XIX International Conference on Building Pathology and Constructions Repair
8th to 10th, june 2023 - Sobral, Brazil

Analysis of pathological manifestations through damage map: case study in Buildings I and K of the Polytechnic School of Pernambuco

Vinícius Francis Braga de AZEVEDO[1], José Maria de MOURA JÚNIOR[2], Bruna Letícia Costa SANTOS[3], Wildson Wellington SILVA[4], José Maria de MOURA[5] e Yeda Vieira PÓVOAS[6]

[1] University of Pernambuco, Pernambuco, Brasil, vinicius.francis.ba@gmail.com
[2] University of Pernambuco, Pernambuco, Brasil, jmmj@poli.br
[3] University of Pernambuco, Pernambuco, Brasil, bruna.costasantos00@gmail.com
[4] University of Pernambuco, Pernambuco, Brasil, wws@poli.br
[5] UNOPAR, Piauí, Brasil, zemariasertaogas@hotmail.com
[6] University of Pernambuco, Pernambuco, Brasil, yvp@poli.br

Abstract: Building inspection in constructions is important to verify that the building is in good safety condition for its occupants, identify problems that harm people's comfort or even determine preventive maintenance to avoid problems early, helping to extend the life of the building. One of the ways to document the condition of a building is through the damage map. The objective of this article is to present the survey of the existing pathological manifestations on the facades of Buildings I and K of the Polytechnic School of Pernambuco, representing them using damage maps to contribute to the maintenance and restoration services of the analyzed buildings. To this end, the architectural survey of the facades of Buildings I and K was carried out, the photographic survey was done using smartphone and drone and finally, the creation of the damage map. With the analysis of the results, it was noticed the presence of 14 pathological manifestations, where the most recurrent were grime and efflorescence. The front and right lateral facades presented the highest and lowest number of pathological manifestations, respectively. With the periodic survey of the pathological manifestations and their representations in damage maps it will be possible to create an evolution chart of the state of Buildings I and K and plan future preventive and/or corrective maintenance.

Keywords: Building inspection; Pathological manifestations; Pathology; Damage map; Drone.

1. Introduction

Buildings are designed and built to have a lifespan of fifty years (DANI et al., 2022; ZOMORODIAN; TAHSILDOOST, 2018). However, many buildings begin to show pathological manifestations a few years after their construction, leading to an early deterioration (FAQIH; ZAYED; SOLIMAN; 2020). Early deterioration of a building can be caused by design failures, construction failures, misuse and the absence of proper maintenance in buildings (ATHIBARANAN; KARTHIKEYAN; RAWAT, 2022; HAUASHDH et al., 2020). In addition to corroborating with the emergence of pathological problems, aesthetically harming the building, early deterioration can reduce the performance of the building, reduce its lifespan, negatively impact the health of users and increase the cost of maintenance (BAUER et al., 2020; OLANREWAJU et al. 2022; SILVA et al., 2022). Therefore, the identification and monitoring of pathological manifestations in buildings are important to avoid the damage caused by their early deterioration.

https://doi.org/10.4322/CINPAR.2023.003

To identify the deteriorating state of buildings and help promote maintenance, it is important to perform building inspections, document the condition of building elements and ensure a systemic monitoring of the state of the building during its lifespan (KHERADRANJBAR; MOHAMMADI; RAFIEE, 2023; SADHU et al., 2023). To carry out the building inspection, it is important to seek techniques that make it possible to record in detail the condition of the building elements (DE MEDEIROS; HELENE, 2021). When possible, non-destructive techniques should be used to avoid damaging or impairing the future usability of the building, and one of these techniques is damage mapping, which consists of identifying and recording the conditions of a building through a map developed in a Computer-Aided Drawing (CAD) software, through two-dimensional projection (ADAMOPOULOS, 2021; AZEVEDO; MORAES; LIRA, 2021). This technique is widely used to perform building inspection of facades (MOURA JR; PÓVOAS, 2022; SILVEIRA DA COSTA; MONTAGNA DA SILVEIRA; DA SILVA TORRES, 2022).

For the building inspection, the facade stands out as one of the main areas to study, since it is the main protection against the weather that acts on a building (BAUER et al., 2020; CARRETERO-AYUSO; SAEZ-PEREZ, 2021). The maintenance of the facades is fundamental to preserve their aesthetics, functionality and safety. The impact caused by the lack of maintenance is further aggravated in buildings of educational institutions, where in addition to the previously mentioned impacts, the deterioration of the facade can compromise cognitive aspects of students and teachers (FAQIH; ZAYED; SOLIMAN; 2020), and because there is a large flow of passers-by, the damage may be greater in case of accidents involving humans, caused by the deterioration of the building (DE ASSUNÇÃO RIOS et al., 2019; LU et al., 2021).

Therefore, building inspection on the facades of educational institution buildings is important for their preservation and to uphold the social aspect that the educational institution represents. This article falls within the field of research in civil engineering, specifically focusing on building inspection and preservation, with the objective of presenting an assessment of the existing pathological manifestations of the facades of Buildings I and K of the Polytechnic School of Pernambuco representing them using damage maps to contribute with the maintenance and restoration services of the buildings analyzed.

2. Literature review

Pathological manifestations in buildings are structural or deterioration problems that affect the physical or functional integrity of a building (BAUER; SOUZA, 2022; TARQUE; PANCCA-CALSIN, 2022). In the topics below there are examples of some recurrent pathological manifestations in facades of buildings.

- Grime: its occurrence is caused by the presence of solid particles on the surface of the cladding, arising from the atmospheric pollution of the environment in which the facade is located (PACHECO; VIEIRA, 2017; TONDELO; BARTH, 2019).
- Mold: this pathological manifestation usually occurs in moist places and with insufficient ventilation, favoring the proliferation of mycotoxins in the cladding, and can cause health problems to the user, such as allergic reactions, fungal infections and even neurological problems (HYVÖNEN; LOHI; Tuuminen, 2020; LINDEMANN et al., 2022; VILJOEN; CLAASSEN, 2023).
- Vegetation: the presence of vegetation usually occurs in places with moisture concentration, such as near ground level, balconies or on top of marquees, because of the wind transposition of seeds or the action of animals that carry seeds, associated with the humidity of the place (BERSCH et al., 2021; PACHECO; VIEIRA, 2017).
- Corrosion: Corrosion can affect the appearance and structural integrity of a material, as well as the ability to perform its function properly. Its occurrence is caused by a chemical or electrochemical process that results in the degradation and deterioration of metallic materials, due to reactions with the environment. In facades, the main factor is the contact of metals with oxygen and water. In coastal regions, there is a higher incidence of corrosion, because of the presence of salts in the sea (DE MEDEIROS; HELENE, 2021; SOCARRÁS-CORDOVÍ; GONZALEZ-DAZ; ÁLVAREZ-DEULOFEU, 2022; TONDELO; BARTH, 2019).

- Efflorescence: it is visibly identified by the appearance of superficial salts in the cladding, with a generally whitish appearance and irregular aspect. It is caused by the accumulation of sulfates or carbonates diluted in the mortars and the presence of water, causing their carriage (CARRETERO-AYUSO; SAEZ-PEREZ, 2021; MARÍN-GARCÍA et al., 2023; PACHECO; VIEIRA, 2017).
- Moisture stain: occurs due to the lack of waterproofing associated with moisture and water infiltration, causing discoloration in the paint (CARRETERO-AYUSO; SAEZ-PEREZ, 2021; OF MEDEIROS; HELENE, 2021; OLANREWAJU et al. 2022).
- Segregation of concrete: its occurrence is caused by failure in the concrete compacting stage, where there is heterogeneity between the coarse aggregates and the cement mortar (PAN et al., 2022; TENZA-APRIL et al., 2020).
- Detachment of the grout: caused by a strong solar incidence on ceramic plates making it difficult for the material to dilate, or by the lack of expansion joints (TONDELO; BARTH, 2019).
- Cracks: they are openings in the surface of some material; it can be caused by factors such as poor construction, mechanical load incident on the element or thermal retraction. In facade claddings, cracks can occur in mortar, grout and ceramics (CARRETERO-AYUSO; SAEZ-PEREZ, 2021; PACHECO; VIEIRA, 2017).
- Ceramic detachment: the ceramic detachment can be characterized by the detachment and fall of ceramic material from facades, which may present risk of accidents (DE MEDEIROS; HELENE, 2021; DIAZ; CORNADÓ; ALBAREDA, 2020). Its cause may be linked to design errors, retraction of the ceramic base, execution errors, expansion of ceramic plates or linked to the fixing mortar. In studies carried out in the city of Recife, the ceramic detachment occurs more in facades facing the west side, with cladding in dark hue (PACHECO; VIEIRA, 2017).

3. Methodology

The present research is classified as a case study, aiming at the analysis of the pathological manifestations of the facades of Buildings I and K of the Polytechnic School of Pernambuco. For this analysis, the methodology was divided into three stages.

The first stage consisted of visiting Buildings I and K to carry out an architectural survey of their facades, through laser measurements and measuring tape, and obtain the dimensions of the facades. With the architectural survey done, it was possible to draw the frontal, right and left side facades. Subsequently, for the second stage, an inspection was made with photographic record or performing a scan on the facades studied using smartphone (iPhone 13) and drone (DJI Mavic 2 Pro), both equipped with camera. The smartphone was used to capture images of the ground floor and the drone to capture images of the other floors.

Finally, the third stage consisted of the creation of the damage maps using the staggered photographic records and overlayed on the facade plans in the AutoCAD software, aiming to analyze individually and thoroughly each photograph to identify the pathological manifestations and represent them on the facades through the color convention used for this research, based on the research of Barreto (2020) and Rocha et al. (2018). The three steps of the methodology are summarized in Figure 1.

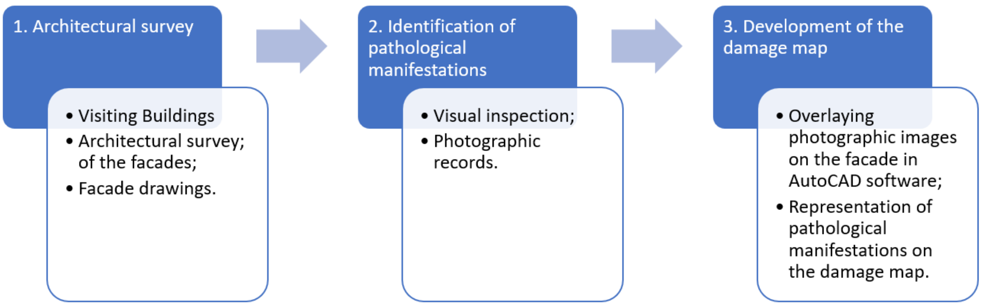

Figure 1 – Steps of the methodology

4. Location of the study

The higher education institution chosen for this study is located in the city of Recife-PE. The Polytechnic School of Pernambuco (POLI) is one of the more than twenty university units of the University of Pernambuco. Founded on January 6, 1912, it is one of the most important educational institutions of engineering courses, with about four thousand students (DA MOTA VILELA et al., 2016; TEIXEIRA et al., 2019).

POLI is located 200 meters from the Capibatibe River and 3.67 kilometers from the Atlantic Ocean. Its physical structure is composed of 11 buildings, two of them, buildings I and K, built in 2006, which were the object of study for this research. The inspection took place between the months of October and November 2022. Buildings I and K are shown in Figure 2 and are the largest buildings of POLI, with 26 classrooms, work safety laboratory, topography laboratory, manufacturing laboratory, professors' room, videoconference room and warehouse.

Figure 2 – Front facade of Buildings I and K

To help with the spatial understanding of the arrangement of Buildings I and K, Figure 3 presents their sectorization, identifying in orthogonal view: the position of the buildings, the elevator shaft and their facades.

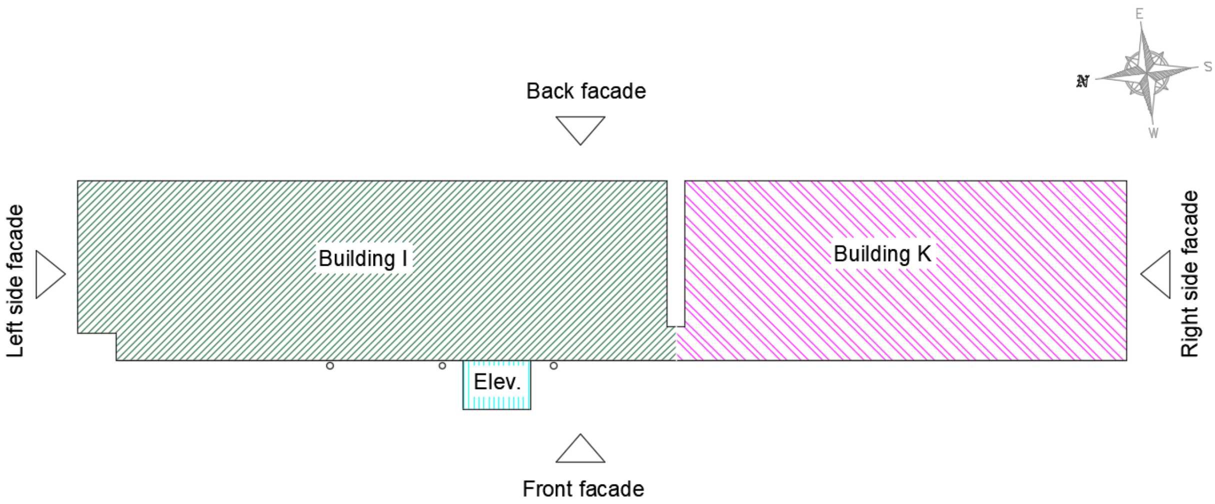

Figure 3 – Sectorization of buildings I and K

The cladding present in buildings I and K were identified and classified into five types, listed below:

- Ceramic tile: composed of ceramic inserts with dimensions 10x10cm in white or blue shades, this type of finish is predominant in the facades of buildings I and K.
- Glass cladding: composed of textured transparent glass blocks, with dimensions 20x20cm, present in the central region of the front facade, between buildings I and K.
- Painted mortar coating: in the turquoise blue hue, this cladding is used to the left of building I, in the warehouse building, composed of two floors. This cladding is present on the front and left side facades.
- Painted metallic cladding: present in the body of the elevator shaft, through blue metal sheets, and present in the blue hue circular metal pillars, located on the front facade of buildings I and K.
- Painted reinforced concrete: in the blue hue, this cladding is used at the base of the elevator shaft.

The structure of the analysis was divided into four stages: elevator shaft, front facade, left-side facade and right-side facade. The elevator shaft will be discussed separately because it is a structure that sits on the outer face of buildings I and K and has different finishing materials. About the back facade, it was not possible to carry out its inspection, because it was very close to residential buildings, therefore inaccessible to the drone.

5. Inspection of pathological manifestations

5.1 Elevator shaft

Regarding the shaft of the elevator, on the front and right-side facades, efflorescence was noted, according to Figure 4a, due to rain that causes the carriage of salts from the structure to closer to its base. Figure 4b shows grime at the top of the elevator shaft, on the front facade; this pathological manifestation was probably due to the carriage of the asphalt blanket and solid waste particles present in the parapet. According to Figure 4c, there was also grime at the base of the elevator shaft, formed by the carriage of solid waste particles and vertical cracks; in addition, the presence of vegetation was also noticeable on the front facade. facades.

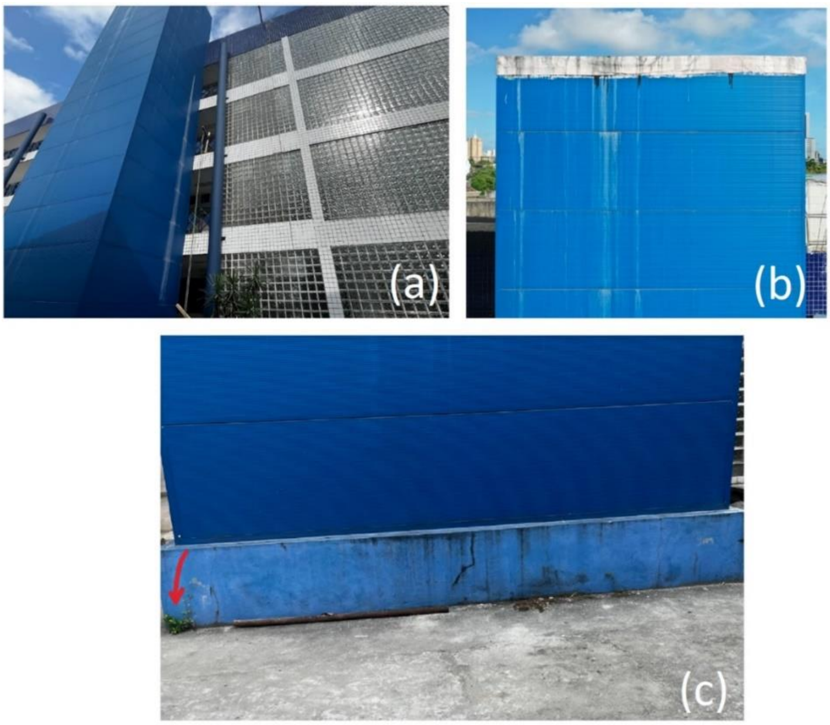

Figure 4 – Efflorescence in the elevator shaft (a), grime at the top of the elevator shaft (b), and dirt, cracking, and vegetation at the base of the elevator shaft (c)

5.2 Front facade

On the upper floors of the facade with ceramic cladding, it was noticeable the presence of grime stains, possibly from the absence of proper cleaning after the application of the grout. It was also noticeable ceramic detachment occurring mainly in regions where the tablets were cut to adapt their dimensions, as shown in Figure 5.

Figure 5 – Grime stains and ceramic detachment

It was noticeable the presence of cracks in the ceramics and grout, which may cause ceramic breakage, as shown in Figure 6. Most cracks occurred in the region of the corners of the windows, tending to form cracks at 45°, possibly caused by the absence of lintels and sill.

Figure 6 – Cracks in the windows

The excess cracking of the grout could cause its separation, noticeable in regions that have indications of being affected by cracks in the grout. In addition, there was separation of the material used in the expansion joint, possibly due to the absence of the use of sealant, as shown in Figure 7.

Figure 7 – Grout separation

In the building were found spots with steel corrosion. The first spot was at the base of the metal pillar as shown in Figure 8a; this pillar is used as an ornament of the façade and part of its base has lost contact with the ground as a result of corrosion. Figure 8b indicates the occurrence of corrosion in the distribution panel present on each floor. And as a result of this pathological manifestation, there was a loss of the integrity of the panel, which may offer risk of electric shock to the students of the educational institution.

Figure 8 – Corrosion of the base of metal pillar (a) and corrosion of the distribution panel (b)

On the third floor of building K, the presence of mold was observed in the region close to the windows frames, as shown in Figure 9a. It was also noted the presence of mold in the grout of the ceramic cladding and on the glass blocks of the facade, as shown in Figure 9b.

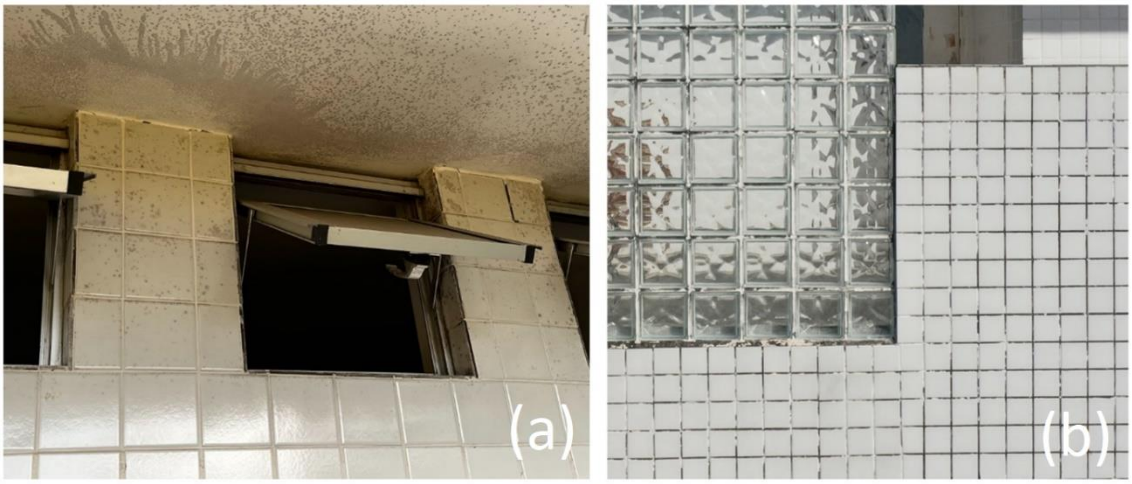

Figure 9 – Presence of mold on the third floor (a) and mold on the grout of the facade (b)

In the region to the left of building I, there is a two-story extension where the warehouse operates from. In this region it was noticeable the presence of grime, coming from the carriage of solid particles from the gutters, and moisture stain, resulting from the infiltration of water from the roof, as shown in Figure 10a, as well as spots where the presence of vegetation occurs near the ground and identification of concrete breakdown, possibly occurred due to failure in concreting, shown in Figure 10b.

Figure 10 – Grime and moisture stains (a); separation of concrete and vegetation (b)

Figure 11 illustrates the damage map of the front facade, indicating the pathological manifestations observed in this facade, with a QRcode to visualize it in higher image resolution. Through the damage map it was possible to perceive that dirt and efflorescence are the most present pathological manifestations in the front facade. It is noticeable the presence of grime predominantly in building I and the elevator shaft, as well as efflorescence from the top to the base of the elevator shaft.

Regarding the presence of mold as a pathological manifestation in the ceramic tile grout and glass block, because it is present in almost all the facades of buildings I and K, it was not represented in the damage map so as not to overlap its graphic representation to the other pathological manifestations and hinder the visualization of the damage map.

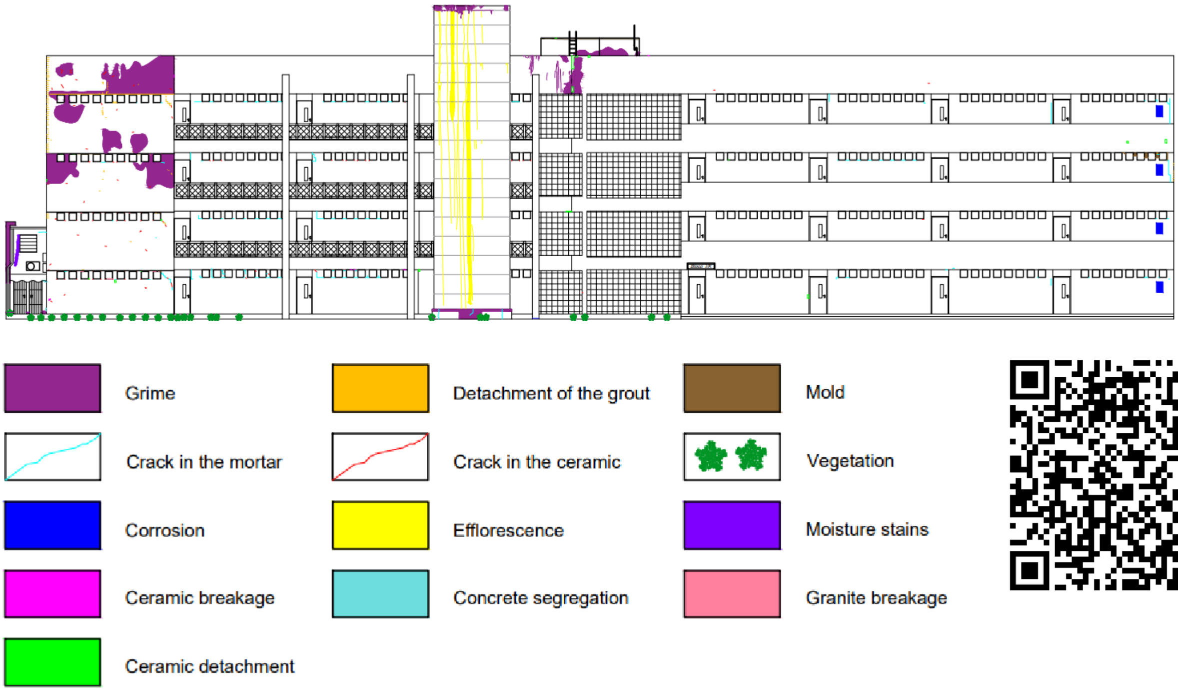

Figure 11 – damage map of the front façade

5.3 Left side facade

As well as in the front facade, the left side facade presents grime in the ceramic cladding of the main facade and of the attic region, as well as grime in the region of the warehouse and in the painted mortar cladding. Cracks in the ceramic and mold in the grout of the ceramic cladding were also noticeable. Figure 12 illustrates the presence of the aforementioned pathological manifestations.

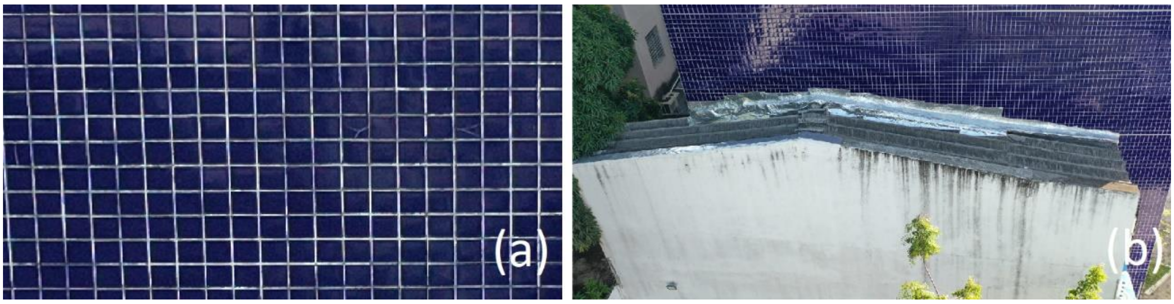

Figure 12 – Mold in the grout and cracks in the ceramic (a); grime in ceramic cladding and grime in the painted mortar coating (b)

Figure 13 shows the pathological manifestations of the left lateral facade on the damage map, with a QRcode to visualize it in a higher image resolution. Through this visualization it was possible to evidence a large presence of grime, especially in the tallest region of the building. The presence of cracks in the ceramic was also noticeable.

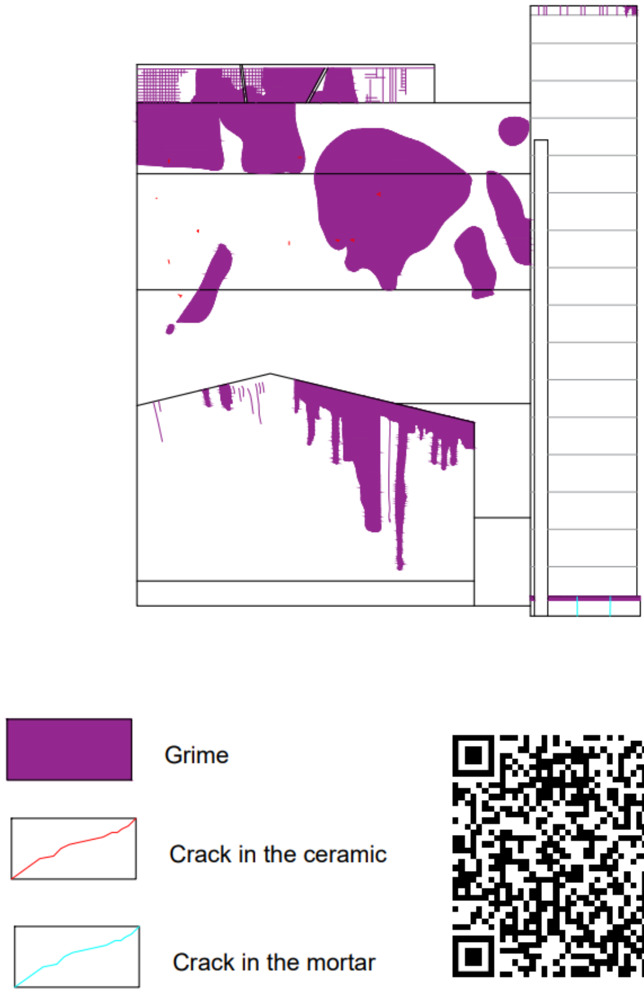

Figure 13 – Damage map of the left side façade

5.4 Right side facade

In addition to the pathological manifestations identified in the elevator shaft, mold was found in the main right-side facade, in the ceramic grout, as shown in Figure 14. During the drone inspection, it was not possible to record the attic, so its pathological manifestations were not recorded.

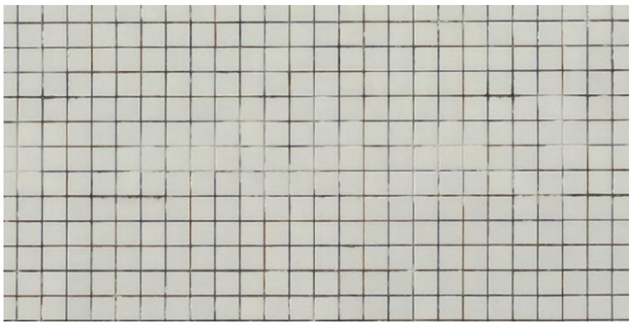

Figure 14 – Mold in the ceramic grout

Figure 15 presents the damage map of the right-side facade, with a QRcode to visualize it in a higher image resolution, identifying only the presence of dirt and efflorescence in the elevator shaft.

The right lateral facade was the facade with less presence of pathological manifestations, this may be due its South facing orientation, receiving less solar incidence. Thus, the front facade faces the West, having a higher solar incidence in relation to the other facades studied and has a greater record of pathological manifestations.

Figure 15 – Damage map of the right-side façade

6. Final considerations

Through the damage map, there is the possibility of providing visual information, facilitating the reader's understanding of the state of the facades of the buildings studied. Among the pathological manifestations, grime and efflorescence were the most expressive. The front facade was the facade with more pathological manifestations, and the right lateral facade presented fewer pathological manifestations in comparison to the other facades analyzed, possibly because it is in the South, receiving less solar incidence.

The use of the drone for photographic inspection helped in the analysis of pathological manifestations on high floors and in the capture of images with low distortion, allowing greater precision of the graphic representation of the pathological manifestations in the damage map. This factor is fundamental to facilitate the analysis of the physical and aesthetic state of the facades of buildings I and K and to use the damage map to create an evolution chart of the state of the analyzed buildings and perform future maintenance.

As for the limitations of the research, it was not possible to record the back facade and the attic of the right lateral facade in the damage map. Moreover, although the damage map provides visual information about the pathological manifestations in a two-dimensional plane, its interpretation can be facilitated by presenting it in a three-dimensional environment.

Therefore, as future research, it is suggested to develop research using the damage map linked to tools with three-dimensional visualization interface, such as 3D CAD, BIM, digital twin, virtual reality or augmented reality. Making use of BIM, for example, parametric information can be used in the representation of pathological manifestations, facilitating planning processes and maintenance budgeting.

Acknowledgements

This work was carried out with the support of the *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (CAPES) - Brazil - Funding Code 001.

Disclosure statement

The authors report there are no competing interests to declare.

References

Adamopoulos, E. (2021). Learning-based classification of multispectral images for deterioration mapping of historic structures. Journal of Building Pathology and Rehabilitation, 6 (1), 1-15.

Athibaranan, S., Karthikeyan, J., Rawat, S. (2022). Investigation on service life prediction models of reinforced concrete structures exposed to chloride laden environment. Journal of Building Pathology and Rehabilitation, 7 (1), 1-15.

Azevedo, V., Moraes, A., Lira, H. (2021). Tutoring as a Tool to Explore New Teaching Methodologies in the Classroom in Engineering Classes of the University of Pernambuco - ICGG 2020-Proceedings of the 19th International Conference on Geometry and Graphics, Springer International Publishing, december 2021.

Barreto, L. M. (2020) Manifestações patológicas em fachadas de edificações religiosas: um estudo na cidade de Recife-PE. Dissertação de mestrado, Faculdade de Engenharia, Universidade de Pernambuco, Brazil.

Bauer, E. et al. (2020). Relative importance of pathologies in the severity of facade degradation. Journal of Building Pathology and Rehabilitation, 5 (1), 1-10.

Bauer, E., Souza, A. L. R. (2022). Failure patterns associated with facade zones and anomalies in the initiation and propagation of degradation. Construction and Building Materials, 347, 128563.

Bersch, J. D. et al. (2021) Diagnosis of pathological manifestations and characterization of the mortar coating from the facades of historical buildings in Porto Alegre—Brazil: A Case Study of Château and Observatório Astronômico. International Journal of Architectural Heritage, 15 (8), 1145-1169.

Carretero-Ayuso, M. J., Sáez-Pérez, M. P. (2021). Construction flaws in facing brick facades and the risk of associated litigation. Journal of Building Engineering, 33, 101633.

Da Mota Vilela, A. L. et al. (2016). Ensino a distância para cursos presenciais de engenharia: o caso da Escola Politécnica de Pernambuco. Revista de Ensino de Engenharia, 35 (1).

Dani, A. A. et al. (2022). A comparative study on the life cycle assessment of New Zealand residential buildings. Buildings, 12 (1), 50.

De Assunção Rios, F. R. et al. (2019). Análise das manifestações patológicas das marquises de concreto armado no centro de Campina Grande-PB. Revista de Geociências do Nordeste, 5, 12-22.

De Medeiros, M. H. F., Helene, P. (2021). Inspection and rehabilitation of the marquee of the Ibirapuera Park in Brazil. Journal of Building Pathology and Rehabilitation, 6 (1) 1-15.

Diaz, C., Cornadó, C., Albareda, A. (2020). Damage in face-brick facades placed between concrete slabs. Journal of Building Engineering, v. 30, 101312.

Faqih, F., Zayed, T., Soliman, E. (2020). Factors and defects analysis of physical and environmental condition of buildings. Journal of Building Pathology and Rehabilitation, 5 (1), 1-15.

Hauashdh, A. et al. (2020). Building maintenance practices in Malaysia: a systematic review of issues, effects and the way forward. International Journal of Building Pathology and Adaptation, 38 (5), 653-672.

Kheradranjbar, M., Mohammadi, M., Rafiee, S. (2023). Application of Multicriteria Decision-Making Methods to Determine the Appropriate Policy for Maintenance of Buildings in Karaj City, Iran. Practice Periodical on Structural Design and Construction, 28 (1), 04022066.

Hyvönen, S., Lohi, J., Tuuminen, T. (2020). Moist and mold exposure is associated with high prevalence of neurological symptoms and MCS in a Finnish hospital workers cohort. Safety and health at work, 11 (2), 173-177.

Lindemann, V. et al. (2022). Analysis of mold and mycotoxins in naturally infested indoor building materials. Mycotoxin Research, 38 (3), 205-220.

Lu, Y. et al. (2021). BIM-integrated construction safety risk assessment at the design stage of building projects. Automation in Construction, 124, 103553.

Marín-García, D. et al. (2023). Deep learning model for automated detection of efflorescence and its possible treatment in images of brick facades. Automation in Construction, 145, 104658.

Moura Jr, J. M., Póvoas, Y. V. (2022). Mapa de danos em fachadas de uma universidade pública: estudo de caso em dois edifícios da Escola Politécnica de Pernambuco. Concilium, 22 (7), 718-732.

Olanrewaju, A. et al. (2022). Defect management of hospital buildings. Journal of Building Pathology and Rehabilitation, 7 (1), 1-11.

Pacheco, C. P., Vieira, G. L. (2017). Análise quantitativa e qualitativa da degradação das fachadas com revestimento cerâmico. Cerâmica, 63, 432-445.

Pan, J. et al. (2022). Theoretical and experimental study on the electrical resistivity method for evaluating fresh concrete segregation. Journal of Building Engineering, 48, 103943.

Rocha, E. A. et al. (2018). Adaptação de mapa de danos para edifícios históricos com problemas patológicos: Estudo de Caso da Igreja do Carmo em Olinda PE. Revista Alconpat, 8 (1), 51-63.

Sadhu, A. et al. (2023). A Review of Data Management and Visualization Techniques for Structural Health Monitoring Using BIM and Virtual or Augmented Reality. Journal of Structural Engineering, 149 (1), 03122006.

Silva, Y. J. et al. (2022). Integrated approach based on non-destructive technique and numerical simulation for assessment of corrosion in bridge. Journal of Building Pathology and Rehabilitation, 7 (1), 29.

Silveira Da Costa, V., Montagna Da Silveira, A., Da Silva Torres, A. (2022). Evaluation of degradation state of historic building facades through qualitative and quantitative indicators: case study in Pelotas, Brazil. International Journal of Architectural Heritage, 16 (11), 1642-1665.

Socarrás-Cordoví, Y., González-Díaz, L., Álvarez-Deulofeu, E. (2022). Significant reductions in the area in corroded steel and its repercussion in prefabricated large-panel buildings. Revista Facultad de Ingeniería, 31 (59).

Tarque, N., Pancca-Calsin, E. (2022). Building constructions characteristics and mechanical properties of confined masonry walls in San Miguel (Puno-Peru). Journal of Building Engineering, 45, 103540.

Teixeira, B. C. et al. (2019). Elaboração de mapa de danos de prédio histórico: um estudo de caso em fachadas com revestimento em pintura da Escola Politécnica da Universidade de Pernambuco. Revista de Engenharia e Pesquisa Aplicada, 4 (3), 1-10.

Tenza-Abril, A. J. et al. (2020). Statistical and experimental study for determining the influence of the segregation phenomenon on physical and mechanical properties of lightweight concrete. Construction and Building Materials, 238, 117642.

Tondelo, P. G., Barth, F. (2019). Análise das manifestações patológicas em fachadas por meio de inspeção com VANT. PARC Pesquisa em Arquitetura e Construção, 10, e019009-e019009.

Viljoen, M., Claassen, N. (2023). Pathophysiological aspects of exposure to dampness-associated indoor mould and mycotoxins: a mini-overview. Journal of Hazardous Materials Advances, 9, 100228.

Zomorodian, Z. S., Tahsildoost, M. (2018). Energy and carbon analysis of double skin façades in the hot and dry climate. Journal of Cleaner Production, 197, 85-96.