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Mapping of pathological manifestations in reinforced concrete beams: a case study in public school buildings

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ABSTRACT

This work focused on the mapping of pathological manifestations in exposed reinforced concrete beams, detected in some buildings of the Faculty of Science and Technology (FCT/UNESP), on the campus of Presidente Prudente, São Paulo. For this, a fieldwork was carried out, which consisted of obtaining digital images of the anomalies and annotation/recording in which each one of them is located. With the data, a table was elaborated that highlights the types of pathological manifestations present in the beams of each image, by means of geometric shapes of different colors with a legend. As for the pathological problems identified, the most common anomalies in the buildings are cracks and reinforcement exposure, showing how the absence of a maintenance and/or repair program for these structural elements can compromise both the aesthetics and the useful life of these buildings.

Keywords: Anomalies, Degradation, Structural system.

INTRODUCTION

According to Gonçalves (2015), the term "pathology" in the context of civil construction is similar to the definition present in medicine, which considers the origins, symptoms, and nature of diseases as an object of study. Thus, pathological anomalies can be understood as all manifestations that, when present in the life cycle of a building, end up affecting the performance for which it was expected of the building and its various parts (subsystems, elements and components).

According to ABNT NBR 15575-1:2013, pathological manifestation is defined as an abnormality that is evident in civil construction in cases of design failures, production processes, execution processes, or even during use and maintenance, as well as in cases of anomalies not resulting from the natural aging process. Thus, pathological manifestations are those that reduce the expected durability of a construction material or structural element, resulting in construction failures.

Thus, just as the symptoms of diseases can arise anywhere in the human body, pathological anomalies can exist in all the constructive elements of a building. Specifically in the case of beams, they are defined by Camacho (2015) as a bar-shaped element, which works predominantly with bending and shear forces and has the function of overcoming spans.

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Concomitantly, the need for a construction material that adequately supports these efforts becomes notorious. To this end, reinforced concrete is one of the most used options in Brazil, which is justified by Botelho and Marchetti (2015), since concrete by itself has a low tensile strength, especially when larger spans are used, making the addition of steel bars of paramount importance to help increase this strength. Thus, it is notorious how the union between the simple concrete and the metallic reinforcement makes this material resistant both to the tensile forces, by means of the main reinforcement, and to the shear forces, by means of stirrups.

BRIEF REPORT ON PATHOLOGICAL MANIFESTATIONS

Among the pathological manifestations that may arise in reinforced concrete beams, the following anomalies were studied in this work: cracks, light and dark spots, reinforcement exposure and displacements.

In view of this, Gonçalves (2015) defines cracks as openings that normally affect the superficial part of the structural element, which allow the penetration of harmful agents to the structure, which can occur in beams due to bending, shear or torsional forces.

According to Helene (1992), cracks occur due to bending forces in cases of unexpected overloads, deficient and/or insufficient reinforcement both in design and execution; due to shear forces in cases of unexpected overloads, deficient and/or insufficient stirrups in design or execution and/or concrete with inappropriate strength; and due to torsional forces in cases of unexpected overloads, deficient and/or insufficient reinforcement also in the design or execution.

In addition, according to Barreto and Parente (2018), deplating is one of the main implications of the corrosion process in concrete reinforcement, since the products formed during this process occupy a larger volume than that of the original steel (from 3 to 10 times more), and this increase in volume allows the emergence of high internal stresses against the surrounding concrete, generating its detachment in the direction parallel to the corroded armor. Thus, the thrusting of the concrete due to the increase in the section of the steel reinforcement, which is caused by the infiltration of water and, consequently, by the corrosion of this material, is interpreted as detachment.

According to Helene (1992), another manifestation related to reinforcement corrosion is the appearance of reddish-brown spots or even green tints on the upper part of the concrete. In this case, the diagnosis is usually associated with the presence of aggressive agents, such as chlorides, which impregnate the structure or are involuntarily incorporated into the concrete.

Another type of stain that can be mentioned are efflorescences, which are defined by Rodrigues (2013) as those that surface on the surface, originate in the laying mortar and alter the appearance of the coating. They present themselves as powdery deposits or incrustations, and can cause changes in the color

of the surfaces of the coatings, manifesting themselves through whitish, grayish, greenish, yellowish or black tones.

And, finally, Cascudo (2005) apud Gonçalves (2015) defines the corrosive process of reinforcement in reinforced concrete as coming from the deterioration of the existing metallic phase, which causes, consequently, the reduction of the cross-section of steel bars. This process can be justified by Helene (1992), who considers the following factors as the main responsible for the corrosion process: concrete with high permeability and/or high porosity, inadequate covering and/or poor execution.

OBJECTIVE

The general objective was to map the pathological manifestations detected in the exposed reinforced concrete beams of the buildings belonging to the Faculty of Science and Technology (FCT/UNESP), campus of Presidente Prudente – SP.

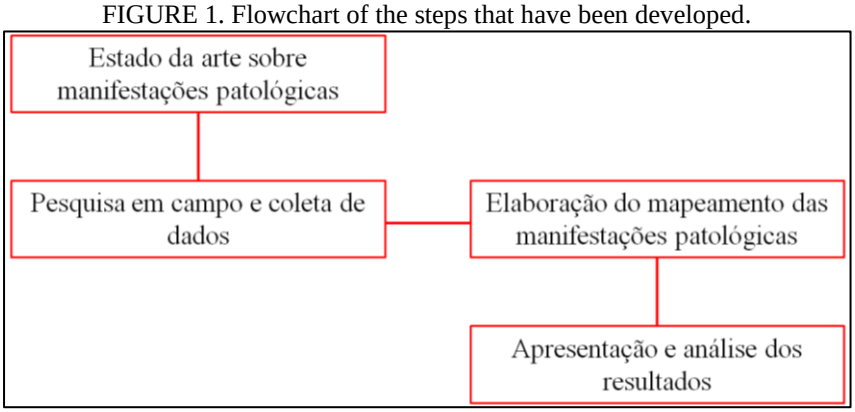
In addition, due to the nature of the work, it is emphasized that the merit of the performance of the professionals and companies responsible for both the execution and the projects of the buildings under study was not part of the scope, focusing only on the mapping of anomalies that can be observed.

METHODOLOGY

The method adopted in the study was based on Silva et al. (2022) – a case study – which offered, according to Pereira et al. (2009), the expansion of vision, combined with the learning of the individual from their integrity as well as in their context. In other words, it allowed the creation of a dynamic analysis of the various processes, constituting a specific condition of contribution to the generation of scientific principles.

In view of this, the flowchart of the steps that were developed during the fieldwork and its unfolding are presented in Figure 1.

FIGURE 1. Flowchart of the steps that have been developed.



Thus:

1st Stage: Study of the generalities of the pathological manifestations that occur in reinforced concrete structures, in order to obtain technical support for the development of the following activities.

2nd Stage: On-site inspections of the buildings under study, in order to identify (symptomatology) the pathological manifestations existing in the beams and their subsequent mapping.

3rd Stage: Presentation of the mapping of the pathological manifestations identified in the beams, containing their general aspects. The mapping was presented using a legend, based on Silva et al. (2022), which identified each type of anomaly detected (Figure 2). A semi-professional Nikon camera (model COOLPIX P600) aided by an aluminum tripod was used at this stage. Regarding the level of inspection carried out, as in Silva et al. (2022), the classification presented by IBAPE (2012) was adopted, summarized in Table 1, in which the technical characteristics of the building are considered, combined with the maintenance and operation plan.

FIGURE 2. Legend to be used in damage mapping.

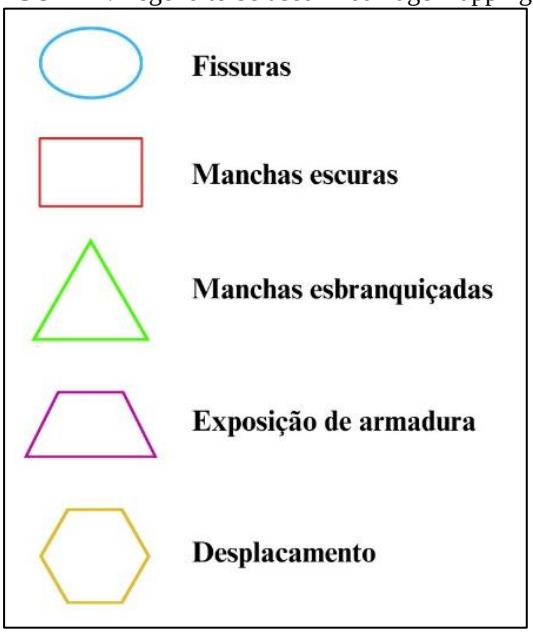


TABLE 1. Classification according to the level of inspection.

Level	Considerations
1	"Buildings considered to have reduced technical complexity, maintenance and handling of elements and construction systems/Buildings with a preventive maintenance program considered simple or non-existent".
2	"Buildings considered to be of medium technical complexity, maintenance and handling of elements and construction systems/Buildings with multiple floors, with or without a preventive maintenance program".
3	"Buildings considered to be highly technically complex, maintenance and handling of elements and construction systems/Buildings with multiple floors or with construction systems equipped with automation".

Fonte: IBAPE (2012).

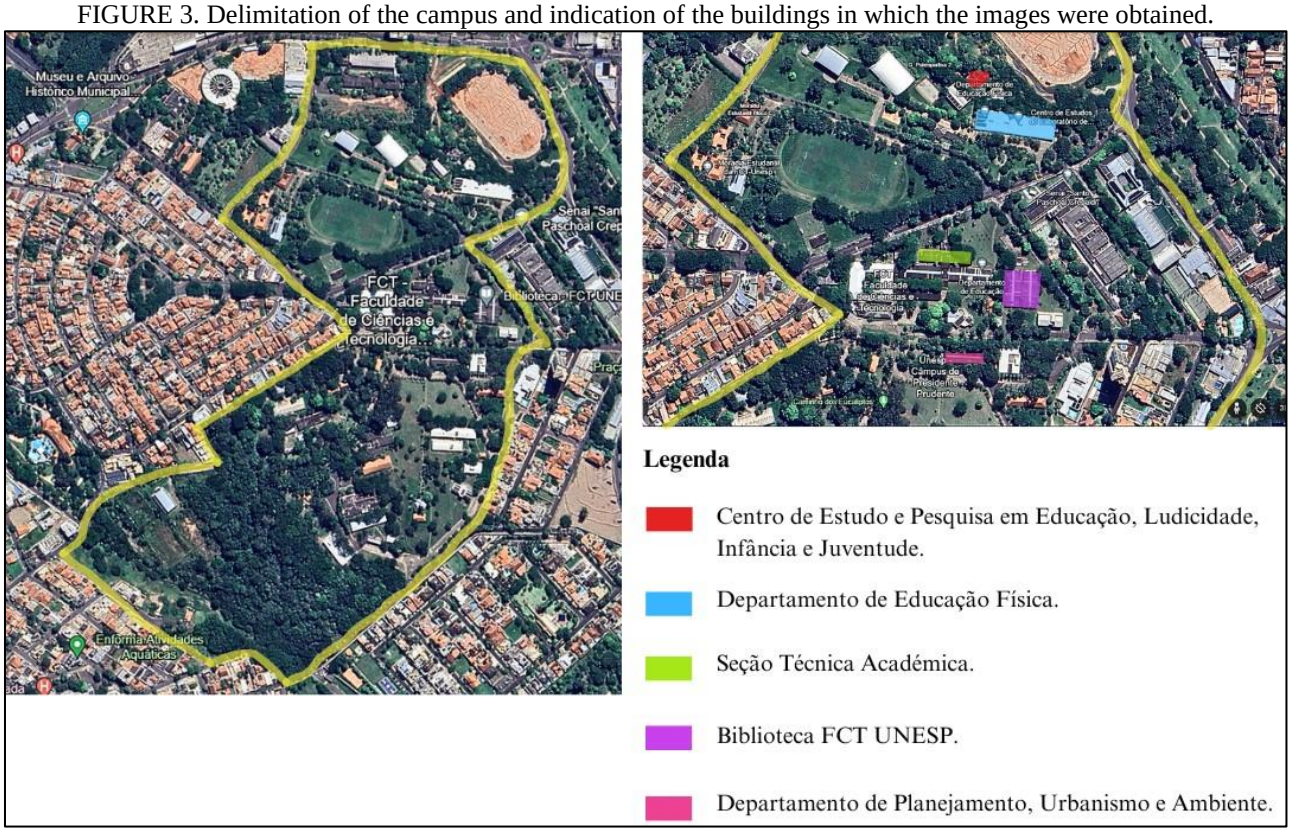
4th Stage: Presentation of the mapping of the identified pathological manifestations, combined with their analysis by means of a quantitative graph that was generated with the aid of Excel software. It should be noted that at this stage of the research, considered initial, only the mapping of anomalies (per element analyzed) was highlighted (cracks, displacements, exposure of reinforcement, stains), and it was not part of the presentation of the probable causes and possible repair solutions.

Aiming to contribute, even if in an incipient way, to the improvement of the conditions of public buildings through the exposure of construction damages, the work in question can help in the search for answers involving the following theme: 'what are the main pathological problems identified in the reinforced concrete beams of FCT/UNESP buildings?'

DEVELOPMENT

Taking into account the pathological manifestations found at FCT/UNESP, Figure 3 presents, respectively, the delimitation of the campus and the indication of the buildings in which the images were obtained.

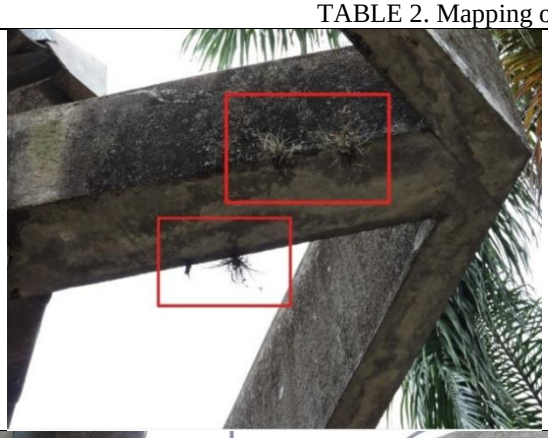
FIGURE 3. Delimitation of the campus and indication of the buildings in which the images were obtained.

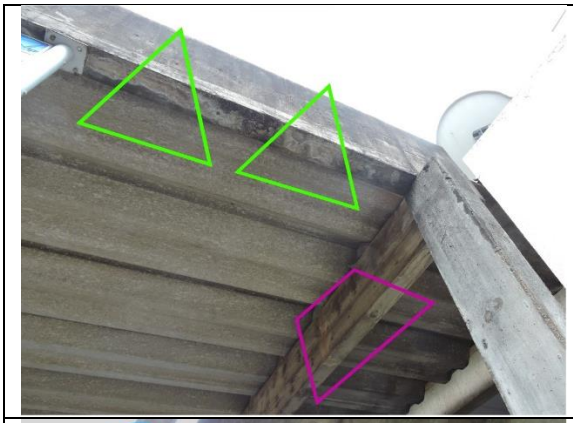
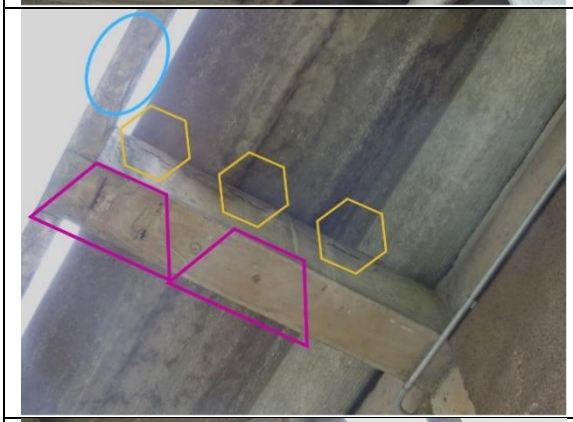
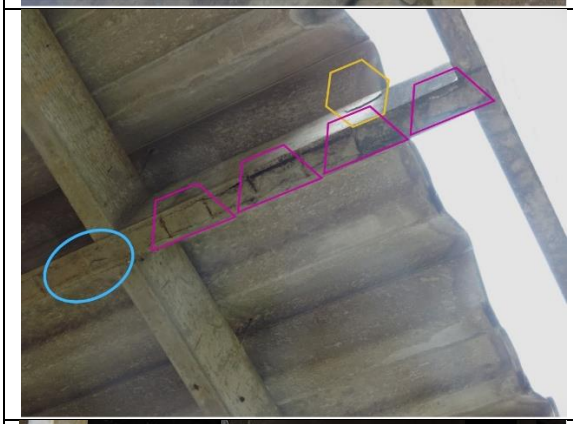
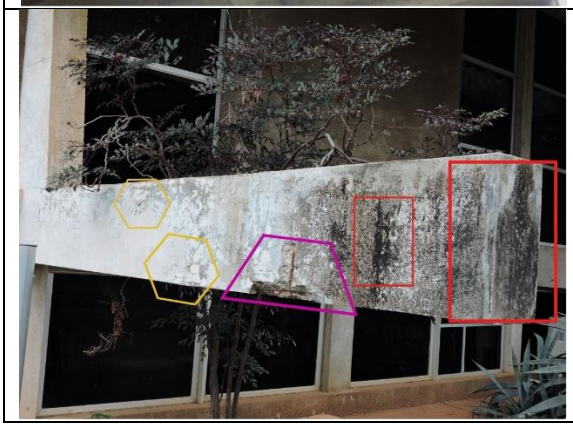


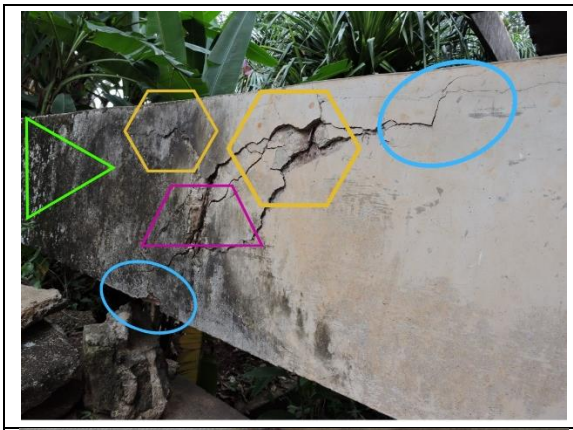
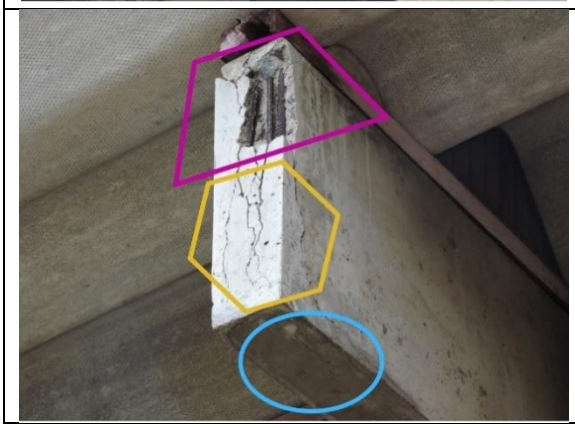
Source: Google Maps – edited.

Thus, although there is a higher number of pathological manifestations in concrete beams at FCT/UNESP, 9 images considered more relevant and presented in Chart 2 were selected for the study in question.

TABLE 2. Mapping of pathological manifestations.

	Building: Center for Study and Research in Education, Playfulness, Childhood and Youth. Pathological manifestation present: **Manchas escuras**
	Building: Center for Study and Research in Education, Playfulness, Childhood and Youth. Pathological manifestations present: **Fissuras** **Manchas escuras**
	Building: Department of Physical Education. Pathological manifestations present: **Fissuras** **Manchas escuras**

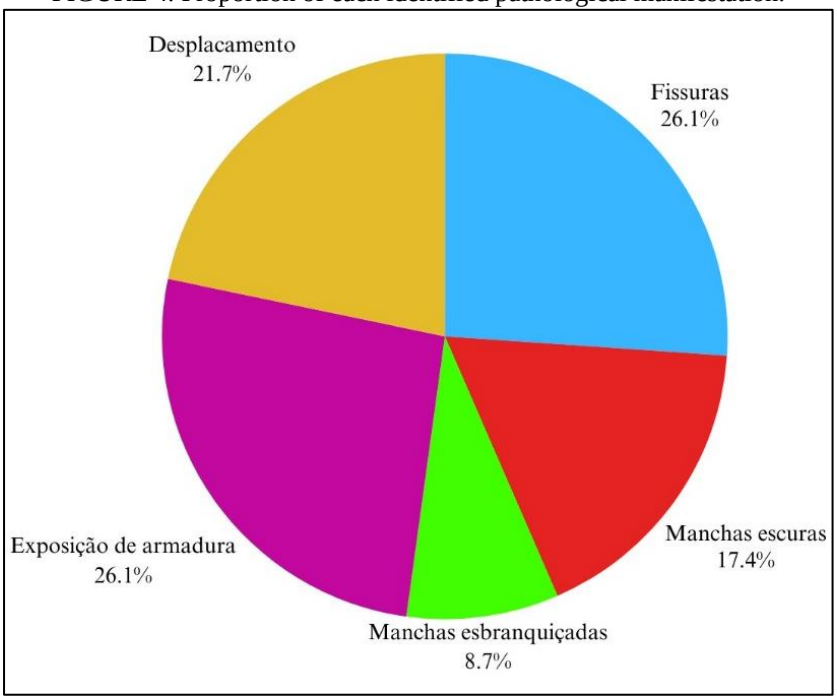
	Building: Academic Technical Section. Pathological manifestations present: **Manchas esbranquiçadas** **Exposição de armadura**
	Building: Library. Pathological manifestations present: **Fissuras** **Exposição de armadura** **Desplacamento**
	Building: Library. Pathological manifestations present: **Fissuras** **Exposição de armadura** **Desplacamento**
	Building: Library. Pathological manifestations present: **Manchas escuras** **Exposição de armadura** **Desplacamento**

	Building: Library. Pathological manifestations present: **Fissuras** **Manchas esbranquiçadas** **Exposição de armadura** **Desplacamento**
	Building: Department of Planning, Urbanism and Environment. Pathological manifestations present: **Fissuras** **Exposição de armadura** **Desplacamento**

By way of observation, it should be noted that in all images there was the presence of dark spots, only those that are most prominent were marked.

Different pathological manifestations were identified in concrete beams of FCT/UNESP and, from the analysis of the data established in Chart 1, a graph was generated (Figure 4) which indicates the proportion of pathological anomalies identified in the buildings under study.

FIGURE 4. Proportion of each identified pathological manifestation.



In view of this, it can be seen that Figure 4, with the exception of whitish spots, the proportion among the anomalies detected in the buildings is relatively similar, which can highlight the cracks and the exposure of reinforcement, which appear more frequently.

Thus, taking into account Chart 1 presented in the sub-item methodology, it is possible to classify all the pathological manifestations under study as level 1 of inspection, since all the buildings in which they are presented have only one floor and low technical complexity, according to IBAPE (2012). Thus, it is clear that the anomalies present in the concrete beams at FCT/UNESP require maintenance and/or repair programs, aiming at improving the quality of buildings with consequent extension of their useful life.

FINAL THOUGHTS

By means of the method of mapping pathological manifestations in digital images, different anomalies were detected in reinforced concrete beams of FCT/UNESP, so that four of the five types of alterations under study (cracks, detachments, exposure of reinforcement and dark spots) appeared with approximately the same frequency, andShowing how the absence of a maintenance and/or repair program for these structural elements can compromise both the aesthetics and the useful life of these buildings.

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