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DURABILITY OF BUILDINGS AND SUSTAINABLE ARCHITECTURE

TRWAŁOŚĆ TECHNICZNA BUDYNKÓW W ARCHITEKTURZE ZRÓWNOWAŻONEJ

Abstract

Life expectancy in architecture and construction is defined in different ways. Technical durability, which is crucial for the existence and usability of buildings, seems to be the most important of them. Designers and investors' attitude towards this problem is inconsistent. The paradigm of sustainable architecture brought a different approach to this issue and made it more significant both in professional discussion and practice. The durability of buildings with its relation to embodied energy in technologies and materials has become an important feature of architecture and brought substantial modification to the designing process. This paper presents different approaches to the problem in some countries as well as ambiguities and inconsistencies in pertinent views.

Keywords: durability of buildings, sustainable architecture and construction, building technologies and materials

Streszczenie

Trwałość w architekturze i budownictwie jest określana na kilka sposobów. Spośród nich najważniejsza jest trwałość techniczna decydująca o istnieniu obiektów oraz o ich cechach użytkowych. Można zauważyć niekonsekwentną postawę zarówno projektantów, jak i inwestorów wobec tej cechy budynków. Paradygmat architektury zrównoważonej spowodował odmienne od dotychczasowego spojrzenie na tę kwestię i przyczynił się do znacznego dowartościowania zagadnienia zarówno w dyskusjach profesjonalnych, jak i w praktyce projektowej. Trwałość techniczna budynków i jej związek z energochłonnością technologii i materiałów budowlanych stały się bardzo istotne, co spowodowało znaczące zmiany w procesie projektowania architektoniczno-budowlanego. Artykuł przedstawia zróżnicowane podejście do tego zagadnienia w niektórych krajach oraz niejasności i niekonsekwencje w panujących na ten temat poglądach.

Słowa kluczowe: trwałość budynków, architektura i budownictwo zrównoważone, materiały i technologie budowlane

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1. Introduction

The capacity of buildings to offer functionally valuable spaces for a long time is defined as its durability or longevity. This parameter is usually used for determination of the real value of buildings, the rate of their depreciation and is included in insurance procedures. Durability or longevity in architecture and construction is not a simple and explicit issue. It can be considered in physical or abstract context. From the architectural and structural point of view in this discussion, the following could be considered:

- technical durability,
- functional longevity,
- aesthetical longevity

There are also other terms in use like operating durability or economic longevity, which are apparently less important for designers. Every aspect of durability in architecture is specific. For designers, durability of their products should be an important issue, mainly for ethical reasons. Their interest in longevity of buildings however, seems to be insufficient and so is their commitment to effectively resolve this problem. The technical durability in particular appears to be a negligible issue for architects as compared with aesthetic concepts and functional performance. It probably results from their incomplete knowledge concerning the effective methods to achieve durable technical solutions in buildings as well as from the ambivalent attitude of investors with regard to this feature of buildings. The methods of designing architecture however, have been recently subject to substantial evolution and modifications. Responsible for this is the dominating acceptance of the paradigm of sustainable architecture. It encourages designers to see buildings as works subject to steady destruction by the time. The paper focuses on the technical durability, which is nowadays one of the major problems of traditional and in the first place, sustainable architecture.

2. The meaning and the role of technical durability in architecture

The technical durability in architecture is an ambiguous and disputable issue. By and large, buildings are considered durable structures. Designers are generally responsible only for anticipated technical durability. For the operational or real longevity, being dependent on the intensity of use and the ways a building is used, they usually consider themselves unaccountable to investors.

The attitude of parties involved in construction procedures towards the problem of durability of buildings is ambiguous. The building owners repeatedly happen to undertake measures leading to the abatement of building's longevity while using them. They have them rebuilt and reshaped or replace the old ones with new structures more appropriate for various functions promoted by the market. More often than not, investors envisage good performance of buildings for one generation only.

Every building material and component is subject to gradual destruction as a result of entropy and the impacts exerted by external and internal destructive factors. But the technical and functional longevity of buildings is continually less dependent on them. Presently, other factors increasingly assume the role of longevity reducers.

The durability of commercial buildings is gradually getting lower in Europe. This process has been stimulated by the need to adjust the buildings constructed in the 19th century to new

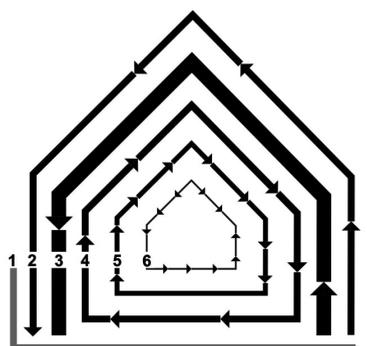
functional requirements and legislative regulations. In some other countries however, quite the reverse occurrence can be seen. An interesting example of that is Japan, where the average durability of buildings reportedly comes to 30 years only. Such a short longevity results from local customs that demand the construction of new houses in every following generation. Moreover, in Japanese society the desire to own completely “fresh”, modern houses is dominating. The new Japanese buildings get rapidly devalued and after 10 years of being in use are subject to total depreciation. Recently, however, experts indicate that the exchange of houses every 25 years carries with it enormous social and environmental consequences and costs. They recommend to speed up building production and to substantially increase the buildings’ longevity.

It is widely assumed that the anticipated durability should be as long as 60 years. In the revised and updated relevant British Standard (BS ISO 15686) this clause has recently been bringing with it the depreciation of the idea of longevity in buildings. It seems that the durability does not present a serious problem for the legislature. The European trend to lessen the longevity of buildings to 50 years appears to be contradictory to the expected extension of their life- expectancy in sustainable architecture. The situation pertaining to the problem of buildings` durability can be perceived nowadays as confusing.

3. The building as a system and problems of technical durability

The analysis of the problem of technical durability of buildings indicates the need for a holistic approach. In consequence, the building needs to be seen as a logical system of connections between components of buildings and multiple factors that determine its longevity. This discussion should not be continued without making reference to the widely known diagram by S. Brand. It presents the layered structure of buildings, the shearing layers of change and their durability (Ill. 1, Table 1). The strongest impact on buildings` technical longevity have the skin and the structure. Other layers depend on them in terms of their durability.

The layered system of buildings has been accurately referred to by F. Duffy saying: “There isn’t such a thing as a building. A building properly conceived is several layers of



1.site 2.skin 3.structure 4.services 5.space plan 6.stuff

Ill. 1. Shearing layers of buildings
by S. Brand [1]

longevity of built components” [1]. Based on Brand’s diagram three derivative schemes can indicate the layers significant for the three aspects of durability: functional, aesthetical and technical (Ill. 3), the latter being obviously essential for the other two. The average longevity of buildings depends on the following factors:

- 1) function of the building,
- 2) applied technology,
- 3) environmental conditions,
- 4) local culture,
- 5) economic and political situation.

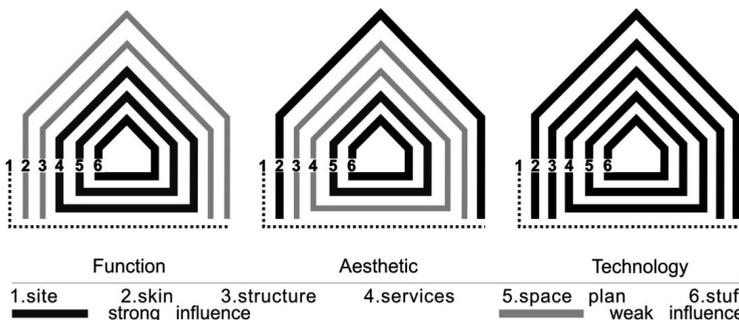
Table 1

Shearing layers of buildings and their longevity (based on S. Brand’s diagram [1])

Layer	Components	Useful Life [years]
Site	Geographical setting,urban location	“ eternal ”
Structure	Foundation,load-bearing elements	30-300years,average 50-60years
Skin	Exterior surfaces	average 20years
Services	Technical installations	7 - 15years
Space plan	Interior walls,ceilings,floors,doors	commercial spaces 3years , homes 30years
Stuff	Furniture,appliances	weeks [10-20 years]

3.1. Function of the building

This is the basic feature of buildings which is tightly linked to their durability. For example, in the case of monumental edifices, the life expectancy is 1000 years, for residential and office buildings, usually 100 years. Commercial structures should perform usually for 50 years, but in practice they endure only 25 years [2]. After that period a thorough renovation including exchange of services, modification of interior arrangement and furniture is necessary in order to adjust the building to new functional requirements. This need reveals discrepancies between the anticipated and operational durability of buildings.



Ill. 2. The impact of building’s layers on its functional, aesthetical and technical durability (based on the S.Brand’s diagram)

3.2. Applied technology

The applied technology covers a wide range of problems pertaining to technical durability of buildings. Optimal selection of materials and methods of their installation, as well as initial state of the building structures, are crucial for their longevity. At the early operational stage the building can be subject to accelerated destruction due to such factors as for example, technological humidity contained within the materials freshly installed.

The materials or components can perform satisfactorily for a long time if they are autonomous within the structure, but coupled with other materials they might make up a new less stable system.

3.3. Environmental impact

The local environmental conditions often prevail over all others as destructors of buildings. Satisfactory performance of buildings in a dry cold climate may be dramatically impeded in a hot humid one leading to premature damage. Depending on the geographical location and climatic zone, buildings are subject to different rate of destruction, and in consequence, various technical durability. The most destructive relevant climatic factors are: precipitation, wind, solar radiation. The impact of some environmental factors on technical durability of basic building materials presents Table 2.

Table 2

Technical durability of some building materials and the impact of environmental factors (based on [2])

	Main material	Environment	Useful Life (years)
Base case	Reinforced concrete	Dry,non-aggressive	60
Variations in Material	Structural steel	Dry,non-aggressive	80
	Masonry and/or Timber	Dry,non-aggressive	100
Variations in Environment	Reinforced concrete	Wet,non-aggressive	40
	Reinforced concrete	Wet,non-aggressive	30

3.4. Local culture

Another factor significant for the durability of buildings is the cultural environment. Aforementioned Japan is very specific in this regard given that the customary cycle of demolishing houses, which is followed by consecutive construction of new structures, is a phenomenon based on traditional cultural principles. The Shinto shrines are also subjected to this process for symbolic religious reasons. The Ise Shrines are systematically demolished and rebuilt every 25 years. This procedure symbolizes the idea of constant renewal. The social and religious system in Japan has developed centuries-old symbolic longevity made possible by the use of specific technical solutions for religious buildings. They are based upon modular construction techniques which enable easy dismantling and reuse of building components.

According to Kisho Kurokawa, the Japanese culture accepts the aesthetics of death whereas the western culture, the aesthetics of eternity, the latter resulting in long-lasting durable European architecture and the way of treatment of building materials [3].

3.5. Economic and political conditions

A study has proved that the structural system has no clearly indicated influence on the long use of buildings. The dismantling of building structures is most frequently caused by non-technical factors like: change in the value of land and new investments (34%), inappropriate function for new emerging needs (22%), insufficient energy and ecological parameters, shortage of appropriate maintenance (24%) [4]. The enumerated factors, of mainly economic and legal character, are subject to fluctuations. Therefore the building should be designed as a set of components sensitive to changes in the real estate market. According to S. Brand, it exerts in reality a much more significant impact on architecture than all architectural and aesthetic theories, as it is in the case of technical durability. The previously Japanese example of increase in the production of buildings, as a result of the government's policy, has also had an unexpected influence on the anticipated durability of buildings achieving currently 90 years. The opposite process could be seen in the command economies of the East European countries where the intensified construction industry brought significant deterioration of the buildings' quality as well as the diminution of their durability. The political factors turn out to be a significant stimulant of durability in construction.

4. Durability in sustainable architecture

Former views of the durability of buildings had to be changed because of the paradigm of sustainable architecture which assumes new methods of design and construction of buildings. The longevity in architecture is now comprehended as a broader and more complex issue than before in traditional architecture. Its significant meaning for sustainable architecture, especially the technical durability, has been emphasized for some time. Despite that, durability is the aspect of ecological assessment of buildings, which unfortunately, is still rarely discussed, compared with the dominating energy problems. Some difficulties in this regard result from emerging collisions between the striving after high commercial values of buildings and the principles of sustainability. The degree of sustainability of buildings and their components in design strategies is defined by many features related in some way to durability:

- functional effectiveness (low cost and simple technologies) – adaptability (easy change in function and potential for relocation in the future) – easiness of demountability and separation of combined materials or components for reuse
- selection of materials susceptible to recycling – aptitude for maintenance – transparency (clarity of applied technical solutions and easy inspection) – evolutive capacity (possibility of future improvements) – dynamism of systems allowing for ecological risks instead of their stability

The analysis of those requirements suggests that sustainable buildings should be constructed within a broad range of possibilities either as durable (permanent) or impermanent renewable, which is only an apparent contradiction. The durability should be considered

in this case, not only as the feature of the integral building as a whole, but also as a set of components and materials designed for reuse in the reshaped original building or a new structure. Such a view allows for a flexible comprehension of the problem being different from the traditional.

The buildings that contain more long-lived components require less technical supervision and are considered more durable, in terms of sustainability, due to savings in energy and materials used for construction. The longer the period of time in which the building is used, the lower is its annual share of embodied energy used for construction. In consequence, the efforts to lower embodied energy of buildings should allow for the necessary increase in their durability. More and more often, it is acknowledged that sustainability of buildings is a function of their durability. The Bullitt Center Building in Seattle, is considered the “greenest” structure in the world because of its designed durability defined as significantly longer than 73 years, which is the average for the USA [5].

The durability of buildings is being now and as it seems, will be steadily increased in the future steadily, because of improvements on technical solutions and energy efficiency. Form and function of buildings are being changed constantly due to the development of technology, economy and new styles in architecture. The character of these changes is unpredictable. But designers have to make some theoretical assumptions in this regard. If the evolution of a building has not been envisaged, its renovation, reshaping or dismantling in the future is bound to be costly, both financially and environmentally, due to the poor flexibility of design solutions. A study of this issue has indicated that the cost of modifications made in buildings during their 50-year operation are twice as high as the cost of the original construction. During that time the plans of buildings are subject to 6 and services to 4 changes [3]. Premature dismantling of structures is detrimental to the environment, due to the discharge of used materials to landfills and the need for the manufacture of new ones. The anticipation of future adaptations of buildings at the design stage would certainly result in financial savings.

The problem of durability in construction is gradually accepted in some regulations of sustainable architecture. The International Green Construction Code (IGCC) is a model document aimed at the promotion of legal acts concerning sustainable architecture as well as an encouragement for its introduction to national building codes. Recent updates therein recommend the service life plan (BLSP) to be added to design documents. It should cover the designed 60-year life span of buildings (Art. 505.1) and permit future reconfiguration, dismantling and disassembly of partitions, modifications of lighting and electrical systems, suspended ceilings, raised floors and interior air distribution systems for a minimum of 25 years. The document stipulates that interior materials, components, and assemblies have a minimum service life of 25 years and are adaptable to future reconfigurations within the interior spaces (Art. 505.1.2).

4.1. Adaptability of buildings

The term “adaptability” denotes the ability to adjust oneself readily to different conditions. In architecture, this means the susceptibility of buildings to changes. The easiness of modifications and reconfiguration is one of the basic elements of strategy for sustainable architecture. It allows buildings to be effectively used far beyond the planned life span of the original structure. Adaptability in architecture is then, its feature that permits to extend the durability of buildings and thus meets the relevant requirement for sustainable construction.

Many guidelines for the design “for adaptation” are in accordance with those of the design “for deconstruction” meaning focusing on easy dismantling, simplicity of construction, repetition and transparency. Complicated structural systems require costly expenditure and conservative technical solutions.

The need for functional and technological changes is characteristic of office buildings as well as industrial, school and religious architecture. Commercial malls are designed for a short period of time, and therefore should be built in conformity with the deconstruction strategy [4]. Adaptability in architecture means:

- accessibility (design of spaces accessible for all stages of use and different physical conditions),
- open plan (enables variable interior plans – mainly in offices),
- expansiveness (interactivity, reactivity to environmental changes through diversified mobility, location and geometry),
- effectiveness (relating to function and susceptibility to maintenance works).

4.2. Technologies and materials in sustainable construction

Applied technologies and materials condition technical durability of buildings. In the strategy for sustainable architecture this issue emerges as different from that in traditional construction. Preferred technologies should correspond with the idea of adaptability which is facilitated by orderly geometry of plans, modular and durable structure. Recommended are large-span prestressed, prefabricated systems. Priority is the application of building technologies characterized by low embodied energy and high durability. A major problem, within this context, is the search for appropriate balance between these two parameters. Materials of higher durability can be exchanged less frequently, and that results in reduced consumption of raw materials and energy. The most advantageous materials for sustainable constructions are those considered most ecological and most durable. During the last 35 years the durability of some building components has risen due to new advanced technologies, while that of some other has decreased. It has been indicated that the durability of buildings or their elements depends mostly on the quality of their maintenance. Durability of materials used in traditional and sustainable architecture is much the same, as they are more often than not, the same materials. The life span of traditional materials is diverse and dependent on the method of their application. As an example, durability of stone, brick or concrete is 75 years, structural steel 50–100 years, prefabricated reinforced concrete structures 100 years and wood 30–300 years [3]. It turns out that industrial methods of construction, offering modular building components recommended for innovative sustainable architecture, allow to attain higher quality of buildings, due to more advantageous climatic conditions outside the building sites. They also contribute to better workmanship and by that increase the life expectancy of buildings.

Some of building technologies are considered controversial in terms of their durability. One of them is the layered structure of exterior walls in the light framing systems, where the permeability of water vapor is a real nuisance, as it exerts a negative impact on the building’s longevity. In some opinions, the vapor barriers in these systems should be avoided in order to counter the problem and to increase their life span. The elimination of some sealing systems, in favor of controlled airflow and vapor penetration through building envelopes, is

a promising idea however, it collides with the formerly applied strategy of air-tight sealing of interiors in traditional architecture. The strategy of sustainability assumes using if possible, reused materials and components. They can be disassembled and directly reinstalled. Another method is the use of materials or components after transformation in a recycling process. Research works have proved that the application of reused materials in construction is advantageous for the environment because its load is reduced by 70% [6]. This method however, should be combined with the analysis of potential durability of reused materials, as they can become “weak elements” within the building’s structure and in consequence, lower the operational durability of a building.

There are some guidelines for materials designed for future reuse, which recommend the application of:

- small size components susceptible to manual installation,
- modular measurement,
- removable connections,
- strong, demountable materials and components,
- layered systems instead of glued ones,
- setting up of storage spaces for dismantled materials and components.

Durable building materials should enable easy exchange within the components and effective maintenance. Their longevity can also be extended by susceptibility to repairs.

5. Durability versus building certification systems and design problems

Within the frames of multicriterial ecological certification systems for buildings, the problems of durability are hardly considered. In different systems it is variously placed and treated. The impact of certification methods on building parameters associated with durability is not the same. Construction experts for instance, claim the BREEAM has an impact on structure in 24%, on quality of materials in 59%, and on services in 63% of the cases [7]. The LEED neglects the values of design “for deconstruction” in the future. The LEED Canada grants only one credit for the durability of selected building materials. This underestimation of the issue of building’s longevity by the certification systems is incompatible with the requirements for ecological architecture, and is contradictory to the increasing role of durability in the design of buildings. The technical durability of buildings is one of their principal aspects considered in the life-cycle assessment method (LCA), being a basic tool for ecological evaluation. It is made out on the basis of assumed 50-year designed durability of buildings. The increase of buildings’ sustainability, due to higher longevity, adaptability and easy dismantling characteristics, is seen as the principal task of environment-conscious designers. The integrated design method enables and facilitates the appropriate comprehension of durability problems and fosters optimal solutions . In the first place it is recommended for important and complex investments and is widely accepted for green constructions. According to this method, it is customary to form design teams including, besides the traditionally participating professionals , also experienced building managing staff . This guarantees the avoidance of serious errors at the design stage and promises both appropriate use and long durability of facilities.

6. Conclusions

As it has been stated, the durability in sustainable architecture is an important issue and sometimes also a major problem which needs to be solved both at the design and the execution stage of buildings. It is however, underestimated and its role in the design strategy for sustainable architecture is unsatisfactory, compared with the prevailing energy issues. The relations between embodied energy of materials and their durability characteristics has not yet been appropriately studied and recognized. Efforts to make the longevity of buildings more attractive and an important task for designers and other members of construction procedures should be undertaken. It is worthwhile to consider the suggestion of carrying out in-depth studies of the building performance long after its erection, and that by the designers. The feedback method would be of use in this case to the advantage of architects who would thus be able, to gain knowledge about errors and faults committed during the design procedure. Given the changing role of architects, as members of the multidisciplinary integrated design teams and the importance of architectural science being a valuable support in professional activity, the knowledge of durability problems should be better appreciated in architectural practice. It should also be taught as part of the architectural educational system.

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