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Study of the prevalence of critical and conflict-prone points in facades

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A B S T R A C T

Facades are one of the most important areas of buildings, where one can find a large quantity of interacting layers, with multiple critical points emerging. This study concerns the complaints made by users in court, resulting in a total of 1374 damages having been analysed and quantified, grouped in 17 different types. The various underlying causes (29 in total) were also determined, as well as the building types and elements in which anomalies occur most frequently. These damages were grouped by similarity, and their prevalence was calculated in order to inform technicians with regard to which aspects should be improved in both design and construction.

1. Introduction

Internationally, several studies related with the pathological characterization of the buildings' envelope have been put forward in the last decades [1,2,3,4]. The inspection and diagnosis methods developed in the literature allow identifying accurately the different anomalies detected, evaluating their severity and extent [5]. The inspection systems comprise a classification system of anomalies, causes, testing methods, repair techniques, and correlation matrices. These systems are validated in an extensive inspection campaign, through visual inspections and applying additional *in situ* diagnosis techniques, thus characterizing the pathological situation of the building's envelope, as well the materials applied and the characterization of the cladding system inspected [6].

The anomalies or defects in the buildings' envelope result from a combination of causes and aggressive factors, which usually occur simultaneously, leading to their loss of performance over the time. Currently, the most important causes of defects are related with design or execution errors, external mechanical actions, environmental actions or faulty maintenance [7]. The correlation matrices of anomalies–probable causes allow defining the adequate diagnosis and repair techniques for each anomaly considered. Furthermore, the quantification of the frequency of causes and the identification of the most common defects in each element of the envelope allow establishing the most adequate strategy to mitigate the presence of these defects (proposing some measures that must be implemented in the design, execution and maintenance phases of ceramic tiling systems in order to prevent the occurrence of anomalies), also adopting some preventive measures related with the causes [8].

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In some Latin American countries, quantitative studies [9] on the influence of age and climatic agents in facade deterioration processes were performed, concluding that the highest degradation levels were found in the walls of ancient buildings and those more exposed to solar radiation.

The inspection processes in some cases depend on a set of tests and on diagnosis reliability through measuring and monitoring parameters. The demonstration of the water penetration in facades using *in situ* tests is an adequate procedure to measure the action of damp on this constructive element [10]. The studies on the water penetration resistance of the walls' constituent elements (claddings and masonry) are also important, namely in terms of the various construction types and their influence on potential infiltrations [11].

Facades are also important in terms of the energy demands of the buildings and their conservation state has an influence on their thermal behaviour. A system has been developed [12] in which the conservation state of these elements was quantified, classing and analysing them in terms of their anomalies.

In these diagnosis systems, each anomaly identified is classified according to the corresponding repair urgency. The need of intervention ranges from immediate intervention (6 months maximum delay) for the more serious defects (*e.g.* the detachment of stone elements) to situations in which it is only necessary to monitor the anomaly's evolution, essentially at the next periodic inspection [8]. Therefore, the information obtained using these tools is extremely relevant, functioning as a support instrument for the informed definition of maintenance and repair strategies, allowing scheduling the periodicity of the maintenance actions, optimizing the use of funds and resources.

The main objective of this study is the identification of the most frequent anomalies in facades, identifying the parameters that characterize them in an unequivocal manner: the “constructive element”, the “damage produced” and the “cause behind it”. A new methodological process is proposed, whose data collecting procedure is unprecedented in the literature: court complaints. The research was applied in relatively new buildings (less than 15 years old at the time of the complaint), which makes the results easily extrapolatable to other environments, through the comparison of the critical and conflicting points obtained.

2. Methodology

The construction sector is one of the Spanish sectors witnessing the highest number of complaints. Construction defects are perceived as one of the main causes of low productivity in projects [13] and of additional costs [14].

The statistical study of these complaints and the detailed analysis of the underlying anomalies can lead to data to determine which types of anomalies are the most frequent in this country. It is for this reason that this research is centred on this reality, specifying values in one of the most significant parts of buildings: facades.

This analysis of the current Spanish panorama has been promoted and supervised by the Musaat Foundation and relies on the records of the civil responsibility insurances subscribed by the technical architects and surveyors [15], which have the necessary condition of having court complaints in the years 2008, 2009 or 2010, with sentences taking place before June 2011 [16]. Records drawn from adjoining buildings, as well as complaints not originating in anomalies of the building, were not included in this research.

1166 records were used (one for each building analysed), making it necessary to establish a protocol for data collection resorting to a software program, which incorporated the figures collected via the perusal of many thousands of pages, in a process that lasted 3 years. From among these, and following the corresponding reading and verification, a total of 1374 damages related to facades were compiled.

This article is based on “National Statistical Analysis on Construction Anomalies: years 2008 to 2010” [17] which scoped all Spanish regions. The sample covers the totality of buildings' constructive areas, classified as: foundations, structure, roofs, facades, *etc.*

The general volume of the parameters dealt with to carry out this research was varied and extensive. All of the data of the 3 above-mentioned years were analysed, for the entirety of the Spanish territory and for all complaints filed. As a grand total, the study scoped 11 distinct constructive areas, 46 types of anomalies, 92 types of causes and 59 constructive elements. In the case of facades, this has resulted in checking 17 types of damages, 29 types of causes and 9 construction elements — belonging to the two zones that facades were divided into: envelope (solid part) and framing (hollow part). The facades analysed here were conventional (external ceramic brick with thermal insulation inside an air-box).

The study is based on the interrelation of parameters “Zone–Element–Damage–Cause”, which constitute the “quadrinomial” that expresses and characterises what is designated the “pathological process”. For the identification of this process, this study relied on the data fields of a study from the 1980s, given the conceptual similarity between some of their aspects [18].

After typifying all the parameters above-mentioned, they are codified: “COD.-Z” for zones, “COD.-e” for construction elements, “COD.-D” for damages and “COD.-C″ for causes. The parameters were ranked from greater to minor as a function of their frequency (percentage of occurrence relative to the research universe in all constructive areas). For example, the most frequent damage was “Infiltration humidity” with code D01. In this paper only the parameters that occur in facades were used, and that is why the numbering is not continuous.

2.1. Classification of zones and their elements

As indicated above, the zones or sub-areas in which facades have been divided for study and analysis are those shown in Table 1. Thus, for the two zones shown (EE and F), a total of 9 different constructive elements were analysed.

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