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Assessment of residences adjacent to rock blasting using NBR 9653 and NP 2074 in the city of Salgueiro - PE

Avaliação de residências lindeiras ao desmonte de rochas por explosivos a partir da NBR 9653 e da NP 2074 na cidade de Salgueiro - PE

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Abstract: The evaluation of the integrity of adjacent residences in rock removal operations is a crucial factor in supporting liability for possible damage to these residences, both on the part of users and the person responsible for the operation. These assessments are carried out using normative criteria established in each country. In this context, this work presents an evaluation of two residences bordering rock blasting operations in the city of Salgueiro, Pernambuco. This evaluation was carried out using the Brazilian standard, NBR 9653 (2018), and the Portuguese standard NP 2074 (2015). The work also made a comparison between the recommendations of the two standards.

Keywords: Vibrations; Explosives; Damage to structures.

Resumo: A avaliação da integridade de residências lindeiras em operações de desmonte de rochas é um fator crucial para o respaldo da responsabilidade de possíveis danos nessas residências, tanto por parte dos usuários como do responsável pela operação. Essas avaliações são realizadas utilizando critérios normativos estabelecidos em cada país. Diante desse contexto o presente trabalho apresenta uma avaliação de duas residências lindeiras a operações de desmonte de rocha na cidade de Salgueiro, Pernambuco. Essa avaliação foi realizada utilizando a norma brasileira, NBR 9653 (2018), e a norma portuguesa NP 2074 (2015). No trabalho também foi realizado um comparativo entre as recomendações das duas normas.

Palavras-chave: Vibrações; Explosivos; Danos em estruturas.

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1. Introduction

The assessment of adjacent residences is essential in rock blasting operations using explosives or in geotechnical activities that may cause damage to these buildings due to dynamic loads induced by these activities. An assessment carried out using normative parameters supports both the person responsible for the blasting and the users of the adjacent buildings, so that the experimental parameters measured at the time of detonation allow quantitative analyses to be carried out in conjunction with qualitative analyses prepared by qualified technical professionals to assess their response to these operations. These operations can be carried out in any location, such as urban or rural areas and in regions with buildings of various types. This type of analysis has variables that depend on the loads generated, the local geology and the characteristics of the structure evaluated and are described in normative procedures established by each country.

In the case of Brazil, the recommendation used for the analysis of adjacent buildings is NBR 9653(2018), while in Portugal the equivalent standard is NP 2074 (2015). These standards, despite using the same analysis parameters, have differences that will be evaluated in the present work in a practical application of rock blasting in the city of Salgueiro, Pernambuco. As specified in the work of Silva and Leão (2020), Brazilian buildings, in general, are not designed for seismic loads, as they are located in a region with low seismicity; however, these loads may arise during the execution of operations provided for in the aforementioned standards. Given the importance of evaluating residences and other infrastructures bordering the dismantling area, several authors have published relevant works on the subject.

A semi-empirical analysis using the Mosler and Penta method was carried out in the work of Cavalcante and Assis (2022) for the analysis of the influence of rock blasting on the stability of a highway slope. The study presented the relationship between the risks identified in the activity and the following variables: risk class, aspect and risk quantification. Grossi (2011) conducted a case study of a building adjacent to a mining company's rock blasting operation using NBR 9653. From the analysis, it was concluded that the vibrations generated by the activity were within acceptable normative limits and that the pathological manifestations identified in the residence had causes unrelated to the blasting operation. Neto and Ferreira (2006) conducted a study to monitor vibrations generated by explosions in a limestone and claystone mine in the city of Limeira, São Paulo. The study developed attenuation and maximum energy equations, serving as parameters for the adoption of operational measures in other blasting operations. Andrade and Rocha (2018) evaluated the influence on the stability of the pump house of the Governador João Alves Filho Dam, popularly called Poção da Ribeira Dam, due to the mineral activity of the Cajaíba Quarry, a producer of gravel. The work is located on the border of the cities of Campo de Brito and Itabaiana, Sergipe. Based on the results, it was found that the use of explosive charges of around 1,000 kg causes extremely high risks to the stability of the structure. The work also indicates the implementation of continuous measures to control and monitor vibrations.

A study to analyze the impacts of vibrations generated by blasting on the stability of a 380m slope height at the Timbopeba Mine in Ouro Preto, Minas Gerais, was carried out by Lima (2001). The mine in question is an iron ore mine and is operated by Vale do Rio Doce. Despite being a geotechnical/geological analysis, the parameters evaluated were the same as those established in the regulations for structures. The work concluded that the maximum value measured for particle speed was equal to 6.4% of the minimum speed to break the quartzite matrix, a value insufficient to compromise the stability of the slope.

The work of Silva and Leão (2020) presents the influence of vibrations on buildings, generated by the dismantling of a gneiss extraction mine to produce gravel by the Compania de Mineração Estrela Ltda, located in the city of São Gonçalo, state of Rio de Janeiro. In the work, 11 measurements were carried out with a seismograph and the results were evaluated according to the recommendations of NBR 9653 and the German standard DIN 4150. All results were below the maximum limits established in the two standards, ruling out the possibility of damage to buildings due to dismantling.

The work of Oliveira and Muñoz (2013) consists of a study analyzing vehicle traffic at the Church of Santo Antônio da Mouraria, in the city of Salvador, Bahia. In this work, the authors verify that there is no specific Brazilian standard for this type of study, and cite international standards, such as NP 2074, which is used for this type of situation. The work used the recommendations of DIN 4150 as a parameter, discarding the influence of traffic on the stability of the building. Gevú, Varela and Niemeyer (2020) and Gevú, Varela and Niemeyer (2015) also present an analysis from the point of view of DIN 4150 for the impact of vibrations generated by vehicle traffic on historic facades on Rua Primeiro de Março, in the city of Rio de Janeiro. These studies conclude that the facades are subject to harmful vibrations that compromise the preservation of the local historical heritage.

Bacci et. al. (2003a) and Bacci et. al. (2003b) presents a paper that presents a compilation of the main standards for controlling vibrations caused by the use of explosives. These papers present comparisons between the recommendations of the European, Brazilian, Indian, Australian and North American standards; in terms of equipment, building classifications and evaluation parameters.

Numerical analyses also emerge as alternatives for evaluating the behavior of structures subject to seismic loads generated by blasting. In the work of Fonseca et. al. (2018) a case study was carried out on the Salamonde dam, installed on the Cávado River, in the northern region of Portugal. The study was carried out during the dismantling activities for the construction of a new power plant and an additional floodgate. The numerical model corroborated the seismographic studies with satisfactory results that can be used in structures of this type.

From the works it is possible to verify that, although Brazilian and Portuguese standards deal with damage to structures, these are used as evaluation parameters for various civil works. Furthermore, it is interesting to note that other techniques, such as numerical analysis, can serve as a complementary tool for studying the behavior of adjacent structures.

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2. Comparison between NBR 9653 and NP 2074

This section shows a comparison between Brazilian and Portuguese standards for analyzing the influence of rock blasting on neighboring residences. The following standards were used for this study: NBR 9653 from 2018, entitled: Guide for evaluating the effects caused using explosives in mining in urban areas, and NP 2074 from 2015, entitled: Evaluation of the influence of impulsive vibrations on structures, which are the standards in force in both countries. Table 1 presents a compilation of the comparison between the two standards, which, for practical purposes, have as their main point of distinction the classification of the buildings evaluated.

One aspect to be considered is that the analysis parameters for vibrations in structures is the particle vibration speed as a function of frequency. These parameters are used in all standards evaluated in the work of Bacci et. al. (2003a) and Bacci et. al. (2003b) which includes 15 standards used in different countries.

Table 1 – Comparison between NBR 9653 and NP 2074.

Evaluated item	Standard	
	NBR 9653	**NP 2074**
Scope	Describe a methodology to reduce the risks inherent in rock blasting using explosives in the mining and construction industries.	Establish criteria for limiting the values of physical quantities characteristic of impulsive vibrations and with a limited number of occurrences, with the aim of avoiding damage to structures.
Application	Emission of impulsive noises, vibrations, ultra launch.	Vibrations.
Activities covered	Rock blasting using explosives in the mining industry and civil construction in general. Applicable in urban areas and optionally in rural areas. Serves as a reference for natural underground cavities.	Mining and geotechnical activities that induce dynamic demands on the ground.
Preliminary assessment	No reference	It specifies that a prior assessment must be carried out on nearby structures to identify existing pathologies.
Device used	Engineering seismograph, used to record vibration and acoustic pressure levels.	Engineering seismograph, used to record vibration levels.
Sensor (microphone) installation	The sensor must be facing the detonation site. Natural or official obstacles must be avoided and must be installed: • On the outside of the building; • On the side of the structure; • At the height recommended by the manufacturer; • With wind protector.	Not applicable
Seismograph programmin	When acoustic pressure is the main measurement, the seismograph must be calibrated so that the measurements are not affected by wind.	Not applicable

g and capture time (microphone)		
Sensor (geophone) installation	When the sensor is installed in locations where there are buildings, install it on natural terrain or consolidated landfill, avoiding disintegrated soil. The sensor should be installed as close as possible to the building to be monitored, less than 3 m or 10% of the distance from the source.	It must be fixed to the element of the structure or building attached to the foundation, at a maximum of 0.5 m above ground level.
Sensor Fixation (geophone)	The sensor must be rigidly fixed to the medium to be measured. If it is not possible to fix it to the ground, the sensor can be installed on the sidewalk, rock or on the structure itself. The sensor can be fixed with mechanical or chemical anchors on rigid surfaces, buried in the ground or nailed.	According to ISO 5348.
Seismograp h programmin g (geophone)	The programming must be done in such a way that it can capture the vibrations and not have interference from other sources.	No reference
Seismograp h characteristi cs	• Composed of a data processing unit, vibration transducer (geophone/accelerometer) and acoustic pressure transducer (microphone); • Have an internal verification system; • Have memory; • Operate at temperatures from -10ºC to 50ºC; • Instantly record VV in 3 directions; • Must record acoustic pressure.	Composed of transducers, signal conditioner, recording and processing system. Speed transducers or accelerometers must be triaxial.
Seismograp h calibration	• It must be carried out in a calibrated laboratory every 12 months. • A study can be carried out to be calibrated every 24 months. • The standard offers other alternatives for seismograph calibration.	It must be charged annually, by a certified laboratory, in accordance with Standard NP EN ISO ISO 17025
Inconvenien ce to humans	In terms of human discomfort, the set of measures presented below should be carried out: • Implementation of an information system; • Implement complaints registry; • Adopt measures to minimize impacts; • Use appropriate techniques and inputs to minimize impacts; • Establish a sector of the company responsible for communication with the community; • Employee training; • Reporting log; • Establish monitoring plan.	It establishes that the values set in the standard are uncomfortable, but bearable, as long as they occur between 7:00 am and 8:00 pm.

Source: Author (2025).

From the analysis of Table 1, some clear conclusions can be drawn about the comparison between the standards. One of the important differences is that while NBR 9653 deals with three aspects, namely noise emissions, vibrations and ultra-thrusts, NP 2074 only deals with vibrations in structures. Another important aspect is that NP 2074 recommends carrying out a prior assessment of buildings, while NBR 9653 does not present a recommendation of the same nature.

The most relevant aspect in terms of divergence between standards is about the limit assessment parameters of the variables that are measured by the seismograph. The first relevant point is that NP 2074 distinguishes between the type of building that will be assessed, having the following classifications: sensitive, current and reinforced. For each of the buildings there is a specific range of particle vibration speed according to the acceptable frequency. These frequencies are defined according to Table 2. Unlike NP 2074, NBR 9653 specifies criteria that can be seen in Table 3, which do not refer to the type of structure to be assessed. This point regarding the lack of classification of the type of structure by NBR 9653 will be the object of criticism in the case study presented in this work, since the standard places structures of buildings with severe damage and newly constructed structures designed for seismic loads, for example, in the same category, and may not contemplate damage in very deteriorated buildings.

Table 2 – Table 1 of NP 2074, which defines the limit values for the vibration parameters of a structure.

Type of structure	Dominant frequency, f		
	f ≤10Hz	10Hz <f ≤40Hz	f > 40Hz
Sensitive	1.5	3.0	6.0
Chains	3.0	6.0	12.0
Reinforced	6.0	12.0	40.0

Source: Author (2025).

Table 3 – Table 3 of NBR 9653, which defines the limit values for the vibration parameters of a structure.

Frequency range a	Peak particle vibration velocity limit
4Hz to 15Hz	Starting at 5 mm/s, increasing linearly up to 20 mm/s
15Hz to 40Hz	Above 20 mm/s, increasing linearly up to 50 mm/s
Above 40 Hz	50 mm/s
[the]For frequency values below 4 Hz, the peak particle displacement criterion of no more than 0.6 mm (from zero to peak) should be used as the limit. Note 1 Hz corresponds to one oscillation per second.	

Source: Author (2025).

3. Methodology

This study was carried out based on an experimental monitoring plan for two residences in an area bordering rock blasting in the city of Salgueiro, Pernambuco. The blasting area consists of a construction site for the installation of a photovoltaic power plant. This type of project has been installed with increasing frequency in the region evaluated, given that the semi-arid climate, which is the climate of Salgueiro, is favorable for the use of this type of energy. To evaluate the buildings, on-site inspections were carried out by qualified technical professionals. During the inspection, cracks and other pathological manifestations of the building were identified, in addition to the preparation of architectural and structural surveys. Although NBR 9653 (2018) does not mention prior assessment, unlike NP 2074 (2015), the company responsible for the dismantling requested these assessments. The residences evaluated are shown in Figure 1 a) and Figure 1 b), referred to in this work as 1st House and 2nd House.

To monitor the cracks, a technique was used to place thin glass plates transverse to the crack and fixed with epoxy resin. The purpose of the plate is to serve as a sacrificial material in case the crack shows any activity. At the end of the monitoring, it should be checked whether the glass plate is broken or not; a diagram of this application is shown in Figure 2. During the inspections, photographic records of the cracks were prepared with their respective plates, with the aim of having a visual record of their situation so that they can be compared.

To evaluate the dynamic response of buildings under the influence of dynamic loads generated during rock blasting operations, seismography tests were performed under the prescriptions of NBR 9653 (2018). The seismography's were performed on 7 occasions of blasting that were carried out during the monitoring period of this work. The point of the seismography was fixed for all blasting operations and can be seen in Figure 3. The results obtained were compared with the parameters established in the Brazilian standard NBR 9653 (2018) and the Portuguese standard NP 2074 (2015).

the) *b)*

Figure 1 – the) Facade of the 1st House. b) Facade of the 2nd House.
Source: Author (2024).

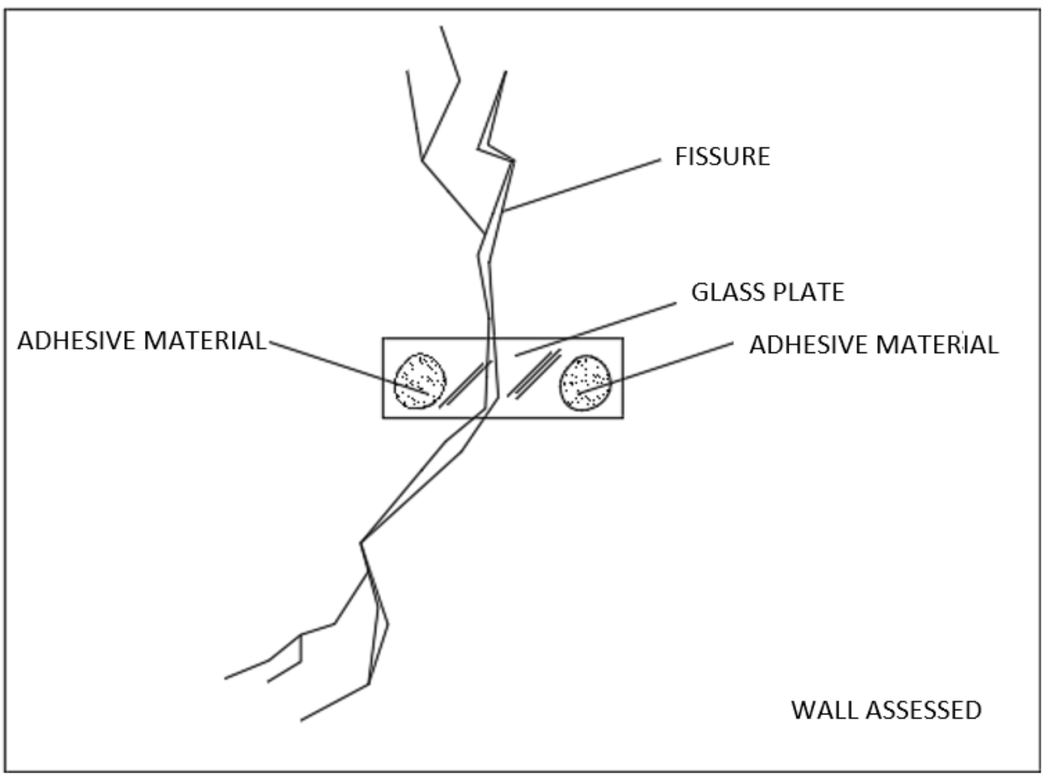


Figure 2 – Installation diagram of monitoring boards.
Source: Author (2024).

4. Analysis of residences

This topic presents the details of the analysis of the residences, addressing physical aspects of the site and presenting the monitoring results. Figure 3 shows a section of the layout of the evaluated residences and the seismography point. It is also possible to see in the image the points that determine the area where the demolitions occurred; this location consists of a rural community in the city of Salgueiro, Pernambuco, called Baixio do Tanque.

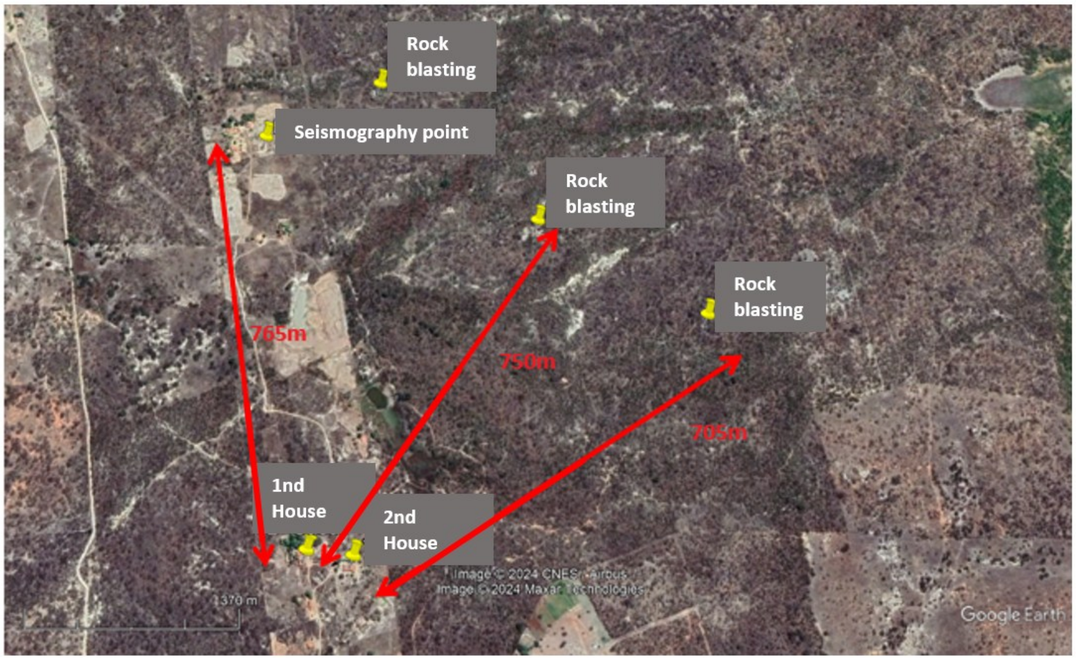


Figure 3 – Location of the houses evaluated, seismography and dismantling point.
Source: Author (2024).

4.1 Geology of the site

The study area is in Folha Salgueiro (SC.24-VB-III), as shown in Figure 4. Folha Salgueiro is in the Northeast region of Brazil, in the southwest portion of the Borborema Province. A section of the geological map of Salgueiro (BRITO E MARINHO, 2012) is shown in Figure 5, corresponding to the study area that is located in the Serrita Intrusive Suite (NP3).γ2s), which includes the following granitoids: serrita-type granite, biotite-hornblende monzodiorite, monzonite, quartz monzonite and biotite granite, from the late orogenic period, with trondhjemitic affinity (CPRM, 2017). All detonations were carried out in granite-type rock.

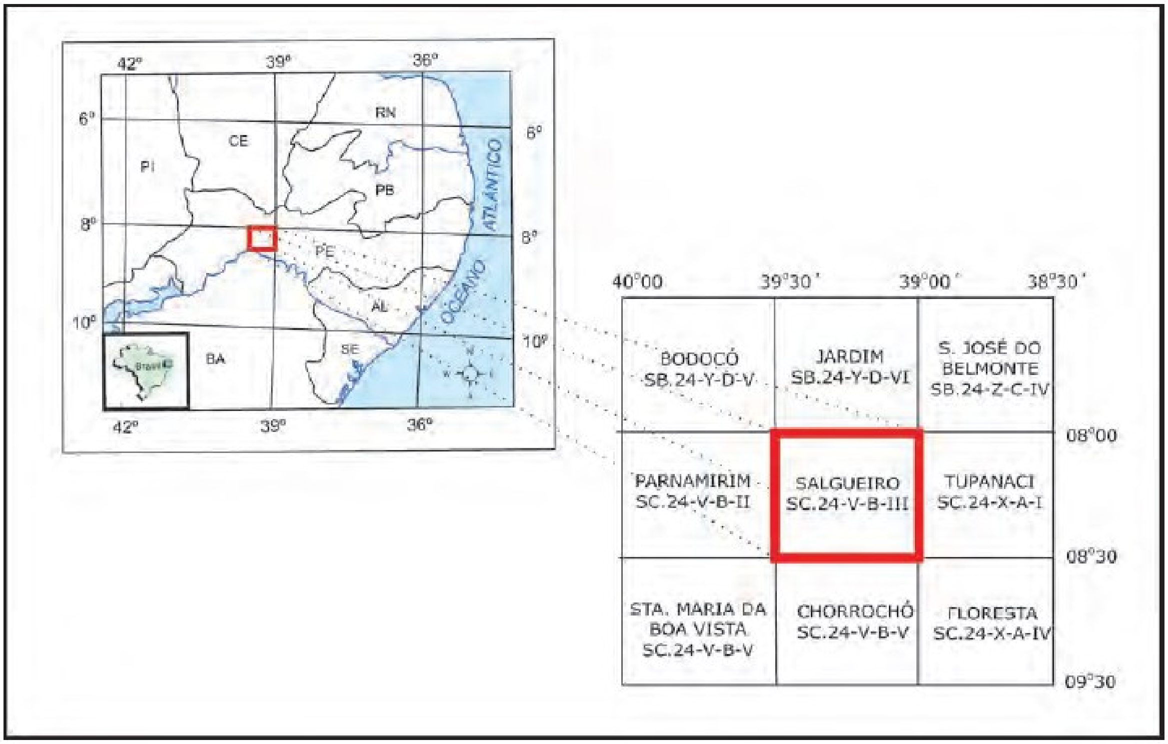


Figure 4 – Location map of Folha Salgueiro (SC.24-VB-III).
Source: CPRM (2017).

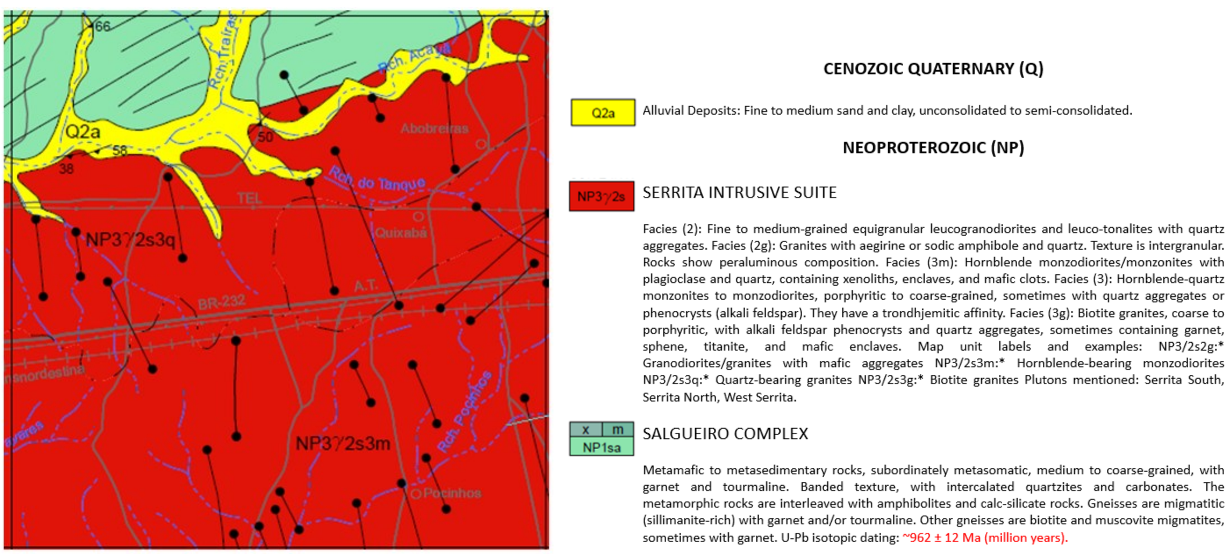


Figure 5 – Geology of Folha Salgueiro (SC.24-VB-III).
Source: Adapted from Brito and Marinho (2012).

4.2 Characteristics of the buildings assessed

The buildings evaluated were designed by lay professionals, without the preparation of architectural and engineering projects and without the supervision of any qualified technical professional during the execution. This information was provided by the users of the buildings who oversaw the construction. The 1st House is designed in resistant masonry on the inside, covered in wood with ceramic tiles and with the porch roof supported by reinforced concrete pillars. The 2nd House was designed entirely in resistant masonry and with the roof in wood with ceramic tiles.

Load-bearing masonry is a technique generally used in low-income buildings without the supervision of technical professionals, where loads are supported by non-structural masonry blocks. This is a very common type of building in the community to which the assessed residences belong.

5. Results and discussion

The results measured by the peak particle velocity (PPV) seismograph by frequency are presented in Tables 4, 5 and 6 for the longitudinal, transverse and vertical components, respectively. These results are compiled in Figure 6, which also presents the normative limits that can be consulted in the legend. In the 1st House, 7 cracks were monitored and in the 2nd House, 17 were monitored. In the first house, there was no activity in any of the cracks evaluated, while in the second house, 2 cracks had activity during the monitored period. Figures 7 and 8 show the records of the cracks that had activity in the 2nd House on the dates of 4 inspections carried out. The inspection dates were 03/19/2024, 03/25/2024, 04/02/2024 and 04/08/2024.

During the preliminary inspection, it was found that, although the two houses were within the same classification, the 2nd House was in a more advanced state of cracking than the 1st House. Furthermore, the cracks in the 2nd House that suffered activity were chosen because they were in two sensitive regions. The crack shown in Figure 6 is in the staircase, as can be seen, this crack runs the entire length of the staircase, which already had problems with its integrity before the dismantling operations. The crack shown in Figure 7 is located above a door that does not have a lintel. Lintels are essential elements in masonry openings, with the function of adequately transmitting the forces along the wall. Furthermore, it was also found that this wall receives loads from the roof, contributing to its selection.

Given the conditions presented and considering the results in Figure 6, it can be concluded that the behavior of the houses analyzed in this study during dismantling corroborates the criteria established in NP 2074 (2015). As can be seen in Figure 6, the results measured have only one result above the threshold between the VPP of sensitive and current buildings and several of the other results are relatively close to this threshold. Considering that there are no specific criteria for classifying buildings and all the other variables that are intrinsic to the problem, the results presented show agreement between the classification of buildings, the choice of cracks to be monitored and the results and requirements of NP 2074 (2015).

When analyzing Figure 6 in terms of NBR 9653 (2018), the results obtained in the monitoring are very far from the limits established in this standard for VPP. Therefore, using its criteria, the recorded activities of the two cracks could not be associated with the dismantling.

It can then be seen that, depending on the standard used to assess vibrations induced by rock blasting, very different conclusions can be drawn regarding the association between crack activity and blasting.

Table 4 – PPV(mm/s) and FREQ(Hz) for the longitudinal component.

Date	PPV(mm/s)	FREQ(Hz)
	Longitudinal	Longitudinal
19/01/2024	4,250	142,900
01/26/2024	2.100	45,500
02/02/2024	0.890	43,500
02/09/2024	0.060	500,000
23/02/2024	2,860	45,500
24/02/2024	3,370	41,700
03/01/2024	4,950	45,500

Source: Author (2024).

Table 5 – PPV(mm/s) and FREQ(Hz) for the transverse component.

Date	PPV(mm/s)	FREQ(Hz)
	Transverse	**Transverse**
19/01/2024	3,940	111.100
01/26/2024	3,430	34,500
02/02/2024	0.950	58,800
02/09/2024	0.060	1000,000
23/02/2024	1,590	41,700
24/02/2024	3.180	41,700
03/01/2024	3.180	62,500

Source: Author (2024).

Table 6 – PPV(mm/s) and FREQ(Hz) for the vertical component.

Date	PPV(mm/s)	FREQ(Hz)
	Vertical	**Vertical**
19/01/2024	2,860	90,900
01/26/2024	1,140	27,800
02/02/2024	0.510	27,000
02/09/2024	0.190	1,600
23/02/2024	1,080	31,300
24/02/2024	1,520	35,700
03/01/2024	1,460	45,500

Source: Author (2024).

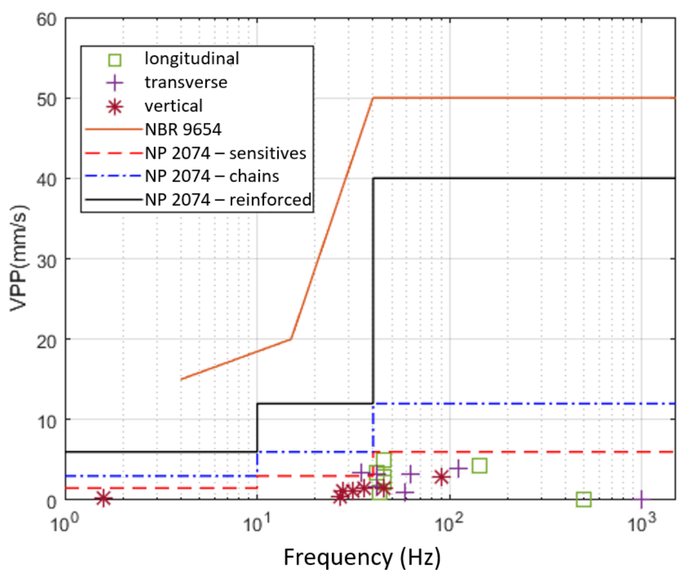


Figure 6 – PPV(mm/s) × Particle oscillation frequency (Hz).
Source: Author (2024).

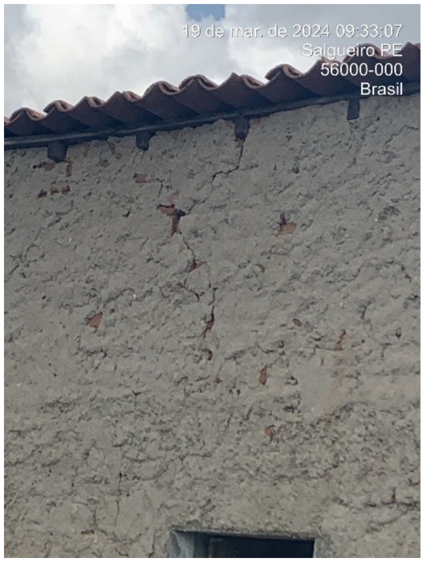
the)

b)

w)

d)

Figure 7 – Cracks in the stairs of the 2nd house. the) 03/19/2024. b) 03/25/2024. w) 04/02/2024 d) 04/08/2024.
Source: Author (2024).



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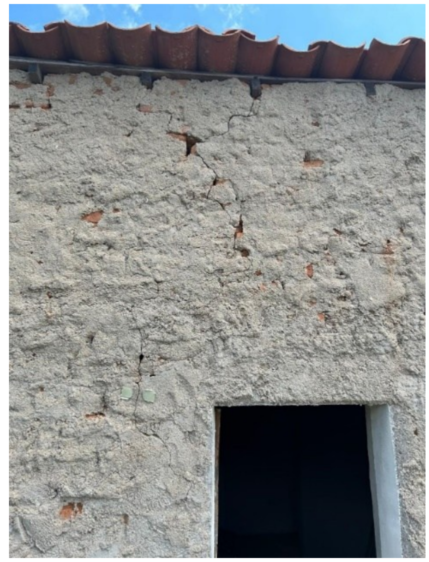

b)

w)

d)

Figure 8 – Cracks in the facade cladding of the 2nd house. the) 19/03/2024. b) 25/03/2024. w) 02/04/2024. d) 08/04/2024.
Source: Author (2024).

6. Final considerations

From the comparative analysis between the measured results and the limits established by NBR 9653 (2018) and NP 2074 (2015), NP 2074 (2015) presented results that are more consistent with those observed in situ. The thresholds presented in this standard were able to predict the behavior of the crack activity in the 2nd House, as expected. However, when the results are compared with the requirements of NBR 9653 (2018), what can be observed is a significant discrepancy between the observed results and the normative limits, which present much less conservative results than NP 2074 (2015).

Another fact to be taken into consideration is that the classification of buildings according to NP 2074 (2015) was carried out consistently, despite the criteria presented in the standard being of a qualitative nature.

Despite the differences between the standards in terms of quantitative criteria, when analyzing Table 1 the complementary use of the two standards can provide a more rigorous analysis of the building analyzed. Furthermore, the importance of a detailed monitoring plan is highlighted, with prior analysis by a qualified professional to define the critical points of the building to be monitored.

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