Case study: analysis of pathological manifestations in a single-family residential building in the municipality of Carlos Chagas-MG, Brazil

Estudo de caso: análise de manifestações patológicas em edificação residencial unifamiliar no município de Carlos Chagas-MG, Brasil

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ABSTRACT
The word pathology is used in civil construction when investigating structural and functional damage produced by endogenous or exogenous actions, in materials, techniques, systems, and construction components. Therefore, it is necessary to understand the structures and construction materials through studies and analyses of pathological manifestations to improve the quality of constructions, and the habitability and durability of the works. The objective of this work is to carry out a case study on pathologies in a single-family residential building in the municipality of Carlos Chagas, MG, Brazil. A bibliographical survey was carried out in different national and international databases to verify published works that addressed the topic proposed. Additionally, on-site visits were carried out to analyze the condition of the building and to catalog the pathologies. The results showed several pathologies, such as the exposure due to corrosion of reinforcement, concrete segregation, cracking, infiltration, efflorescence, mold, and flaking, which indicated the need for interventions in the building to provide safety, stability, aesthetics, and comfort to residents.
Keywords: Residential Construction, Pathological Manifestations, Civil Construction, Causes, Preventive Measures.

RESUMO
A palavra patologia é empregada na construção civil quando se investiga danos estruturais e funcionais produzidos por ações endógenas ou exógenas, nos materiais, nas técnicas, nos sistemas e nos componentes construtivos. Logo, é necessário conhecer as estruturas e os materiais de construção através de estudos e análises das manifestações patológicas, para permitir melhorar a qualidade das construções, a habitabilidade e durabilidade das obras. O objetivo desse trabalho foi realizar um estudo de caso em patologias de edificação residencial unifamiliar no município de Carlos Chagas-MG, Brasil. Foi realizado um levantamento bibliográfico em diferentes bases de dados nacionais e internacionais para verificar os trabalhos publicados que abordassem o tema proposto. Adicionalmente, foram feitas visitas in loco para analisar o estado da edificação e catalogar as patologias. Os resultados mostraram diversas patologias como exposição de corrosão das armaduras, segregação do concreto, trinca, infiltração, eflorescência, bolor e descamação, que indicou a necessidade de intervenções na edificação para proporcionar segurança, estabilidade, estética e conforto aos moradores.

Palavras-chave: Edificação Residencial, Manifestações Patológicas, Construção Civil, Causas, Medidas Preventivas.

RESUMEN
La palabra patología se emplea en la construcción civil cuando se investigan los daños estructurales y funcionales producidos por acciones endógenas o exógenas, en los materiales, las técnicas, los sistemas y los componentes constructivos. Por lo tanto, es necesario conocer las estructuras y los materiales de construcción a través de estudios y análisis de las manifestaciones patológicas, para permitir mejorar la calidad de las construcciones, la habitabilidad y durabilidad de las obras. El objetivo de este trabajo fue realizar un estudio de caso en patologías de una edificación residencial unifamiliar en el municipio de Carlos Chagas, MG, Brasil. Se realizó un levantamiento bibliográfico en diferentes bases de datos nacionales e internacionales para verificar los trabajos publicados que abordasen el tema propuesto. Además, se hicieron visitas in situ para analizar el estado de la edificación y catalogar las patologías. Los resultados mostraron diversas patologías como exposición de corrosión de las armaduras, segregación del hormigón, grietas, infiltración, eflorescencia, moho y descamação, lo que indicó la necesidad de intervenciones en la edificación para proporcionar seguridad, estabilidad, estética y confort a los moradores.

Palabras clave: Edificación Residencial, Manifestaciones Patológicas, Construcción Civil, Causas, Medidas Preventivas.
1 INTRODUCTION

The word “pathology” has its origins in the Greek language through pathos, which means illness, and logos, which relates to study. When applied to civil construction, it investigates structural and functional alterations in materials, techniques, systems, and constructive components, produced by endogenous and exogenous actions (Barreto, 2019; Tinoco, 2009). In order to avoid pathological manifestations, it is fundamental to realize a study of their origins for a better understanding of the phenomenon and assistance in moments of decision, and for a definition of the conduct and action plans to resolve these problems (Gualberto, 2020; Nazario; Zancan, 2011).

Pathology focused on construction sites is a study that identifies the causes, nature of defects, and the manner of recovery (Nóbrega; Leite, 2017). After its manifestation, the pathology may evolve into an injury, depending on the gravity of the case. This is the final stage that makes the construction improper for its final purposes.

Due to the problems caused by pathologies and the cost of repair, the investment in technologies related to construction has originated a longer service life (Fioriti et al., 2017). The limitations of materials still remain. Human and execution failure, such as corrosion, aggregates, and cracks that enable the performance of particular structures, interfere with the time of durability and provoke the loss and decrease in performance of a structural assembly or just a component.

In a situation in which the mechanical condition is altered, the pathology affects the resistance of the structure. However, if the irregularity presents a functional nature, the capacity of usage of a structure as preestablished in a project may be compromised (Barreto, 2019; Cánovas, 1988). Besides the mechanical, functional, and aesthetical capacity, the analysis of the pathology also considers two essential aspects: the time and the conditions of exposure. This is associated with the concepts of durability, service life, and building performance (Souza et al., 2018; Vazquez et al., 2016).

Durability is related to the capacity of the structure to maintain a minimum performance for a determined moment under the influence of aggressive agents. This structure is compromised by a deterioration that external factors or internal causes may
originate through the actions of physical, chemical, or mechanical nature (Cánovas, 1988; LI et al., 2020; Vazquez et al., 2016).

There is difficulty in defining the necessary time for the treatment and the study of the durability of structures due to the complexity of the mechanisms of deterioration involved. So, in order to state that a building is durable, it is necessary to establish the minimum performance of materials in a particular period of time to be obtained in the environment to which these structures will be exposed (Bolina; Tutikian; Helene, 2003; Souza; Ripper, 2009; Souza; Ripper, 1998; Zheng; Zhuo; Zhang, 2021).

The loss of performance is associated with the structural level, which is one of the most severe parameters since it presents a direct relation to the stability of the structure and the safety of its users. However, it may also compromise the comfort and the aesthetics of the structure (Vazquez et al., 2016).

From the above, the necessity of deeper knowledge about structures and materials through studies and analyses of pathological manifestations may be inferred. At least, it may be realized hypothetically due to the fact that it allows the improvement of the quality of constructions, which consequently allows the improvement of habitability and durability of buildings (Silva, Cuperschmid, 2019).

Apart from the precautions in construction, pathologies in buildings occur and can be observed through characteristic symptoms from which analyses and diagnoses are initiated. These allow the verification of compromised basic functions (Bauer et al., 2020; Couto et al., 2013).

Therefore, the objective of this research is to realize a case study on pathological manifestations in a single-family residential building in the municipality of Carlos Chagas, MG, Brazil. Also, this article focuses on the probable causes, consequences, and adequate solutions to determined conditions.

2 METHODOLOGICAL PROCEDURES

This study refers to the description, data collection, and detailed analysis of pathological manifestations in a single-family residential building, and in the search for
propositions and solutions for such a problem, which characterizes a case study (PEREIRA et al., 2018). The process may be classified as qualitative since the interpretation of the researcher of the collected information and the attribution of solutions to the phenomenon studied are based on research of a qualitative nature. Frequent and pertinent situations of structural pathologies have been investigated both in the national and international literature, which makes the research theoretical ("SILVA et al., 2021). The history of occurrences of treated pathologies in this study has been shared by local inhabitants, who affirmed that the lack of maintenance and restoration in the building contributed to the pathological evolution and degradation of the studied building.

2.1 PROCEDURES ADOPTED DURING THE STUDY AND ANALYSIS OF RESULTS

Data collection occurred as it is described by Silva et al. (2021), being this stage the one in which essential and sufficient information is organized for the complete understanding of pathological manifestations. This information has been obtained in three manners: local surveys, historical research on the problems in the building, and the analysis result (Arivabene, 2015).

Building inspections were effectuated, in which pathological manifestations, such as cracks, advanced corrosion, stains, and infiltration, were identified (Silva et al., 2021). Pathological manifestations, that were found, were photographed, and appropriately characterized since the technique and methodology of record and organization of collected subsides are highly relevant for its usage in the formulation of a diagnosis (Arivabene, 2015; Silva et al., 2021).

In the local inspection, data collection was completed through a photographic survey of the pathologies of the building with a Moto G8 Plus model cell phone. In this stage of the study, some data was collected through verbal research with the owner of the building. Data collection through projects, memorials, used materials, history of labor and its methods have not been used in this study as a request of the owner with the objective of not exposing one’s identity nor harming the image of the building.
In the process of understanding a pathological problem, it is necessary to create hypotheses or models, and test them, that is, based on some fundamental data that were collected in earlier stages of the study. The professional creates hypotheses to examine the situation and faces these models to the general picture of symptoms and to the knowledge one possesses on the pathology, according to what is described by Lichtenstein (1986) and Silva et al. (2021).

The following proceedings for control have been adopted, according to Krug (2006): Identification of the problem, bibliographical research, initial study, identification of possible causes of pathological manifestations, and elaboration of conclusion. After the collection, and cataloging, data from the building were minutely analyzed and propositions of solutions were elaborated so that the building could present a better performance in the technical, economic, and environmental aspects.

3 RESULTS AND DISCUSSION

3.1 EXPOSITION OF THE STEEL FRAME AND SEGREGATION IN CONCRETE

In Figures 01-A and 01-B, the following pathologies may be observed: exposition of the steel frame and segregation in concrete.

![Figure 1 – Exposition of the steel frame and segregation in concrete](Source: Prepared by the author (2023).)
Segregation in concrete is generally caused by the concrete cast in exceeding heights. However, NBR 14.931:2004 - Execution of concrete structures – Procedure – establishes that concrete must not be laid at a height superior to 2 meters. This inadequate action may boost the separation of coarse aggregates from mortar, and lead to the lack of homogenization of concrete, mainly in pillar bases, due to the difficulty in accessing the concrete vibrator, which generates the absence of minimum cover and the posterior oxidation of the structure. Unskilled labor, materials of poor quality, the lack of consideration towards curing time and the poor execution of molds are additional factors for the manifestation of this pathology (Lottermann, 2013; Vazquez et al. 2016; Rosa; Rosa, 2020).

For the segregation in concrete, several solutions may be adopted, thus, the choice of method to be executed depends on numerous factors, such as the possibility of access to the location of repair, economic and conditioning aspects of techniques, though, the initial preparation must be maintained in all options of adopted solutions, according to the characteristic of each site. The procedure that attends every solution is the cleaning of the location both mechanically and manually till it reaches the concrete. After that, the reconstitution of the area with cement and sand mortar, glued with epoxy, the reconstitution of the area with synthetic mortar (epoxy + grainy sand and quartz), the reconstitution with pasty epoxy resin, reconstitution with a dry pack closing mortar, and the injection of cement grout to fill the internal gaps may be realized (Arivabene, 2015; Bozio; Fisch, 2023; Ásila, 2021).

Steel frames inserted in concrete structures, according to Figures 01-A and 01-B, should be protected by the cover as envisaged by the NBR 14.931:2004 and the project so that it promotes a physical barrier to external factors and avoids phenomena of electrochemical nature (Helene, 2003; HU et al., 2022). The loss of this protection may have caused and accelerated the corrosive process identified in the building.

In framed concrete, steel finds itself in the interior of a highly alkaline medium (that comes from the existing liquid phase of its holes that contain hydroxyl originating from the ionization of calcium, sodium, and potassium hydroxides) in which it would be protected from the process of corrosion due to the presence of a protective film of passive...
character (Rosa; Rosa, 2020; Broomfield, 2023). In advanced ages, concrete propitiates a basic medium that protects the frame from the corrosive phenomenon.

The building’s concrete frames have been exposed to environmental agents, such as oxygen and humidity present in the atmosphere, that provoked oxidation and compromised the durability of the material (Soares; Vasconcelos; Nascimento, 2015; Fuhaid; Niaz, 2022). This promoted the manifestation of superficial stains, cracks, detaching of the concrete cover from the rebar and the loss of mass in the frames.

In order to avoid such conditions, some solutions may minimize the frequency of this pathological manifestation, such as the reduction of the relation water/cement, the increase in thickness of the cover and impermeabilization of the surface with direct contact with the environment (Bolina; Tutikian; Helene, 2019).

It may be verified through the images that the corrosion is in its initial stage, in this sense, the technique of recovery described by Soares, Vasconcelos e Nascimento (2015) is applied, which presents that initially a proper cleaning of the base, covering of bars with anticorrosive paint, and finally, the filling of the section once more with a new concrete must be effectuated if the loss of the bar section is up to 10%.

3.2 CRACKS

In Figures 2-A, 2-B, 2-C, and 2-D, the following pathologies may be observed: crack in concrete, infiltration, and efflorescence.

Figure 2 – Crack in concrete, infiltration, and efflorescence

The analysis of the photographs shows that the characteristics of the cracks are similar, with the exception of Figure 02-D. These manifest in the same constructive system, which induces the conclusion that the probable causes are the same and provenient of the same factor.

Figures 02-A and 02-C present a vertical crack in slab plans, possibly provoked by the excessive loading of compression. Figure 02-B also in slab plans overhanging, being all in the inferior level of the slab plan. This occurred in the building due to a connection between the slab plan and the mortar, which may have generated tension in horizontal traction and provoked these vertical cracks parallel to the loading shaft (Oliveira, 2012; Rosa; Rosa, 2020; Gaspar, 2021).

Cracks seen in Figure 02-D are evenly distributed in shapes of maps and constantly crossed by one another, roughly forming 90-degree angles, making it possible the observation of a crack in the vertical and two others in the horizontal, crossing the vertical one, with an opposite sense and direction. In this case, the possible causing agents of this type of pathology in the building are numerous, for example, the lack of adherence with the base, the number of applied layers and their thickness, elapsed time of application among layers, and the rapid loss of water during the cure caused by external actions (Bozio; Fisch, 2023; Thomaz, 1992; Zuchetti, 2015; Rosa; Rosa, 2020).

In the cracks with horizontal configurations, in Figure 02-D, it may be considered that the most likely cause may be the excessive loading or the possible requests of flexo-compression. As to the vertical cracks, it may be considered that these may have been originated by the movement of the base or support (Thomaz, 1992; Zuchetti, 2015; Rosa; Rosa, 2020).

In order to mitigate the effects of this pathology, considering the progressive nature of cracks, meaning, the increase of the gap with the elapsed time, there must be a contention of problems associated with infiltration due to the presence of excessive humidity since the crack allows the access of water and other aggressive agents (Santos et al., 2024; Zuchetti, 2015; Rosa; Rosa, 2020).

So, the calculus must be coherent to the correct destination of the building, being fundamental to the compatibility between the structural project and its execution. In
addition, it is necessary to analyze the stages of the project in relation to its dimensioning and materials used in the process which must provide good quality, stability, and safety (Zuchetti, 2015).

3.3 INFILTRATION, EFFLORESCENCE, FLACKING, AND MOLD

In Figures 2-B and 3, the following pathologies are presented: efflorescence, infiltration, and flacking in different regions of the building studied.

Figure 3 –Infiltration, Efflorescence, Flacking, and Mold

Efflorescence observed in Figures 02-B, 03-A, 03-B, and 03-C may have been caused as a consequence of humidity. The constant presence of water may have allowed the loading of salts to the surface since it is described by Gonzalez, Oliveira, and Amarante (2020), this pathology usually occurs on brick walls that possess a great concentration of salt, which end up being transported within the material to the surface of the coating by water used in the construction or originated in infiltration, forming a whitish crust.

This situation may have provoked the displacement of the painting since leached salts up to the interface of the painting damage the adherence, causing its displacement. Normally, deposited salts are calcium or magnesium carbonate, calcium hydroxide,
sulfate, chlorides, and nitrates even though the analysis of samples by diffraction of X-rays is necessary (Santos et al., 2024)

For the treatment of efflorescence found in the building, Ahmad and Rahman (2010) suggest that it may happen through a chemical injection, mortar injection, electroosmosis, and insertion of hydrofuge waterproofs. Puim (2010) numbers the following techniques that may be applied in the treatment for the elimination or attenuation of the action of salts that caused this pathology: mechanical removal of efflorescence, removal of contaminating materials, application of compresses over the contaminated material or intermediate, electrochemical removal of salts, application of microorganisms on the surface of the porose material, the usage of modifiers of crystallization, application of plaster, control of the variations of environmental conditions, control of the ascensional humidity that relates to the elimination or reduction of humidity entry through the support of the walls, the usage of barium hydroxide that consists of transforming drywall that contaminates the porose material into barium sulfate (Morais et al., 2020; Santos et al., 2024).

In Figure 03, it is possible to verify the emergence of infiltration, presenting as one of the most likely causes the contact of rain on external plans of construction that may present cracks, resulting in stains, mold, detachment of the plaster, and excessive humidity (Lottermann, 2013). The action of the wind and the constitution of materials used will influence capillarity, diffusion, and absorption of humidity and the action of the gravity force in the penetration of water in gaps (Ferreira, 2010). Thus, it is important that the correct usage of the waterproof be made, which was selected according to the conditions of the location, frequency of humidity, exposition to the sun, extension of the application, movement of the base, exposition to loads, and hydrostatic pressure so that infiltrations may be treated (Sabbatini, 2006).

For the anomaly of plaster flacking, the recommended treatment is the removal of non-adherent or disaggregated areas through scraping and cleaning, eliminating the existing adherent residues, followed by the application of the waterproof material for a posterior casting of a new layer of plaster and finishing (Gaspar; Colen; Brito; 2007).
Mold is characterized by the conglomerate of filamentous fungi as in Figures 03-A and 03-D, that form dark undesirable shades in black, brown, and green tones (MIOTTO, 2010). Humidity has a fundamental role in the manifestation of this pathology since the absorption or the presence of humidity in the paint, especially in the PVA types, promotes good conditions for the proliferation of fungi and bacteria due to resin and additives.

Mold is predominant in environments with elevated levels of humidity, and, usually, with little ventilation, and its development occurs between temperatures from 10ºC to 35ºC. It is highlighted that these environmental conditions are generic since there are situations in which mold may occur, depending on the species of fungi considered, even though they present distinct conditions (Alucci; Flauzino; Milano, 1988; Mioto, 2010; Pereira, 2021).

In this case, in order to treat this pathology, it is recommended to use the combination of one leached solution and water with trace 1:1, which must be applied in the region where the mold is presented. This solution consists of sodium hypochlorite, which is highly efficient in finishing fungi and mold spores. The application is directly done to the substrate till the removal. Clean water must be applied to the location, leaving it to dry naturally (Pereira, 2021).

4 CONCLUSION

This study allowed the conclusion that pathological manifestations are usually related to the components of materials used and to the applied constructive technique, which is possibly associated with the ignorance of regulations by professionals that deal with the subject and the lack of capacitation that englobes the constructive process. From the diagnosis, it was possible to verify that the building presented high indexes of pathologies, making an intervention and an immediate treatment of pathological manifestation necessary: infiltration, cracks, efflorescence, corrosion of steel frames, and mold. To mitigate such context, it is necessary to be cautious, especially in the stage of
the project, since a well-elaborate and detailed project that follows the technical orientations of construction may minimize or eliminate pathologies.

Apart from the refinement of techniques, improvement of the quality of materials employed in the industry of civil construction, and good capacitation of labor, pathological manifestations continue to appear. This indicates the necessity of implementing efficient programs of constant inspection/maintenance to provide longer durability, comfort, and safety for users through a rapid and efficient preventive methodology.

One of the limitations of this study was the lack of access to the architectural and structural projects of the building. Thus, for future articles, this analysis may be realized again since it allows deeper studies of causes that provided pathological problems besides the refinement of methods of diagnosis used and suggestion of repair. In addition, the necessity of studies that express the economical dimension that these pathologies represent in the cost of the building may be verified.
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