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Conforto térmico e termografia infravermelha: análise da Igreja Centro Mariápolis Santa Maria em Igarassu/PE

Thermal comfort and infrared thermography: analysis of the Centro Mariápolis Santa Maria Church in Igarassu/PE

Conforto térmico y termografía infrarroja: análisis de la Iglesia Centro Mariápolis Santa María en Igarassu/PE

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Resumo: Neste estudo foram analisadas as estratégias construtivas para promover o conforto térmico da Igreja Centro Mariápolis Santa Maria, localizada em Igarassu/ PE, região de clima tropical úmido. Quando não trabalhadas corretamente, as estratégias construtivas e o uso de materiais inadequados podem comprometer a eficiência energética e a sustentabilidade da edificação, fazendo com que o uso de aparelhos de climatização seja indispensável para garantir o conforto térmico dos usuários. O objetivo deste artigo é avaliar o conforto térmico da edificação por meio de análises termográficas e das estratégias construtivas e materiais empregados. Para tal, foram identificadas e analisadas as estratégias utilizadas no projeto, em relação com sua zona bioclimática, foi feita caracterização dos materiais empregados nas fachadas, análise da carta solar e rosa dos ventos e aferição, com a câmera termográfica, das fachadas. Os resultados obtidos mostram que as estratégias utilizadas no projeto e construção da igreja, bem como os materiais utilizados nas fachadas, com exceção da pintura amarela e esquadrias em vidro, contribuíram favoravelmente para o conforto térmico do edifício.

Palavras-chave: Desempenho térmico; Termografia infravermelha; Eficiência energética.

Abstract: In this study, the constructive strategies adopted to promote the thermal comfort of the Centro Mariápolis Santa Maria Church, located in Igarassu, Pernambuco, a region with a humid tropical climate, were analyzed. When not properly applied, constructive strategies and the use of inappropriate materials can compromise the building’s energy efficiency and sustainability, making the use of air-conditioning systems indispensable to ensure users’ thermal comfort. The aim of this article is to evaluate the thermal comfort of the building through thermographic analyses, as well as an assessment of the constructive strategies and materials employed. For this purpose, the strategies adopted in the design were identified and analyzed in relation to its bioclimatic zone, the materials used on the facades were characterized, a solar chart and wind rose analysis was carried out, and thermographic measurements of the facades were performed. The results demonstrate that the design and construction strategies employed for the church, alongside the facade materials (excluding the yellow paint and glass fenestration), favorably contributed to the building's thermal comfort

Keywords: Thermal performance; Infrared thermography; Energy efficiency.

Resumen: En este estudio se analizaron las estrategias constructivas para promover el confort térmico de la Iglesia Centro Mariápolis Santa María, ubicada en Igarassu/PE, región de clima tropical húmedo. Cuando no se trabajan

Author Contributions according to the CrediT Taxonomy

SRSR: conceptualization, data curation, formal analysis, methodology, project administration, validation, visualization, writing – original draft, review & editing.

MESGV: conceptualization, data curation, formal analysis, investigation, methodology, visualization, resources, writing – original draft.

WAS: conceptualization, methodology, project administration, resources, supervision, validation, writing – original draft, review & editing.

EAR: conceptualization, methodology, supervision, validation, writing – review & editing.

VMEL: validation, writing – review & editing.

adecuadamente, las estrategias constructivas y el uso de materiales inadecuados pueden comprometer la eficiencia energética y la sostenibilidad de la edificación, haciendo indispensable el uso de equipos de climatización para garantizar el confort térmico de los usuarios. El objetivo de este artículo es evaluar el confort térmico de la edificación mediante análisis termográficos y del estudio de las estrategias constructivas y los materiales empleados. Para ello, se identificaron y analizaron las estrategias utilizadas en el proyecto en relación con su zona bioclimática; se realizó la caracterización de los materiales empleados en las fachadas, el análisis de la carta solar y de la rosa de los vientos, y la medición de las fachadas con una cámara termográfica. Los resultados obtenidos muestran que las estrategias utilizadas en el proyecto y la construcción de la iglesia, así como los materiales empleados en las fachadas —con excepción de la pintura amarilla y de las carpinterías de vidrio—, contribuyeron favorablemente al confort térmico del edificio.

Palabras clave: Rendimiento térmico; Termografía infrarroja; Eficiencia energética.

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Nothing to declare.

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1 INTRODUCTION

Between 2000 and 2018, approximately 48.000 people died in Brazil due to sudden increases in temperature; with heat wave events becoming more frequent and intense, those who do not have access to adaptation resources are the most affected (Santos *et al*., 2024). Given this scenario, the thermal conditions provided by a building become increasingly relevant and important to be studied in their general context, providing comfortable environments adapted to the local climate, avoiding excessive energy use, making buildings energy efficient without losing user comfort.

Nunes *et al.* (2021) highlight that the validity of the Residential Building Performance Standard (NBR 15575) broadens the discussion about meeting users' needs, bringing changes to the development of projects, since it establishes mandatory requirements to ensure safety, habitability, and sustainability. Dias *et al*. (2023) state that studies carried out over the years have highlighted the importance of building energy-efficient buildings, which value the thermal comfort of users and aim to reduce energy consumption. Oliveira and Alves (2021) point out the importance of analyzing the impact of the construction techniques used on the thermal performance of the building. To this end, Bioclimatic Architecture, defined by Corbella and Yannas (2003) as "an architecture concerned with its integration with the local climate, aiming at enabling the environment centered on the environmental comfort of human beings and its impact on the planet", becomes fundamental for the development of projects, since it allows the application of techniques and materials that will favor the thermal conditions inside the building.

Linked to the concept of thermal performance, roofing and vertical sealing systems play a fundamental role in the energy efficiency of a building and must be well dimensioned to ensure the lowest possible consumption (ABNT, 2024). To analyze the thermal performance over time of walls composed of thermal insulation panels, Gonçalves *et al*. (2022) used infrared thermography.

This article aims to evaluate the thermal comfort of the Igreja do Centro Mariápolis Santa Maria, located in the city of Igarassu, Pernambuco, by integrating thermographic analyses, constructive strategies, and the materials used, correlating the results with local climatic parameters and energy efficiency guidelines.

2 METHODOLOGICAL PROCEDURE

This research is an applied case study. Initially, a literature review was conducted, and then the object of study was selected based on data availability (project) and accessibility, which led to the site inspections. The methods applied to evaluate the church's thermal conditions included studying the incidence of sun and wind on the facade through solar chart and wind rose analysis, examining design and constructive strategies, verifying compliance with the requirements specified by NBR 15220-3 (2005) for its bioclimatic zone, followed by the identification and analysis of the strategies employed to promote thermal comfort and the characterization of the materials used on the facades. Finally, the data obtained from the images generated by the FLIR ONE Edge thermographic camera were analyzed, which provided thermograms and reports through the FLIR Thermal Studio software (Flir, 2024).

The data collection with the thermographic camera took place during June 2024, a period considered the winter solstice, on the East, South, and North facades at 3 different times: 7:00 AM, 12:00 PM, and 5:00 PM. The West facade was not analyzed because, in addition to being difficult to access, the corresponding internal area is not intended for people to stay. The selection of times aimed to analyze the behavior of the different materials used on the facades throughout the day under varying solar incidence. To avoid interference, the measurements were only carried out when the sky was clear, without the interruption of rain.

The camera used has a thermal resolution of 80 × 60 pixels and a visual resolution of 640 × 480 pixels. The Object Temperature Range varies from -20 °C to 120 °C, and the accuracy is ±3 °C or ±5%. It is applicable 60 seconds after startup when the humidity is between 15 °C and 35 °C and the scene is between 5 °C and 120 °C. The emissivity setting is automatic.

3 DATA ANALYSIS AND DISCUSSION

3.1 Characterization of the object of study

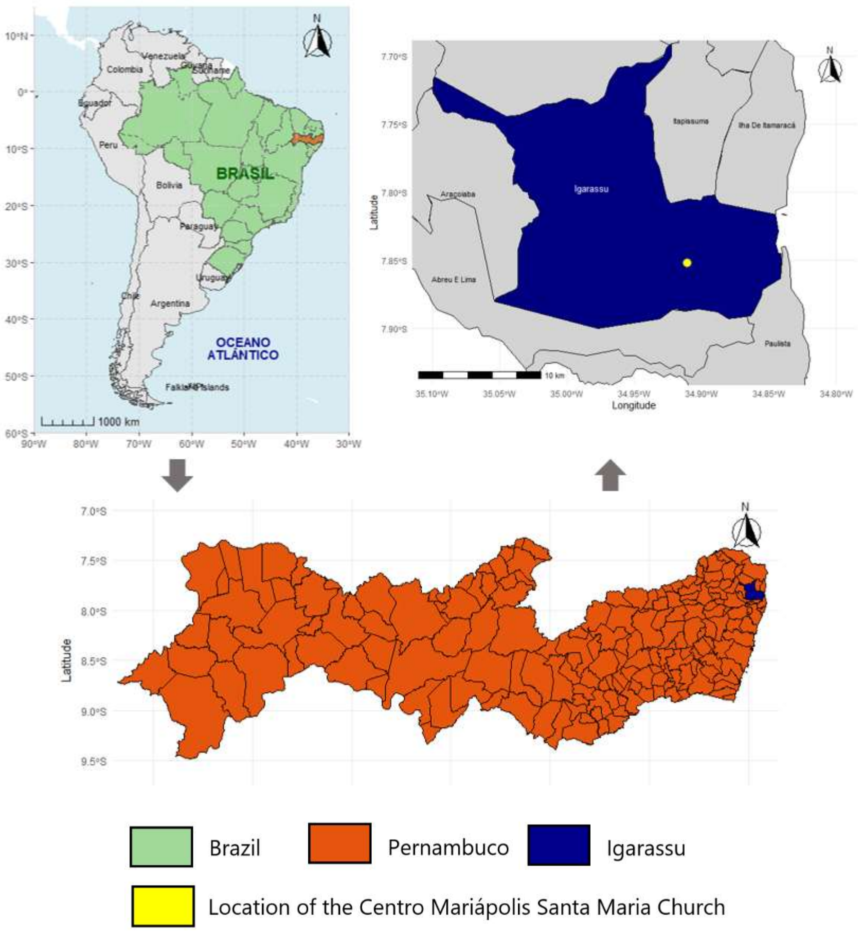
The church is located in the Mariápolis Santa Maria Center, in Igarassu/PE (Figure 1), and was chosen mainly because it does not require or use air conditioning equipment. Its location is not affected by surrounding buildings that interfere with and obstruct natural lighting and ventilation, and it is surrounded by vegetation (Figure 2).

The part of the main hall where the Temple and the Presbytery are located will be studied, corresponding to the North, South and East facades.

The building has a single floor and a walkway on the mezzanine that is approximately 2 meters wide in the arch part. Between the East and South faces is the bell tower, located on the ground floor as a confessional. The external walls are made of ceramic brick masonry, the South and East facades are filled with frames with sliding doors and windows with pivoting leaves, and on the North and West facades there are some loopholes with pivoting leaves and tall windows around the perimeter (Figure 3).

The city of Igarassu-PE is located in bioclimatic zone number 8. The region studied is defined as As by the Köppen climate classification system (Medeiros, 2018).

Figure 1 – Location of the Centro Mariápolis Santa Maria Church



Source: Authors.

Figure 2 - Site plan of the Centro Mariápolis Santa Maria Church complex

Source: Google Maps, 2025.

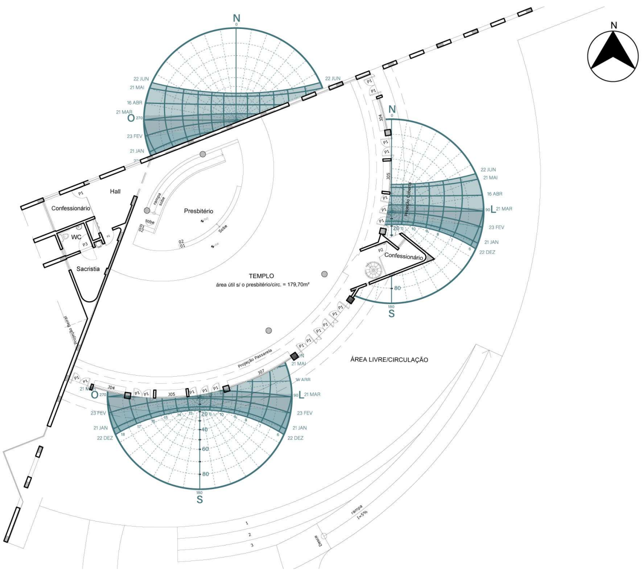
Figure 3 – South Facade of the Centro Mariápolis Santa Maria Church

Source: Authors.

3.2 Analysis of the Strategies Identified in the Project

Initially, the solar radiation on the facades was analyzed through a graphic study using the solar chart, ventilation was examined with the wind rose, and shading was evaluated by considering the building's placement on the plot. The solar chart for the city of Recife was adopted as a reference for Igarassu due to the small variation in latitude between the two cities, which results in no significant difference between the charts (Recife Latitude: -8.05 | Igarassu Latitude: -7.83). Figure 4 illustrates the study conducted with the solar chart on the North, South, and East facades, disregarding any shading effects caused by trees.

Figure 4 – Analysis of the incidence of solar radiation on the building



Source: Authors.

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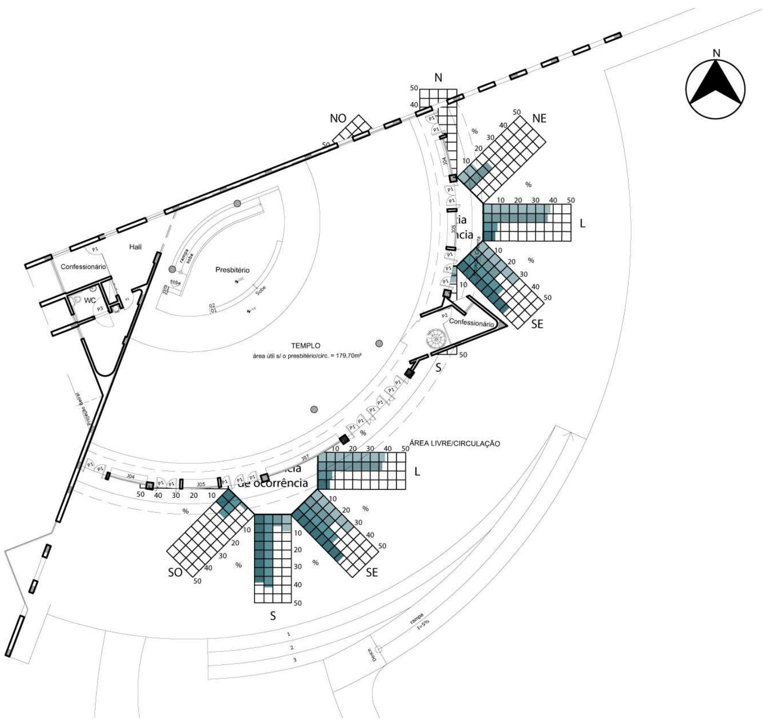
The North Facade has solar radiation incidence throughout the day in winter and summer from 12:00 p.m. until sunset; the East Facade has solar radiation incidence in winter and summer until 12:00 p.m., in some points it can be incident until 12:30 p.m. and the South Facade has high incidence of radiation throughout the day in summer and winter until 8:00 a.m.

Figure 5 summarizes the study carried out with the wind rose graph on the South and East facades, considering that these have a greater number of door and window openings. As the tropical climate has two well-defined seasons, winter and summer, these two seasons were considered in the analysis.

Figure 5 – Analysis of wind incidence on the building



Source: Authors.

The East Facade has an incidence of winds of 15% coming from the Northeast, 20% from the Southeast and 38% from the East in the summer; and during the winter 8% from the East and almost 40% Southeast and South and 10% Southwest in the winter. Thus, it can be established that the highest frequency of winds in the Summer comes from the East and in the Winter it comes from the South and Southeast.

The study of the climatic characteristics of the site is essential for the project to result in an energy-efficient and comfortable building for the user. Gurgel (2012) highlights the following strategies that can be adopted in buildings located in hot and humid climates, such as the city where the Church is located: shading;

protection of the east and west sides from the sun; materials with cool surfaces; avoiding heat gain through conduction; high openings/strategic ventilation; protection against humidity; avoiding heat gain.

In order to analyze the application of some constructive strategies that can contribute to the thermal performance of the building, characteristics such as: the shape and layout of the project, window openings, cross-ventilation, eaves, and the use of vegetation were studied.

The church has two rectilinear facades with openings at the top and surrounded by vegetation, facing north and west, where there is the greatest solar radiation, preventing greater sunlight on these sides, as indicated by Gurgel (2012), and enabling cross-ventilation. On the north facade, 3 loopholes were also placed near the east facade, which allows for increased cross-ventilation flow.

NBR 15220-3 (2005) suggests large ventilation openings for bioclimatic zone 8, which represents more than 40% of the floor area in openings in environments where people spend a lot of time. Since the area under study, the main hall, which includes the Temple and the Presbytery, is approximately 300 m², more than 120.00 m² in openings would be necessary. A survey of the window frames was carried out and the total area of openings is 111.06 m². Considering that all the frames are either pivot or central pivot, there is full use of ventilation in all openings, which is very close to what is recommended by the standard.

Since the Church is not characterized as an environment where people spend a lot of time, it would not be necessary to reach the percentage established by the standard. However, the project has 37% of the opening area related to the floor area.

Cross ventilation is one of the most widely used strategies for passive cooling and one of the principles of passive design. In this building, since the largest openings are located on the sides where there is the greatest occurrence of ventilation throughout the year, and the tall windows were placed on the opposite sides, favoring the elimination of hot air that rises during cooling, it can be considered that the positioning of the windows was adequate. Furthermore, the absence of internal partitions (Figure 6) in the building allows for better ventilation and favors cross-ventilation.

In the building under study, two of the most commonly used types of shading were implemented: the eaves and the surrounding vegetation. The eaves were designed as a horizontal element that extends across the east, southeast and south facades, following the perimeter of the 1.5 meter wide arch.

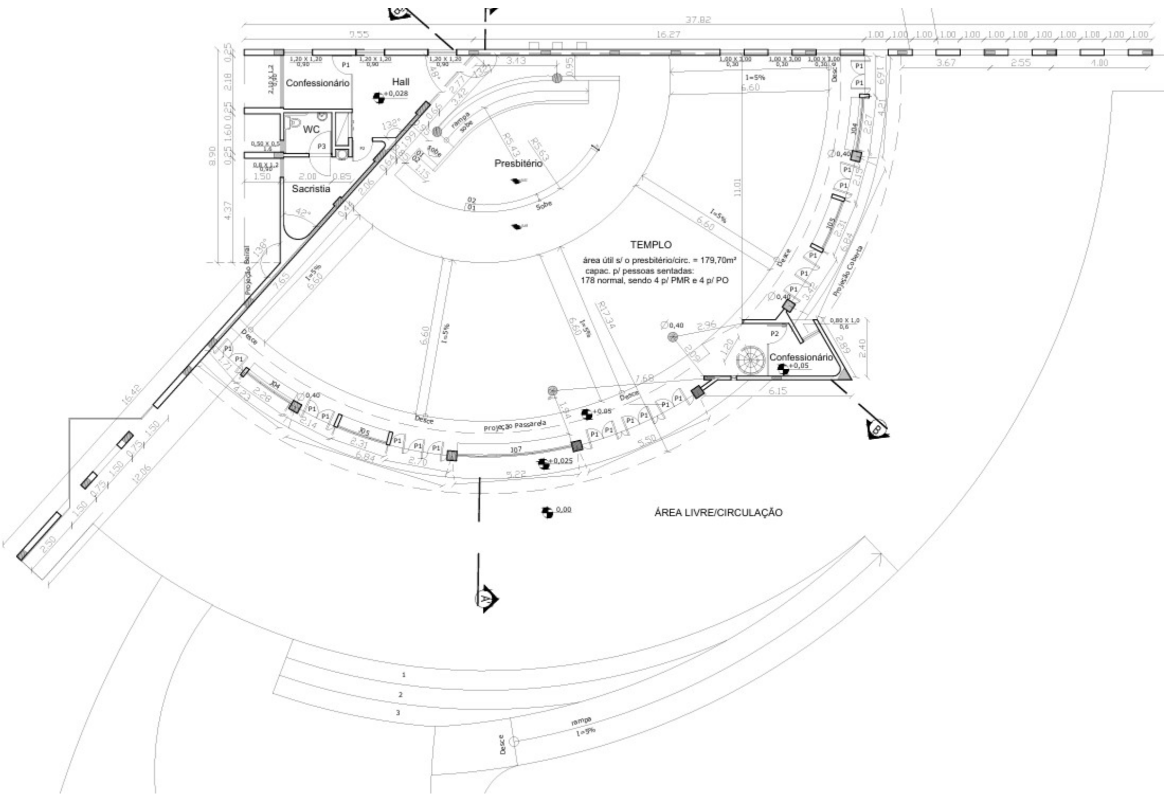
As the sun reaches higher temperatures, the eaves become more effective. NBR 15220-3 (2005) suggests shading all year round for zone 8. The vegetation, on the other hand, surrounds the entire building with medium and large trees, the North and West facades benefit most from the use of vegetation due to their proximity to the facade, preventing solar radiation in some points.

The church's external masonry, made of ceramic bricks with plaster, meets the requirements proposed in the NBR 15220-3 (ABNT, 2005), as seen in its thermal transmittance (U) and thermal delay.

The building has a cast-in-situ concrete slab covered with fiber cement tiles. It was not possible to access the project sections to determine the exact thickness of the slab, so it was assumed that the slab is 20 cm thick. Therefore, the transmittance is in accordance with that suggested by the standard, which would be below 2.30.FT W/m².K, with FT = 1 for roofs with non-ventilated attics, therefore U = 1.99.1. W/m².K The thermal delay is higher than that suggested by the standard, which should be less than or equal to 3.3 hours. However, a plaster ceiling is used throughout the building, which acts as a good thermal and acoustic insulator, reducing the transmission of heat from the roof to the interior of the building.

The height of the ceiling is also a great ally in this construction, since the double ceiling height directly influences the thermal performance of the building: the lower the ceiling, the closer the hot air accumulated in the environment will be to the user.

Figure 6 – Ground plan of the Centro Mariápolis Santa Maria Church



Source: Authors.

3.3 Measurement with a thermographic camera

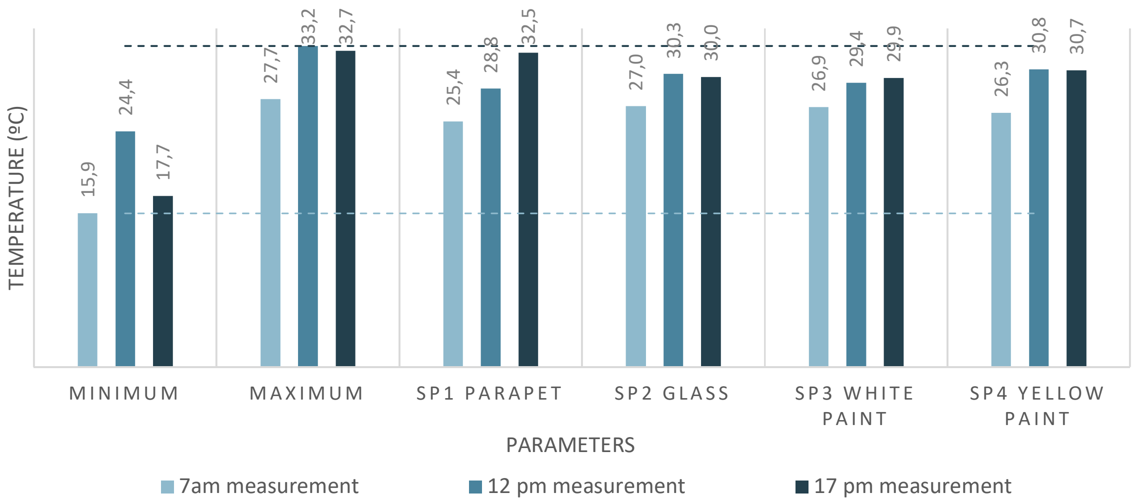
Infrared thermography is a technique used not only for diagnosing pathological manifestations, but also for analyzing the thermal performance of facades.

The results of the analysis of the thermograms, the temperature variations according to the time of day and the materials used, and all the steps already verified in the method, such as analysis of the solar chart and wind rose, construction strategies and materials, will be presented below for each orientation of the facades studied.

3.3.1. South Facade

By checking the variation in surface temperature of the south facade (Figure 7), it can be seen that at each measurement time there are some temperature variations due to the surface of the different materials and the height of the sun, which generates some shading points through trees and eaves.

Figure 7 – Temperature variations on the south façade



Source: Authors.

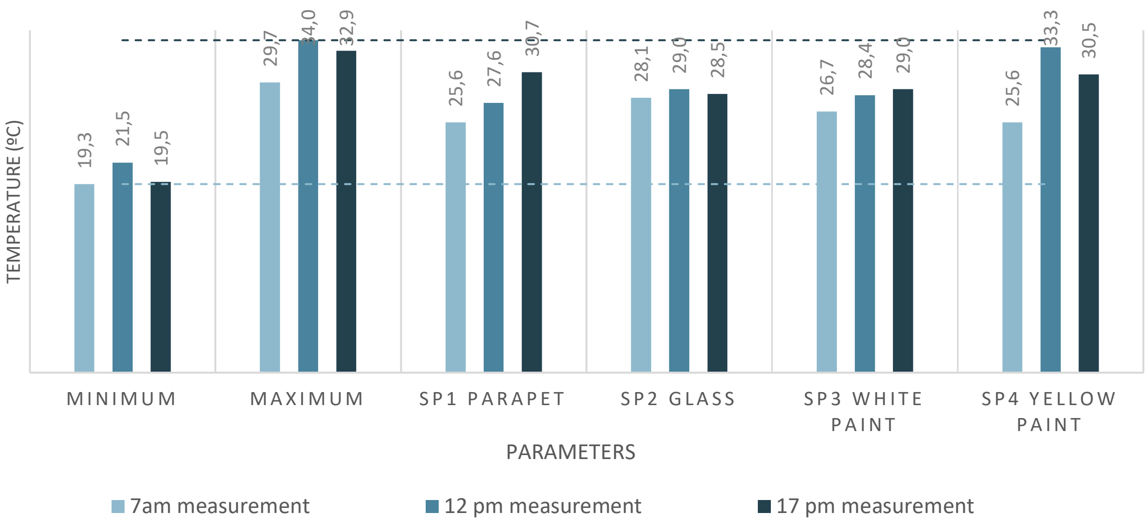
In buildings located in hot climates, the use of materials with lower heating, due to the lower absorption of solar radiation, provides lower heat gains, improving user comfort and minimizing energy consumption with air conditioning (Lamberts *et al.*, 2016).

Through the measurements, it was found that there is not much variation in the temperature of these materials during the day, with only the increase in temperature of the parapet and yellow areas after the 7:00 am measurement, due to the incidence of sunlight during this period. The white surfaces and glass did not show large temperature variations. Thus, it was found that the south facade, during the period of analysis, does not receive much sunlight during the day; it is the facade with the highest frequency of ventilation, together with the southeast; it benefits from the shape and layout of the building; It has the largest number of openings, aiding ventilation and promoting passive cooling, and has a generous eaves, which serves as a horizontal brise-soleil and provides good shading on the glass frames during the day.

3.3.2. East Facade

Analyzing the temperature variation of the East Facade (Figure 8), it was found that it has higher minimum temperatures than the South Facade in the morning, due to the greater incidence of sunlight. It was also identified that the tower, a yellow surface, has a higher temperature in the measurement taken at noon, due to its greater absorbency, being preferable, for this climate zone, the use of lighter colors (Viana; Souza; Gomes, 2019).

Figure 8 – Temperature variations on the east facade



Source: Authors.

The temperatures of the glass, however, do not show a large variation, as well as the white surface, due to low absorption, but its capacity to transmit heat is high, leaving the internal environment more susceptible.

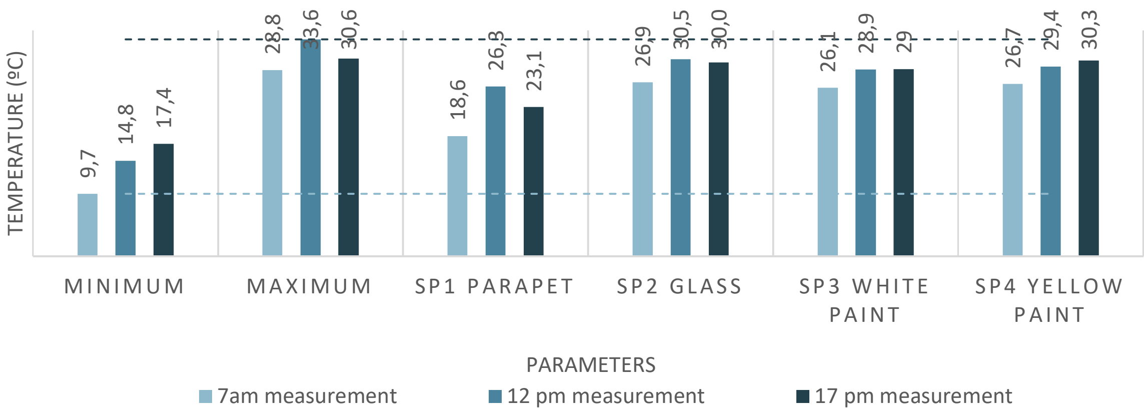
The use of the eaves, with the function of a horizontal brise-soleil, protects both the glass and the white surface walls of this facade, favoring thermal comfort inside the church, which is in agreement with the statement by Frota and Schiffer (2001).

Since the materials absorb heat slowly and retain the absorbed heat for a while, in the last measurement of the day, the measurements are similar, indicating, therefore, the need for further measurements.

3.3.3. North Facade

In Figure 9, it is possible to verify that the minimum temperature is the lowest in the general analyses in the early morning and the parapet presents a greater variation in temperature in relation to the other surfaces, although with lower temperatures in the first and last measurements.

Figure 9 – Temperature variations on the North facade



Source: Authors.

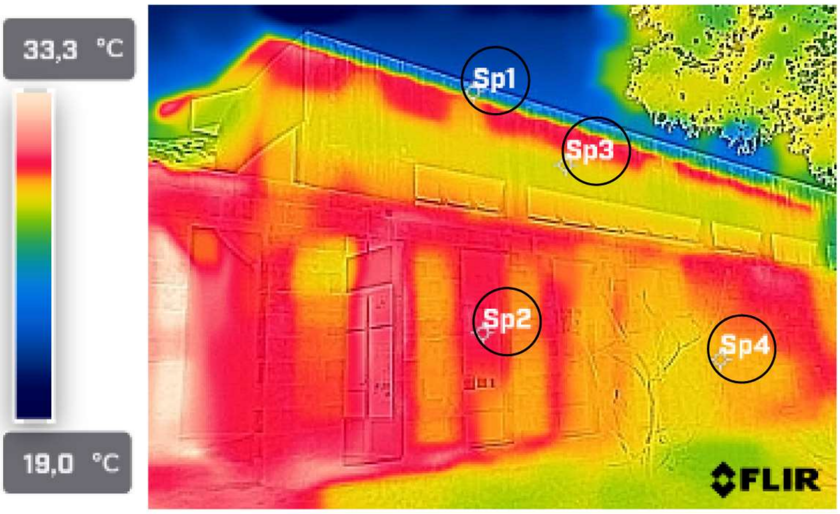
Through the analysis of the thermograms (Figure 10), it is possible to identify that, although the North facade receives sunlight throughout the day, its minimum temperature is the lowest among the measurements of the 3 facades. This is due to the fact that this face is the most shaded by the vegetation in the area.

Point Sp 1 (top of the parapet), which in the measurements of the other two facades presented higher temperatures, on the North facade presents milder temperatures in relation to the others.

The glass gaps (point Sp2) present higher temperatures, especially at noon measurement, indicating that the combination of the use of some shading technique, such as eaves, with the horizontal brise-soleil function, could be more effective.

In view of this, it is clear that the North facade does not present significant frequencies in the occurrence of ventilation either in winter or in summer. Its sunlight is present throughout the day in winter, but the use of shading provided by trees ensures solar protection for a large part of the facade. The way the building is located on the site, in addition to ensuring this shade from vegetation, also benefits cross ventilation, as it has tall windows all around the perimeter, favoring cross ventilation with the openings on the East and South facades.

Figure 10 – Thermogram of the measurement taken at 12:00p.m. on the North facade



Legend:
Point Sp1: top of the parapet
Point Sp2: glass loopholes
Point Sp3: white paint
Point Sp4: natural stone

Source: Authors.

A “chimney effect” can also be created, where openings at different levels can generate an upward air flow. As the building has a double ceiling height and the windows are located close to the ceiling, the cold air exerts pressure on the hot air, forcing it to rise and be expelled. Regarding the materials, this facade has one that differs from the others (East and South), which is the natural stone cladding.

Natural stone cladding (quartzite) is used in most of this facade, and is used both internally and externally. It is known as “cold stone” because it is a porous rock, has low water absorption and thermal properties. According to Queiroz and Melo (2018), quartzite, when used as facade cladding, can help reduce heat flows to internal environments, since when it receives solar radiation, it has low propagation of heat waves.

The three analyzed facades were positively influenced by the building’s form and layout, as well as by the number of openings, which enhanced ventilation and facilitated internal cooling. Only minor considerations remain regarding the use of yellow paint and the potential need for additional maintenance on the North facade due to the presence of glass window frames.

Ferreiro and Carlo (2023) state that, in general, the main variables that influence the thermal comfort of buildings are the solar absorptance of the envelope, the thermal transmittance of the roofs and ventilation. Cândido, Dornelles and Lukiantchuki (2023) recommend that materials with lower absorptance values be used in warmer bioclimatic zones. Therefore, the building in question meets several criteria established to promote thermal comfort.

Although infrared thermography is a versatile tool for analyzing the thermal performance of buildings, its accuracy and reliability directly depend on the control of instrumental parameters, such as emissivity, distance, capture angle, and camera resolution, as well as the environmental conditions during measurements, such as air temperature and relative humidity (Kim *et al*., 2023). However, for the qualitative and comparative analysis proposed in this research, the tool proved to be adequate.

As pointed out by Soares and Martinez (2023), the use of solutions that favor the thermal performance of the building even during the design phase contributes to the building's energy efficiency and, therefore, to environmental sustainability. Machado *et al*. (2022) demonstrated that passive thermal conditioning strategies are effective in significantly reducing the period of thermal discomfort and, consequently, reducing the energy consumption associated with the use of fans and air conditioning.

4 CONCLUSIONS

It was found that several variables interfere with the outcome of the energy efficiency analysis of a building, and that this characteristic is strongly linked to its thermal performance.

Regarding the strategies adopted in the study, it was observed that both the implementation and the internal layout were well designed, favoring natural ventilation during the period investigated, facilitating passive cooling and cross-ventilation. Cross-ventilation, one of the most widely used passive cooling strategies, is used quite effectively in this building. The windows are appropriately positioned, with the largest openings located on the sides with the highest ventilation throughout the year, and tall windows were installed on opposite sides, favoring the elimination of hot air that rises during cooling, also characterizing the "chimney effect" strategy. Protection against sunlight was well designed, with a large overhang running along the entire East and South facades and shading with medium- and large-sized vegetation on all facades. This is further enhanced by the smaller spacing on the North and West facades, as these receive the most sunlight, which is mitigated by the shading.

The facade finishes were designed to have a low absorption rate, reducing the surface temperature of the materials. The stones used on the North and West facades have thermal properties that help reduce heat flow to the interior spaces, acting as insulation. They are also used on the interior surfaces, increasing the benefit. The glass used on much of the facade has low absorption and emissivity rates, but has a high transmissivity rate, increasing the heat flow between the exterior and interior of the building. However, when combined with all the aforementioned strategies, it does not interfere with the building's overall thermal performance, as it features ample ventilation areas in prime locations, efficient cross-ventilation, and active shading that eliminates heat transmitted through the glazed areas.

The measurements obtained using the thermal imaging camera contributed to validating the information gathered from the analysis of the design strategies—such as reducing the heating of lighter surfaces and shaded facades—and to identifying areas for improvement, as mentioned previously.

For the development of the research and verification of the thermal performance of the building under study, an effort was made to integrate analyses of construction strategies, climatic conditions, and thermograms. Analyzing the results, it can be stated that the methodology was effective for this purpose, highlighting the relationship between design techniques and actual building performance.

Thus, it can be concluded that the set of strategies employed in the building was effective in ensuring thermal comfort for users without the need for artificial air conditioning during the study period, contributing to the building's energy efficiency and sustainability. It is noteworthy that the use of yellow paint presented higher temperatures than other surfaces, as did the glass frames when exposed to direct sunlight, as on the North facade. Future studies would consider analyzing the building's thermal performance during periods of higher temperatures and conducting more frequent daily measurements.

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