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Diagnosis of degradation state through non-destructive tests: case study of the public building of federal education institution

Diagnóstico del estado de degradación mediante ensayos no destructivos: estudio de caso del edificio público de una institución educativa federal

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Abstract

Historically, public buildings are not importantly addressed in Brazil, resulting in several buildings dropped to the ruins and unnecessary acquisitions of new spaces by public institutions. The present study was carried out in a building part of the extinct industrial building of the Anglo fridge in Pelotas. The main objective was to evaluate state of degradation state through non-destructive tests in a case study of a public building of Federal Education Institution. Visual analysis, damage map, measurement of nominal coverings, sclerometry tests, silver nitrate spray and phenolphthalein test were performed. The building presents worrying deterioration levels, chlorides, and carbonation presence and several stains moisture. These facts lead concrete detachment, reinforcements corrosion and losses in slabs, beams, and pillars sections.

Keywords: Conservation, pathological manifestations, reinforced concrete, public buildings, preventive maintenance, non-destructive testing

Resumen

Históricamente en Brasil, el mantenimiento de edificios públicos no se aborda de manera importante, lo que resulta en varios edificios caídos a las ruinas, así como adquisiciones innecesarias de nuevos espacios por parte de instituciones públicas. El presente estudio se llevó a cabo en un edificio que forma parte de la extinta nave industrial del Frigorífico Anglo en Pelotas. El objetivo fue evaluar el estado de degradación mediante pruebas no destructivas en un estudio de caso del edificio público de la Institución Educativa Federal. Se realizó análisis visual, mapa de daños, medición de revestimientos nominales, pruebas de esclerometría, spray de nitrato de plata y prueba de fenolftaleína. El edificio presenta preocupantes niveles de deterioro, con presencia de cloruros, carbonatación y varias manchas de humedad. Estos hechos conllevan desprendimientos del hormigón y corrosión de armaduras, así como pérdidas en las secciones de losas, vigas y pilares.

Palabras clave: Conservación, manifestaciones patológicas, concreto reforzado, edificios públicos, mantenimiento preventivo, pruebas no destructivas

1. Introduction

(Helene, 2003) defines Buildings Pathology as Engineering field studying structural and/or functional changes caused by diseases in building body, everything promoting material degradation or its physical properties, not meeting expected performance requirements. Buildings can present pathological manifestations and the most recurrent are cracks, moisture stains, detachments, corrosion, and mold stains. This damage can compromise the structure performance to stability, aesthetics, impairing durability.

Pathological manifestations study raises subsidies for the realization of corrective measures and conservation of public heritage in the city of Pelotas, southern zone of Rio Grande do Sul state. Brazil. (Torres and Bezerra, 2015) conducted a qualitative study surveying pathological manifestations in a building listed as a historical heritage built in 1923. (Peres, 2001) conducted a similar study in a historic building built in 1878 through qualitative and quantitative pathological manifestations survey. (Costa et al., 2021) proposed a study in historical heritage buildings to evaluate the degradation state of facades through qualitative and quantitative indicators - damage map, degradation measurement method (MMD) and element performance index (Ip). (Costa et al., 2020) carried out the survey of degradation state of historical buildings facades through the application of MMD.

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In addition to historical buildings studies, some data collections, and pathological manifestations diagnosis in central region of Pelotas were also performed. (Moura et al., 2014) visually analyzed eighty-three buildings marquees. (Torres et al., 2016) analyzed pathological manifestations in four elevated reservoirs and pathological manifestations presented a strong relationship with use errors, but mainly with execution and design errors, leading to insufficient concrete coverings compared to ideal coverings.

After decades characterized by a permanent rapid growth, Federal University of Pelotas (UFPel) experienced in recent years an expansion triggered from its support program to the Plan of Restructuring and Expansion of Federal Universities in 2007 (UFPEL, 2015). To satisfy the new academic institution configuration, expand its useful physical space and consequently studies and strategies to better use the spaces already available at university were necessary. Between 2005 and 2006, UFPel received a part of the industrial complex of a refrigerator as donation. The complex was inaugurated in 1943 and closed in 1990 (UFPel, 2017). Among various buildings localized in the complex, there is one of them called “Paliteiro”, nomenclature related to its current state, only pillar, beams, and slabs remained in its structure by time action.

Thus, considering historical buildings studies importance, the present study aimed to evaluate the degradation state of pillars and perimeter beams of “Paliteiro” ground floor. The study was restricted to the first floor due to high degree of deformation of horizontal structural element in floor slabs of the second floor.

2. Methodology

Initially, the building was characterized; then, visual analysis and photographic recording were performed using Lichtenstein adapted method (Lichtenstein, 1986). Damage map of structural parts of two among four facades were elaborated. From the most degraded areas obtained through damage map, the sclerometry test was performed in the pillars faces. Moreover, nominal coverings as well as the diameter of the main reinforcement, pillars, and beams were measured using a caliper. Finally, chloride action and carbonation verification were carried out.

2.1 Study Object

The building is in Pelotas, Rio Grande do Sul state, located on the banks of São Gonçalo Channel (Figure 1). This is proximity to the canal and the high humidity indexes in Pelotas increase the environmental aggressiveness, leading to a more marked degradation considering improper maintenance on structures close to this type of environment.

Figure 1. Aerial view of Campus Anglo, UFPel.
Source: Google Earth Pro (2021).

Several modifications have been made over years in the complex buildings, but the complex buildings have maintained their industrial aesthetic. "Paliteiro" has not been revitalized, highlighting the north facade in (Figure 2a) and the south facade in (Figure 2b). The building consists in two floors, both containing twelve pillars in longitudinal and ten in transversal, connected between themselves by beams, which support the structure slabs. Currently, "Paliteiro" has been used as a parking (Figure 2c).

(a) (b) (c)

Figure 2. (a) North Facade. (b) South Facade. (c) Building used as parking

Using preliminary visual analysis, perimeter structural of East and North facades were the most damaged, and, therefore, specific objects of this study. Moreover, West and South facades have been closed with masonry limiting their study. The access to West facade is hampered by vegetation. Aiming to facilitate their identification, the pillars elements were numbered and identified as "P" and beams as "V". The pillars and beams were numbered from 1 to 11 localized in North facade and from 12 to 21 localized in East facade (Figure 3).

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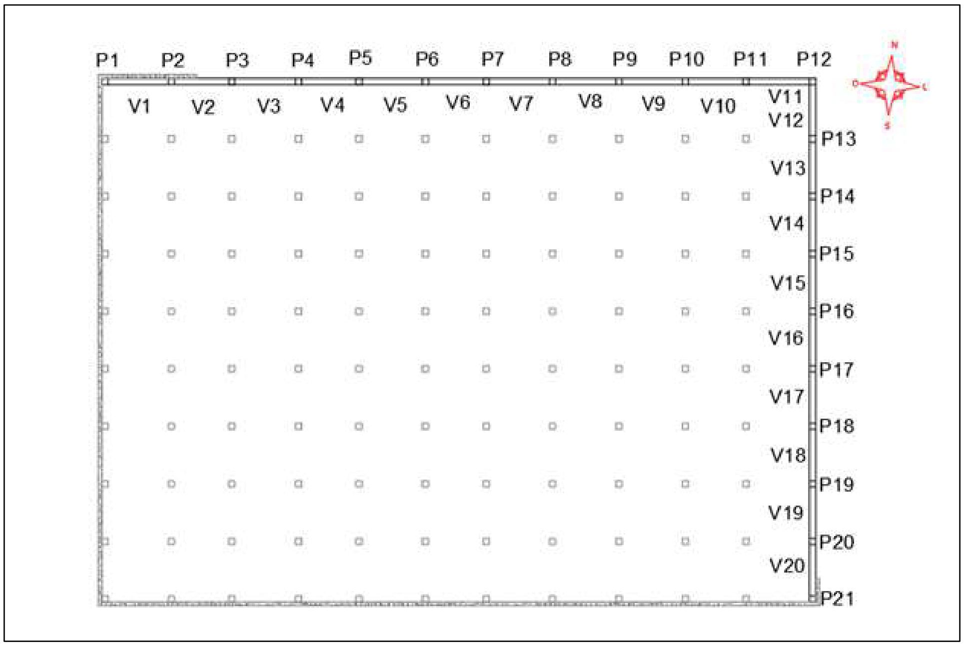

Figure 3. Identification and mapping of the studied elements

2.2 Damage map, visual inspection, and photographic survey

In the selected area, the damage map of slabs, beams and pillars was demarcated (Figure 4).

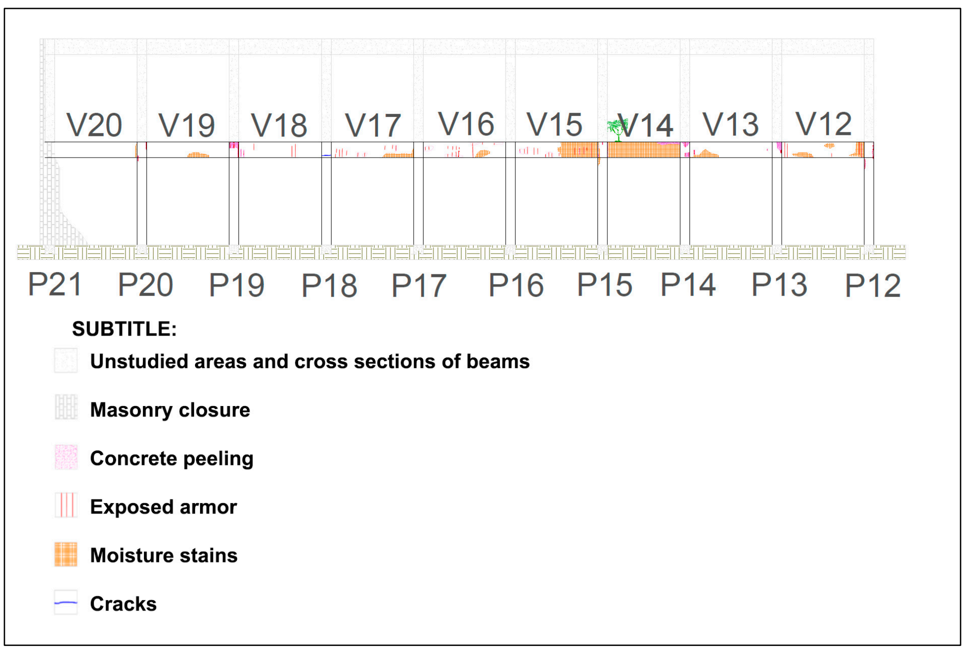

Figure 4. East facade damage map

2.3 Sclerometric test

Sclerometry test was performed according to NBR 7584 (ABNT, 2012) in the concrete surface hardness in pillars selected in degraded areas determined through damage map. The test was carried out on two among four faces of twenty pillars using Schmidt type L rebound hammer. One pillar was eliminated due to guarantee safety for the performance of the test, since two faces available for the test are coated in higher height than others. The faces chosen were those with the highest and lowest percentage of surface degradation (factor determined by the damage map).

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2.4 Armor cover check

Coverage and diameter of the main reinforcement of columns and beams with exposed and easily accessible reinforcement were measured using a caliper. Four pillars and one beam were ideal to obtain those values. The nominal coverage values were compared to those recommended by NBR 6118 (ABNT, 2014), and compared to the regulations used in data construction.

2.5 Checking of carbonation and chloride attack

The same elements in sclerometry test were used in view of their detachment and exposed reinforcement with the aid of a hand chisel, peeling a small portion of the concrete. To identify a possible carbonation action, a phenolphthalein solution was used. The recommendation by (Rilem, 1988) was adopted as there is no current Brazilian standard for determining concrete carbonation. According to (Cadore, 2008), a phenolphthalein solution turns non-carbonated concrete (pH ≥12) carmine red and remains colorless in carbonated concrete (pH <9).

To determine chloride penetration depth, a silver nitrate solution is sprayed on concrete surface. The presence of free chlorides forming a white precipitate of silver chloride, a brown precipitate of silver oxide can be formed in the region without chlorides or with combined chlorides (Mota, 2011).

3. Results

3.1 Damage map, visual inspection, and photographic survey

The damage map allowed a clear and objective visualization of pathological manifestations existing scenario, providing a powerful instrument of conservation evaluation. In addition, the damage map helped to select elements of sclerometry tests execution, coverings measurement and carbonation and chloride verification. For further evaluation, the elements with higher and lower degradation percentage were clear observed. Apparent pathological manifestations were not observed in internal pillars and beams. However, dirt was present in all building elements as can be seen in (Figure 5a) and (Figure 5b).

(a) (b)

Figure 5. (a) Dirt - North Facade. (b) Dirt - South Facade

The most representative pathological manifestations in the slabs on the first floor are concrete displacements with the exposed reinforcement shown in (Figure 6a) and (Figure 6b). In addition, mold stains near the metal tubes placed near the slabs.

(a) (b)

Figure 6. (a) Opening the slab. (b) Slab with peeling and exposed reinforcement

The highest pathological manifestations were identified in the perimeter pillars and beams. Moisture stains, concrete detachment, exposure, and reinforcements corrosion, some at a high degradation level can be seen in (Figure 7a) and (Figure 7b).

(a) (b)

Figure 7. (a) Beam armature exposure and mold stains. (b) Beam with concrete detachment and corrosion and exposure of reinforcements

After damage map, superficial degradation elements percentages divided by pathological manifestation type and by elements face were achieved. (Figure 8) shows the surface degradation of elements on East facade.

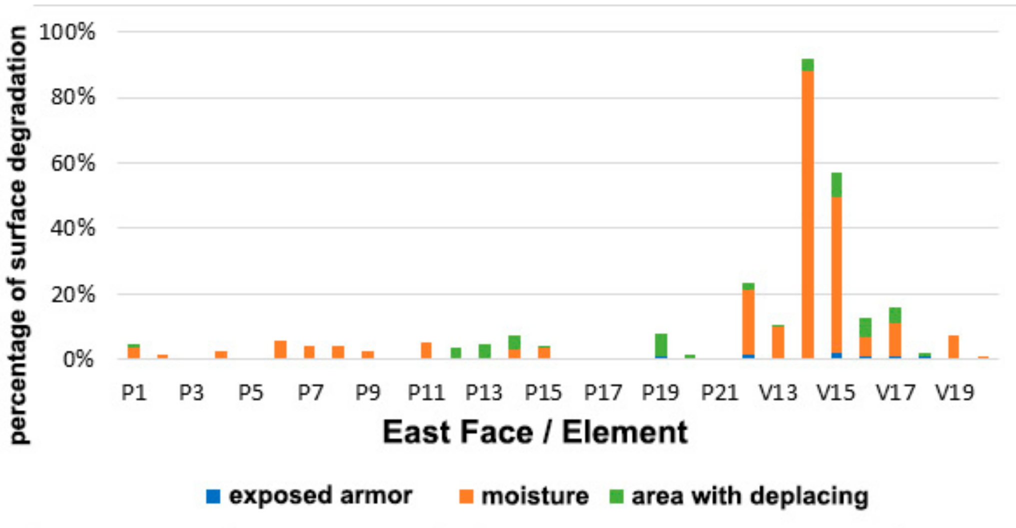

Figure 8. Percentage of surface degradation - Face East

As presented in (Figure 8), there are some peak of surface degradation of elements in beams V14 and V15 (Figure 9a) and (Figure 9b) on East face, due to moisture spots reaching 88% and almost 60% of total faces area affected beams. Both are located on East facade, and they are the most affected by pathological manifestations, probably due to the sun exposure period of shortened by shadow of the neighboring building. These peaks are linked to plant formation in V14, which concentrates moisture in its roots, seeking or creating flaws in concrete, increasing susceptibility to pathological manifestations caused by moisture. Pillars of East facade did not present moisture stains. However, they are concentrated in South and West faces in view of the lowest sun exposure. Detachment was the pathological manifestations most found in the pillars of the East facade. Some points of armor exposure were found, mostly, in the upper part of the column, at the height of the beam, possibly by concentrations of stresses in these regions added to the thermal variations. This factor is subjected to the facades of longer sun exposure periods.

Figure 9a. V14

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Figure 9b. V15

(Figure 10) shows the surface degradation percentage on the south facade.

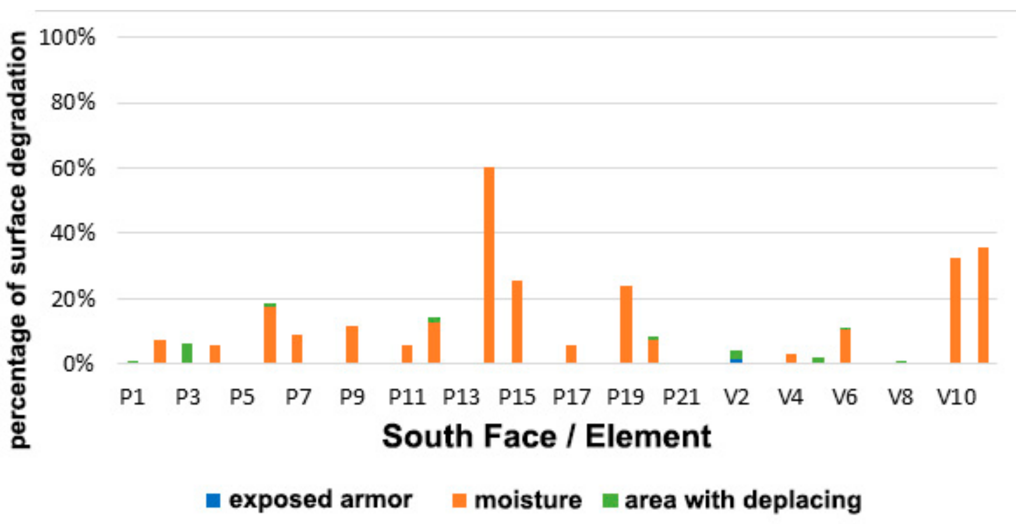

Figure 10. Percentage of surface degradation - South face of the elements

(Figure 10) shows peaks in beams V10 and V11 belonging in North facade reaching 32% and 36% of degraded area percentage. These peaks, possibly, are due to the beams faces close to the São Gonçalo channel, increasing the aggressive agent actions. The interior beam in North facade is not receiving solar radiation and fungus spots are founded. There is a peak in P14 pillar (Figure 11) of East facade, probably related to their proximity to the most degraded beams V14 and V15. The cause of the faults in pillar are related to moisture from these beams and the pillar faces presented the lowest sun exposure in sight of the shade from the neighboring building.

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Figure 11. P14

(Figure 12) shows the surface degradation percentage on the North façade.

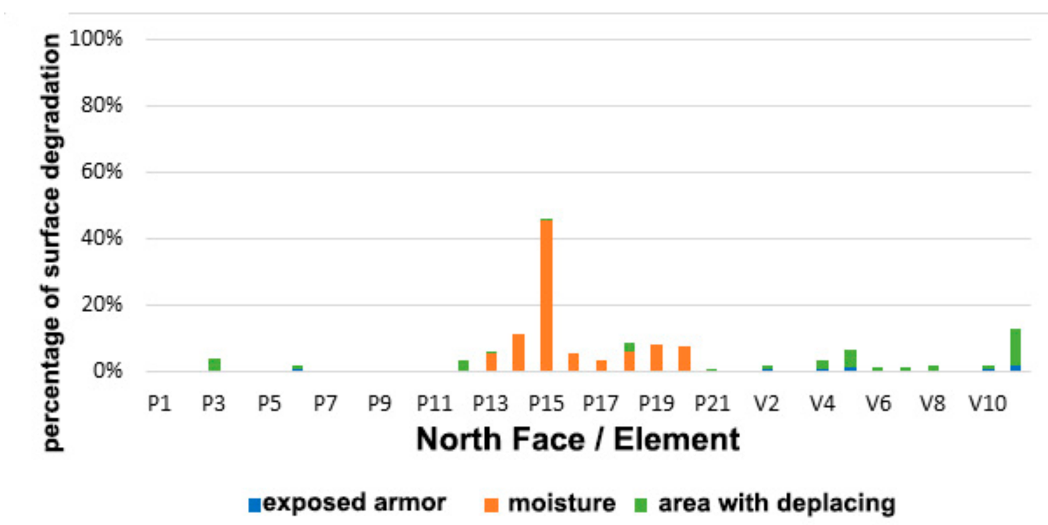

Figure 12. Percentage of surface degradation - North Face

(Figure 12) shows moisture degradation in North face. Only on the pillars of East facade presented a peak of surface degradation of elements in P15 column (Figure 13) presenting 46% surface degradation area. Among the pillars of the North facade with greater sun exposure, none presented moisture stains. Only detachment and exposed reinforcement were observed in two pillars (Figure 14). On the North face of the pillars located at East facade, moisture stains were found as in P15 (Figure 15), evidencing the shadow period is sufficient to facilitate pathological manifestations mechanisms. The sun exposure favored the facade beams and the absence of moisture stains in North face of the pillars. The elements presented concrete detachment and exposed reinforcements areas due to the absorbed stresses, resulting in material deformation from temperature variations, carbonation, and chloride occurrence, and adequate nominal cover lack.

Figure 13. P15

Figure 14. V11

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Figure 15. P3.

Surface degradation percentages of West face is shown in (Figure 16). Pillar P14 presented the highest percentage of degradation, 29% of degraded in East face. In addition, V14 (Figure 17) presented 20% of percentage of detachment area. This fact was attributed to failures in the material due to the accumulation of moisture and degrading agents. All aspects evidence moisture coming from the interior of the beam reached the pillars as can be seen in beam V14 (Figure 9a) with the present of plant. Moisture stain on pillar P15 (Figure 13), which is connected to P14 (Figure 11) by V14 was observed.

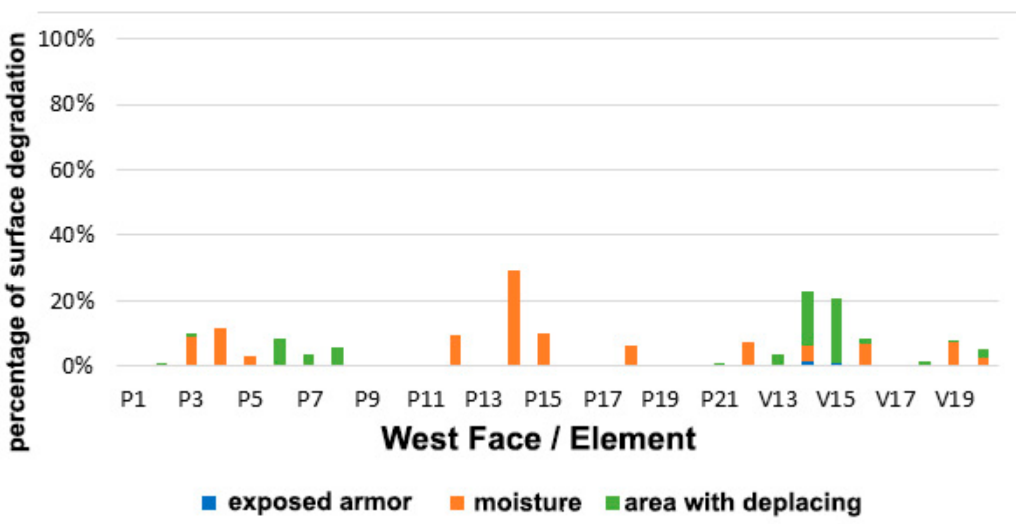

Figure 16. Percentage of surface degradation - West Face

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Figure 17. V14

(Figure 18) represents the degradation of the lower face of the beams. These faces of the elements presented higher degradation index due to the accumulation by gravity of moisture from the other faces. North facade presented four beams with more than 60% degradation area of its lower face, while the most degraded beam of the East facade presented 51% of degraded area.

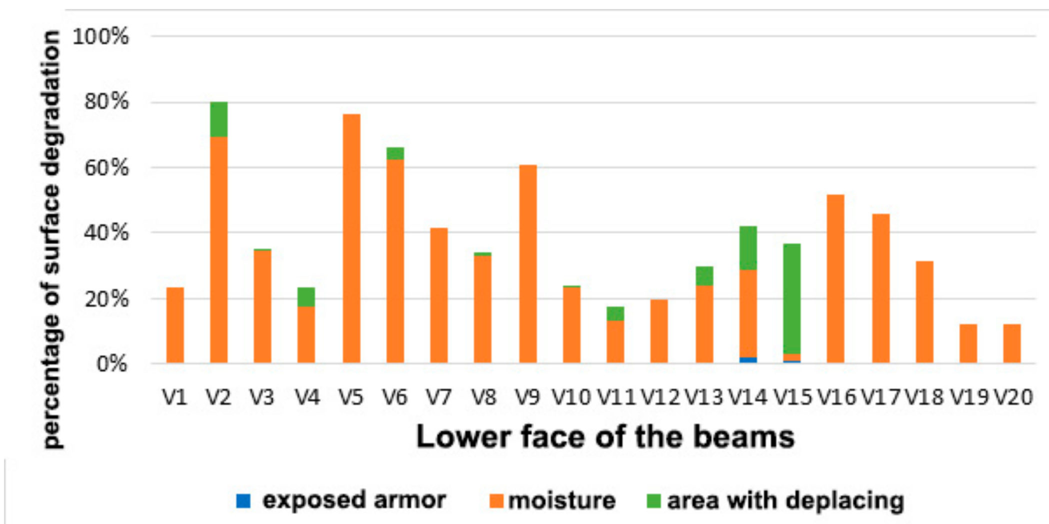

Figure 18. Percentage of degradation - Lower face of the beams

Considering the twenty beams, six of them have an index higher than 50%, adding moisture, exposed armor, and detachment area, especially V2 and V5, in addition to V15, presenting 34% of its lower area (Figure 19).

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Figure 19. V15.

According to (Figure 20), humidity spots are the highest incidence among the pathological manifestations observed, totaling 82% area of pathological manifestations. This result can avidinated the need to maintain the building.

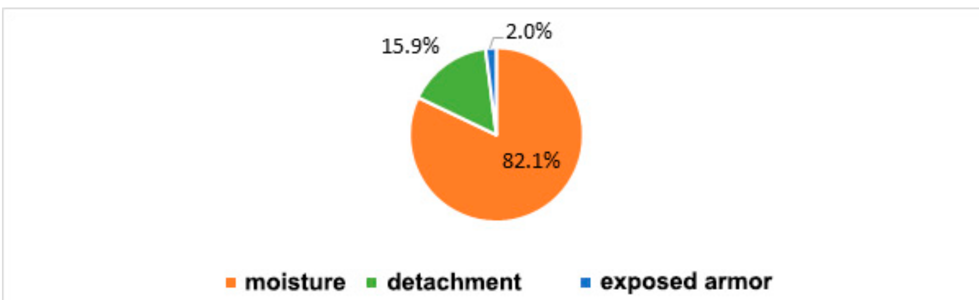

Figure 20. Pathological manifestations identified in structural parts

(Figure 21) and (Figure 22) represent the surface degradation of the pillars percentage per face.

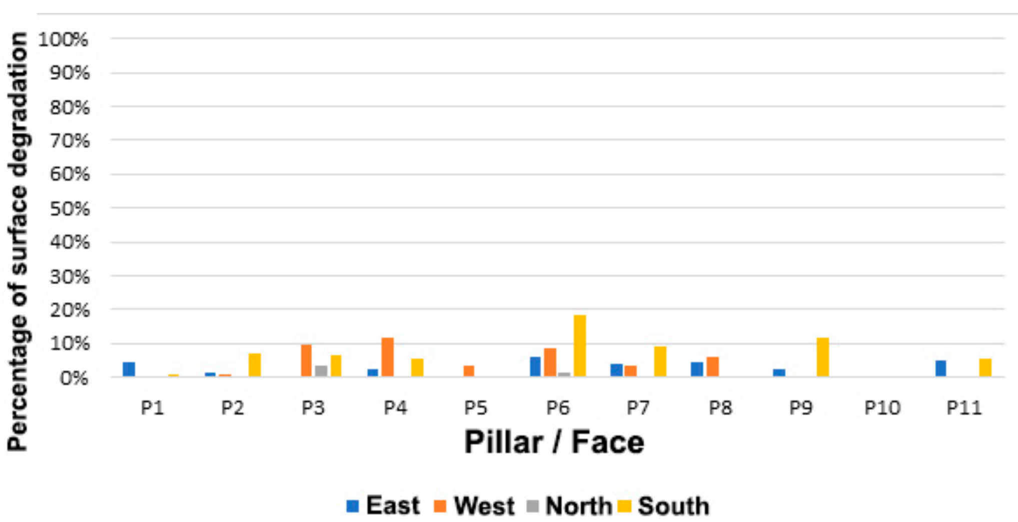

Figure 21. Percentage of surface degradation of the pillars of the North facade.

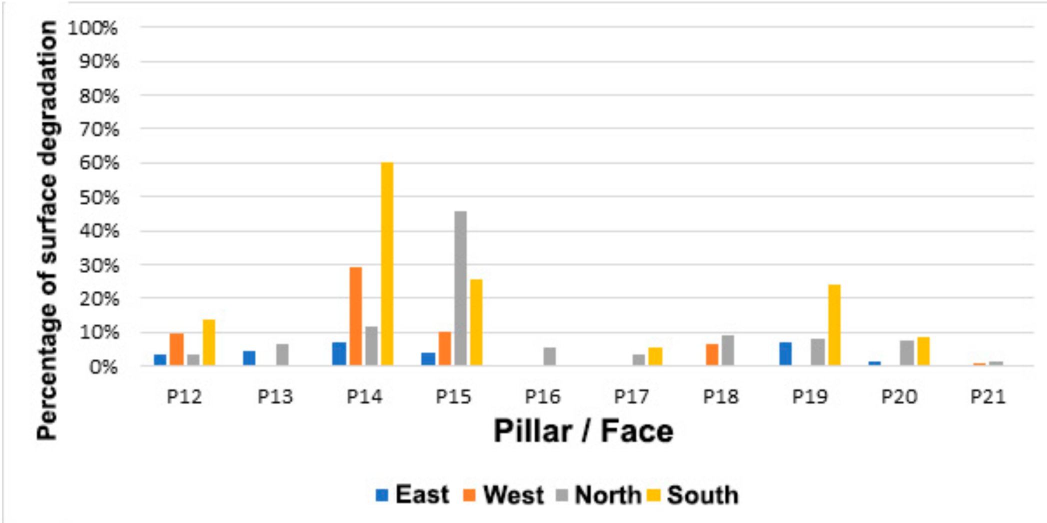

Figure 22. Percentage of surface degradation of the pillars of the East facade

Pillars P14, P15, and P19 in East facade presented the higher indexes of surface degradation than others, but without maintaining a face pattern of sun exposure. P14 presented degradation in the 4 faces, being 60% in South face, 29% in West, 12% in North and 4% in East. P15 presented degradation in 46% in North face, followed by South face in 26%, West in 10% and maintains a standard with P14 for the less degraded face, East in 4%. P18, P19 and P20 presented high indices in West, South and North faces, but absence of pattern, having in common only moisture presence in North face, which is seen in almost all pillars in East facade. P19 and P20 are covered by tile, presenting only dirt, without unplacating of the pieces or cracking.

Although with relatively low indexes, pillars of North facade and South face are the most degraded due to the lower sun exposure. For the pillars of the East facade, the North face is the most impaired due to the temperature gradients, given the longest time of sun exposure. The elements on the East solar faces through a period of shade got values closer than South facade.

(Figure 23) and (Figure 24) show the pillars degraded areas, the North facade have percentages lower than 8%. On the East facade, five pillars exceed this percentage of degradation, three of them higher than 15%. P14 was the most degraded element with 26% of degraded area mainly due to the moisture stains found in South face. Among all the pillars, only P10 did not present pathological manifestations.

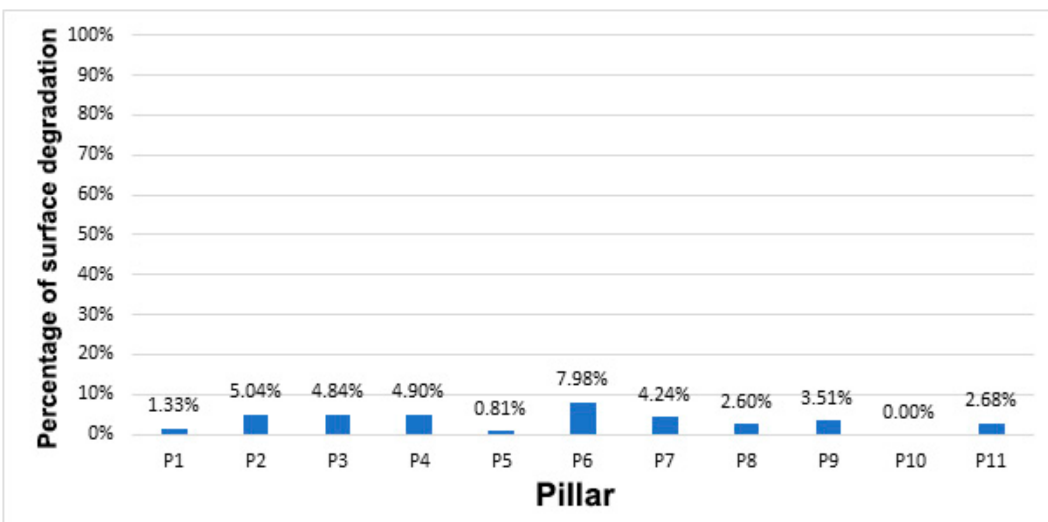

Figure 23. Percentage of surface degradation of the pillars of the North facade

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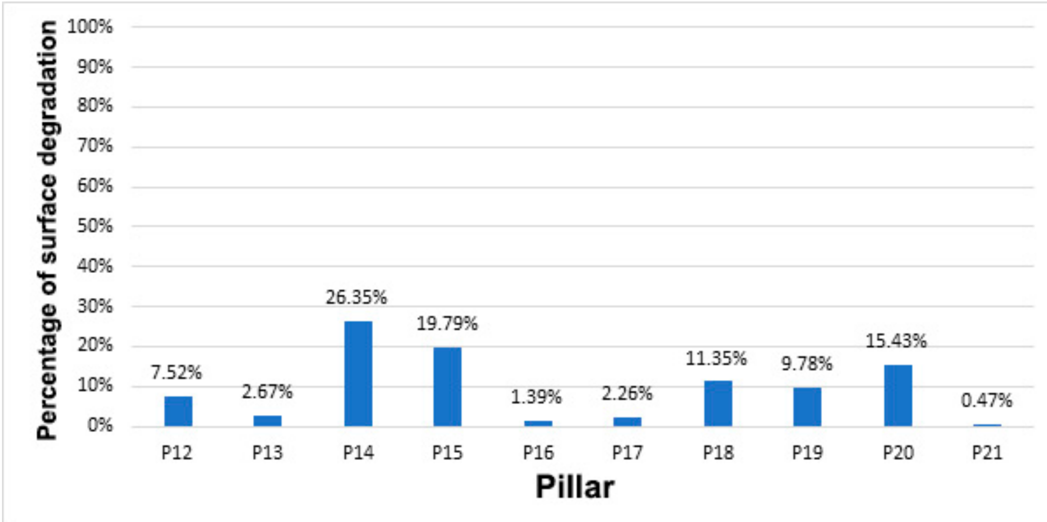

Figure 24. Percentage of surface degradation in the pillars of the East facade

For the beams, a similar procedure was performed (Figure 25) and (Figure 26). Considering two different directions of studied beams, the same solar orientations were not evaluated for beams localized in East and North facade, only the lower face was studied. The lower face of the beams was the most impaired due to the accumulation of water by gravity coming from the other faces and the interior of the pieces. The second most degraded face was to the east because of the high humidity levels found in the perimeter beams of the East facade.

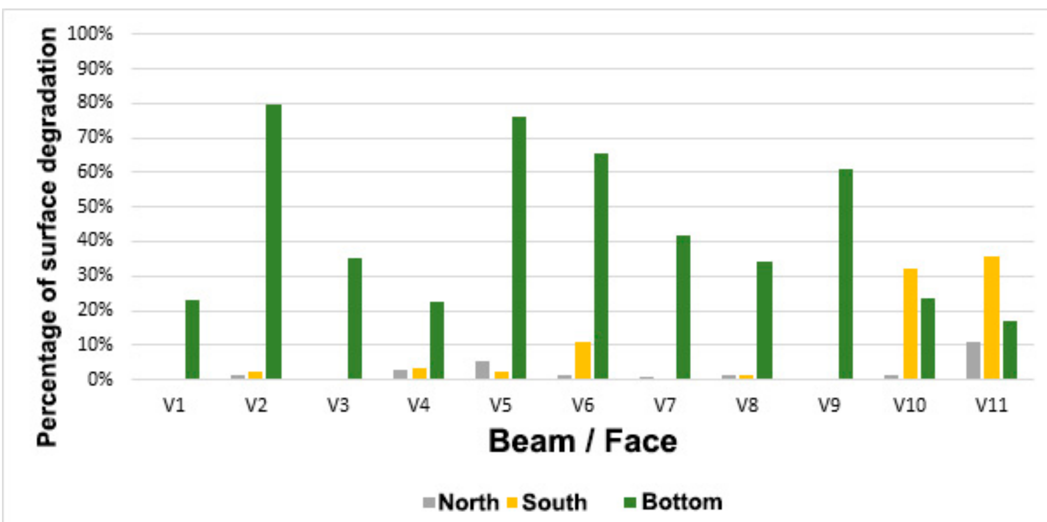

Figure 25. Percentage of degradation of the beams of the North facade

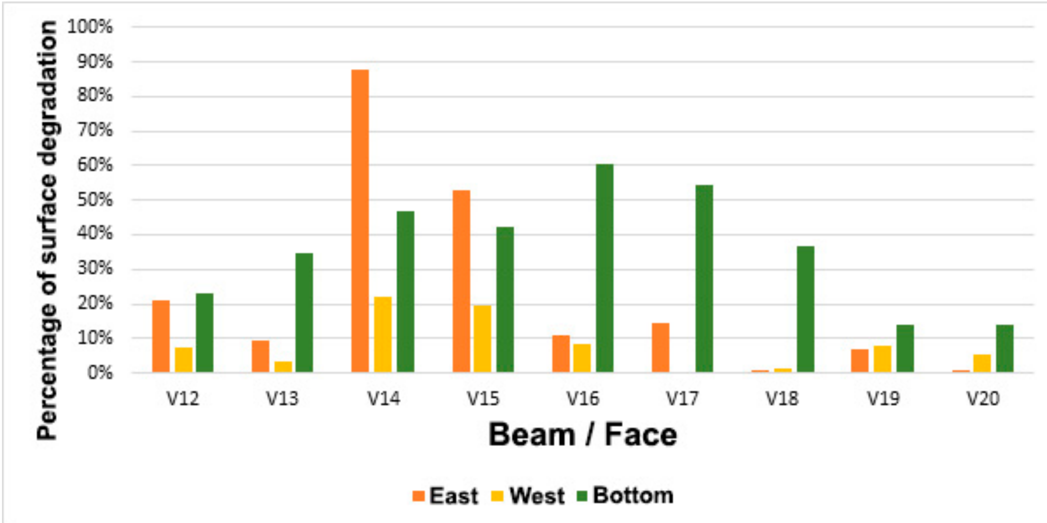

Figure 26. Percentage of degradation of the beams of the East facade

(Figure 27) and (Figure 28) show the beams surface degradation percentage considering the total area of the beams. The beams do not present standard, and they are relatively close. On East facade are found the beams with the two highest individual percentages, 60% and 30% for V14 and V15. On North facade are the two lowest percentages of 8% for V1 and 9% for V4. The peak in the values of the East facade is due to the vegetation present in V14.

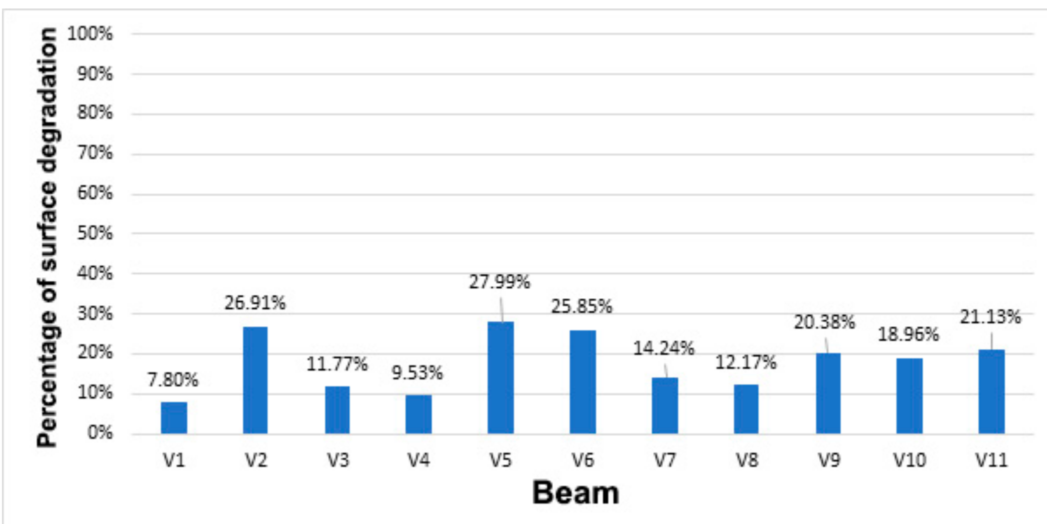

Figure 27. Percentage of surface degradation of the beams of the North facade

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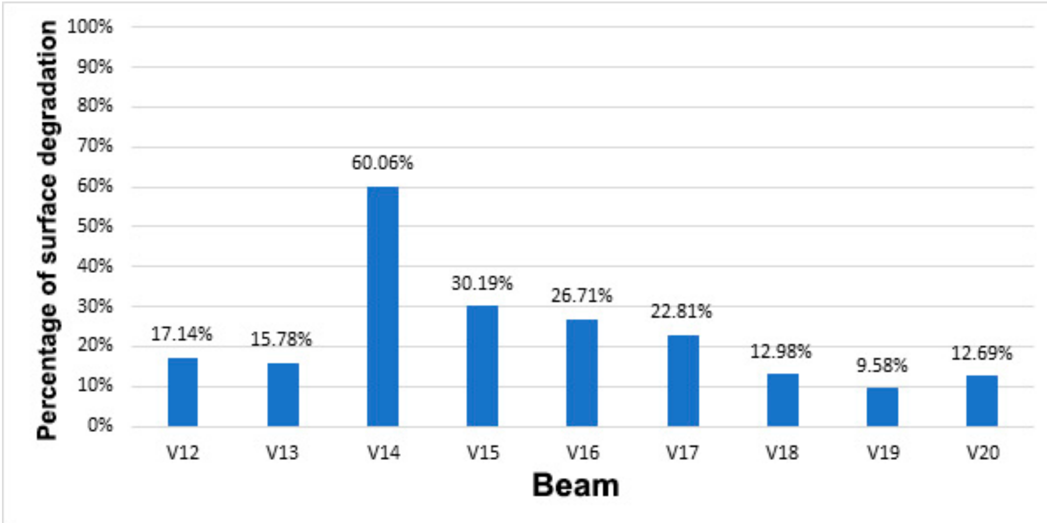

Figure 28. Percentage of surface degradation of the beams of the East facade

3.2 Sclerometric test

The values obtained from the correlation of the mean sclerometric index through the sclemeter abacus present the compressive strength values (Figure 29) and (Figure 30). The pillars of the East facade presented on average values of compressive strength of 58.39 MPa. This value is close them results of North facade with 60.7 MPa of average values of compressive strength.

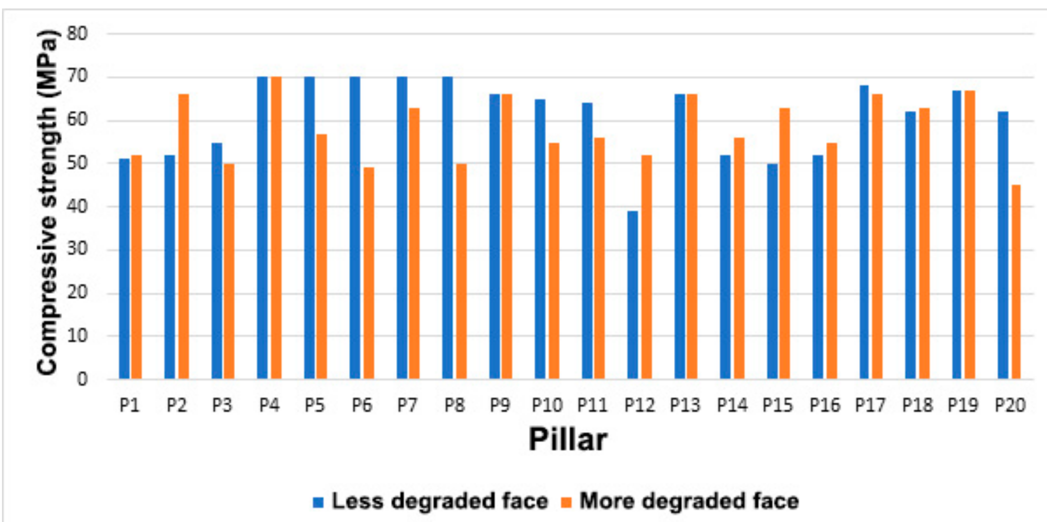

Figure 29. Compressive strength by state of the pillar face

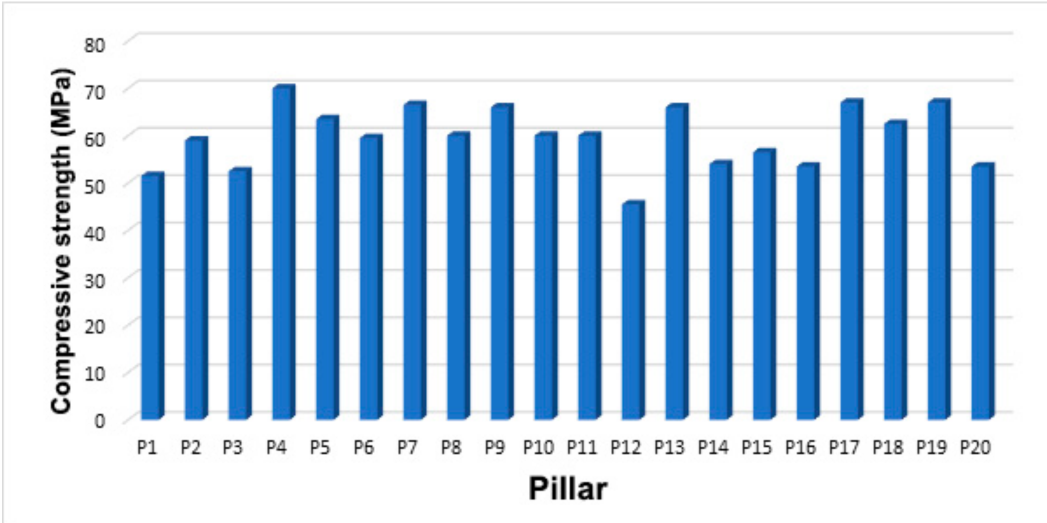

Figure 30. Medium compressive strength between two faces of the pillars

North face presents effective sclerometric indices higher than other faces as can be seen in (Figure 31). This result can be caused by high incidence of sunlight, accelerating the degrading agents flow as CO_2 in the pores leading to the filling of these voids. After being filled, this occurrence led to a present sclerometric indices higher than those obtained in pieces of less intensity phenomenon occurrence as suggested by (Lima and Martins, 2014). The other faces did not show a pattern. The lowest average compressive strength with 45.5 MPa was in P12. This pillar presented 2% of degraded area total. The most degraded elements as P14, P15 and P20, presented effective sclerometric indices greater than 53.5 MPa. Columns presenting low degradation rates as P1, P5 and P10 presented average rates of 51.5 MPa, 63.5 MPa and 60 MPa.

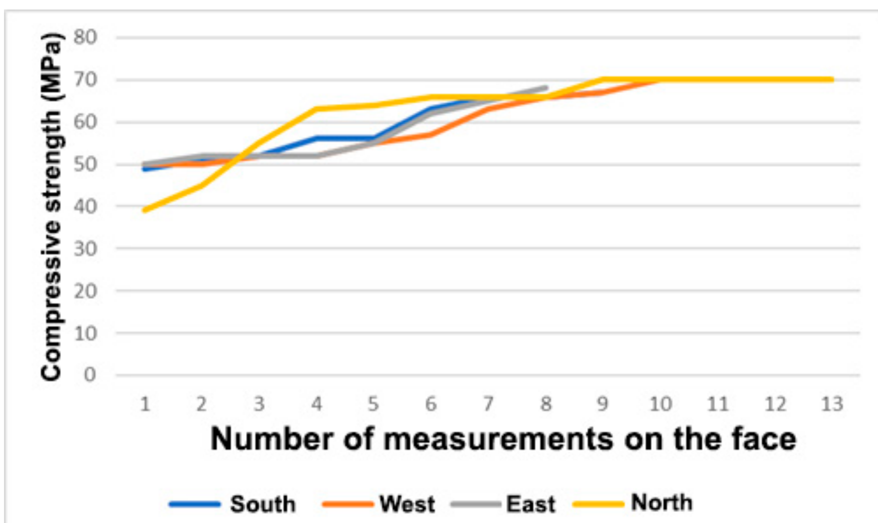

Figure 31. Compressive strength by the face of the pillars

3.3 Carbonation assay

(Figure 32a) and (Figure 32b) show the existence of carbonation in all five pieces tested, including around the reinforcements.

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(a) (b)

Figure 32. (a) Carbonization test near the vertical center of the column. (b) Carbonization test at the base of the column

Comparing the results with those obtained by (Canteiro et al., 2019) in building built at the same time and belonging to the same industrial complex, carbonation was observed only in some specific regions. Differently from the results obtained in "Paliteiro", (Ferreira et al., 2019) and (Nicolini et al., 2019) conducted the carbonation depths in specimens exposed on the second floor of "Paliteiro", proving the occurrence of this phenomenon in all specimens. Currently, the building is used as parking with daily traffic of vehicles, exposing the structural parts to the high concentration of carbon dioxide (CO_2), which may be contributing to the parts of the structure are carbonated. In addition, the absence of sealing masonry on two of the four facades and roofing, as well as the lack of maintenance, may also be collaborating.

3.4 Chloride penetration assay

In the chloride penetration assay, chlorides presence was confirmed (Figure 33a) and (Figure 33b). Comparing the results to those obtained in (Canteiro et al., 2019), which the presence of chlorides in beams with exposed reinforcement, the sealing with masonry and the coverage of the building hindered the action of chlorides. In the situation of lack of coverage and sealing, the results obtained by (Teixeira, 2019) and (Ferreira et al., 2019) confirmed the presence of chlorides in the environment of "Paliteiro". The action of chlorides presents its mechanisms facilitated in this building with the long period of exposure to weather and its location on the banks of a canal combined with the high rates of relative humidity of the air in Pelotas.


(a) (b)

Figure 33. (a) Application of silver nitrate in the abutment stripped area. (b) Silver nitrate applied in abutment peeling

3.5 Assay: size of the armor cover

The reinforcement covers of four pillars were measured, the same in which phenolphthaletin and silver nitrate were aspersated. In all measurements, nominal cover was recorded between 7 mm and 10 mm. All presented longitudinal reinforcement of 20 mm in diameter. The values for the beam varied between 9 and 15 mm. In the same beam, the thickness of the main reinforcement was measured, presenting 20 mm in diameter.

All the covers elements off the "Paliteiro" do not meet with the one recommended by NBR 6118 (ABNT, 2014) in its current or predecessor edition as in 1978. (Torres et al., 2016) also found the nominal coverings verified were lower than those stipulated in the project, besides not meeting with the recommended as standard. The recurrence of this constructive failure in Pelotas is worrying given its consequences. The lack of minimum nominal cover facilitates the appearance of pathological manifestations in structural parts.

4. Conclusions

The analysis of the damage map allows observe the prevalence of stains moisture totaling 82% of the total area affected by pathological manifestations. Unplacated areas and exposed reinforcements were visualized, presenting corrosion with loss of bar section. These indicators provide the need of a deeper evaluation in the structure. The highest percentage of surface degradation is in the East face of the elements. Furthermore, the East facade of the "Paliteiro" presents the structural parts with higher percentage of degradation than North facade. An important factor of this analysis is the lower solar incidence in East facade than North. Thus, increasing the period in which moisture remains retained in the pores of concrete. Noteworthy, there is a building next and higher than “Paliteiro” located less than 20 m, parallel to East facade causing shade favoring the concentration of moisture.

The results obtained through the carbonation verification assay *in loco* are in accordance with the studies by (Ferreira et al., 2019) and (Nicolini et al. 2019), verifying the carbonatation in “Paliteiro”. The verification of the presence of chlorides in the “Paliteiro” was in accordance with (Teixeira, 2019) and the (Ferreira et al., 2019), consequence where the building is located. Another important issue is the without information regarding specific use of the building or degradation state when refrigerator was still operating. From the analysis of the obtained data, the building presents worrying deterioration levels with the presence of chlorides, carbonation, and several moisture stains, causing concrete detachment, exposure, and corrosion of reinforcements. Further future investigations are still needed, as well as important interventions to guarantee the security and stability of the building, so that, this building can be used as a useful space of the Federal University of Pelotas.

5. References

ABNT (Associação Brasileira de Normas Técnicas) (2012). NBR 7584: Avaliação da dureza superficial pelo esclerômetro de reflexão — Método de ensaio [NBR 7584: Surface hardness evaluation by the reflection hammer — Test method], Rio de Janeiro, BR.

ABNT (Associação Brasileira de Normas Técnicas) (2014). NBR 6118: Projeto de estruturas de concreto — Procedimento [NBR 6118: Design of Concrete Structures – Procedure], Rio de Janeiro, BR.

Cadore, WW (2008). Estudo da carbonatação da camada de cobrimento de protótipos de concreto com altos teores de adições minerais e cal hidratada [Study of the carbonation of the covering layer of concrete prototypes with high levels of mineral additions and hydrated lime] Masters, Universidade Federal de Santa Maria, Santa Maria, BR.

Canteiro, MN; Ferreira, RH et al. (2019). Manifestações patológicas em estrutura de concreto armado: Campus Anglo da UFPel/RS [Pathological manifestations in reinforced concrete structure: Anglo Campus of UFPel/RS] In *61º Congresso Brasileiro do Concreto* Fortaleza, BR.

Costa, V., Silveira, AM et al. (2021). Evaluation of degradation state of historic building facades through qualitative and quantitative indicators: case study in Pelotas, Brazil. International Journal of Architectural Heritage. https://doi.org/10.1080/15583058.2021.1901161

Costa, VS, Silveira, AM.; Torres, A. (2020). Sampling selection methodology: inventoried facades of Pelotas/RS. Research, Society and Development 9 (11): p. e4759119988, https://doi.org/10.33448/rsd-v9i11.9988

FERREIRA, CF; PALIGA, C. M et al. (2019). Comportamento do concreto frente à ação de cloretos e CO^2 na cidade de Pelotas/RS [Behavior of concrete against the action of chlorides and CO^2 in the city of Pelotas/RS] REEC – Revista eletrônica de Engenharia Civil 15(2): 35-49, https://doi.org/10.5216/reec.v15i2.51363

Helene, PRL. (2003). *Manual de reabilitação de Estruturas de Concreto – Reparo, Reforço e Proteção [Concrete Structures Rehabilitation Manual - Repair, Reinforcement and Protection]* RedRehabilitar, São Paulo, BR.

Lichtenstein, NB. (1986). Patologia das Construções - Boletim Técnico 06/86 [Construction Pathology - Technical Bulletin 06/86] Escola Politécnica da Universidade de São Paulo, São Paulo, BR.

Lima, GES, Martins, ROG (2014). Determinação da correlação entre a profundidade da frente de carbonatação e a resistência superficial do concreto [Determination of the correlation between the depth of the carbonation front and the surface strength of concrete] In *21º Congresso Brasileiro de Engenharia e Ciência dos Materiais* Cuiabá, BR.

Mota, ACM (2011). Avaliação da presença de cloretos livres em argamassas através do método colorimétrico de aspersão da solução de nitrato de prata [Evaluation of the presence of free chlorides in mortars using the colorimetric method of spraying the silver nitrate solution] Masters, Escola Politécnica da Universidade de Pernambuco, Recife, BR.

Revista Ingeniería de Construcción. RIC
Vol 37 Nº2 2022 www.ricuc.cl
DOI: 10.7764/RIC.00024.21

Moura, MM; Krause, VL et al. (2014). Levantamento de dados e realização de diagnóstico de marquises da região central do município de Pelotas [Data collection and diagnosis of marquees in the central region of the city of Pelotas] In *XXIII Congresso de Iniciação Cientifica da UFPel* Pelotas, BR.

Nicolini, NG.; Ferreira,CF et al. (2019). .Análise do Efeito da Carbonatação no Processo de Degradação de Estruturas de Concreto da Cidade de Pelotas/RS [Analysis of the Effect of Carbonation on the Degradation Process of Concrete Structures in the City of Pelotas/RS] In *2º Encontro de Ciência e Tecnologia do IFSul Campus Bagé* Bagé, BR.

Peres, RM (2001). Levantamento e identificação de manifestações patológicas em prédio histórico – um estudo de caso [Survey and identification of pathological manifestations in a historic building - a case study] Masters, Universidade Federal de Pelotas, Pelotas, BR.

RILEM TC 56-MHM (1988). CPC 18: Measurement of hardened concrete carbonation depth.

Teixeira, FR (2019). Concretos com substituição parcial do cimento pelo resíduo do beneficiamento de rochas ornamentais: Análise quanto à ação de íons cloreto [Concrete with partial replacement of cement by residue from ornamental stone processing: Analysis regarding the action of chloride ions] Masters, Universidade Federal de Pelotas, Pelotas, BR.

Tomazeli, A (2017). Diretrizes para a inspeção, análise e aceitação de superestruturas em concreto armado de edifícios habitacionais com obras paralisadas [Guidelines for the inspection, analysis and acceptance of reinforced concrete superstructures in residential buildings with stalled works] Masters, IPT, São Paulo, BR.

Torres, AS; Bezerra, MT (2015). Castelo Simões Lopes -um descaso com a história e o dinheiro público na cidade de Pelotas/RS [Castelo Simões Lopes - a disregard for history and public money in the city of Pelotas/RS] PARC Pesquisa em Arquitetura e Construção **6 (3):** 129-138, https://doi.org/10.20396/parc.v6i2.8635014

Torres, AS; Silva, VMB et al. (2016). Análise das manifestações patológicas em reservatórios elevados na cidade de Pelotas/RS [Analysis of pathological manifestations in elevated reservoirs in the city of Pelotas/RS] REEC – Revista eletrônica de Engenharia Civil **12(1):** 12-22, https://doi.org/10.5216/reec.v12i1.37740

UFPel (Universidade Federal de Pelotas) (2015). Institucional Histórico [Institutional History] Pelotas, BR. See http://portal.ufpel.edu.br/historico (accessed 25/08/2021).

UFPel (Universidade Federal de Pelotas) (2017). Memorial do ANGLO [ANGLO Memorial] Pelotas, BR. See https://wp.ufpel.edu.br/rededemuseusdaufpel/memorial-do-anglo/ (accessed 25/08/2021).