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Use of Thermography in the Analysis of Pathological Manifestations of Historical and Artistic Building Facades in the City of Sobral - Ceará

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Abstract: This article aims to discuss the importance of thermology in the identification of pathological manifestations in civil construction, as well as the application of thermography in 6 facades of the artistic and cultural heritage of the city of Sobral, in the state of Ceará, in Brasil, using the thermographic camera Flir model C2 – XT. Two analyzes were carried out in each structure, one in a period of direct contact with the sun's rays and the other in the absence of this solar incidence, with the objective of having two maps with different temperatures, with a greater possibility of verifying the problems on the facades of the chosen buildings, namely, São João Theater, Church of Sorrows, São Francisco Church, Church of the Rosary, Dom José Museum and Vale do Acaraú State University (UVA) – Betânia Campus. All buildings were analyzed, as well as identifying existing problems and possible potential manifestations, demonstrating and exposing solutions with applications of more modern technologies that guarantee the good performance and durability of the structures.

Keywords: Thermology. Pathological. Thermography. Historic Patrimony. Buildings

1. Introduction

Heritage buildings are of great importance to the human perception of the culture of a community (Rubens, 2023). Cultural heritage is susceptible to damage caused by natural hazards and other factors, and it is difficult to guarantee their eternality. A vital aspect of heritage conservation is the knowledge about the presence of damages threatening the stability of the structure (Tiwari, 2023).

The entire history and culture of a city can be discussed from its historical and cultural heritage, living there all the marks of generations that shared moments and experienced situations over the years, giving the local population a sense of belonging to the place and to the history, passed down from generation to generation.

All this experience and use of the municipal heritage are reflected in the historic buildings that, added to the environmental and execution factors, suffer a physical degradation which in the course of time intensifies and ends up manifesting itself in pathologies, which may compromise its integrity and functioning.

To preserve the identity of a city, region or people, it is necessary to encourage the preservation of its historical, cultural, natural, architectural and urban heritage. Knowing the useful life and the deterioration curve of each material used in the historic building is necessary for preservation and for the adoption of the necessary restorative measures (Barbosa, 2010).

Pathology can be understood as the part of engineering that studies the symptoms, mechanisms, causes and origins of defects in civil constructions, that is, it is the study of the parts that make up the diagnosis of the problem. (Helene, 1992).

Many pathological manifestations are easy to detect and the diagnosis of the problem extends to several other pathologies of the same type, that is, they are easy to perceive and repair. However, when these pathological manifestations are not visible to the naked eye, it is necessary to use technological tools that can identify and map these problems in order to give us a better diagnosis so that the solution is made in the most coherent and economical way, in view of that a single problem can occur due to several causes.

There are methods used to diagnose the deficiencies of a structure, which can be classified as destructive, semi-destructive and non-destructive. Non-destructive methods are non-invasive techniques used to determine the characteristics of the examined material. Unlike destructive methods, non-destructive methods allow the analysis of the object in question without harming or causing irreversible damage to the structure (Plesu, 2012).

Taking thermography as an example, whose technique consists of analyzing the temperature on the surface of objects, mapping them through the temperature distribution of the image field, without direct contact with the structure. Tensile, torsion, and shear tests are examples of techniques in which a part of the structure is removed and subjected to tests, making this an example of destructive testing.

Observing all these problems over the years and added to the advancement of studies of pathological manifestations, new equipment was developed to help identify visible and mainly invisible manifestations, so that possible problems can be quickly located and thus reduce risks. One of the studies that made the most progress in identifying pathological manifestations was the one that used thermography, which manages to generate a heat map capable of highlighting anomalies present in the structure that are not so noticeable to the naked eye.

The use of non-destructive techniques to inspect cultural assets is essential to evaluate building pathologies without causing damage or altering their structure. Infrared thermal imaging may be applied to identify superficial damages in construction elements and monitor the conservation of these buildings. Then, interventions may be performed to minimize the possibility of damage that could cause problems to the integrity of the building (Resende, 2022).

In many cities, the building envelope is deteriorating and aging. Understanding the defect characteristics of the envelope is essential to increasing the safety of the house and reducing the loss of energy (Li, 2022).

Infrared Thermography (IT) is a procedure in civil construction that consists of the perception of infrared radiation emitted by a body through a device capable of detecting and assimilating this type of heat transfer (radiation); with this, it becomes possible to accurately analyze some pathological manifestations that occur in buildings (Medeiros, 2010).

Infrared thermography (IRT) has been employed to identify defects illustrated on building facades. However, environmental conditions (such as a shadow) do affect the IRT by making it difficult to identify defects (Huang, 2020).

Thermography basically consists of observing the surface temperature of a body by the mechanism of radiation, and there must be a temperature difference between the target and the medium (Cortizo, 2007). Through thermographic equipment it is possible to map the studied structure and make an analysis of the heat flow present in the building, thus finding possible pathological manifestations that have not yet been identified without the aid of the device.

According to Mendonça (2005) the applications of the infrared thermography technique in civil construction range from the evaluation of the performance and thermal comfort of buildings to the detection of pathological manifestations. The use of IT also allows an efficient thermal analysis of buildings and the identification of the systems that compose them (structural, sealing, electrical, among others). In addition to infiltrations and the presence of moisture, there are other pathological manifestations that are hardly noticeable to the naked eye and are common in our daily lives.

Inspection, as with building facades, becomes a complex logistical activity due to the high height of the buildings, the difficult access conditions, and the need to carry out assessments with the buildings in use, consequently making it difficult to obtain data (Bauer, 2014).

Researchers showed that infrared thermography was sensitive to detect areas affected by precipitation humidity presenting lower temperatures than those sectors without any problem. Furthermore, the higher the temperature difference, the better definition of the area affected by the humidity was, thus allowing the location of potential spots (Rocha, 2018).

Researchers showed good possibilities for assessing characteristics of historical constructions integrating HBIM tools and experimental procedures. The technology of digitalization and experimental tests can effectively provide results on the damage to heritage buildings (Rubens, 2023).

In the reintegration applications of the destroyed blocks in stone monuments, the compatibility of the petrographic and engineering properties of the material selected for restoration with the original building stones provides benefits in the sustainable preservation of the structures. Infrared thermography can be an important tool in evaluating this compatibility (Hatır, 2022).

Researchers contributed to the evolution of a simplified procedure, considering an approach on the different types of moisture present on the façade of buildings infrared thermography. The non-destructive tests assess pathological manifestations in buildings and the thermography test is a viable, economical, and efficient inspection strategy (Barbosa, 2021).

Researchers have developed a methodology that helps the scientific community in measuring (qualification and quantification) the degree of degradation of the facades, as well as in identifying the origin of the moisture present, enabling the elaboration of strategies that assist in a more efficient intervention in the maintenance and repair services of buildings (Antunes, 2016).

The present work aimed to carry out a study of facades of historical and artistic heritage in the municipality of Sobral, making a non-destructive analysis with the aid of thermographic equipment Flir C2 - XT in order to find and map possible visible and invisible pathologies present in the place, as well as identifying a possible correction to the problem in a simplified and highlighted way to contribute to the maintenance, functionality and security of the site.

2. Methodology

In order to carry out this work, on-site visits were made to some old buildings of historical and artistic heritage in the municipality of Sobral in the State of Ceará in Brazil. The thermographic camera Flir model C2 -XT, which was used according to the manufacturer's catalog, can perform an infrared reading of 4800 pixels, managing to operate in a temperature range between -10 °C and 150 °C, with an error margin of 2% on surfaces above 0 °C. The identification of a variation of 1°C to 2°C with the use of IT equipment is, generally, an indication of problems. A variation of 4°C or more indicates an abnormality in the body (Cortizo, 2007).
The equipment used to carry out the tests was the thermographic camera Flir model C2 - XT (Figure 1), a compact camera that can, according to the manufacturer's catalog, perform an infrared reading of 4800 pixels, managing to operate in a temperature range between - 10°C and 150°C. The equipment has a margin of error of plus or minus 2% on surfaces above 0 °C, which was the situation found in the appropriate studies.

Figure 1 - Model FLIR thermographic camera C2 - XT.

Source: Flir, 2021.

The thermographic camera Flir model C2 -XT is a reliable piece of equipment in the analysis of pathological manifestations, since it has the function of automatic adjustment of emissivity, which performs a more detailed reading without the need for direct contact with the structure, which characterizes a test not destructive.

In order to carry out a thermographic analysis, it is necessary for the analyzed body to present different temperatures on the same surface, so it is necessary that this studied object undergoes a thermal change, either by receiving heat (heating) or by losing heat (cooling), and thus may expose visible or invisible present anomalies.

This study also used the passive thermography technique, which is applied when the source of heat transmission is obtained naturally, usually the solar source is used, which through the incidence of its rays causes the surface heating of the surface. analyzed structure. This technique results in a more qualitative analysis, considering that the natural source is beyond the researcher's control and always expresses a normal functioning of the use of the building in its natural form (Rocha; Póvoas, 2018).

As for the active thermography technique, it is necessary to use an artificial heat source, which transmits or absorbs heat from the structure, performing the necessary thermal alteration for the study of specific anomalies to be identified and studied. This technique allows a more quantitative analysis since the researcher manages to control the transmitted heat and, consequently, the thermal variations necessary for the presentation of the investigated pathologies (Bauer et al. 2014).

Therefore, reading the images taken allows us to control the predefined temperature range, through a color scale on the right side of the images, where the blue color refers to lower temperatures and reddish regions to higher temperatures. The incidence of sunlight on these facades varied from one to another in relation to their geographical position in relation to the sun, but in all the records in the morning were taken around 7:00 am to 9:00 am and in the afternoon from 2:00 pm.

When evaluating a civil construction system using the infrared thermography technique, it is assumed that materials with discontinuities present a non-uniform heat flow. Such differences in heat flow can be perceived on the surface of materials through IT, showing localized discrepancies that can be associated with anomalies or discontinuities in the system (Cortizo, 2007).

2.1 Thermographic analysis techniques

To carry out a thermographic analysis, it is necessary that the analyzed body presents different temperatures on the same surface, so the object studied must have undergone a thermal change, either by receiving heat (heating) or by losing heat (cooling), and thus can expose visible or invisible present anomalies. There are two applicable techniques that are classified by the type of source that will induce the analyzed structure to a thermal variation: passive and active thermography techniques.

The passive thermography technique is applied when the source of heat transmission is obtained in a natural way, usually the solar source is used, which through the incidence of its rays causes the superficial heating of the analyzed structure. This technique results in a more qualitative analysis, bearing in mind that the natural source is beyond the researcher's control and always expresses a normal functioning of the use of the building in its natural form. In qualitative analysis, some applications do not require the determination of the exact temperature, the temperature studied is only apparent, collecting data to be interpreted more quickly (Rocha; Póvoas, 2018).

As for the active thermography technique, it is necessary to use an artificial heat source, which transmits or absorbs heat from the structure, performing the necessary thermal alteration for the study of specific anomalies to be identified and studied. This technique allows a more quantitative analysis since the researcher manages to control the transmitted heat and, consequently, the thermal variations necessary for the presentation of the investigated pathologies. The method becomes quantitative from the moment the objective is to classify the level of severity of the anomaly, requiring adjustments and measurements of the thermographic measurement parameters (emissivity, distance, reflected temperature, among others) (Bauer et al. 2014).

3. Results and discussions

The city of Sobral is in the northern region of the State of Ceará in Brazil and has a population of over 200000 habitants. Sobral has a historic center that has already been overturned by IPHAN (National Historical and Artistic Heritage Institute).

Through thermographic equipment it is possible to map the studied structure and make an analysis of the heat flow present in the building, thus finding possible pathological manifestations that have not yet been identified without the aid of the device.

3.1 Analyzed facades

The facades of São João Theater, Church of Sorrows, São Francisco Church, Church of the Rosary, Dom José Museum and Vale do Acaraú State University (UVA) – Betânia Campus in the city of Sobral in the State of Ceará in Brazil were analyzed.

3.1.1 - São João Theater

Analyzing Figure 2, the difference in temperature between the base of the building and the top is notorious, the red spots present higher temperatures already approaching the maximum recorded by the equipment, which was 45.8°C, while the more yellowish top presented a clearer and more pleasant color.

In the morning (Figure 3) with a much lower temperature and better distribution across the facade, it was possible to see only small darker heat lines in the lower part of the facade, in the line of contact between the sidewalk and the building, in addition to a larger spot in the lower right corner, which may characterize the presence of moisture coming from the soil by capillary ascending.

When carrying out an analysis closer to the site (Figure 4), the temperature difference was confirmed by the thermographic camera, thus making clear the presence of moisture on the facade wall as a result of capillary rise, a property of water that enables it to overcome the force of gravity and climbing on walls that do not have waterproofing protection on the foundation, including already having white stains on the paint due to the presence of moisture.

In order to repair the presented manifestation, it is recommended that the entire plaster coating be removed and a layer of polymeric cement applied in order to isolate the contact of moisture with the coating, which is applied as soon as the layer of polymeric cement is already completely dry, ensuring the protection of the coating to be made.

Figure 2 - Thermographic map of the facade of São João Theater in the afternoon.

Source: Own, 2021.

Figure 3 - Thermographic map of the facade of São João Theater in the morning.

Source: Own, 2021.

Figure 4 - Verification of possible pathology on the facade of São João Theater.

Source: Own, 2021.

3.1.2 - Church of Sorrows

By analyzing Figure 5, the facade presented a constant and uniform thermographic map, which at that first moment ruled out any wear or manifestation due to the presence of humidity or detachment of the coating.

In the morning (Figure 6) it presented a higher temperature due to the direct contact with the sun's rays. Again, the structure presented a constant and well-distributed thermal distribution, confirming that it does not have external agents interfering with the health and appearance of the front facade.

According to Figure 7, the stains on the wall showed a thermal difference that extends over an area greater than that visible on the facade, which presents a problem caused by absorption of external moisture. An application of flexible waterproofing would both absorb the deformations caused by temperature variation and ensure the durability of the coating.

Figure 5 - Thermographic map of Church of Sorrows in the afternoon.

Source: Own, 2021.

Figure 6 - Thermographic map of the facade of Church of Sorrows in the morning.

Source: Own, 2021.

Figure 7 - Verification of manifestations on the lateral facade of the Church of Sorrows.

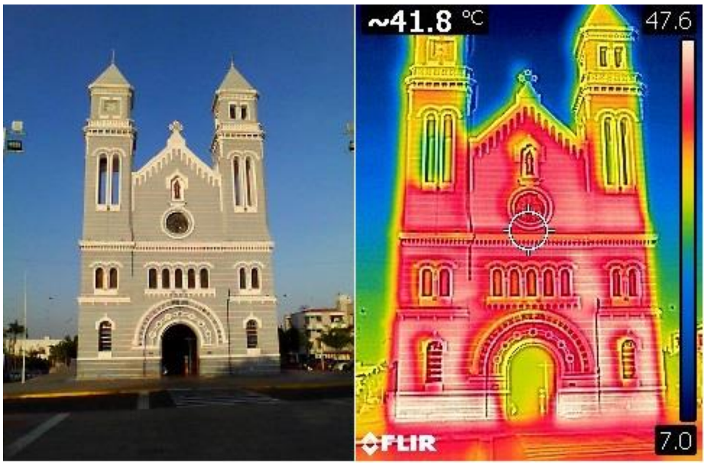
Source: Own, 2021.

3.1.3 - São Francisco Church

In Figure 8, with the aid of the thermographic camera, it is possible to notice a uniform distribution, but in the lower part of the building it has higher temperatures that drop as the height increases, this characterizes the presence of moisture by ascending capillary, transmitted from the ground to the the structure, with concentration in the lower part of the building.

With the temperature a little lower and better distributed in the facade area (Figure 9), the change in the base of the building was better visible, which confirmed the assumptions obtained in the analysis of Figure 8, making it necessary to check the building more closely (Figure 10) to confirm the pathological manifestation. Approaching the structure, an opening in the wall cladding was visible, as well as dark stains. Through the thermographic image of Figure 10, it is possible to notice that there is a transmission of heat between the floor and the facade through the rising humidity by capillarity, common in old structures that do not have waterproofing in the foundation, thus also causing a detachment of the coating or which is also absorbing moisture.

Figure 8 - Thermographic map of the facade of São Francisco Church in the afternoon.

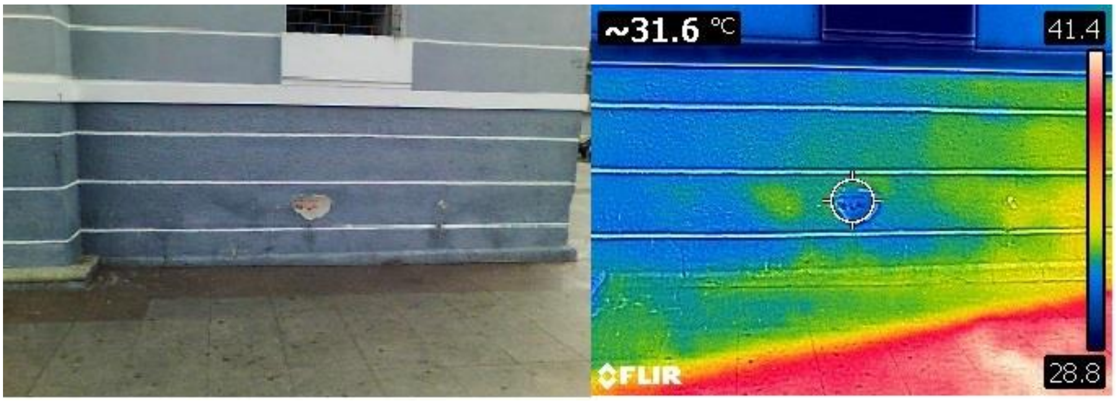


Source: Own, 2021.

Figure 9 - Thermographic map of the facade of São Francisco Church in the morning.

Source: Own, 2021.

Figure 10 - Verification of pathological manifestations on the facade of São Francisco Church.



Source: Own, 2021.

3.1.4 - Church of the Rosary

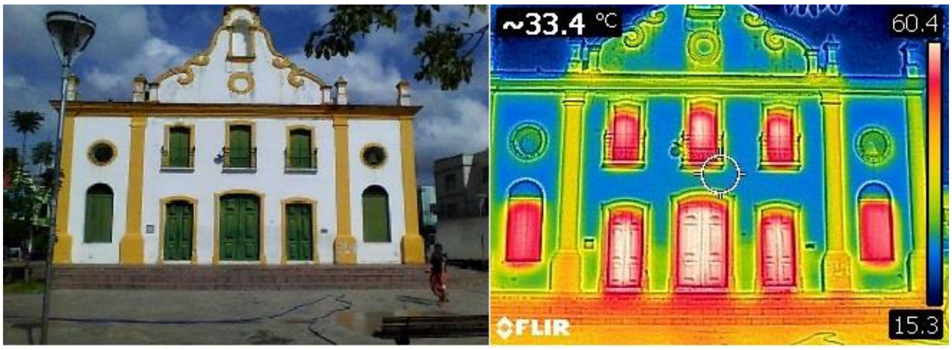
Figure 11 shows us a period in which the building does not have direct contact with the sun's rays. The presented heat map has a uniform distribution, with a slight elevation in the lower part of the building and a constant temperature in the rest, which shows a good integrity of the facade, without manifestations in the second half of the building, but in the lower part this change can be caused by the same factor as the other analyzes carried out previously.

In another period (Figure 12) the pattern of thermal distribution on the facade was maintained, even with a higher temperature, due to this period the structure is in direct contact with the sun's rays. Higher temperatures are found in the lower part, while a uniform distribution is maintained in the upper part, confirming the presence of moisture by capillary rise (Figure 13).

Figure 11 - Thermographic map of the facade of Church of the Rosary in the afternoon.

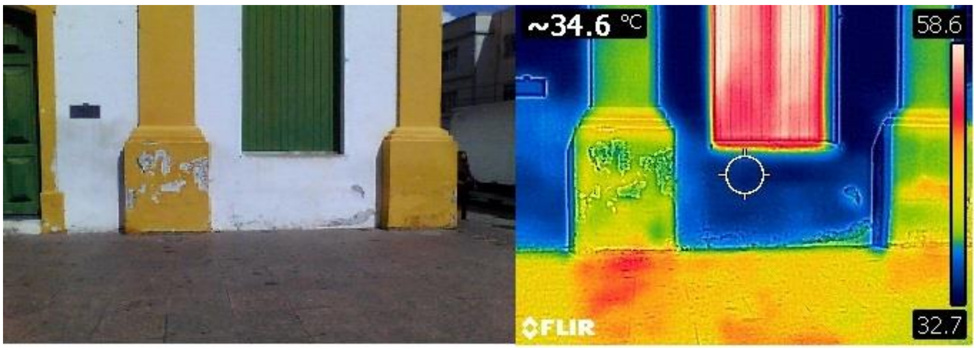
Source: Own, 2021.

Figure 12 - Thermographic map of the facade of Church of the Rosary in the morning.



Source: Own, 2021.

Figure 13 - Verification of pathological manifestations on the facade of the Church of the Rosary.



Source: Own, 2021.

3.1.5 - Dom José Museum

By analyzing the facades both in the afternoon (Figure 14) and in the morning (Figure 15), the same pattern of thermal distribution was observed, proving the excellent quality of the museum's facade.

In Figure 16, a small change was noticed in the lower part, which had a higher temperature than the upper part, which raised suspicions of pathological manifestations, but this difference is caused by the change in the tone of the paint, while the lower part has a darker tone with greater heat absorption capacity, the higher a lighter tone, consequently with a lower absorption capacity.

However, on the side facade (Figure 17) some stains were visibly identified on the upper part, which could be caused by an outcrop of internal or external agents, but with the help of the thermal camera it was possible to guarantee that it was only a matter of wear on the paint, which with a restoration using a suitable product with flexibility and resistance to humidity in the new painting, it solves the visual problem, in addition to guaranteeing a greater durability of the structure.

Figure 14 - Thermographic map of the facade of the Dom José Museum in the afternoon.

Source: Own, 2021.

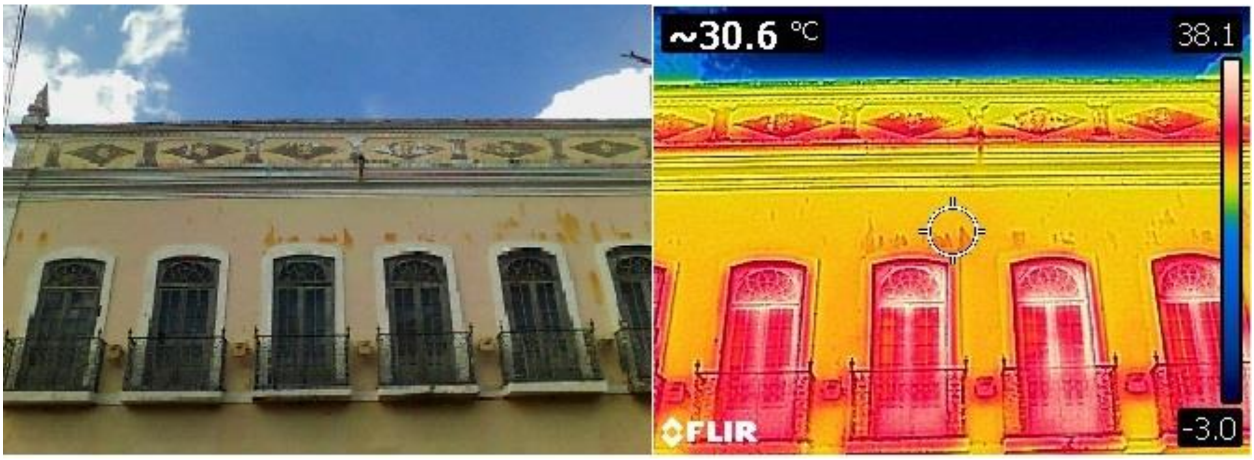
Figure 15 - Thermographic map of the facade of the Dom José Museum in the morning.

Source: Own, 2021.

Figure 16 - Verification of pathological manifestations on the facade of the Dom José Museum.

Source: Own, 2021.

Figure 17 - Verification of pathological manifestations on the facade of the Dom José Museum.



Source: Own, 2021.

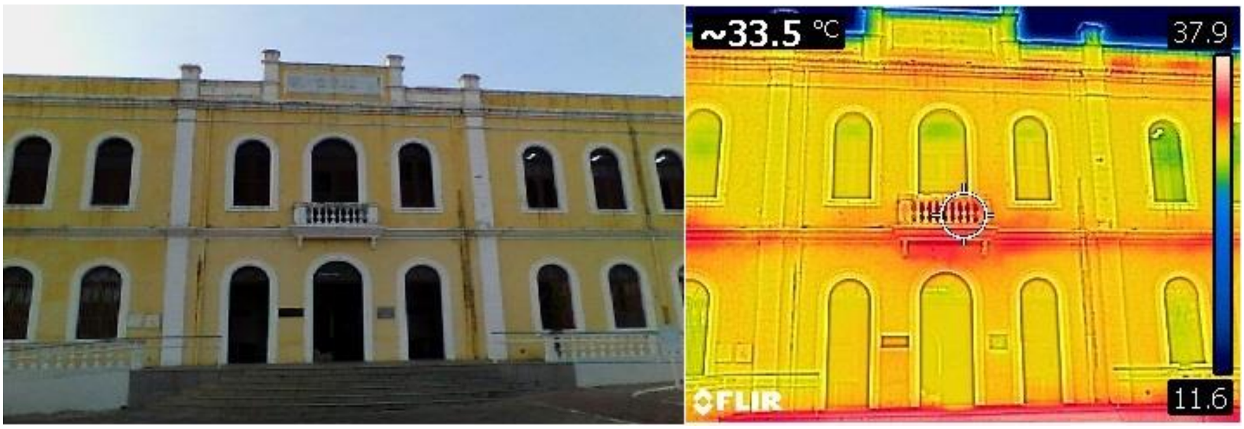
3.1.6 - Vale do Acaraú State University (UVA) – Betânia Campus

In the general view of the thermographic map (Figure 18), it showed a uniform distribution without sudden or perceptible alteration of agents that cause pathological manifestations, leaving the only marked differences due to the alternation of shades. Already in the morning (Figure 19) with a higher temperature it is possible to find darker marks around the rainwater pipes that pass through the facade, this shows the transmission of humidity between the elements due to leaks in the pipes, in addition to the bottom of the building, characterizing the presence of capillary rise.

By analyzing Figure 20, a large red spot can be seen exposing the outcrop in a shape that tapers down, like a funnel, in addition to, just above the thermal anomaly, there is a galvanized iron pipe responsible for the rainwater runoff from the roof, caused by the presence of from this device that is splashing this water on the facade, which, added to the wear of the paint, infiltrates the wall.

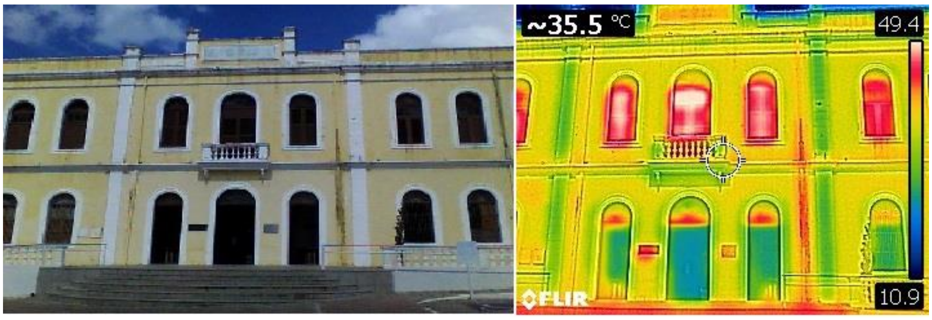
Figure 21 shows the intensification of humidity near the inspection boxes and grease present on the sidewalk through leaks in the same that are absorbed by the structure. In Figure 22, a constructive defect due to the lack of a structural element, tit, causes infiltration through the wall.

Figure 18 - Thermographic map of the Vale do Acaraú State University (UVA) - Betânia Campus façade in the afternoon.



Source: Own, 2021.

Figure 19 - Thermographic map of the Vale do Acaraú State University (UVA) - Betânia Campus facade in the morning.

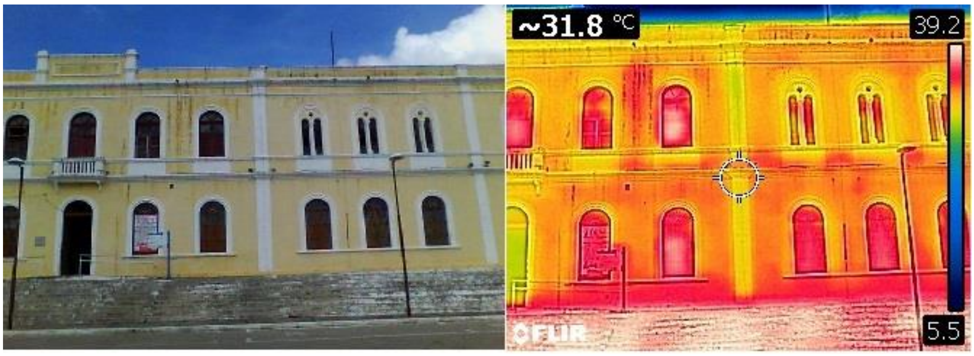


Source: Own, 2021.

Figure 20 - Thermographic map of the Vale do Acaraú State University (UVA) - Betânia Campus facade in the morning at the secondary entrance.

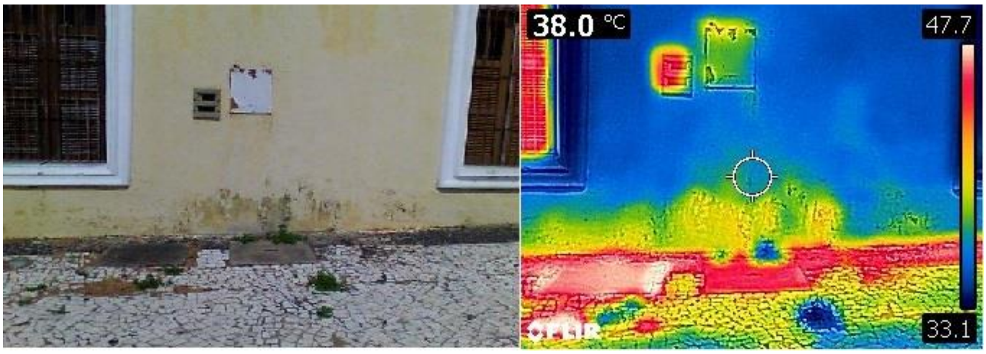
Source: Own, 2021.

Figure 21 - Thermographic analysis of an outcrop on the facade of Campus Betânia- Vale do Acaraú State University (UVA).



Source: Own, 2021.

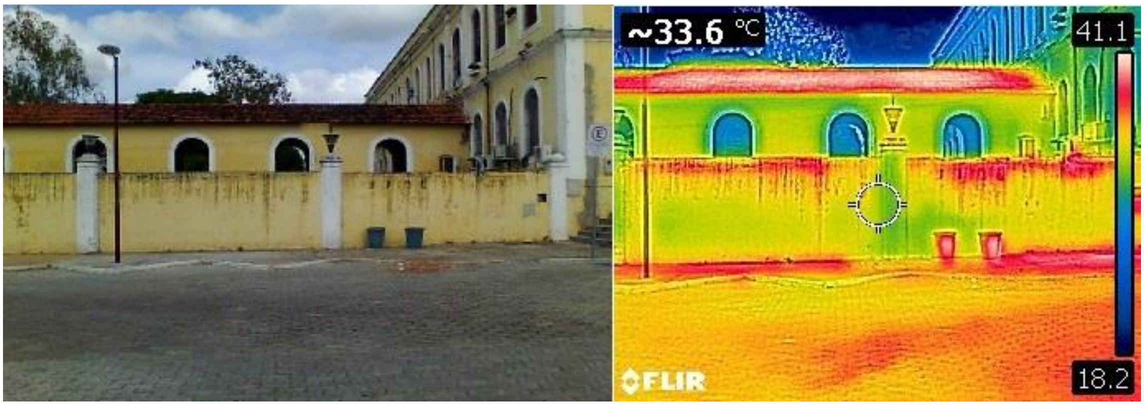
Figure 22 - Thermographic analysis of moisture transmission from inspection boxes and grease to the façade walls of Vale do Acaraú State University (UVA) - Betânia Campus.



Source: Own, 2021.

A Figure 23 show the thermographic analysis of the wall on the façade of Vale do Acaraú State University (UVA) – Betânia Campus with a temperature of 33.6 ^{0}C.

Figure 23 - Thermographic analysis of the wall on the façade of Vale do Acaraú State University (UVA) – Betânia Campus



Source: Own, 2021.

4. Conclusions

The technical application of thermography in the study of this work is relevant, since these structures are very old and often become built in constructive vices or even due to lack of knowledge at the time of their construction.

The temperature variations analyzed from the reading of the thermographic camera allowed us to identify many pathological manifestations even before they are presented to the naked eye, which allows us to quickly provide for or proliferate worse pathological manifestations, such as moisture present in a slab or body. structure that results in an oxidation of the existing reinforcement and consequently compromises the resistance of the equipment used.

The analyzed buildings showed an excellent structural quality, without the need for reinforcements, but the most relevant problem was humidity, both by capillary ascending and by outcropping caused by internal or external agents. Another recorded problem was the detachment of the coating, a common execution error, which could be caused by the lack of roughcast or low resistance/poor application of the laying mortar.

With technological advancement, all these problems can have a lasting correction if applied and executed correctly. Combined with effective management in the maintenance and conservation of the equipment, always aiming the improvement in the quality of the architectural appearance, one can preserve what is the greatest legacy that the municipality can leave for the population, the history of generations being passed down in a safe and usable way in the historical and cultural heritage of the buildings.

References

Rubens, T., Ribeiro, G., Paulo, R. *et al*. (2023). Digitalization based on high-resolution scanning and HBIM tools damage assessment of the José de Alencar house. *J Build Rehabil* . 8, 30. https://doi.org/10.1007/s41024-023-00275-5

Tiwari, P.S., Pande, H., Gupta, S. *et al*. (2023). Damage Detection and Vitual Reconstruction of Built Heritage: An Approach Using High-Resolution Range and Intensity Data. *J Indian Soc Remote Sens*. https://doi.org/10.1007/s12524-022-01661-1

Barbosa, M. T. G. et al. (2010). Patologias de Edifícios Históricos Tombados. Encontro Nacional da Associação Nacional de Pesquisa e Pós Graduação em Arquitetura e Urbanismo – I ENAPARQ, Rio de Janeiro, Brasil; December 2010.

Helene, P. (1992). Manual para Reparo, Reforço e Proteção de Estruturas de Concreto. Editora Pini. São Paulo. SP. Brasil.

Plesu, R., Teodoriu, G., Taranu, G. (2012). Infared thermography applications for building investigation. Universitatea Tehnicã "Gheorghe Asachi" din Iasi Tomul LVIII, 61 (1), 157-168.

Resende, M. M., Gambare, E. B. *et al*. (2022). Infrared thermal imaging to inspect pathologies on façades of historical buildings: A case study on the Municipal Market of São Paulo, Brazil. *Case Studies in Construction Materials*. Volume 16, 2022, e01122. https://doi.org/10.1016/j.cscm.2022.e01122.

Li, Zhisheng ., Jin, Yukai ., Liang, Xiguan., Zeng, Jiangyi. (2022). Thermography evaluation of defect characteristics of Building envelopes in urban villages in Guangzhou, China. *Case Studies in Construction Materials*. 17, e01373. https://doi.org/10.1016/j.cscm.2022.e01373.

Medeiros, G. (2010). Métodos de Ensaios Não Destrutivos para Estruturas de Concreto. Disponível em: <http://www.cimentoitambe.com.br/metodos-de-ensaios-nao-destrutivos-para-estruturas-de-concreto/>. Acesso em: 01 set. 2021.

Huang, Y., Shih, P., Hsu, K.T., Chiang, C.H. (2020). To identify the defects illustrated on building facades by employing infrared thermography under shadow. *NDT & E International*. Volume 111, 102240. https://doi.org/10.1016/j.ndteint.2020.102240

Cortizo, E. C. (2007). Avaliação da técnica de termografia infravermelha para identificação de estruturas ocultas e diagnóstico de anomalias em edificações: Ênfase em Edificações do Patrimônio Histórico. p.1-178, Belo Horizonte, MG. Brasil.

Mendonça, L. V. (2005). Termografia por Infravermelhos: Inspeção de Betão. Engenharia & Vida. nº 16. p. 53-57. Lisboa, Portugal.

Bauer, E. et al. (2014). Critérios para aplicação da termografia de infravermelho passiva como técnica auxiliar ao diagnóstico de patologias em fachadas de edifícios. IPB - Revista do Instituto Politécnico da Bahia. edição especial. 266.

Rocha, J.H.A., Santos, C.F., Póvoas, Y.V. (2018). Detection of precipitation infiltration in buildings by infrared thermography: a case study. *Procedia Structural Integrity*. Vol 11, pg 99-106. https://doi.org/10.1016/j.prostr.2018.11.014

Hatır, M.E., Ince, I., Bozkurt, F. (2022). Investigation of the effect of microclimatic environment in historical buildings via infrared thermography. *Journal of Building Engineering*. Volume 57, 1, 104916. https://doi.org/10.1016/j.jobe.2022.104916

Barbosa, M.T.G., Rosse, V.J., Laurindo, N.G. (2021). Thermography evaluation strategy proposal due moisture damage on building facades. *Journal of Building Engineering*. Volume 43, 102555. https://doi.org/10.1016/j.jobe.2021.102555

Antunes, G.R., Masuero, A.B. (2016). Flexural tensile strength in mortar coating reinforced with different types of metal mesh: A statistical comparison. *Construction and Building Materials*. Vol 121, 15, Pages 559-568. https://doi.org/10.1016/j.jobe.2022.104916

FLIR, 2021. 3 principais aplicações da análise termográfica. Disponível em: <https://www.flir.com.br/support/products/c2/#Overview>. Acesso em: 16 dez. 2021.