Analysis of pathological manifestations in the interface between metallic structure and closing system: case study

Análise de manifestações patológicas na interface entre estrutura metálica e sistemas de fechamento: estudo de caso

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ABSTRACT
The steel structure, together with conventional closing systems, does not always present the expected performance, as the solutions for the bonding between these two elements are not always adequate and can result in pathologies in buildings. In this context, the objective of this work was to analyze pathological manifestations in a steel-structured building with a ceramic brick masonry closing system. For this purpose, inspections were carried out in the building, which is in use, to identify existing degradations in the structure's interfaces with the closure, as well as the causes of the damage observed, and proposals were made to correct and prevent them. It was possible to verify that the adoption of construction techniques and elements was inadequate, due to the lack of details, specifications and compatibility in projects, and also periodic maintenance, which resulted in the appearance of pathological manifestations throughout the entire building. Solutions and constructive techniques aimed at correcting the damage and preventing the appearance of new pathological manifestations were presented. The analysis indicated that, however, a treatment of the pathologies should be carried out, as they are phenomena in constant advancement and that the pathologies identified in the building are subject to recovery.

Keywords: pathological manifestations, steel structure, closing system.

RESUMO
A estrutura de aço, em conjunto com sistemas de fechamento convencionais, nem sempre apresenta o desempenho esperado, pois, as soluções para a solidarização entre esses dois

elementos nem sempre é adequada e pode resultar em patologias nas edificações. Nesse contexto, o objetivo deste trabalho foi analisar manifestações patológicas em uma edificação estruturada em aço com sistema de fechamento de alvenaria de tijolo cerâmico. Para isso, foram realizadas inspeções na edificação, que está em uso, para identificar as degradações existentes nas interfaces da estrutura com o fechamento, bem como as causas dos danos observados, e propostas medidas de correção e prevenção dos mesmos. Foi possível constatar que a adoção de técnicas e elementos construtivos foi inadequada, devido à falta de detalhamentos, especificações e compatibilizações em projetos e, ainda, manutenção periódica, que resultou no surgimento de manifestações patológicas ao longo de toda a edificação. Foram apresentadas soluções e técnicas construtivas visando correção dos danos e o impedimento do aparecimento de novas manifestações patológicas. A análise indicou que, no entanto, seja realizado um tratamento das patologias, pois são fenômenos em constante avanço e que as patologias identificadas na edificação são passíveis de recuperação.

Palavras-chave: manifestações patológicas, estrutura de aço, sistema de fechamento .

1 INTRODUCTION

Construction pathology is defined as the study of the causes, effects and consequences of the unsatisfactory performance of buildings, aimed at ascertaining and correcting defects in constructions, thus preventing and avoiding future problems. Pathological manifestations, in turn, are construction defects or defects that are installed in buildings due to design, execution, use or lack of maintenance (SILVA, 2012).

It is known that most problems found in buildings have mechanisms of occurrence very similar to those found in buildings in reinforced concrete, such as displacements and fissures. In the case of steel-structured buildings, the pathological manifestations are specific to this structural system, mainly due to the different properties of steel (CASTRO, 1999; WAHAB; HAMID, 2011).

It is understood, therefore, that the steel structure, together with conventional closing systems, does not always present the expected performance. The difficulty of obtaining a solidarity of the structure with these elements can result in pathologies due to the use or inadequate choice of the typology of the finish or the treatment given to the steel-concrete, steel-masonry or steel with closing systems interfaces.

Among the systems that interface with the structure, vertical systems, which define and limit spaces in buildings, also called vertical closures, have several usual systems according to the region or country, and the local predominance of a certain type depends on the raw material usually found in the market and also of the climatic typology, which demand special systems, such as, for example, thermal performance favorable to more rigorous climates.

In Brazil, the most usual closing system is composed of ceramic brick masonry coated with cement mortar, which may have a finishing in mass, plaster and paint. However, other systems have been used. But, even with the emergence of new techniques and materials, the use of the conventional masonry system is still predominant, characterizing steel-structured works as semi-industrialized constructions, since the application of this type of structural system indicates an industrialization of construction (CASTRO, 1999).

Considering this situation, studies were carried out in this work on recurrent pathologies in a building structured in metallic profiles that uses masonry as a closing system and a mapping of pathological manifestations was carried out, proposing therapies and preventive measures to avoid the appearance of deterioration. This research aims to contribute to the internationalization of the subject of pathologies in buildings, disseminate in the scientific and academic environment about the techniques and methodologies for therapies and preventive measures, provide relevant information to professionals and users on how to act in similar situations, as well as register existing methodologies in different formats and procedures in order to analyze the anomalies converging to the same result, obtaining diagnosis and solutions (LIMA, 2009).

2 OBJECTIVE

In this context, the main objective of this study was to analyze the pathological manifestations of a steel structured building that has a conventional closing system in ceramic brick masonry.

It had as specific objectives to indicate the causes of the damages and to propose measures of correction and prevention of the same, presenting solutions and constructive techniques that also aim at the prevention of new pathological manifestations.

3 METHODOLOGY

In order to fulfill the objectives, visual inspections were carried out in the building adopted as a case study, which is a building of the Federal Institute of Minas Gerais, former Unit II of Campus Betim, see Figure 1. The existing degradation mechanisms at the interfaces of the structure with the closing, as well as the causes of the damages relating them to the adopted constructive system.

Figure 1 – Main facade

Source: The authors (2021).

The four-story building was designed for educational purposes and is approximately 29 years old since its construction. Its structure has structural elements such as reinforced concrete slabs and pillars, beams and vertical bracing systems in I profiles. The structural system is composed of longitudinal and transverse frames and vertical delta bracing.

The visual inspection of the building and the mapping of the pathologies of the structure took place through the observation of the interfaces of the masonry and concrete slabs with beams, pillars and metallic frames. The methodology consisted, therefore, in the investigation of infiltrations, stains, defragmentations, detachments, fissures, oxidations and structural joints. A survey of damages was carried out in the different types of interaction between the closure and the structure, the causes were evaluated and solutions were proposed for the treatment and prevention of pathological manifestations.

4 MAIN PATHOLOGIES OF CLOSING SYSTEMS FOR STRUCTURED STEEL BUILDINGS AND THEIR CONTROL

In the analysis of structures, it is usual to consider the transmission of forces to load-bearing elements, such as slabs, beams, pillars and foundations. However, the elastic deformation due to the accommodation of the structure and the dynamic action of the wind tends to cause distortions in the planes of the enclosures. This situation requires extra care in predicting treatments related to the significant deformability of the steel structure. Such techniques depend on the closure systems that are used. In the case of ceramic brick masonry, it can be built with or without connection to the structure, emphasizing that, for both cases, specific treatments must be foreseen in the joints of its union with the structure. Failure to properly treat this interface is usually the major cause of infiltration problems, causing pathologies in this type of closure.

According to Castro (1999), bad weather causes deterioration of the components subject to its action, with external closures being the most affected. In this case, the mechanical stresses can reach any external or internal component, depending on their origin. Therefore, the main occurrence of these phenomena is the appearance of fissures and infiltrations that, even not representing any structural risk, constitute a certain discomfort to the users of the building.

In this case, the determination of the causes of the pathologies becomes an important advance in the diagnosis, which is the object of an inspection procedure, survey and data analysis, enabling the identification of the nature, consequences, scope and origins of pathological phenomena (RIBAS, 2006).

4.1 INFILTRATIONS

One of the biggest problems in the design of metal structure enclosures is to perform watertight enclosures and at the same time resistant to weather and to the deformation mechanisms of the structure. The structural elements, due to their low roughness and low porosity, make the connection of the interface with the masonry a problem that favors the appearance of damages, such as infiltrations (CASTRO, 1999).

4.2 FISSURES

In general, closures show good behavior when subjected to compressive stresses; however, they have little mechanical resistance when requested by traction or shear forces (ASSUNÇÃO, 2005). The load-bearing structures are responsible for supporting the loads acting on the entire system. However, a portion of loads can be transmitted to closures that do not have mechanical strength, causing the appearance of fissure.

4.3 CORROSION AT THE INTERFACES BETWEEN STRUCTURE AND CLOSING SYSTEM

According to Silva *et al.* (2015), corrosion is defined as the deterioration of a metal or alloy, from its surface, by the environment in which it is inserted. The shape of a structure can influence its susceptibility to corrosion. Thus, structures must be designed in such a way that corrosion cannot establish itself in a specific location, or through which it can spread.

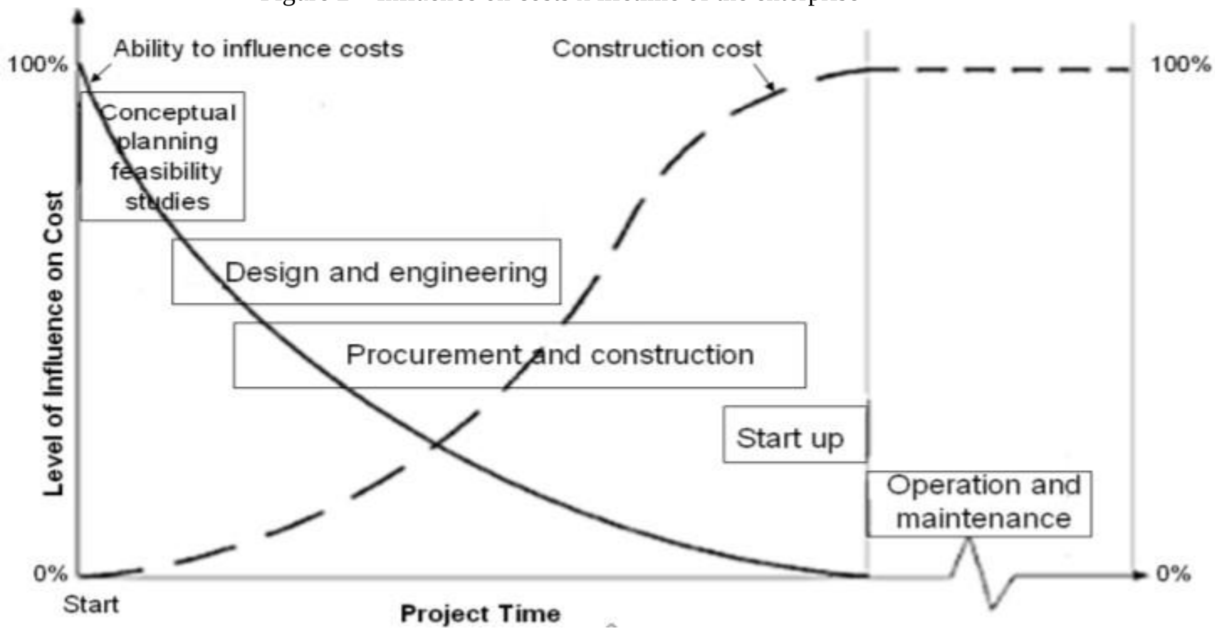
In this way, the shapes of the structural elements and the methods for joining them must be such that the fabrication, joining and any subsequent treatment do not promote corrosion and pathologies, and the design must be simple, thus avoiding the excessive complexity of the parts. For example, you should: avoid corners, sharp edges, crevices, points of accumulation of moisture and dirt; promote drainage and ventilation by projecting sloping surfaces; use welds with good finishing and continuous, avoiding pockets and recesses; provide drainage holes in the structure where there are stiffeners; and plates; and avoid direct contact between metals with different electrochemical potentials (SACCHI, 2016). Metallic components, when coated or enclosed in other building materials, are not accessible, making it difficult for pathological manifestations to appear. It is observed that the corrosion protection measures must be considered even in the design phase and be effective throughout the entire useful life of the structure.

4.4 CONTROL OF PATHOLOGIES THROUGH ADEQUATE DETAILING

The control of pathologies in the design stage can be implemented in a very significant way by acting on the geometry of the components. The geometric shape that allows the accumulation of water and foreign materials must be avoided. Designers must have a diversified vision for various recurring problems due to errors or lack of detail, providing a longer quality and useful life to the building (ARAÚJO; PAES; VERÍSSIMO, 2013). Thus, those responsible for the project must be aware of the possible secondary effects that can cause pathologies to the building.

The planning and management in the initial phases of the project can directly impact the intervention costs during the life cycle of the work. Figure 2 shows the possibility of interfering with costs according to the production phases of an enterprise, and it can be noted that the initial design phases have the lowest costs, while, over the life of the building, the possibility of cost interference tends to decrease (SACKS *et al*., 2018).

Figure 2 – Influence on costs x lifetime of the enterprise



Source: Sacks *et al.* (2018).

A project that favors solutions that prevent pathologies can reduce expenses during the useful life of the building. According to Pannoni (2015), several precautions must be taken when designing a project, citing:

- The geometry of a component must not be analyzed in isolation from the rest of the structure or system. It does not exist completely isolated from the rest of the building, having great interdependence with other components, which must be considered;
- Excessive complexity must be avoided; preference should be given to simplicity and practicality, so as not to hamper or prevent the maintenance of the structure;
- Functional and environmental conditions must be taken as uniformly as possible. Do not unnecessarily create conditions in which large residual stresses, temperature gradients, flow differences and cross-section differences can occur;
- Cleaning of components must be facilitated both internally and externally, during assembly and during use;
- The adverse influence of a non-structural component on the structure must be considered. Drip of condensed liquids, emission of gases from combustion, vapors, chemical or thermal effects can be agents that cause pathologies in the structure;

- The structure, whenever possible, should be arranged so that it cannot be adversely affected by local weather conditions or by polluting agents such as gases, liquids or solids.

4.5 STEEL STRUCTURE PROTECTION

The steel corrosion protection system, carried out according to design recommendations, effectively contributes to the durability of the entire structure. And painting is the lowest cost and most appropriate method for protecting steel structures and equipment from corrosion. And the ease of application and maintenance makes painting the most viable method for protecting these surfaces. According to Krankel (2017) and Pereira (2018), a painting system or painting procedure specification must start with the steps: surface preparation with the removal of oils, greases, fats and mainly corrosion products (oxides); and recovery of damaged surfaces by eliminating gaps and corners with the possibility of accumulation of moisture and dirt.

Paints can perform, under favorable conditions, for a lifespan of up to five years or more. In adverse conditions, the same painting could last for about a year or two. In view of the above, the paint is considered very efficient in the anticorrosive protection, verifying that the thickest films of paint systems for steel exposed to atmospheric corrosion are in the order of ¼ of a mm or 250 micrometers. However, it is necessary to choose the appropriate paints and make a correct application to guarantee the protection of the metallic surface.

5 STRUCTURE ANALYSIS

In the building under analysis, there is no adequate treatment at the interface between the structure and the masonry, causing points where moisture or rainfall on the facade penetrate by capillarity in the closing (Figures 3 (a) and 3 (b)). In this case, there was no use of a moisture-resistant finish, nor the use of drip mould on the outside and expansive joints, which allowed for infiltrations and the appearance of stains that highlight the shape of the ceramic bricks in various parts of the façade closure, in the interior of the building.

Figure 3 - Closure with infiltration pathologies

Source: The authors (2021).

Figure 4 shows the connection region where there was a probable transmission of tensile and/or shear stresses. Such fissures can come from the deformation of the structure due to its loading, masonry shear and hygrothermal movement, in which the temperature variation causes expansion and contraction movements in the building's construction materials, which are normally subject to restrictions by the various constraints of the structure (RIBAS, 2016; Figures 4 (a) and 4 (b)).

Figure 4 – Fissure at the meeting of the structure and masonry (a); Fissure near the door frame (b)

The external facades, in turn, exposed to weathering agents, including moisture, show coating peeling. Figure 5 shows the formation of bubbles in the paint and the detachment of the paint and mortar. At this point, there is a lack of application of systems that prevent the flow of water at the interface of the facade with the metallic structure, causing infiltration and, consequently, the pathologies shown. It is important to point out that the lack of maintenance and abandonment cause a series of damages that could often be avoided with preventive correction measures (SANTOS; FIORITI; TSUTSUMOTO, 2016). However, with the appearance of long-term pathological manifestations, the adoption of corrective measures becomes necessary and must be frequent.

Figure 5 - Front facade with pathological manifestations in the masonry

Source: The authors (2021).

It is clear, at the interface points of the structure with the masonry, where the fixation occurs only by contact, that the action of external agents or bad weather causes the pathological effects that spread not only in the masonry, but also in the structural elements themselves (Figure 6).

Figure 6 - Corrosion due to infiltration at the structure and masonry interface

Source: The authors (2021).

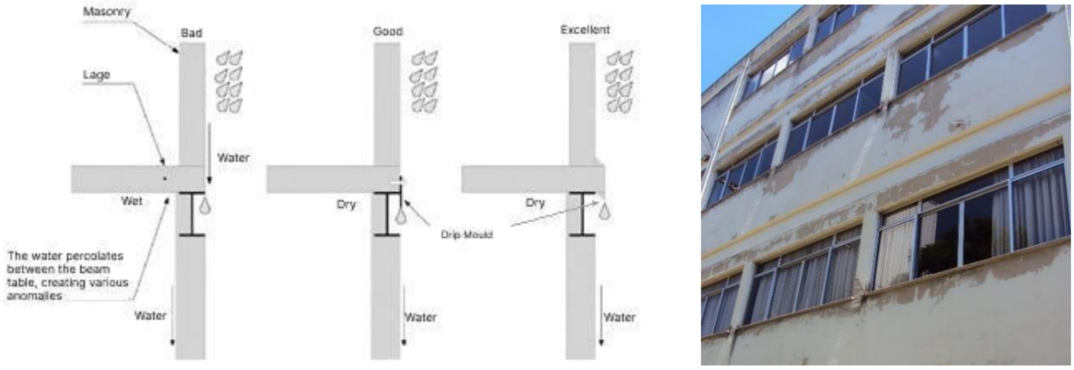
6 SOLUTIONS, PREVENTION AND CORRECTION

In addition to the care taken with the masonry and its fixation, as well as the details that guarantee the watertightness of the system, it is important to note that the structure deserves attention in terms of its protection. Some details were pointed out to be adopted for the treatment of the interface between the masonry and the structure, but this building has a project designed in such a way that the structure is exposed to the weather, being also subject to deterioration.

With these considerations and taking into account the technical approach, the meticulous detailing regarding the geometry of the constructive elements can, then, influence the occurrence of critical points in the building. One of these details can be seen in Figure 7 (a), in which the linkage of the structure with the closure without proper protection of the system promotes the penetration of moisture, causing pathologies. Measures adopted in projects can avoid such problems (Figures 7 (b) and 7 (c)).

It can be seen from the constructive aspect of the facade of the building under study, portrayed in Figure 7 (d), that the example in Figure 7 (a) shows the same situation throughout the facade. A treatment for the problem would be the application of a drip mould, shown in the examples of Figures 7 (b) and 7 (c).

Figure 7 – Constructive detail of the structure interface (a), (b) e (c); Constructive aspect of the facade (d)

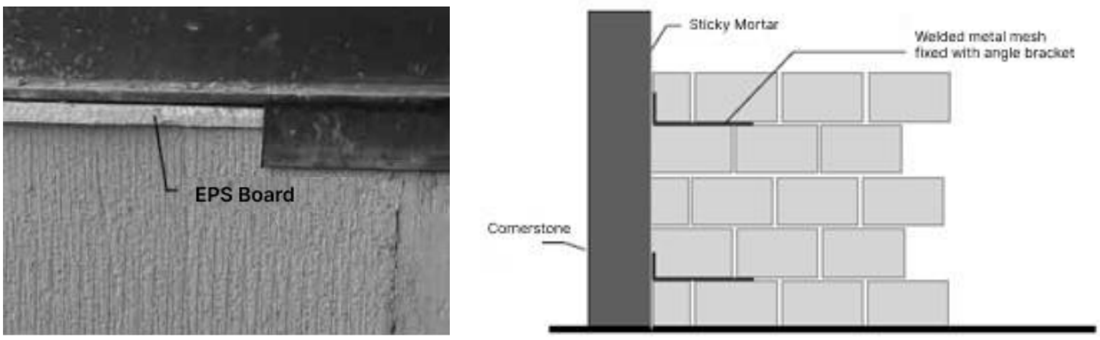


(a) (b) (c) (d)

Source: Pannoni (2009); The authors (2021).

In addition to the possibility of infiltration on the upper surface of the beam, moisture may penetrate the lower surface in contact with the masonry. The treatment, in this case, differs a little from the previous one, since, in addition to the drip mould detail, it is recommended to create a flexible joint with expansive material, which can be expanded polyurethane (PU) or expanded polystyrene (EPS), in the contact of the masonry with the beam at the top. For deformable systems, lateral confinement can be adopted by applying angles (Figure 8 (a)), due to the need to absorb the effects of movement of the structure without transmitting significant portions of efforts to the masonry (NASCIMENTO, 2004; BELLEI, 2006). The proper fixing of the masonry to the structure tends to guarantee both watertightness and deformability to the system. A fixation error can lead to compromised deformation and the occurrence of fissures. It is indicated to observe the positioning in each row, ensuring the alignment of the bricks. When laying the brick, place welded metal meshes carefully on the mortar, ensuring that the mortar has a thickness of around 20 mm to 30 mm, adjusting the leveling and covering of the mesh before laying the next layer of bricks (Figure 8). (B)).

Figure 8 – EPS board joint at the masonry and structure interface (a); Detail lateral fixing of the masonry with pillar (b)



(a) (b) Source: Nascimento (2004).

In addition to the care taken with the masonry and its fixation, as well as the details that guarantee the watertightness of the system, it is important to note that the structure deserves attention in terms of its protection. Some details were pointed out to be adopted for the treatment of the masonry interface with the structure, but it is known that certain projects are designed in a way that the structure is exposed to the weather.

Taking into account the approach of the detailing techniques and surface treatment, as a way to correct and avoid pathological manifestations and damages in the closing systems, mainly in the interface with the structure, it is proposed below a list of necessary repairs for correction. of the pathologies existing in the case study:

- Installation of deformable joints at the interface between steel beams and masonry;
- Installation of screens in the mortar at the interface between pillars and masonry to prevent the appearance of fissures in this region;
- Recomposition and repainting of the coating after proper fixing of the closure to the structure, ensuring the watertightness of the interfaces;
- Treatment of critical points on the facade, such as installation of drip mould and restoration of the coating;
- Installation of lintels and counter lintels in the openings of the frames to combat the transmission of possible efforts to the closing;
- Cleaning of areas affected by corrosion, elimination of fissures and application of anti-corrosive paint throughout the structure, observing the specification of paint and film thickness that must be correctly indicated;

- Installation of auxiliary structures or enclosures such as louvers, in regions where the structure interacts with the glass enclosure frames and the incidence of bad weather can be more aggressive.

7 FINAL CONSIDERATIONS

The study indicates that the adoption of inappropriate construction techniques and elements, lack of compatibility in projects and periodic maintenance resulted in the emergence of pathological manifestations, in which treatment may have a higher cost than the adoption of preventive measures.

The problems identified in the building do not compromise its performance and are recoverable. It is suggested, however, that a treatment of the pathologies be carried out, as they are phenomena in constant advancement. The measures adopted should focus both on the recovery of existing degradation and on the prevention of the emergence of new pathologies.

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