



Application of the factor method to the estimation of the service life of natural stone cladding



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HIGHLIGHTS

- A model to estimate the service life of natural stone claddings is put forward.
- Is based on field data of the state of deterioration of in-service buildings.
- 269 Stone claddings located in Portugal were analysed.
- The factors that affect the durability of natural stone claddings were examined.
- Models like this are an important tool in the definition of maintenance strategies.

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ABSTRACT

The last few years have seen expressions of concern about the sustainability of construction from all actors in the sector. The durability of the materials used has, in particular, been mentioned as a determining factor in increasing the service life of structures and consequently in reducing energy consumption and environmental impacts as a whole. With the introduction of new products and/or the adoption of new constructive techniques it has become necessary to develop the fields of durability and service life prediction of construction products, with the purpose of evaluating their performance throughout their life cycle.

A model to estimate the service life of natural stone claddings is put forward, based on the factor method initially proposed by the Architectural Institute of Japan. This method involves the appraisal of the degradation phenomena in stone claddings under real use conditions, through a field survey. 269 stone claddings located in Portugal were analysed. The factors that affect the durability of natural stone claddings were examined. The quantification of the factors affecting the durability of stone claddings is affected by some subjectivity. Therefore it does not seem viable to propose standard values that can be applied in all circumstances. Analysis of the scenarios proposed for that quantification shows that the use of generic values for durability factors, such as those in ISO 15686:2000, does not lead to the best results. The best solution is to adopt durability factors adjusted to the reality of the phenomenon to be modelled at a regional or local scale.

This is a first approach to applying the factor method to estimate the service life of natural stone cladding. It is considered that the method proposed shows very promising results, though it still needs to be supplemented, particularly in terms of the comprehensiveness of the sample.

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1. Introduction

Even though there is a growing concern with the durability of constructions, as expressed in the publication of specific codes, it is a fact that recent buildings do not perform as planned for. Among

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the reasons for this deficient behaviour, especially of the building envelope, are: the absence of adequate constructive detailing, execution errors, the use of merely economic criteria in the selection of materials, poorly qualified personnel, the speed demanded of the construction process, the application of new materials that have not been previously properly characterized, lack of technical know-how and attention given solely to aesthetics.

The durability of an element may be defined as its ability to continue to adequately perform the function for which it was devised,

within a specified environment (i.e. the balance between the intrinsic resistance of the material and the aggressiveness of in-service actions). It is one of the most important issues in construction since it influences sustainability, service life, repair and rehabilitation costs and environmental impact of the buildings [17].

Buildings, just like human beings, are not eternal. It can be said that every construction has a service life, characterized as the time during which the assembly or its elements are “in use”, from construction (birth) until the moment when the minimum acceptable performance requirements are no longer met (terminus) [14].

The requirements that establish the end of the service life of buildings may be intrinsic to the element, when related to the physical performance, or be imposed by objective codes or regulations, e.g. related to safety, or subjective rules, e.g. related to aesthetic criteria [10]. Siemes [25] mentions the following factors as being mainly responsible for the end of the service life of a construction: technical aspects (ageing causes the building to no longer comply with functional requirements); economic aspects (when demolition is the best economic option of all the available alternatives, such as doing nothing, changing the use or rehabilitation); environment-related aspects (e.g. a building with asbestos may risk the health of users); planning-related aspects (e.g. when the demolition of a building enables an important infrastructure to be built); and societal or technological development requirements. Moser [19], however, is stricter by identifying safety (the integrity of the construction is kept at a standard level), functionality (the use for which the building was erected is being fulfilled) and appearance (the “surface” of the assembly is acceptable from that point of view) as analysis criteria of the service life.

In the present context, it is highly relevant that there are studies that aim at understanding the durability of buildings and their components. A method to estimate the service life is established in this article. It is based on the factor method initially proposed by the Architectural Institute of Japan (1993), applied to the specific case of natural stone claddings. The application of the method is based on the appraisal of the degradation state of 269 claddings. Stone claddings were chosen as the subject of this study mostly because façades are the first image we have of buildings and natural stone claddings, even though commonly associated with high durability and aesthetic richness, exhibit degradation levels that are often incompatible with that perception. The intention was therefore to contribute to the knowledge of the durability of construction elements so that in the future maintenance and rehabilitation strategies for these elements could be defined in an informed way.

2. Background

During the 1980s several Japanese researchers concentrated on developing methods to predict the service life of buildings, their elements and components, both at the design stage and in-service. Consequently, a guide was published in 1989 by the Architectural Institute of Japan. It was later translated into English (Principal Guide) [3] and describes principles for service life estimation, giving birth to the “factor method”. This method was developed by CIB/W80 and later adopted by [14], whose purpose is to regulate the service life prediction of buildings.

The factor method can determine the service life of elements subjected to specific conditions, based on a reference service life that is corrected by several modifying factors, which lead to an increase of the predicted service life if favourable or a decrease if unfavourable. In short this method is based on two fundamental concepts [5,12]: the reference service life, characterized as the expectable service life under normal use and maintenance conditions; and the modifying factors, that shift the reference service life up or down. According to ISO 15686, the factor method can be expressed by Eq. (1).

$$ESL = RSL \times A \times B \times C \times D \times E \times F \times G \quad (1)$$

where *ESL* – estimated service life; *RSL* – reference service life; *A* – factor related to the quality of the material, its finishing or its treatment; *B* – factor related to the quality of the design; *C* – factor related to the quality of the on-site execution; *D* – factor related to the inner environmental conditions; *E* – factor related to the external environmental conditions; *F* – factor related to the use conditions of the construction; *G* – factor related to the level of maintenance.

ISO 15686 suggests that the reference service life should be obtained by performing ageing tests for subsequent comparison with data from experts in the field. As for quantifying the modifying factors, the standard mentions that these variables may change between 0.8 for less favourable and 1.2, for more favourable conditions, and takes the value 1.0 for standard conditions or whenever the factor cannot be applied.

This method has been criticized by several authors who highlight the following limitations [5,19,12,10]:

- The result is an absolute value (representing the expectable limit of the service life) and does not provide data on results scatter; since it is very often necessary to know from when substantial renovations must be made and since that occurs well before the end of the service life, this type of result provides no guidance for that.
- The uncertainty associated with the reference service life, because if this value is not accurately determined it cannot be adjusted by the modifying factors.
- The number and type of factors are not specified, nor is their quantification, which is usually done empirically.
- All the factors have the same weight, i.e. this method does not provide a ranking of the variables; it does not take into account that different variables may affect the element's service life in different ways and to varying degrees.
- The definition of the factors is generally based on the behaviour of the element subjected to a given set of conditions, instead of on the influence of individual parameters, such as seasonal rainfall and temperature, or type of use.

Even though the factor methods based on the general method from the Architectural Institute of Japan are subject to the above criticisms, they are still the most widely accepted because of their clarity, ease of application and high operability, even when not all the data to estimate the service life are available, since data can be added or completed at any stage of the process. The factor method is currently no longer seen as a deterministic method but rather as a general framework for service life prediction; for example it allows the inclusion of statistical variables or ranges instead of absolute values. Because it is considered that this method achieves the desired balance between accuracy, swiftness, low cost and ease of application, which is probably why it is the only method generically accepted internationally, it was adopted in the study.

3. Loss of performance of stone claddings over time

As they age, stone claddings suffer continuous degradation that reduces their ability to comply with the performance requirements. This loss of capacity varies according to the deterioration agents and the nature of the material itself.

Knowing the degradation exposure stone claddings are subject to, it is possible to model their deterioration through a degradation curve [20,23], which graphically represents the loss of performance over time. This method is implemented in three main phases: evaluation of the performance of the construction elements;

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