VERNON-HARCOURT

ON THE

MILAN NAVIGATION CONGRESS OF 1905.

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AND

ITALIAN NAVIGATION WORKS AND PORTS VISITED.

BY

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THE INSTITUTION OF CIVIL ENGINEERS.

SECT. II.—OTHER SELECTED PAPERS.

(*Paper No. 3621.*)

"The Milan Navigation Congress of 1905; and Italian Navigation Works and Ports Visited."

By LEVESON FRANCIS VERNON-HARCOURT, M.A., M. Inst. C.E.

THE Tenth International Navigation Congress was inaugurated by His Majesty the King of Italy, accompanied by the Queen, in the Scala Theatre at Milan, on the morning of the 25th of September, 1905; and in the afternoon the ordinary meetings of the Congress were commenced in the Villa Reale, a royal residence on the outskirts of the town. The Author had the honour of attending the Congress as the delegate of the Institution, as well as serving as a representative of the British Government, in conjunction with Colonel Sir Charles M. Watson, K.C.M.G.; and this Paper on the visits to works at the conclusion of the proceedings at Milan, has been prepared at the special request of the Secretary.[1]

VISITS TO WORKS.

Visits to lake and river navigations, comprising the oldest and newest navigable lateral canals of Northern Italy, and to two of the most important hydro-electric power-stations in the neighbourhood, were made on two days during the session of the Congress at Milan. After the close of the proceedings, two tours of inspection were organized, one to the River Po and the Port of Venice, with its outlet-channels into the Adriatic at Lido, Malamocco, and Chioggia, and the other to the harbour-works at Genoa, Spezia, and Naples, which form the subject of this Paper.

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[1] The original Paper, as deposited in the Institution, contains a summary of the proceedings of the Milan Congress, supplemented by an Appendix giving a list of the questions submitted to the Congress and the conclusions arrived at, and a comparison of the number of Papers presented with those of previous navigation congresses; and it also gives concise accounts of the visits to works in the neighbourhood of Milan during the Session of the Congress. A second Appendix,

The River Po.

The River Po, by far the largest inland waterway of Italy, was visited by members of the Congress after the close of the session in Milan, who went along it for a few miles by steamer between Pontelagoscuro and Polesella, on their way to inspect Chioggia and the Port of Venice, as well as the two other outlet-channels from the Venetian lagoons.

The river rises on Monte Viso, and traverses Northern Italy from west to east in a length of about 417 miles, flowing through the centre of the extensive plains of Lombardy, and receiving numerous tributaries coming down from the Alps and the Apennines; it has a basin of 26,780 square miles, of which 15,847 square miles are mountainous regions and 10,933 square miles are plains; and owing to the 35 million cubic yards of detritus, on the average, carried down in a year by the river from the mountains to the sea, its basin is increased each year by about 333 acres by the advance of its delta into the sea. The ordinary flow of the Po at Pontelagoscuro, about 57 miles from the sea, is 60,745 cubic feet per second; whilst the discharge of the greatest flood that has been measured, in October, 1868, was 220,870 cubic feet per second, though a higher flood occurred in October, 1872, which caused widespread inundations. The bed of the Po consists of pebbles and gravel down to about the confluence of the River Trebbia, 137 miles below Turin, of sand from thence to Borgoforte, 101 miles farther down, and of silt or mud along the remaining 111 miles to the mouth of the river. The average fall of the Po, which is $8\frac{1}{4}$ feet in a mile between Turin and Casale, is reduced to 3 feet in a mile between Casale and the confluence of the River Tanaro, and to 2 feet between Casale and the Ticino; whilst the surface velocity of the river at the low stage in this section, $102\frac{1}{2}$ miles long, ranges between $6\frac{1}{2}$ and 5 feet per second. From Ticino to Cavanella di Po, a length of 224 miles, the average fall is $9\frac{1}{2}$ inches in a mile, and the surface velocity varies from 5 feet per second at Piacenza to 20 inches at Cavanella; and from Cavanella to the sea, along the Tolle branch, a distance of $22\frac{1}{3}$ miles, the fall is under 2 inches per mile, but is influenced by the tide, which is felt above Cavanella.

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moreover, describes the position and functions of the Permanent International Association of Navigation Congresses, the remarkable amount of support accorded to it by foreign Governments and public bodies, and the prominent part it takes in the arrangements for the triennial sessions. Owing, however, to the limited space available in the Minutes of Proceedings, these portions of the Paper have been omitted in its published form.

Navigation.—Between Turin and Casale, navigation is almost impracticable on account of the large fall and the weirs at Chivasso and Casale for directing the water into the Cavour and Lanza irrigation-canals, thereby diverting almost all the water during the low stage away from the river. Moreover, the river winds considerably and shifts its bed for most of the distance below Casale to the confluence of the Ticino, and does not become fairly stable till a little farther down;[1] whilst the depth in this section at the ordinary low stage varies between 4 feet and $16\frac{1}{2}$ feet. The navigation, indeed, in this section only begins regularly at the confluence of the River Sesia, about $6\frac{3}{5}$ miles below Casale; and this part of the river is regarded as a second-class waterway in affording a normal depth of between $3\frac{1}{4}$ and $6\frac{1}{2}$ feet. The portion of the Po from the confluence of the Ticino down to Cavanella, 224 miles long, with depths at the ordinary low stage ranging for the most part from $8\frac{1}{5}$ feet to $19\frac{3}{5}$ feet, is the most important in respect of navigation, and the best adapted for it, possessing an ample depth, except over a few shoals, found generally at the confluence of the turbid tributaries from the Apennines coming in on the right bank, or in unduly wide parts of the river, or where the channel crosses over between two bends on opposite banks. These shoals prevent full advantage being taken of the remarkably favourable flow of the Po for navigation, owing to the main influx into it of the tributaries from the Apennines occurring in winter and spring, and of the tributaries from the Alps in summer and autumn. Moreover, though most of this portion of the Po is reckoned as being a first-class waterway, implying a minimum navigable depth throughout of $6\frac{1}{2}$ feet, the shoals reduce the assured navigable depth to 4 feet, only allowing of the passage of barges of 120 tons; but this navigation is only liable to be hindered or stopped during an average of 77 days in a year, by the lowness of the water, by floods, by fog, or other exceptional causes. The last section of the river, from Cavanella to the sea, being entirely comprised within the delta of the Po, which at the present time commences at the divergence of the Goro branch from the river about 9 miles above Cavanella, is of less importance commercially than the long central portion above, though it possesses an ample depth, except over the bar in front of the Tolle outlet, where the depth is reduced to between $2\frac{1}{4}$ feet and $2\frac{3}{5}$ feet at high tide.

Embankments along the River Po.—Floods are retained within the

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[1] "Atti della Commissione per lo Studio della Navigazione Interna nella Valle del Po. Relazione Quarta: il Po da Torino al Mare," Roma, 1903, Tavola VII.

river-banks down to Gerola Bridge, 89 miles below Turin, except at a few low places which have been embanked; but from this point embankments have been formed along both sides of the river down to its outlet, having lengths of 268½ miles along the right bank and 261 miles along the left bank, to protect the riparian lands from inundation. Parts of the embankments were carried out below Cremona long ago, and have been gradually extended both above and below; but during the flood of 1872 they were overtopped in several places, and thirty-three breaches formed, through which the river inundated large areas of land. The Po, however, has since risen higher in some places than in 1872, as, for instance, in 1879, when large breaches were formed, in 1886, and in 1887; whilst the embankments have been only partially raised above the flood-level of 1872. The raising of the bed of the Po by the deposit of materials brought down by the torrential tributaries into the river flowing slowly across the Lombardy plains, has been disputed; but assuming that the longitudinal sections of the river from Turin to the sea in 1874 and 1901, accompanying the report of the Commission of 1903, were taken under comparable conditions, it is evident that the bed of the river has been materially raised since 1874 from the confluence of the Ticino to below Cavanella.[1] Under these conditions, any further restriction of the high floods by raising the embankments would only sooner or later aggravate the injuries caused by the inundations, owing to the raising of the river-bed, and consequently the flood-level, by confining the detritus brought down from the mountains, instead of allowing it to spread over the adjacent plains.

Dredging in the River Po.—With the view of removing the shoals which at present restrict the navigation between the Ticino and Cavanella, experiments were recently undertaken with a suction dredger at places in the Po above the confluence of the Taro, the Oglio, and the Panaro, along a total length of 1¾ mile, when about 180,000 cubic yards of materials were removed, at an average cost of 2¾*d.* per cubic yard. The results of these trials were very satisfactory, especially at the two upper places, where the current remains fairly constant along the line of the trench formed in its direction; and by extending the operations across the various shoals which at present reduce considerably the available depth in this important section of the river, there is every prospect that the navigable condition of the river would be greatly improved.

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[1] "Atti della Commissione per lo Studio della Navigazione Interna nella Valle del Po. Relazione Quarta: il Po da Torino al Mare," Roma, 1903, Tavola I.

Navigation Works proposed in the Valley of the Po, and Venetia.

Waterway from Venice to Milan.—The principal work contemplated consists in the establishment of a first-class waterway, with a minimum depth of 6½ feet, between Venice and Milan, for vessels of 600 tons. This is intended to be accomplished by deepening the channel across the lagoon from Venice to Chioggia, and then following along the existing canals past Brondolo, a portion of the Adige, from Cavanella d' Adige to Tornova, and along the Loreo Canal to the Po at Cavanella,[1] up the Po, deepened over the shoals, to the Adda, and up this river to Pizzighettone, and thence by a new canal,[2] with nine locks of large lift, passing by Lodi to the Pavia Canal in the vicinity of Milan, which goes to that town.

Works proposed for completing the System of Inland Waterways.—In addition to the principal waterway just referred to, various existing waterways in the plains of Lombardy are to be improved so as to be navigable for barges of 100 tons to 250 tons, according to their situation; and new canals are proposed to be constructed to complete the network and to put them in communication with the River Po. The chief of these new waterways are, a lateral canal to the Mincio to connect the isolated Lake Garda with Mantua, and from thence with the Po; a canal from Brescia to the Fusia Canal, so as to put the isolated Lake Isco in communication with the Oglio; a canal to join the Modena navigation with the River Panaro; and some channels to complete the waterways across the Venetian marshes.

Cost of proposed Extensions and Improvement of Waterways.—The estimated cost of the whole of the proposed works amounts to £4,722,000, the most expensive portions of which are the canal from the Adda at Pizzighettone to Milan, estimated at £1,144,000, works for connecting Lake Garda with the Po, £964,600, and the canals from Lake Isco to the Oglio, £320,000; whereas the deepening of the Po below the confluence of the Ticino, so as to afford a minimum depth throughout of 6½ feet, is estimated at £48,000.[3] Some of these works, however, would enable water-power to be utilized to

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[1] "Atti della Commissione per lo Studio della Navigazione Interna nella Valle del Po. Relazione Terza: da Venezia al Po," Tavole II e III.

[2] *Ibid.* "Relazione Settima: Fiumi, Canali, e Laghi Navigabili di Lombardia," Allegata B, p. 173, Tavole I, II, e III.

[3] "Lacs, Fleuves, et Canaux de Navigation d'Italie, Notice Illustrée," MM. Cozza et Berta Milan, 1905, pp. 228–235.

the extent altogether of 48,570 HP., which would serve to reduce the actual expenditure.

Lengths eventually of the Waterways of Northern Italy.—The present length of the navigable waterways of Northern Italy is 1,733 miles, and this will be increased to 2,119 miles by the works. Of this latter length, 438 miles are to be made capable of accommodating vessels of 600 tons, 247 miles of which consist of the waterway between Milan and Venice, 726 miles are to be available for barges of 250 tons, 792 miles for barges of 100 tons, and 163 miles for barges of less than 100 tons.

Advantages to be derived from the proposed Works.—The proposed improvement and extensions of waterways in Northern Italy will provide a first-class waterway from Milan to Venice, to the great benefit of both these great centres of commerce, as well as the other important towns situated on the Po, a waterway for barges of 250 tons extending from the eastern frontier, past Venice, to Ravenna, and the connection of the isolated lakes Garda and Isco with the Po and all the other waterways; whilst Lodi, Brescia, Verona, Cremona, and other towns, at present devoid of access by water, will be put in communication with the entire system of waterways; Ferrara, Bologna, and Ravenna will be linked to the network by navigable waterways; and Vicenza, Treviso, Modena, and other towns will have their communications by water considerably improved.[1]

Port of Venice and its Lagoon.

Venice, owing to its excellent natural position, situated on an extensive lagoon, and well sheltered from the sea, though in close proximity to it, has been a renowned seaport for centuries.

Venetian Lagoon.—The lagoon extends from the diverted River Brenta on the south to the River Sile on the north-east, along a distance of about 33 miles, with a maximum width of 9⅓ miles. It has an area of 226½ square miles, of which, however, only 107 square miles are sufficiently below high-water of spring-tides to affect materially the volume of tidal water entering and leaving the lagoon each tide through the openings in the narrow fringe of coast separating the lagoon from the sea, where the rise of tide in this embayment of the Adriatic is 2 feet 3½ inches at equinoctial spring-tides, and 1 foot 3¾ inches at neap-tides. Numerous channels intersect the lagoon, which, converging to the outlets, assist in filling and emptying the lagoon

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[1] "Atti della Commissione per lo Studio della Navigazione Interna nella Valle del Po. Relazione Generale," Roma, 1903, Tavola I.

each tide, and serve for navigation between Venice and other places on the lagoon and the sea[1] (Fig. 1, Plate 1).

Two dangers require to be guarded against in such a lagoon, namely, the silting up of the lagoon by the alluvium brought into it by rivers, thereby gradually reducing the tidal scour which maintains the depth of the channels and their outlets, and the formation of breaches during severe storms in the narrow strip of land adjoining the sea, which, by increasing the number of outlets from the lagoon, would diminish the scour, and consequently the depth, of the channels through the existing outlets. To provide against the first injury, the rivers Brenta and Bacchiglione were diverted southwards outside the lagoon in the sixteenth century, so as to fall into the sea at Brondolo, though, owing to frequent breaches in the embankments of the Brenta, this river was readmitted into the lagoon from 1840 to 1896, in order to enable thoroughly complete and durable works for its permanent exclusion to be carried out, which necessarily, during that period, injuriously affected the lagoon. In the first half of the seventeenth century, by means of very extensive works, the Po was diverted away from the lagoon to the south and the Piave to the north, and the River Sile was led into the former bed of the Piave at the north-eastern extremity of the lagoon; whilst the smaller rivers which flowed into the lagoon were also excluded. Nevertheless, the drainage from 402,800 acres of land adjoining the lagoon still flows into it, as well as the discharge from a small branch from the River Sile; but though this inflow appears to be regarded as unfavourable in excluding tidal water, yet, considering that it is probably fairly free from alluvium, it must be valuable in reinforcing the ebb, and thereby helping in carrying out again to the sea the sand brought in by the flood-tide during storms. The narrow strip of land enclosing the lagoon has been protected on its sea-face in early times by wooden sheeting, subsequently by timber and rubble combined, and latterly by sea-walls of masonry and rubble.

The restriction of the tidal capacity of the lagoon by private persons, chiefly by enclosing water-areas by embankments for fishery purposes, has been checked to some extent by laws passed from time to time; but it has proved necessary to petition for a more stringent enactment to stop this cause of injury.

Port of Venice.—There is a naval arsenal at the eastern end of Venice with a basin and two graving-docks, having access to the main channel by the Maroni channel and thence to the Lido outlet.

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[1] "Ports Maritimes de l'Italie, Notice Illustrée," MM. Coen-Cagli et Bernardini, Milan, 1905, pp. 269-274, et carte.

The commercial port of Venice consists of a Commercial Basin with the Scomenzera Canal, at the western extremity near the railway, surrounded by quays and provided with railway-sidings, constructed in 1868–1880[1] (Fig. 2, Plate 1), and the old natural portions of the port, comprising the Giudecca Canal with its western end near the basin and running across the southern part of Venice towards St. Mark's Channel, the eastern outer portion of the port, in both of which vessels can lie at anchor. The total water-area of the port is about 445 acres; whilst there are depths of over 23 feet at ordinary high-water, and for the most part between 26¼ and 33 feet, in 50 acres of the Commercial Basin with the canal, in 160 acres of the Giudecca Canal, and in 104 acres of St. Mark's Channel. The quays have been gradually extended as required in the Commercial Basin and on the north side of the Giudecca Canal, so that whereas in 1880 there were only 1,136 lineal yards of quays, there are now 3,291 yards, the most recent and deepest of which are shown in Figs. 3, Plate 1,[2] nearly two-thirds of the length affording depths alongside of 26¼ to 28 feet; whilst on the Giudecca Canal there are 367 lineal yards of quays with depths of 29½ to 33 feet in front of them. The cost of construction of the Commercial Basin with its warehouses, railway-sidings, and connecting bridges, up to 1880, was £150,000; but the subsequent extension of the quays and sidings alongside the basin and canal, warehouses and sheds, hydraulic machinery and cranes, and electric cranes and lighting, have raised the total expenditure on this part of the port to £480,000.

As the trade of the port of Venice has risen from 960,330 tons in 1887 to 1,987,865 tons in 1904, and during the last five years has been increasing at the rate of about 65,000 tons a year, fresh accommodation is urgently needed; but the designs for extensions are complicated by the necessity of avoiding any works which might reduce the tidal capacity of the lagoon, or interfere with the influx and efflux of the tide. The most satisfactory, from this point of view, of the various proposals submitted, is the construction of a second basin bordering the lagoon near the end of the railway-bridge, to be reached by a prolongation of the Giudecca Canal, for receiving all merchandise in transit, especially coals, which would thereby relieve the existing quays of the commercial port and the railway of the most cumbersome goods.

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[1] "Ports Maritimes de l'Italie, Notice Illustrée," MM. Coen-Cagli et Bernardini, Milan, 1905, pp. 282–293, et planches.

[2] The quays represented by sections A, C, and E, Fig. 3, Plate 1, were constructed with concrete deposited within frames; and sections B and F with caissons sunk by aid of compressed air.

Navigation Channels in the Venetian Lagoon.—The first work for improving the navigable communications in the lagoon, was the formation of a channel connecting the depression, or basin, facing the Malamocco outlet with that of Lido, undertaken early in the eighteenth century; whilst other channels have been since deepened and maintained by dredging. The principal channels of the lagoon at the present time are, the Grand Navigation Channel, with a depth of 34½ feet at ordinary high-water, connecting the eastern end of Venice and the naval arsenal with the Malamocco outlet-channel, nearly 9½ miles long; the Poveglia Channel, 28 feet deep and 1,100 yards long, branching off from the previous one near Malamocco village, serving as a quarantine station; St. Mark's Channel and the Giudecca Canal joining the Grand Navigation Channel to the Commercial Basin, having a combined length of 3½ miles and depths of 26¼ to 29½ feet; and, lastly, the branch from St. Mark's Channel to the Lido outlet-channel, 690 yards long and over 33 feet deep. These main channels, together with the Malamocco and Lido outlet-channels, 2,230 and 4,920 yards long respectively, have a total length of about 18 miles.

The minor channels of the lagoon have a total length of about 96 miles, comprising the numerous canals intersecting Venice in every direction, measuring altogether 11 miles; the various channels providing means of communication to numerous places and industrial establishments on the islands and borders of the lagoon; and the channels to the south and north connecting the lagoon with the inland waterways of the valley of the Po, and of the Venetian plains, respectively; and depths of 6½ feet to 13 feet are maintained in these channels by dredging.

Dredging has been carried on for a long period in the principal channels, and since 1841 in the minor channels of the lagoon; and the maintenance of the depth in those channels necessitates an annual removal of about 78,500 cubic yards of deposit, at a cost of £2,560 or 7·8*d.* per cubic yard. This dredging, however, does not merely maintain the depth of the channels, but also assists in preserving the tidal capacity of the lagoon. The navigation channels are marked by oak piles, driven singly or in clusters of two or more along the sides, at intervals of 164 feet to 230 feet.

Outlet-Channels from the Venetian Lagoon.—There are at the present time three outlets by which the channels of the lagoon have access to the Adriatic, namely, Chioggia near the southern extremity, Malamocco in a central position, and Lido to the north; and the action of the sea constantly tends to form a continuous beach across these outlets, which is only prevented by the influx and efflux of the tide filling and emptying the large expanse of the lagoon. Accordingly, these outlet-channels, in their natural condition, are impeded by a bar outside, where the tidal current, being unconfined, loses to a great extent its scouring efficiency. No works having been carried out at the Chioggia outlet, it is only accessible to vessels of small draught; and till works were undertaken at Lido in 1882 to concentrate the tidal current, which was divided between three outlet-channels, into a single channel across the bar, the Malamocco outlet-channel, which had been deepened by jetties during the middle portion of the nineteenth century, formed the main channel for the trade of Venice (Fig. 1, Plate 1).

Chioggia Outlet-Channel.—Numerous little anchorages exist alongside the islands scattered over the lagoon; but the only other regular port besides Venice is Chioggia, which, till recently, consisted merely of some old quays along the canals intersecting the town, with a small depth of water in front of them, these canals serving mainly to connect the lagoon with the inland waterways of the valley of the Po. Quite recently, however, a basin has been formed close to the town, and partially lined with quay-walls having a depth of 23 feet of water in front of them. Nevertheless, as nothing has been hitherto done to concentrate the current across the bar outside, and the tidal capacity of the lagoon in the neighbourhood of the outlet was considerably reduced by deposits brought into it by the River Brenta in the 56 years during the progress of the diversion-works last century, the available depth of the Chioggia outlet-channel is too small to enable vessels of good draught to come alongside the new quays. The maritime trade, accordingly, of the fishery port of Chioggia has remained stationary, and has never exceeded 40,000 tons in a year. Works, however, have been recently proposed for deepening the outlet-channel at Chioggia similarly to the other two; and when this port becomes accessible to vessels of large draught, and the improvement and extensions of the waterways of the Po valley have been carried out, the trade of Chioggia is certain to develop considerably as being the natural outlet of the inland navigation traffic of the Lombardy plains.

Malamocco Outlet-Channel.—The improvement of the depth over the bar in front of the Malamocco outlet was carried out between 1839 and 1872, by means of fairly parallel jetties extended out seawards across the foreshore.[1] These works, by directing and concentrating the

[1] "Ports Chioggia, Malamocco, and Lido, and the channels leading to Venice," Admiralty Chart, London.

tidal current into and out of the lagoon across the bar, have provided a minimum depth of 31 feet in the outlet-channel at ordinary high-water, enabling vessels of large draught to reach Venice (Fig. 4, Plate 1). The northern jetty has been given a length of 6,962 feet, and the southern jetty 3,137 feet; and the width between the centre lines of the two jetties is 1,545 feet. The jetties consist of a rubble mound raised to ordinary high-water level, 28 feet wide at the top, with slopes of 1½ to 1, protected by large blocks at the outer end, and surmounted by a masonry superstructure 6½ feet high (Fig. 5, Plate 1). They cost £320,930, or £31 15*s.* 6*d.* per lineal foot; whilst the expenses of maintenance are about £640 annually. At ordinary tides the average velocity of the ebb-current through the jetty-channel is 2 feet per second.

It appears probable that by carrying the south jetty as far out as the other, and by shortening a little the groyne projecting from the south side of the outlet, the available depth might be still further increased.

Lido Outlet-Channel.—The success which resulted from the jetty-works at the Malamocco outlet naturally led to the construction of similar works for improving the Lido outlet, commenced in 1882 and not yet fully completed; but at Lido it was essential to lead the three somewhat conflicting outlet-channels of Lido, St. Erasmo, and Treporti, into a single channel guided by jetties across the foreshore. The jetties, accordingly, starting from the land side of the two side channels, Lido and Treporti, have been made to converge in front of the smaller central St. Erasmo Channel, so as to make the three channels combine into a single outlet-channel of the requisite width, which is then directed by the jetties, prolonged parallel to each other, into deep water[1] (Fig. 6, Plate 1). The length of the north-east jetty is 11,926 feet, and of the south-west jetty 10,351 feet; and the width between the jetties along their outer parallel portions is 2,970 feet. These jetties are very similar in construction to those of Malamocco, with a rubble base and small solid superstructure, the rubble base in this case being only 21 feet in width at the top, but raised 1 foot 8 inches above the ordinary high-water level; whilst the superstructure, which is 5 feet high, varies in width from 5 to 10 feet (Fig. 7, Plate 1). The rubble mounds are not quite finished, and 5,413 feet of superstructure have still to be built on the north-east jetty and 5,085 feet on the south-west; but it is estimated that the cost of the two jetties when completed will amount to £304,000, or

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[1] "The Lido Entrance at Venice," E. Cucchini, Milan Navigation Congress, 1895, Section II, 4th Communication.

£13 13*s.* per lineal foot, the much smaller cost of these longer jetties, in proportion to their length, than those at Malamocco, being probably due to the shallower depth of the inner portion of the jetties, the smaller width of the rubble mound and dimensions of the superstructure in a less exposed site, and the better appliances available for the construction of the jetties of late years.

The jetties at Lido have already, in their unfinished state, produced an increase in the depth of the channel between them, from the original 10 to 13 feet up to from 23 to 33 feet at ordinary high-water; and though at present there is a sandbank at the outlet of the jetty-channel with a maximum depth of only 23½ feet over it at ordinary high-water, it is anticipated that a greater depth will be obtained over this bar, on the completion of the jetties, owing to the expected increase in the scour. The advance, however, of the sandy foreshore to the north-east of this outlet under the influence of the prevailing north-easterly winds, which has been rendered more rapid by the projection of the north-east jetty, may in the future occasion a diminution in the depth in front of the outlet obtained by the works, and necessitate dredging for maintaining it.

Protection of the Sea-coast bordering the Venetian Lagoon.—The works for defending the narrow fringe of coast bordering the lagoon from the attacks of the waves, forming the only barrier separating the lagoon from the Adriatic, extend along a total length of 12¾ miles, divided into four portions by the three outlets. The short length of 1,100 yards of shore-protection to the north-east of the Lido outlet is no longer required, on account of the stretch of sandy beach which has accumulated between it and the sea, owing to the south-westerly littoral drift of the alluvium brought down by the rivers Piave and Sile by the action of the prevailing north-east winds. This accretion, which is still discernible for some distance to the south of the Lido outlet, eventually disappears on the exposed stretch of coast leading towards Malamocco, along which protective works have been carried out for a length of 6,665 yards, against which the waves dash, especially during south-easterly gales; but accretion again occurs under the shelter of the Malamocco jetties (Fig. 1, Plate 1). The general nature of the defensive works along this part of the coast is shown in G, Figs. 8, Plate 1, except that, in the less exposed parts, rubble stone takes the place of the pitched slope, and is the most common arrangement for these works.[1] Protective works have been especially necessary along the very narrow belt of exposed coast

[1] "Ports Maritimes de l'Italie, Notice Illustrée," Milan, 1905, pp. 274–275, et planches.

between the Malamocco and Chioggia outlets; so that, though sheltered for a short distance by the southern Malamocco jetty, the defensive works practically extend along all its length of about 7⅕ miles. The systems adopted in the most exposed parts, and where the ground behind is near, or at, the level of ordinary high-water, are shown in H and I, Figs. 8, Plate 1; and in the last case the sea-wall forms the only barrier between the sea and the lagoon. In some places groynes have been carried out in front of these embankments or sea-walls to collect the drifting sand. These protective works have also been extended from the southern point of the Chioggia outlet for 1,996 yards along the coast; but southward of this, accretion takes place from the drift of the alluvium from the rivers Brenta and Adige, under the action of the waves raised by south-easterly winds. The total cost of these works of protection has been estimated at £800,000; and the expenses of their maintenance amount to about £1,200 a year.

Genoa Harbour and Ports.

Genoa, the principal seaport of Italy, owed its rise in early times, like so many ancient ports, to its position on a small fairly sheltered bay with deep water and good anchorage close to the shore at the head of the Gulf of Genoa, especially in a country bordered by the practically tideless Mediterranean Sea, where the rivers flowing into it are shallow and narrow down to their outlets when draining small basins, and obstructed by a delta when coming down from mountain ranges and draining large basins, so that they are not accessible to sea-going vessels of large draught, and ports have therefore to be provided in sheltered situations on the sea-coast. As traffic develops at these places, and vessels increase in size and draught, the sheltered bay becomes inadequate in area and depth; and extensive works have to be carried out in the sea beyond the bay, and in deeper water, to increase the sheltered area and the accommodation of the port. This is, in general outline, the history of several Mediterranean ports, such as Marseilles, Genoa, Naples, and Alexandria.

Inner Harbour of Genoa, and Old Port.—The old harbour of Genoa is a semicircular bay, nearly a mile in diameter, with hills rising near the shore to the north, sheltered on the west side by Cape Faro, and on the east by the coast of Sarzana; and the depth reaches 6½ fathoms at the entrance to this harbour, and exceeds 5 fathoms over most of the harbour, and is little affected by the tide which only rises 1 foot, though under the influence of strong winds and changes in atmospheric pressure the sea occasionally may be 2 feet above or below its mean level. The prevailing winds are from the south-east, and the strongest from the south-west, to the first of which quarters the bay was most open; whilst the worst seas come from about south-south-west, in which direction the fetch to the African coast is about 600 sea-miles. The Old breakwater, now serving as a jetty with quays, was gradually extended out from the south-eastern extremity of the bay, in a westerly direction, at intervals between the years 1283 and 1563, to protect the bay from south-easterly storms; and a basin was also commenced in 1283 alongside the north-eastern shore of the bay for a naval station, approximately on the site of the present basin; and the commercial port was situated between the basin and the Old breakwater which sheltered this part of the bay[1] (Fig. 9, Plate 2). The tranquillity, however, of the sheltered portion of the bay was impaired by degrees by the extension of the town on to stretches of sloping beach bordering the harbour, on which the waves originally expended their force; and, consequently, the New breakwater was commenced in 1634, starting near the south-western end of the bay and running in an east-south-easterly direction, for protecting the harbour from the worst waves coming in from south-south-west. Nevertheless, though the shelter of the harbour was improved by this incomplete breakwater, it remained sufficiently exposed for severe storms to injure the port and the shipping in the harbour, till both breakwaters were prolonged in 1846-68; but by this time the trade of the port had outgrown the accommodation.

Extension of Genoa Harbour.—Breakwaters were carried out in 1877-88 for forming an outer harbour beyond the limits of the bay, which, with the construction of jetties, quays, and graving-docks, the diversion of sewers from the harbour and improvements in the equipment of the port during the same period, and additional works since 1897 for increasing the accommodation, have brought the harbour and port to its present position.

The principal work carried out for the extension of the harbour is the Galliera breakwater, commencing near the outer end of the New, or western breakwater, and after proceeding nearly due south for 2,156 feet, turning round to an east-south-easterly direction for a length of 2,766 feet, thereby fully protecting the water-area between the breakwater and the south-eastern shore from south-westerly seas. The Giano breakwater was at the same time carried out from the south-eastern shore in a west-south-west direction

[1] "Ports Maritimes de l'Italie, Notice Illustrée," MM. Coen-Cagli et Bernardini, Milan, 1905, pp. 23–61, et planches.

for a distance of 1,952 feet, well within the shelter of the Galliera breakwater from the south-south-west, so that vessels entering the outer harbour are protected by the Galliera breakwater from the worst waves before reaching the actual entrance, between the pier-head of the Giano breakwater and the Galliera breakwater, which is exposed to storms from south-east to about east-south-east. A return-portion was also added at the end of the New breakwater to increase the shelter in the inner harbour; and the concrete blocks protecting the upper part of the outer slope of the rubble mound were arranged as spurs projecting 10 feet, so as to break the waves and check the swell tending to enter the inner harbour.

The Galliera breakwater, situated in depths increasing regularly from 49 feet to 73 feet, consists mainly of a sorted rubble mound, protected on the lower portion of the sea-slope by large rubble, 5 tons to 50 tons in weight, and on the upper part by concrete blocks laid in stepped-back courses; and it is surmounted by a masonry superstructure, with a quay along the inner side sheltered by a high parapet-wall having a thick masonry apron extending in front of it on the sea side, protecting both the outer toe of the wall and the top of the rubble mound (Fig. 14, Plate 2). The rubble mound settled one-tenth of its height under the weight of the superstructure; whilst the subsequent settlement, resulting from the waves and the wear of the materials, has been slight and uniform. This breakwater occupied 11 years (1877-88) in construction; and its original cost was £654,600, or £133 per lineal foot. An exceptionally severe south-westerly storm on 27th November, 1898, produced a breach in the parapet-wall of the outer portion, 720 feet in width; the protecting concrete blocks were removed in places to a depth of 6½ feet to 20 feet; and the apron was destroyed near the angle of the two arms. In repairing this damage, the interval which had previously been left on the top of the rubble mound between the narrow apron and the courses of concrete blocks, was filled in by a thick, continuous apron covering the top of the mound and the top courses on the sea side, and protecting the parapet-wall up to more than half its height, as shown by the section of the reconstructed outer breakwater in Fig. 14, Plate 2. The New breakwater, which is 2,950 feet long, was also damaged by the same storm along the 820 feet constituting its outer, deepest portion, by the drawing down of the large rubble and concrete blocks protecting its mound below water, and the partial destruction of the apron. The cost of the repairs and strengthening of the Galliera breakwater amounted to about £32,000, and of the New breakwater £3,770.

The Giano breakwater, extending out into a depth of 52 feet, is very similar in general construction to the Galliera breakwater in its original form, but considerably smaller and slighter, owing to its much smaller depth and less exposure (Fig. 13, Plate 2). This breakwater was carried out in 1883-88; and its cost was £84,000, or £43 per lineal foot.

The inner harbour has a water-area of 234 acres, with depths of 26 feet to 43 feet, but for the most part not less than 30 feet; whilst the outer harbour, enclosed by the Old, Giano, and Galliera breakwaters, has an area of 247 acres, with depths of 30 feet to 65 feet. The ample depths which now prevail throughout the harbour have been obtained by the aid of dredging with bucket dredgers, and preliminary blasting of rock where necessary, from 1877 to 1904, at a cost of over £179,200; and at the present time a small area in the angle of the outer harbour between the Old breakwater and Boccardo quay, in which the depth is under 5 fathoms, is being deepened to that extent, in a bottom of schistous limestone, by blasting and removing the fragments by a movable caisson under compressed air.

Extension of Jetties, Quays, and Graving-Docks.—During the extension of the harbour, numerous jetties were built out from the shore round the inner harbour, which have been equipped with sidings, cranes, and sheds (Fig. 9, Plate 2). The quay-walls lining these jetties are somewhat varied in type, as shown by their cross sections (Figs. 10 to 12, Plate 2); but they all rest upon a rubble base, and for the most part are backed up also with rubble. The type given in Fig. 10 is simply an improvement of the design of the older quay-walls along the shore, formed with courses of concrete blocks deposited under water, and its extension to deeper water, a system which has proved quite satisfactory, except on a high rubble base or a silty foundation; and this quay-wall cost £13 7*s.* per lineal foot. The quay-wall of the jetty enclosing the basin leading to the graving-docks under the shelter of the Giano breakwater, is shown in Fig. 11, Plate 2, and consists of a masonry monolith from the top of the rubble base to the water-level, constructed by aid of compressed air in movable caissons. The quay-wall to be built in the enlargement of the Caracciolo jetty, indicated by dotted lines on the plan (Fig. 9, Plate 2), is a combination of the above two systems; for it is to be constructed as a masonry monolith in movable caissons under compressed air for a height of 16¾ feet above the rubble base, and then raised to the water-level by concrete blocks to expedite the work and also cheapen it (Fig. 12, Plate 2). This jetty, the construction of which will necessitate the removal of the jetty projecting from the centre of the New breakwater, will afford a depth of 29½ feet in front of the quay-walls.

The quay-walls along the shore in the outer harbour, between the Old jetty and the graving-docks, being exposed to swell during south and south-easterly winds, have been built with masonry piers founded on rock by compressed air, placed at intervals apart with hollow spaces between, into which the swell can enter and spend its force against a rubble slope inside, instead of being reflected from a continuous quay-wall. The Grazie quay, which was exposed to the swell before the basin in front of it was enclosed by the projecting jetty, spans the intervals between the piers of 39⅓ feet by brick arches just above the water-level, built on iron centres suspended from above; but at the Boccardo quay, in a position of greater exposure between the Grazie quay and the Old jetty, lintels of ferro-concrete have been used in place of arches for spanning the spaces, 37¾ feet in width, between the piers, so as to reduce the surface of the face exposed to the waves to a minimum. The cost of the latter quay, with the spaces running back 26¼ feet, including the rubble slope inside, was £24 6*s.* per lineal foot.

Two graving-docks have been constructed under the shelter of the Giano breakwater, with lengths at coping-level of 588 feet and 721 feet, and along the blocks of 525 feet and 656 feet; widths at coping-level of 96 feet and 81 feet, and in the entrance at sea-level of 82 feet and 59 feet; and depths over the sill of 31 feet and 28 feet respectively. They are closed by ship-caissons; and the longer graving-dock can be divided into two docks by an intermediate caisson, with lengths of either 295 feet and 361 feet, or 426 feet and 230 feet. The cost of these graving-docks, with the approach-basin and accessory works, amounted to £355,650.

Expenses of Extensions, Equipment, and Various Works.—The works carried out by the Government between 1877 and 1904, for the extension and improvement of the Port of Genoa, have altogether cost about £2,359,700, of which the largest items, besides those of breakwaters, graving-docks, and dredging already given, are for quays and jetties, £658,560; warehouses and sheds, £134,880; hydraulic machinery, £105,700; custom-house and contingent works, £47,970; and sewers, £24,090.[1]

Commercial Progress of Genoa.—In 1874, when the commerce of the recently-established kingdom of Italy settled down to normal conditions, the total traffic of the port of Genoa was 700,569 tons of goods; and this traffic has increased rapidly since 1881, with only occasional fluctuations in years of abnormal trade, at the average rate of about 175,000 tons of merchandise per annum, so that it reached

[1] "Ports Maritimes de l'Italie, Notice Illustrée," Milan, 1905, p. 54.

5,652,158 tons in 1903, raising Genoa to the position of the fifth port of the Continent of Europe. Of the above total, 4,891,417 tons consist of imports, or 86 per cent. of the whole; and slightly more than half this weight of imports was coals. In 1874 three-fourths of the vessels entering Genoa harbour were sailing-vessels; but the change to steamers in the case of many of these, so that sailing-vessels are now little more than one-third of the whole, has produced a drop in the number of vessels from 7,336 in 1874 to 6,335 in 1903, accompanied by an increase in the average tonnage from 212 tons to 906 tons.

The rapid growth of the traffic of the port has already outstripped the accommodation, consisting of 27,230 lineal feet of quays available for the loading and unloading of vessels, so that the inner harbour is encumbered with vessels waiting to discharge their cargoes. Accordingly, large extension-works have been designed, which were inaugurated by the King of Italy in October 1905.

Extension-Works authorized and in progress at the Port of Genoa.— The works already authorized comprise the extension of quays and railway-sidings in the existing port, a prolongation of the Galliera breakwater to improve the shelter in the outer harbour, and the construction of a breakwater from the angle of the Galliera breakwater running in a direction slightly north of west, approximately parallel to the New breakwater and the shore-line to the west of the bay, so as to shelter a basin to the south of the New breakwater, and provide for future extensions on the same principle as adopted for many years past at Marseilles, the works being indicated by thick dotted lines on the plan of the harbour[1] (Fig. 9, Plate 2).

The small Caracciolo jetty is to be enlarged to a length of 1,180 feet and a width of 410 feet, so as to be available for the coal traffic, and leave the adjacent Assereto jetty more free for a varied trade; and the Boccardo quay is to be completed, and a quay formed in continuation on the south side of the Old breakwater or jetty. Railway-sidings are to be provided along the quay to the north of the Assereto jetty, the Grazie, Boccardo, and extension quays, the quays of the new basin to the south of the New breakwater, and on the reconstructed Caracciolo and Old jetties.

The prolongation of the Galliera breakwater for 656 feet is designed to reduce the swell entering the outer harbour, especially during south-south-easterly storms, by more thoroughly overlapping the Giano breakwater from this quarter.

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[1] "Porto di Genova. Projetto di Ampliamento e Sistemazione approvato del Consorzio Autonomo," L'Ispettore del Genio Civile, I. Inglese, 1905.

The new outer breakwater will practically constitute a westerly extension almost in a line with the outer arm of the Galliera breakwater, and will hide the awkward bend of the inner arm by converting it into the eastern quay of the new Victor Emanuel III Basin, which will have an area of 96⅓ acres with a depth of 6½ fathoms, and will provide 4,430 lineal feet of quay available for vessels. The eastern side of the basin is to be closed by a wide embankment for quays projecting out beyond Cape Faro, and a jetty carried out from the protecting breakwater, between which an entrance to the basin is to be left, 328 feet wide, which will be sheltered by the extension of the protecting breakwater about 2,200 feet west of it, making the total length of the breakwater, as at present authorized, 5,580 feet. Another entrance of the same width is to be formed on the opposite side of the basin, by cutting the opening for it through the inner arm of the Galliera breakwater; and it will be amply sheltered by the outer arm of the Galliera breakwater. The cost of these authorized works, which are designed to provide for the needs of the trade of the port for the next twenty years, is estimated at £2,000,000.

Provision has been made for future extensions in designing the present works; for it will be only necessary to continue the protecting breakwater in the same westerly direction parallel to the coast-line, and to carry out an embankment to it from the shore, in order to enclose a very large additional water-area, as shown by faint dotted lines on the plan (Fig. 9, Plate 2); whilst ample quays can be constructed alongside this extension, by reclaiming the foreshore along the coast to the north.

Spezia Harbour and Ports.

The harbour of Spezia, situated in a deep north-eastern embayment at the head of the Gulf of Spezia, is on a much grander scale than the old harbour of Genoa (compare Figs. 9 and 15, Plate 2), and is very well sheltered by the projecting coast and islands, on its western and south-western sides, from the prevalent and stormy south-westerly winds, which raise the worst seas on that coast; so that it was only exposed to south-easterly winds, from which it has been protected by a breakwater, submerged except at the two extremities, stretching across the opening of the bay, and leaving only narrow entrances at the two ends between the pierheads and the coast. The breakwater was constructed solely for naval objects; but it is of great benefit in sheltering the commercial port, which occupies a site more exposed in its natural condition than the arsenal and its basins, which constitute the principal naval station in Italy. Spezia harbour presents a considerable resemblance to Plymouth harbour, both in its general form and method of protection; and, like Plymouth, it affords sheltered access and ample anchorage, with good holding ground, to a very important naval arsenal, and to a small commercial port. Spezia does not possess the same excellent central position for railway communication as Genoa; and the propinquity of a naval station tends to check commercial development; but as regards shelter and space for extensions, Spezia has much greater natural advantages than Genoa.

Naval Port of Spezia.—The arsenal occupies a very well-sheltered recess on the north-west side of the bay, where deep water comes close inshore, so that both the basins and their approach-channels possess depths of 5 to 6 fathoms, with similar depths across the harbour in front, increasing towards the south-east to 6½ and 7 fathoms inside the harbour, and greater depths in the gulf outside[1] (Fig. 15, Plate 2). Besides two large basins, the naval port possesses some smaller basins, building-slips, fitting- and repairing-shops, and all the appliances for the construction and equipment of warships, several graving-docks, coal-sheds and coaling-jetties, railway-sidings, electric-light installations, and everything necessary for a first-class naval port. A large experimental tank of considerable length has also been constructed, with elaborate measuring-apparatus, along which models of the hulls of vessels moulded in paraffin, are drawn through water to ascertain the best forms for speed, and trials of different forms of models of screw-propellers are conducted.

Commercial Port of Spezia.—The commercial port adjoins the naval port on the north-eastern side, and extends along the coast to the northern extremity of the bay, on a comparatively shallow site where the depths ranged for the most part between 2 and 3¾ fathoms. Up to the construction of the naval arsenal and the drainage of the extensive marshes bordering the eastern shore of the bay, carried out during the latter half of last century, a very small trade was conducted alongside some old quays which constituted the port in this sparsely populated and unhealthy district; but the works, and the opening of the railway from Parma to Spezia, produced a rapid increase of the population, and, consequently, in the commerce of the port. Two small jetties and some quays along the shore near the naval arsenal were accordingly constructed to improve the shelter of a small basin, and extend the accommodation for vessels. Works subsequently carried out to the north-east of the previous

[1] "Gulf of Spezia," Admiralty Chart, London.

works, between 1890 and 1900, at a cost of £140,000, have extended the port to its present state (Fig. 15, Plate 2).

The old commercial port of Spezia, adjoining the naval arsenal, consists of a little basin of 5 acres, which will soon be taken over by the arsenal, and 3,740 feet of sheltered quays extending to the battery. The new port, formed in 1890-1900, comprises a water-area of 50 acres, protected by a breakwater, or jetty, extending out at right-angles to the northern shore of the bay for a length of 1,312 feet, with a quay-wall along its sheltered western side for 984 feet, and a quay along the adjacent northern shore to the west, 656 feet long; and the sheltered area has been gradually deepened to 26¼ feet by dredging in the silty bed of the harbour. The inner portion of the projecting jetty has been given a width of 177⅜ feet, so as to provide sufficient space for three lines of railway, a wagon-road, and a coal-depot; and the quay-wall alongside the sheltered area had been constructed of concrete blocks deposited under water on a rubble mound, with a small masonry wall on the top, affording a depth of about 23 feet in front; whilst the eastern side of the jetty consists of a rubble mound raised to sea-level, having a small retaining-wall on the top to keep back and protect the earthen embankment of which the jetty is mainly composed[1] (Fig. 16, Plate 2). The outer portion of the jetty is composed of a rubble mound raised 6½ feet above sea-level; and it has been made 330 feet longer than originally designed, in order to protect the sheltered area better from the littoral drift of silt from the eastern shore of the gulf.

Growth of Commerce at Spezia.—The total goods-traffic of the commercial port of Spezia, which was only 109,300 tons in 1894, rose to 200,000 tons in 1899 when the extension-works had become available, and reached 345,000 tons in 1904, of which about 310,000 tons were imports, coals alone amounting to 205,000 tons. Sailing-vessels trading with this port have remained up to the present more numerous than steamers, numbering 1,151 in 1904 out of a total of 1,955.

Extensions authorized and proposed at the Commercial Port of Spezia.—An extension of the port was authorized in 1904 to provide for the rapidly increasing traffic. The chief works consist of the prolongation of the north breakwater, or jetty, in a south-westerly direction, at an angle to its original southern course, for a length of 330 feet, to improve the shelter; the transformation of a length of 656 feet of the outer protecting rubble mound into a jetty; and the provision of

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[1] "Ports Maritimes de l'Italie, Notice Illustrée," Milan, 1905, pp. 64–69 et planche.

additional sidings, electric cranes, and sheds. Quay-walls are to be built on both sides of the prolongation of the jetty, as it has been found that the sea is calm enough for a great part of the year on the eastern side for the loading and discharging of vessels; and these quay-walls are to be constructed in a similar manner to the quay-wall of the inner jetty (Fig. 16, Plate 2), providing a depth in front of them of 28 feet on the side of the port and 19⅓ feet on the outer eastern side, and giving a width of jetty of 216½ feet. The extension of the mound beyond the jetty is to be effected by a rubble mound up to sea-level, surmounted by a row of rubble masonry blocks, 13 feet wide and 6½ feet high.

In anticipation that even these new works will soon become inadequate for the growing traffic, further works have been proposed, sufficient to supply the needs of the estimated traffic for the next twenty years at least. The scheme thus drawn up comprises the formation of a little basin for sailing-vessels on the north-east side of the battery; a further prolongation of the south-western branch of the protecting mound beyond the jetty for 1,150 feet, with an inner quay-wall; the construction of a new quay from the eastern end of the north quay to the new basin; the formation of a wide embankment for quays along the northern shore for about 1,300 feet to the east of the jetty, with a quay-wall accessible by sailing-vessels; and the equipment of these new quays. These proposed works would increase the length of quays available for commercial operations to a total of 6,560 feet.

Naples Harbour and Ports.

The ports of Naples, both naval and commercial, are situated at the northern extremity of the magnificent Bay of Naples, bounded by Gaiola Point on the west and Torre del Greco on the east; whilst the gulf extends out to the open sea between the islands of Ischia and Capri, being somewhat sheltered from the west-south-west by the islands of Ischia and Procida, and by the island of Capri from the south, and fully protected by the mainland from Cape Miseno at the west round by north to Cape Campanella at the south-east, as shown by the little map (Fig. 17, Plate 2). The gulf and bay, however, are fully exposed to south-westerly winds, which are the prevalent and strongest winds during the winter all along the Tyrrhenian coast, and have a fetch in this locality of 300 sea-miles to the African coast; and though the bay is considerably sheltered from south-easterly storms by the peninsula of Sorrento, nevertheless, the seas rushing through the opening between Cape Campanella and the island of Capri, and being propagated by the wind during south-easterly gales through the wide entrance to the harbour, produce a considerable motion inside, the worst winds in this respect being east-south-east, in spite of the apparent fair protection from this quarter.

The Bay of Naples was under less favourable natural conditions for the formation of a small harbour, sufficient for the wants of early days, than the Gulf of Genoa ; but it is decidedly better suited, both in form and extent, for the large extensions necessitated at the present time by the increase of traffic, than Genoa, and even in some respects than Spezia, though requiring more artificial shelter than that land-locked bay (compare Figs. 9, 15, and 18, Plate 2). The ordinary rise of tide at Naples is about 1 foot 4 inches; but under certain conditions of wind and atmospheric pressure, the sea-level may vary to the extent of 2 feet 9½ inches.

Origin of Naples Harbour.—In ancient times there appears to have been a creek to the north of the Old port, which provided shelter for the small vessels of that remote period, but was gradually silted up; and the first work for forming a harbour was the construction of a breakwater, undertaken in 1302, on the site of the existing Angioino breakwater on the south side of the Old port, which was destroyed by a storm in 1343, and whose reconstruction was commenced in 1447, and a short northern arm added later on; whilst further accommodation was provided in 1668, by the formation of a basin to the south of the Castel Nuovo. The Old port being still exposed to south-easterly storms, the San Gennaro breakwater was built out in prolongation of the short northern arm in 1743[1] (Fig. 18, Plate 2).

Enlargement of the Harbour of Naples.—Up to 1836, the only shelter provided for shipping consisted of the old commercial port, and the little basin to the south of the Castel Nuovo, now forming part of the naval port; but at this period the principal protective work, known as the San Vincenzo breakwater, sheltering the harbour from south-westerly storms, was commenced, extending from the western shore of the bay in a direction slightly south of east, for a length in the first instance of 1,800 feet, under the shelter of which the present naval port was formed. In 1862, soon after Naples had come under Italian rule, extensive enlargements were approved, which, carried out by degrees up to the present time, though with some important modifications, have formed the existing harbour. The works comprised the prolongation of San Vincenzo breakwater, the construction of an eastern breakwater stretching out from the north

[1] "Ports Maritimes de l'Italie, Notice Illustrée," Milan, 1905, pp. 110-137, et planches.

shore in a southerly direction far enough towards the San Vincenzo breakwater to reduce the opening between them to 1,312 feet facing east, and the construction of basins, jetties, quays, and graving-docks for the new port. In 1880, a further prolongation of the San Vincenzo breakwater was decided upon, and also the formation of a new commercial port by the projection from the end of the Eastern breakwater of the two canted Martello and curved arms, the building of quays along the shore to the west and south-west of the Eastern breakwater, the general deepening of the sheltered areas, and the connection of the port with the railway. The curved breakwater, however, would have left an opening between its pierhead and the San Vincenzo breakwater of 1,800 feet, facing slightly south of east, through which sufficient swell was likely to enter to disturb unduly the tranquillity of the harbour. Accordingly, in 1900, the construction of a detached outer curved breakwater was authorized, turning the entrance of the harbour so as to face due south, and reducing its width to 984 feet (Fig. 18, Plate 2).

Description of the Harbour of Naples, and its Ports.—The outer harbour, enclosed by the San Vincenzo, Gennaro, Martello, and curved breakwaters, has an area of about 136 acres, having depths of from $5\frac{1}{2}$ to $16\frac{1}{2}$ fathoms; the naval port, bounded by the Angioino breakwater, the quay in front of the Castel Nuovo, and the inner part of the San Vincenzo breakwater, is $22\frac{1}{4}$ acres in extent, and has depths of $2\frac{3}{4}$ to $6\frac{1}{2}$ fathoms; and the commercial port, comprising the Old and New ports and the basin leading to the graving-docks to the east of the Eastern breakwater, has a total water-area of 84 acres, with depths of $2\frac{1}{3}$ to 5 fathoms in the Old port, $4\frac{2}{3}$ to 6 fathoms in the New port, and $5\frac{3}{4}$ fathoms in the graving-docks basin. In the existing state of the works, only the most violent south-westerly storms affect the water in the harbour; but ordinary south-easterly storms disturb the water in every part of the harbour, except the graving-docks basin; and great storms produce an inconvenient swell in the most remote parts of the harbour, and even in many parts of the inner basins, endangering the safety of the vessels. It is anticipated that the completion of the curved, detached outer breakwater will stop this disturbance, especially if the original design is reverted to of limiting the width of the entrance to 984 feet and making it face south by a prolongation of the detached breakwater 197 feet, as shown by dotted lines (Fig. 18, Plate 2), instead of the present plan of leaving the entrance 1,150 feet in width and facing slightly east of south.

The naval port is surrounded by quays, and, together with a portion of the harbour in front of it, the old basin, and the little graving-dock alongside the San Vincenzo breakwater, is exclusively reserved for the requirements of the royal navy; and an arsenal, with numerous workshops and stores, has been established round it.

The commercial port possesses 12,025 lineal feet of quay-walls bordering the jetties and shore, of which, however, only 4,530 feet are available for large vessels; and the extent of accessible quays is generally so inadequate for the number of vessels frequenting the harbour, that vessels have constantly to discharge and take in their cargoes by means of lighters. Most of the quay-walls have been built, below sea-level, with concrete blocks laid directly on the sea-bed or on a rubble foundation, though in a few instances concrete-in-mass deposited within wooden frames had been adopted. For the new quay-walls, however, in progress round the graving-docks basin, and at the enlargement of the trapezoidal jetty, masonry built under compressed air in movable caissons has been employed. The largest graving-dock is 690 feet long, and has a depth of water of 33¾ feet over its entrance sill.

Breakwaters protecting the Harbour of Naples.—As in the case of Genoa harbour, the early protecting breakwaters at Naples harbour, being converted into interior works by the later extensions, have been turned into jetties with quays, such as the Angioino and San Gennaro breakwaters. The inner curved breakwater, originally designed to form the eastern protection of the harbour in continuation of the Eastern breakwater, and constructed, like most of the recent Italian breakwaters, of a sorted rubble mound, surmounted at about sea-level by a superstructure with a quay and sheltering parapet-wall, and protected on the sea slope by large rubble below and large concrete blocks in courses on the upper part to above sea-level (Fig. 19, Plate 2), has now, owing to changes in the mode of protecting the harbour dictated by experience, ceased to be of service, and has, indeed, been cut away from the Eastern breakwater to provide an entrance to the graving-docks basin, a work which has necessitated the construction of a small breakwater to the east of the Eastern breakwater for enclosing and sheltering the basin. Moreover, the shallower Martello breakwater of similar construction, though still useful in protecting the new commercial port from south-easterly storms, should, if the anticipations of the shelter provided by the detached outer breakwater are realized, soon cease to be required for protection.

Accordingly, the breakwaters which in future will alone serve to protect the harbour of Naples are the Vincenzo breakwater, the most important, both on account of its length and its direct exposure to the worst seas, the outer detached breakwater, and to a minor extent the graving-docks basin breakwater, together with any easterly extension of the outer breakwater that may hereafter be carried out.

The Vincenzo breakwater was built out from the shore between 1836 and 1883, for a distance of 3,800 feet, as a simple rubble mound, surmounted by a superstructure of masonry forming a quay, though it was given a stronger form after being injured by storms in 1866, 1872, and 1879, mainly by concrete blocks deposited at random on the outer slope, and a triple row of masonry blocks at the top of the mound on the sea side of the parapet-wall. Along a length, however, of 1,115 feet the outer protection of concrete blocks was overlaid with rubble, for fear that any break in continuity of the protecting blocks, due to scour of the waves, settlement of the mound or other cause, might result in serious damage; but experience has proved that this precaution has not prevented the constant displacement of blocks, and the formation of breaches in the superstructure nearly every year; and it appears that the remedy adopted has tended to lead up the waves to the superstructure, with a corresponding dangerous recoil, instead of their being broken by the interstices between the blocks in their passage up and down the slope. The outer portion of the breakwater adjoining the pierhead has been strengthened, by reducing the stepping back of the courses of concrete blocks on the outer slope, the provision of a masonry apron in front of the parapet-wall, and the omission of the covering of rubble (Fig. 20, Plate 2); and this part of the breakwater, though situated in the deepest water, has remained intact since its completion about 7 years ago. The breakwater is 4,920 feet long, and the outer portion, beyond the inner 1,804 feet belonging to the naval port, cost about £520,000, averaging between £121 and £242 per lineal foot according to the depth, which increases from about 5½ fathoms near the shore-end up to 19 fathoms at the pierhead. The cost of maintenance of the outer 3,116 feet is about £2000 annually, mostly expended on repairs of the length of 1,115 feet referred to above.

The outer, detached breakwater, in course of construction, is the only other breakwater of importance in the Naples harbour-works; and though it only protects the harbour from south-easterly winds with a moderate fetch, storms from this quarter have produced considerable disturbance in the harbour. Moreover, it is situated in depths increasing from about 11 fathoms at the shallowest north-eastern end, to 17½ fathoms at the south-western pierhead; and it possesses the interest of being apparently the first large breakwater on the Italian coast which has been constructed according to the modern composite type, of a rubble mound surmounted by a superstructure founded on the top of the mound at a sufficient depth below sea-level for the waves not to disturb the large stones covering the mound (Fig. 21, Plate 2). The breakwater is to have a length of 1,640 feet; and the superstructure increases in width, according to the exposure and depth, from 33 feet at $1\frac{1}{3}$ foot above sea-level for the first 984 feet from the north-eastern end, to $42\frac{2}{3}$ feet for the next 541 feet, and 74 feet for the remainder, serving as a pierhead and a site for a lighthouse at the most exposed south-western end. These widths are maintained below for 13 feet, or two courses of blocks, and then are stepped out 2 feet at each course of blocks on the sea face, and $1\frac{1}{3}$ foot on the harbour face, the superstructure being formed up to sea-level of five courses of concrete blocks founded 31 feet below sea-level, except at the south-western pierhead which is founded at a depth of $37\frac{3}{4}$ feet, the outer blocks in each course being connected with the inner blocks by iron cramps. In view of the importance of keeping the superstructure perfectly compact, the rubble mound was carried out in lengths 2 years in advance of the superstructure, and was formed of rubble stones of all sizes to reduce the interstices to a minimum, so as to diminish its settlement as much as possible; and the superstructure had been laid on the mound in lengths consisting of one or two courses at a time, so as to avoid sudden and unequal settlement, and to enable the whole length to be levelled before laying the next course. The superstructure is capped above sea-level by solid masonry forming a quay, and a sheltering parapet-wall, as shown by Fig. 21, Plate 2, representing the outer length of 541 feet adjoining the pierhead. The estimated cost of this breakwater is rather over £120,000, or £72 12*s.* per lineal foot, considerably less than the cost of the outer 3,116 feet of the San Vincenzo breakwater built in a smaller average depth, which may be attributed, in addition to economy of modern appliances in construction, to the great reduction in materials effected by the modern composite type, as illustrated by a comparison of Figs. 20 and 21, Plate 2.

The much smaller breakwater protecting the graving-docks basin, in comparatively shallow water, has been built similar in type to the outer breakwater, with a superstructure founded on a rubble mound at a depth of $12\frac{1}{2}$ feet below sea-level. It is 2,460 feet long, and cost £22,400.

Cost of the Extension- and Improvement-Works at the Harbour of Naples.—The works carried out by the Government at the commercial harbour of Naples from 1862 to the present time, including the works in progress, involve an expenditure of £1,404,000. The principal items of cost, in addition to the breakwaters already given, are the rearrangement of the Old commercial port, £52,000; the construction and equipment of the New commercial port, £308,000; graving-docks and contingent works, £200,000; and buildings for the passenger and emigrant services, £29,000.

Commercial Development of Naples Harbour.—The commerce of the port of Naples has been advancing during the last twenty years at a continually increasing rate, with the exception of a short period of depression after 1890; for the traffic has grown from 741,760 tons of merchandise in 1885 to 893,216 tons in 1895, and up to 1,205,366 tons in 1903, of which 933,132 tons were imports and 272,234 tons were exports, coals again appearing as one of the principal imports. The increase, however, of the shipping has been still more rapid, owing to the remarkable development of the passenger and emigrant traffic, Naples having become a port of call since the opening of the Suez Canal, and the first port in Italy for passenger and postal service, as well as the chief port for the embarkation of emigrants. Thus in 1885 about 8,000 vessels, registering 3,500,000 tons, entered and cleared from the port of Naples; in 1895, 12,011 vessels, of 5,054,055 tons total tonnage; and in 1893, 12,591 vessels, consisting of 6,331 steamers and 6,260 sailing-vessels, of 9,186,779 tons total tonnage.

Extension-Works proposed for the Port of Naples.—Even when the works in progress at the graving-docks basin shall have been completed, the length of quays accessible by large merchant-vessels at the commercial port of Naples will be only 6,890 feet, which will be inadequate to accommodate the rapidly growing traffic. Accordingly, the expenditure of £500,000 was authorized in 1904 on an extension of the port of Naples along the Granili shore, to the east of the present port. This extension is to consist of a large water-area to be sheltered by a breakwater starting from the inner extremity of the outer breakwater, and running in a south-easterly direction, parallel to the shore, for a length of 3,280 feet, in which area three wharves are to be carried out from the shore, each 984 feet long and 394 feet broad, leaving spaces of water between them 394 feet in width, as shown by dotted lines in Fig. 18, Plate 2; and these wharves are to be surrounded by quay-walls affording a depth of 33 feet of water in front of them, capable of accommodating eighteen vessels at the same time, and fully equipped for the handling of cargoes. By this addition the commercial port will be enabled to deal with a traffic attaining 2½ million tons of merchandise in a year.

Concluding Remarks.

The basin of the River Po is a very interesting instance, in which, having trusted hitherto to the facilities of navigation afforded by nature, and having neglected all works of improvement beyond the mitigation of floods by embanking the river, whilst the system of communication by means of light railways has been very extensively developed, it has at length been decided to improve and extend inland navigation throughout the whole of the Lombardy and Venetian plains according to a comprehensive scheme, adapting the enlargement of the waterways to the requirements of the districts and the possibilities offered by nature at a reasonable cost, and completing the intercommunication of the inland waterways, and access to important centres of commerce and isolated lakes, by the construction of canals.

The port of Venice affords a remarkable instance of a lagoon harbour whose preservation from being silted up by the alluvium carried into it by rivers, and from inroads of the sea, has been carefully guarded from remote periods by extensive works; and it has been gradually adapted to the increasing requirements of shipping and a growing commerce; and the improvement of its deep-water access to the sea is still in progress, as well as further extensions of the port.

Italy having only tideless rivers impeded by their alluvium, but a very extensive sea-coast, is dependent on its harbours for its maritime commerce; whilst the natural harbours are few in number, or of inadequate size, and require to have their shelter improved, or their area increased, by artificial means. The three most important commercial harbours have been described in the Paper, namely, Genoa, Venice, and Naples, whose improvement and extension have necessitated very extensive maritime works, as well as the provision of quays, jetties, and other facilities for trade; whereas Spezia, the fourth harbour described, one of the best natural harbours of Italy, has required a breakwater at its entrance to complete its shelter, and is the most important naval station of the kingdom.

The breakwaters constructed for the extension of the harbours of Genoa and Naples have, with one exception, followed hitherto the type usually adopted for Mediterranean harbours, namely, a rubble mound with a superstructure founded at sea-level, with a quay on the inside sheltered by a parapet-wall, and protected on the sea side, and partly down the outer slope of the mound, by large concrete blocks (Plate 2), of which the Marseilles breakwater is a notable example. The only change introduced by Italian engineers, for several years past, has been the laying of the concrete blocks in courses stepped back on the sea-slope, and, more recently, leaving narrow spaces between the rows of blocks protecting the top of the mound, instead of depositing the blocks at random. The outer breakwater, however, in progress at Naples, is being built in accordance with the more modern type of composite breakwater in deep water, introduced probably for the first time at Alderney, after the early injuries at that very exposed site, more than fifty years ago, in which type the superstructure is founded on the rubble mound at a depth at which it is anticipated that the waves will not disturb the mound, as adopted by British engineers at Karachi, Madras, Colombo, Mormugao, and other harbours, in place of the old system of a superstructure founded at low-water level on the mound, of which Holyhead, Portland, and Cherbourg breakwaters furnish notable examples. The difficulty is to determine the level below low-water or sea-level at which the mound is not liable to be disturbed by the waves; and this depth, depending upon the exposure and the depth of water in front of the breakwater, has had to be increased, from the results of experience, as pointed out by the Author in his Paper on "The most recent Works at some of the Principal British Seaports and Harbours" for the Paris Navigation Congress of 1900, from 12 feet below low-water, as first adopted at Alderney—which proved quite inadequate there—down to 30¾ feet at the Colombo north-west breakwater, and 43 feet below low-water at Peterhead.[1] The adherence to the old type of composite breakwater so long by Italian engineers has probably been due to the less exposure, and, consequently, smaller waves in the Mediterranean as compared with those experienced at the other harbours mentioned above, notably Alderney, Madras, Colombo, and Peterhead. As, however, the change in construction introduced at the outer breakwater at Naples, besides being calculated to diminish materially the cost of maintenance by avoiding the breaking of waves on a sloping mound, appears to be also considerably less costly than the old system followed at the San Vincenzo breakwater, probably the breakwater for sheltering the extensions commenced at Genoa harbour will be similarly constructed. Moreover, it should be noted that a quay on an outer sheltering breakwater is of no use for purposes of trade, and merely gives

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[1] "VIII[th] International Congress on Navigation, Paris, 1900: 7th Question, The most recent Works at some of the Principal British Seaports and Harbours," report by L. F. Vernon-Harcourt, p. 14; and "X[th] Congress, Milan, 1905, Section II, Ocean Navigation: 4th Question, Conditions affecting the Force of Waves and the Construction of Breakwaters to resist them," L. F. Vernon-Harcourt, p. 9.

access in fairly calm weather to a lighthouse at its extremity, which might be otherwise provided for; and therefore, in most cases, the protecting parapet-wall might be omitted with advantage, as it increases the shock of the waves against the breakwater during storms, and also their recoil, and, consequently, renders the breakwater more liable to injury.

The harbour-works described in the Paper, and the extensions in progress or proposed, and also the comprehensive scheme submitted for improving and extending inland navigation in North Italy, indicate very forcibly the solicitude displayed by the Italian Government to adopt every means in their power for promoting inland navigation, and the capabilities and safety of their harbours for maritime traffic, as being the surest method of developing the resources of their country and increasing its prosperity and progress.

The Paper is accompanied by two tracings, from which Plates 1 and 2 have been prepared.

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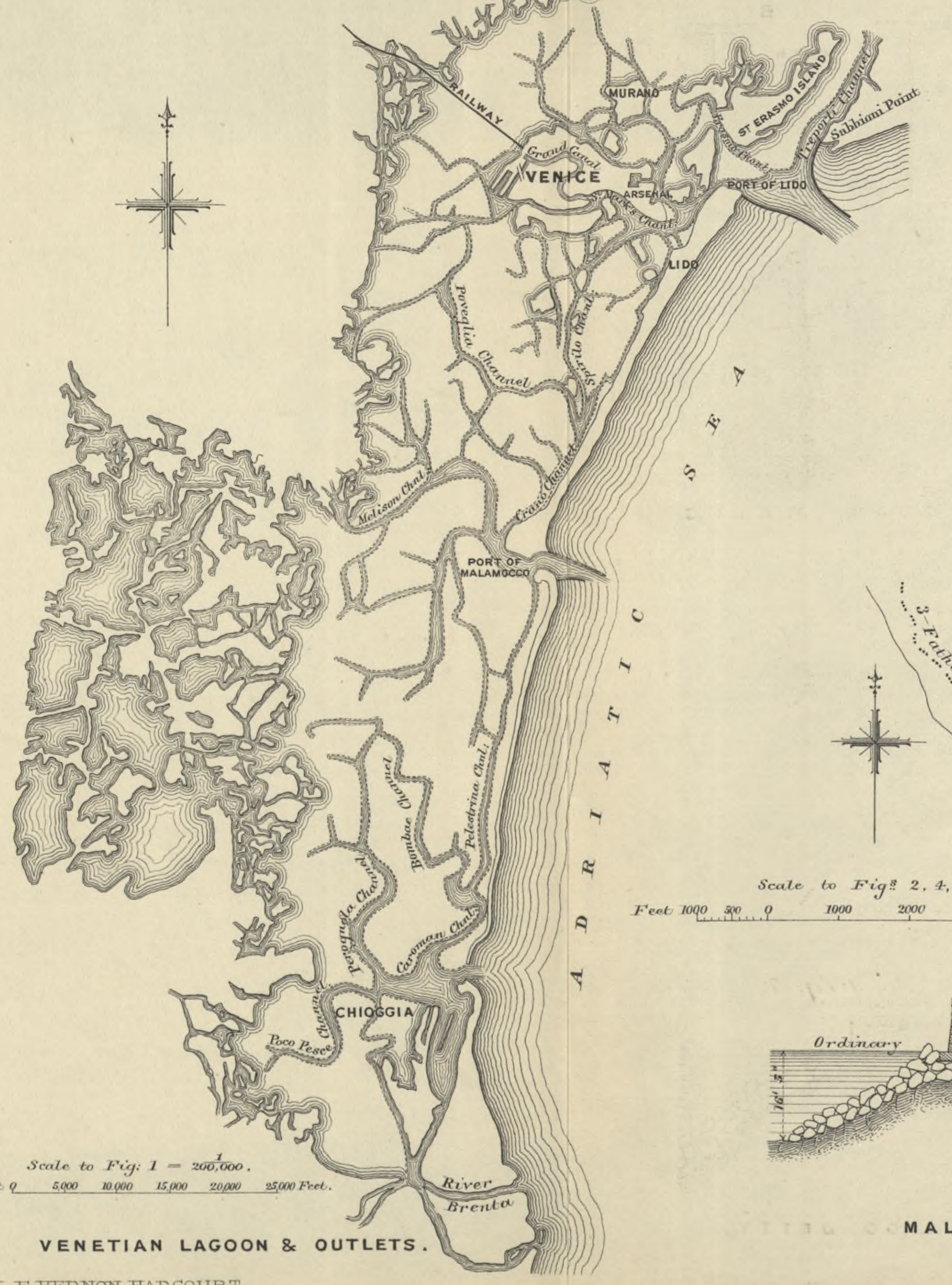
ITALIAN MARITIME NAVIGATION WORKS.

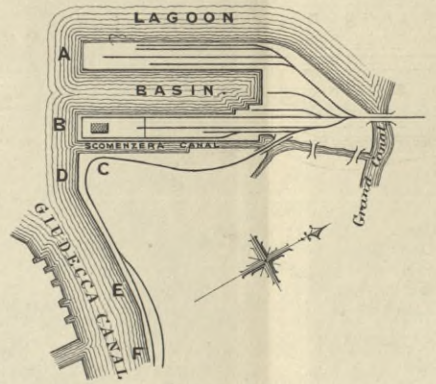
PORT OF VENICE.

Fig: 1.



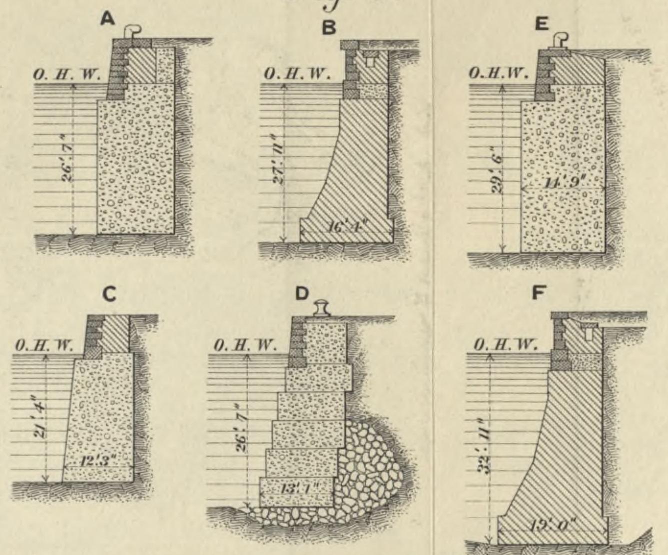
VENETIAN LAGOON & OUTLETS.

Fig: 2.



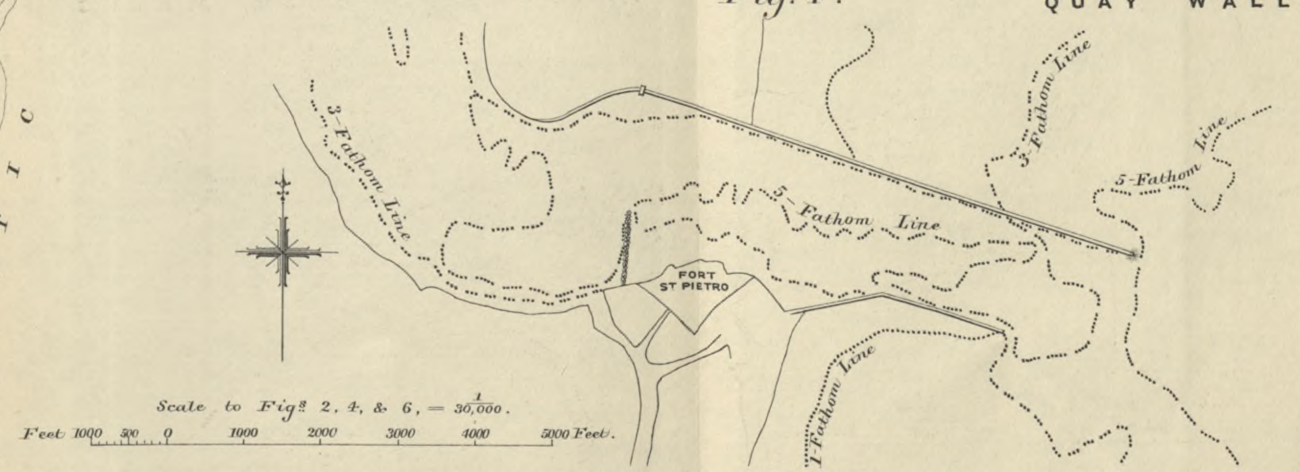
COMMERCIAL BASIN AND CANALS.

Figs 3.



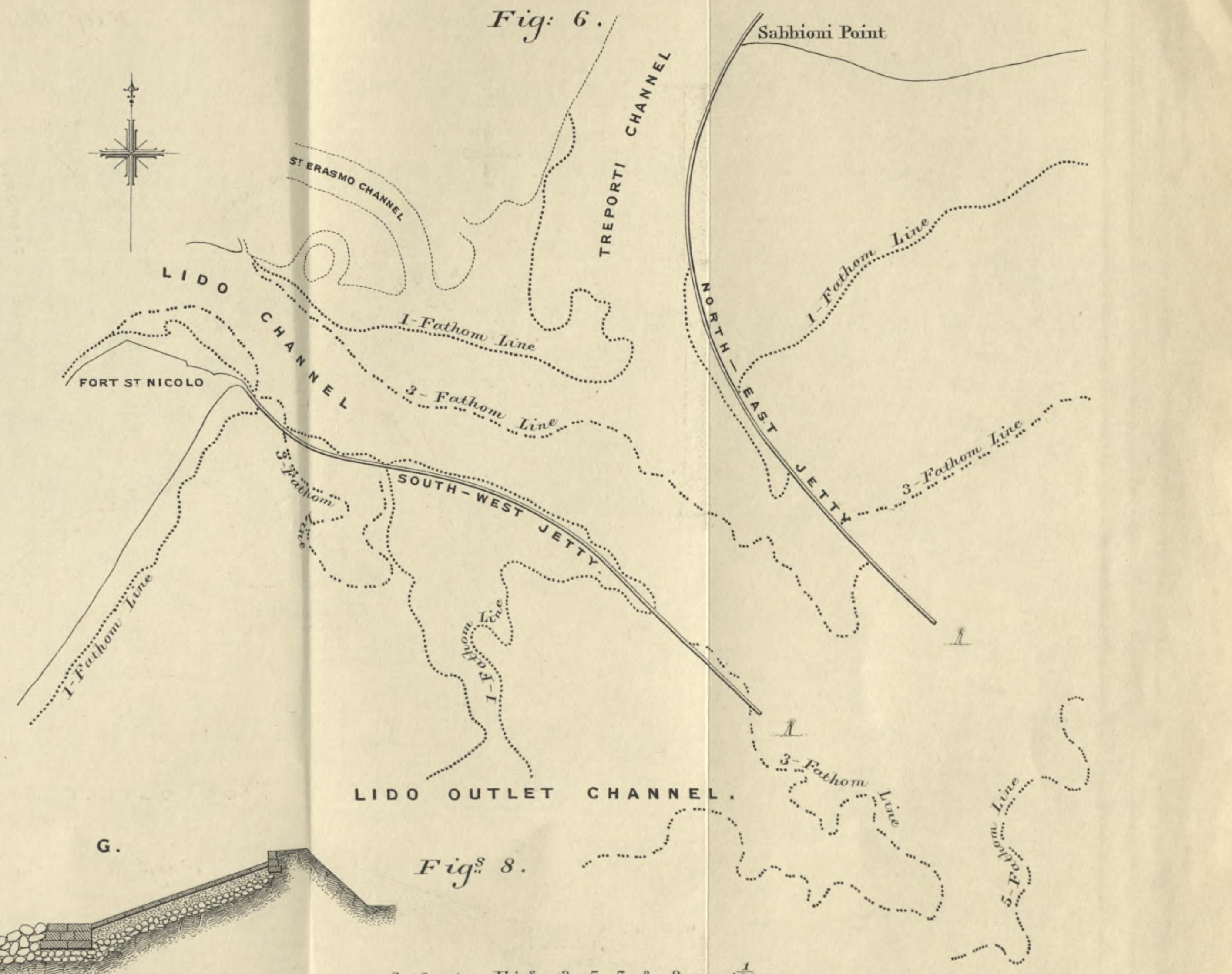
QUAY WALLS.

Fig: 4.



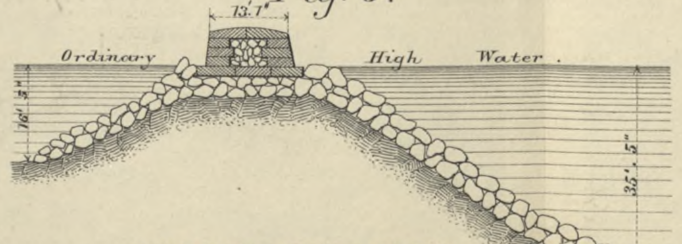
MALAMOCCO OUTLET CHANNEL.

Fig: 6.



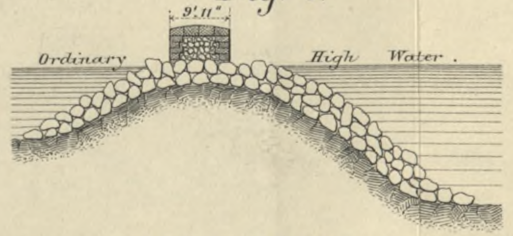
LIDO OUTLET CHANNEL.

Fig: 5.



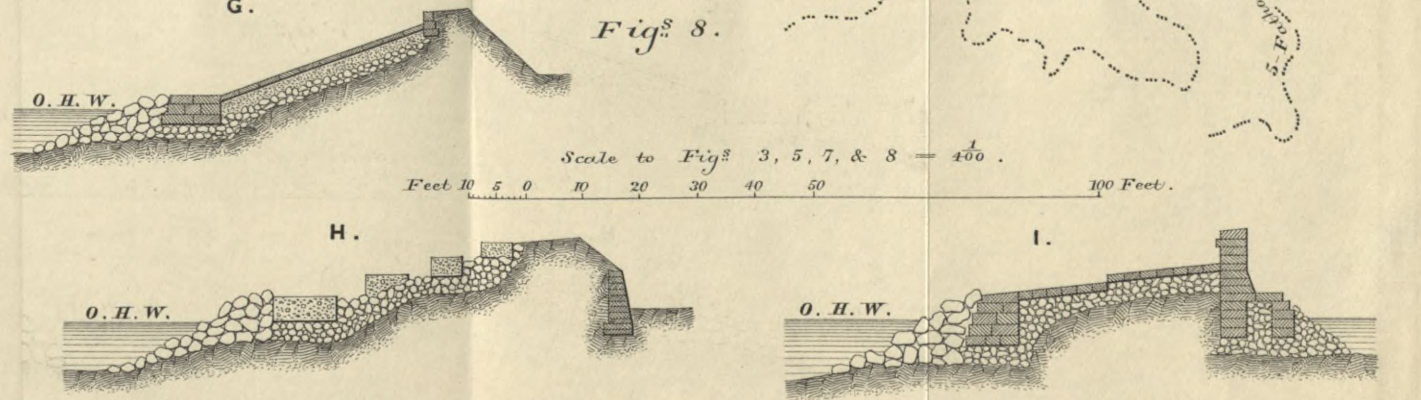
MALAMOCCO JETTY.

Fig: 7.



LIDO JETTY.

Figs 8.



SEA-WALLS PROTECTING OUTER SHORE OF LAGOON.

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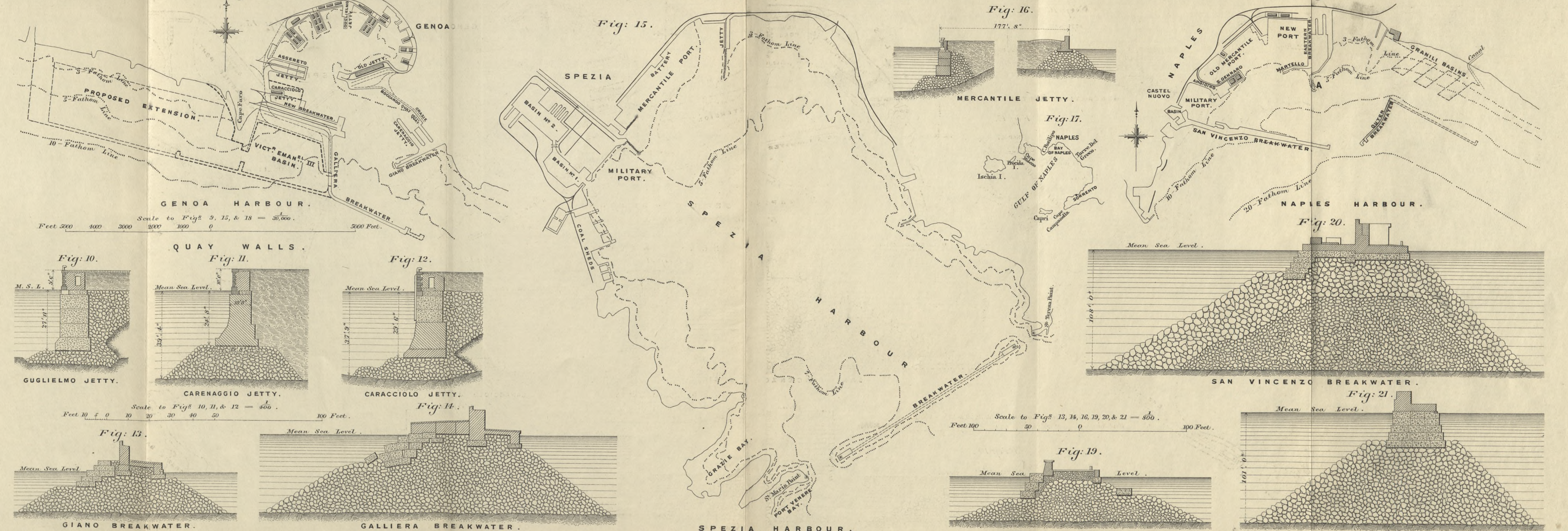
ITALIAN MARITIME NAVIGATION WORKS.

HARBOURS OF GENOA, SPEZIA, AND NAPLES.



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