

Article

Durability of Building Facades and Sustainable Architecture

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Abstract

This research aims to identify the causes of flawed envelope components and materials, and conduct analyses of various exemplary selected cases. The intention was to find ways to extend the lifetime of building facades through suitable and recommended design measures to meet the sustainability requirements. Another goal of this paper is to identify principal errors committed in architectural design at spatial and technical scales, and also to suggest possible technical solutions to ensure the safety of façades. The method used is based on analyses of cases of building façade materials covering various types of buildings and building materials, and classifies them into three different types, which are illustrated and suitably assessed. The results of this work emphasize the insufficient care taken by designers to provide an effective performance of the analyzed building technologies applied to façades and that designers' knowledge in this aspect of the design process should be enhanced.

Keywords: sustainable architecture; durability of buildings; durability of facades



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1. Introduction

Sustainability is a framework upon which can be built a specific strategy for guiding decision making [1]. The built environment has provided numerous opportunities to promote sustainability as a paradigm for shaping our living spaces. This human activity requires resources. Our goal is the reduction in resources used, saving the natural environment, and making it sustainable. One obvious way to reduce resource consumption is to extend product life, making it more durable [2] (p. 66). This product is the building. Contemporary sustainable architecture is characterized by a set of various parameters, among which two are the most substantial; these are low energy demand and the longevity of buildings, as durability and energy efficiency are the cornerstones of sustainability [3] (p. 3). The latter is closely related to the first one, as the short-lived materials require the extension of their technical life by the replacement materials or other maintenance techniques, which are associated with the use of energy. Durability is the most important characteristic associated with building products in general, and 'green' building products in particular. Many authors claim that sustainability is not possible without durability [3–5]. *The durability of buildings lies at the core of sustainable architecture* [6] (p. 1). There is an opinion that by doubling the life of a building its environmental impacts can be halved [7]. The basic role of durability in the sustainability assessment of office buildings has been emphasized in certification systems, where durability is a goal [8].

In official nomenclature, durability is the *capability of a structure or any component to satisfy, with planned maintenance, the design performance requirements over a specified period of*

time under the influence of the environmental actions, or as a result of a self-ageing process [9] (p. 2).

The term durability can be considered equivalent to longevity or the property of being long-lasting [5,10], and all are used interchangeably in the professional literature. They will each be used in this paper. Durability or longevity in architecture and construction can be considered in a physical or abstract context. M.F. Ashby has listed six types of lives that determine the life expectancy of the built environment: physical, functional, technical, economic, legal, and the loss of desirability [2]. From an architectural and structural perspective, this discussion should also consider aesthetic longevity.

Another classification of factors that negatively impact the durability of buildings has been established by the International Standard ISO 13823. It stipulates that the durability of building components and materials is largely dependent on environmental action, which includes chemical, electrochemical, biological, physical, and/or mechanical actions that cause material degradation of a component. Except for mechanical action, an environmental action is the consequence of the expected environmental agents, such as moisture, oxygen, and temperature, the chemical, electrochemical, and physical properties of the materials of the components, and the interaction of different elements [9,11,12]. The mechanical action, however, classified as environmental officially, should be considered a different type because the active factor is human-induced, so it is of anthropogenic origin.

Durability is not an inherent property of a material or component. It is the outcome of complex interactions among all the factors: service conditions, material characteristics, design and detailing, workmanship, and maintenance. Considerations of all of these should be part of the design process [13] (p. 2).

There is a multitude of publications on the durability of buildings; however, they usually consider the natural wear of building components over time, and concern situations undisturbed by the occurrence of unforeseen and extreme factors. In the professional literature, it is the building as an entity that most frequently appears as an object of research on its durability. However, the longevity of single components of the entire structure should be considered separately, as they are substantially differentiated. *Permanent components are long-life components which are generally structural components; expected to last the life of the building, 60 years, 100 years or longer* [14] (p. 6). However, given the synergistic performance of all building components, these periods are, as a rule, reduced. It is assumed that the minimum durability of intelligent buildings is 25 years [15]. Refurbishment projects are executed every 25 years of the service life of a building [16].

The analysis by Steward Brand indicates that the exterior part of the building, defined as the building envelope, is the most short-lived part of the building structure [17]. It is the most exposed to adverse factors negatively impacting it, and is decisive as far as the durability of a building is concerned. *There is great interest in durability by the international building research community, predominantly in the materials and assemblies comprising building envelopes* [6] (p. 1). Therefore, the subject of this research refers to this particular component of the building structure, which is insufficiently researched, especially in some specific aspects closely related to the design process on various scales.

Technical durability is nowadays one of the major problems in traditional, and primarily sustainable, architecture. Therefore, designers consider buildings as works subject to steady destruction over time [18]. Changes in the technical condition of buildings require an appropriate response to sustain the building's performance. This fosters technical advances in construction technologies, and in the case of existing objects, it refers to the replacement of materials and components or repairing operations. Thus, durability and the tendency to change are conflicting because every change or modification requires energy and new materials, which is contrary to the sustainability paradigm. However, this is not

the only conflict within the present tendencies in architecture, which are characterized by constant changes in function and technology [19]. The concept of impermanence has become a prevalent environmental certainty in contemporary design [20], whereas the idea of longevity has become a necessity.

2. Durability of Building Facades as a Composite Design Problem

A satisfying longevity of buildings and their components is defined at the time of design. It is then that suitable spatial, functional, and technical decisions should be made following the analysis of the local environmental factors that determine the future durability of a building. Under consideration in this regard should be a multitude of relevant agents usually acting in a synergic way.

A special position among environmental physical agents is assigned to various climatic factors. They should be considered for each façade, taking into account its orientation. A suitable building's spatial position can mitigate the damaging effect of rain, wind, sun, and snow on building materials [21] (p. 87). Such a formative aspect of building design is underestimated or even rejected by designers as it tends to offer a differentiated treatment of each façade, leading to stylistic incoherence. As a result of that attitude, design decisions made in no relation to the local climatic agents acting on each elevation cause an accelerated, unequal deterioration of the building components and materials. The technical durability of facades is reduced in such situations. Among the façade materials that are especially vulnerable to deterioration caused by climatic factors, like rainwater, are wooden cladding materials [22]. They can be bleached in patch-like markings, which are the result of the configuration of local winds directed by surrounding objects or protruding building components. Another climatic factor is polluted air, which at some locations contains gases attacking building structures in the form of corrosive acid rain [21] (p. 87) and [23]. Adverse environmental factors can negatively impact the technical and aesthetic condition of facades when located in polluted air locations, where dust deposits on porous surfaces are washed by rainwater and are impossible to remove. Another environmental factor, chemically aggressive air, can be a detrimental agent, causing delamination of HPL panels when in coastal locations.

Yet another group of adverse factors refers to the spatial configuration of buildings, their spatial components, and surrounding objects, with emphasis on nearby vegetation, which fosters the growth of algae, molds, and moss. They can accelerate destruction in synergistic action with rainwater, wind, high temperature, or UV radiation. Some authors also indicate other façade elements. They claim that the location of openings on the building's façade is another factor that defines its performance [21].

The technical durability usually appears to be a negligible issue for architects, who consider the aesthetic concepts and functional performance as primary. However, traditionally, a close relation between the aesthetic features of buildings and their good technical condition is the norm. It occurs when the universal canons of beauty are respected. In Japanese art, traditionally based on wabi-sabi principles, it is works of art, including architectural objects, imperfect and unaesthetic from our viewpoint, which are valued [24]. In European or universal architecture, endeavors toward maintaining the building components and materials in good technical condition to meet aesthetic standards should be a primary task for designers and later building managers. This is especially important in the case of the building envelope, which is primarily responsible for the building's durability. However, to do this, a multiplicity of the factors mentioned above should be taken into account.

The technical structural solutions, including materials and fixing systems, are substantial elements of a building, given its durability. Faulty fixing systems can cause aesthetically displeasing deformations of material if they do not allow its thermal expansion. They

can also lead to potentially dangerous situations when the fixing anchors do not allow for thermal movement of cladding panels, or the concrete bedding is insufficiently adhesive.

Crucial for the durability are the interfaces of building components and materials. There are numerous cases of apparent damage to building facades caused by the interfaces of chemically incompatible materials. Responsible for such effects are faulty decisions as to the application of inappropriate materials for fixing systems of façade cladding exposed to the action of rainwater or aggressive humid air, which produces electrolytic corrosion. Among the environmental deterioration that occurs on facades, it is the mechanical, human-induced damage that can be caused by individuals, such as users, pedestrians, or vehicles, intentionally or unintentionally. This category will be analyzed later.

Figure 1 presents some of the basic factors and agents mentioned above that negatively impact the durability of building facades. They will be further exemplified and analyzed through the examples of selected cases in the next chapter.

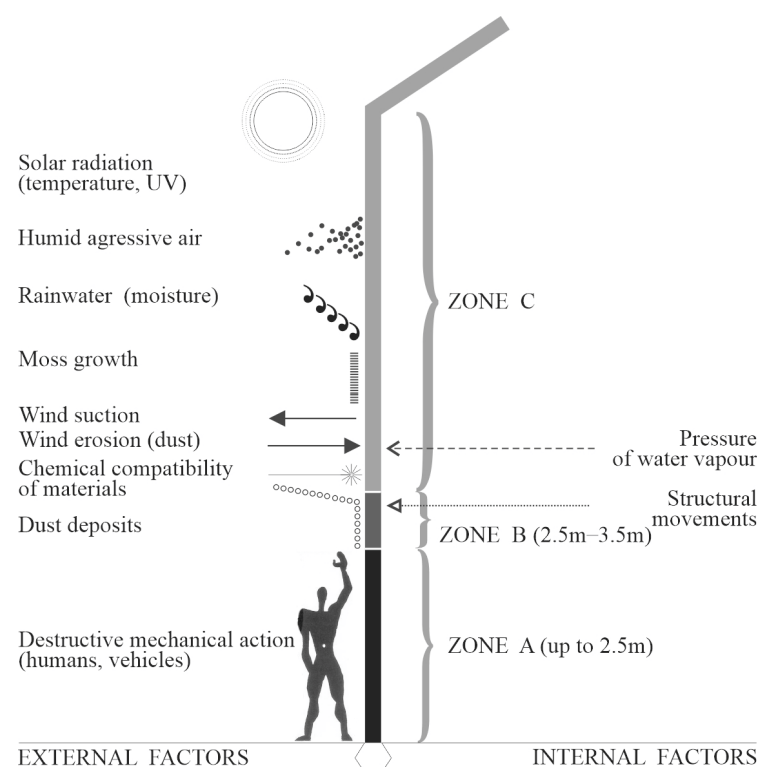


Figure 1. Basic external and internal factors negatively affecting the durability of building facades. Source: authors' diagram.

3. Method

The analysis of durability issues in buildings considered in this paper focuses on building facades. This approach draws on Brand's concept [17], which indicates the durability of subsequent building layers, beginning with the exterior walls, the most important and visible component of the building structure. Their average longevity has been defined as 20 years. This is a strikingly short period compared to that of the structural elements. The durability of a building envelope is closely related to the function of the analyzed object. It is quite comprehensive, given the type of exterior finish customarily associated with a building function. However, as suitable cases prove, the theoretical lifespan of the façade materials and the applied technologies can differ significantly from the value mentioned earlier. The reasons for that can be multiple.

Relevant inspections of damaged materials applied in building facades can indicate the mechanisms triggering the destructive processes to which the facades are subjected.

However, there can be some uncertainty and risks specified in other sources [25]. To analyze this problem, the case method was used in this research. It concerns the selected cases of damaged materials presented in four tables, which demonstrate the complexity of this issue and suggest certain ways to extend the longevity of exemplary building technologies. These considerations allow for their illustration in the following sets of relevant cases:

1. Damaged façade materials—Group 1, presenting irreparable applications and a reduced lifespan;
2. Damaged façade materials—Group 2, presenting the cases of reparable versions of applied materials;
3. Unsuccessful methods of preventing damage to façade materials.

The presented cases of the degraded building envelopes have been located in the European moderate climatic zone (Figure 2). Their evaluation, specified in tables, will allow for the qualification of certain materials as irreparable and thus requiring replacement.

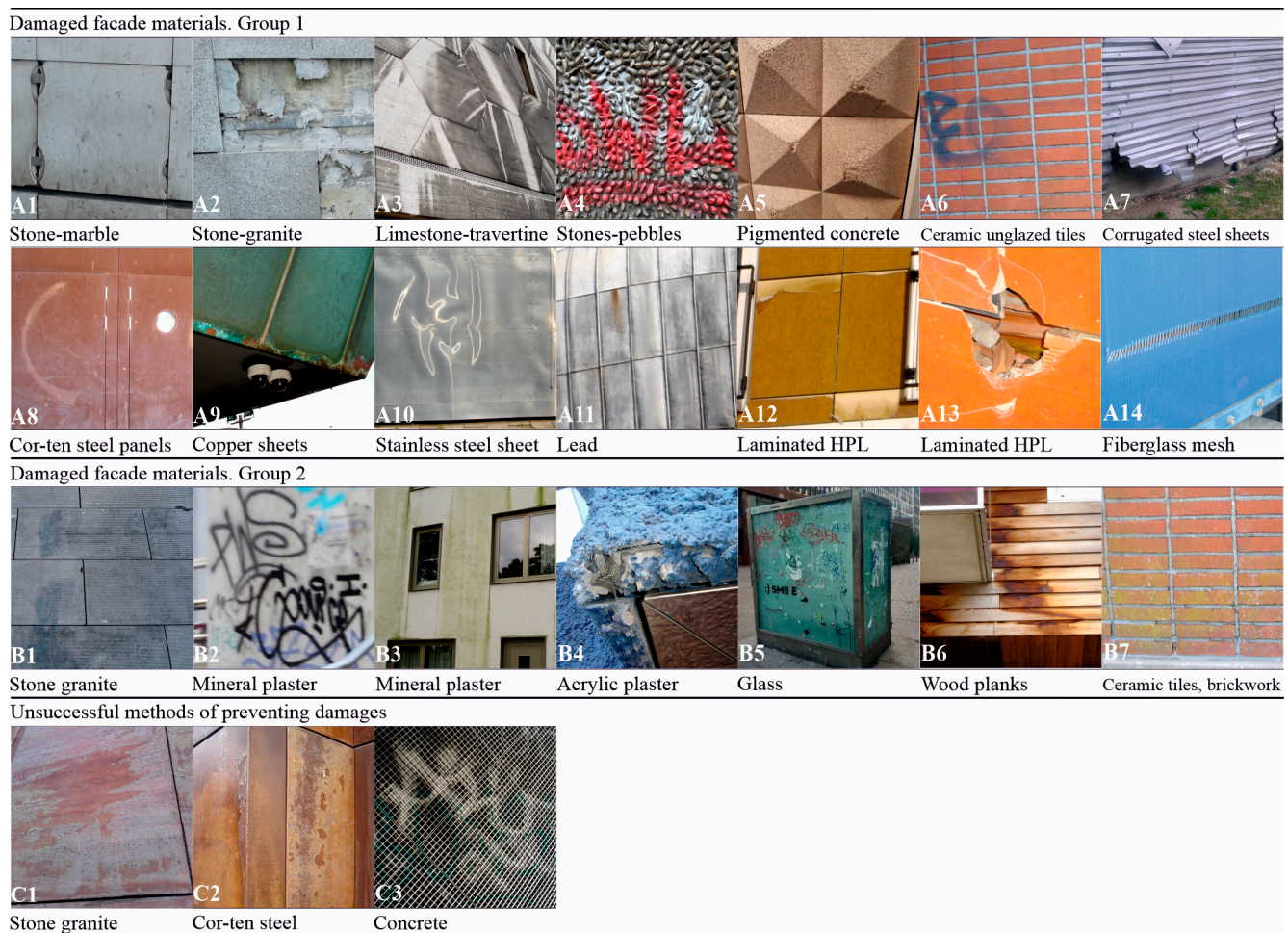


Figure 2. Analyzed cases of damaged façade materials. Photos source: authors' archive.

Another table of selected façade materials will identify those that, after some minor renewal and moderate maintenance works, will be suitable for extended performance without substantial financial or environmental cost. It is understandable that, for various reasons, buildings tend to be maintained in acceptable, if not good, technical and aesthetic condition. The assessment of the analyzed situations includes the type of material, degrading agent, effect of its degradation, qualification of damage, and advice for extended durability. The degrading agents have been specified according to the International Standard ISO 13823 [9] (pp. 1–5).

There are specific measures that can be taken, given the possibility of a potential extension of the technical life, to avoid the use of replacement materials or components. We can identify several recommended methods preventing human-induced mechanical damage to façade materials, which are aesthetically acceptable and, as proven in practice, discourage vandalistic acts that disfigure applied materials and contribute to their extended longevity.

4. Façade Materials and the Effects of Destructive Factors

This research aims to identify façade materials and solutions that cannot be restored to an acceptable technical and aesthetic condition and require replacement, either partially or completely, to extend the façade's technical life. An alternative is extensive repair work, which can be complicated and expensive. However, simple maintenance operations are impossible in the case of these materials classified as Group 1. Table 1 presents a set of examples of façade finishing materials that fall within this classification. Inspection in situ and analysis of every case have been based on a visual assessment of the symptoms of disfigurement and logical reasoning that leads to the formulation of the causes of materials' deterioration. Based on this assumption, and respecting the ISO standard, we can classify the causes of damage done to these façade materials, specifying them as follows:

- physical (e.g., temperature, moisture, wind, chemically aggressive or polluted air);
 - biological (vegetal overgrowth);
 - mechanical (anthropogenic);
- but also:
- technical (i.e., faulty solutions or unsuitable materials).

As the next step, we describe the results of the destructive actions and formulate the specification of the mechanisms that led to damage.

Table 1. Damaged façade materials—Group 1 (irreparable, reduced technical lifespan).

	Degrading Agent	Effect of Degradation	Qualification of Damage	Advise for Extension of Durability
A1	Environmental, Physical	Cracking and falling off stone pieces caused by thermal expansion—faulty method of fixing with anchors	Unintentional	More reliable design and execution of anchors, and the system of fixing stone panels
A2	Environmental, Physical	Separation and falling off caused by the imperfect traditional technology of fixing	Unintentional	Better system of fixing stone panels, e.g., steel anchors
A3	Environmental, Physical, Polluted air	Irregular pattern on porous material resulting from rain-washed dust settled on the facade	Unintentional	A more appropriate location with lower traffic intensity
A4	Environmental, Mechanical, Anthropogenic	Colored graffiti fuzzy markings	Intentional	Location in zone C or zone A, B—if defensive space
A5	Environmental, Mechanical, Anthropogenic	Damaged tops of concrete protruding pyramids	Unknown (intentional or unintentional)	Location in zone B, C, or zone A—if defensive space

Table 1. Cont.

	Degrading Agent	Effect of Degradation	Qualification of Damage	Advise for Extension of Durability
A6	Environmental, Mechanical, Anthropogenic	Graffiti spraying	Intentional	Location in zone C, or zone A, B in a watched defensive space, treatment with anti-graffiti coating
A7	Environmental, Mechanical, Anthropogenic	Torn and deformed edges of corrugated steel sheeting	Unknown (intentional or unintentional)	Location in zone B, C, or heavily watched defensive space with anti-shock barriers against vehicles
A8	Environmental, Mechanical, Anthropogenic	Scratched and rubbed surface of panels	Intentional and possibly unintentional	Zone C, or heavily watched lower zones, anti-vandalistic coating in moderate climates without high temperatures, and avoidance of coastal locations
A9	Environmental, Physical	Corrosion of sheet's edges—result of leaking water and chemical incompatibility of materials	Unintentional	Location in zone C and a suitable fixing system, carefully controlled rainwater path, and chemically non-aggressive air
A10	Environmental, Physical	Rippled steel sheets result of thermal expansion of improperly fixed finishing material	Unintentional	Location in zone C, or lower in heavily watched defensive space, allowance for thermal expansion, and chemically compatible adjacent materials
A11	Environmental, Physical	Trapped condensation under sheet lead, faulty envelope ventilation system	Unintentional	Location in zone C, or heavily watched lower positions in defensive space, treatment with anti-graffiti coating, effective cavity ventilation
A12	Environmental, Physical	Laminate panels peeling off—action of humid, aggressive ambient air	Unintentional	Location in zone C, chemically non-aggressive air, possibly watertight panel edges in coastal areas
A13	Environmental, Mechanical, Anthropogenic	Damage by vehicle's bumper	Unknown (intentional or unintentional)	Location in zone C, chemically non-aggressive air, protective measures against vehicle impact, and anti-vandalistic coating if in zone A
A14	Environmental, Mechanical, Anthropogenic	Fracture of tensioned mesh—human curiosity	Unknown (intentional or unintentional)	Location in zone C, controlled tension of mesh envelope

Some Group 2 materials can be subjected to operations that allow a relatively easy and inexpensive extension of their technical life, despite the damage done. These operations include cleaning with water and some chemical compounds, repainting, or replastering work (Table 2).

Table 2. Damaged façade materials—Group 2 (reparable, possible extended technical life).

	Degrading Agent	Effect of Degradation	Qualification of Damage	Advise for Extension of Durability
B1	Environmental, Mechanical, Anthropogenic	Graffiti spraying	Intentional	Anti-graffiti coating
B2	Environmental, Mechanical, Anthropogenic	Graffiti spraying	Intentional	Anti-graffiti coating after repainting
B3	Environmental, Biological,	Algae growth, mold, and moss formation	Unintentional	Location at a distance from vegetation and application of biocidal and anti-graffiti coating
B4	Environmental, Mechanical, Anthropogenic	Plaster finish detached	Intentional	Replastering and repainting of damaged areas
B5	Environmental, Mechanical, Anthropogenic	Graffiti spraying	Intentional	Intensive maintenance, fast removal of vandalistic effects
B6	Environmental, Physical	Wood stain washed out, leaving patches—result of protruding balconies controlling rainwater flow	Unintentional	Study of local wind patterns and protruding building components, wood protective coating
B7	Environmental, Biological	Vegetal growth on a water-splashed surface	Unintentional	Glazed bricks, anti-graffiti coating

These endeavors, however, frequently encounter unexpected obstacles that bring negative effects. The application of anti-graffiti coatings designed to discourage intentional sprayings and the expectation of their easy removal is not a reliable means to thwart vandalistic acts. The coating performs unsatisfactorily, peeling off the material and revealing the patches of the original exterior finish. This effect depends on the local climate (high temperature, chemically aggressive air, rainwater) or other factors, including the spatial configuration of the coated surface. There are also examples of unconventional endeavors to resolve the issue of spraying, as the use of protective steel grills installed at a distance before the affected finish layer. It also proved to be ineffective (Table 3).

Table 3. Unsuccessful methods of preventing damage to façade materials.

	Protection Method	Degrading Agent	Effect of Degradation	Qualification of Damage	Advise for Extension of Durability
C1	Anti-graffiti coating	Climatic—rainwater	Anti-graffiti protective coating washed off the leaning wall	Unintentional	Application on a vertical wall
C2	Anti-graffiti coating	Climatic—rainwater, high temperature	Anti-graffiti protective coating peeling off	Unintentional	Avoidance of solar exposition. Compatibility of Cor-ten steel and some coating systems
C3	Galvanized steel grill	Physical—(human-induced)	Graffiti spraying through the protective grill	Physical (human-induced)	Increase in distance of grate from wall

Some cases from above present situations in which the application of protective coatings or metal grills not only fails to fulfill the assigned role properly but also aggravates the condition of materials. It lowers their performance and negatively affects their aesthetic values. This can lead, in many cases, to the abandonment of such protective operations and, eventually, to replacements, rendering these endeavors futile and contributing to further reduction in the longevity of building components.

5. Preventive Measures to Reduce the Risk of Intentional Damage to Façade Materials

The cases mentioned above demonstrate the need for effective protection of finishing materials against vandalistic acts to extend their lifespan. There are other methods than those presented earlier that turned out to be ineffective. It is specially targeted systems developed for façade materials that have proven their utility in building practice (Figure 3).

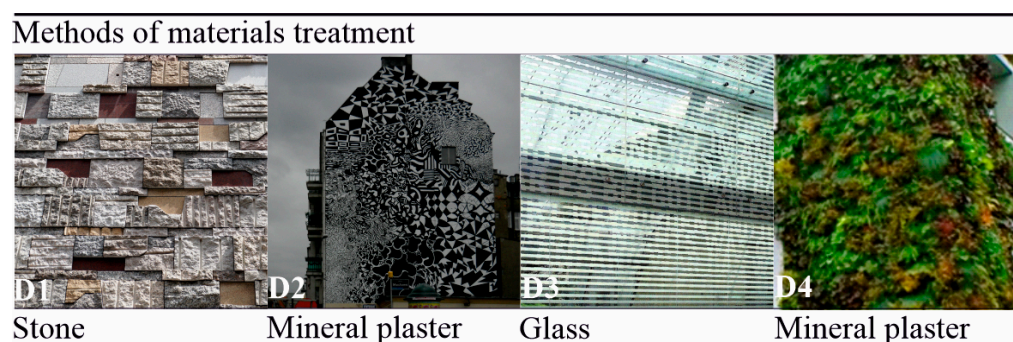


Figure 3. Suggested preventive anti-vandalistic measures. Photos source: authors archive.

They effectively render vandalistic acts, such as spraying, scratching, and chipping off, difficult or only partly effective. The illustrations in Table 4 present various methods of deterrence, each based on a different idea. There are two systems in use: flat with irregular painting or stripes, and a second sculptural mineral or organic system, which is based on plants (creepers).

Table 4. Methods of material treatment to discourage damage to building facades.

	Protection Method	Accepted Location
D1	Irregular pattern of relief treatment	Zone A—accessible for pedestrians
D2	Irregular pattern of wall painting	Zone A—accessible for pedestrians
D3	Horizontally striped etching	Zone A—accessible for pedestrians
D4	Creepers—inaccessible wall surface	Zone A—accessible for pedestrians

Case D1 demonstrates a special 3-dimensional irregular treatment of the wall surface, which discourages spraying more compared to another stone surface, A4 (from Table 1), formed regularly with finer pebbles, making graffiti more legible. Cases D2 and D3 have less potential for distinct graffiti than plain surfaces, usually dominating in the ambient urban space. Case D3 is especially interesting as it presents a glazed wall that can be more effective defensively compared to the defaced glass in Case B5. Creepers growing on walls (D4) are a very effective means of protection as they render the wall surface inaccessible. Protective measures require additional expenditure and energy input, but they can be considered relatively low compared to the replacement of materials or components, also from an ecological viewpoint.

It has been proven that there are also other anti-vandal strategies. One of them refers to the special design of environs around buildings based on the idea of defensive space [26].

It relies on ensuring the visibility of protected walls to neighbors and thus dissuading potential vandals. In specific locations, however, a double security is recommended. The idea of defensive space encompasses a set of recommendations for designers. They refer to a suitable urban shaping, advantageous configuration of buildings, and cues for the appropriate selection of façade materials. A potential range of wall area and its height accessible to vandals should be considered. The maximum height is defined as 3.5 m above ground [27], marked in Figure 1 as zone B. The anti-vandal measures taken assume that graffiti and similar disfiguring markings on facades should be removed as soon as possible to discourage further destructive acts. The idea is to prevent so-called ‘erosion vandalism’ [27], which occurs in the case of failure to respect the fast removal of damages. Another theory maintains that the most effective way to prevent vandalism in public areas is to eliminate targets that cannot stand up to damage [26]. The approach is defined as target hardening, which means the use of robust materials and a marked texture [28].

6. Results and Discussion

This research project, conducted in line with the above method, has delivered multiple results that revealed various aspects and impacting factors of the durability issue identified in the tables. It emphasized the important role of professional and kindred knowledge necessary to implement while designing architectural objects and the surrounding space.

The cases depicted in Table 1 present deteriorated materials, mainly in the lower parts of facades, where damage occurs most frequently. This is where the concentration of adverse agents is highest. Anthropogenic factors dominate in this set of examples, as they usually do. It seems obvious that, given the frequency of human-induced degradation of facades, this occurrence should be taken more seriously than it usually is. Therefore, much more emphasis should be put on the designers’ commitment to this issue. Additionally, their awareness in this regard can substantially improve this situation and contribute to the increase in the buildings’ durability, rendering these structures more sustainable. Elaboration of appropriate recommendations for a suitable design should be a necessary task for consideration.

This research has been undertaken in this view. After analyzing the presented cases and relevant written sources by other authors, we identified areas of facades that should be treated appropriately to reduce vandalistic acts, defined as intentional or unintentional (Figure 1). The basic requirement is to indicate the areas of facades where anthropogenic damage can occur. Therefore, three zones should be considered crucial for analysis in the preliminary design. The closest-to-ground is marked as ‘A’ and has a height up to 2.5 m; the second, Zone B, is between 2.5 and 3.5 m; and the third is the remaining zone above, marked as Zone C (Figure 1). The first façade zone is defined by the possible reach of individuals who can negatively affect it. Zone B is attainable by persons who can climb up in whatever way to disfigure it [27]. The technical and material solutions applied in the cases presented in Table 1 manifest a faulty way of dealing with Zone A, as they excessively confine the durability of the relevant facades, regardless of the implemented building materials (Cases A4–8, 11, 13, 14—mechanical damage), which cannot be easily replaced without apparent negative aesthetic effects and technical challenges, and can be considered irreparable or requiring proportionally excessive expenditure.

Another group of technical solutions for façade finishing is presented in Table 2. The degradations depicted there can be relatively easily removed by cleaning, repainting, re-plastering, or similar treatments. These operations require relatively little input of materials and energy to restore the original technical and aesthetic condition of the disfigured façade components. Efforts to control intentional or unintentional damage to building facades have long been practiced to thwart the vandalistic acts. The methods applied, however, fail

in many cases (Table 3) and even aggravate the situation, making the problem more difficult to resolve successfully. This entails more technical issues for a proper treatment, along with additional financial resources. Traditional thinking about anti-vandalistic measures in the past recommended the implementation of specific materials to prevent anthropogenic damage to facades. This was the use of coarse surfaces, making the old methods of writing on walls ineffective. Unfortunately, this protective measure proved faulty because spraying emerged as the dominating graffiti method used. It is difficult, if not impossible, to remove it from such surfaces. In the cases included in Table 4, various methods of wall treatment are suggested to cope with this issue. They are based on the idea of forming uneven, sculptured surfaces, very distinct pattern treatment of wall rendering, or the implementation of a similar idea for glass panels. A good proposal is the use of creepers to protect the walls by making them inaccessible to aggressors. In the Case D1, the stony wall surface features a double, harsh, three-dimensional treatment, which, due to the irregular pattern of the stone blocks and deep cavities, makes a substantial difference to the Case A4. It renders it much less vulnerable to vandalistic acts.

These relations sometimes escape our attention to the disadvantage of the quality of design and the reduced longevity of building materials and components. Given the analyzed cases and the presented results, it seems logical to make efforts to create an effective strategy towards the development of durability-oriented design methods, which would account for the prevention of human-induced deterioration of building facades. A special approach based on a sequential basis, featuring consecutive steps leading toward a final vandal-proof design, was assumed. It would reduce the future need for costly operations, which would be disadvantageous from a sustainable viewpoint. Such an idea should take into account not only the methods of the vandal-proof treatment of facades, but also consider a much wider range of impacting factors specified above. Figure 4 presents a proposed pathway to durability. It includes all the above-mentioned influencing factors.

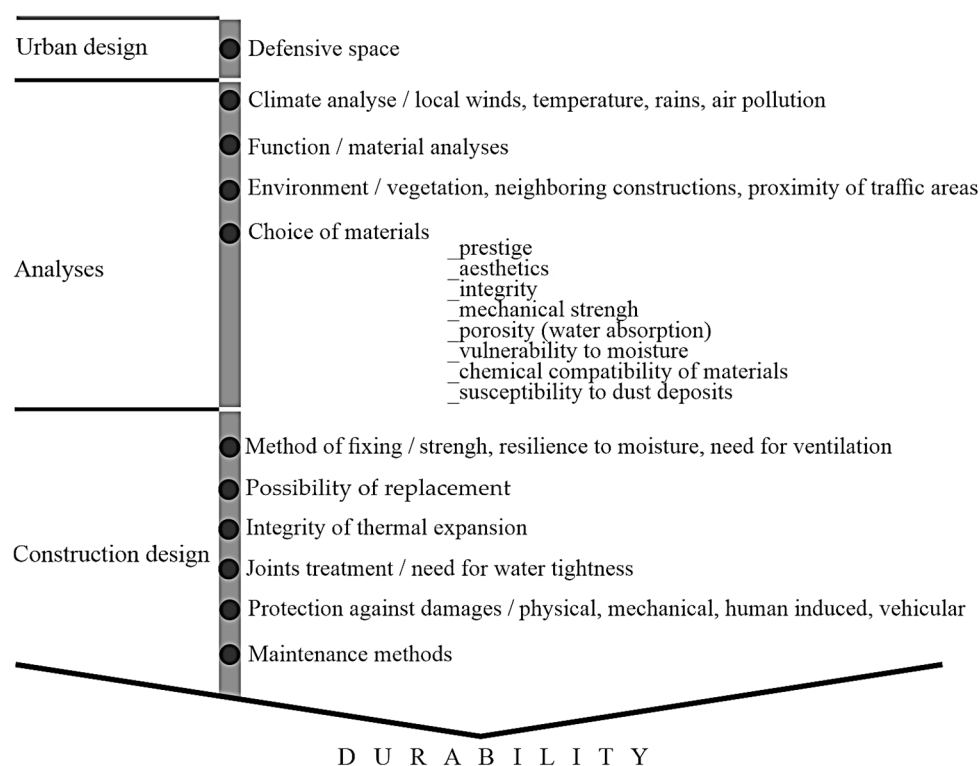


Figure 4. Pathway to durability: sequence of design stages. Source: authors' drawing.

The pathway to durability can be disrupted and compromised by the application of a strategy for adaptation implemented in a design. Adaptation-oriented design also includes potential exchange or modification of building facades, making them more suitable for new functions in buildings, and can be considered in conflict with the durability-friendly design. Therefore, it would be advantageous in the design for adaptation to also respect the guidelines for durability-oriented design, meeting the sustainability paradigm. On the other hand, however, the process of building's adaptation to new functions can have a positive impact on the durability of facades through the extension of their technical longevity by retaining their unchanged form and materials. Paradoxically, this functional dynamism can assure a longer durability. An extended longevity of materials or components can also be achieved as a result of a design for disassembly, where they are considered to be easily transferred to another structure, thus contributing to the dematerialization of building processes [29].

As the primary concern of this research is directed towards mechanical degradation by agents that negatively impact the durability of building facades, other factors mentioned above also play a significant or decisive role in the deterioration mechanisms [30,31]. Climate, its factors, and related phenomena—temperature fluctuations, UV radiation, wind action, and water penetration—exert a significant impact on building facades [32]. The in-depth analyses of the presented examples specify cues as to the threats of reduced durability [33]. An appropriate selection of materials compatible with local climatic or environmental conditions, as well as reliable fixing technology, are the basic factors ensuring satisfactory durability of facades. *There is no general method for calculating durability. However, the expert method for calculating the service life of structures based on physical wear is widespread* [34] (p. 2) and [35,36]. The recommendations that result from this research aim to enhance these methods.

Based on the analyses conducted for the cases in the tables, recommendable advice concerning the increase in durability of building facades was formulated as a result of this research. The durability of facades is also determined by the maintenance operations, their quality, and frequency [37,38]. They depend on the façade materials in various ways. For instance, exposed brickwork is a low-maintenance system, whereas a rendered finish requires more maintenance [39].

The durability issue is still debated, as there are some intriguing signals claiming that *(...) as energy efficiency is increased, durability is typically compromised* [3] (p. 3). There is also heat damage, which comes into play. It has been proven that every 20 °F reduction in the material's temperature doubles its useful life. Crucial is the synergic action of a high temperature and UV radiation [3].

This research explores primarily the issue of technical durability of facades; however, it also relates indirectly to their aesthetic longevity, which is, as a rule, compromised accordingly. Cultural aspects play a crucial role, as degenerated materials and components can be accepted or rejected by the public. However, there are examples of buildings demonstrating the idea of destruction as a creative aesthetic choice [24,40]. Such an approach would certainly contribute to the extension of durability, dematerialization of buildings, and sustainability.

7. Conclusions

The durability of building components, including facades, has been the subject of extensive research in various aspects. The sustainability approach is of special value. Among many involved factors analyzed, the anthropogenic one is not sufficiently researched, and accessible works dealing with this issue still seem to not be updated, which illustrates the unchanged behavioral approach of the public to buildings and their components. A

proportionally significant number of human-induced damages to buildings indicates the need for more serious treatment of this problem, which, as everyday practice proves, is too frequently played down, both in the social environment and in relevant scientific circles. The principal objective of this article was to present the results of the research concerning the problems of durability of façade finishing technologies in the form of readable tables specifying the principal unquantifiable parameters of analyzed cases, assessing their technical condition visually, and elaborating suitable recommendations aiming at increasing their longevity. The aim of this article is to contribute to the enhancement of relevant knowledge. It is architects and building designers who are the main targeted group of professionals and researchers.

This research explores the issue and aims to analyze the cases of façade deterioration inspected and to formulate suitable recommendations that will contribute to the extension of the service life of related technologies and materials. This was designed to enable the improvement of sustainability parameters, including increased durability, along with the resulting dematerialization, savings in material resources, and the reduction in energy demand in building construction. But this approach can be disputable from some specific aesthetic viewpoint. The recommendations specified in this research may conflict with the prevailing conviction within the designers' circles, considering the desired aesthetic cohesion of their architectural works. Therefore, this aspect of the subject of research—harmonization of applied technologies with the expected artistic façade vision—should also be taken into account, rendering the issue even more complicated.

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References

1. Kibert, C.J.; Thiele, L.; Peterson, A.; Monroe, M. The Ethics of Sustainability. Available online: <http://rio20.net/wp-content/uploads/2012/01/Ethics-of-Sustainability-Textbook> (accessed on 3 August 2025).
2. Ashby, M.F. *Materials and the Environment. Eco-Informed Material Choice*; Elsevier: Amsterdam, The Netherlands, 2009; p. 66.
3. Lstiburek, J. *Increasing the Durability of Building Constructions*; BSD-144; Building Science Digest: Ottawa, ON, Canada, 2006; p. 3.
4. Canepa, M.; Piccardo, C.; Giachetta, A. Durability in a resilient design approach. In *Resilience—Between Mitigation and Adaptation*; Palermo University Press: Palermo, Italy, 2020; Volume 3, pp. 98–111.
5. Andersson, D.E.; Andersson, A.E. Sustainability and the Built Environment: The Role of Durability. *Sustainability* **2019**, *11*, 4926. [CrossRef]
6. CSA S478:19; Durability in Buildings. Canadian Standard Association Group: Toronto, ON, Canada, 2019.
7. Wilson, A. Durability: A Key Component of Green Building. Trellis. 24 July 2024. Available online: <https://trellis.net/article/durability-key-component-green-building/> (accessed on 18 August 2025).
8. Błaszczynski, T.; Wojciechowski, M. The relationship of office-objects certification with their durability. In *Materialy Budowlane*; Wydawnictwo SIGMA-NOT Sp. z o.o.: Warszawa, Poland, 2016; Volume 11, p. 72.
9. ISO 13823; General Principles on the Design of Structures for Durability. International Organization for Standardization: Geneva, Switzerland, 2008. Available online: <https://standards.iteh.ai/catalog/standards/sist/0af6fd6b-7e4f-40d3-bc0d-00d61e0f8a91/iso-13823-2008> (accessed on 1 August 2025).

10. Gil-Martin, L.M.; Gonzales-Lopez, M.J.; Grindlay, A.L.; Segura-Naya, A.; Aschheim, M.; Hernandez-Montes, E. Toward the production of future heritage structures: Considering durability in building performance and sustainability—A philosophical and historical overview. *Int. J. Sustain. Built Environ.* **2012**, *1*, 269–273. [\[CrossRef\]](#)
11. Lacasse, M.A.; Gaur, A.; Moore, T.V. Durability and Climate Change—Implications for Service life Prediction and the Maintainability of Buildings. *Buildings* **2020**, *10*, 53. [\[CrossRef\]](#)
12. Lacasse, M.; Ge, H.; Hegel, M.; Jutras, R.; Laouadi, A.; Sturgeon, G.; Wells, J. *Guideline on Design for Durability Building Envelopes*; National Research Council: Ottawa, ON, Canada, 2022. [\[CrossRef\]](#)
13. Australian Building Codes Board. *Australian Building Codes Board Guideline Document. Durability in Buildings*; Australian Building Codes Board: Canberra, Australia, 2006; p. 7.
14. Mayer, P.D.; Bourke, K.P. Durability rankings for building component service life prediction. In Proceedings of the International Conference on Durability of Building Materials and Components, Lyon, France, 17–20 April 2005.
15. Clements-Croome, D. *Intelligent Buildings. Design, Management, and Operation*; Thomas Telford Publishing: London, UK, 2010.
16. Aikivuori, A.M. Critical loss of performance—What fails before durability. In *Durability of Building Materials and Components, Proceedings of the 8th International Conference on Durability of Building Materials and Components, 8dbmc, Vancouver, BC, Canada, 30 May–3 June 1999*; Lacasse, M.A., Vanier, D.J., Eds.; Institute for Research in Construction: Ottawa, ON, Canada, 1999.
17. Brand, S. *How Buildings Learn: What Happens After They Are Built*; Penguin: New York, NY, USA, 1994.
18. Lacasse, M.A. Durability and performance of building envelopes. In Proceedings of the BSI 2003 Conference, 15 Cities Across Canada, October 2003. Available online: <https://nrc-publications.canada.ca/eng/view/object/?id=163e3de7-e153-469d-ac8e-5a505b0204b8> (accessed on 27 September 2025).
19. Celadyn, W. Durability of buildings and sustainable architecture. *Tech. Trans.* **2014**, *7A*, 17–26.
20. Grabow, S.; Spreckelmeyer, K. *The Architecture of Use*; Routledge: New York, NY, USA, 2015; p. 17.
21. Aronoff, S.; Kaplan, A. *Total Workplace Performance*; WDL Publications: Ottawa, ON, Canada, 1995.
22. Sandeford, P. Planning for durability and life cycle maintenance of buildings during design. In Proceedings of the International Conference on Performance-Based and Life-Cycle Structural Engineering, Brisbane, Australia, 9–11 December 2015.
23. Li, Z. Atmosphere and Material Durability. *Build.* **2021**. Available online: <https://www.buildmagazine.org.nz/articles/show/atmosphere-and-material-durability> (accessed on 10 July 2025).
24. Celadyn, M.; Celadyn, W. Apparent destruction architectural design for the sustainability of building skins. *Buildings* **2022**, *12*, 1220. [\[CrossRef\]](#)
25. CIB W086; New Trends on Building Pathology. International Council for Research and Innovation in Building and Construction: Ottawa, ON, Canada, 2021.
26. Poyner, B. *Design Against Crime: Beyond Defensible Space*; Butterworths: London, UK; Boston, MA, USA; Toronto, ON, Canada; Wellington, New Zealand, 1983.
27. Van Oik, N.; Broersen, P. Architecture, more than an art of building. In Proceedings of the SAFE Space, Kraków, Poland, 28–29 October 2005.
28. Ward, C. *Vandalism*; Architectural Press: London, UK, 1973.
29. Vallero, D.; Brasier, C. *Sustainable Design: The Science of Sustainability and Green Engineering*; Wiley: Hoboken, NJ, USA, 2008.
30. Bomberg, M.; Kisilewicz, T. Durability of Materials and Components. In *Methods of Building Physics*; Cracow University of Technology: Kraków, Poland, 2015.
31. Geiker, M.R.; Hendriks, M.A.N.; Elsener, B. Durability-based design: The European perspective. *Sustain. Resilient Infrastruct.* **2021**, *8*, 169–184. [\[CrossRef\]](#)
32. Hernandez-Moreno, S.; De Hoyos-Martinez, J. Planning for Durability in Building Projects: Strategies and Technical Recommendations According to LEED® Canada. *Bus. Excell. Manag.* **2012**, *2*, 5–10.
33. Celadyn, W. Climatic Aspects of Durability in Contemporary Architecture. *Tech. Transactions. Archit.* **2015**, *2*, 33–51. [\[CrossRef\]](#)
34. Shafranovsky, T.; Rimshin, V.; Varlamov, A.; Merkulov, S. Comparison of the Durability of Buildings in a Group. In Proceedings of the International Science and Technology Conference, Vladivostok, Russia, 6–9 October 2020; p. 2.
35. Rudbeck, C. Assessing the Service Life of Building Envelope Constructions. In *Durability of Building Materials and Components, Proceedings of the 8th International Conference on Durability of Building Materials and Components, 8dbmc, Vancouver, BC, Canada, 30 May–3 June 1999*; Lacasse, M.A., Vanier, D.J., Eds.; Institute for Research in Construction: Ottawa, ON, Canada, 1999.
36. Hed, G. Service Life Planning of Building Components. In *Durability of Building Materials and Components, Proceedings of the 8th International Conference on Durability of Building Materials and Components, 8dbmc, Vancouver, BC, Canada, 30 May–3 June 1999*; Lacasse, M.A., Vanier, D.J., Eds.; Institute for Research in Construction: Ottawa, ON, Canada, 1999.
37. Flint, M.; Baker, J.; Billington, S. A Probabilistic Framework for Performance-Based Durability Engineering. In *Durability of Building Materials and Components*; Peixoto, V., Delgado, J.M.P.Q., Eds.; Springer: Berlin/Heidelberg, Germany, 2013; pp. 1–35.
38. Designing for The Long Now: Time, Maintenance and Architectural Durability, VQ DESIGN PLLC. Available online: <https://vqdesignpllc.com/designing-for-the-long-now/> (accessed on 26 September 2025).

39. Smith, P.F. *Architecture in a Climate of Change*, 2nd ed.; Routledge Taylor & Francis Group: Abingdon, UK, 2005.
40. Adjaye Associates. Mole House in London. *Detail* **2021**, 4, 51.

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