Engineering Failure Analysis 83 (2018) 141–155

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Analysis of the influencing factors of external wall ceramic claddings' service life using regression techniques

Jéssica Souza[a], Ana Silva[b,*], Jorge de Brito[b], Elton Bauer[c]

[a] Civil and Environmental Engineering Department, PECC - University of Brasília, Campus Darcy Ribeiro, Asa Norte, 70910-900 Brasília, Brazil
[b] Department of Civil Engineering and Architecture, IST - Technical University of Lisbon, Av. Rovisco Pais, 1049-001, Lisbon, Portugal
[c] Civil and Environmental Engineering Department, PECC - University of Brasília, Campus Darcy Ribeiro, Asa Norte, 70910-900 Brasília, Brazil

ARTICLE INFO

Keywords:
Buildings' façades
Durability
Service life
Adhesive ceramic external wall claddings
Regression techniques

ABSTRACT

Buildings' façades play an important role in the protection of buildings and, therefore, their envelope system must comply with its function, fulfilling the performance requirements and withstanding the external environmental agents during the buildings' life cycle. Although the degradation of buildings is a natural process, there are various factors that influence their durability. The assessment of the buildings' durability and service life is a research field that brings together several knowledge areas, e.g. construction technology, building physics and meteorology. This paper intends to identify the main factors that influence the durability of adhesive ceramic external wall claddings, developing models to predict their service life that involve these variables. The service life prediction models proposed in this study are defined based on simple and multiple regression analysis, both linear and nonlinear. The proposed models are defined based on the in situ evaluation of the degradation condition of 96 ceramic claddings of residential buildings in Brasília. The methodology led to coherent results and its applicability and adequacy to predict the service life of ceramic claddings in Brasília is demonstrated. The knowledge regarding the influence of the façades' characteristics on their durability is extremely useful to designers, in order to improve the selection of a given cladding for a specific situation, and to managers and stakeholders, allowing the optimization of maintenance policies and thus increasing the sustainability of the solutions adopted during the buildings' life cycle.

1. Introduction

The concern regarding the quality and safety of buildings and the need to optimize the use of scarce resources, improving the economic and environmental sustainability of the construction industry, encouraged the study of the durability and service life of buildings and components. Therefore, several studies have been put forward in the last decades, developing tools to assess the durability of buildings' components through the analysis of their performance and their degradation processes over time [1–4]. The assessment of buildings' durability is a research field that brings together several areas of knowledge, e.g. construction technology, buildings' physics and meteorology. Despite the difficulty of making accurate estimates of the buildings' service life, Frohnsdorff et al. [5] refer that, when the estimations are based on the knowledge acquired through these areas of expertise, the results obtained are extremely valuable to improve the buildings' performance, reducing defects' frequency during the buildings' life cycle. Moreover, the information related with the diagnosis of the buildings' pathology, and the data regarding their service life is crucial for the establishment of maintenance policies, thus allowing reducing and avoiding the presence and evolution of defects, and consequently

* Corresponding author.
E-mail addresses: jss.siqueira@gmail.com (J. Souza), anasilva931@msn.com (A. Silva), jb@civil.ist.utl.pt (J. de Brito), elbauerlem@gmail.com (E. Bauer).

http://dx.doi.org/10.1016/j.engfailanal.2017.10.005
Received 7 July 2017; Received in revised form 3 October 2017; Accepted 7 October 2017
Available online 07 October 2017
1350-6307/

reducing the maintenance and rehabilitation costs.

Façades play an important role for the buildings' protection and performance, and therefore the envelope system of the building must comply with its function and withstand the external environmental agents, such as rain, wind, solar radiation and pollutant emissions, during the buildings' life cycle [6,7]. Although the degradation of buildings and their components is a natural process, there are several factors that influence this process, such as the use of adequate materials, the quality of design and execution, the environmental exposure conditions, the conditions of use and the maintenance frequency [2,8,9].

This research intends to establish viable mathematical models of the degradation mechanisms. However, the conjugation between the knowledge concerning mathematical functions and the buildings' performance over time, to establish service life prediction models, is a difficult challenge since the degradation process is a complex phenomenon, not fully understood, which encompasses several degradation agents that act simultaneously and synergistically. Therefore, the lack of knowledge of the degradation behaviour of a specific element of a given building, which involves the response of materials and components to environmental exposure conditions, is the main barrier to develop accurate service life prediction models [10,11].

This study intends to identify the main factors that influence the durability of adhesive ceramic external wall claddings applied in the buildings' façades, applying statistical regression analysis to propose a model to predict the service life of these claddings. For that purpose, a sample of 96 cases studies is analysed through an extensive fieldwork, based on visual inspections and complementary diagnosis techniques performed to residential buildings in Brasília, collected by team of Materials Testing Laboratory of the University of Brasília (LEM/UnB). The overall degradation level of the ceramic claddings is estimated using a numerical index, called severity of degradation (S_w). Simple and multiple regression models are proposed, with linear and nonlinear formulations, which allow identifying the most accurate model to predict the service life of adhesive ceramic external wall claddings of buildings, identifying the most relevant parameters for the explanation of the degradation phenomena of these claddings.

2. Background

In the last decades, several studies have been developed on the subject of durability and service life of buildings and components, proposing various methods to evaluate the degradation pattern of the buildings' elements, as well as identify the necessity and urgency of maintenance actions, thus improving the durability and sustainability of the building component under analysis [1,3,10,12].

The degradation process occurs naturally over time, and begins as soon as the building or component is subjected to the environmental degradation agents' action. However, the pattern and rate of this process depend on a set of factors, e.g. inadequate design and execution [10,13,14]. Therefore, the knowledge of the influence of these factors on the degradation process allows avoiding premature degradation and mitigating the presence of some defects.

According to [15]), the representation of the evolution of the degradation phenomena, based on real data analysis, allows developing service life prediction methodologies and, consequently, identifying the instant after which the system's reaches the end of its service life. Although the relationship between performance and degradation is not direct, Flores-Colen et al. [16] refer that the loss of performance of the building's components is characterized by an increased degradation condition. Shohet et al. [13] proposed four typical degradation patterns (linear, “convex-shaped” pattern, “concave-shaped” pattern and “S-shaped” pattern) to describe the loss of performance of the buildings façades over time according to the deterioration mechanisms. These degradation paths are described in a graphical way, expressing the pace at which the systems lose their functional and physical capacity to fulfil the performance requirements.

Various authors [3,17,18] adopted a polynomial curve, in an “S-shaped” pattern to illustrate the degradation process of external wall claddings. This curve, whose intensity changes over time, has three stages: i) the first one concerns premature degradation, which occurs, at a fast pace, due to defects originated by the quality of the materials or/and construction; ii) the second stage is a period of maturation, which occurs due to natural ageing process associated with the exposure to environmental degradation agents, being influenced by the use conditions and the frequency of maintenance actions; and iii) the third stage is the final stage, where the degradation path accelerates due to the synergy between different degradation agents and the simultaneous presence of defects.

These degradation curves, based on simple regression analysis, assess the degradation as a function of a unique variable (i.e. the age of the cladding), thus analysing the degradation process in only one dimension. However, time is not the only factor that influences the deterioration process. Each building and component is a unique prototype, and therefore, the different function, requirements and exposure, use and maintenance conditions should be considered in the evaluation of the component's service life [3,19]. The multiple regression analysis is a relevant and widely used statistical technique that allows identifying the most relevant variables for the explanation of the degradation of adhesive ceramic claddings; moreover, this technique allows estimating the service life of these claddings, analysing the degradation process at a multidimensional level, i.e. allows encompassing all the relevant variables in the mathematical formulation at same time.

3. Methodology adopted to determine the overall degradation condition of ceramic claddings

To apply statistical techniques to model the degradation process of ceramic claddings and to predict their service life, it is crucial to quantify the degradation condition of these claddings. There are various methods to assess the degradation state of buildings and their components [3,10,12,13,20,21]. In the majority of these studies, the degradation condition of the element under analysis is evaluated through in situ visual inspections, based on a qualitative and quantitative analysis of the defects observed, their extent and severity. In this sense, several classification systems are proposed, which consist in classifying the defects according to a scale of