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Study of the pathological manifestations of the São Pedro and São Paulo Apóstolos Church

Estudo das manifestações patológicas da Igreja de São Pedro e São Paulo Apóstolos

Estudio de las manifestaciones patológicas de la Iglesia de São Pedro y São Paulo Apóstolos

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Abstract
The investigation of pathological manifestations in buildings is fundamental to the development of effective intervention strategies aimed at correcting existing problems and preventing future damage. The main objective of this article is to present the results of a detailed analysis of the pathological manifestations identified in the São Pedro and São Paulo Apóstolos Church, located in Belo Jardim, Pernambuco (Brazil). The study's methodology consisted of qualitative field research, of the case study type, carried out through technical visits, photographic records and the creation of damage maps. After a thorough visual inspection, the anomalies were analyzed and compared with specialized literature. The results showed that the most common pathological manifestations are caused by the presence of humidity and that cracks due to probable corrosion of the reinforcement were also identified. Based on the results obtained, the study proposed therapies and interventions to mitigate the problems identified, emphasizing the importance of these proposals to ensure the preservation of the church for future generations.
Keywords: Historic buildings; Building pathology; Therapies; Damage mapping; Durability.

Resumo
A investigação de manifestações patológicas em edifícios é fundamental para o desenvolvimento de estratégias de intervenção eficazes, visando à correção de problemas existentes e à prevenção de danos futuros. O principal objetivo deste artigo é apresentar os resultados de uma análise detalhada das manifestações patológicas identificadas na Igreja de São Pedro e São Paulo Apóstolos, localizada em Belo Jardim, Pernambuco (Brasil). A metodologia do estudo consistiu em uma pesquisa de campo qualitativa, do tipo estudo de caso, realizada por meio de visitas técnicas, registros fotográficos e criação de mapas de danos. Após uma inspeção visual completa, as anomalias foram analisadas e comparadas com a literatura especializada. Os resultados mostraram que as manifestações patológicas mais comuns são causadas pela presença de umidade e que fissuras devido a uma provável corrosão da armadura também foi identificada. Com base nos resultados obtidos, o estudo propôs terapias e intervenções para mitigar os problemas identificados, enfatizando a importância dessas propostas para garantir a preservação da igreja para as gerações futuras.
Palavras-chave: Edifícios históricos; Patologia de edifícios; Terapias; Mapeamento de danos; Durabilidade.

Resumen
La investigación de las manifestaciones patológicas en los edificios es fundamental para el desarrollo de estrategias de intervención eficaces destinadas a corregir los problemas existentes y prevenir daños futuros. El objetivo principal de este artículo es presentar los resultados de un análisis detallado de las manifestaciones patológicas identificadas en la Iglesia de San Pedro y San Pablo Apóstoles, situada en Belo Jardim, Pernambuco (Brasil). La metodología del estudio consistió en una investigación de campo cualitativa, del tipo estudio de caso, realizada mediante visitas técnicas, registros fotográficos y elaboración de mapas de daños. Tras una minuciosa inspección visual, se analizaron las anomalías y se compararon con la bibliografía especializada. Los resultados mostraron que las manifestaciones patológicas más comunes están causadas por la presencia de humedad y que también se identificaron grietas debidas a una probable corrosión de la armadura. A partir de los resultados obtenidos, el estudio propuso terapias e intervenciones para mitigar los problemas identificados, destacando la importancia de estas propuestas para garantizar la conservación de la iglesia para las generaciones futuras.
Palabras clave: Edificios históricos; Patología de edificios; Terapias; Cartografía de daños; Durabilidad.

1. Introduction

The advancement of human civilization is intrinsically linked to the ability to identify, manipulate, and perfect the materials available to satisfy its needs (Isaia, 2017). This historical process can be seen in the evolution of buildings, which, in their early days, still had limited knowledge of construction techniques and materials. However, with the advent of industrialization and especially after the Second Industrial Revolution, man began to be more emphatically concerned with requirements such as safety, durability, and comfort.

Nowadays, technical specifications play a vital role in establishing quality and safety requirements that must be rigorously met at all stages of construction. In light of these facts, the Performance Brazilian Standard (NBR 15575, 2013) was established, which deals with the performance of buildings and defines indispensable characteristics to meet the expectations of the end consumer, establishing a minimum standard of quality. However, despite the technical standards already established, a considerable proportion of buildings still show pathological manifestations throughout their useful life.

For Souza and Ripper (1998), the appearance of pathological manifestations generally indicates the presence of flaws during the execution period and quality control of one or more stages of the construction process. Specifically, Sena, Nascimento and, Nabut Neto (2020) mention that the problems found in buildings usually occur due to a lack of knowledge and/or planning. In any case, pathological manifestations represent a risk to the stability of buildings, especially historic buildings, which have significant value for the city's cultural memory (Borba, 2022). In this context, it is essential to assess the symptoms, mechanisms, causes, and origins of these manifestations to develop effective strategies for the preservation and restoration of buildings.

Nevertheless, the proper selection of materials, as well as the context in which the system or construction element will be inserted, together with maintenance (especially preventive maintenance), are extremely crucial factors in ensuring more durable, safe, and sustainable buildings (Batlouni Neto, 2017; Isaia, 2017).

Historic buildings have cultural, religious, scientific, documentary, and aesthetic value, representing the achievements of past eras. They constitute a fundamental part of a society's cultural heritage, preserving its history and identity (Zhou et al., 2024; Suh et al., 2024; Brandão et al., 2016). On the other hand, historic buildings can show various pathological manifestations due to the use of old construction systems and techniques, as well as exposure to weathering over the years (Resende et al., 2020).

Recent research evaluates pathological manifestations in buildings, seeking to identify the main causes, to develop more efficient prevention and maintenance strategies (Lemos et al., 2022; Soares et al., 2022; Rêgo et al.; 2022). Lemos et al. (2022) carried out a detailed damage map on facades of a historic building, identifying cracks, corrosion, paint peeling, and plaster peeling in several areas. This study highlighted the need to carry out investigations that allow the preservation of historical and cultural heritage, through the early identification and adequate treatment of pathologies that affect buildings.

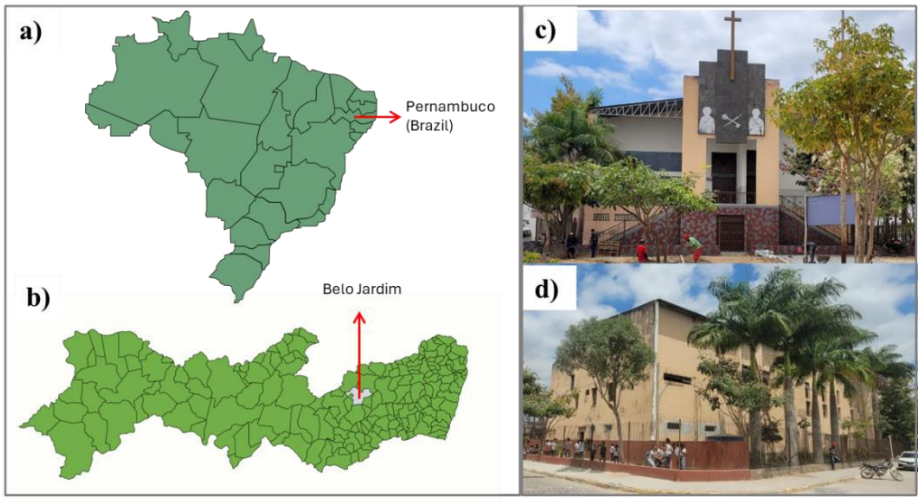
Therefore, this paper aims to present the results obtained in an analysis of the pathological manifestations identified in the São Pedro and São Paulo Apóstolos church, located in the city of Belo Jardim/PE, and to propose therapies for the anomalies presented.

2. Methodology

This research was carried out at the São Pedro and São Paulo Apóstolos church, a parish under the Diocese of Pesqueira (Pernambuco, Brazil), located in the São Pedro neighborhood of Belo Jardim (Pernambuco, Brazil). Activities in this church began on April 27, 1964, but during this period it underwent a series of renovations and adaptations.

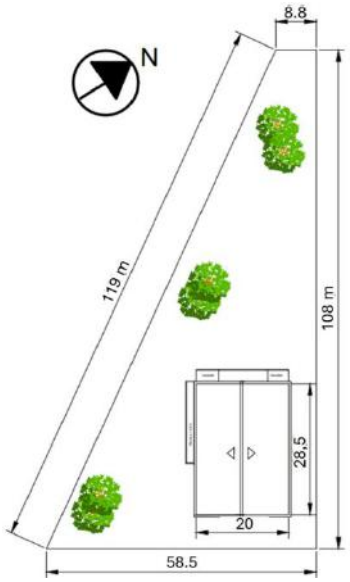
Currently, the parish priest in charge is Priest José Luiz Gomes da Silva and the parochial vicar is Priest Eliseu Francisco dos Santos. It is a semi-detached building with two floors. Figures 1, 2, 3 and, 4 show the location/view map, the location plan, and the first and second floor plans of the church, respectively. Figure 1a) shows the location of the state of Pernambuco. Figure 1b) shows the location of the municipality of Belo Jardim within the state. Figures 1c) and 1d) show views of the church's facades.

Figure 1 - Location (a and b) and views (c and d) of the São Pedro and São Paulo Apóstolos Church.



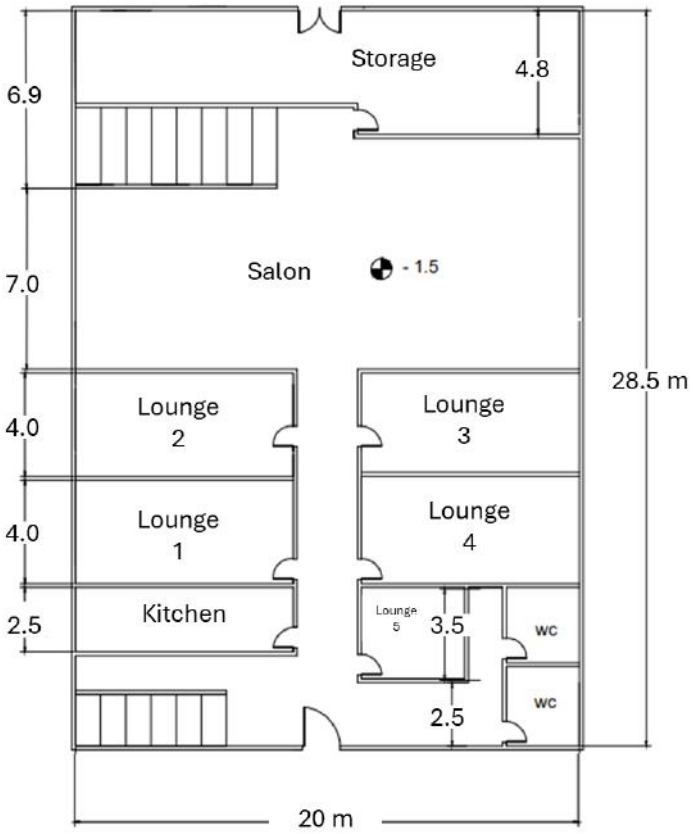
Source: Authors.

Figure 2 - Location plan of the church in Belo Jardim. Scale -1:200.



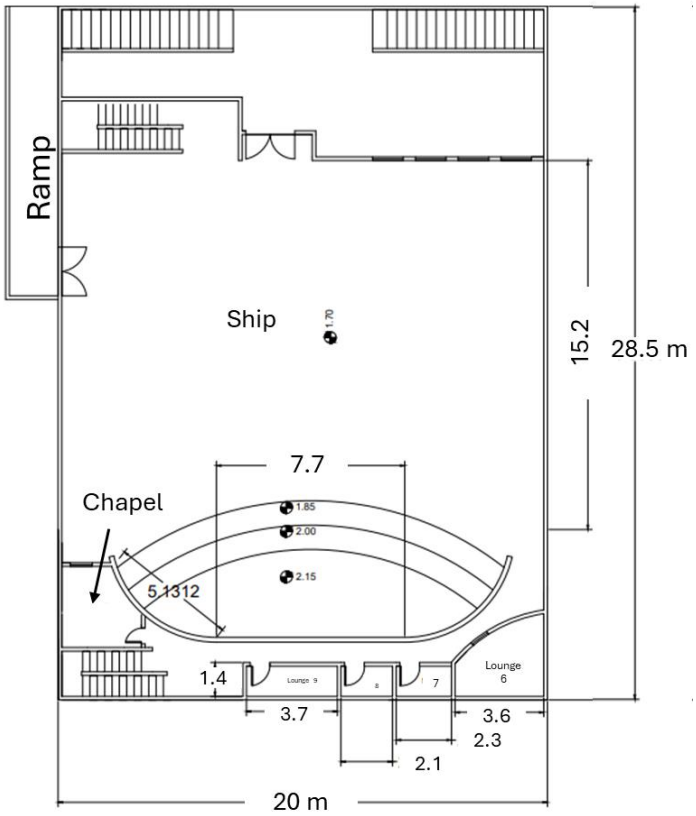
Source: Authors.

Figure 3 - Ground floor plan. Scale - 1:40.



Source: Authors.

Figure 4 - Floor plan of the upper floor. Scale – 2:65.



Source: Authors.

This case study (Pereira et al., 2018; Yin, 2015) investigates the occurrence of pathological manifestations in a historic religious building founded in 1964. It is also a qualitative, field study that collected data directly on-site (in situ) and, specifically, to identify places in the building where anomalies are present

The survey of pathological manifestations present in São Pedro and São Paulo Apóstolos Church was carried out through technical visits to the building, to locate defects in the construction systems and collect information about them. To do this, we used tools such as photographic records, the preparation of support material (plans and damage maps), and anamnesis with the person responsible for the site.

After getting to know all the church's rooms in-depth and carrying out a visual inspection, the pathological manifestations found were analyzed and compared to the pathological manifestations presented in the specialized literature.

This initial phase represents a crucial step in assessing the condition of a building and detecting damage and deficiencies that affect both its structural safety and habitability (Mesquita et al., 2015).

The Damage Map is part of the diagnostic phase and is an essential activity for determining the state of conservation. It is a graphic-photographic document that summarizes the results of the investigations, highlighting the structural and functional alterations to materials, techniques, systems, and building components/processes (Tinoco, 2009). Thus, this tool becomes essential for mapping and managing the location of each pathological manifestation.

Although the building has two floors, no pathological manifestations were identified on the second floor. Consequently, all the notes presented in this work are entirely restricted to the first floor.

3. Results and Discussion

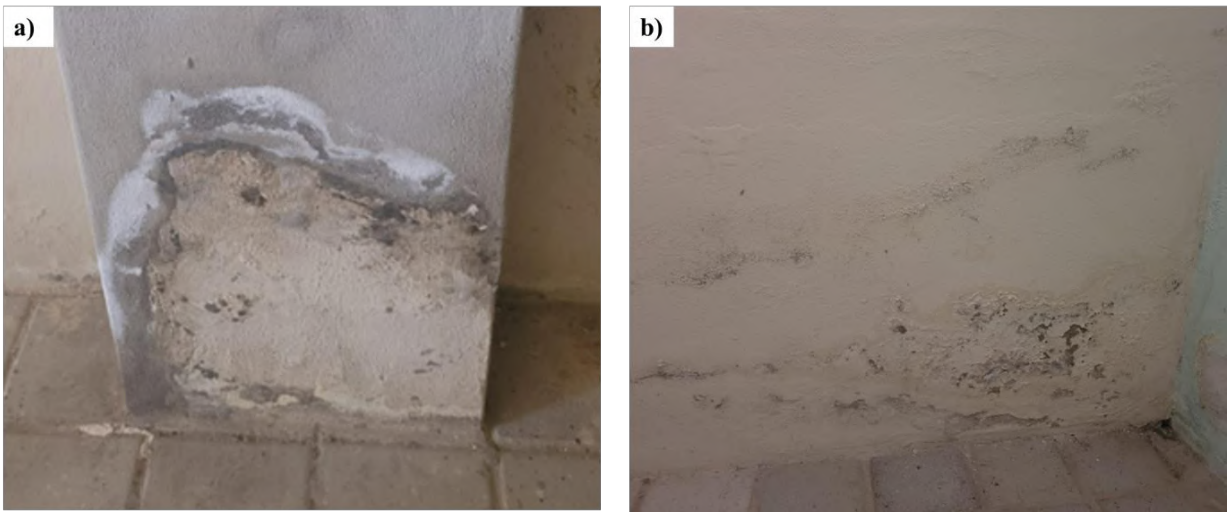
In summary, the main pathological manifestations identified in the building are efflorescence/smudge, detachment of paintwork, and occasional cracks. Figure 5 shows the damage map of the first floor. Stains caused by mold and efflorescence were the most common symptoms, as can be seen on the damage map (Figure 5).

Figure 5 - Damage map of the first floor.

Source: Authors.

Figures 6a) and 6b) illustrate the stains from efflorescence and mold, respectively. The occurrence of mold was triggered by the high humidity retained in the rooms, resulting from the lack of waterproofing in the foundations and masonry, as well as the lack of ventilation and natural lighting. On the other hand, efflorescence was caused by the presence of soluble alkalis in the masonry components (bricks, sand, mortar, etc.) which are leached to the surface by the water present. These alkalis (also bases) react with carbonic acid and give rise to salts (calcium carbonate) which crystallize when the water evaporates (Figueiredo, 2005; Villain et al., 2007; Cascudo & Carasek, 2011; Ribeiro, 2014).

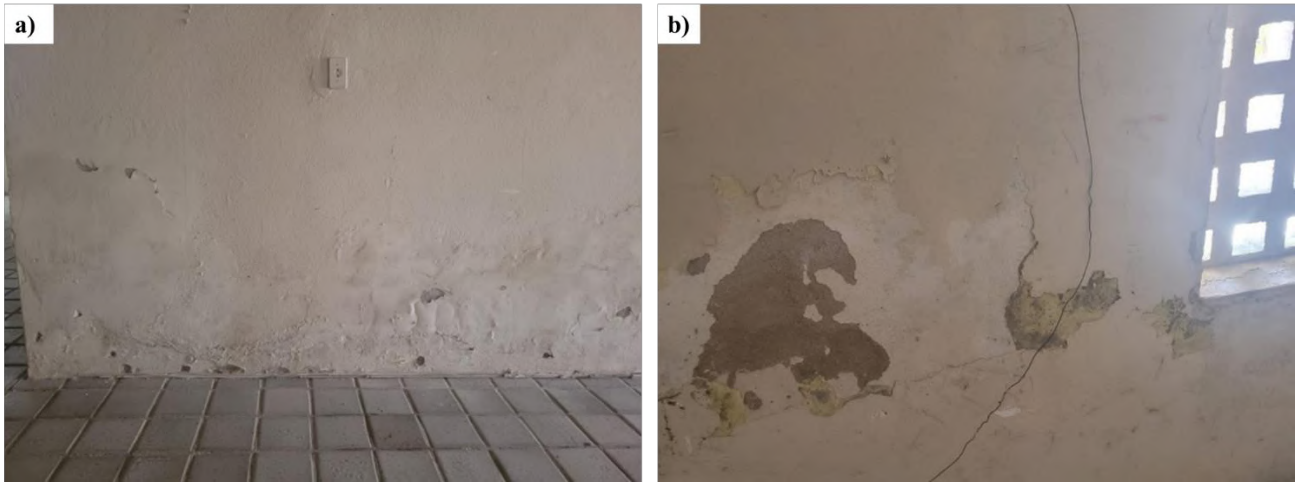
Figure 6 - (a) whitish spots (efflorescence) at the base of a pillar and (b) dark spots (mold) on the wall.



Source: Authors.

In all the rooms on the first floor and in the meeting room area, the paint was detached from the mortar coating layer (Figure 7 a and b). Some of these displacements are characterized by detachments with blistering, which indicates the separation of the plaster and render. As a result, in addition to the detachment of the paint, bubbles appear which increase progressively. On the other hand, the other displacements have the characteristics of detachment with powdering, in which the paint detaches together with the mortar.

Figure 7 - Displacement of the coating/paint system with a) blistering and b) pulverulence.



Source: Authors.

In addition to the pathologies mentioned above, the inefficiency of the building's roofing system was found in the warehouse, which was unable to provide effective protection against rainwater. This resulted in the deterioration of the plaster in the affected area since plaster is not resistant to the action of water. Figure 8 shows the infiltration and deterioration of the plaster in the warehouse.

Figure 8 - Infiltration and deterioration of the plaster ceiling.

Source: Authors.

Due to the large size of the church, it was decided to build it in two stages, resulting in two buildings that were later interconnected. In this way, as shown in Figure 9, a visible separation can be found in the area at all the meeting places.

Figure 9 - Connecting the two buildings.

Source: Authors.

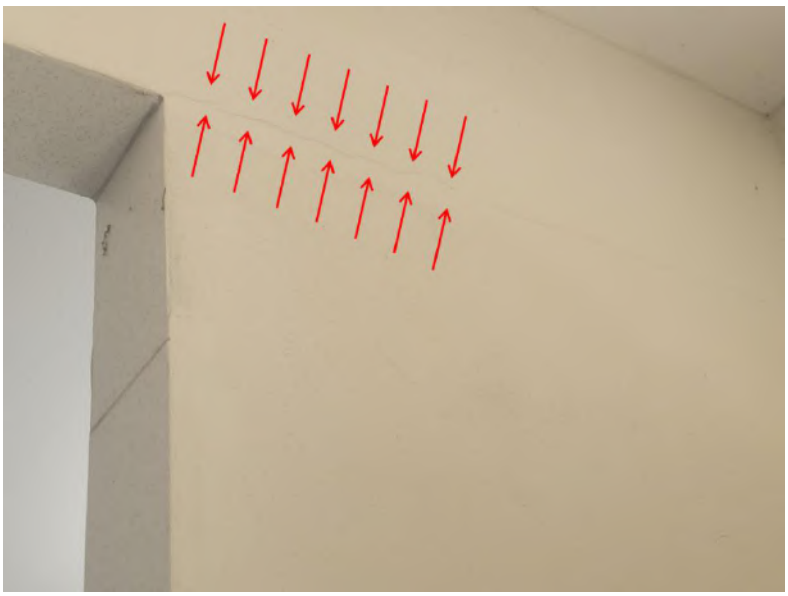
In addition, vertical cracks were identified in the pillars of the warehouse and the meeting room (Figure 10). These cracks are the result of corrosion of the reinforcement present in these structural elements. Corrosion can be triggered by the presence of carbon gas and/or chlorides and is primarily responsible for the degradation of reinforcement, making it more fragile and reducing its load-bearing capacity (Figueiredo, 2005; Villain et al., 2007; Cascudo & Carasek, 2011; Ribeiro, 2014). These cracks appear as a result of the expansion of the longitudinal bars due to the formation of rust, which consequently generates tensile stresses in the concrete.

Figure 10 - Vertical crack that follows the path of the longitudinal reinforcement.

Source: Authors.

Figure 11 shows a crack in the upper corner of the bathroom door. The origin of this pathological manifestation is related to the absence or poor sizing of the lintel. When the lintel is absent or inadequately dimensioned, the stresses are not well distributed, resulting in the appearance of cracks at the points where the stresses are concentrated. These findings are in line with previous research (Chaves Neto; Mesquita; Martini, 2017; Leite et al., 2022) and emphasize the importance of proper sizing of lintels and/or counter-lintels as a preventive measure to avoid the appearance of cracks at the corners of openings.

Figure 11 - Crack caused by poor sizing of the lintel.



Source: Authors.

On the outside of the church, as shown in Figure 12, irregular cracks resembling spider webs can be seen. Cracks with these characteristics are commonly caused by expansion or shrinkage in the mortar's hardening phase (Thomaz et al., 2009; Thomaz, 2020).

Figure 12 - Some cracks on the outside of the church.

Source: Authors.

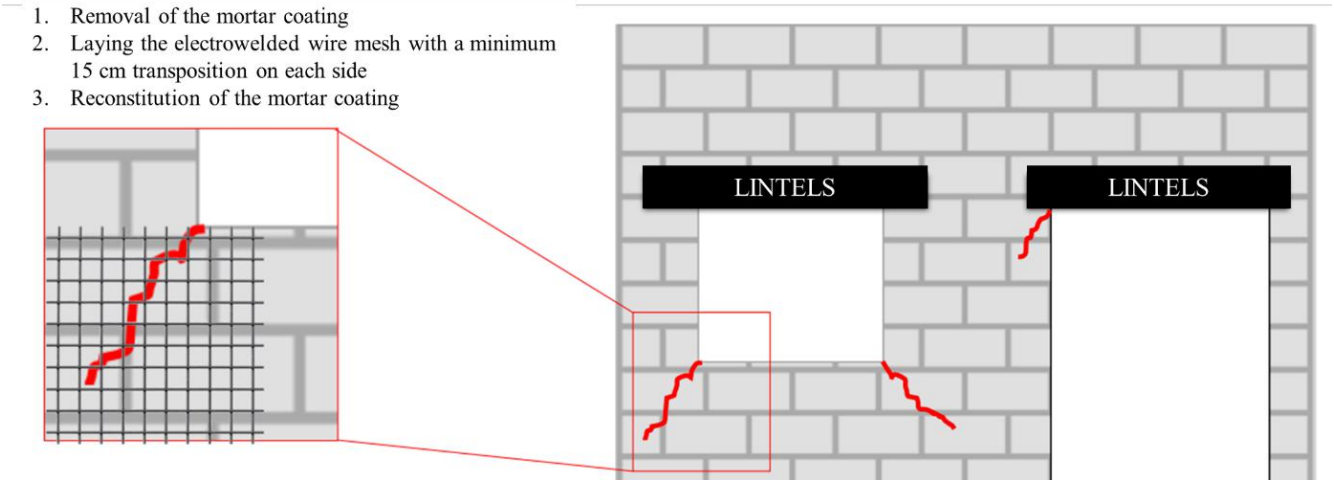
Analysis of the damage map revealed the presence of various anomalies in the building, which need to be examined carefully so that they can be treated in the best viable way. The main manifestations found in the building include:

- The appearance of cracks in the upper part of the doors, caused by the lack or inadequate sizing of the support structures above them (lintels and counter-lintels).
- Mildew and salt deposits (efflorescence) on the walls, the result of humidity and soluble salts in the masonry.
- The occurrence of detachments, due to rising damp caused by the lack of waterproofing.
- Inefficiency of the building's roofing system.
- Localized cracks in pillars caused by corrosion of the reinforcement.

Before correcting cracks, it is necessary to check whether they are active or inactive. Proper assessment of cracks can be done by monitoring them with cores. If the crack is inactive, with openings greater than 0.1 mm, Souza and Ripper (1998) suggest injecting epoxy resin.

On the other hand, to correct the cracks located on the outside of the church, which are small and irregular, it is recommended to apply mastic to the affected area. In the case of cracks resulting from the lack or inadequacy of lintels and counter-lintels, it is advisable to install electro-welded metal mesh, with a square mesh opening of 25 mm and with a 25 cm transposition on each side of the opening, as recommended in the specialized literature (Sena, Nascimento & Nabut Neto, 2020; Thomaz, 2020). A schematic for this type of repair can be seen in Figure 13.

Figure 13 - Basic scheme for recovering cracks in masonry caused by the absence or insufficiency of lintels and counter-lintels.



Source: Leite et al. (2022).

4. Conclusion

The purpose of this study was to examine the pathological anomalies found in São Pedro and São Paulo Apóstolos Church. In addition, the main pathological manifestations affecting the building were investigated, to propose solutions to the problems identified. Consequently, based on the observations made during the work, it is possible to conclude that:

- The most common pathologies in the building stem from humidity, highlighting the need for solutions to address this anomaly. Options include installing new ventilation systems, enhancing natural light, and/or applying waterproofing.
- The pathological manifestations that pose the greatest risk to the lives of the people living in the building are the corrosion process present in the reinforcement of some pillars.
- The lack of preventive and corrective maintenance aggravates the difficulties mentioned above.

Finally, it is essential to emphasize the importance of more detailed investigations using non-destructive testing to identify the origin of pathological manifestations more precisely and thus propose more effective therapies. Future research includes the evaluation of the performance of the concrete structural elements of the church considering aspects of durability, resistance and stability. Furthermore, it is expected that studies like this will make those responsible for the more than 178.000 churches throughout Brazil aware of the need to carry out interventions in religious buildings to re-establish the performance requirements for building systems with anomalies and, consequently, provide a comfortable, quality environment for the population.

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have

appeared to influence the work reported in this paper.

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