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The importance of the quality of sampling in service life prediction

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HIGHLIGHTS

- The research analyses the influence of the sample quality and size in service life prediction models.
- The methodology adopted is based on field work data collection.
- An empirical model is used that estimates the service life of the building elements.
- The model is applied to evaluate the service life of ceramic external claddings.
- The results confirm that more and better data conducts to more reliable results.

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ABSTRACT

In recent years the interest on the durability of buildings and their materials has been increasing. The reasons behind that attention are mainly economic and environmental. Service life prediction methods are an essential tool to support decision-making during the building's life cycle. Service life prediction must be used to estimate the duration of a building component and allows a more rational definition of the maintenance operations, reducing unnecessary costs. However, service life prediction can be a complex issue. The results obtained are closely related to the quality of data used to define these models. In this study, the influence of the sample on the results of a service life prediction model applied to ceramic external walls is analysed. The methodology adopted is based on field work data collection, concerning the state of degradation of the façades. Two samples were used: the initial one, composed of 117 case studies, without a pre-selection of the cases analysed, and an improved sample, composed of 195 claddings, with more complete and reliable data. The results obtained confirm that more and better data conducts to more reliable results.

1. Introduction

Numerous service life prediction methods have been put forward in recent years. The existing methodologies have different levels of complexity and accuracy, ranging from stochastic models, more complex but more precise, to deterministic models, more user-friendly but incapable of dealing with the uncertainty related with complex phenomena such as buildings' degradation. The majority of these approaches are based on the assessment of building's performance and on the analysis of the durability and longevity of their elements [15]. Service life evaluation of buildings materials and components can be used to ensure a more realistic planning of management, refurbishment and maintenance actions [21], based on the specific conditions of each project. Furthermore, the data related with the durability of building components can be applied in Life Cycle Assessment (LCA) and Life Cycle Cost (LCC) analysis [30].

According to Gray and Baird [16], the building evaluation techniques can be classified within two broad approaches: "empirical" and "theoretical" methods. The use of empirical methods [8,10,11,24–26] is a simplified and powerful tool for service life prediction. These methods try to define the degradation condition of claddings over time in real service conditions. Grant et al. [15] argues that empirical data are arguably the most accurate data to be used in methods for service life prediction. However, the acquisition of this type of data can be changeling due, essentially, to time constraints. To obtain accurate models it is crucial to use precise service life data. In empirical methods, the durability data can be obtained through fieldwork, based on the visual assessment of

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the condition level of buildings and their elements according to the location, extension, severity and risk of the defects detected [11].

These methods are expedient, do not usually require costly equipment, and are often perfectly adequate to determine the degradation state of the elements under inspection [27]. In most situations, a straightforward visual inspection is sufficient for the surveyor to collect *in situ* the data needed to evaluate the degradation state of a building or its elements [31]. Van Noortwijk [32] argues that in models based on linear degradation patterns (with an average degradation rate for the sample), a single inspection can reveal the future deterioration evolution of buildings and their components. However, visual inspections have some limitations since their accuracy depends significantly on the experience/background and classification criteria of the surveyor; they also depend on the weather conditions at the time of the inspection (e.g. the difficulty of detecting defects in smooth and dark claddings when sunshine is falling directly on them).

Regardless of the method of collecting data, the size of the sample is paramount when establishing service life prediction models. The sample size and the complexity of the phenomenon that it is intended to model are mutually related. Objectively, more data, and consequently more information and knowledge, lead to models that can deal more efficiently with problems of greater complexity. Furthermore, the nature of data is even more important than the size of the sample itself. In fact, better quality data is better than more data. The data used in service life prediction models should be representative of the problem and must be carefully obtained. In some cases, the degradation of the buildings is related with causes and events that cannot be modelled (e.g. vandalism) and these data should not be included in service life prediction models. The inclusion of these data in service life prediction models leads to untrustworthy conclusions; models with biased data are unable to illustrate conveniently the degradation evolution of the buildings and cannot be used to predict their residual service life.

In this study, the influence of the sample on the results of a service life prediction model is analysed. An empirical model is used that estimates the service life of the building elements based on the evolution of its loss of performance over time (through degradation paths). The model is applied to evaluate the service life of ceramic external claddings. The methodology adopted is based on field work data collection, concerning the state of degradation of the façades. The model was applied to two different samples: (i) the initial sample, composed of 117 case studies, without a careful pre-selection of the cases analysed; (ii) and the improved sample, composed of 195 claddings (including some but not all of the claddings from the previous sample), with more complete and reliable data; this sample was collected four years after the inspection of the cases contained in the first sample. The results obtained confirm that the model based on the second sample leads to more realistic and precise results.

2. Background

According to Goldberg [13], “direct adhered façade” refers to an exterior wall that is clad on the exterior surface with a weather-resistant, non-combustible cladding material, which is directly adhered to a structural substrate material with an adhesive. Specifically, our study takes into consideration ceramic external walls. Emerging from this definition, such cladding system consists of various components; more in detail, these are: ceramic tiles, bedding materials and joints filling materials. It is essential to ensure that the properties of the parts of the system are compatible. Kočí et al. [20] refers that is not sufficient to use one excellent material; rather, it is necessary to develop a working multi-layered system consisting of materials with different properties.

The quality of design of a façade is one of the main guarantees of the cladding’s durability; this will be confirmed in Section 6. Concerning this matter, several characteristics need to be taken into consideration in a proper cladding design. Among these are: structure type, deformability of the substrate, environmental aspects and maintenance availability [4]. Such characteristics affect the selection of these components: tiles’ type, sizing of joints and choice of bedding and filling materials.

The most common defects detected in ceramic external wall claddings can be divided in four categories, each of them including several defects [3]: (i) aesthetic defects; (ii) cracking; (iii) joints deterioration; (iv) adhesion failure. However, not all anomalies have the same consequences for the cladding system service life: some of them affect the façade decay more than others. For example, aesthetic anomalies usually do not contribute to the loss of performance of the cladding, but only involve a visual degradation; it is clear that such anomalies do not have the same severity as cracks or detachment. Furthermore, the consequences of each defect are also related with the component affected. In fact, the same anomaly can concern different parts of the cladding, thus being less or more severe. For example, cracking can affect only the outer layer (tiles) or the entire cladding system (tiles, bedding layer and, more occasionally, the substrate). A study performed by Silvestre and de Brito [29] examined the causes of the anomalies that affect ceramic claddings and developed a matrix of correlation between anomalies and related causes. This tool is characterised by its simplicity, but also by practicality and completeness.

The identification and quantification of the defects of the ceramic external wall claddings are important to evaluate the overall degradation level of the buildings (analysed in the next section).

3. Degradation classification and definition of the end of the service life

The method adopted in this study for the assessment of the degradation level has been developed by Gaspar and de Brito [11,12] and has been successfully applied by other authors [3,9,27,28]. Regardless of the sample size, the method is based on the evaluation of the performance of buildings elements. In this model a numerical index is defined that provides an estimate of the overall degradation of the claddings based on data acquired on site. This numerical index, named severity of the degradation, is determined by the ratio between the weighted degraded area, considering the extent and condition of defects detected, and a reference area, equivalent to the total cladding area having the highest possible level of degradation, as shown in Eq. (1) [11,12].

$$S_w = \frac{\Sigma(A_n \times k_n \times k_{a,n})}{A \cdot \Sigma(k_{\text{max.}})} \tag{1}$$

where S_w represents the normalized severity of the degradation of the façade, expressed in percentage, A_n the area of cladding affected by defect n, in m^2, k_n the anomalies n multiplying factor, as a function of their degradation level (between 0 and 4), $k_{a,n}$ the weighting coefficient correspondent to the relative weight of each anomaly, A the total area of the cladding, in m^2 and $\Sigma(k_{\text{max.}})$ the sum of the weighting coefficients equals to the highest level of degradation of an A cladding area; it has the value of 15 (3 + 4 + 4 + 4 – aesthetic defects, cracking defects, joint deterioration defects, detachment defects).

The survey on the ceramic façades’ includes the analysis of the façade condition and information concerning the coatings durability. The collection of information concerning the façade condition includes: (i) the façade’s size; (ii) description of the defects detected; (iii) the location and extension of the defects in the façade; (iv) definition of the gravity of the defects detected to be