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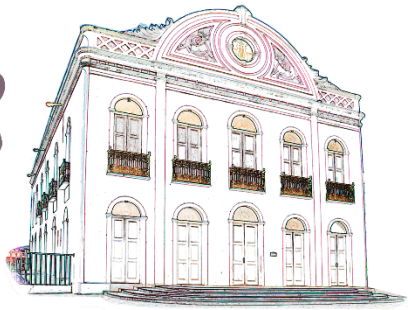

Analysis of cracks in family houses buildings in the city of Erechim - RS

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Abstract: Among the numerous pathological problems, cracks are considered of greater relevance, as they are treated as a warning of element collapse. They directly affect the internal structure of the component, that is, the mechanism of occurrence is correlated with cracks; sessing the cause, it is possible to perform an effective correction. This study sought to present the behavior and causes that originate such pathological manifestation in single-family residences, completed in up to 10 years, in the city of Erechim - RS. Through on-site visits, monthly monitoring of the units was carried out to assess the progression or stagnation of the cracks for adequate therapy. Promoting the evaluation of the rheological behavior of materials, which if neglected in the design and execution phase, will show constructive failures, such as those presented in the study. As a result, 69.23% of the cataloged cracks are manifested in the sealing masonry, due to external factors, such as overload and differential settlement, and these cracks are considered to be at risk, as they present a risk to the physical integrity and to the environment. equity, in case it collapses; recommending the prescribed immediate intervention. As for the other openings, 15.38% are made of rigid mortar coating, 7.69% of porcelain tiles and the same for connection between structure and sealing masonry. All the homes evaluated were built or renovated without any project and a qualified technician to monitor the work, being able to observe the consequences, due to the number of pathological manifestations, not just the anomaly in the study.

Keywords: cracks; mechanism of occurrence; pathological manifestation; technical responsible.

1. Introduction

A building is the result of a combination of diverse and heterogeneous materials, generally unskilled labor and high turnover. Add to this the environmental aggressiveness, misuse and lack of conservation, so that pathological phenomena that tend to compromise the functionality and safety of the property begin to manifest (MOURA et al., 2019).

Not all fissures are dangerous, but excessive fissuring and the progression to cracks imply three fundamental aspects: a possible warning of collapse of the structure, compromising the performance of the work or the psychological effect it has on the people who live in the area (THOMAZ et al., 2020). Cracks can directly affect the internal structure and not only the coating layer, as happens in fissures, which can lead to collapse (CAPORRINO et al., 2018). By definition, Seeley (1987), Vitório (2003) and Lopes et al. (2017) state that cracks correspond to sharp openings, characterized by the separation between parts of the element, being more dangerous when compared to fissures.

In this sense, it is of fundamental importance to improve engineering professionals focused on the investigation of failures and breakdowns. In addition to causing numerous accidents of a serious nature, such

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as landslides, they also lead to asset depreciation and high recovery costs. Characterized by empiricism and the lack of adequate procedures (BOLINA et al., 2019). Thomaz (2001) states that it is necessary to know in depth the agents of degradation and the most frequent pathological manifestations of the project object, in order to avoid them through the elaboration of constructive details and meticulous specifications.

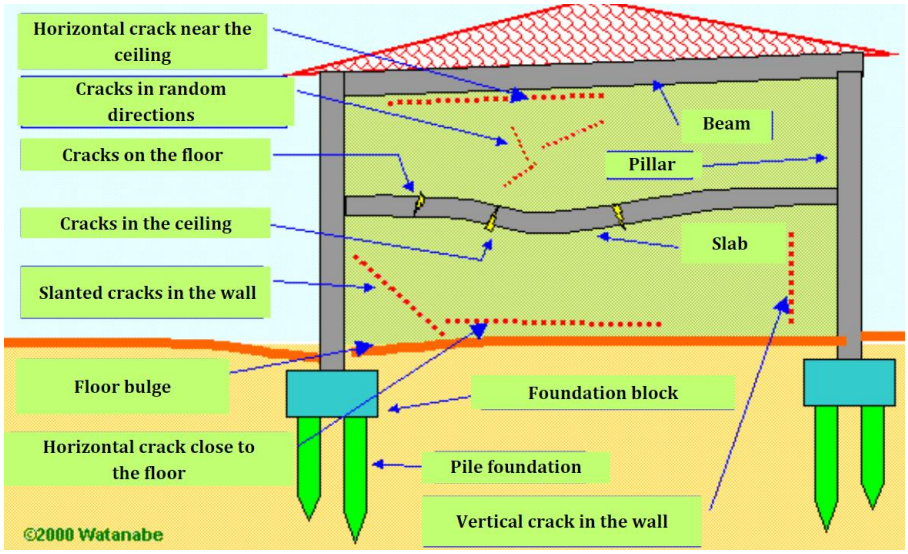
According to a survey by Datafolha (2022), approximately 82% of residential buildings in Brazil in that year were being built without technical monitoring, causing serious problems. On the other hand, the lack of monitoring causes the frequent appearance of various pathological manifestations in new or recently repaired buildings, bringing to the fore a great concern regarding the durability of buildings (FREIRE, 2010).

In view of this, the present study aims to bring an analysis of cracks in masonry, in reinforced concrete structures and coatings, addressing the configuration of cracks and their mechanism of occurrence, in the city of Erechim - RS; the choice for the city was based on the population (approximately 100,000 inhabitants), since most studies are carried out in larger cities, and on the proximity to the University where the study was carried out.

2. Theoretical Reference

A crack is not a pathology, but a symptom, arising from a degradation mechanism (such as a disease), and whose therapy (what to do to restore the structure) must take into account the causes of the disease (SILVA et al., 2011). Figure 1 shows possible fissures and/or cracks found in a residence.

Figure 1 – Possible fissures and cracks found in a residence. From: Watanabe.

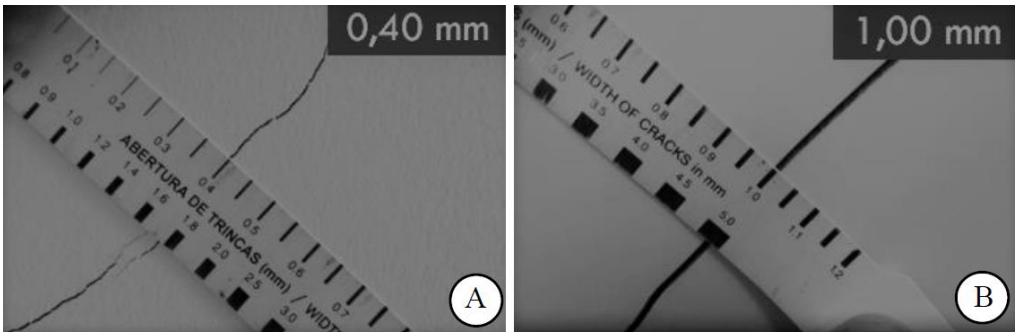


The sooner the corrections are performed, the more durable, effective, easy to perform and cheaper they will be (HELENE, 1992; MILITITSKY et al., 2008). IBAPE (2014) points out that cracks are mainly observed in slabs, beams, pillars, floors, walls and coatings and have typical characteristics, as shown in Figure 1.

2.1 Fissures and cracks

According to NBR 15575-2 (2013), structural components cannot present in their service limit state fissures with openings larger than the limits indicated in NBR 6118 (2014) and NBR 9062 (2017), that is, of the order of 0 .4mm or 0.5mm, as shown in Figure 2A. Therefore, openings greater than or equal to 0.6mm will be considered a crack, as shown in Figure 2B, with no limit restriction, so the crack limit will be adopted as in the literature, in the order of 2mm or 3mm (THOMAZ, 2020).

Figure 2 – (A) Fissures of 0,40 mm e (B) cracks of 1,00 mm. From: Nacimento and Cicuto (2019).



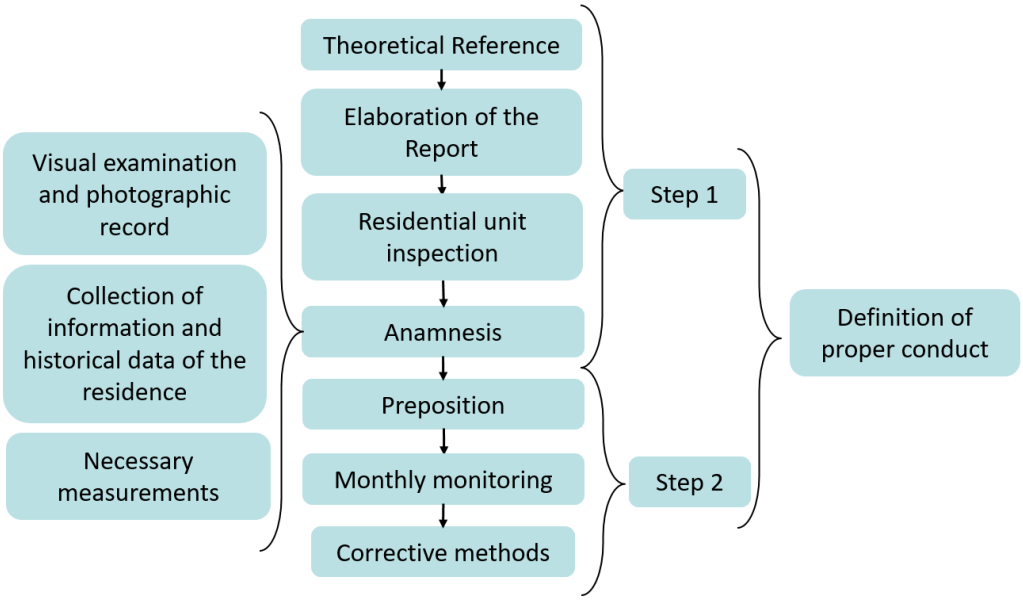
Cracks occur due to imposed traction, shear or bending actions, and originate in the places where traction occurs. Such tensions that come from actions such as retraction, differential settlements, temperature variation, overload and use (CUNHA, 2011; CAPORRINO, 2018). They are considered as a synonym of warning of the pathological manifestation, requiring investigation to understand its cause (BENTO, 2021).

In order for existing cracks to be treated, it is essential that a characteristic and in-depth study be carried out regarding their causes, as it is necessary to identify whether the propagation is active or passive (NBR 15575/ 2013). For Vitório (2003) passives occur when their opening reaches its maximum amplitude and stabilize due to the cessation of the causes that generated them; as is the case with hydraulic retraction cracks or those caused by differential settlement of the foundation that is already stabilized. Active cracks are caused by actions of variable magnitude that cause deformations in the element, this is the case of cracks of thermal origin and those originated by bending dynamic actions.

3. Methodology

The described study aims to identify, point out, compare and lead to an adequate and definitive correction of cracks, where the flowchart presented in Figure 3 shows the steps of the research and evaluation process for the definition of conduct established in the experimental program.

Figure 3 – Proposed flowchart for defining appropriate conduct for the study.



The object of study for the evaluation of the cracks were the single-family residences in masonry of medium standard sealing, concluded up to 10 years in the city of Erechim-RS. All residences were then located in the same region of the city, in the Parque dos Imigrantes, São Cristóvão and Koller neighborhoods, with the aim of making the comparison and evaluation more consistent, and not having a large variation in temperature at the extremes of the city. For privacy and security purposes, the residences contain numerical denomination: residence 1, residence 2, residence 3 and residence 4.
The survey of cracks was carried out in loco, with monthly monitoring in the year 2022. Starting in the month of May until the month of October in residences 1 and 2; and from July to October in residences 3 and 4. All mapped cracks are cataloged by files, which contain the cause of the problem, analysis and therapy (your intervention) of the anomaly; as well as the entire history of measurements taken during the study.

3.1 Growth of the studied neighborhoods

Of the residences seen and evaluated in the Parque dos Imigrantes, São Cristóvão and Koller neighborhoods, most of them were built without the help of technical managers. process thereof. In addition to the MPU (Movimento Popular Urbano) seen until 2016, which was the last year to register an irregular occupation, a case reported by Jornal Diário da Manhã apud Psidonik (2019. Another failure is the need to present what is a project, where Prof. Dr. Eng. Geilma Lima Vieira at CBPAT 2022 found “executing and contracting a project needs to be something normal, something intrinsic in engineering, that in addition to many constructions not having projects in many others, the projects arrive incipient in the works” .

In May 2022, Datafolha recorded new data: 82% of new or renovated homes were built without the help of a technical manager in that year, with a 2% growth compared to 2015. This mirrors what has already been seen and noticed in the neighborhoods under study, Psidonik (2019) pointed out that the region of the city under study lacks a favorable topography, harming projects, that is, making it more expensive. Associated with irregular occupation movements, which end up harming inspections and especially the safety of residents who live in the area. In short, this has gradually been regularized and updated in the master plan, adapting to the reality of neighborhoods considered to be of medium income (SILVA, 2016). Understanding the existing shortage in the evaluated places, where many residences do not have basic sanitation, requiring basic investments, before many regularizations.

3.2 Data survey

The data collection was carried out from monthly visits to the units to monitor the opening of the crack, whether its situation is active or passive. Defining an adequate conduct, in a concrete way, checking the opening measurement at each visit, making use of the non-destructive test (fissurometer, equipment used to measure the magnitude of the opening of fissures and cracks) and the temperature of the place at the moment, always measuring the temperature in the same site for comparison purposes. Thus, forming Table 1, filled in according to the progress of the study, serving as a basis for completing the forms and aiding in the inspections.

Table 1 – Monthly monitoring of residential units.

MONITORING RECORD					
Residence	Date	Crack location	Record N°	Measure (mm)	Temperature (°C)
Residence 1	/ /				
	/ /				
	...				
Residence 2	/ /				
	/ /				
	...				
Residence 3	/ /				
	/ /				
	...				
Residence 4	/ /				
	/ /				
	...				

3.3 Damage sheet

For easy and quick understanding, damage identification forms were developed, shown in Figure 4. Divided into two parts, first, for a description of the property and the anomaly, with a photographic record of the anomaly and a brief questionnaire for collecting information; and in the second part, focused on the preposition stage, relying on the tail of the anomaly, measurement analysis and intervention.

Figure 4 – Damage identification sheet.

URI ERECHIM	IDENTIFICATION RECORD OF DAMAGE DUE TO CRACKS IN SINGLE-FAMILY HOMES IN MASONRY		RECORD N°	ENGENHARIA CIVIL
	Residence:	Residence X		
	Building age:	X years	XX	
	Date of inspection:	___/___/___		

Residence Description:				
Information collection:	Where on the wall does this crack appear?			
	What is the position of the crack?			
	How long has it been noticed?			
	Has there been any nearby construction recently? If so, did you already have this manifestation before this work?			
Photographic record				
PREPOSITION				
Cause:				
Intervention:				
Historical data of the residence:	**Date**	**Measure (mm)**	**Crack location**	**Temperature (°C)**
	___/___/___			
	...			

4. Results and discussions

In this chapter, the results obtained from the experimental program presented in the previous chapter will be discussed. Each house was duly inspected in order to meet the proposed objectives, eliminating hypothetical causes and offering concrete therapy for the anomaly.

The incidence of variation in the type of cracks located in item 4.5, shows the percentage of cracks in the building elements found in loco during inspections. In this analysis, the cracks found are being evaluated as a whole and not by housing.

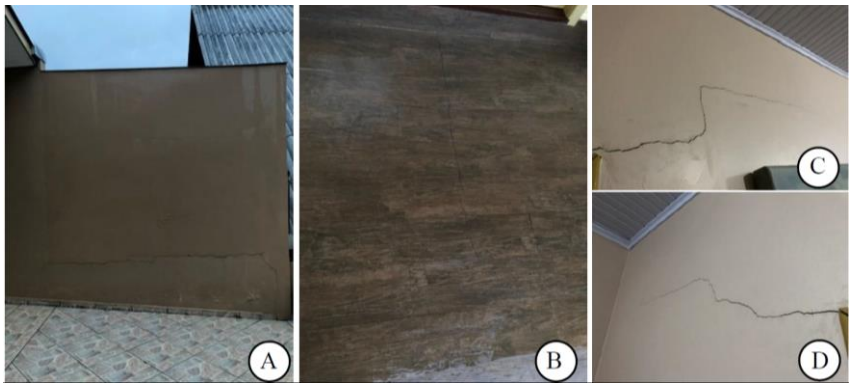
4.1 Residence 1

DESCRIPTION: This is a single-family house in masonry, completed 7 years ago, it has 87 m² of built area and the façade of the house is positioned in the southwest direction of solar orientation. According to the residents, the residence had several cracks in a short time of life of the building. The owners corrected the most visible ones, however, the solution adopted was not effective and the crack reappeared.

INFORMATION COLLECTION: The residence does not have a superstructure, that is, it does not have structural elements such as beams and pillars; it has shallow foundations (footings) and had no technician responsible for the execution. In the house, a wall reinforcement has already been executed, due to the absence of structure, reaching the state of almost collapsing due to the high formation of cracks. Thus, a pillar was executed next to the masonry wall to support such a load.

CATALOGED: Four cracks were found in the residence and a high level of cracks, among the cracks shown in Figure 6 are on (A) the external wall, due to its history and currently has the presence of moisture; (B) porcelain floor, caused by poor application of the laying mortar, allowing the piece to be affected by the traffic of people and (C and D) internal wall on both sides, caused by the presence of concentrated load not foreseen in the project.

Figure 6 – Cracks found in residence 1.



4.1.1 – Crack A

Photographic record (first	 Location 1 Location 2

CAUSE: The wall is located at the boundary of the house; the house does not have a superstructure where such a wall already needed reinforcement, as it arrived in a state of almost collapsing due to the high formation of cracks, thus flaming; this happens because the slenderness of the element does not support such a load, generating an imbalance in the element that is not associated with any structural element, such as a beam or column.

Currently, the masonry wall has a pillar on the side to support the weight of the masonry; however, the cracks reappeared, starting vertically at the meeting of the masonry-pillar and progressing horizontally along the entire length of the masonry. The main cause associated with existing cracks is the presence of moisture; that behind the wall there is the roof of the neighbor with one of the waters descending towards the wall, with a gutter next to this masonry wall, where this horizontal crack manifests itself, at the height of the gutter along its entire length.

MEASUREMENT HISTORY: Starting in the month of May until the month of October.

Table 2 – Home measurement history, crack A.

	Date	Measure (mm)	Crack location	Temperature (°C)
Home measurement history:	05/13/2022	0,70	External wall – Location 1	10
	05/13/2022	0,70	External wall – Location 2	10
	06/11/2022	0,80	External wall – Location 1	1
	06/11/2022	0,75	External wall – Location 2	1
	07/26/2022	1,00	External wall – Location 1	28
	07/26/2022	0,75	External wall – Location 2	28
	08/19/2022	1,10	External wall – Location 1	7
	08/19/2022	1,00	External wall – Location 2	7
	09/20/2022	1,00	External wall – Location 1	18
	09/20/2022	1,00	External wall – Location 2	18
	10/10/2022	1,20	External wall – Location 1	10
	10/10/2022	1,10	External wall – Location 2	10

MEASUREMENT ANALYSIS: The crack behaves as progressive active, where it is having a progressive increase over time. Being the worst type of crack when related to therapy, according to the literature.

INTERVENTION: Regarding the analysis of measurements, its behavior is directly related to its nature, if you perform a correction even with the use of screens, it may open again due to its slenderness, firstly it is recommended to stop the moisture present and treat it as a joint of movement. Therefore, this joint will serve to relieve and absorb its active movement. Like this:

1st) With a chisel, widen the active crack along its entire length;

2nd) Clean the surface, removing the dust caused by the widening of the opening;

3rd) Carefully fill the opening with plastic sealant;

4th) Finishing.

4.1.2 – Crack B

Photographic record (first inspection)

Location 1 Location 2

CAUSE: The case is a crack in a porcelain floor, the piece is 20x100cm, the application was carried out on a ceramic floor using an ACIII mortar; one can point out the workability between the divergent pieces, where the crack appears perpendicular to the longest length of the piece, the most susceptible side. In addition to the cracks, it is possible to observe displacement and hollow pieces, due to the size of the piece, it is also possible to point out the poor application of the laying mortar, allowing the piece to suffer when someone steps on it.

MEASUREMENT HISTORY: Starting in the month of May until the month of October.

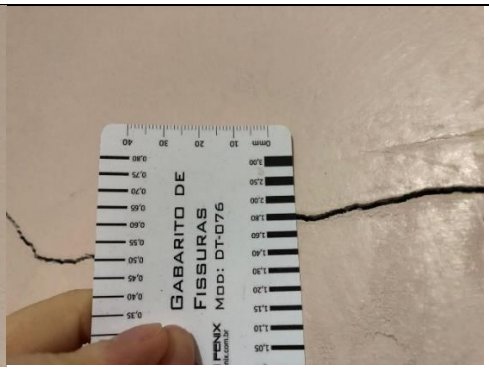
Table 3 – Home measurement history, crack B.

	Date	Measure (mm)	Crack location	Temperature (°C)
Home measurement history:	05/13/2022	2,00	Porcelain floor – Location 1	10
	05/13/2022	1,80	Porcelain floor – Location 2	10
	06/11/2022	2,50	Porcelain floor – Location 1	1
	06/11/2022	2,00	Porcelain floor – Location 2	1
	07/26/2022	2,50	Porcelain floor – Location 1	28
	07/26/2022	2,00	Porcelain floor – Location 2	28
	08/19/2022	2,50	Porcelain floor – Location 1	7
	08/19/2022	2,50	Porcelain floor – Location 2	7
	09/20/2022	2,50	Porcelain floor – Location 1	18
	09/20/2022	2,00	Porcelain floor – Location 2	18
	10/10/2022	3,00	Porcelain floor – Location 1	10
	10/10/2022	2,50	Porcelain floor – Location 2	10

MEASUREMENT ANALYSIS: The crack remained active, with this variation due to temperature, colder days with larger openings and hot days with smaller openings.

INTERVENTION: Restoring rigid coatings, in this case porcelain tiles, is not feasible. Therefore, what I would recommend doing is replacing the plate, or the entire set, reviewing and/or placing expansion joints on the floor, so that there is a gap that the piece can suffer when there is movement under it. Applying these pieces following the manufacturer's guidelines, arranged in the box itself or on the site, and maintaining its application using an ACIII mortar.

4.1.3 – Cracks C and D

Photographic record (first inspection)	 Crack C - Location 1  Crack D - Location 2

CAUSE: The main associated cause is the presence of a concentrated load not foreseen in the project, it is a 1,000-liter water tank resting on the roof trusses, the crack originates where this load is located and progresses to the apex of the go, in this case the door; because it is a weakened region mainly because it does not have a lintel.

MEASUREMENT HISTORY: Starting in the month of May until the month of October.

Table 4 – Home measurement history, cracks C e D.

	Date	Measure (mm)	Crack location	Temperature (°C)
Home measurement history:	13/05/2022	1,60	Inner wall – Location 1	10
	13/05/2022	1,80	Inner wall – Location 2	10
	11/06/2022	1,80	Inner wall – Location 1	1
	11/06/2022	2,00	Inner wall – Location 2	1
	26/07/2022	1,60	Inner wall – Location 1	28
	26/07/2022	1,60	Inner wall – Location 2	28
	19/08/2022	1,80	Inner wall – Location 1	7
	19/08/2022	1,80	Inner wall – Location 2	7
	20/09/2022	1,60	Inner wall – Location 1	18
	20/09/2022	1,70	Inner wall – Location 2	18
	10/10/2022	1,80	Inner wall – Location 1	10
	10/10/2022	1,80	Inner wall – Location 2	10

ANALYSIS OF MEASUREMENTS: The crack behaves as an active one, in colder temperatures it has a more accentuated opening, being a characteristic considered typical.

INTERVENTION: It is recommended to eliminate this concentrated load, correct it with a hexagonal mesh steel or polyester mesh in the cracked area, closer to the anchorage area, and use flexible mortars (PVA, acrylic, etc.). In addition to the execution of a lintel at the top of the door, to receive possible relief of tensions. Like this:

1st) Remove the old coating from the cracked area plus the anchoring area (supporting area of the screen, which may vary from 30 to 50cm);

2nd) Clean the surface, removing the dust caused by the old coating;

3rd) Execute chapisco;

4th) Place the screen on the roughcast layer, considering the support region of at least 30cm;

5th) Redo the plaster over the applied canvas;

6th) Finishing.

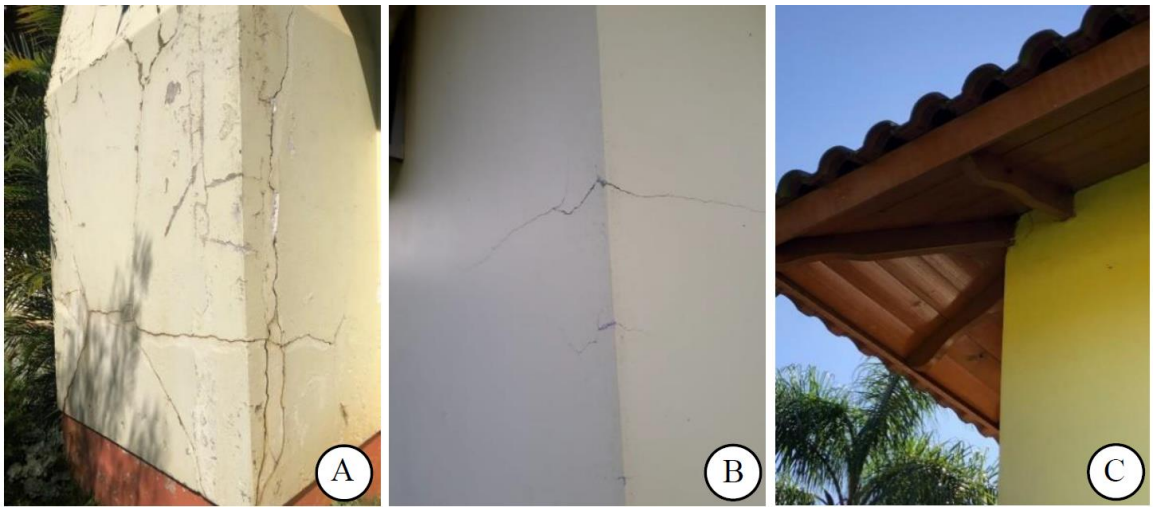
4.2 Residence 2

DESCRIPTION: Residence 2 consists of a single-family house in masonry, completed 10 years ago, with 148 m² of built area. The facade of the residence is positioned in the northeast direction in solar orientation. This residence has several visible cracks, which appeared more than a year ago. As in the previous residence, the correction was not effective.

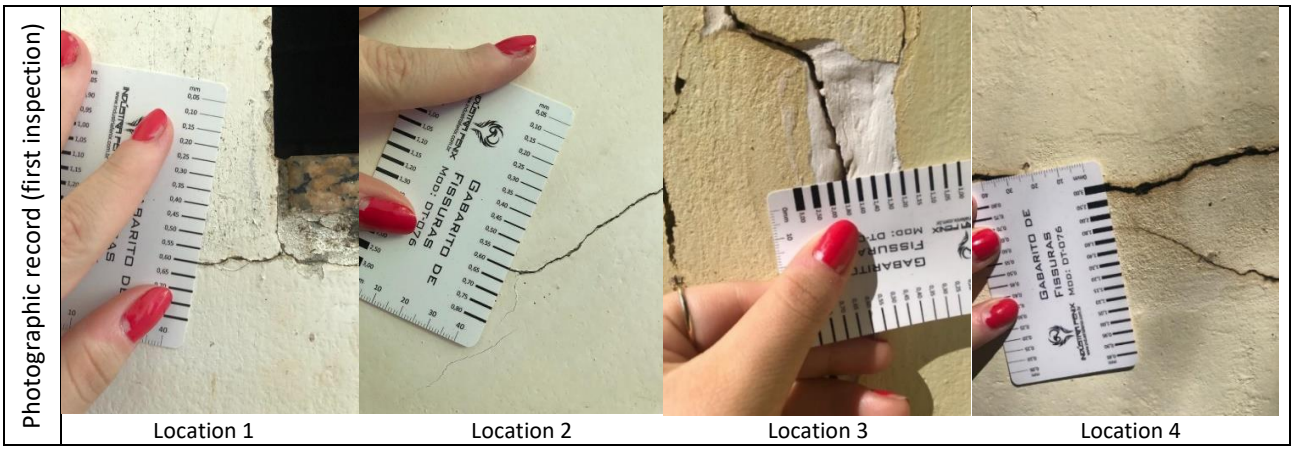
DATA COLLECTION: House 2 has a superstructure, consisting of pillars and tie-down straps, has footing-type foundations (superficial) with varying heights, between 55 centimeters and 2 meters deep; however, there was also no technical responsible for the execution.

CATALOGED: Three cracks stood out in the house in addition to a high number of cracks. Figure 6 presents the cracks found, being (A) barbecue, due to the thermal movement associated with the architectural details; (B) back wall of the house, caused by effects on the top of the element and (C) below the roof, due to overload.

Figure 8 – Cracks found in residence 2.



4.2.1 – Crack A



CAUSE: A possible cause is thermal movement, where the resistance of the blocks used is less than the resistance of the laying mortar, thus bursting cracks crossing the blocks; On the front face of the barbecue, there are also no beams in the span, promoting the progression of cracks. The detail of the architecture of the house (the orange/yellow tooth) in the state where the cracks are found is allowing the parts to collapse,

this is possible to observe by the behavior of the crack in this tooth, it is as if it were suffering deflection of the component.

MEASUREMENT HISTORY: Starting in the month of May until the month of October.

Table 5 – Home measurement history, crack A.

	Date	Measure (mm)	Crack location	Temperature (°C)
Home measurement history:	05/08/2022	0,60	Brazilian grill – Location 1	18
	05/08/2022	0,60	Brazilian grill – Location 2	18
	05/08/2022	1,80	Brazilian grill – Location 3	18
	05/08/2022	3,00	Brazilian grill – Location 4	18
	06/12/2022	1,00	Brazilian grill – Location 1	7
	06/12/2022	0,75	Brazilian grill – Location 2	7
	06/12/2022	2,50	Brazilian grill – Location 3	7
	06/12/2022	3,00	Brazilian grill – Location 4	7
	07/24/2022	0,55	Brazilian grill – Location 1	21
	07/24/2022	0,55	Brazilian grill – Location 2	21
	07/24/2022	2,00	Brazilian grill – Location 3	21
	07/24/2022	3,00	Brazilian grill – Location 4	21
	08/19/2022	0,60	Brazilian grill – Location 1	7
	08/19/2022	0,60	Brazilian grill – Location 2	7
	08/19/2022	*3,10	Brazilian grill – Location 3	7
	08/19/2022	*4,00	Brazilian grill – Location 4	7
Home measurement history:	09/20/2022	0,65	Brazilian grill – Location 1	18
	09/20/2022	0,65	Brazilian grill – Location 2	18
	09/20/2022	*3,10	Brazilian grill – Location 3	18
	09/20/2022	*4,00	Brazilian grill – Location 4	18
	10/10/2022	0,60	Brazilian grill – Location 1	10
	10/10/2022	0,60	Brazilian grill – Location 2	10
	10/10/2022	*3,30	Brazilian grill – Location 3	10
	10/10/2022	*4,20	Brazilian grill – Location 4	10

NOTE * Crack evolved to slit.

ANALYSIS OF MEASUREMENTS: The cracks are active and regardless of the temperature they are progressing, based on their measurement history and appearance, a possible collapse of the parts can be concluded. So much can be said about it, due to its evolution into a crack.

INTERVENTION: It is recommended as soon as possible to condemn the element and redo it. Because due to the number of existing openings in the element and in the behavior in the measurements, the repair is impracticable. So, to redo follow the recommendations:

1st) Clean the site after demolition and use materials of origin and quality;

2sd) Use a 1:3 ratio (1 measure of cement to 3 of sand) for laying the ceramic blocks;

3rd) Joint thickness of 1 cm, in addition to not having plumb joints and completely filled;

4th) The service must be started by the corners, obeying plumb, level and square in the survey;

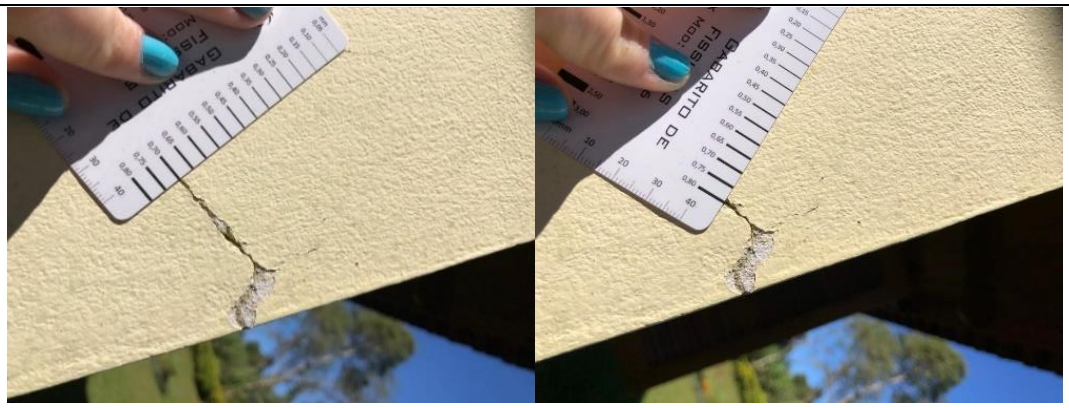
5th) Carry out mooring at the corners of the element;

6th) Where the existing element (not demolished) meets the reconstructed part, use a tie screen to avoid cracking, that is, when roughcasting apply a polyester screen on top of it and then normally apply the subsequent layers on top of it;

7th) On the face of the barbecue opening, make a lintel and counter-beam of 30 cm on each side of the gap;

8th) Finishing.

4.2.2 – Crack B

Photographic record (first inspection)	 Location 1 Location 2

CAUSE: This crack is located below the crack on Sheet 03, which due to the tensions exerted by the overload can result in openings in the supported body, that is, the tensions acting on the top of the element influence the body, looking for a corner to manifest itself .

MEASUREMENT HISTORY: Starting in the month of May until the month of October.

Table 6 – Home measurement history, crack B.

	Date	Measure (mm)	Crack location	Temperature (°C)
Home measurement history:	05/08/2022	0,70	Back wall – Location 1	18
	05/08/2022	0,80	Back wall – Location 1	18
	06/12/2022	0,75	Back wall – Location 1	7
	06/12/2022	0,80	Back wall – Location 1	7
	07/24/2022	0,65	Back wall – Location 1	21
	07/24/2022	0,80	Back wall – Location 1	21
	08/19/2022	0,75	Back wall – Location 1	7
	08/19/2022	0,80	Back wall – Location 1	7
	09/20/2022	0,75	Back wall – Location 1	18
	09/20/2022	0,80	Back wall – Location 1	18
	10/10/2022	0,75	Back wall – Location 1	10
	10/10/2022	0,80	Back wall – Location 1	10

ANALYSIS OF MEASUREMENTS: The opening remained constant, there was no great variation in opening when comparing opening x temperature. For this reason, it can be stated that the crack occurred due to the element having worked due to the tensions exerted on its top, as stated in its cause of manifestation. That is, if the tensions exerted at the top cease, this crack also ceases, and can be treated monolithically, thus its therapy being treated as passive.

INTERVENTION: With stagnation of crack progression due to excessive load, it is recommended to correct the openings with an epoxy resin, throughout the opening, as follows:

1st) With a chisel, widen the active crack along its entire length;

2nd) Clean the surface, removing the dust caused by the widening of the opening;

3rd) Carefully fill the opening with epoxy resin;

4th) Finishing.

4.2.3 – Crack C

Photographic record (first inspection)	 Location 1  Location 2

CAUSE: The main cause associated in the case presented is the concentrated load overload, typical case of load not foreseen in the design, generating high compressive stresses; vertical and inclined openings appear. In addition to being possible to observe that in all corners of the house there are openings of this type, because they always look for the most fragile way to appear, that is, the corners.

MEASUREMENT HISTORY: Starting in the month of May until the month of October.

Table 7 – Home measurement history, crack C.

	Date	Measure (mm)	Crack location	Temperature (°C)
Home measurement history:	05/08/2022	3,00	Below the Roof – Location 1	18
	05/08/2022	2,50	Below the Roof – Location 2	18
	06/12/2022	3,00	Below the Roof – Location 1	7
	06/12/2022	3,00	Below the Roof – Location 2	7
	07/24/2022	2,50	Below the Roof – Location 1	21
	07/24/2022	2,00	Below the Roof – Location 2	21
	08/19/2022	3,00	Below the Roof – Location 1	7
	08/19/2022	3,00	Below the Roof – Location 2	7
	09/20/2022	3,00	Below the Roof – Location 1	18
	09/20/2022	3,00	Below the Roof – Location 2	18
	10/10/2022	3,00	Below the Roof – Location 1	10
	10/10/2022	3,00	Below the Roof – Location 2	10

MEASUREMENTS ANALYSIS: As predicted by crack B, the movement of the opening was stopped, working as passive. For this to have occurred, this opening also needs to be behaving passively, since it is responsible for the occurrence of the previous crack. To explain this occurrence of overload on the element, it is as if the deformations that the overload exerts had “settled”, that is, the element has already deformed to the maximum with such existing overload.

INTERVENTION: With stagnation of crack progression due to excessive load, it is recommended to correct the openings with an epoxy resin, throughout the opening, as follows:

1st) With a chisel, widen the active crack along its entire length;

2nd) Clean the surface, removing the dust caused by the widening of the opening;

3rd) Carefully fill the opening with epoxy resin;

4th) Finishing.

4.3 Residence 3

DESCRIPTION: Residence 3 is a single-family masonry residence, completed 10 years ago, with 96 m² of built area. The façade is positioned towards the east of solar orientation. Consisting of two floors, one being considered a basement, and the other the floor of housing. Figure 9 shows the facade of the house.

INFORMATION COLLECTION: residence features infrastructure and superstructure, including footings, pillars, eucalyptus beams supporting the house and lashing straps to support the roof; It has lintels and lintels on the floor of the house. It is technically responsible for the execution and began to show signs of cracks after the expansion reform of the residence carried out 5 years ago. There was no attempt to correct it during this period, and this renovation was not followed up by a professional.

CATALOGED: The house has cracks with characteristic causes, mainly because they manifest themselves in the places where the expansion is being carried out. In Figure 10, the cracks mapped in the house can be seen, (A) at the base of the window, running along the corner of the wall, caused due to the absence of a slat in the basement window associated with differential settlement, (B) located in the basement, caused by overload not foreseen in the project and (C1, C2 and C3) settlement in the expansion area of the house.

Figure 10 – Cracks found in residence 3.

4.3.1 – Crack A

Photographic record (first inspection)	 Wall 1 – Location 1

CAUSE: The wall is located in the basement of the residence, part where it was enlarged in the renovation of the house for the execution of a bathroom in the basement, the repression of the area can be observed during the inspection, in addition to the lack of lintel and lintel in the window, point out the cause in the alteration of the soil by the unforeseen expansion reform.

MEASUREMENT HISTORY: Starting in the month of July until the month of October.

Table 8 – Home measurement history, crack A.

	Date	Measure (mm)	Crack location	Temperature (°C)
Home measurement history:	07/24/2022	1,60	Wall 1 – Location 1	21
	08/19/2022	1,60	Wall 1 – Location 1	7
	09/20/2022	1,80	Wall 1 – Location 1	18
	10/10/2022	2,00	Wall 1 – Location 1	10

MEASUREMENT ANALYSIS: The crack can be seen as active and progressive, which is an expected behavior due to the existence of settlement at the site. This occurs because when the foundations are tested against repression, there are requests that are not foreseen in the project and that are manifested in the masonry and in the superstructure, which are the tensile and shear stresses.

INTERVENTION: In the same way as mentioned in Sheet 01, remedy the problem with the soil, assessing the need for reinforcement in the foundations to perform any crack correction, following the correction in the same way, but executing lintel and counter lintel in the window:

1st) Remove the old coating from the cracked area plus the anchoring area (supporting area of the screen, which may vary from 30 to 50cm);

2nd) Clean the surface, removing the dust caused by removing the old coating;

3rd) Execute chapisco;

4th) Place the screen on the roughcast layer, considering the support region of at least 30cm;

5th) Redo the plaster over the applied canvas;

6th) Carry out a 30cm lintel and counter lintel on each side of the window;

7th) Finishing.

4.3.2 – Crack B

Photographic record (first inspection)

Wall 2 – Location 1

CAUSE: The renovation was divided into two stages, first the execution of the lower floor (the basement) and after it was built on top, at that time the ceiling slab of the lower floor was used as support for a 1000 liter water tank, in this representing a concentrated load on the slab, still placed early on, which a while later was removed for the execution of the upper floor. In that exact place where the water tank was supported, there is currently the evaluated crack.

MEASUREMENT HISTORY: Starting in the month of July until the month of October.

Table 9 – Home measurement history, crack B.

	Date	Measure (mm)	Crack location	Temperature (°C)
Home measurement history:	24/07/2022	1,05	Wall 2 – Location 1	21
	19/08/2022	1,10	Wall 2 – Location 1	7
	20/09/2022	1,05	Wall 2 – Location 1	18
	10/10/2022	1,10	Wall 2 – Location 1	10

ANALYSIS OF MEASUREMENTS: From the measurement history carried out, it can be pointed out that the cause of the opening was momentary, since its observation appeared right when there was a water tank precociously supported in the place and there was no variation in its magnitude over time, according to locals. Although they do not point out the existence of opening movement, in the history there was a minimal variation, which can be pointed to the temperature and humidity existing on the day.

INTERVENTION: Correction is recommended using a hexagonal mesh steel or polyester mesh in the cracked region, more in the anchorage area, and using flexible mortars (PVA, acrylic, etc.). Like this:

1st) Remove the old coating from the cracked area plus the anchoring area (supporting area of the screen, which may vary from 30 to 50cm);

2nd) Clean the surface, removing the dust caused by removing the old coating;

3rd) Execute chapisco;

4th) Place the screen on the roughcast layer, considering the support region of at least 30cm;

5th) Redo the plaster over the applied canvas;

6th) Finishing.

4.3.3 – Cracks C

Photographic record (first inspection)

Location 1

Location 2 Location 3

Location 4

CAUSE: Upon inspection, it can be seen that the enlarged part of the residence is descending, giving evidence of the existence of repression, where the existing side sidewalk is completely cracked. An aggravating factor can be pointed out with the lack or poor compaction of the soil after the execution of the new foundation next to the existing one. In the first Figure, the enlarged area can be seen, the one with the lowest roof; in

this process, a bathroom was built in the basement, a bathroom and service area on the floor of the house, in addition to the access stairs.

MEASUREMENT HISTORY: Starting in the month of July until the month of October.

Table 10 – Home measurement history, crack C.

	Date	Measure (mm)	Crack location	Temperature (°C)
Home measurement history:	07/24/2022	3,00	Connecting wall – Location 1	21
	07/24/2022	2,50	Connecting wall – Location 2	21
	07/24/2022	1,80	Connecting wall – Location 3	21
	07/24/2022	2,50	Connecting wall – Location 4	21
	08/19/2022	*4,00	Connecting wall – Location 1	7
	08/19/2022	3,00	Connecting wall – Location 2	7
	08/19/2022	2,00	Connecting wall – Location 3	7
	08/19/2022	3,00	Connecting wall – Location 4	7
	09/20/2022	*4,00	Connecting wall – Location 1	18
	09/20/2022	3,00	Connecting wall – Location 2	18
	09/20/2022	2,50	Connecting wall – Location 3	18
	09/20/2022	*4,00	Connecting wall – Location 4	18
	10/10/2022	*4,20	Connecting wall – Location 1	10
	10/10/2022	3,00	Connecting wall – Location 2	10
	10/10/2022	2,50	Connecting wall – Location 3	10
	10/10/2022	*4,10	Connecting wall – Location 4	10

NOTE * Crack evolved to slit.

ANALYSIS OF MEASUREMENTS: The cracks are manifesting themselves as active and progressive, with a marked magnitude, proving the existence of settlement. From the collection of information obtained, it is possible to point out different soil resistances, being the resistance where the existing foundation was (before the renovation) and the resistance after touching the soil to execute the expansion foundation, where this ends up affecting the resistance of the layers of this soil, which is called a stress bulb. Creating as if it were a neighboring work destabilizing the soil of the existing construction.

INTERVENTION: Soil analysis is recommended, to monitor settlement, using equipment such as a tassometer and inclinometers. To be able to perform a correction, monitoring will be necessary, as due to proof of the magnitude of the opening working progressively regardless of the temperature variation, any apparent correction is inefficient, as there are chances of this movement continuing. If proven, immediately reinforce the foundations and then correct the crack as follows:

1st) Remove the old coating from the cracked area plus the anchoring area (supporting area of the screen, which may vary from 30 to 50cm);

2nd) Clean the surface, removing the dust caused by removing the old coating;

3rd) Execute chapisco;

4th) Place the screen on the roughcast layer, considering the support region of at least 30cm;

5th) Redo the plaster over the applied canvas;

6th) Finishing.

4.4 Residence 4

DESCRIPTION: Residence 4 consists of a mixed single-family house, with a built area of 75 m², where the pathological manifestation analyzed is presented in the masonry part of the residence. The masonry area was built first and then an extension was made using wood. The residence is 8 years old and the facade of the residence is positioned in the south direction in solar orientation. Figure 47 shows the facade of the house.

INFORMATION COLLECTION: The house did not have a technical responsible for the execution. It presents infrastructure, namely footings and superstructure (beams and pillars). In June 2022, a correction was carried out, covering the cracks with a lime mortar and executing the painting layer, but in July, in the first inspection,

they had already evolved as cracks again, thus proving the correction to be ineffective, not being able to stop the cause of the problem.

CATALOGED: Figure 12 shows the mapped cracks, namely, (A) below the window, progressing downwards (crack caused due to the absence of a lintel); (B) on a flat wall, that is, without the presence of openings (crack characteristic of overload); (C) thermal movement of the reinforced concrete structure, manifesting itself in the sealing masonry blocks and (D) in an external wall in the connection between the structure and the masonry.

Figure 12 – Cracks found in residence 4.

4.4.1 – Crack A

Photographic record (first inspection)	 Internal wall – Location 1

CAUSE: It appears just below the window, due to the absence of a lintel, this happens because all constructions exert vertical loads that are transmitted to the ground, when there is an opening (a window) there is a vanishing point for this load passing through the masonry , where it generates a relief of tensions and if there is no adequate lintel and counter lintel, it will crack.

MEASUREMENT HISTORY: Starting in the month of July until the month of October.

Table 11 – Home measurement history, crack A.

	Date	Measure (mm)	Crack location	Temperature (°C)
Home measurement history:	07/26/2022	0,65	Internal wall – Location 1	28
	08/19/2022	0,75	Internal wall – Location 1	7
	09/20/2022	0,70	Internal wall – Location 1	18
	10/10/2022	0,75	Internal wall – Location 1	10

MEASUREMENT ANALYSIS: From the history, it can be observed that the temperature variation is directly related to the magnitude of the crack. As in Sheet 01 of Residence 04, it can be pointed out that the correction was inefficient, as it was incorrectly corrected, dealing with an active crack, the correction performed is not

sufficient, as it does not have the capacity to absorb the movements exerted on the element , thus cracking again.

INTERVENTION: In view of the lack of lintel and counter lintel, its execution will first be necessary. Like this:

1st) Remove the frames;

2sn) Make a 30cm lintel and counter lintel on each side of the window;

3rd) Replace the frames;

After that, you can correct the crack, because if you correct it without the previous step, it could crack again, as the sealing masonry does not support great efforts, especially if there is a miter gap, considered this, a point of stress relief. Like this:

1st) Remove the old coating from the cracked area plus the anchoring area (supporting area of the screen, which may vary from 30 to 50cm);

2nd) Clean the surface, removing the dust caused by the old coating;

3rd) Execute chapisco;

4th) Place the screen on the roughcast layer, considering the support region of at least 30cm;

5th) Redo the plaster over the applied canvas;

6th) Finishing.

4.4.2 – Cracks B and C

Photographic record (first inspection)	 Location 2  Location 3

CAUSE: The crack in Figure B occurs in a wall without an opening, appearing vertically, being a typical crack due to overload, where it is promoted by the transverse deformation of the mortar under this load exerted. In Figure C, it occurs on the same wall, but in the lower right corner, being characteristic of the thermal expansion of the structure, which ends up manifesting itself in the masonry as it is the most fragile element.

Analyzing it in context, as they are cracks in the same wall, it is the deformation of the structural elements, due to the undersized structure given by the lack of materials, this is evidenced by the lack of a technical manager, the absence of a structural project and the correction carried out in June 2022 have been inefficient.

MEASUREMENT HISTORY: Starting in the month of July until the month of October.

Table 12 – Home measurement history, cracks B and C.

	Date	Measure (mm)	Crack location	Temperature (°C)
Home measurement history:	07/26/2022	0,60	Internal wall – Location 2	28
	07/26/2022	1,20	Internal wall – Location 3	28
	08/19/2022	0,65	Internal wall – Location 2	7
	08/19/2022	1,30	Internal wall – Location 3	7
	09/20/2022	0,60	Internal wall – Location 2	18
	09/20/2022	1,20	Internal wall – Location 3	18
	10/10/2022	0,65	Internal wall – Location 2	10
	10/10/2022	1,30	Internal wall – Location 3	10

MEASUREMENT ANALYSIS: The opening of cracks is constant, varying with temperature; it can be pointed out that the correction was inefficient since it was performed as if it were a passive opening, but it was an active one, due to thermal movement varying the magnitude of the opening.

INTERVENTION: At first, correction is recommended, dealing with an active opening. Like this:

1st) Remove the old coating from the cracked area plus the anchoring area (supporting area of the screen, which may vary from 30 to 50cm);

2nd) Clean the surface, removing the dust caused by the old coating;

3rd) Execute chapisco;

4th) Place the screen on the roughcast layer, considering the support region of at least 30cm;

5th) Redo the plaster over the applied canvas;

6th) Finishing.

Note: If screen correction is ineffective, it is recommended to immediately structurally reinforce the residence.

4.4.3 – Crack D

Photographic record (first inspection)	

External wall – Location 1

CAUSE: The main cause associated with this manifestation, which is considered common to all, is the thermal movement of the reinforced concrete structure; characterized by the separation of the masonry interface and reinforced concrete structure. This occurs due to the absence of adequate constructive details in this connection between interfaces, in addition to the excess of water present in the component, which can expand the masonry and when dry it retracts. The presence of water can be pointed out due to its degradation aspect, such as dark spots and the accumulation of dust on the surface, with fungi proliferating in the element.

MEASUREMENT HISTORY: Starting in the month of July until the month of October.

Table 13 – Home measurement history, crack D.

	Date	Measure (mm)	Crack location	Temperature (°C)
Home measurement history:	07/26/2022	1,30	External wall – Location 1	28
	08/19/2022	1,80	External wall – Location 1	7
	09/20/2022	2,00	External wall – Location 1	18
	10/10/2022	2,00	External wall – Location 1	10

MEASUREMENT ANALYSIS: The cracks are working as a progressive active, one of the aspects that characterizes this behavior and that is happening in the element is the proliferation of fungi that bring the indication of water present, thus preventing the crack from retracting, as normally happens in cases of thermal movement. If the presence of water does not cease, it will continue to progress regardless of the temperature variation.

INTERVENTION: Firstly, eliminate any presence of water, brush the surface to correct the crack, following the steps for an active crack, in the case of thermal movement. Like this:

1st) Once the presence of water has been corrected, remove the old coating from the cracked area plus the anchorage area (supporting area of the screen, which can vary from 30 to 50cm);

2nd) Clean the surface, removing the dust caused by the old coating;

3rd) Execute chapisco;

4th) Place the screen on the roughcast layer, considering the support region of at least 30cm;

5th) Redo the plaster over the applied canvas;

6th) Finishing;

7th) At a certain time interval, wash with hypochlorite solution, to avoid the appearance of new fungi.

4.5 Incidence analysis of the variation of types of cracks

The cause of the incidence of cracks proved to be very characteristic of what was expected, with a greater number due to overload, as shown in Table 3. In the absence of projects, this situation worsens, especially when related to structural projects, not predicting the loads to dimensioning of a coherent project, such as fixed NBR 6120 (2019). Thus, impacting the emergence of pathological manifestations, impairing the useful life of the building (LUDOVICO, 2016).

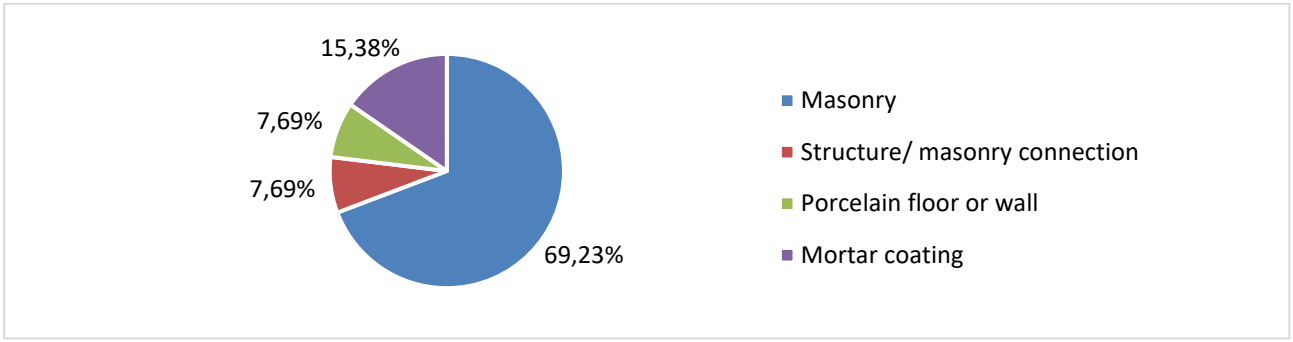
It is possible to analyze their degree of risk, considering a high degree that presents a risk to physical integrity and property, that is, that need immediate intervention. In orange in Table 3, it is analyzed as a high degree, due to the collapse being fatal if it occurs, and in green as a low/moderate degree, which does not present risks to residents. It is important to point out that the residences need an in-depth study of the structure to assess the risks at the site, not just the cracks as considered in this study.

Table 2 – Análise da incidência da variação de tipos de trincas.

Recidences	Cause	Affected constructive element
Recidence 1	Overload not fixed in the project	Masonry
Recidence 1	Humidity combined with the history of the affected element	Masonry
Recidence 1	Poor application of laying mortar	Porcelain floor or wall
Recidence 2	Thermal movement combined with architectural detail	Masonry
Recidence 2	Overload not fixed in the project	Masonry
Recidence 2	Overload not fixed in the project	Masonry
Recidence 3	Default of lintels and sills of doors and/or windows and settlement tilt	Masonry
Recidence 3	Settlement tilt	Masonry
Recidence 3	Overload not fixed in the project	Masonry
Recidence 4	Thermal movement	Mortar coating
Recidence 4	Overload not fixed in the project	Masonry
Recidence 4	Default of lintels and sills of doors and/or windows	Mortar coating
Recidence 4	Structure/ masonry connection	Structure/ masonry connection

Cracks in the building elements were quantified, considering all residences, accounting for 9 cracks in sealing masonry, 1 in connection structure/sealing masonry, 1 in porcelain coating and 2 in rigid mortar coating. In total, 13 cracks were evaluated; Figure 13 shows the incidence of crack variation in construction elements.

Figure 13 – Incidence of crack variation in construction elements.



As expected, the most affected building elements, with an incidence of 69.23%, are the sealing masonry, as it is a more fragile building element, in addition to the composition of ceramic blocks being susceptible to the appearance of pathological manifestations (NETO, 2022). As in the study carried out by Lourenço (2022), it was observed that the constructive system that presents the highest occurrence of cracks was in masonry with 50% of the total observed.

Marcolino et al. (2019), Bento et al. (2021) and Silva (2022), emphasize the need for projects and details, making the lack a failure for the emergence of pathological manifestations. That is, as evaluated in the present study, they are endogenous causes, which if they had met the minimum requirements given in regulations, they would have been avoided. Silva (2022) still proposes in his study that the most recurrent manifestations are due to the absence of structural elements, such as beams and pillars; which is confirmed in this study.

In the study carried out by Reis et al. (2018), 75% of the cracks were found in masonry and in the vertical position (caused by overload, due to crushing of the block and mortar); where the authors bring out the behavior of the material, concluding that the components (block and mortar) do not support the necessary weight. That is, the cause is not the incipient lack of a project and/or technical manager, but the material.

For Barbosa et al. (2022), in the existence of financial conditions, neglecting a professional to monitor a work, is to be subject to suffering psychic and physical consequences, due to the shaking of a structure, as the damage evolves. Like the Law of Evolution of Costs or Law of Sitter, which points out that recovery costs increase exponentially in relation to their time, an example cited by the author of a generic nature is: a dollar spent on the correct execution of a construction corresponds to five dollars in maintenance of the same work (SITTER, 1984).

4.6 Final recommendation for residences

It can be inferred that the main culminating agent of anomalies in residences is imprudence in hiring a technical manager for execution and design. It is recommended the therapy of the problem given in the inspection sheets located in Appendices B, C, D and E; such a correction that prevents aggravation and progression to possible other pathological manifestations or even a collapse; as is the case of one of the cracks presented that evolved into a crack.

As Lima (2015) points out, to verify the need for structural reinforcement, it is recommended to hire a technical manager duly registered and active in the CREA (Conselho Regional de Engenharia e Agronomia). In addition to the elaboration of the details of the activities to be developed for the purposes of expertise and recovery of the element, in view of the proof of the anomaly provided in the present study.

All materials to be used in the recovery must follow a quality standard (KUHL, 2020). As well as the workforce employed, follow the guidance of the technician in charge and what the inspection sheets prescribe.

5. Conclusions

Based on the results obtained, the study showed the need for trained professionals in the design and execution phases, making use of techniques, constructive details thought out in the design phase to prevent

any pathological manifestation in the work. Thus, performing project compatibility, having quality control of materials and being present at the work site, ensuring the design, which is responsible for the technician, to avoid future problems. Above all, an engineer or architect has final obligations, and there is no exemption if he has not achieved the purpose he proposed.

A professional need to be able to envision the pathological manifestations in the design phase, knowing and understanding the mechanisms by which cracks occur, as in this process it is possible to interfere with the existing addiction that is still being carried out. Since the mechanisms of occurrence come from technical domain, being able to make use of tests to prevent settlement (SPT and any other type of test that allows the prevention of mechanisms of occurrence), the use of waterproofing to prevent humidity, the prediction of loads in design to check component overload and avoid it.

As is the case with the residences mentioned in the study, the correction of the cracks was not effective, bringing to light a warning, be it the compromised performance of the work, the psychological shock caused to the residents or some collapse of the component. In short, by ceasing the occurrence mechanism, it is possible to carry out an effective correction, however more important than the correction is the prevention still in the project phase.

The study highlighted the importance of studying the Pathology of Constructions, first, to show the need to envision the most relevant pathological manifestations; second, point out their causes to avoid them; and third, if it does occur, indicate the solution based on analyses, in addition to proving the evolution of problems due to endogenous causes.

In view of what was exposed in the execution of the study, it was possible to present the causes of cracks, the main mechanisms of occurrence and the main repair techniques in different types of components. In loco, it was possible to bring real situations of cracks, cases in which an inefficient correction was carried out, showing the incipience of a layperson, objectifying the need for professionals to intervene in this cause.

Above all, the study fulfilled the proposed objectives, analyzing cracks in single-family residential buildings completed up to 10 years old, carrying out monthly monitoring in the units, to assess the magnitude of the cracks, comparing them with compliance with current regulations, NBR 13752 (1996), NBR 15575-2 (2013), NBR 15575-4 (2013), NBR 6118 (2014), NBR 9062 (2017) and NBR 6120 (2019). Finally, reaching the main focus of the study, the therapy of the problem; with the aid of the theoretical foundation reached and the monitoring of the stagnation or progression of the cracks.

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