	2.88	4.32	1.49	2.46	3.69	2.39	3.43	4.83
8″ × 16″	0.79	1.26	2.04	1.77	2.99	4.52	1.55	2.59	3.90	2.52	3.64	5.13
9″ × 18″	0.81	1.36	2.15	1.86	3.14	4.70	1.61	2.72	4.09	2.61	3.81	5.39
10″ × 20″	0.85	1.42	2.27	1.91	3.20	4.83	1.67	2.86	4.28	2.69	3.97	5.64
11″ × 22″	0.97	1.67	2.66	1.95	3.32	5.00	1.70	2.96	4.49	2.79	4.14	5.86
12″ × 24″	1.02	1.75	2.77	1.97	3.41	5.15	1.76	3.09	4.65	2.85	4.29	6.09
13″ × 26″	1.04	1.82	2.87	2.00	3.48	5.25	1.81	3.18	4.81	2.95	4.45	6.31
14″ × 28″	1.08	1.87	2.98	2.03	3.53	5.40	1.85	3.28	4.97	3.01	4.59	6.50
15″ × 30″	1.11	1.94	3.08	2.07	3.63	5.54	1.87	3.37	5.11	3.09	4.68	6.71
16″ × 32″	1.15	1.99	3.16	2.09	3.69	5.63	1.91	3.46	5.23	3.15	4.83	6.90
2-inch Lumber (Nominal)												
3″ × 6″	0.71	0.96	1.67	1.70	2.69	3.89	1.52	2.20	3.23	2.24	3.20	4.47
4″ × 8″	0.77	1.05	1.82	1.77	2.85	4.22	1.58	2.31	3.55	2.46	3.50	4.94
5″ × 10″	0.81	1.16	1.95	1.86	3.06	4.59	1.67	2.58	3.87	2.66	3.77	5.31
6″ × 12″	0.85	1.26	2.08	1.95	3.24	4.80	1.72	2.79	4.20	2.83	4.05	5.68
7″ × 14″	0.87	1.34	2.20	2.03	3.41	5.03	1.80	2.96	4.45	2.98	4.29	6.05
8″ × 16″	0.91	1.45	2.35	2.09	3.56	5.30	1.87	3.13	4.71	3.13	4.55	6.42
9″ × 18″	0.93	1.56	2.46	2.19	3.66	5.52	1.94	3.31	4.97	3.26	4.77	6.72
10″ × 20″	0.97	1.62	2.59	2.24	3.80	5.70	2.02	3.46	5.19	3.37	4.97	7.04
11″ × 22″	1.11	1.94	3.08	2.28	3.92	5.88	2.05	3.57	5.42	3.49	5.16	7.34
12″ × 24″	1.16	2.00	3.18	2.33	4.04	6.08	2.13	3.71	5.63	3.55	5.35	7.61
13″ × 26″	1.20	2.08	3.32	2.36	4.11	6.20	2.20	3.85	5.82	3.68	5.57	7.87
14″ × 28″	1.22	2.13	3.42	2.42	4.17	6.36	2.23	3.94	6.01	3.77	5.74	8.13
15″ × 30″	1.28	2.23	3.53	2.45	4.28	6.51	2.28	4.07	6.16	3.85	5.90	8.38
16″ × 32″	1.32	2.28	3.62	2.48	4.37	6.63	2.31	4.19	6.31	3.92	6.05	8.62

* If old form lumber is used add 90% to "Make Forms."
† Values increased 50% as labor is generally inefficient on first set up.

TABLE 144] LABOR ON GIRDER FORMS [TIMES

ONE INTERSECTING BEAM—Figs. 53 and 56, pp. 499 and 503

For costs see opposite page. *See pp. 623 and 648*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 653

Size of Girder Below Slab	Time in Hours per Girder											
	Make Forms for Different Column Spacing*			Place and Remove Forms 1st Time†			Place and Remove Forms After 1st Time (Same size girder)			Remake, Place and Remove Forms		
	10 ft. hr.	20 ft. hr.	30 ft. hr.	10 ft. hr.	20 ft. hr.	30 ft. hr.	10 ft. hr.	20 ft. hr.	30 ft. hr.	10 ft. hr.	20 ft. hr.	30 ft. hr.
1-inch Lumber (Nominal).												
3″ × 6″	1.0	1.6	2.7	2.7	4.1	5.9	2.2	3.5	5.0	3.9	5.4	7.5
4″ × 8″	1.1	1.8	2.9	2.9	4.4	6.2	2.4	3.7	5.2	4.1	5.7	7.8
5″ × 10″	1.2	1.9	3.1	3.0	4.5	6.5	2.4	3.7	5.4	4.4	6.0	8.2
6″ × 12″	1.3	2.0	3.3	3.2	4.8	6.8	2.6	3.9	5.7	4.6	6.3	8.6
7″ × 14″	1.3	2.1	3.5	3.3	5.0	7.1	2.7	4.1	5.9	4.8	6.6	9.0
8″ × 16″	1.4	2.2	3.6	3.5	5.3	7.4	2.8	4.4	6.3	4.9	6.8	9.4
9″ × 18″	1.5	2.3	3.8	3.6	5.4	7.7	2.9	4.5	6.5	5.1	7.1	9.7
10″ × 20″	1.5	2.4	4.0	3.8	5.7	8.0	3.0	4.7	6.8	5.3	7.4	10.1
11″ × 22″	1.8	2.8	4.6	3.9	5.9	8.3	3.2	4.9	7.0	5.5	7.6	10.5
12″ × 24″	1.8	2.9	4.8	4.1	6.2	8.7	3.3	5.1	7.3	5.8	7.9	10.9
13″ × 26″	1.9	3.0	5.0	4.2	6.3	9.0	3.4	5.2	7.5	5.9	8.2	11.3
14″ × 28″	2.0	3.1	5.2	4.4	6.5	9.3	3.5	5.4	7.8	6.2	8.5	11.7
15″ × 30″	2.1	3.2	5.3	4.5	6.8	9.6	3.7	5.6	8.1	6.4	8.8	12.1
16″ × 32″	2.1	3.3	5.5	4.7	6.9	9.9	3.8	5.8	8.3	6.6	9.0	12.4
2-inch Lumber (Nominal).												
3″ × 6″	1.2	1.9	3.1	3.2	4.8	6.9	2.7	4.2	6.0	4.9	6.8	9.3
4″ × 8″	1.3	2.0	3.3	3.3	5.1	7.2	2.8	4.4	6.4	5.2	7.1	9.7
5″ × 10″	1.4	2.1	3.5	3.5	5.3	7.5	2.9	4.5	6.5	5.5	7.5	10.3
6″ × 12″	1.4	2.3	3.7	3.8	5.6	8.0	3.1	4.8	6.8	5.7	7.8	10.8
7″ × 14″	1.5	2.4	4.0	3.9	5.8	8.4	3.2	5.0	7.2	5.9	8.2	11.3
8″ × 16″	1.6	2.5	4.2	4.1	6.2	8.7	3.4	5.2	7.6	6.2	8.5	11.7
9″ × 18″	1.7	2.6	4.4	4.2	6.5	9.2	3.5	5.5	7.9	6.4	8.9	12.2
10″ × 20″	1.8	2.8	4.6	4.5	6.6	9.5	3.7	5.7	8.2	6.7	9.2	12.7
11″ × 22″	2.0	3.2	5.3	4.7	6.9	9.8	3.8	5.9	8.5	6.9	9.5	13.1
12″ × 24″	2.1	3.3	5.5	4.8	7.2	10.2	4.0	6.1	9.8	7.2	9.9	13.7
13″ × 26″	2.2	3.4	5.7	5.5	7.4	10.5	4.1	6.3	9.1	7.5	10.3	14.1
14″ × 28″	2.3	3.6	5.9	5.1	7.7	11.0	4.2	6.6	9.4	7.7	10.6	14.6
15″ × 30″	2.4	3.7	6.1	5.3	8.0	11.3	4.4	6.8	9.8	7.9	11.0	15.1
16″ × 32″	2.4	3.8	6.3	5.4	8.3	11.7	4.6	7.0	10.1	8.2	11.3	15.5

* If old form lumber is used add 90% to "Make Forms."
† Values increased 50% as labor is generally inefficient on first set up.

TABLE 145] **LABOR ON GIRDER FORMS** [COSTS

ONE INTERSECTING BEAM —Figs. 53 and 56, pp. 499 and 503

For times see opposite page *See pp. 623 and 648*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 653

Size of Girder Below Slab	Cost in Dollars per Girder											
	Make Forms for Different Column Spacings*			Place and Remove Forms 1st Time†			Place and Remove Forms After 1st Time (Same size girder)			Remake, Place and Remove Forms		
	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $
1-inch Lumber (Nominal)												
3″ × 6″	0.66	1.03	1.71	1.70	2.58	3.66	1.42	2.20	3.16	2.49	3.43	4.71
4″ × 8″	0.71	1.11	1.83	1.82	2.72	3.89	1.49	2.31	3.32	2.61	3.60	4.94
5″ × 10″	0.75	1.17	1.95	1.89	2.85	4.05	1.53	2.37	3.40	2.76	3.80	5.22
6″ × 12″	0.79	1.24	2.05	2.00	3.00	4.25	1.61	2.49	3.57	2.89	3.97	5.45
7″ × 14″	0.85	1.32	2.19	2.09	3.14	4.47	1.69	2.61	3.76	3.01	4.16	5.71
8″ × 16″	0.89	1.38	2.29	2.19	3.27	4.67	1.79	2.75	3.96	3.13	4.31	5.94
9″ × 18″	0.92	1.45	2.39	2.30	3.44	4.89	1.85	2.86	4.12	3.26	4.49	6.16
10″ × 20″	0.97	1.52	2.53	2.37	3.57	5.07	1.92	2.97	4.28	3.38	4.66	6.42
11″ × 22″	1.11	1.74	2.88	2.46	3.69	5.25	2.00	3.09	4.44	3.50	4.82	6.64
12″ × 24″	1.16	1.82	3.02	2.55	3.86	5.48	2.07	3.20	4.60	3.64	5.02	6.90
13″ × 26″	1.20	1.88	3.14	2.64	3.98	5.66	2.15	3.32	4.77	3.70	5.20	7.16
14″ × 28″	1.25	1.96	3.26	2.72	4.11	5.85	2.22	3.43	4.94	3.90	5.38	7.40
15″ × 30″	1.30	2.03	3.37	2.84	4.25	6.08	2.31	3.55	5.12	4.02	5.55	7.64
16″ × 32″	1.34	2.09	3.48	2.93	4.41	6.27	2.38	3.66	5.28	4.14	5.72	7.86
2-inch Lumber (Nominal)												
3″ × 6″	0.75	1.19	1.98	2.00	3.03	4.34	1.72	2.65	3.83	3.11	4.29	5.88
4″ × 8″	0.81	1.26	2.11	2.13	3.20	4.59	1.80	2.79	4.02	3.27	4.49	6.16
5″ × 10″	0.85	1.34	2.24	2.22	3.36	4.77	1.85	2.86	4.12	3.46	4.74	6.51
6″ × 12″	0.91	1.42	2.35	2.36	3.53	5.03	1.95	3.01	4.31	3.60	4.96	6.81
7″ × 14″	0.97	1.52	2.51	2.46	3.69	5.30	2.05	3.16	4.55	3.75	5.19	7.14
8″ × 16″	1.01	1.60	2.63	2.58	3.87	5.52	2.16	3.32	4.79	3.92	5.39	7.41
9″ × 18″	1.07	1.66	2.75	2.70	4.05	5.78	2.23	3.46	4.99	4.07	5.61	7.71
10″ × 20″	1.12	1.75	2.90	2.79	4.22	6.00	2.33	3.59	5.17	4.22	5.82	8.01
11″ × 22″	1.26	2.00	3.32	2.91	4.37	6.20	2.42	3.72	5.36	4.37	6.02	8.31
12″ × 24″	1.33	2.09	3.46	3.02	4.55	6.47	2.50	3.86	5.56	4.54	6.27	8.64
13″ × 26″	1.38	2.16	3.61	3.14	4.70	6.68	2.59	4.01	5.77	4.71	6.50	8.94
14″ × 28″	1.44	2.25	3.75	3.20	4.85	6.89	2.69	4.17	5.97	4.86	6.72	9.25
15″ × 30″	1.50	2.33	3.87	3.33	5.03	7.14	2.79	4.29	6.18	5.02	6.93	9.53
16″ × 32″	1.54	2.41	4.01	3.44	5.19	7.41	2.89	4.43	6.38	5.18	7.16	9.83

* If old form lumber is used add 90% to "Make Forms."

† Values increased 50% as labor is generally inefficient on first set up.

TABLE 146] LABOR ON GIRDER FORMS [TIMES

2 INTERSECTING BEAMS—Figs. 53 and 56, pp. 499 and 503

For costs see opposite page. *See pp. 623 and 648.*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 653

Size of Girder Below Slab	Time in Hours per Girder											
	Make Forms for Different Column Spacing*			Place and Remove Forms 1st Time†			Place and Remove Forms After 1st Time (Same size girder)			Remake, Place and Remove Forms		
	10 ft. hr.	20 ft. hr.	30 ft. hr.	10 ft. hr.	20 ft. hr.	30 ft. hr.	10 ft. hr.	20 ft. hr.	30 ft. hr.	10 ft. hr.	20 ft. hr.	30 ft. hr.
1-inch Lumber (Nominal)												
3″ × 6″	1.0	1.6	2.6	3.3	4.8	6.6	2.6	3.9	5.5	4.3	5.8	7.9
4″ × 8″	1.1	1.7	2.8	3.5	5.0	7.1	2.8	4.1	5.8	4.5	6.1	8.3
5″ × 10″	1.2	1.8	3.0	3.6	5.3	7.4	2.8	4.2	5.9	4.7	6.4	8.7
6″ × 12″	1.3	1.9	3.2	3.8	5.6	7.8	3.0	4.4	6.2	5.0	6.8	9.2
7″ × 14″	1.3	2.0	3.3	3.9	5.9	8.1	3.1	4.6	6.5	5.2	7.0	9.6
8″ × 16″	1.4	2.1	3.5	4.2	6.0	8.6	3.3	4.8	6.9	5.4	7.3	9.9
9″ × 18″	1.5	2.2	3.7	4.4	6.3	8.9	3.4	5.0	7.1	5.6	7.6	10.4
10″ × 20″	1.5	2.3	3.9	4.5	6.6	9.3	3.6	5.2	7.4	5.9	7.9	10.7
11″ × 22″	1.7	2.7	4.4	4.7	6.8	9.6	3.7	5.4	7.7	6.1	8.1	11.1
12″ × 24″	1.8	2.8	4.6	4.8	7.1	9.9	3.8	5.6	8.0	6.3	8.5	11.6
13″ × 26″	1.9	2.9	4.8	5.0	7.4	10.4	4.0	5.8	8.3	6.5	8.8	12.0
14″ × 28″	2.0	3.0	5.0	5.3	7.5	10.7	4.1	6.0	8.5	6.8	9.1	12.4
15″ × 30″	2.0	3.1	5.1	5.4	7.8	11.1	4.2	6.2	8.9	7.0	9.4	12.8
16″ × 32″	2.1	3.2	5.3	5.6	8.1	11.4	4.4	6.4	9.1	7.2	9.7	13.2
2-inch Lumber (Nominal)												
3″ × 6″	1.2	1.8	3.0	3.9	5.6	7.8	2.9	4.7	6.6	5.4	7.3	9.9
4″ × 8″	1.3	1.9	3.2	4.1	5.9	8.3	3.4	4.9	7.0	5.7	7.6	10.4
5″ × 10″	1.3	2.1	3.4	4.2	6.2	8.7	3.4	5.0	7.1	5.9	8.0	10.9
6″ × 12″	1.4	2.2	3.6	4.5	6.5	9.2	3.6	5.3	7.5	6.2	8.4	11.4
7″ × 14″	1.5	2.3	3.8	4.7	6.9	9.6	3.8	5.6	7.9	6.5	8.8	12.0
8″ × 16″	1.6	2.4	4.0	4.8	7.1	10.1	4.0	5.9	8.3	6.8	9.2	12.4
9″ × 18″	1.7	2.5	4.3	5.1	7.5	10.5	4.2	6.1	8.6	7.0	9.5	12.9
10″ × 20″	1.8	2.7	4.5	5.3	7.7	11.0	4.3	6.3	9.0	7.3	9.9	13.4
11″ × 22″	2.0	3.0	5.1	5.6	8.0	11.3	4.5	6.6	9.3	7.5	10.2	13.8
12″ × 24″	2.1	3.2	5.3	5.7	8.4	11.7	4.6	6.8	9.6	7.8	10.6	14.4
13″ × 26″	2.2	3.3	5.5	5.9	8.7	12.2	4.8	7.1	10.0	8.1	11.0	15.0
14″ × 28″	2.3	3.4	5.7	6.2	8.9	12.6	5.0	7.3	10.3	8.4	11.4	15.5
15″ × 30″	2.3	3.5	5.9	6.3	9.3	13.1	5.1	7.5	10.7	8.7	11.8	16.0
16″ × 32″	2.4	3.7	6.1	6.6	9.6	13.5	5.3	7.8	11.0	9.0	12.1	16.5

* If old form lumber is used add 90% to "Make Forms."

† Values increased 50% as labor is generally inefficient on first set up.

TABLE 147] **LABOR ON GIRDER FORMS** [COSTS

2 INTERSECTING BEAMS—Figs. 53 and 56, pp. 499 and 503

For times see opposite page *See pp. 623 and 648*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 653

Size of Girder Below Slab	Cost in Dollars per Girder: Make Forms for Different Column Spacing* 10 ft. $	20 ft. $	30 ft. $	Place and Remove Forms 1st Time† 10 ft. $	20 ft. $	30 ft. $	Place and Remove Forms After 1st Time (Same size girder) 10 ft. $	20 ft. $	30 ft. $	Remake, Place and Remove Forms 10 ft. $	20 ft. $	30 ft. $
1-inch Lumber (Nominal)												
3″ × 6″	0.65	0.99	1.66	2.06	3.00	4.22	1.66	2.44	3.46	2.72	3.69	5.01
4″ × 8″	0.70	1.07	1.76	2.16	3.17	4.46	1.75	2.57	3.64	2.86	3.86	5.25
5″ × 10″	0.74	1.13	1.88	2.28	3.32	4.67	1.79	2.63	3.72	3.01	4.07	5.53
6″ × 12″	0.79	1.20	1.99	2.39	3.48	4.91	1.89	2.76	3.92	3.16	4.27	5.79
7″ × 14″	0.83	1.26	2.11	2.49	3.66	5.16	1.98	2.91	4.13	3.29	4.45	6.05
8″ × 16″	0.87	1.33	2.23	2.61	3.81	5.36	2.09	3.06	4.34	3.43	4.64	6.29
9″ × 18″	0.92	1.40	2.33	2.75	3.99	5.63	2.17	3.18	4.51	3.57	4.82	6.55
10″ × 20″	0.96	1.48	2.45	2.84	4.14	5.85	2.26	3.31	4.68	3.70	4.99	6.79
11″ × 22″	1.09	1.67	2.79	2.94	4.29	6.05	2.35	3.43	4.86	3.83	5.16	7.01
12″ × 24″	1.15	1.75	2.91	3.08	4.47	6.30	2.43	3.55	5.03	3.93	5.38	7.31
13″ × 26″	1.19	1.82	3.03	3.17	4.64	6.51	2.52	3.69	5.23	4.12	5.61	7.58
14″ × 28″	1.24	1.88	3.14	3.27	4.77	6.74	2.60	3.81	5.40	4.27	5.76	7.83
15″ × 30″	1.28	1.95	3.24	3.41	4.97	6.99	2.69	3.94	5.60	4.42	5.96	8.09
16″ × 32″	1.32	2.01	3.37	3.50	5.10	7.20	2.77	4.07	5.77	4.55	6.14	8.35
2-inch Lumber (Nominal)												
3″ × 6″	0.74	1.13	1.91	2.42	3.53	4.98	1.86	2.96	4.20	3.40	4.61	6.25
4″ × 8″	0.81	1.22	2.03	2.55	3.74	5.25	2.12	3.11	4.40	3.57	4.82	6.56
5″ × 10″	0.85	1.30	2.16	2.69	3.92	5.49	2.16	3.18	4.51	3.75	5.08	6.90
6″ × 12″	0.91	1.38	2.29	2.81	4.11	5.78	2.28	3.34	4.74	3.94	5.33	7.23
7″ × 14″	0.95	1.45	2.43	2.94	4.34	6.09	2.41	3.53	4.99	4.12	5.56	7.56
8″ × 16″	1.00	1.52	2.55	3.08	4.50	6.33	2.52	3.70	5.25	4.29	5.79	7.84
9″ × 18″	1.05	1.60	2.69	3.23	4.70	6.63	2.63	3.85	5.46	4.45	6.02	8.18
10″ × 20″	1.11	1.70	2.82	3.35	4.89	6.89	2.74	4.00	5.68	4.61	6.24	8.46
11″ × 22″	1.25	1.92	3.22	3.47	5.07	7.13	2.83	4.14	5.88	4.77	6.45	8.75
12″ × 24″	1.32	2.01	3.34	3.63	5.30	7.44	2.94	4.29	6.09	4.96	6.72	9.12
13″ × 26″	1.36	2.09	3.48	3.74	5.46	7.68	3.03	4.46	6.33	5.14	6.97	9.46
14″ × 28″	1.42	2.16	3.61	3.87	5.63	7.97	3.15	4.61	6.53	5.33	7.19	9.78
15″ × 30″	1.46	2.24	3.73	4.04	5.85	8.25	3.26	4.77	6.77	5.51	7.44	10.12
16″ × 32″	1.51	2.31	3.87	4.13	6.03	8.49	3.35	4.92	6.97	5.68	7.68	10.42

* If old form lumber is used add 90% to "Make Forms."
† Values increased 50% as labor is generally inefficient on first set up.

TABLE 148] LABOR ON SLAB FORMS [TIMES

For costs see table below *See Fig. 61, p. 509, also p. 623*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 653

These values include time making, erecting and removing necessary posts.
1 Panel equals 1 bay, surrounded by beams, supported by columns.
2 Panels applies to a bay with one intermediate beam.
3 Panels applies to a bay with two intermediate beams.

Thickness of Sheathing (Nominal)	Time in Hours per 100 Square Feet of Slab Surface											
	Make Forms*			Place and Remove Forms 1st Time†			Place and Remove Forms after 1st Time (Same Size Column)			Place and Remove Forms (Size of Column Reduced)		
	1 Panel hr.	2 Panel hr.	3 Panel hr.	1 Panel hr.	2 Panel hr.	3 Panel hr.	1 Panel hr.	2 Panel hr.	3 Panel hr.	1 Panel hr.	2 Panel hr.	3 Panel hr.
1-inch Lumber (Nominal)												
1-inch	1.40	1.28	1.17	4.24	4.00	3.75	3.25	3.00	2.75	3.58	3.25	2.92
1¼-inch Lumber (Nominal)												
1¼-inch	1.50	1.37	1.20	4.40	4.16	3.90	3.38	3.12	2.86	3.77	3.38	3.04

TABLE 149] LABOR ON SLAB FORMS [COSTS

For times and for notes see table above

Thickness of Sheathing (Nominal)	Cost in Dollars per 100 Square Feet of Slab Surface											
	Make Forms*			Place and Remove Forms 1st Time†			Place and Remove Forms after 1st Time (Same Size Column)			Place and Remove Forms (Size of Column Reduced)		
	1 Panel $	2 Panel $	3 Panel $	1 Panel $	2 Panel $	3 Panel $	1 Panel $	2 Panel $	3 Panel $	1 Panel $	2 Panel $	3 Panel $
1-inch Lumber (Nominal)												
1-inch	0.88	0.81	0.76	2.68	2.53	2.37	2.06	1.90	1.74	2.27	2.06	1.85
1¼-inch Lumber (Nominal)												
1¼-inch	0.95	0.87	0.79	2.79	2.64	2.47	2.14	1.97	1.81	2.39	2.14	1.93

* If old lumber is used add 90% to "Make Forms."
† Values increased 50% as labor is generally inefficient on first set up.

TABLE 150] LABOR ON WALL FORMS [TIMES

TYPE I—3-FOOT SECTIONAL FORM—Fig. 70, p. 520.

For costs see table below. *See p. 623 and 648.*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 653

Thickness of Sheathing (Nominal)	Time in hours per 100 square feet of wall surface								
	Make Forms* For Different Lengths			Place and Remove Forms 1st Time†			Place and Remove Forms after 1st Time		
	8 ft. hr.	12 ft. hr.	16 ft. hr.	8 ft. hr.	12 ft. hr.	16 ft. hr.	8 ft. hr.	12 ft. hr.	16 ft. hr.
1 inch	2.8	3.4	2.7	13.3	12.0	11.9	13.9	13.0	13.0
1½ inches	3.2	2.7	2.4	15.1	12.6	12.2	14.9	13.3	13.1
2 inches	2.9	2.6	2.3	15.5	13.2	13.0	15.3	13.7	13.6

TABLE 151] LABOR ON WALL FORMS [COSTS

For times and for notes see table above

Thickness of Sheathing (Nominal)	Cost in dollars per 100 square feet of wall surface								
	Make Forms* For Different Lengths			Place and Remove Forms 1st Time†			Place and Remove Forms After 1st Time		
	8 ft. $	12 ft. $	16 ft. $	8 ft. $	12 ft. $	16 ft. $	8 ft. $	12 ft. $	16 ft. $
1 inch	1.63	1.97	1.56	8.51	7.58	7.54	8.15	7.57	7.55
1½ inches	1.84	1.55	1.41	9.52	7.96	7.79	8.79	7.78	7.57
2 inches	1.68	1.51	1.34	9.79	8.32	8.20	8.96	8.00	7.92

* If old lumber is used add 90% to "Make Forms."
† Values increased 50% as labor is generally inefficient on first set up.

TABLE 152] LABOR ON FLAT SLAB FORMS [COSTS

SUPPORTED BY COLUMNS WITHOUT BEAMS—Fig. 62, p. 510.

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 653

Column Spacing C. to C.	Joists		Stringers		4 in. × 4 in. Posts		Ft. B. M. Lumber per Sq. Ft. Area	Labor Cost per 100 Sq. Ft. of Slab Surface	
	Size	Spacing	Size	Spacing	No. per Section	Spacing		1st Time	After 1st
ft.	in.	in.	in.	in.		in.		$	$
1-inch Sheathing									
10×10	2×6	20	3×8	60	4	60	4.3	7.90	6.80
15×15	2×6	20	3×8	60	9	60	4.3	6.40	5.50
18×18	2×6	24	3×8	54	16	60	4.4	6.20	5.30
20×20	2×6	24	3×8	60	16	60	4.1	6.10	5.20
25×25	2×6	20	3×8	60	25	60	4.2	5.90	5.00
30×30	2×6	20	3×8	60	36	60	4.3	5.80	4.90

TABLE 153] LABOR ON BEAM FORMS FOR FIREPROOFING I-BEAM CONSTRUCTION [TIMES

See Fig. 59, p. 507

For costs see opposite page *See pp. 626 and 648*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 653

Size of I-Beam	Time in Hours per Beam											
	Make Forms for Different Column Spacing *			Place and Remove Forms First Time †			Place and Remove Forms After First Time			Remake, Place, and Remove Forms		
	10 ft. hr.	20 ft. hr.	30 ft. hr.	10 ft. hr.	20 ft. hr.	30 ft. hr.	10 ft. hr.	20 ft. hr.	30 ft. hr.	10 ft. hr.	20 ft. hr.	30 ft. hr.
	1-inch Lumber (Nominal)											
6″	1.4	2.8	4.0	2.5	4.2	5.1	1.8	3.1	4.2	3.2	5.0	6.5
7″	1.4	2.9	4.1	2.5	4.3	5.3	1.8	3.2	4.2	3.3	5.1	6.7
8″	1.5	3.0	4.2	2.6	4.4	5.5	1.9	3.3	4.3	3.4	5.3	6.9
9″	1.5	3.0	4.2	2.6	4.5	5.6	1.9	3.3	4.4	3 4	5.4	7.0
10″	1.6	3.1	4.3	2.7	4.6	5.8	2.0	3.4	4.6	3.5	5.5	7.2
12″	1.6	3.3	4.6	2.7	4.8	6.1	2.1	3.6	4.9	3.6	5.7	7.5
15″	1.7	3.4	4.7	2.8	5.0	6.4	2.1	3.8	5.1	3.8	5.9	7.8
18″	1.8	3.6	4.9	2.9	5.2	6.8	2.2	3.9	5.4	3.9	6.1	8.1
20″	1.8	3.7	5.1	3.0	5.4	7.0	2.3	4.2	5.7	4.0	6.3	8.4
24″	1.9	3.9	5.2	3.1	5.6	7.3	2.4	4.3	5.9	4.2	6.5	8.7
	2-inch Lumber (Nominal)											
6″	1.8	3.6	5.1	3.8	6.0	7.0	2.8	4.5	5.9	5.6	8.6	10.5
7″	1.8	3.7	5.2	3.8	6.1	7.2	2.8	4.8	6.0	5.7	8.8	10.8
8″	1.9	3.8	5.3	3.9	6.3	7.4	2.9	5.1	6.2	5.8	9.0	11.1
9″	1.9	3.9	5.4	3.9	6.4	7.6	2.9	5.2	6.4	5.9	9.1	11.3
10″	2.0	4.0	5.5	4.0	6.6	7.9	3.0	5.3	6.6	6.1	9.3	11.5
12″	2.1	4.2	5.7	4.1	6.8	8.3	3.2	5.6	7.0	6.3	9.7	12.1
15″	2.2	4.4	6.0	4.2	7.1	8.7	3.3	5.8	7.4	6.6	10.1	12.6
18″	2.3	4.6	6.2	4.4	7.4	9.2	3.4	6.1	7.8	6.8	10.5	13.1
20″	2.4	4.7	6.4	4.5	7.7	9.6	3.5	6.4	8 1	7.0	10.8	13.6
24″	2.5	4.9	6.6	4.6	8.0	10.0	3.7	6.6	8.5	7.2	11.2	14.1

Beams are assumed to be not over 10 feet apart.

* If old form lumber is used, add 90% to "Make Forms."
† Values increased 50% as labor is generally inefficient in first set up.

TABLE 154] **LABOR ON BEAM FORMS FOR FIREPROOFING I-BEAM CONSTRUCTION** [COSTS

See Fig. 59, p. 507

For times see opposite page. *See pp. 626 and 648*

BEFORE USING THIS TABLE, OPEN FOLDING PAGE 653

Size of I-Beam	Cost in Dollars per Beam											
	Make Forms for Different Column Spacing*			Place and Remove Forms First Time†			Place and Remove Forms After First Time			Remake, Place, and Remove Forms		
	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $	10 ft. $	20 ft. $	30 ft. $
1-inch Lumber (Nominal)												
6″	0.89	1.78	2.56	1.58	2.66	3.30	1.13	1.96	2.64	2.03	3.19	4.13
7″	0.91	1.83	2.61	1.60	2.71	3.37	1.16	2.01	2.69	2.07	3.25	4.24
8″	0.95	1.89	2.67	1.63	2.77	3.45	1.19	2.06	2.74	2.12	3.32	4.36
9″	0.97	1.93	2.71	1.66	2.83	3.55	1.22	2.11	2.82	2.17	3.39	4 44
10″	0 99	1.98	2.75	1.69	2.90	3.65	1.26	2.17	2.91	2.22	3.46	4.53
12″	1.04	2.07	2.88	1.73	3.02	3.85	1.31	2.27	3.08	2 30	3.60	4.72
15″	1.08	2.17	2.99	1.78	3.17	4.04	1.36	2.38	3.24	2.39	3.73	4.94
18″	1.13	2.25	3.10	1.84	3.29	4.33	1.42	2.48	3.42	2.48	3.87	5.13
20″	1.17	2.34	3.21	1.88	3.41	4.42	1.47	2.65	3.58	2.51	4.00	5.32
24″	1.22	2.44	3.32	1.93	3.54	4.61	1.52	2.69	3.75	2.65	4.14	5.52
2-inch Lumber (Nominal)												
6″	1.15	2.30	3.23	2.39	3.79	4.44	1.75	2.86	3.71	3.51	5.44	6.67
7″	1.18	2.36	3.29	2.42	3.88	4.57	1.79	3.03	3.83	3.59	5.56	6.83
8″	1.21	2.42	3.35	2.45	3.97	4.71	1.83	3.21	3.95	3.67	5.68	6.99
9″	1.24	2.47	3.41	2.49	4.06	4.85	1.87	3.29	4.07	3.75	5.79	7.14
10″	1.27	2.53	3.48	2.53	4.16	4.99	1.91	3.37	4.19	3.83	5.91	7.30
12″	1.32	2.65	3.63	2.60	4.33	5.24	1.99	3.53	4.43	3.99	6.14	7.63
15″	1.38	2.77	3.77	2.68	4.51	5.52	2.08	3.70	4.66	4.15	6.39	7.95
18″	1.44	2.88	3.93	2.75	4.70	5.79	2.15	3.86	4.90	4.30	6.61	8.28
20″	1.49	2.99	4.04	2.83	4.89	6 06	2.24	4.02	5.14	4.46	6.89	8.60
24″	1.55	3.11	4.17	2.91	5.06	6.31	2.33	4.18	5.40	4.58	7.07	8.93

* If old form lumber is used add 90% to "Making Forms."
† Values increased 50% as labor is generally ineffective in first set up.

TABLE 155] [HOISTING

HOISTING MATERIALS WITH BREAST DERRICKS*

Story†	Cost in dollars per hundred pounds of materials									
	Use when forms are made up in sections					Use when lumber is in separate boards or for steel				
	Weight in pounds per Load					Weights in pounds per Load				
	100 $	200 $	300 $	400 $	500 $	100 $	200 $	300 $	400 $	500 $
1	0.031	0.026	0.025	0.024	0.024	0.039	0.034	0.031	0.030	0.030
2	0.040	0.033	0.032	0.030	0.030	0.048	0.040	0.038	0.037	0.037
3	0.042	0.036	0.033	0.032	0.032	0.051	0.043	0.040	0.039	0.039

In Hoisting table, labor is figured at $0.20 per hour.
If labor cost $0.25 per hour take $\frac{25}{20}$ of value in table or increase by 25%.
* Breast Derrick is provided with winch but this is seldom used. The drum of winch is used to take a turn or two around it to hold rope when hoisting heavy loads.
† Height of story is taken as 12 feet.

EXAMPLES OF USE OF UNIT TIMES

The following examples show the way in which the unit times are combined to make complete operations. They also show the way in which the tables of times and costs in this chapter were made up.

Notice that not all of the operations are by the same men.

These times should not be used direct for task-work. (See p. 623).

The operations are given in detail and are taken direct from Tables 161 and 162, pages 662 and 664, of unit times.

TIME MAKING COLUMN FORMS

Example 1: Figure time required to make 4 sides of a column form—Type 1.

Design of form: See Fig. 48, p. 491.

Size of column: 22″ × 22″.

Story height: 12 feet.

Form lumber: 1″ × 6″ tongue and grooved, sawed to length on a mill-saw.

Cleats: 2″ × 4″ placed on edge.

Spacing of cleats: See Fig. 78, p. 614.

Mill-saw: All lumber sawed on a mill-saw.

Solution: Take items from Unit Time Tables, pp. 662 to 665.

Description	Table Number	Item Number	Number of Units	Unit Time	Time per Column
				min.	min.
Rip △ strips for corner beading........	162	(1)	4	1.47	5.88
Saw 2″ × 4″ cleats....................	161	(14)	4×7	0.24	6.72
Carry 2″ × 4″ cleats 50 feet to bench.	162	(4)	28	0.12	3.36
Place 2 - 2″ × 4″ cleats on bench........	162	(7)	28	0.13	3.64
Saw off form boards, both ends......	161	(3)	32	0.19	6.08
Rip form boards for pockets on mill-saw	162	(9)	8	1.24	9.92
Rip 12-foot form boards on mill-saw..	162	(11)	4	2.94	11.76
Carry form boards 50 feet—Table 156, p. 655..............................	162	(13)	16	0.30	4.80
Place form boards on bench..........	162	(14)	16	0.40	6.40
Wedge form boards together with wood wedges............................	162	(16)	16	0.30	4.80
Measure and mark for nailing.........	162	(17)	16	0.05	0.80
Nail 4 - 12 foot form boards to cleats.	162	(19)	28	0.83	23.24
Throw form aside on pile............	162	(33)	4	0.53	2.12
Extra for making cleanout hole.......	162	(34)	1	2.20	2.20
Saw 1″ × 4″ pocket pieces............	161	(2)	12	0.12	1.44
Carry pocket pieces 50 feet to bench..	162	(28)	4	0.09	0.36
Place pocket pieces on form..........	162	(29)	4	0.30	1.20
Nail pocket pieces to form...........	162	(30)	4	0.74	2.96

Total time to make 1 column form complete...............		97.68 min.
Add for unavoidable delays, ineffective work, etc............	30%	29.30 "
		126.98 "
Add for foremen, making benches and contingences due to weather, etc. (see p. 625)................................	27%	34.28 "
		161.26 "
Total overall "Make Time"	=	2.69 hrs.

This total coincides with the time given direct in Table 134, p. 630.

If work is scientifically managed the carrying items will be practically eliminated and other items reduced.

HAND SAWING vs. MILL SAWING

Example 2: How much longer will it take to make the above form if all the sawing except Δ strips is done by hand instead of on a mill-saw?

Solution: Mill-saw items used above: Items (14) + (3) + (2) from Table 161 + Items (9) + (11) from Table 162 = 35.92 minutes.

Replace these by hand saw items which amount to 90.00 minutes.

Difference is 90.00 − 35.92 = 54.08 minutes = 0.90 hours net.

Adding percentage as above, gross time is 89.28 minutes = 1.49 hours.

Total time if sawing is done by hand is 2.69 hours + 1.49 hours = 4.18 hours, or an increase of 55%.

Example 3: If only the 2″ × 4″ cleats and Δ strips in Example 1 are sawed on a mill-saw and all other sawing is done by hand including squaring and sawing ends of form, what will be the difference in time?

Solution: Mill-saw Items (3) + (2) from Table 161 + Items (9) + (11) from Table 162 = 29.20 minutes.

Using hand saw Items (10) + (12) + (31) + (32) from Table 162 + Item (23) from Table 161 = 60.90 minutes.

Difference is 60 90 − 29.20 = 31.70 minutes = 0.53 hours net.

Adding 30% and 27%, gross time = 52.34 minutes = 0.87 hours. This added to "Make Time" in Example 1 gives a total of 3.56 hours or an increase of 32.3%.

CARRYING DONE BY LABORERS vs. BY CARPENTERS

Example 4: If all the carrying is done by laborers at one-half carpenters' wages, what will be the difference in cost in making the above column form?

Solution: Take one-half of the time of the carrying items, $\frac{8.52}{2}$ = 4.26 minutes net or 7.04 minutes gross. This subtracted from the "Make Time" given above reduces it to 2.57 hours or 4.5% decrease in cost.

COLUMN FORMS TO BOTTOM OF GIRDERS

Example 5: If the column form is only made up to the bottom of the beam and girder forms, what will be the time in making the above column form?

Solution: The time taken for making forms for beam and girder pockets is the sum of Items (9), (28), (29), and (30) of Table 162 and (2) of Table 161, or 15.88 minutes net = 26.20 minutes gross. This subtracted from the "Make Time" given above gives 2.25 hours, showing 16.3% decrease in time.

VARIATION IN TIME DUE TO NUMBER OF CLEATS

Example 6: If forms are made with 8 cleats instead of 7, how much will this increase the time for making the column form?

Solution: Take $\frac{1}{7}$ of Items (14) of Table 161 and (4), (7), and (19) of Table 162 = 5.28 minutes net, or 8.71 minutes gross, which added to the "Make Time" given above gives 2.83 hours, a 5.2% increase in time.

TIME PLACING AND REMOVING COLUMN FORMS

Example 7: Figure time placing and removing column forms, first time.

See Example 1 for details of form.

Solution: Take items from Unit Time Table 163, pp. 668 to 670.

Description	Table Number	Item Number	Number of Units	Unit Time	Time per Column
				min.	min.
Locate, line, and brace columns	163	(1)	1	61.60	61.60
Carry sides of forms 50 ft.	163	(3)	4	2.40	9.60
Place 4 sides of form on horses	163	(4)	1	1.75	1.75
Measure sides for 4 △ strips, mark and ready to place them	163	(5)	1	8.00	8.00
Place new △ strips on 4 sides of column	163	(6)	1	20.20	20.20
Get wedging boards 50 feet away	163	(10)	4	0.30	1.20
Mark cleats and nail on wedging boards	163	(9)+(11)	7	1.60	11.20
Place and drive wedges, get, place, and tighten iron clamps	163	(14)+(19)+(20)	7	2.00	14.00
Nail 4 sides of column together	163	(12)	1	1.04	1.04
Carry 3 sides to place, 50 feet	163	(15)	1	7.20	7.20
Carry 4th side to place, 50 feet	163	(16)	1	2.40	2.40
Lift and place 3 sides (attached), place 4th side	163	(17)+(18)	1	3.00	3.00
Square form, place temporary braces. Place piece at cleanout hole, change to next column	163	(21)+(22)+(24)	1	16.80	16.80
Make and carry wood wedges 50 feet	163	(29)+(30)	1	10.00	10 00
Oil forms	163	(33)	1	5.00	5.00
Saw off 1 × 2 inch strips	161	(22)	8	0.38	3.04
Clean out rubbish from column	163	(35)	1	2.75	2.75
Remove forms	163	(36)	1	69.60	69.60
					248.38
Add for unavoidable delays and ineffective work (see p. 625)				30%	74.51
Carried forward to next page					322.89

Brought forward from last page		322.89
Add for foremen, contingencies due to weather, etc. (see p. 625)	17%	54.89
		377.78
Values increased 50% as labor is generally inefficient on first set up*	50%	188.89
		566.67
Total overall "Place and Remove Time"		9.5 hrs.

* If work is systematically planned in advance this percentage will be small.
The total time coincides with the time given direct in Table 134, p. 630.
If work is scientifically managed the carrying items will be practically eliminated and other items reduced.

VARIATION IN TIME DUE TO STORY HEIGHT

Example 8: If story height in Example 1 is 9 feet instead of 12 feet, what would be the "Make Time" per column form?

Solution: Take $\frac{2}{7}$ of Items (14) of Table 161 and (4), (7), and (19) of Table 162 due to the reduction in number of cleats, and $\frac{1}{4}$ of Items (13) and (33) of Table 162 due to the reduction in story height, which gives 12.30 minutes net or 20.30 minutes gross. Subtracting this from the total time in Example 1 gives 2.35 hours, or a reduction of 12.6%.

Example 9: If story height is 9 feet instead of 12 feet, how would this affect the total time in Example 7?

Solution: Take $\frac{2}{7}$ of items (9), (11), (12), (19), (20), (29), and (30) of Table 163 due to the reduction in number of cleats, and $\frac{1}{4}$ of items (3), (5), (6), (15), and (33) of Table 163 due to reduction in story height, which equals 21.45 minutes net or 48.96 minutes gross; subtracting this from the total time above gives 8.6 hours or a reduction of 9.5%.

CARRYING DONE BY LABORERS vs. CARPENTERS

Example 10: If all the carrying and oiling is done systematically by laborers at one-half carpenters' wages, what percentage of total time would be saved in placing and removing column form first time?

Solution: Take one-half of the time of the carrying items or 16.58 minutes net or 37.82 minutes gross, which subtracted from the total time above gives 8.1 hours, or a reduction of 6.3%.

Example 11: Figure time "Placing and Removing Column Form after first time;" column form same as in Example 7.

Solution: Time is figured in same manner as Example 7. The total time with the percentages added amounts to 7.8 hours.

EXAMPLES OF USE OF COST TABLES

Example 1: Find cost of labor on column forms (type 2) for a three-story building having 14 interior and 22 exterior columns for a building 60 feet by 100 feet. Story heights 12 feet from floor surface to floor surface. Columns 24 inches square on first and second floors and 12 inches square on third floor. Carpenter labor at 50 cents per hour. Form lumber, 1 inch planed and t. and g. One set of forms used.
Solution: Use Table 137, p. 633.

Item	Cost per Interior Column Form from Footing to Roof.	Cost per Wall Column Form from Footing to Roof.
Make 1 24-inch square column form....	$3.18	$3.18
Place and remove 1 24-inch square column form for first floor...........	7.86	11.79
Place and remove 1 24-inch column form for second floor.......................	6.51	9.76
Remake, place and remove 1 12-inch column form for third floor	7.33	11.00
Totals..............................	$24.88	$35.73

$24.88 × 14 (interior) = $348.32
$35.73 × 22 (exterior) = 786.06

Total cost of column forms for entire building = $1134.38

Example 2: In above example how much does the column form work cost per square foot of column surface area?
Solution: Total surface area of one column through building (i.e., 2, 24-inch and 1, 12-inch column) is 240 square feet.
There are 14 plus 22, or 36 columns in building running from footings to roof.
Therefore 36 × 240 = 8640 square feet of column surface area in building.

$\frac{\$1134.38}{8640}$ = $0.1313 per square foot of column surface area.

Example 3. What would be the cost of the column forms if the story height is 10 feet instead of 12 feet as in example above?
Solution: Interpolate in Table 137, page 633, between values found in 6-foot column and 12-foot column.

Example 4: In above examples, if carpenter labor costs 40 cents per hour instead of 50 cents, how should this be taken into account?
Solution: After getting cost as above, take $\frac{4}{5}$ of this value or deduct $\frac{1}{5}$. Total cost is therefore $1134.38 × $\frac{4}{5}$ = $907.50.

Example 5: If profit and home-office expense in the above example is estimated at 10%, how should this be figured?
Solution: Add 10% to total cost or $1134.38 plus $113.44 = $1247.82.

EXAMPLE OF USE OF TIME TABLES

Example 6: Find cost of labor in Example 1 by first finding amount of labor and then multiplying by the given rate per hour.
Solution: From Table 136.

Item	Time per Interior Column Form from Footing to Roof	Time per Wall Column Form from Footing to Roof
Total time, made up same as costs..	39.3 hours	56.4 hours

39.3 × 14 (interior)	=	550.2 hours
56.4 × 22 (exterior)	=	1240.8 hours
		1791.0 hours
Add 10%, i.e. 15% for contingencies occurring on ordinary form construction, less 5% to take care of work done by common labor at 25 cents per hour (see p. 625)........	=	179.1 hours
		1970.1 hours
Add 15% for superintendence, contingencies, etc. (see p. 625).......	=	295.5 hours
Total.........		2265.6 hours

2265.6 hours at 50 cents per hour = $1132.50 = Total cost of column forms for entire building.
This substantially agrees witl the cost as figured above.

EXPLANATION FOR USE OF FORM TABLES, PAGES 630 TO 648

Use Cost Tables ordinarily.

Use Time Tables only when estimator is thoroughly familiar with make-up of tables (see p. 623).

Use columns marked "Average Men" ordinarily. Use "Quick Men" only where labor is exceptionally efficient.

For $1\frac{1}{4}$-inch or $1\frac{1}{2}$-inch lumber, use values quarter-way, or half-way between 1-inch and 2-inch values.

For rectangular columns, select values for square columns having the larger dimension of rectangle.

For wall columns, add 50% to all except "Make Forms."

In "Make Forms" allow 10% to 50% for special design.

If no mill-saw on job, add 50% to "Make Forms."

If old lumber is used, add from 75% to 100% to "Make Forms" according to thickness and condition of lumber.

Story heights are from floor surface to floor surface. The lengths of beams are distances between centers of columns. For intermediate heights or lengths, interpolate.

COST TABLES

Costs are given in "Dollars per Member."

Select cost per member corresponding to thickness of lumber, size and length or area of member.

Costs are figured for carpenter labor at 50¢ per hour and ordinary labor at 25¢ per hour.

Costs are based on *average workmen* and *ordinary construction* and include handling, carrying, and sawing lumber.

With inexperienced builders, increase costs by one-third.

Costs are figured from Times by adding 10% for ordinary construction and 15% extra for superintendence, contingencies, etc., as explained on page 625, but they do not include profit or home-office expense.

TIME TABLES

Times are given in "Hours per Member."

Select time per member corresponding to thickness of lumber, size, and length or area of member.

Multiply by average wage rate per hour.

Add proper per cent for superintendence, contingencies etc. (15% used in Cost Tables, see p. 625).

Add another 15% unless work is exceptionally well managed. (If carrying done by laborers deduct 5% from this), or—Add 50% (instead of 15%) if work is done by inexperienced builders.

Times are based on *average workmen* and *well organized* construction, and include all handling, sawing, necessary delays, and allowance for foremen, etc., but no allowance for superintendence, contingencies, etc., or for profit or home-office expenses (see p. 625).

EXPLANATION OF USE OF FORM TABLES OF TIMES AND COSTS

With examples

TABLE 156] NUMBER OF PIECES AND FEET B. M. OF LUMBER CARRIED PER LOAD AND PER HOUR (See p. 626) [CARRYING LUMBER

An average man carries not over 70 pounds.

For quick men increase values in table for "Boards per Load" and "Boards carried per Hour" by 10%. For first-class men under task and bonus increase values by 25%.

Dimensions in Inches	Description	Length of Board in Feet: 2	4	6	8	10	12	14	16	18
1″ × 2″	Ft. B. M. Per Piece	0.33	0.66	0.99	1.32	1.65	1.98	2.31	2.64	2.97
	Boards Per Load			25	21	17	14	25	21	19
	Men per Load	1	1	1	1	1	1	2	2	2
	Boards carried Per Hour, 50 Ft.			1250	1050	850	700	625	525	475
	Boards carried Per Hour, 100 Ft.			825	693	561	462	413	347	314
1″ × 4″	Ft. B. M. Per Piece	0.66	1.32	1.98	2.64	3.30	3.96	4.62	5.28	5.94
	Boards Per Load			14	11	8	7	12	10	9
	Men Per Load	1	1	1	1	1	1	2	2	2
	Boards carried Per Hour, 50 Ft.			700	550	400	350	300	250	225
	Boards carried Per Hour, 100 Ft.			462	363	264	231	198	165	148
1″ × 6″	Ft. B. M. Per Piece	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
	Boards Per Load		14	9	7	5	4	8	7	6
	Men Per Load	1	1	1	1	1	1	2	2	2
	Boards carried Per Hour, 50 Ft.		700	450	350	250	200	200	175	150
	Boards carried Per Hour, 100 Ft.		362	297	231	165	132	132	115	99
1″ × 8″	Ft. B. M. Per Piece	1.32	2.66	4.99	6.32	7.65	8.98	10.3	11.6	13.0
	Boards Per Load	15	10	5	4	3	3	5	4	4
	Men Per Load	I	1	1	1	1	1	2	2	2
	Boards carried Per Hour, 50 Ft.	750	500	250	200	150	150	125	100	100
	Boards carried Per Hour, 100 Ft.	495	330	165	132	99	99	82	66	66
1″ × 10″	Ft. B. M. Per Piece	1.66	3.32	4.98	6.64	8.30	9.96	11.6	13.3	14.9
	Boards Per Load	12	8	5	4	3	2	4	4	3
	Men Per Load	1	1	1	1	1	1	2	2	2
	Boards carried Per Hour, 50 Ft.	600	400	250	200	150	100	100	100	75
	Boards carried Per Hour, 100 Ft.	396	264	165	132	99	66	66	66	49
1″ × 12″	Ft. B. M. Per Piece	2.00	4.00	6.00	8.00	10.00	12.0	14.0	16.0	18.0
	Boards Per Load	10	7	4	3	2	2	4	3	3
	Men Per Load	1	1	1	1	1	1	2	2	2
	Boards carried Per Hour, 50 Ft.	500	350	200	150	100	100	100	75	75
	Boards carried Per Hour, 100 Ft.	330	231	132	99	66	66	66	49	49
1½″ × 2″	Ft. B. M. Per Piece	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
	Boards Per Load	35	28	18	14	11	9	16	14	12
	Men Per Load	1	1	1	1	1	1	2	2	2
	Boards carried Per Hour, 50 Ft.	1750	1400	900	700	550	450	400	350	300
	Boards carried Per Hour, 100 Ft.	1155	924	594	462	363	297	264	231	198
1½″ × 4″	Ft. B. M. Per Piece	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
	Boards Per Load	20	14	9	7	5	4	8	7	6
	Men Per Load	1	1	1	1	1	1	2	2	2
	Boards carried Per Hour, 50 Ft.	1000	700	450	350	250	200	200	175	150
	Boards carried Per Hour, 100 Ft.	660	462	297	231	165	132	132	115	99
1½″ × 6″	Ft. B. M. Per Piece	1.50	3.00	4.50	6.00	7.50	9.00	10.5	12.0	13.5
	Boards Per Load	16	9	6	4	3	3	5	4	4
	Men Per Load	1	1	1	1	1	1	2	2	2
	Boards carried Per Hour, 50 Ft.	800	450	300	200	150	150	125	100	100
	Boards carried Per Hour, 100 Ft.	528	297	198	132	99	99	82	66	66

TABLE 156] NUMBER OF PIECES AND FEET B. M. OF LUMBER CARRIED PER LOAD AND PER HOUR—Continued [CARRYING LUMBER

(See p. 626)

An average man carries not over 70 pounds.

For quick men increase values in table for "Boards per Load" and "Boards carried per Hour" by 10%. For first-class men under task and bonus increase values by 25%.

Dimensions in Inches	Description	Length of Board in Feet: 2	4	6	8	10	12	14	16	18
1½" × 8"	Ft. B. M. Per Piece	2.00	4.00	6.00	8.00	10.0	12.0	14.0	16.0	18.0
	Boards Per Load	12	7	4	3	2	2	4	3	3
	Men Per Load	1	1	1	1	1	1	2	2	2
	Boards carried Per Hour, 50 Ft.	600	350	200	150	100	100	100	75	75
	Boards carried Per Hour, 100 Ft.	396	231	132	99	66	66	66	49	49
1½" × 10"	Ft. B. M. Per Piece	2.50	5.00	7.00	10.0	12.5	15.0	17.5	20.0	22.5
	Boards Per Load	10	5	3	2	2	1	3	2	2
	Men Per Load	1	1	1	1	1	1	2	2	2
	Boards carried Per Hour, 50 Ft.	500	250	150	100	100	50	50	50	50
	Boards carried Per Hour, 100 Ft.	330	165	99	66	66	33	33	33	33
1½" × 12"	Ft. B. M. Per Piece	3.00	6.00	9.00	12.0	15.0	18.0	21.0	24.0	27.0
	Boards Per Load	8	4	3	2	1	1	2	2	2
	Men Per Load	1	1	1	1	1	1	2	2	2
	Boards carried Per Hour, 50 Ft.	400	200	150	100	50	50	50	50	50
	Boards carried Per Hour, 100 Ft	264	132	99	66	33	33	33	33	33
2" × 2"	Ft. B. M. Per Piece	0.67	1.33	2.00	2.66	3.33	4.00	4.66	5.33	6.00
	Boards Per Load	30	20	14	10	8	7	12	10	9
	Men Per Load	1	1	1	1	1	1	2	2	2
	Boards carried Per Hour, 50 Ft.	1500	1000	700	500	400	350	300	250	225
	Boards carried Per Hour, 100 Ft.	990	660	462	330	264	231	198	165	148
2" × 4"	Ft. B. M. Per Piece	1.33	2.66	4.00	5.33	6.66	8.00	9.32	10.66	12.00
	Boards Per Load	15	10	7	5	4	3	6	5	4
	Men Per Load	1	1	1	1	1	1	2	2	2
	Boards Carried Per Hour, 50 Ft.	750	500	350	250	200	150	150	125	100
	Boards Carried Per Hour, 100 Ft.	495	330	231	165	132	99	99	82	66
2" × 6"	Ft. B. M. Per Piece	2.00	4.00	6.00	8.00	10.0	12.0	14.0	16.0	18.0
	Boards Per Load	12	6	4	3	2	2	4	4	3
	Men Per Load	1	1	1	1	1	1	2	2	2
	Boards carried Per Hour, 50 Ft.	600	300	200	150	100	100	100	100	75
	Boards carried Per Hour, 100 Ft.	396	198	132	99	66	66	66	66	49
2" × 8"	Men Per Load	2.67	5.33	8.00	10.66	13.3	16.0	18.7	21.3	24.0
	Boards Per Load	10	5	3	2	2	1	3	2	2
	Men Per Load	1	1	1	1	1	1	2	2	2
	Boards carried Per Hour, 50 Ft.	500	250	150	100	100	50	50	50	50
	Boards carried Per Hour, 100 Ft.	330	165	99	66	66	33	33	33	33
2" × 10"	Ft. B. M. Per Piece	3.33	6.66	10.0	13.3	16.6	20.0	23.3	26.6	30.0
	Boards Per Load	8	4	2	2	1	1	2	1	1
	Men Per Load	1	1	1	1	1	1	2	2	2
	Boards carried Per Hour, 50 Ft.	400	200	100	100	50	50	50	25	25
	Boards carried Per Hour, 100 Ft.	264	132	66	66	33	33	33	16	16
2" × 12"	Ft. B. M. Per Piece	4.00	8.00	12.0	16.0	20.0	24.0	28.0	32.0	36.0
	Boards Per Load	6	3	2	1	1	1	2	1	1
	Men Per Load	1	1	1	1	1	1	2	2	2
	Boards carried Per Hour, 50 Ft.	300	150	100	50	50	50	50	25	25
	Boards carried Per Hour, 100 Ft.	198	99	66	33	33	33	33	16	16

TABLE 156] NUMBER OF PIECES AND FEET B. M. OF LUMBER CARRIED PER LOAD AND PER HOUR—Continued [CARRYING LUMBER

(See p. 626)

An average man carries not over 70 pounds.

For quick men increase values in table for "Boards per Load" and "Boards carried per Hour" by 10%. For first-class men under task and bonus increase values by 25%.

Dimensions in Inches	Description	Length of Board in Feet								
		2	4	6	8	10	12	14	16	18
3″ × 4″	Ft. B. M. Per Piece	2.00	4.00	6.00	8.00	10.0	12.0	14.0	16.0	18.0
	Boards Per Load	10	6	4	3	2	2	3	3	3
	Men Per Load	1	1	1	1	1	1	2	2	2
	Boards carried Per Hour 50 Ft.	500	300	200	150	100	100	75	75	75
	Boards carried Per Hour 100 Ft.	330	198	132	99	66	66	49	49	49
3″ × 6″	Ft. B. M. Per Piece	3.00	6.00	9.00	12.0	15.0	18.0	21.0	24.0	27.0
	Boards Per Load	8	4	3	2	1	1	3	2	2
	Men Per Load	1	1	1	1	1	1	2	2	2
	Boards carried Per Hour 50 Ft.	400	200	150	100	50	50	50	50	50
	Boards carried Per Hour 100 Ft.	264	132	99	66	33	33	33	33	33
3″ × 8″	Ft. B. M. Per Piece	4.00	8.00	12.0	16.0	20.0	24.0	28.0	32.0	36.0
	Boards Per Load	6	3	2	1	1	1	2	1	1
	Men Per Load	1	1	1	1	1	1	2	2	2
	Boards carried Per Hour 50 Ft.	300	150	100	50	50	50	50	25	25
	Boards carried Per Hour 100 Ft.	198	99	66	33	33	33	33	16	16
3″ × 10″	Ft. B. M. Per Piece	5.00	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0
	Boards Per Load	5	2	1	1	1	1	1	1	1
	Men Per Load	1	1	1	1	1	2	2	2	2
	Boards carried Per Hour 50 Ft.	250	100	50	50	50	25	25	25	25
	Boards carried Per Hour 100 Ft.	165	66	33	33	33	16	16	16	16
3″ × 12″	Ft. B. M. Per Piece	6.00	12.0	18.0	24.0	30.0	36.0	42.0	48.0	54.0
	Boards Per Load	4	2	1	1	1	1	1	1	1
	Men Per Load	1	1	1	1	2	2	2	2	2
	Boards carried Per Hour 50 Ft.	200	100	50	50	25	25	25	25	25
	Boards carried Per Hour 100 Ft.	132	66	33	33	16	16	16	16	16
4″ × 4″	Ft. B. M. Per Piece	2.67	5.33	8.00	10.6	13.3	16.0	18.6	2.13	2.40
	Pieces Per Load	8	4	3	2	2	1	3	2	2
	Men Per Load	1	1	1	1	1	1	2	2	2
	Pieces carried Per Hour 50 Ft.	400	200	150	100	100	50	50	50	50
	Pieces carried Per Hour 100 Ft.	264	132	99	66	66	33	33	33	33
4″ × 6″	Ft. B. M. Per Piece	4.00	8.00	12.0	16.0	20.0	24.0	28.0	32.0	36.0
	Pieces Per Load	6	3	2	1	1	1	2	1	1
	Men Per Load	1	1	1	1	1	1	2	2	2
	Pieces carried Per Hour 50 Ft.	300	150	100	50	50	50	50	25	25
	Pieces carried Per Hour 100 Ft.	198	99	66	33	33	33	33	16	16
4″ × 8″	Ft. B. M. Per Piece	5.33	10.6	16.0	21.3	26.6	32.0	37.3	42.7	48.0
	Pieces Per Load	4	2	1	1	1	1	1	1	1
	Men Per Load	1	1	1	1	1	2	2	2	2
	Pieces carried Per Hour 50 Ft.	200	100	50	50	50	25	25	25	25
	Pieces carried Per Hour 100 Ft.	132	66	33	33	33	33	16	16	16

TABLE 157] LABOR MAKING ONE SIDE OF A COLUMN FORM [TIMES

Based on Systematically Managed Work (see p. 627)

Use for timing carpenters at work bench.

BEFORE USING THIS TABLE, READ NOTES ON PAGE 663

TYPE 1 COLUMN FORMS WITH IRON CLAMPS FIG. 48

Width of Side	6 Ft. Column				12 Ft. Column				18 Ft. Column			
	1″ Lumber		2″ Lumber		1″ Lumber		2″ Lumber		1″ Lumber		2″ Lumber	
	Aver. Men	Quick Men	Aver. Men	Quick Men	Aver. Men	Quick Men	Aver. Men	Quick Men	Aver. Men	Quick Men	Aver. Men	Quick Men
in.	min.	min.	min.	min.	min.	min.	min.	min.	min.	min.	min.	min.
8	5.0	3.3	6.0	4.0	9.0	6.0	10.8	7.2	15.0	10.0	18.0	12.0
12	6.1	4.1	7.3	4.9	11.0	7.3	13.2	8.8	18.5	12.3	22.2	14.8
16	7.5	5.0	9.0	6.0	12.5	8.3	15.0	10.0	22.0	14.7	26.4	17.6
18	8.5	5.7	10.2	6.8	13.5	9.0	16.2	10.8	23.5	15.7	28.2	18.8
20	9.0	6.0	10.8	7.2	15.0	10.0	18.0	12.0	25.5	17.0	30.6	20.4
22	10.0	6.7	12.0	8.0	16.0	10.7	19.2	12.8	27.5	18.3	32.9	21.9
24	11.0	7.3	13.2	8.8	17.0	11.4	20.2	13.5	29.5	19.7	35.4	23.6
26	11.5	7.7	13.8	9.2	19.0	12.7	22.8	15.2	31.5	21.0	37.8	25.2
28	12.0	8.0	14.4	9.6	20.5	13.7	24.6	16.4	33.5	22.4	40.1	26.8
30	13.1	8.7	15.7	10.5	22.0	14.7	26.4	17.6	36.0	24.0	43.2	28.8
34	15.1	10.1	18.1	12.1	26.5	17.7	31.8	21.2	42.0	28.0	50.3	33.5
38	18.5	12.3	22.2	14.8	32.5	21.7	39.0	26.0	51.0	34.0	61.1	40.7

For Spacing of 2″×4″ cleats See Fig. 78, p. 614

TYPE 2 COLUMN FORMS WITH WOOD WEDGE CLAMPS FIG. 49B

Width of Side	6 Ft. 1″ Aver.	6 Ft. 1″ Quick	6 Ft. 2″ Aver.	6 Ft. 2″ Quick	12 Ft. 1″ Aver.	12 Ft. 1″ Quick	12 Ft. 2″ Aver.	12 Ft. 2″ Quick	18 Ft. 1″ Aver.	18 Ft. 1″ Quick	18 Ft. 2″ Aver.	18 Ft. 2″ Quick
8	6.0	4.0	7.2	4.8	11.0	7.3	13.2	8.8	18.0	12.0	21.6	14.4
12	6.9	4.6	8.3	5.5	13.0	8.7	15.6	10.4	21.0	14.0	25.2	16.8
16	8.5	5.7	10.2	6.8	15.0	10.0	18.0	12.0	24.5	16.3	29.4	19.6
18	9.0	6.0	10.8	7.2	16.1	10.7	19.3	12.9	26.5	17.7	31.7	21.1
20	10.0	6.7	12.0	8.0	18.0	12.0	21.6	14.4	28.5	19.0	34.2	22.8
22	11.0	7.3	13.2	8.8	19.5	13.0	23.4	15.6	30.5	20.3	36.5	24.3
24	11.5	7.8	13.8	9.2	21.0	14.0	25.1	16.7	32.5	21.7	39.0	26.0
26	12.5	8.3	15.0	10.0	22.5	15.0	27.0	18.0	35.0	23.4	42.0	28.0
28	13.5	9.0	16.2	10.8	24.0	16.0	28.8	19.2	37.5	25.0	45.0	30.0
30	14.0	9.3	16.8	11.2	26.0	17.3	31.1	20.7	41.0	27.4	49.2	32.8
34	17.0	11.3	20.4	13.6	30.0	20.0	35.9	23.9	50.0	33.4	60.0	40.0
38	21.5	14.3	25.8	17.2	36.5	24.3	43.7	29.2	60.0	40.0	72.0	48.0

1″×2″ battans spaced 24″ apart

TYPE 3 COLUMN FORMS WITH BOLTED CLAMPS FIG. 49A

Width of Side	6 Ft. 1″ Aver.	6 Ft. 1″ Quick	6 Ft. 2″ Aver.	6 Ft. 2″ Quick	12 Ft. 1″ Aver.	12 Ft. 1″ Quick	12 Ft. 2″ Aver.	12 Ft. 2″ Quick	18 Ft. 1″ Aver.	18 Ft. 1″ Quick	18 Ft. 2″ Aver.	18 Ft. 2″ Quick
8	5.0	3.3	6.0	4.0	9.0	6.0	10.8	7.2	15.0	10.0	18.0	12.0
12	6.1	4.1	7.3	4.9	11.0	7.3	13.2	8.8	18.5	12.3	22.2	14.8
16	7.5	5.0	9.0	6.0	12.5	8.3	15.0	10.0	22.0	14.7	26.4	17.6
18	8.5	5.7	10.2	6.8	13.5	9.0	16.2	10.8	23.5	15.7	28.2	18.8
20	9.0	6.0	10.8	7.2	15.0	10.0	18.0	12.0	25.5	17.0	30.6	20.4
22	10.0	6.7	12.0	8.0	16.0	10.7	19.2	12.8	27.5	18.3	32.9	21.9
24	11.0	7.3	13.2	8.8	17.0	11.4	20.2	13.5	29.5	19.7	35.4	23.6
26	11.5	7.7	13.8	9.2	19.0	12.7	22.8	15.2	31.5	21.0	37.8	25.2
28	12.0	8.0	14.4	9.6	20.5	13.7	24.6	16.4	33.5	22.4	40.1	26.8
30	13.1	8.7	15.7	10.5	22.0	14.7	26.4	17.6	36.0	24.0	43.2	28.8
34	15.1	10.1	18.1	12.1	26.5	17.7	31.8	21.2	42.0	28.0	50.3	33.5
38.	18.5	12.3	22.2	14.8	32.5	21.7	39.0	26.0	51.0	34.0	61.1	40.7

For Spacing of 2″×4″ cleats See Fig. 77, p. 613

TABLE 158] **LABOR ASSEMBLING AND SETTING A COLUMN FORM** **[TIMES**

Based on Systematically Managed Work (see p. 627)

Use for timing carpenters on erection.

BEFORE USING THIS TABLE, READ NOTES ON PAGE 663

Width of Side	6 Ft. Column				12 Ft. Column				18 Ft. Column			
	1″ Lumber		2″ Lumber		1″ Lumber		2″ Lumber		1″ Lumber		2″ Lumber	
	Aver. Men	Quick Men	Aver. Men	Quick Men	Aver. Men	Quick Men	Aver. Men	Quick Men	Aver. Men	Quick Men	Aver. Men	Quick Men
in.	min.	min.	min.	min.	min.	min.	min.	min.	min.	min.	min.	min.
TYPE 1 COLUMN FORMS WITH IRON CLAMPS FIG. 48												
8	62	41	74	49	100	66	120	80	142	94	170	113
12	65	43	78	52	106	70	127	84	150	100	180	120
16	69	46	82	55	111	73	133	89	159	106	190	127
18	71	47	85	56	114	76	136	90	164	109	196	131
20	72	48	86	58	118	78	141	93	168	112	201	134
22	75	50	89	60	121	80	145	96	173	115	207	138
24	77	51	93	61	125	83	150	100	179	119	214	143
26	81	54	97	64	130	86	155	104	186	124	223	148
28	84	56	100	67	135	90	162	108	193	129	231	154
30	87	58	105	70	141	94	169	113	201	134	241	160
34	95	63	113	75	153	102	183	122	220	147	264	176
38	105	70	126	84	167	111	200	133	245	163	294	196
TYPE 2 COLUMN FORMS WITH WOOD WEDGE CLAMPS FIG. 49B												
8	93	62	111	74	150	100	179	119	214	143	257	171
12	98	65	117	78	158	105	189	126	226	151	271	181
16	104	69	124	83	168	112	201	134	238	159	275	183
18	106	70	127	84	171	114	205	137	245	163	294	196
20	110	73	132	88	177	118	212	141	252	168	302	202
22	113	75	135	90	182	121	218	145	260	173	312	208
24	118	79	141	94	188	125	226	151	269	179	323	217
26	122	81	146	97	197	131	236	157	280	187	335	224
28	128	85	153	102	205	137	245	164	290	193	347	232
30	133	88	159	106	213	142	255	170	301	201	360	240
34	144	96	172	115	231	154	277	185	328	218	393	262
38	158	105	189	126	255	170	306	204	370	246	442	295
TYPE 3 COLUMN FORMS WITH BOLTED CLAMPS FIG. 49A												
8	100	66	120	80	160	107	191	128	230	153	268	179
12	106	70	127	84	170	113	204	136	243	162	292	194
16	111	74	133	88	178	119	213	142	258	172	309	206
18	114	67	136	91	184	123	220	146	265	177	317	211
20	117	78	140	93	189	126	226	150	273	182	327	218
22	120	80	143	95	194	129	232	155	282	188	338	225
24	125	83	149	99	202	135	242	161	290	193	358	239
26	130	86	156	104	210	140	252	168	302	202	362	242
28	135	90	162	108	219	146	262	175	313	209	375	250
30	141	94	169	113	228	152	273	182	326	218	390	260
34	153	102	183	122	246	164	295	197	353	235	423	282
38	168	112	201	134	272	181	325	217	390	260	467	312

TABLE 159] LABOR MAKING ONE SIDE OF A BEAM AND A GIRDER FORM [TIMES

Based on Systemaiically Managed Work (see p. 627)

Use for timing carpenters at work bench

BEFORE USING THIS TABLE, READ NOTES ON PAGE 663

MAKING BEAM SIDE FORMS FIG. 54

Depth of Beam Below Slab	10 Ft. C. to C. Columns				20 Ft. C. to C. Columns				30 Ft. C. to C. Columns			
	1″ Lumber		2″ Lumber		1″ Lumber		2″ Lumber		1″ Lumber		2″ Lumber	
	Aver. Men	Quick Men	Aver. Men	Quick Men	Aver. Men	Quick Men	Aver. Men	Quick Men	Aver. Men	Quick Men	Aver. Men	Quick Men
in.	min.	min.	min.	min.	min.	min.	min.	min.	min.	min.	min.	min.
6	10.6	7.1	12.2	8.1	14.8	9.9	17.1	11.4	25.8	17.2	29.7	19.8
8	11.6	7.7	13.4	8.9	16.5	11.0	19.0	12.7	28.0	18.7	32.2	21.5
10	12.4	8.3	14.3	9.5	18.3	12.2	21.0	14.0	30.6	20.4	35.2	23.4
12	13.3	8.9	15.3	10.2	20.1	13.4	23.1	15.4	33.0	22.0	38.0	25.4
14	14.1	9.4	16.2	10.8	21.8	14.5	25.1	16.8	35.5	23.7	40.8	27.2
16	15.0	10.0	17.2	11.5	23.6	15.7	26.2	17.5	37.8	25.2	43.5	29.0
18	16.0	10.7	18.4	12.3	25.6	17.1	29.4	19.6	40.3	26.8	46.4	30.8
20	17.2	11.5	19.8	13.2	28.0	18.6	32.2	21.5	44.6	29.8	51.4	34.2
22	18.5	12.3	21.3	14.2	30.8	20.6	35.4	23.6	49.0	32.6	56.5	37.6
26	20.5	13.7	23.6	15.7	35.0	23.4	40.3	26.8	55.6	37.1	64.0	42.6
30	21.8	14.5	25.2	16.8	37.6	25.1	43.3	28.8	60.0	40.0	69.0	46.0
34	23.1	15.4	26.6	17.7	40.2	26.8	46.4	30.9	64.5	43.0	74.4	49.5
MAKING GIRDER SIDE FORMS—1 INTERSECTING BEAM FIG. 56												
6	10.2	6.8	11.7	7.8	14.6	9.7	16.8	11.2	24.2	16.1	27.8	18.5
8	11.1	7.4	12.8	8.5	16.0	10.7	18.4	12.3	26.8	17.9	30.8	20.6
10	12.0	8.0	13.8	9.2	17.7	11.8	20.4	13.6	29.2	19.5	33.6	22.4
12	12.8	8.5	14.7	9.8	19.2	12.8	22.1	14.7	31.8	21.2	36.6	24.4
14	13.8	9.2	15.9	10.6	20.8	13.9	24.0	16.0	34.3	22.9	39.5	26.4
16	14.5	9.7	16.7	11.1	22.3	14.9	25.7	17.1	37.0	24.7	42.5	28.3
18	15.5	10.3	17.8	11.9	24.0	16.0	26.6	17.7	39.6	26.4	45.6	30.4
20	17.2	11.4	19.8	13.2	26.8	17.9	30.8	20.5	44.6	29.8	51.3	34.2
22	19.0	12.7	21.9	14.6	29.7	19.8	34.2	22.8	49.6	33.0	57.2	38.2
26	22.4	15.0	25.8	17.2	34.5	23.0	39.7	26.5	58.0	38.7	66.7	44.5
30	25.0	16.8	28.8	19.2	38.5	25.7	44.4	29.6	65.0	43.3	74.8	49.8
34	27.7	18.5	31.9	21.3	42.5	28.3	49.0	32.7	71.7	47.8	82.5	55.0
MAKING GIRDER SIDE FORMS—2 INTERSECTING BEAMS FIG. 56												
6	9.2	6.1	10.6	7.1	14.1	9.4	16.2	10.8	23.8	15.9	27.4	18.2
8	10.1	6.7	11.6	7.7	15.6	10.4	17.9	11.9	26.0	17.3	29.9	19.9
10	11.1	7.4	12.8	8.5	17.2	11.5	19.8	13.2	28.6	19.0	33.0	22.0
12	12.0	8.0	13.8	9.2	18.7	12.5	21.5	14.3	31.2	20.8	35.9	23.9
14	13.2	8.8	15.2	10.1	20.3	13.5	23.3	15.5	33.8	22.6	38.9	25.9
16	14.2	9.5	16.3	10.9	21.8	14.5	25.1	16.7	36.0	24.0	41.5	27.7
18	15.2	10.1	17.5	11.7	23.5	15.7	27.0	18.0	38.8	25.9	44.6	29.8
20	17.0	11.3	19.6	13.1	26.0	17.3	29.9	19.9	43.0	28.7	49.5	33.0
22	18.8	12.5	21.6	14.4	28.8	19.2	33.2	22.1	47.8	31.8	55.0	36.6
26	22.0	14.7	25.4	16.3	33.6	22.4	38.6	25.8	55.8	37.2	64.3	42.7
30	24.5	16.3	28.2	18.8	37.5	25.0	43.2	28.8	62.0	41.3	71.5	47.6
34	27.0	18.0	31.0	20.7	40.2	26.8	46.3	30.8	68.4	45.5	78.7	52.5

TABLE 160] LABOR ASSEMBLING A BEAM AND A GIRDER FORM [TIMES

Based on Systematically Managed Work (see p. 627)

Use for timing carpenters on erection.

BEFORE USING THIS TABLE, READ NOTES ON PAGE 663

ASSEMBLING BEAM FORMS FIG. 54

Depth of Beam Below Slab	10 Ft. C. to C. Columns				20 Ft. C. to C. Columns				30 Ft. C. to C. Columns			
	1″ Lumber		2″ Lumber		1″ Lumber		2″ Lumber		1″ Lumber		2″ Lumber	
	Aver. Men	Quick Men	Aver. Men	Quick Men	Aver. Men	Quick Men	Aver. Men	Quick Men	Aver. Men	Quick Men	Aver. Men	Quick Men
in.	min.	min.	min.	min.	min.	min.	min.	min.	min.	min.	min.	min.
8	29	19	35	23	50	33	60	40	65	43	78	52
12	32	22	38	26	57	38	69	46	75	50	90	60
16	35	23	42	28	63	42	76	51	83	55	100	67
18	36	24	43	29	65	43	78	52	87	58	104	69
20	37	25	44	30	67	45	81	54	90	60	108	72
22	38	25	46	30	68	45	82	55	93	62	111	74
24	38	25	46	30	70	47	84	56	94	63	113	75
26	39	26	47	31	72	48	86	57	97	65	116	77
28	39	26	47	31	73	49	88	59	98	66	117	78
30	39	26	47	31	74	49	89	59	100	67	120	80
34	40	27	48	32	76	51	91	61	103	69	124	83
38	40	27	48	32	77	51	92	61	107	71	129	86
ASSEMBLING GIRDER FORMS—1 INTERSECTING BEAM FIG. 56												
8	38	25	46	31	61	41	73	49	80	53	96	64
12	42	28	50	33	67	45	80	53	88	59	106	71
16	46	31	55	37	73	49	88	59	95	63	114	76
18	48	32	57	38	77	51	93	62	99	66	119	79
20	50	33	60	40	79	53	95	64	104	69	125	83
22	52	35	62	41	82	55	99	66	107	71	128	85
24	54	36	65	43	86	57	103	69	113	75	136	91
26	56	37	67	45	88	59	105	70	117	78	140	93
28	58	39	70	47	92	61	110	73	121	81	145	97
30	60	40	72	48	95	63	114	76	125	83	150	100
34	64	43	77	51	102	68	122	81	133	89	160	107
38	68	45	82	55	109	73	131	87	141	94	169	113
ASSEMBLING GIRDER FORMS—2 INTERSECTING BEAMS FIG. 56												
8	51	34	61	41	78	52	94	63	101	67	121	81
12	55	37	66	44	87	58	104	69	112	75	134	89
16	62	42	75	50	94	63	113	75	122	81	146	98
18	64	43	77	51	99	66	119	79	127	85	152	101
20	66	44	79	53	103	69	124	83	133	89	160	107
22	68	45	82	55	106	71	127	85	137	92	164	109
24	70	47	84	56	110	73	132	88	142	95	170	113
26	72	49	88	59	115	77	138	92	148	99	178	119
28	77	51	93	62	117	73	141	94	153	102	184	123
30	79	53	95	63	122	81	147	98	159	106	191	128
34	83	55	100	67	132	88	158	105	168	112	202	135
38	88	59	105	70	141	94	170	113	176	117	211	141

Times include placing and removing lumber from saw.

Times assume saw working continuously with no allowance for rest and delays.

Lumber before cutting is taken as 12 feet long, but values are approximately correct for other lengths.

Use "2 cuts per Length" column for squaring ends or sawing into two lengths.

Use "6 cuts per Length" column for sawing into 6 lengths.

Use "12 cuts per Length" column for sawing into 12 or more lengths.

In any case multiply the unit time by the number of cuts.

Dimensions of Lumber	Item Number	On Mill-Saw — Time per Cut — Average Men			On Mill-Saw — Time per Cut — Quick Men			Item Number	By Hand — Time per Cut — Average Men			By Hand — Time per Cut — Quick Men		
		2 Cuts per Length. min.	6 Cuts per Length. min.	12 Cuts per Length. min.	2 Cuts per Length. min.	6 Cuts per Length. min.	12 Cuts per Length. min.		2 Cuts per Length. min.	6 Cuts per Length. min.	12 Cuts per Length. min.	2 Cuts per Length. min.	6 Cuts per Length. min.	12 Cuts per Length. min.
1" × 2"	(1)	0.17	0.11	0.08	0.11	0.07	0.05	(22)	0.38	0.33	0.31	0.25	0.22	0.21
1" × 4"	(2)	0.18	0.12	0.09	0.12	0.08	0.06	(23)	0.49	0.42	0.41	0.33	0.27	0.27
1" × 6"	(3)	0.19	0.13	0.10	0.13	0.09	0.07	(24)	0.60	0.53	0.50	0.40	0.35	0.33
1" × 8"	(4)	0.24	0.16	0.12	0.16	0.11	0.08	(25)	0.70	0.62	0.60	0.47	0.41	0.40
1" × 10"	(5)	0.28	0.19	0.14	0.19	0.13	0.09	(26)	0.81	0.71	0.67	0.54	0.47	0.45
1" × 12"	(6)	0.32	0.22	0.16	0.21	0.15	0.11	(27)	0.96	0.82	0.76	0.64	0.55	0.51
1½" × 2"	(7)	0.24	0.17	0.11	0.16	0.11	0.07	(28)	0.43	0.38	0.36	0.29	0.25	0.24
1½" × 4"	(8)	0.26	0.18	0.12	0.17	0.12	0.08	(29)	0.60	0.53	0.50	0.40	0.35	0.33
1½" × 6"	(9)	0.31	0.22	0.15	0.21	0.15	0.10	(30)	0.76	0.68	0.66	0.51	0.45	0.44
1½" × 8"	(10)	0.36	0.26	0.18	0.24	0.17	0.12	(31)	0.92	0.80	0.77	0.61	0.53	0.51
1½" × 10"	(11)	0.41	0.29	0.20	0.27	0.19	0.13	(32)	1.10	0.95	0.92	0.73	0.63	0.61
1½" × 12"	(12)	0.46	0.33	0.23	0.31	0.22	0.15	(33)	1.31	1.12	1.09	0.87	0.75	0.73
2" × 2"	(13)	0.31	0.22	0.15	0.21	0.15	0.10	(34)	0.49	0.42	0.41	0.33	0.28	0.27
2" × 4"	(14)	0.33	0.24	0.17	0.22	0.16	0.11	(35)	0.70	0.62	0.60	0.47	0.41	0.40
2" × 6"	(15)	0.39	0.29	0.20	0.26	0.19	0.13	(36)	0.92	0.80	0.77	0.62	0.53	0.51
2" × 8"	(16)	0.46	0.34	0.24	0.31	0.23	0.16	(37)	1.17	1.02	0.99	0.78	0.68	0.66
2" × 10"	(17)	0.53	0.39	0.28	0.35	0.26	0.19	(38)	1.41	1.28	1.25	0.94	0.85	0.83
2" × 12"	(18)	0.60	0.44	0.31	0.40	0.29	0.21	(39)	1.66	1.46	1.41	1.11	0.97	0.94
3" × 4"	(19)	0.32	0.22	0.16	0.21	0.15	0.11	(40)	0.92	0.80	0.77	0.61	0.53	0.51
4" × 4"	(20)	0.41	0.29	0.23	0.27	0.19	0.15	(41)	1.17	1.02	0.99	0.78	0.68	0.66
4" × 6"	(21)	0.60	0.44	0.31	0.40	0.29	0.21	(42)	1.66	1.46	1.41	1.11	0.97	0.94

The following assumptions have been made in Tables 157 to 160. All times are given in terms of minutes per one man.

TABLE 157. LABOR MAKING ONE SIDE OF A COLUMN FORM

Allowance has been made for necessary delays occurring throughout the day.

All sheathing and cleats assumed cut to right length and sorted in piles at hand near bench (see p. 485).

Finished forms are lifted from bench and placed on pile at hand.

Times do not include △ strips attached to forms or cutting of beam and girder pockets.

Beam and girder pockets are not cut on bench (see p. 489).

Column clamps, type 2, made separate from column sides hence not included in values.

Cleats, type 3, should be bored before being made up into forms, hence boring not included in values.

Times only apply if the design of the forms is exactly like that shown in drawings corresponding to the type selected.

Times are in minutes per column side.

TABLE 158. LABOR ASSEMBLING AND SETTING A COLUMN FORM

Allowance has been made for necessary delays, occurring throughout the day.

A 50-foot carry by carpenters described in text is allowed for in setting forms.

Three sides of forms are nailed together on horses then placed in position and fourth side attached. (see p. 490).

Wall columns take about 50 per cent longer to assemble and set than the times given, which apply to interior columns.

Times only apply if the design of the forms is exactly like that shown in drawings corresponding to the type selected.

Times are in minutes per column.

TABLE 159. LABOR MAKING ONE SIDE OF A BEAM AND A GIRDER FORM

Allowance has been made for necessary delays occurring throughout the day.

All sheathing and cleats assumed cut to right length and sorted in piles at hand near bench (see p. 485).

Finished forms are lifted from bench and placed on pile at hand.

Form sides are held together by 2 by 4-inch cleats spaced about 24 inches c. to c.

Times do not include △ strips attached to forms.

Times only apply if the design of the forms is exactly like that shown in drawings corresponding to the type selected.

Times are in minutes per side.

TABLE 160. LABOR ASSEMBLING A BEAM AND A GIRDER FORM

Allowance has been made for necessary delays occurring throughout the day.

Forms are made up on horses then placed on floor ready for laborers to carry, pulled up to place and set.

Times only apply if the design of the forms is exactly like that shown in drawing (p. 501) for beam forms and (p. 503) for girder forms.

Times are in minutes per beam or girder.

TABLE 162] MAKING COLUMN, BEAM, GIRDER, SLAB, AND WALL FORMS ON BENCH READY TO PUT TOGETHER [UNIT TIMES

For explanation of this table see p. 627.

No allowance made for rests and delays.
For ordinary construction add 50% to times for unavoidable delays.
For large well organized work add ⅓ to times for unavoidable delays.
For small jobs with inexperienced builders add 100% for unavoidable delays.
Add 50% to total of making when old lumber is used.
Times based on form side 24 inches wide by 12 feet long.
For lengths over 12 feet increase time proportionately; for lengths under 12 feet add 20% to proportionate times.

Item Number	Description	Members to Which Times Apply[1]						Net Time Per Operation					
								Average Men			Quick Men		
		Columns	Beams	Girders	Slabs	Walls	Unit	1-inch Form Lumber	1½-inch Form Lumber	2-inch Form Lumber	1-inch Form Lumber	1½-inch Form Lumber	2-inch Form Lumber
								min.	min.	min.	min.	min.	min.
(1)	Rip △ strips for corner beading on mill-saw	C1-2-3	B	G	S	W	Corner	1.47	1.47	1.47	0.98	0.98	0.98
(2)	Rip △ strips for corner beading by hand	C1-2-3	B	G	S	W	Corner	6.70	6.70	6.70	4.45	4.45	4.45
(3)	Carry[2] 1″ × 2″ cleats 50 feet to bench[3]	C	B 2	G 2	S		Cleat	0.03	0.03	0.03	0.02	0.02	0.02
(4)	Carry[2] 2″ × 4″ cleats 50 feet to bench[3]	C	B	G	S	W 1-2	Cleat	0.12	0.12	0.12	0.08	0.08	0.08
(5)	Carry[2] 4″ × 4″ cleats 50 feet to bench[3]	C	B	G			Cleat	0.30	0.30	0.30	0.20	0.20	0.20
(6)	Place 1″ × 2″ cleats on bench	C	B 2	G 2	S		Cleat	0.09	0.09	0.09	0.06	0.06	0.60
(7)	Place 2″ × 4″ cleats on bench	C	B	G	S	W 1-2	Cleat	0.13	0.13	0.13	0.09	0.09	0.09
(8)	Place 4″ × 4″ cleats on bench	C	B 2-3	G 2-3			Cleat	0.17	0.17	0.17	0.11	0.11	0.11
(9)	Rip form boards for pockets on mill-saw	C					Side	1.24	1.40	1.56	0.83	0.93	1.04
(10)	Rip form boards for pockets by hand[4]	C					Side	1.70	2.15	2.70	1.13	1.43	1.80
(11)	Rip 12 ft. form boards on mill-saw[5]	C	B	G	S		Side	2.94	3.32	3.72	1.96	2.21	2.48
(12)	Rip 12 ft. form boards by hand[5]	C	B	G	S		Side	8.70	12.68	17.34	5.80	8.45	11.56

(13)	Carry[2] form boards 50 feet	C	B	G	S	W 1-2	Board		See Table 156, page 655.				
(14)	Place form boards on bench	C	B	G	S	W 1-2	Board	0.40	0.47	0.55	0.27	0.31	0.37
(15)	Wedge form boards together using iron clamps[6] (see p.491)	C	B	G	S	W 1-2	Cleat	0.20	0.20	0.20	0.13	0.13	0.13
(16)	Wedge form boards together with wood wedges[6]	C	B	G	S	W 1-2	Cleet	0.30	0.30	0.30	0.20	0.20	0.20
(17)	Measure and mark for nailing[6]	C	B	G	S	W 1-2	Cleat	0.05	0.05	0.05	0.03	0.03	0.03
(18)	Nail 2-12 ft. form boards to cleats[7]	C	B	G	S	W 1-2	Cleat	0.42	0.48	0.54	0.28	0.32	0.36
(19)	Nail 4-12 ft. form boards to cleats[7]	C	B	G	S	W 1-2	Cleat	0.83	0.96	1.08	0.55	0.64	0.72
(20)	Nail 6-12 ft. form boards to cleats[7]	C	B	G	S	W 1-2	Cleat	1.25	1.44	1.62	0.83	0.96	1.08
(21)	Nail 2 form boards to 1″ batten[8]	C			S		Batten	0.37	—	—	0.25	—	—
(22)	Nail 4 form boards to 1″ batten[8]	C			S		Batten	0.74	—	—	0.49	—	—
(23)	Nail 6 form boards to 1″ batten[8]	C			S		Batten	1.11	—	—	0.74	—	—
(24)	Turn form over for clinching nails	C			S		Side	0.90	1.10	1.30	0.60	0.73	0.87
(25)	Clinch nails 2 form boards per batten[8]	C			S		Batten	0.15	—	—	0.10	—	—
(26)	Clinch nails 4 form boards per batten[8]	C			S		Batten	0.30	—	—	0.20	—	—
(27)	Clinch nails 6 form boards per batten[8]	C			S		Batten	0.45	—	—	0.30	—	—
(28)	Carry[2] 1″ × 4″ pocket pieces 50 feet (see p. 655)	C	B	G			Side	0.09	0.09	0.09	0.06	0.06	0.06
(29)	Place 1″ × 4″ pocket pieces on form	C	B	G			Side	0.30	0.30	0.30	0.20	0.20	0.20
(30)	Nail 1″ × 4″ pocket pieces to form	C	B	G			Side	0.74	0.74	0.74	0.49	0.49	0.49
(31)	Mark and square across end of form	C	B	G	S	W 1-2	Board	0.10	0.10	0.10	0.07	0.07	0.07
(32)	Saw off end of form 24″ wide by hand	C	B	G	S	W 1-2	Board	0.23	0.41	0.60	0.15	0.27	0.40
(33)	Throw form aside on pile	C	B	G	S	W 1-2	Side	0.53	0.68	0.82	0.35	0.45	0.55
(34)	Extra for making clean-out hole	C					Col.	2.20	2.65	3.10	1.47	1.77	2.07
(35)	Level and mark across top of column	C					Side		See Table 163, Item 23				
(36)	Cutting beam pocket	C		G			Pocket	12.45	14.60	16.75	8.30	9.73	11.17

[1] For example, for any column select proper items from those marked C choosing from items marked C1 for type 1, see Fig. 48, p. 491, from C1-2 for both types 1 and 2 see Fig. 49, p. 493. Those marked C only apply to all types of form construction.

[2] Can be done by laborers—figuring costs at laborers' rates.

[3] For cleats over 4 ft. long see Table 156, p. 655.

[4] This operation finished in erecting, see Table 163, Item 23.

[5] This considers ripping 2 side edges of each form, if one side only is ripped off take ½ of item.

[6] Based on 8 cleats per form.

[7] Based on 2 nails per 6-inch board per cleat using 8d nails for 1 inch boards, 10d nails, for 1½-inch plank and 12d nails for 2-inch plank.

[8] Based on 2 nails per 6-inch board per batten using 6d nails.

TABLE 162] MAKING COLUMN, BEAM, GIRDER, SLAB AND WALL FORMS ON BENCH READY TO PUT TOGETHER—Continued [UNIT TIMES

Item Number	Description	Members to Which Times Apply: Columns	Beams	Girders	Slabs	Walls	Unit	Time per Operation — Average Men: 1-inch Form Lumber, min.	Average Men: 1½-inch Form Lumber, min.	Average Men: 2-inch Form Lumber, min.	Quick Men: 1-inch Form Lumber, min.	Quick Men: 1½-inch Form Lumber, min.	Quick Men: 2-inch Form Lumber, min.
(37)	Sawing off top of column	C					Side	See Table 163, Item 23					
(38)	Carry form side to mill-saw and rip off side[9]	C	B	G	S	W 1-2	Side	4.30	5.50	6.70	2.87	3.67	4.47
(39)	Nail on joist bearer 4 nails per cleat (see Fig. 53, p. 499)		B				Cleat	0.41	0.41	0.41	0.27	0.27	0.27
(40)	Lay out bench for making forms	C	B	G	S	W 1-2							
(41)	Bore ⅞" holes by hand through 2" × 4" cleat	C 2-4	B 3	G 3		W 1-2	Cleat	0.74	0.74	0.74	0.49	0.49	0.49
(42)	Bore ⅞" holes by hand through 4" × 4" cleat	C 2-4				W 1-2	Cleat	1.38	1.38	1.38	0.92	0.92	0.92
(43)	Place 2" × 4" cleat on bench and remove after boring	C 2-4	B 3	G 3		W 1-2	Cleat	0.26	0.26	0.26	0.17	0.17	0.17
(44)	Place 4" × 4" cleat on bench and remove after boring	C 2-4				W 1-2	Cleat	0.34	0.34	0.34	0.23	0.23	0.23
(45)	Make knee braces on mill-saw (see p. 502)	For Scaffolding					Brace	5.20	5.20	5.20	3.47	3.47	3.47
(46)	Make knee braces by hand (see p. 502)	" "					Brace	6.70	6.70	6.70	4.47	4.47	4.47
(47)	Cut triangular block for head of octagonal column (see p. 495)	C 4					Col.	3.20	3.20	3.20	2.13	2.13	2.13
(48)	Make 4" × 4" post by mill-saw (see p. 502)		B	G	S		Post	7.40	7.40	7.40	4.93	4.93	4.93
(49)	Make 4" × 4" post by hand (see p. 502)		B	G	S		Post	11.10	11.10	11.10	7.40	7.40	7.40
(50)	Make post for lintels on mill-saw (see p. 502)			G			Post	6.80	6.80	6.80	4.53	4.53	4.53
(51)	Make post for lintels by hand (see p. 502)			G			Post	10.40	10.40	10.40	6.93	6.93	6.93
(52)	Make 2" × 4" wood wedge clamps on mill-saw	C 2					Clamp	9.60	9.60	9.60	6.40	6.40	6.40
(53)	Make 2" × 4" wood wedge clamps by hand	C 2					Clamp	14.20	14.20	14.20	9.47	9.47	9.47
(54)	Make 2" × 4" bolted clamp on mill-saw[10]	C 3-4					Clamp	7.60	7.60	7.60	5.07	5.07	5.07
(55)	Make 2" × 4" bolted clamp by hand[10]	C 3-4					Clamp	9.20	9.20	9.20	6.13	6.13	6.13

[9] If both sides are ripped multiply by 2.

TABLE 162] MAKING FORMS—Continued [UNIT TIMES

(56)	Make 4″ × 4″ bolted clamp on mill-saw[10]	C 3-4					Clamp	13.80	13.80	13.80	9.20	9.20	9.20
(57)	Make 4″ × 4″ bolted clamp by hand[10]	C 3-4					Clamp	16.60	16.60	16.60	11.07	11.07	11.07
(58)	Make 4″ × 4″ slotted blocks for exterior column on mill-saw	C					Col.	3.30	3.30	3.30	2.20	2.20	2.20
(59)	Make 4″ × 4″ slotted blocks for exterior column by hand	C					Col.	7.90	7.90	7.90	5.27	5.27	5.27

[10] Four bolts to a clamp or four cleats to a clamp.

ASSEMBLING AND ERECTING COLUMN FORMS

For explanation of this table see p. 627.

No allowance has been made for rests and delays.
For ordinary construction add 50%; for large well organized work add ⅓ to the times for these delays.
For small jobs with inexperienced builders add 100% for unavoidable delays.
For wall column forms add 50% to times, and if each side of column form is erected separately in place add 12% to times.
If column form is put together on horses and then placed as one member add 16% to times, see page 490.
Type 1—Iron clamps. Type 2—Wood wedge clamps. Type 3—Bolted clamps. Type 4—Octagonal forms.

Item Number	Description	Type: Figure 48 Page 491	Type: Figure 49 Page 493	Type: Figure 49 Page 493	Type: Figure 50 Page 495	Unit	Net Time per Operation — Average Men: 1-inch Form Lumber	Average Men: 1¼-inch Form Lumber	Average Men: 2-inch Form Lumber	Quick Men: 1-inch Form Lumber	Quick Men: 1¼-inch Form Lumber	Quick Men: 2-inch Form Lumber
							min.	min.	min.	min.	min.	min.
(1)	Locate, line and brace columns	1	2	3	4	Col.	61.60	61.60	61.60	41.08	41.08	41.08
(2)	Hoist sides of forms[1]	1	2	3	4	Col.	See Table 155. page 648.					
(3)	Carry sides of forms 50 feet[1]	1	2	3	4	Col.	See Table 156. page 655.					
(4)	Place 4 sides of form on horses	1	2	3	4	Col.	1.75	1.90	2.00	1.17	1.27	1.33
(5)	Measuring sides for 4 △ strips, marking and ready to place them	1	2	3		Col.	8.00	8.00	8.00	5.34	5.34	5.34
(6)	Place new △ strips on 4 sides of column	1	2	3		Col.	20.20	20.20	20.20	13.34	13.34	13.34
(7)	Patch old △ strips on 4 sides of column	1	2	3		Col.	6.50	6.50	6.50	4.34	4.34	4.34
(8)	Tip or raise two sides of form on edge on horses and hold	1	2	3	4	Col.	2.65	3.30	3.90	1.77	2.20	2.60
(9)	Measure and mark cleats for wedging boards	1				Clamp	0.20	0.20	0.20	0.13	0.13	0.13
(10)	Get wedging boards 50 feet away[1]	1				Col.	See Table 156 page 655.					
(11)	Nail on wedging boards, (see page 491)	1				Clamp	1.40	1.70	2.00	0.93	1.13	1.33
(12)	Nail four sides of column together	1				Col.	1.04	1.20	1.50	0.69	0.80	1.00
(13)	Nail four sides of column together		2	3	4	Col.	6.00	7.30	8.70	4.00	4.87	5.80
(14)	Place and drive wedges	1				Clamp	0.70	0.70	0.70	0.47	0.47	0.47
(15)	Carry 3 sides to place 50 feet[1]	1	2	3	4	Col.	See Table 156, page 655.					
(16)	Carry 4th side to place 50 feet[1]	1	2	3	4	Col.	See Table 156. page 655.					

[1] Can be done by laborers—figuring costs at laborers' wages.

TABLE 163] ASSEMBLING AND ERECTING COLUMN FORMS—Continued **[UNIT TIMES**

(17)	Lift and place 3 sides (attached)	1	2	3	4	Col.	1.80	1.80	1.80	1.20	1.20	1.20
(18)	Lift and place 4th side	1	2	3	4	Col.	1.20	1.20	1.20	0.80	0.80	0.80
(19)	Get iron clamp (see p. 491)[1]	1				Clamp	0.20	0.20	0.20	0.13	0.13	0.13
(20)	Place and tighten clamps	1				Clamp	1.10	1.10	1.10	0.73	0.73	0.73
(21)	Square form with square and nail on temporary braces to hold sides	1	2	3	4	Col.	5.80	5.80	5.80	3.87	3.87	3.87
(22)	Place piece at cleanout hole, (see Fig. 52 p. 497)	1	2	3	4	Col.	10.00	12.00	14.00	6.67	8.00	9.34
(23)	Mark and saw off top of column from scaffold	1	2	3		Col.	10.00	13.20	16.00	6.67	8.80	10.67
(24)	Change to next column	1	2	3	4	Col.	1.00	1.00	1.00	0.67	0.67	0.67
(25)	Hoist 1 × 4 pocket pieces 1 story[1]	1	2	3	4	Col.	1.30	1.90	2.60	0.87	1.27	1.73
(26)	Add for each additional story of hoist	1	2	3	4	Col.	0.40	0.40	0.40	0.27	0.27	0.27
(27)	Patch in girder pocket[2]	1	2	3	4	Col.	Aver. 45.00			Aver. 30.00		
(28)	Carry iron clamps up 1 story[1]	1	2	3	4	Col.	9.00	9.00	9.00	6.00	6.00	6.00
(29)	Make wood wedges	1	2	3	4	Col.	6.40	6.40	6.40	4.27	4.27	4.27
(30)	Carry wedges 50 feet[1]	1	2	3	4	Col.	3.60	3.60	3.60	2.40	2.40	2.40
(31)	Hoist wedges 1 story[1]	1	2	3	4	Col.	1.85	1.85	1.85	1.23	1.23	1.23
(32)	Add for each additional story of hoist[1]	1	2	3	4	Col.	0.60	0.60	0.60	0.40	0.40	0.40
(33)	Oil forms[1]	1	2	3	4	Col.	5.00	5.00	5.00	3.34	3.34	3.34
(34)	Hoist cross braces 1 story[1]	1	2	3	4	Col.	6.50	6.50	6.50	4.34	4.34	4.34
(35)	Clean out rubbish from column[1]	1	2	3	4	Col.	2.75	2.75	2.75	1.83	1.83	1.83
(36)	Remove forms	1				Col.	69.60	78.50	87.50	46.40	52.30	58.30
(37)	Remove forms		2	3		Col.	88.40	98.30	108.30	58.96	65.60	72.23
(38)	Remove forms				4	Col.	90.30	100.70	111.20	60.20	67.17	74.17
(39)	Get line and chalk	1	2	3	4	Col.	2.00	2.00	2.00	1.33	1.33	1.33
(40)	Measure and snap lines	1	2	3	4	Col.	7.60	7.60	7.60	5.07	5.07	5.07
(41)	Wind up line	1	2	3	4	Col.	2.00	2.00	2.00	1.33	1.33	1.33
(42)	Rip off both sides of form by hand	1	2	3	4	Col.	53.80	79.80	105.80	35.88	53.20	70.53
(43)	Saw 2-1″ × 2″ cleats		2	3		Clamp	3.00	3.00	3.00	2.00	2.00	2.00
(44)	Saw 2-2″ × 4″ cleats	1	2	3	4	Clamp	5.60	5.60	5.60	3.73	3.73	3.73
(45)	Saw 2-4″ × 4″ cleats			3	4	Clamp	9.40	9.40	9.40	6.28	6.28	6.28
(46)	Bore 4-⅞″ holes through 2-1″ × 2″ cleats			3	4	Clamp	2.60	2.60	2.60	1.73	1.73	1.73
(47)	Bore 4-⅞″ holes through 2-2″ × 4″ cleats			3	4	Clamp	4.00	4.00	4.00	2.67	2.67	2.67
(48)	Bore 4-⅞″ holes through 2-4″ × 4″ cleats			3	4	Clamp	6.40	6.40	6.40	4.27	4.27	4.27
(49)	Throw form on pile	1	2	3	4	Col.	2.12	2.72	3.28	1.40	1.84	2.20
(50)	Pick up blocks for bolt spacers[3] string on wire and hoist 1 floor			3	4	Clamp	0.75	0.75	0.75	0.50	0.50	0.50

[1] Can be done by laborers—figuring costs at laborers' wages.
[2] Time varies from 30.00 min. to 60.00 min.
[3] Used only where bolts are too long for spacing out to washer.

Item Number	Description	Type: Figure 48 Page 491	Type: Figure 49 Page 493	Type: Figure 49 Page 493	Type: Figure 50 Page 495	Unit	Net Time per Operation — Average Men: 1-inch Form Lumber	Average Men: 1½-inch Form Lumber	Average Men: 2-inch Form Lumber	Quick Men: 1-inch Form Lumber	Quick Men: 1½-inch Form Lumber	Quick Men: 2-inch Form Lumber
							min.	min.	min.	min.	min.	min.
(51)	Hoist 2" × 4" wood wedge clamp 1 floor		2			Clamp	1.62	1.62	1.62	1.08	1.08	1.08
(52)	Attach 2" × 4" wood wedge clamp to column form		2			Clamp	11.30	11.30	11.30	7.53	7.53	7.53
(53)	Remake 2" × 4" wood wedge clamps to make smaller column		2			Clamp	6.40	6.40	6.40	4.27	4.27	4.27
(54)	Hoist bolts for clamps 1 floor[4]			3	4	Clamp	1.30	1.30	1.30	0.87	0.87	0.87
(55)	Place and tighten bolts in clamp[4]			3	4	Clamp	11.30	11.30	11.30	7.53	7.53	7.53
(56)	Place extra 2" × 4" bolted clamp on column form[4]			3	4	Clamp	12.20	12.20	12.20	8.14	8.14	8.14
(57)	Place extra 4" × 4" bolted clamp on column form[4]			3	4	Clamp	13.35	13.35	13.35	8.90	8.90	8.90
(58)	Fitting blocks back of bolt washers			3	4	Clamp	4.80	4.80	4.80	3.20	3.20	3.20
(59)	Place wedges behind bolts			3	4	Clamp	3.75	3.75	3.75	2.50	2.50	2.50
(60)	Hoist interior sides of column 1 floor[1]				4	Col.	See Table 155, p. 648.					
(61)	Carry sides of column 50 feet[1]				4	Col.	See Table 156, p. 655.					
(62)	Lift sides and place in column				4	Col.	15.40	16.60	18.10	10.27	11.07	12.06
(63)	Add to placing if column is small[5]				4	Col.	14.50	16.80	19.10	9.66	11.20	12.73
(64)	Place cap of column				4	Col.	13.30	15.30	17.30	8.87	10.20	11.53
	Extra Items for Wide Wall Column Forms											
(65)	Carry 4" × 4" slotted blocks up 1 floor	1	2	3	4	Col.	4.50	4.50	4.50	3.00	3.00	3.00
(66)	Place 4" × 4" blocks on wall	1	2	3	4	Col.	7.00	7.00	7.00	4.67	4.67	4.67
(67)	Place 4" × 4" blocks on floor	1	2	3	4	Col.	2.95	2.95	2.95	1.97	1.97	1.97
(68)	Place 2" × 4" on top of 4" × 4" block	1	2	3	4	Col.	3.50	3.50	3.50	2.23	2.23	2.23
(69)	Raise wall column to place and nail it together and plumb column	1	2	3	4	Col.	76.00	85.00	92.60	50.67	56.67	61.73
(70)	Attach brick bonds to form	1	2	3	4	Col.	13.00	13.00	13.00	8.67	8.67	8.67

[1] Can be done by laborers—figuring cost at laborers' wages.

[4] Four bolts to a clamp.

[5] If too small for man to get inside of col.

TABLE 164] ASSEMBLING AND ERECTING BEAM AND GIRDER FORMS [UNIT TIMES

For explanation of this table, see page 627

No allowance has been made for rests and delays.
For ordinary construction, add 50% to times for unavoidable delays.
For large well organized work, add ⅓ to times for unavoidable delays.
For small jobs with inexperienced builders, add 100% for unavoidable delays.
Method (a)—make up and place after assembled. Method (b)—make up at place.
Type 1—Iron clamps. Fig. 54, p. 501.
Type 2—Wood bottom cleats. Fig. 54, p. 501.
Type 3—Bolts. Fig. 54, p. 501.
Type 4—Hang from I-beams. Fig. 59, p. 507.

Item Number	Description	Type: Figure 54 Page 501	Type: Figure 54 Page 501	Type: Figure 54 Page 501	Type: Figure 59 Page 507	Unit	Net Time per Operation — Average Men: 1-inch Form Lumber	Average Men: 1½-inch Form Lumber	Average Men: 2-inch Form Lumber	Quick Men: 1-inch Form Lumber	Quick Men: 1½-inch Form Lumber	Quick Men: 2-inch Form Lumber
							min.	min.	min.	min.	min.	min.
(1)	Hoist forms one floor[1]	1	1	3		B or G*	See Table 155, p. 648					
(2)	Carry beam or girder sides 50 feet[1]	1	2	3		B or G	See Table 156, p. 655					
(3)	Carry beam or girder sides 50 feet over tops of I-beams				4	B or G	Add 50% to Table 156, p. 655					
(4)	Carry bottom of form 50 feet[1]	1	2	3		B or G	See Table 156, p. 655					
(5)	Carry bottom of form 50 feet over tops of I-beams				4	B or G	Add 50% to Table 156 p. 655					
(6)	Measuring for length	1	2	3		B or G	5.30	5.30	5.30	3.53	3.53	3.53
(7)	Place beam sides on horses ready to assemble	1a	2a	3a		B side	0.45	0.55	0.65	0.30	0.37	0.43
(8)	Place girder sides on horses, 1 intersecting beam	1a	2a	3a		G side	0.60	0.75	0.90	0.40	0.50	0.60
(9)	Place girder sides on horses, 2 intersecting beams	1a	2a	3a		G side	0.80	1.00	1.20	0.53	0.67	0.80
(10)	Place bottom of form on horses	1a	2a	3a		B or G	0.45	0.45	0.45	0.30	0.30	0.30
(11)	Lift beam sides from floor to scaffold[1]	1b	2b	3b		B side	1.95	2.40	2.85	1.30	1.60	1.90

* B = beam. G = girder. [1]Can be done by laborers—figuring cost at laborers' wages.

TABLE 164] ASSEMBLING AND ERECTING BEAM AND GIRDER FORMS [UNIT TIMES
Continued

Item Number	Description	Types: Figure 54 Page 501	Types: Figure 54 Page 501	Types: Figure 54 Page 501	Types: Figure 59 Page 507	Unit	Net Time per Operation — Average Men: 1-inch Form Lumber	Average Men: 1½-inch Form Lumber	Average Men: 2-inch Form Lumber	Quick Men: 1-inch Form Lumber	Quick Men: 1½-inch Form Lumber	Quick Men: 2-inch Form Lumber
							min.	min.	min.	min.	min.	min.
(12)	Lift girder sides to scaffold if 1 intersecting beam[1]	1b	2b	3b		G side	2.60	3.20	3.80	1.73	2.13	2.53
(13)	Lift girder sides to scaffold if 2 intersecting beam[1]	1b	2b	3b		G side	3.50	4.30	5.10	2.33	2.87	3.40
(14)	Lift bottom form to scaffold[1]	1b	2b	3b		B or G	2.40	2.40	2.40	1.60	1.60	1.60
(15)	Tip or raise beam sides of form on edge	1a	2a	3a		B side	1.30	1.60	1.90	0.87	1.07	1.27
(16)	Tip or raise girder sides of form on edge 1-intersecting beam	1a	2a	3a		G side	1.80	2.20	2.60	1.20	1.47	1.73
(17)	Tip or raise girder sides of form on edge 2-intersecting beams	1a	2a	3a		G side	2.30	2.80	3.40	1.53	1.87	2.27
(18)	Lift bottom from scaffold to place and nail it to column	1b	2b	3b		B or G	4.45	4.45	4.45	2.97	2.97	2.97
(19)	Swing bottom form from top of I-beam to place				4	B or G	0.80	1.00	1.20	0.53	0.67	0.80
(20)	Bend ¼ inch wire over flange of I-beam				4	B or G	0.50	0.50	0.50	0.33	0.33	0.33
(21)	Place U wire at center				4	Beam	1.00	1.00	1.00	0.67	0.67	0.67
(22)	Lift beam sides from scaffold to place	1b	2b	3b		B side	1.90	2.35	2.80	1.27	1.57	1.87
(23)	Lift beam from top of I-beam to place				4	B side	0.25	0.30	0.35	0.17	0.20	0.23
(24)	Lift girder from top of I-beam to place, 1 intersecting beam	1b	2b	3b		G side	2.50	3.10	3.60	1.67	2.07	2.40
(25)	Lift girder from top of I-beam to place, 2 intersecting beaams	1b	2b	3b		G side	3.40	3.90	4.50	2.27	2.60	3.00
(26)	Nail beam sides to place	1b	2b	3b	4	B side	2.70	3.30	3.90	1.80	2.20	2.60
(27)	Nail girder sides to place, 1 intersecting beam	1b	2b	3b		G side	3.60	4.45	5.30	2.40	2.97	3.53
(28)	Nail girder sides to place, 2 intersecting beams	1b	2b	3b		G side	4.80	5.90	7.00	3.20	3.93	4.67
(29)	Nail pieces across girder sections, 1 intersecting beam	1a	2a	3a		G side	0.43	0.43	0.43	0.29	0.29	0.29
(30)	Nail pieces across girder sections, 2 intersecting beams	1a	2a	3a		G side	0.86	0.86	0.86	0.57	0.57	0.57
(31)	Nail beam sides to bottom and hold on horses	1a	2a	3a		B side	3.10	3.80	4.50	2.07	2.53	3.00
(32)	Nail girder sides to bottom and hold on horses, 1 intersecting beam	1a	2a	3a		G side	3.80	4.70	5.60	2.53	3.13	3.73
(33)	Nail girder sides to bottom and hold on horses, 2 intersecting beams	1a	2a	3a		G side	4.55	5.60	6.60	3.03	3.73	4.40

[1] Can be done by laborers—figuring cost at laborers' wages.

Continued

(34)	Fix joints between girder side and intersecting beam (1 per girder)	1b	2b	3b	4	G side	1.80	1.80	1.80	1.20	1.20	1.20
(35)	Fix joints between girder side and intersecting beam (2 per girder)	1b	2b	3b	4	G side	3.60	3.60	3.60	2.40	2.40	2.40
(36)	Carry 1" × 2" cleats 50 ft. (see p. 655)[1]		2			Clamp	0.06	0.06	0.06	0.04	0.04	0.04
(37)	Hoist 1" × 2" cleats, average 3 floors[1]		2			Clamp	0.14	0.14	0.14	0.09	0.09	0.09
(38)	Nail on temporary spreaders[2]	1	2	3		B or G	3.30	3.30	3.30	2.20	2.20	2.20
(39)	Turn form over		2a			B or G	0.53	0.67	0.82	0.35	0.45	0.55
(40)	Chop off a little from side of cleat		2a			Clamp	0.26	0.26	0.26	0.17	0.17	0.17
(41)	Attach 1" × 2" cleats		2a			Clamp	1.70	1.70	1.70	1.13	1.13	1.13
(42)	Get mark for and place new △ strips form on horses	1a	2a	3a	4	B or G	10.10	10.10	10.10	6.73	6.73	6.73
(43)	Get and place old △ strips—form on horses	1a	2a	3a	4	B or G	3.25	3.25	3.25	2.17	2.17	2.17
(44)	Get mark for and place new △ strip after beam bottom is set	1b	2b	3b		B or G	12.40	12.40	12.40	8.27	8.27	8.27
(45)	Get and place old △ strip after beam bottom is set	1b	2b	3b		B or G	4.00	4.00	4.00	2.67	2.67	2.67
(46)	Place form on ground	1a	2a	3a		B or G	0.70	0.90	1.10	0.47	0.60	0.73
(47)	Carry assembled form 50 feet ready to put in place[1]	1a	2a	3a		B or G	See Table 156, p. 655.					
(48)	Pull up to place[1]	1a	2a	3a		B or G	6.10	7.75	9.40	4.07	5.17	6.27
(49)	Nail form to place	1a	2a	3a		B or G	1.00	1.00	1.00	0.67	0.67	0.67
(50)	Place iron clamps (see p. 501)	1				Clamp	0.66	0.66	0.66	0.44	0.44	0.44
(51)	Carry iron clamps up one floor[1]	1				Clamp	0.50	0.50	0.50	0.33	0.33	0.33
(52)	Hoist post one floor (see p. 648)[1]	1	2	3		Post	1.60	1.60	1.60	1.07	1.07	1.07
(53)	Make over post	1	2	3		Post	5.40	5.40	5.40	3.60	3.60	3.60
(54)	Place post	1	2	3		Post	5.20	5.20	5.20	3.47	3.47	3.47
(55)	Place x-brace between posts	1	2	3		Post	1.00	1.00	1.00	0.67	0.67	0.67
(56)	Hoist x-braces one floor[1]	1	2	3		Post	1.62	1.62	1.62	1.08	1.08	1.08
(57)	Remove posts[1]	1	2	3		Post	1.00	1.00	1.00	0.67	0.67	0.67
(58)	Remove beam forms[1]	1				Beam	24.00	30.00	35.00	16.00	20.00	23.33
(59)	Remove beam forms[1]		2	3		Beam	26.00	32.00	40.00	17 33	21.33	26.67
(60)	Remove beam forms[1]				4	Beam	26.00	32.00	40.00	17.33	21.33	26.67
(61)	Remove girder form (1 intersecting beam)[1]	1				Girder	32.00	40.00	47.00	21.33	26.67	31.33
(62)	Remove girder form (1 intersecting beam)[1]		2	3		Girder	35.00	43.00	51.00	23.33	28.67	34.00
(63)	Remove girder form (2 intersecting beam)[1]	1				Girder	43.00	53.00	61.00	28.67	35.33	40.67
(64)	Remove girder form (2 intersecting beam)[1]		2	3		Girder	47.00	58.00	69.00	31.33	38.67	46.00

[1] Can be done by laborers—figuring cost at laborers' wages.

TABLE 164] ASSEMBLING AND ERECTING BEAM AND GIRDER FORMS [UNIT TIMES
Continued

Item Number	Description	Types: Figure 54 Page 501	Types: Figure 54 Page 501	Types: Figure 54 Page 501	Types: Figure 59 Page 507	Unit*	Net Time per Operation, Average Men: 1-inch Form Lumber	Average Men: 1½-inch Form Lumber	Average Men: 2-inch Form Lumber	Quick Men: 1-inch Form Lumber	Quick Men: 1½-inch Form Lumber	Quick Men: 2-inch Form Lumber
							min.	min.	min.	min.	min.	min.
(65)	If end of form is broken and must be sawed off—time sawing	1	2	3		B or G	0.80	1.20	1.60	0.53	0.80	1.07
(66)	Piece bottom to lengthen	1	2	3		B or G	Varies from 9.10 to 15.50					
(67)	Piece sides to lengthen between columns	1	2	3		B or G	Varies from 25.00 to 45.00			18.00 to 30.00		
(68)	Piece sides to lengthen between girders	1	2	3		B or G	Varies from 12.00 to 20.00			8.00 to 15.00		
(69)	Place tin sleeve in beams	1	2	3		Sleeve	1.83	1.83	1.83	1.22	1.22	1.22
(70)	Oil form[1]	1	2	3		B or G	3.30	3.30	3.30	2.20	2.20	2.20
(71)	Bore 3-⅞″ holes for bolts			3	4	B or G	5.00	7.00	9.00	3.33	4.67	6.00
(72)	Place 3-¾″ bolts through forms			3		B or G	7.40	7.40	7.40	4.93	4.93	4.93
(73)	Carry posts 50 feet	1	2	3		Post	0.60	0.60	0.60	0.40	0.40	0.40
(74)	Nail corner piece at intersection of beam with girder				4	Beam	1.00	1.00	1.00	0.67	0.67	0.67
(75)	Make and place stop blocks for side, (see Fig. 59, p. 507)				4	Clamp	0.20	0.20	0.20	0.13	0.13	0.13
(76)	Make and place woodwedge				4	Clamp	0.20	0.20	0.20	0.13	0.13	0.13
(77)	Rip off sides and bottom of forms				4	B or G	40.00	60.00	80.00	26.80	40.00	53.60

* B = beam. G = girder.
[1] Can be done by laborers—figuring cost at laborers' wages.

TABLE 165] **ERECTING SLAB FORMS** **[UNIT TIMES**

For Explanation of this Table see p. 627

No allowance has been made for rests and delays.
For ordinary construction add 50% to times for unavoidable delays.
For well organized work add ⅓ to times for unavoidable delays.
For small jobs with inexperienced builders add 100% for unavoidable delays.
Forms assumed made up in sections as shown in Fig. 60, p. 508.
Section of form assumed to have 30 square feet surface area.
Times apply for joists up to 10 ft. long.

Item Number	Description	Unit	Net Time per Operation: Average Men, 1 Inch Sheathing	Average Men, 1½ Inch Sheathing	Quick Men, 1 Inch Sheathing	Quick Men, 1½ Inch Sheathing
			min.	min.	min.	min.
(1)	Hoist joists to floor above[1]	Joist	see	Table	155	
(2)	Carry joists 50 feet[1]	Joist	see	Table	156	
(3)	Lift joists to scaffold[1]	Joist	0.25	0.25	0.17	0.17
(4)	Lift joist from scaffold to place	Joist	0.26	0.26	0.17	0.17
(5)	Make blocks	Joist	0.25	0.25	0.17	0.17
(6)	Mark for attaching blocks	Joist	0.42	0.42	0.28	0.28
(7)	Get blocks ready	Joist	0.30	0.30	0.20	0.20
(8)	Nail two blocks on joist	Joist	0.91	0.91	0.61	0.61
(9)	Nail joist to place	Joist	0.43	0.43	0.29	0.29
(10)	Line in beam form	Joist	0.05	0.05	0.04	0.04
(11)	Change to next joist	Joist	0.11	0.11	0.07	0.07
(12)	Change to next bay	Joist	0.14	0.14	0.09	0.09
(13)	Hoist slab form floor[1]	section	see	Table	155	
(14)	Carry 50 feet[1]	section	see	Table	156	
(15)	Place form approx[1]	section				
(16)	Make form ready[1]	section	2.23	2.39	1.49	1.59
(17)	Place and nail forms	section	2.52	2.70	1.68	1.80
(18)	Change to next panel	section	0.70	0.75	0.47	0.50
(19)	Alterations due to each column	Col.	7.91	8.48	5.30	5.66
(20)	Alterations due to different size panels	section	4.67	5.00	3.12	3.33
(21)	Remove slab form	sq. ft.	1.40	1.50	0.93	1.00
(22)	Place △ strip around edge	section	0.65	0.69	0.43	0.46
(23)	Oil form[1]	sq. ft.	0.17	0.18	0.11	0.12

[1] Can be done by laborers—figuring cost at laborers' wages.

TABLE 166] ERECTING WALL FORMS [UNIT TIMES

For Explanation of this Table see p. 627

No allowance has been made for rests and delays.
For ordinary construction add 50% to times for unavoidable delays.
For well organized work add $\frac{1}{3}$ to times for unavoidable delays.
For small jobs with experienced builders add 100% for unavoidable delays.
Section refers to one side of form only.
Forms assumed made up in sections as shown in drawing for each type.
Type 1—3 feet sectional form.
Type 2—curtain wall forms below windows.
Type 3—Full panel or wall forms between columns.
Type 4—Cellar wall forms.

Item Number	Description	Net Time Per Operation							
		Unit		Average Men			Quick Men		
		Inside Form	Outside Form	1" Form Lumber	1¼ Form Lumber	2" Form Lumber	1" Form Lumber	1¼ Form Lumber	2" Form Lumber
				min.	min.	min.	min.	min.	min.
	Type I { 3 Feet Sectional Form, (See fig. 70, p. 520). 3 Feet High × 12 Feet Long.								
(1)	Lift exterior side of section 3 feet, and hold form		Section	9 to	18	min.	6 to	12	min.
(2)	Lift interior side 3 feet and hold till braced	Section		4.70	4.70	4.70	3.14	3.14	3.14
(3)	Nail on temporary braces	Section	Section	1.00	1.20	1.40	0.67	0.80	0.93
(4)	Carry bolts 50 ft[1]		Bolt	0.03	0.03	0.03	0.02	0.02	0.02
(5)	Place bottom bolts in exterior form section		Bolt.	1.00	1.00	1.00	0.67	0.67	0.67
(6)	Pry up bolts and place thimbles on bolts		Bolt.	0.65	0.65	0.65	0.43	0.43	0.43
(7)	Rip braces off inner form section	Section		2.10	2.10	2.10	1.40	1.40	1.40
(8)	Drive in bottom bolts		Bolt.	0.44	0.44	0.44	0.29	0.29	0.29
(9)	Place blocks, washers and nuts (no cutting of blocks)		Bolt.	1.50	1.50	1.50	1.00	1.00	1.00
(10)	Place blocks, washers and nuts (blocks chopped and fitted)		Bolt.	3.40	3.40	3.40	2.30	2.30	2.30
(11)	Place top row of bolts (spreader placed at same time)		Bolt.	0.25	0.25	0.25	0.17	0.17	0.17
(12)	Stretch line for lining in form	Section	Section	2.80	2.80	2.80	1.90	1.90	1.90
(13)	Line in forms and brace by cross-bracing	Section	Section	15 to	25	min.	10 to	17	min.
(14)	Fix connection between forms	Section	Section	15 to	30	min.	10 to	20	min.
(15)	Brace back of cleats with 4" × 4" horizontal ledger	Section	Section	25.00	25.00	25.00	17.00	17.00	17.0
(16)	Wedge forms with wedges against 4" × 4" ledgers	Section	Section	0.70	0.70	0.70	0.47	0.47	0.47
(17)	Place 4" × 4" in corner to close angle connection	Corner		9.50	9.50	9.50	6.30	6.30	6.20
(18)	Oil forms[1]	Section	Section	1.80	1.80	1.80	1.20	1.20	1.30
(19)	Remove bolts complete[1]		Bolt.	2.80	2.80	2.80	1.90	1.90	1.90

[1] Can be done by laborers—figuring cost at laborers' wages.

TABLE 166] **ERECTING WALL FORMS** **[UNIT TIMES**

Continued

Item Number	Description	Net Time Per Operation							
		Unit		Average Men			Quick Men		
		Inside Form	Outside Form	1" Form Lumber	$1\frac{1}{4}$ Form Lumber	2" Form Lumber	1" Form Lumber	$1\frac{1}{4}$ Form Lumber	2" Form Lumber
				min.	min.	min.	min.	min.	min.
	Type 2 { Curtain Wall Forms Below Windows, (See fig. 69, p. 519.) 3 Feet High × 12 Feet Long.								
(1)	Carry section 50 feet[1]	Section	Section	(see	table	156	p. 65	5)	
(2)	Hoist section to floors above[1]	Section	Section	(see	table	155p.	648)		
(3)	Slide section on floor 100 ft. and return for next[1]	Section	Section	5.00	6.50	8.00	3.34	4.30	5.30
(4)	Pick out section and slide out of window[1]		Section	1.10	1.50	2.00	0.73	1.00	1.33
(5)	Place exterior side of section and hold		Section	4.70	4.70	4.70	3.10	3.10	3.10
(6)	Place interior side of section and hold	Section		1.33	1.53	1.74	0.89	1.02	1.16
(7)	Carry spreaders 50 feet[1]	Section	Section	0.30	0.30	0.30	0.20	0.20	0.20
(8)	Hoist spreaders to floor above[1]	Section	Section	0.20	0.20	0.20	0.13	0.13	0.13
(9)	Carry bolts 50 feet[1]		Bolt.	0.15	0.15	0.15	0.10	0.10	0.10
(10)	Hoist bolts to floor above		Bolt.	0.10	0.10	0.10	0.07	0.07	0.07
(11)	Place bolts, spreaders, blocks, washers and nuts[1]		Bolt.	4.20	4.20	4.20	2.80	2.80	2.80
(12)	Oil forms[1]	Section	Section	1.80	1.80	1.80	1.20	1.20	1.20
(13)	Remove bolts complete[1]		Bolt.	2.80	2.80	2.80	1.90	1.90	1.90

All labor involving carrying and hoisting should be performed by laborers and figured at laborers' wages instead of carpenters'.

[1] Can be done by laborers—figuring cost at laborers' wages.

CHAPTER XXIII

ESTIMATES FOR REINFORCED CONCRETE CONSTRUCTION

In making an estimate for a reinforced concrete structure—and the same rule applies to all kinds of structures—the unit quantities should be taken off and entered in a systematic manner. If the unit costs of materials and labor are known, the various items then may be carried out and summarized.

The various tables in this book give quantities and average labor costs in such a way that they can be used directly for an estimate. To conveniently tabulate these for an estimate, a form is shown at the end of this chapter, pages 693 and 695, and an example is given illustrating its use in practice.

ACCURACY OF ESTIMATES

Most jobs of engineering construction are made up of definite and distinct items that can be summarized by multiplying the quantity of each by its unit price. For example, in the estimate for a dam the items of earth excavation, rock excavation, masonry, fill, riprap, and so on, are either distinct in themselves or are divided into distinct classes. The price for each division can be computed by multiplying the quantity of each by the unit price.

Even in building construction of wood or brick or steel, the plans show the complete design so that the quantities may be taken off exactly and the labor costs estimated in terms of each unit.

Concrete building construction and, in fact, all types of reinforced concrete construction are difficult to estimate. In the first place, the plans, as usually provided, furnish only the drawings of the finished construction, sometimes even omitting the details of reinforcement and scarcely ever indicating the design of the forms. In the second place, the variation in cost of similar items, such as the forms for different structures or even for different parts of the same structure, is so great as to cause in some cases errors as large as 25% in the total estimate. The ordinary contractor and, in fact, many architects and engineers, are so accustomed to routine methods of estimating that the subdivision and classification necessary for approximating the actual cost in reinforced concrete construction is not understood or appreciated.

Form construction is the most costly item of labor in reinforced concrete work, and the greatest variations occur in this branch of the work.

In suggesting more accurate methods of estimating, it is realized that certain features of cost are impossible to accurately foretell. For example, a particular job may have a high labor cost because of the delay in obtaining material or because of labor conditions; in cities, politics may introduce an element of uncertainty. In other cases, the inability to obtain permits or locations for the storage of material may increase the cost. Notwithstanding, however, such indeterminate factors as these, which, with any method of estimating, the contractor must trust more or less to chance, there is no reason why the estimate itself should not be carefully worked out. On the other hand, where certain features are indeterminate, there is all the greater need for accuracy in the rest of the estimate. As a matter of fact, such variations are no greater than are liable to occur in the estimate of cost of materials, yet no one thinks of making a lump guess at material costs.

NECESSITY OF SEPARATING ITEMS

Any one who attempts to figure the cost of a reinforced concrete building by multiplying the number of cubic yards of concrete by a unit price per cubic yard for materials and by another unit price per cubic yard for labor, will certainly find himself badly in error unless the figures he uses happen to be based upon another structure practically identical in design and size with that under consideration.

The quantities of materials for the concrete are readily obtained after computing the number of cubic feet or cubic yards of solid structure. The cost per cubic yard of labor laying concrete can be estimated with comparative accuracy on the basis of previous work performed. The cost of forms, however, is an item that cannot be handled correctly in this simple fashion. During the first few years of reinforced concrete development, even the most experienced and careful contractors made the mistake of figuring with too little separation of units and they were at a loss to know why their contract costs were so far from their bids. This rough method of estimating was followed by many even after they possessed enough data to estimate more exactly and with scarcely any more trouble.

A mistake frequently made in estimating forms is to adopt unit prices for labor and material and use these without regard to the design of the building or to the number of times the lumber is used. When computed thus, in unit costs per cubic yard or even in costs per square foot of surface area, a contractor may find that the forms on a certain building cost 50% to 100% more per cubic yard of concrete or per square foot of surface than in another case. Frequently this difference may be due simply to the design of the two structures, to the number of times the forms can be used, or to the unsymmetrical layout which necessitates a large cost in remaking.

Effect of Design on Cost. The following factors will affect the cost of form construction and to a lesser degree the cost of the concrete itself. Various other minor points are discussed in connection with form construction on page 475.

Number of Stories in Building. The more stories in a building, the less is the cost of form lumber per square foot of total surface or per cubic yard of concrete because the forms are used a greater number of times.

Floor Area. A small floor area gives a more expensive building per unit of horizontal surface than a large area. When the surface of a floor is large, (1) the carpenters work to better advantage, (2) the same forms can be used in different portions of the floor, and (3) there is a smaller proportion of the more expensive exterior work.

Cubical Contents. Plant costs and overhead charges may be nearly the same for a small as for a large building, with a consequently greater cost per unit of volume. More forms in proportion are needed for the small building.

Length of Exterior Circumference. A long narrow building is more expensive than one of the same area more nearly square. Its greater circumference gives more curtain walls and windows and more expensive form construction.

Floor Loads. A heavy floor load requires larger beams and columns and more form surface.

Floor Designs. Form construction where beams are closely spaced is more expensive than when they are further apart, although the difference is less than would be expected because large beams require more lumber for supports and also more labor in erecting. Flat slabs with no beams at all give the cheapest type of floor form construction, although the reduction in cost is partially balanced by the expense of enlarging the heads of the columns.

Symmetry. A change in size of members from story to story through different floor loadings or different total loads greatly increases the cost of form construction. Unsymmetrical design in any one part of the building, if carried up from story to story, has less effect on the cost than when changes are made in the different stories, except as it increases the cost of the first layout for the carpenters.

DIFFERENT METHODS OF ESTIMATING IN PRACTICE

Ordinary methods of estimation adapted to certain conditions are as follows:

(1) Estimating by cubic contents of building.
(2) Estimating by square foot of floor area.
(3) Estimating by solid volume of concrete.
(4) Estimating by area of surface in contact.
(5) Estimating by member.

The last method, estimating by member, is the simplest accurate way of estimating costs of reinforced concrete building construction, provided tables are at hand to assist in computation. The quantities are taken off member by member, obtaining both the amount of material and the labor costs per member directly from the tables in this book as outlined on a following page.

All of the methods are worthy of brief consideration.

Estimating by Cubic Contents of Building. A rough idea of the construction cost of buildings may be obtained by figuring their total cubic contents from basement to roof, as given on page 51. When selecting a unit price per cubic foot, allowances must be made for the design, as indicated in preceding pages, and for the character of finish. Notice especially whether the unit price is to include complete finish or only structural features. This method of estimating is not exact enough to form a basis for a contractor's bid. A table of approximate costs per cubic foot is given on page 51.

Estimating by Square Foot of Floor Area. Estimates based on the total floor area in a building are liable to the same inaccuracies noted in the cubic foot method. They are not subject to the error caused by variation in story heights. Curves and tables of approximate costs per square foot are given in Chapter III.

Estimating by Solid Volume of Concrete. For the concrete itself, both for labor and materials, the quantity method is the most accurate method of estimating. A rough idea can be obtained of the quantity and cost of the steel by assuming a certain percentage of the volume.

The volume method is inaccurate for the estimation of the most costly part of reinforced concrete work, namely, the forms. For example, the total cost of concrete forms for the two sides of a continuous wall 8 feet thick will be substantially the same as for a wall 2 feet thick. On the other hand, if expressed in terms of per cubic yard of concrete, the cost of forms for the 8-foot wall will be only one-fourth the cost for the 2-foot wall. This is so great a discrepancy, and it is not an unusual one in large work, that the error would seem obvious and yet many engineers and contractors will make their records and actually figure the costs of form construction on such work in terms of per cubic yard of concrete.

In building construction the error is somewhat less because there is less difference between volume and surface measurement. Even here, however, the estimating of forms by the volume of the concrete is too inaccurate to be used. Take, for example, a column 24 inches square by 10 feet high. This will contain 40 cubic feet, while another column 18 inches square and the same height will contain only 22½ cubic feet or but slightly more than one-half. Although the volume of the 24-inch column is nearly 80% greater than the other, the cost of making forms for the 24-inch column will be only 17% greater than for the 18-inch, thus giving an error of 63% in labor cost if the forms for the 24-inch column are figured by the cubic yard on the same basis as the 18-inch column cost. Similarly, an 8-inch slab will have double the quantity of concrete of a 4-inch slab, but the forms will cost but slightly more for the thicker than for the thinner slab. The volume method of figuring forms also takes no account of the number of times the forms are used.

The cost of the steel is figured by weight, and labor of bending and placing also can be estimated quite accurately by weight.

Estimating by Area of Surface in Contact. Estimating forms by actual surface area is more exact than any of the methods just described, especially if it separates the different kinds of members, using, for instance, a unit price for slabs, another price for columns, and still another for walls. It is inaccurate, however, because of the fact that the cost of a form does not vary directly with the size of the member. For example, referring to the relative costs of the 18-

and 24-inch column forms mentioned in a previous paragraph, while the cost of form labor making a 24-inch column is only 17% greater than for an 18-inch column form of the same length, the surface of the 24-inch column is 33⅓% greater than the 18-inch, so that there is an error of 16⅓% by surface figuring.

For the form lumber, the area of contact surface is sufficiently accurate for practical purposes.

With surface measurements, however, account must be taken of the number of times the forms are used. The cost of the lumber for any structure is based on the surface requiring new forms. The cost of form labor per square foot depends not only upon the design, but, even to a greater extent, upon the number of times the forms are used or are remade.

Estimating by Member. All the methods of estimating just described have intrinsic errors either in the computation of materials or labor. In view of these inaccuracies, and especially in view of the difficulty and trouble in correcting for the variable conditions on any one job, the authors have rejected for accurate estimating all of these, and have selected the method of estimating by member. With the aid of the tables of concrete quantities in this book, it is possible to take off quickly the quantities in terms of each member and add them together to obtain the total concrete. The costs are found from other tables in terms of each member, and the steel from still other tables.

The general scheme of the method of estimating is clearly indicated in the forms on pages 693 and 695, where an actual case is partially worked out for illustration.

To use this method and figure the quantities and costs in the quickest possible manner and with an accuracy sufficient for almost any purpose for which an estimate is to be used, the following sets of tables have been provided.

(1) Form for general estimating (pp. 693 and 695).

(2) Tables of volumes of concrete (pp. 526 to 533).

(3) Tables of cost of concrete per cubic yard (pp. 165 to 172, pp. 312 to 317 and pp. 438 to 443).

(4) Tables of weights of steel in different combinations of sizes, spacings and lengths (see pp. 536 to 561).

(5) Tables of cost of bending and placing steel (pp. 570 to 599 and p. 605).

(6) Tables of quantities of form lumber in feet board measure for members of different dimensions (pp. 617 to 620).

(7) Tables of cost of making, erecting, and removing forms, for different sized members (pp. 630 to 647).

(8) Tables of approximate costs of special features which ordinarily do not require analysis (p. 10).

(9) Tables of approximate costs of machinery (pp. 371 to 375).

(10) Tables and curves of approximate costs by floor area and by volume for checking totals (p. 51).

By the method illustrated in detail in the pages that follow and with the aid of the tables, a man can take off the quantities from the plans and compute accurately the costs for a building, say, of 6 stories high and 20,000 square feet of floor area, in a time ranging from 3 to 12 hours. This time of estimating varies with the symmetry of design, i. e., whether the same size members are repeated over and over again or whether there is a large variety in spans and loading. This method, properly followed out, will produce an accurate estimate, exact enough for the engineeer or architect to obtain a very close figure, or for the contractor to make up a bid.

DISTRIBUTION OF PLANT COSTS AND MISCELLANEOUS EXPENSES

Certain items of cost in construction do not vary proportionally with the output. A part of the cost of the plant that is practically useless after completion, and the cost of plant installation, must be charged to each job. For machinery and apparatus that can be used again, a large depreciation, in most cases as high as 25% per year, should be charged off to the job. Sometimes these items are charged as a lump sum and sometimes charged at a unit price per cubic yard.

The cost of the foremen is generally included in the daily pay roll, and is always included in the costs in this book. The foremen's labor may or may not be considered in the times, according to the conditions.

The cost of general superintendence, time keepers, and clerks, may depend upon the length of the job as well as upon its size, and therefore may be figured either as a lump sum for the job or as a part of the unit cost of labor. For convenience in estimating, we have included them in our cost tables but not in the times (see p. 625).

Liability insurance is necessary in many classes of construction and is properly a percentage of the pay roll. In our tables it is included in the costs but not in the times (see p. 625).

The traveling expenses vary with the locality of the job. If the work is located in the same town as the office of the contractor or builder, the traveling expenses may be practically zero; if at a distance from the home office, there will be the expense of trips of inspection to the work, and in some cases also the traveling expenses, and perhaps the board, of a number of skilled workmen. This item must be worked out for any particular job. Since no approximation can be made which will be of general accuracy, the item of traveling expenses is not included in the costs in this volume.

Home office expense and profits, which also are not included, are discussed below.

Contingencies must always be allowed for. These may be in the nature of unforeseen conditions, such as bad weather or slow delivery of materials or labor troubles, or they may include small items which have been neglected in making up the estimates or which come up after the work is undertaken and yet cannot be charged as extras.

All these items of cost except, as stated, traveling expenses, home office expense, and profit, have been included in the unit costs given in the various tables. This method of estimating is in line with that adopted by engineers and architects, and is followed also by many first-class contractors, so as to be sure to avoid the error of omitting some of the items, and also for better comparing the daily cost records with the original bids. The allowances which the authors have fixed upon for each division of the work are taken up in each chapter in connection with the discussion of the various tables.

For those who prefer to figure each of these miscellaneous expenses separately and consider them as one lump sum, which is perhaps the most accurate plan, the "time" values given in the tables may be selected and combined as described on page 649.

Home Office Expense and Profit. No allowances have been made in the costs either for the expenses of the home office of the contractor or builder, or for profit. Our costs do include all the job charges, such as superintendence, time keepers, etc., but the expense of making up estimates, drafting, central office rent, etc., vary with the contractor's or builder's organization, and also, rather curiously, are interdependent with the profit.

If the business of the contractor is in the form of a corporation where all of the officials who are directly connected with the construction are paid definite salaries, the overhead charges and profit are two distinct items which bear no relation to each other. On the other hand, if, as is frequently the case, the contractor or owner of the business devotes his time to the various jobs, and the amount of time which he gives to each depends upon the number of jobs, which he has on hand, the fixed charges and the profit are interdependent. To illustrate, a contractor frequently makes the statement that when he began contracting and had only one job on hand he used to make, say, 10% clear profit or even more, but with his larger offices and more work on hand, the percentage is only a small fraction of this. Now, as a matter of fact, this is a reasonable condition. If he makes no charge for his own time, the larger percentages really include remuneration for his own time in superintendence, whereas, when he has many jobs, he has to hire men to take his place and his time is distributed over a larger territory, so that the percentage he receives for his services will be less upon each, although it should of course aggregate much more as a total. Besides this, when personally superintending the work, his own services are presumably so much more efficient than those of anyone whom he can hire that the profit is naturally greater.

A small contractor must be sure to take these facts into consideration when he makes up his bid, that is, he must include the value of his own time when determining the amount of profit which he should receive.

MISCELLANEOUS ITEMS INCIDENTAL TO BUILDING CONSTRUCTION

It is impossible, without extending this volume into several books, to analyze all of the auxiliary operations relating to concrete construction. However in Chapter II, pages 16 to 31, are given approximate costs of many of the items that a contractor has to include. Some of these are also listed in the estimates of a typical building on page 42.

MAKING AN ESTIMATE

On folding pages, 693 and 695, is a form of estimate blank with a partial estimate figured out to illustrate its use in practice. The plan, in general, as has been stated, is to figure both labor and material in terms of per member. Without tables such as are given in this book, this method would be impracticable, but with the tables it is the simplest possible way of making up a careful estimate, and reduces the labor of figuring a large reinforced concrete building to a few hours' time.

To make an estimate, schedule, in the first three columns of the estimate sheet, the dimensions and number of members from the drawings of the structure; find from the tables designated at the top of the estimate sheet the quantities of material required for these members and enter in the Material column; find from other tables the cost of the labor and enter in the Labor column; figure cost of materials from the quantities; collect and add together the totals.

The estimate of the volume of concrete may be used for figuring the bill of materials for the cement and aggregates. For the steel and the form lumber, more detail schedules are needed than can be made up with the original estimate, but the totals in the estimate are useful for comparison with the totals in the bills of materials that are prepared after the contract is let. The process of estimating for each kind of material is described more at length in the following paragraphs.

CONCRETE ESTIMATE

(1) Schedule, in the first three columns of the estimate sheet, the dimensions and number of members in the structure. For slabs and walls enter areas and thicknesses.

(2) Separate into groups the members to be built with the same proportions of concrete. Also, group the members having the same labor cost per unit of volume.

(3) Find volume of concrete per member in columns, beams, girders, slabs, and walls, directly from tables, pages 526 to 533, and enter in Material columns.

(4) Figure volumes of footings, masses, and irregular members in the ordinary manner in cubic feet, and enter the volumes under "Material."

(5) Multiply each of these volumes by the number of members, entering the total number of cubic feet in the Material Total column.

(6) Add together the quantities in each group having similar proportions of concrete and similar unit labor costs.

(7) Convert the sums of the volumes to cubic yards by dividing by 27.

(8) After determining the unit prices of the cement and aggregate delivered on the job, find the cost per cubic yard of the materials in each group from tables, pages 165 to 172. Multiply the volumes in paragraph (7) by these costs.

(9) Select from tables, pages 438 to 443, the cost of labor per cubic

yard, or else select a unit cost from private personal records on previous jobs carried on under similar conditions and management, and multiply the quantities obtained from paragraph (7) by this cost.

(10) Tabulate the various costs thus found for concrete materials and labor at the foot of the sheet or else on an independent sheet.

(11) Correct the total labor cost, to provide for the difference between the wage rate of the table and the average rate to be paid the concrete men on the job.

(12) Do not add to this sum any percentages for waste or contingencies. The volumes in the concrete tables allow for waste and excess measurement and the labor costs allow for contingencies and overhead charges at the job.

(13) To the final total add a percentage or a lump sum for home office expense and profit.

(14) Do not omit, in making up the schedule, the surface finish, the stairs, and other incidental quantities. For costs of miscellaneous details, reference may be made to Chapter I.

NOTE: In making an estimate it is not necessary to go into great refinement in quantities. For example, in columns, beams, and girders, it is usually exact enough to take the volume of each member in even feet. Footings of different sizes, if small in volume compared with the total amount of concrete, frequently may be taken at an estimated average volume.

STEEL ESTIMATE

(1) Schedule, in the first columns of estimate sheet, for ordinary members, such as columns, beams, and girders, merely the number and size of bars, length of member (not length of bars since the tables allow for lap), and the number of members. For slabs and walls, record the areas of surfaces and the size and spacing of bars.

(2) For steel in special construction not included in paragraph (1), enter the size, total length and number of bars.

(3) For steel in columns, girders, beams, slabs, and walls, take the weights directly from tables, pages 554 to 561, and enter these weights in the Material columns.

(4) For special steel referred to in paragraph (2), figure weights directly from table, page 537.

(5) Find cost of labor per member for handling and placing steel in columns, beams, girders, slabs, and walls, from tables, pages 570 to 599. Use either 30¢ or 10¢ values, correcting as noted in paragraph (7).

(5a) An alternate method for figuring costs of labor on steel is to take the total weight from the Material columns and multiply it by an average price per pound, selected from previous knowledge of labor costs on jobs of similar character.

(6) Multiply the sum of the weights of steel by the unit costs of the material delivered on the job.

(7) Correct the total labor cost to provide for the difference between the wage rate per hour in the table and the average wage rate to be paid the steel men on the job.

(8) Do not add, either to the weight of steel or to the labor cost, any percentages for waste or contingencies. The weights per member allow for lap and the labor costs allow for contingencies and overhead charges at the job.

(9) To the final total add a percentage or a lump sum for home office expense and profit.

FORM ESTIMATE—LUMBER AND LABOR MAKING

(1) Schedule, in first columns of estimate sheet, the dimension, length, and number of all the members for which new forms are to be made and only these. For walls, for example, enter only the surfaces where the forms will be first used.

(2) Take the quantities of lumber required for columns, beams, girders, slabs, and walls, from tables, pages 618 to 620, and enter in Material columns.

(3) Figure lumber required for other parts of the structure in usual way, allowing for necessary waste, and enter in Material columns.

(4) Multiply the total quantity of lumber by the average cost per foot board measure delivered on the job. If, as is usual, the price varies for different stock, take an approximate average price.

(5) Find labor costs of Making from tables, pages 630 to 648, and enter in Labor columns.

(6) Correct sum of total labor costs for difference between wage rate per hour in the tables and average wage rate to be paid the carpenters on the job.

(7) If the values in tables disagree with actual detail costs on previous jobs under the same conditions and management, correct the labor totals by a ratio based on this difference.

(8) Do not add either to quantity of lumber obtained from the tables, or to the labor cost, any percentages for waste or contin-

gencies. The quantities allow for waste, and the labor costs allow for contingencies and overhead charges at the job. Be sure, however, to include all items for which lumber is required and provide for staging, hoists, platforms, runs, ladders, etc.

(9) To the final total add a percentage or a lump sum for home office expense and profit.

FORM ESTIMATE—ERECTION

(1) Schedule, in first columns of estimate sheet, the dimensions, length, and number of all the members in the structure. For slabs and walls enter the surface area. Indicate the members for which forms are to be selected only once; those for which the forms can be reset without remaking and those where remaking is required.

(2) Take the cost of labor erecting forms for columns, beams, girders, slabs, and walls, from pages 630 to 648, and enter in Labor columns. Select the values from the proper column in the tables, depending upon whether the forms are erected for the first time, whether they are erected after the first time without remaking, or whether they are remade and then erected after the first time.

(3) Correct sum of total labor costs for difference between rate per hour in the tables and average wage rate to be paid the carpenters on the job.

(4) If the values in tables disagree with actual detail costs on previous jobs under the same conditions and management, correct the labor totals by a ratio based on this difference.

(5) Do not add either to quantity of lumber obtained from the tables, or to the labor cost, any percentages for waste or contingencies. The quantities allow for waste and the labor costs allow for contingencies and overhead charges at the job.

(6) To the final total add a percentage or a lump sum for home office expense and profit.

(7) In the Material columns, opposite this erection schedule, may be entered, if desired, the surface measurement of the members for purposes of checking.

ESTIMATE SHEETS

The specimen sheets on folding pages, 693 and 695, are reduced about half size. For convenience in figuring and also in filing, they may be made in practice letter size, say, $8\frac{1}{2}$ by 11 inches. The ruling shown is adapted to this size. The narrow vertical columns are $\frac{1}{8}$ inch wide on the regular sheet. The width of the other vertical columns may be obtained by measuring the specimen sheet and multiplying by 2. The horizontal ruling may be 6 lines per inch or 4 lines per inch. For general clerical use, four lines are preferable. In any case, be sure that every third horizontal line is of a different color or a different weight, so that the eye will readily carry across the sheet. Satisfactory colors for horizontal lines are green with every third line orange.

The use of the columns is shown in the description, just given, of the method of making the estimate, and is illustrated more clearly on the sheets themselves, where the practical example is figured out.

In order to find quickly the tables in the book containing the varied information on quantities and costs, the page numbers of these tables are printed at the head of the estimate sheet.

Another form for an estimate blank consists of a sheet similar to that shown on the folding pages, except that several sets of columns are given, instead of one set for materials and one for labor. The advantage of such a long sheet is in avoiding separate schedules of the members for the different materials. The objection is the difficulty in carrying the eye across the sheet with the greater liability of making mistakes on this account, and the necessity for handling the same sheets over and over for the different parts of the structure.

EXAMPLE OF ESTIMATE FOR REINFORCED CONCRETE BUILDINGS

A partial estimate of a concrete building is figured on folding pages 693 and 695. In order to make the illustration as clear and simple as possible only some of the principal members are scheduled. The estimate, however, is complete so far as given, including materials and labor for concrete, steel, and forms. The labor on concrete includes wheeling the materials 50 feet in wheelbarrows, mixing, wheeling the concrete about 50 feet in wheelbarrows, and then dumping to place. The labor on steel includes bending, carrying, placing, and handling the steel. The labor on forms includes the making of one set of forms and the erecting, removing and remaking where necessary. The remaining parts of the structure are to be handled in the same way. The methods of figuring the examples are described on preceding pages.

The estimate is based on average conditions and average men at work by the day not on scientifically managed work.

When each item is checked, enter a vertical line in the "Check" column. This must extend from line to line, as shown in the example, so that when the entire work is checked, a vertical line will extend from top to bottom of the sheet. This avoids the chance for errors that constantly occur with the ordinary check mark.

SUMMARY SHEET

Structure ____________ Job ____________
Location ____________ Date ____________
Owners ____________ Estimator ____________
Architect ____________ Checker ____________

Excavation ....
Piling or caissons ....
Damp proofing ....
Concrete:—Footings; basement floors;* walks... Columns;* floors;* roofs;* walls; partitions Granolithic ....
Reinforcing steel ....
Forms ....
Masonry:—Pressed and common brick ....
Cut Stone:—Setting; carving; cutting; cartage ...
Terra Cotta:—Setting; cartage ....
Fireproofing:—Tile; partitions ....
Plastering:—Lathing; suspended ceiling; corner beads; patching; ornamental ....
Carpentry:—Roughing; finishing; rough hardware; building papers ....
Mill Work:—Frames; sash; trim ....
Fireproof Windows and Doors ....
Roofing ....
Sheet Metal:—Skylights; flashing; cornices; roof covering ....
Marble, Mosaic and Tile:—Scaciola; Terrazza; cinder concrete base for floors; black boards
Glass and Glazing:—Leaded glass; wire glass; screen prisms ....
Painting and Varnishing:—Tinting; paperhanging
Ornamental Work:—Iron; bronze; prismatic lights; stair treads; setting ....
Structural Steel and Iron Castings:—Stack; cartage; painting; inspection; setting ....
Hardware ....
Plumbing:—Gas fitting; sewers; drains; water pipes ....
Heating:—Ventilating ....
Power Plant:—Boilers; engines; dynamos; foundations; switch boards ....
Electric Wiring:—Conduits; bells; tubes; telephones ....
Electric and Gas Fixtures:—Lamps ....
Elevators:—Sidewalk lifts; dumbwaiters; signal device; esculators ....
Pneumatic Tubes or other mechanical devices ...
Mail Chute ....

Total ....
Add for profit ....
Estimate price ....

*These items figured on Estimate Sheets.

ESTIMATE SHEET 1

Structure Factory Building — Job 1216
Location 10th Street — Date 2-9-12
Harvey, Washington — Estimator J. A.
Checker F. A. B.

Concrete Volumes–Tables pp. 526 to 533
Ft.B.M. in Forms–Tables pp. 618 to 620
Weight of Steel–Tables pp. 554 to 561
Concrete Materials Cost–Tables pp. 165 to 172
Concrete Labor Cost . Tables pp. 438 to 443
Form Labor Cost . . Tables pp. 630 to 648
Steel Labor Cost . . Tables pp. 570 to 599

Story	Dimensions*	Number of Members	Reference Page	Description	Material Per Member	Check	Material Total	Check	Reference Page	Description	Labor Per Member	Check	Labor Total	Check	Remarks
	Columns			Concrete					Cost of labor per cu yd based on						
1	1st Floor on Fill				Cu. Ft		Cu. Ft		wheeling material in wheelbarrows						
2	24"x24"x12 Ft.	42	527		48		2016		to 4 bag batch mixer and dumping						
3	24"x24"x12 Ft.	42			48		2016		concrete to place from wheelbarrows						
Roof	12"x12"x12 Ft.	42			12		504								
	Beams														
	Depth below slab														
2	9"x18"x18 Ft.	100	530		20		2000								
3	9"x18"x18 Ft.	100			20		2000								
Roof	7"x14"x18 Ft.	100			12		1200		Materials - Concrete						1:2:4
									Cement @ $1.60 per bbl. }						Table 31 p.167
	Girders below slab								Sand @ $1.25 per cu. yd. }						$4.64 per cu yd.
2	11"x22"x18 Ft.	39	530		30		1170		Stone @ $1.80 per cu. yd. }						
3	11"x22"x18 Ft.	39			30		1170		∴ 882 cu yd. @ $4.64 =						$4092.48
Roof	9"x18"x18 Ft.	39			20		780								
		No. of 100							Labor - Table 59 p 438						
	Slabs	Sq. Ft. Areas							882 cu. yd @ $0.94 =						$829.08
1	3"x117 Ft.x90 Ft.	10530	526		25		2633								$4921.56
2	3"x117 Ft.x90 Ft.	10530			25		2633								
3	3"x117 Ft.x90 Ft.	10530			25		2633								
Roof	3½"x117 Ft.x90 Ft.	10530			29		3054								
							23809		Cu. Ft = 882 Cu. yd						
		No. of 100		Granolithic					Finish						
		Sq. Ft. Areas							Materials per cu yd Table 20 p.149						
3 Floors	1"x117 Ft x 90 Ft.	31590	526		831		2633		Cu. Ft. Cement 4 bbl @ $1.60				$6.40		
					= 97.5		cu. yd		Sand 0.84 cu yd @ $1.25 =				1.05		
									∴ 97.5 cu yd. @				$7.45		= $726.37
			Labor (p.10)	Finish cost 1¢					per sq ft = per cu yd				$3.24		
				Mixing and Laying					Granolithic per cu yd				0.94		
									∴ 97.5 cu yd @				$4.18		= $407.55
															$1133.92
	Columns			Steel											
	1st Floor on Fill				Pounds										
2	4-7/8" ϕ 5/16" Hoops	42	554		137		5754		570		$072		$3024		Assembled
3	4-7/8" ϕ 5/16" Hoops	42			137		5754				072		3024		on horses,
Roof	4-3/4" ϕ 1/4" Hoops	42			98		4116				063		2646		then placed
	Beams														
2	6-3/4" ϕ 1/4" Stirrups	100	556		215		21500		575		$1.05		$10500		Assembled
3	6-3/4" ϕ 1/4" Stirrups	100			215		21500				1.05		10500		on horses,
Roof	4-3/4" ϕ 1/4" Stirrups	100			141		14100				071		7100		then placed
	Girders														
2	5-1" ϕ 3/8" Stirrups	39	557		329		12831		575		$117		$4563		Assembled
3	5-1" ϕ 3/8" Stirrups	39			329		12831				117		4563		on horses
Roof	4-1" ϕ 3/8" Stirrups	39			261		10179				094		3666		then placed
	Slabs	No. of 100 Sq. ft. areas													
2	1/2" ϕ 8" C.C.	10530	561		160		16848		597		$069		$7266		} 3 Panels
3	1/2" ϕ 8" C.C.	10530			160		16848				069		7266		
Roof	3/8" ϕ 5" C.C.	10530			148		15584				097		10214		per bay
	Total weight of			Steel			157845		Cost of Labor				$74332		

*For steel in columns and beams enter number and size of bars, and for steel in slabs and walls enter size and spacing of bars.

†P = place forms, R = remove forms, C = cut down forms for smaller members.

ESTIMATE SHEET 2

Structure Factory Building — Job 1216
Location 10th Street — Date 2-9-12
Harvey, Washington — Estimator J. A.
Checker F. A. B.

Concrete Volumes–Tables pp. 526 to 533
Ft.B.M. in Forms–Tables pp. 618 to 620
Weight of Steel–Tables pp. 554 to 561
Concrete Materials Cost–Tables pp. 165 to 172
Concrete Labor Cost . Tables pp. 438 to 443
Form Labor Cost . . Tables pp. 630 to 648
Steel Labor Cost . . Tables pp. 570 to 599

Story	Dimensions*	Number of Members	Reference Page	Description	Material Per Member	Check	Material Total	Check	Reference Page	Description	Labor Per Member	Check	Labor Total	Check	Remarks
	Column Forms				1" Sheathing										
1	1st Floor on Fill	none			Ft. B.M.		Ft. B.M.				Making				
2	24"x24"x12 Ft.	42	620		260		10920		633		$318		$13356		Type 2
											Placing				
2	24"x24"x12 Ft.	42							633	P&R†	$786		$33012		
3	24"x24"x12 Ft.	42								P&R†	651		27342		
Roof	12"x12"x12 Ft.	42								PRC†	733		30786		
	Beam Forms										Making				
2	9"x18"x18 Ft.	100	619		201		20100		639		$125		$12500		Posts 4x4"
															4 Ft. C.C.
											Placing				
2	9"x18"x18 Ft.	100							639	P&R†	$288		$28800		
3	9"x18"x18 Ft.	100								P&R†	250		25000		
Roof	7"x14"x18 Ft.	100								PRC†	322		32200		
	Girder Forms										Making				
2	11"x22"x18 Ft.	39	619		231		9009		643		$155		$6045		2 Intersecting beams
											Placing				
2	11"x22"x18 Ft.	39							643	P&R†	$402		$15678		
3	11"x22"x18 Ft.	39								P&R†	321		12519		
Roof	9"x18"x18 Ft.	39								PRC†	457		17823		
	Slab Forms				per Sq. Ft.						Making per 100 Sq. Ft.				
2	4"-117 Ft.x90 Ft.	10530 Sq. Ft.	617		25		26325		644		$076		$8003		3 Panels
			Total	Ft. B.M.			66354								per bay
				@	$3000		$199062				Placing per 100 Sq. Ft.				
2	4"-117 Ft.x90 Ft.	10530 Sq. Ft.								P&R†	$237		24956		
3	4"-117 Ft.x90 Ft.	10530 Sq. Ft.								P&R†	174		18322		
Roof	3½"-117 Ft.x90 Ft.	10530 Sq. Ft.								PRC†	185		19481		
											Labor Cost		$325823		

Summary Sheet

Concrete - sheet 1 Material and Labor	$4921.56
Granolithic - sheet 1 Material and Labor	113392
Steel - sheet 1 157845 lbs @ $0.02	315690
" - sheet 1 Labor	74332
Forms - sheet 2 Lumber	199062
" - sheet 2 Labor	325823
Total	1520455
Add 10% for profit	152045
	$1672500

*For steel in columns and beams enter number and size of bars, and for steel in slabs and walls enter size and spacing of bars.

†P = place forms, R = remove forms, C = cut down forms for smaller members.

ESTIMATE SHEET

With example showing use of tables for making up an estimate

INDEX

CONVERSION TABLE

To Convert American Units	To Metric Units	Multiply* by these Values	Crowns ‡	Florins	Francs	Lires	Marks	Pesos §	Pounds	Rubles	Yen
			To Convert Dollars to Foreign Moneys Multiply by Values given below the Name of each Money								
			3.73	2.49	5.18	5.18	4.20	1.036	0.205	1.942	2.008
			To Convert Dollars per American Unit to Foreign Money per Metric Unit Multiply by Values below								
Inches	Mm.	25.400	0.147	0.098	0.204	0.204	0.165	0.041	0.205†	0.777	0.079
Feet	Meters	0.3048	12.24	8.175	16.98	16.98	13.76	3.400	0.205†	6.360	6.560
Yards	Meters	0.9144	4.078	2.723	5.670	5.670	4.600	1.133	0.205†	2.126	2.189
Miles	Km.	1.6094	2.318	1.548	3.222	3.222	2.610	0.644	0.205†	1.206	1.243
Sq. in.	$Cm.^2$	6.4516	0.578	0.385	0.803	0.803	0.651	0.160	0.205†	0.300	0.310
Sq. ft.	$M.^2$	0.0929	40.18	26.82	55.80	55.80	45.20	11.16	0.205†	20.95	21.52
Sq. yd.	$M.^2$	0.8361	4.460	2.980	6.190	6.190	5.025	1.239	0.205†	2.322	2.392
Cu. in.	$Cm.^3$	16.387	0.228	0.152	0.316	0.316	0.256	0.063	0.205†	0.118	0.122
Cu. ft.	$M.^3$	0.0283	131.7	88.00	183.1	183.1	148.4	36.60	0.205†	68.60	70.65
Cu. yd.	$M.^3$	0.7646	4.880	3.255	6.780	6.780	5.490	1.355	0.205†	2.540	2.618
Pounds	Kg.	0.4536	8.225	5.490	11.42	11.42	9.260	2.285	0.205†	4.284	4.414
Gallons	Liters	3.7854	0.986	0.658	1.369	1.369	1.109	0.274	0.205†	0.513	0.528

To convert lb. per sq. in. to kg. per $cm.^2$ multiply by 0.0703.

* Do not use these values when converting money values.

† American and English units of measure are practically alike.

‡ Denmark, Norway, and Sweden.

§ Argentine Republic.

Example: Change $1.25 per cu. yd. to francs per cubic meter. Solution: $1.25 \times 6.78 = 8.48$ francs per $M.^3$