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Maintenance planning of facades in current buildings

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HIGHLIGHTS

- Inspections of 30 buildings' facades in service conditions in a coastal area.
- Pathology in each maintenance-source element.
- Proactive maintenance plan for facades in current buildings.
- Methodology to rank the priority of the interventions.

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ABSTRACT

A methodology to implement a maintenance plan for buildings' facades is presented. The theoretical proposal is based on relevant literature and was applied and adjusted in a survey of 30 buildings. It considers a three-step methodology: detailed inspection, post-inspection maintenance actions, and proactive maintenance planning. The proposal is based on systematized procedures, involving detailed information on the facade. A methodology to use multi-criteria to prioritize maintenance actions is suggested, namely environmental; extension; consequences; and safety requirements. Considering four types of maintenance operations, they are used to solve the main anomalies in facades (aesthetical, adhesion loss and fastening defects).

1. Introduction

The absence of adequate building maintenance policies, led to the current degradation of the housing stock and to the early ageing of building's elements, including facades' elements. According to ISO 15686-1 [1], maintenance combines all technical and administrative actions, including supervision, that are necessary to reinstate an element to a condition in which it fulfills adequate performance requirements. During a building's service life, costs can occur at three stages: design, construction and use and maintenance. Although design and construction costs are subject to great concern, according to Perret [2], about 75–80% of costs occur during the use and maintenance stage, for a building with a service life of 50 years. The economic impact proves the importance of building maintenance. If maintenance plans were implemented at the design stage with predefined performance levels, they would allow optimizing global costs and fulfilling user's satisfaction through the knowledge of the buildings' in-service behaviour, and its degradation mechanisms and agents, as well as the type and main causes of anomalies. A maintenance plan is an additional document to the project which anticipates proactive maintenance actions, according to different time ranges, with minimal interference in the regular functioning of the building [3,4]. It should not eliminate the possibility of unforeseen corrective maintenance actions and it should be periodically updated.

The building envelope is determinant for the comfort level of a building. In this context, facades define the building's appearance, simultaneously working as a barrier to external aggressions and a communication element between inside and outside (through light, visibility and ventilation). Facades play a fundamental role on the building's performance, being a complex system to design, build and maintain [5,6]. Facades are composed of walls, openings and different types of claddings (continuous or discontinuous, directly or indirectly fastened). Identifying the facade's components is useful to determine the maintenance needs, according to the most probable anomalies and causes. To evaluate the facade's durability performance, it is necessary to know the aggressive

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agents to which the facade is exposed [6]. Humidity is the main cause of anomalies in facades, but loads, stress, deformation, radiation, extreme temperatures, dirt, pollution, salts, bacteria, plants, mould, insects, birds, to name a few factors, combined with poor constructive details, may also significantly affect the facade's performance. They may originate stains, cracks, detachment, cohesion loss and fastening defects. The facade of a building requires periodic maintenance like all the other major systems within the building; although the roof is widely recognized as needing preventive maintenance, few owners understand that the vertical closure also requires a similar commitment to preventive maintenance [7]. According to the research of Pires et al. [8], the main anomaly in painted rendered facades is staining resulting from dirt deposits on the wall surface. Results on adhesive ceramic tiling facades are similar [9], as mainly two anomalies were detected: "staining, change of colour or brightness of the tiles" and "change of colour of joints", both related with the effect of dirt deposits. In facades with natural stone cladding, colour variations are also the most frequent anomalies, according to Neto and de Brito [10]. With a comprehensive knowledge of a facade, it is possible to plan proactive maintenance operations, such as inspection, cleaning, surface protection treatment, local repair, local replacements and minor and major interventions [11].

Some countries have extensive studies on the definition of building's maintenance plans, and legislation to oblige builders and/or homeowners to implement them [4,11–16]. In Europe, mainly three Mediterranean countries were considered in this research: France, Italy and Spain [12,14,16]. In France and Italy buildings' maintenance plans are more detailed and meticulous than in Spain. In France, there is a great focus on inspection, recording and processing all the inspection information; it is the only country, out of these three, that regards costs planning of maintenance operations. As for Italy, buildings' maintenance plans refer to new buildings and expect the active involvement of the users and building managers, through user's manuals with instruction and respective planning of actions. In Spain, buildings' maintenance plans are similar to those of Italy, adding the mandatory identification of those responsible for the building's construction and for the installed equipment.

This study proposes a structured methodology to implement a facades' maintenance plan, based on the analysis of 30 buildings' facades. The proposed methodology may be adjusted to buildings at the design stage or existing buildings, towards extending their service life with satisfying performance levels. This approach will allow regular in-time maintenance actions on facades with a better use of economic resources. The paper describes the methodology in the context of the literature, and characterizes the sample of the buildings facades' survey and main anomalies. The applied theoretical principles are also described, namely the criteria to prioritize maintenance actions and the probable post-inspection maintenance actions. Results are discussed considering both a theoretical proposal of maintenance operations and an adjusted one. The conclusions section presents the main findings on planning proactive maintenance actions.

2. Methodology

2.1. Context methodology

Throughout a building's service life, its constructive elements should present the performance levels defined at the design stage, contributing to the fulfillment of the user's needs [5].

Planning maintenance operations is only possible after analyzing the building's elements performance, their predicted service life, maintenance needs, degradation models and the most frequent anomalies. Subjective factors also influence decision-making at this stage, such as the user's acceptance of the plan, according to their needs and expectations [17]. Palmer [18] divided maintenance operations into proactive actions (preventive and predictive) and corrective actions.

Preventive maintenance strategies anticipate degradation signs, acting before any significant physical or functional change in the building's elements occurs. Through regular maintenance actions, unexpected anomalies are avoided, extra work is minimized and there is minimal interference in the building's use. To plan preventive actions, it is necessary extensive information on each element, concerning service life, in-service performance, degradation patterns, adequate maintenance operations and costs. This maintenance strategy is highly associated with a theoretical behaviour, which may not correspond to real in-use conditions and thus should be monitored [11,19].

Predictive maintenance strategies, on the other hand, are based on inspections to assess the maintenance needs of each element. These inspections are planned and maintenance actions are performed according to the inspection results on the elements' degradation condition. Predictive strategies are also based on a vast number of technical and statistical information about the behaviour of building's elements [20]. Predictive maintenance actions require qualified experts and valid diagnosis methods, in order to evaluate the functional parameters, anomalies symptoms and related causes. This strategy should increase the capacity to determine when an intervention is needed, although prioritizing maintenance operations still depends on the perspective of decision-makers while assessing degradation conditions [21,22]. In contrast, corrective maintenance responds to advanced degradation and emergency actions, intervening after anomalies' claims, putting sometimes the life or integrity of users in danger. Although, in the short-term, a corrective maintenance strategy may seem cheaper, it leads to high costs, since in-depth urgent interventions are needed resorting usually to after-hours outsourced maintenance services [11].

This study intends to set up a maintenance plan for the facades of current buildings, based on the analysis of in-service facades behaviour. A maintenance plan, at the design stage, is an additional document to the project, which intends to maintain performance levels, functionality and efficiency of the building, rationalizing costs and resources with minimal interference in the regular use of the building [3]. If implemented in existing buildings, a maintenance plan should be based on a detailed evaluation of the in-service building's degradation. This plan is fundamental to implement proactive maintenance strategies during the service life of the building's elements. Initially, the most probable preventive actions and inspections (predictive) are defined. Through this process, considering an adequate level of unpredictability, corrective maintenance actions should also be accounted for. In the long term, a maintenance plan should be regularly updated. A maintenance plan should contain all the essential information to prevent and monitor the performance of the building's elements [4]: it should list all the maintenance-source elements and expected service lives; maintenance operations routines; in-service degradation mechanisms; technical maintenance recommendations; resources; costs; and interventions' records.

To efficiently manage resources and costs, a maintenance plan for facades should be well structured and documented. To implement the proposed maintenance plan, there are three main steps and corresponding actions to accomplish them:

(i) detailed inspection (existing buildings);
   a. identifying every facade element subject to maintenance (maintenance-source elements (MSE), described in section 2.2.1);