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ENGINEERING SKILLS AID BY THERMOGRAPHY AND BIM

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Abstract: The quality of building operation management is related to the accuracy of the information collected in technical inspections. Monitoring existing conditions, required in the operational phase of the life cycle, challenges asset managers in identifying anomalies and retrieving information that helps plan priority intervention actions. In line with global governance actions, which have demonstrated adherence to the Building Information Modeling (BIM) system, this article uses as its object of study an engineering expertise applied to a public hospital building that requires renovation work. Applying the constructive research method, the objective of the work is to present a new expert work process that guides interventions of this nature. In this direction, Thermography was selected to capture the built reality and the parameterization of the solar chart, with the specific objective of supporting the analyzes of the thermographic and photographic records collected. It was concluded that BIM adds significant value to the expert work process as it was able to reflect the State of the Art in the final model. In this context, the construct represented by the As-is model represents an asset database, as well as a valuable tool for other project teams.
Keywords: Operation Management; BIM; Engineering Expertise; Thermography; Solar Chart.

INTRODUCTION

The operation management of the built environment has represented a major challenge for local authorities around the world. Characterized by the operational phase of the life cycle, existing buildings require subjective criteria for the diversity of structural typologies and, consequently, in the planning of maintenance inspections. Associated with this scenario, access to original copyright projects and As-built projects is not always available, which makes the work of asset managers difficult.

In line with global governance actions, Decree 10,306 (2020) instituted the adoption of the BIM system by the Brazilian public platform, for new developments, renovations and rehabilitations [1]. In this context, traditional engineering expertise can benefit from the application of new technologies such as 3D Laser Scanning and Infrared Thermography, adding significant value to the process, as they enable the registration of the State of the Art aiming at the development of renovation projects and rehabilitation in BIM. The As-is model [2] represents the real conditions of the building (as is) and formats a database capable of assisting the operation and maintenance management process.

In the preliminary design study stage, the mass model is developed with the aim of inspiring the technical inspection action plan, inserting the geographic location and parameterizing the true north at the inspected latitude. Sequentially, reference and substantiate the analysis of the records collected in the preparation of the technical report. The simulation of the sun's path allows the visualization of the interference of solar radiation on structures and the shading effects caused by neighboring buildings, enabling critical analyzes of the records collected (day and time) during technical inspections.

Figure 1 illustrates the virtual simulation of the solar chart of a building (mass of smaller volume) and its surroundings (mass of larger volume) on July 1st, at 5:22 pm. Once the time is fixed on the celestial dome, the parametric software allows the sun to move to different positions, along the infinity-shaped trajectory (yellow color), simulating the Earth's translational movement. As the sun moves throughout the twelve months of the year, the software interface becomes dynamic and for this reason, on one side of the circumference the months are actively indicated (black color) and, on the other, passively (gray color).

THEORETICAL FOUNDATION

Thermography is a method applied to identify the temperature of objects [3] characterized by quantitative and qualitative typologies (passive and active) [4]. Applied to the construction industry, it represents a potential tool for engineering expertise, since infrared is capable of identifying hidden elements, present in construction systems, through thermograms, in addition to anomalies caused by the presence of water (seepage). Because it captures invisible images in the spectrum of human vision, thermography supports scientific studies on the reverse process.

In Brazil, most old buildings do not have project management, requiring reverse engineering efforts to retrieve information. In this scenario, the application of new technologies such as 3D Laser Scanning, Infrared Themography and BIM become relevant to the forensic process.

The BIM model of a project enables the design, construction and virtual operation by formatting an information base (graphic and non-graphic) [5]. Through interoperability, the exchange of information occurs at a high semantic level between parametric software, allowing the easy retrieval of State of the Art information throughout the entire life cycle of the building [6].

Modeling of Existing Conditions (planning phase) [7] is one of the most developed BIM uses worldwide, as it contemplates the universe of already existing buildings, and in this context, the model portrays the State of the Art as it really is (As-is) or as found (As-found). To enable this specific use, expert engineering reports are essential and their results represent inputs for parametric software, enabling access to information by the teams involved in the project.

APPLIED METHOD

The constructive research method, according to Lukka (2003), aims to present a construct [8] which, in this study, is represented by an expert work process applied to the built environment, using BIM. To achieve this objective, the object of study was selected, represented by a building for public hospital use, located in the city of Florianópolis (Brazil), built in the 1960s. The asset management entity developed a needs plan for the project of renovation, but it did not have a collection of its original projects. In this context, the expert process aimed to identify and characterize the construction systems to document the State of the Art and support the conception of the new project.

Due to the hospital use of the building, it was decided to apply the passive qualitative thermographic technique. The inspection took place during the winter solstice of the southern hemisphere, between July 4th and 6th. Figure 2 illustrates the Revit software interface and the simulation of the solar chart at the latitude of the study object, on July 5th at 12:00 pm (expertise start time) and the sunrise and sunset times at 07:09h and 17:28h, respectively.

The mass models of the inspected building and its surroundings allowed the simulation of the effects caused by solar radiation and, consequently, the shading of the facades of the inspected building. In this sense, it assisted in the analysis of the records collected linked to the goreferencing of the object of study (north, south, east and west facades).

Figure 3 illustrates the developed workflow.

DEVELOPMENT

Initially, the satellite image (Google Earth Pro) was captured to reference the true north of the investigated object. Sequentially,

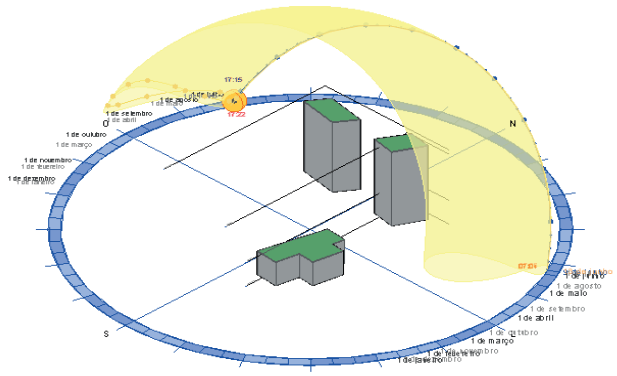

Figure 1: Solar chart in the software interface

Source: Revit (2021)

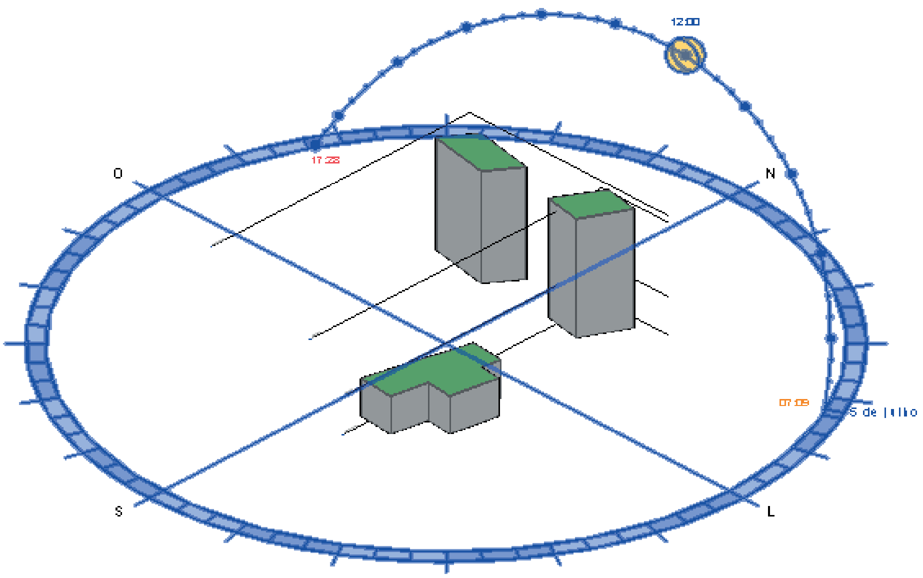

Figure 2: Solar chart

Source: Revit (2021)

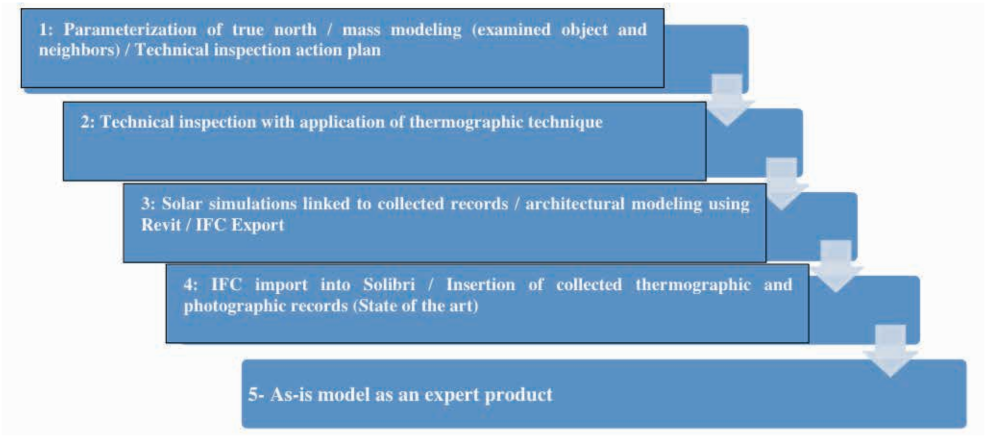

Figure 3: Work flow

Source: Authors (2021)

mass modeling of the examined object and neighboring buildings that could cause shading effects on the facades was developed.

Once the capture technique adhered to the use of the building was selected, a technical inspection of the installations was carried out within twenty-four hours, during the 4th to 6th of July 2019. Due to the controlled air conditioning of the internal environment (in compliance with health legislation), we opted for the passive qualitative thermographic technique. The technique requires continuous thermal monitoring until the contrast between the internal and external media is adequate to visualize the hidden elements present in the sealing systems.

In the post-inspection phase, the architectural BIM model was developed with the aim of hosting the State of the Art of the asset. Aiming for interoperability and integration with other multidisciplinary project teams, the Industry Foundation Classes (IFC) file was exported to the BIM management software Solibri Model Checker [5]. At this stage, the collected records are inserted through hyperlinks (Figure 4), reflecting the real conditions of the structure and acting as a tool that, technically, will support the development of new project solutions. (Model: *As-is*).

RESULTS

Table 1 presents the thermographic and respective photographic records of the south, west and east facades of the building, in addition to the internal and external slabs. The thermal recording times were parameterized in the architectural modeling software, enabling the simulation of the sun's path at the exact moment of capture, revealing the shading effects of the immediate surroundings.

In the thermal record of the south facade (17:36h) the structural typology of the reinforced concrete building (pillars and beams) can be seen. It can be seen that the roof of the building had a lower temperature record than other points, however this is a reflective response due to the high reflection rate of the tile material.

On the west facade (5:15 pm) it is possible to identify the existence of structural parts (pillars) in the vertical fence system and, on the east facade (8:00 pm) it was possible to characterize the typology of the traditional vertical fence (ceramic bricks).

The recording of the external slab (18:53h) revealed greater clarity of the hidden elements present in the structure, which is justified by the incidence of solar radiation during the day and the drop in temperature in the external environment at night, thus creating thermal contrast ideal for thermographic recording. The recording of the internal slab (7:19 pm) was made possible by completely eliminating the artificial light in the environment, which, due to the controlled air conditioning required in the hospital environment (21 degrees Celsius), made any contrast impossible.

In this study, the recordings occurred at dusk and during the night, due to the winter solstice, which requires more time of exposure to solar radiation and, consequently, the heating of external sealing systems. In order for there to be ideal thermal contrast, the temperature of the external environment must reduce, making it possible to perceive the temperature of hidden elements (invisible to the naked eye) present in the external and internal vertical (walls) and horizontal (slabs) sealing systems.

Figure 4 illustrates the insertion of records collected in the architectural model, to the objects modeled through hyperlinks. In Figure 4(a), the WALL element (located on the west facade) and the respective thermographic record stand out in blue, revealing the existing structural elements (pillars). In Figure 4(b), the SLAB element (located in

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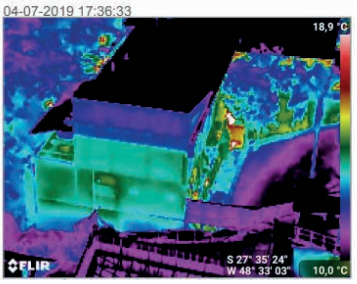
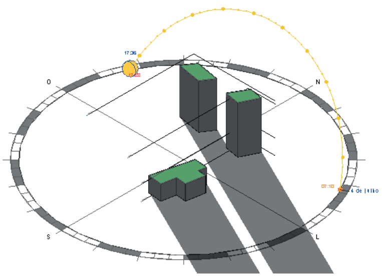
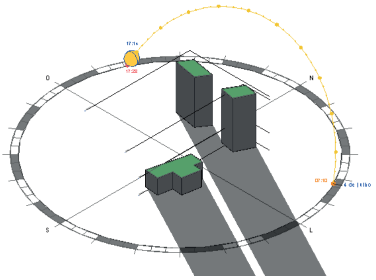
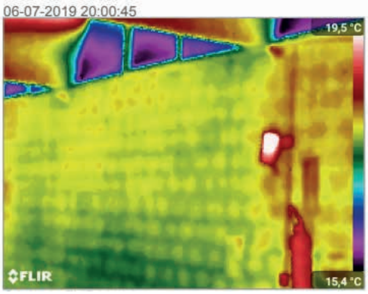
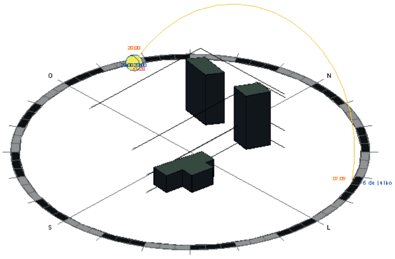
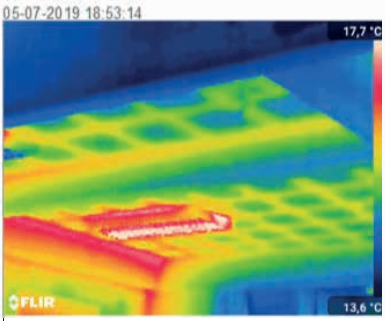
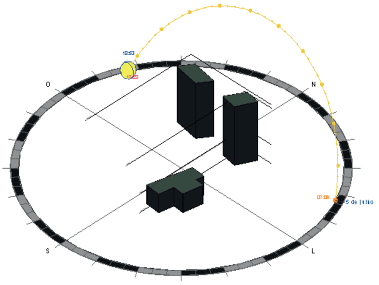
Thermographic Record	**Photographic register**	**Solar simulation**
 **South facade**		 **07/04 at 5:36 p.m.**
 **West facade**		 **04/07 at 17:14h**
 **East facade**		 **06/07 at 8:00 p.m.**
 **External slab**		 **07/05 at 6:53 p.m.**

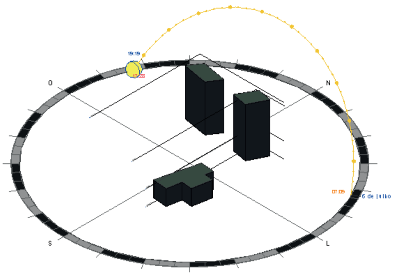
 **Internal slab**		 **07/06 at 7:19 p.m.**

Table 1: Records and Solar Simulation

Source: Authors (2021)

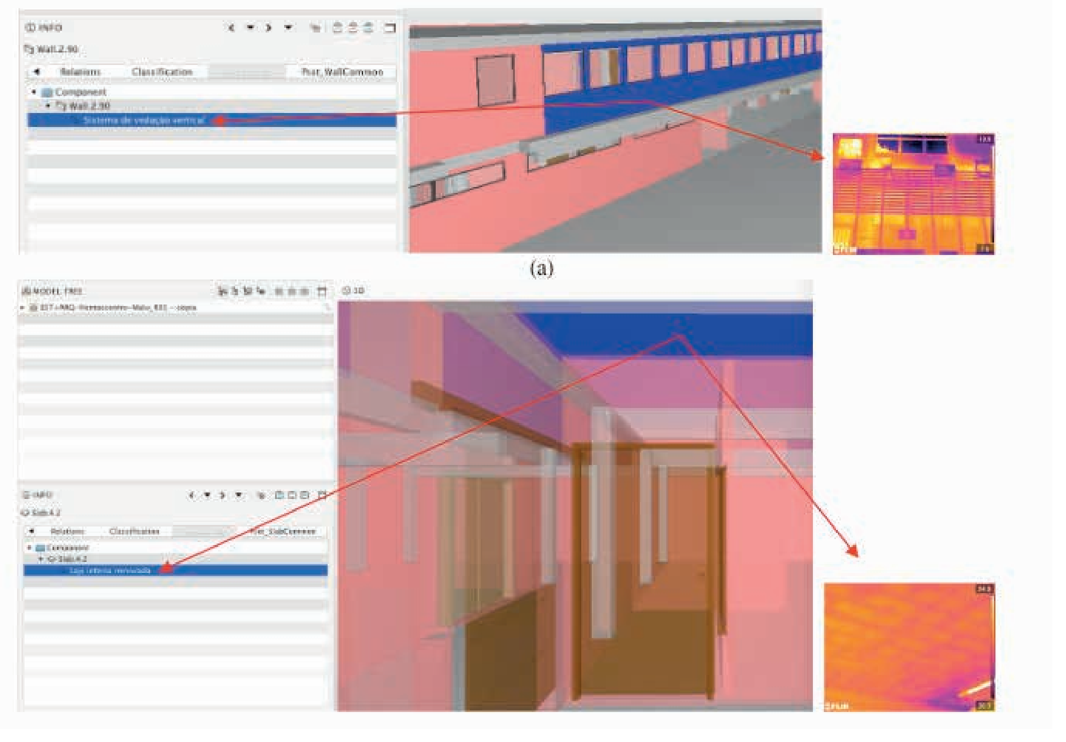


Figure 4: As-is model: 4(a) Vertical sealing system; 4(b) Horizontal sealing system

Source: *Solibri Model Checker* (2021)

the internal environment of the building) and the respective thermal register stand out in blue, revealing the type of ribbed slab, characterizing the horizontal sealing system.

CONCLUSIONS

The solar geometry applied to the examined object and its urban surroundings represents a relevant perspective for carrying out engineering expertise. Solar parameterization, made possible by the project's true north input, allows the simulation of the sun's position aligned with the capture of reality and, in this context, the records collected during the technical inspection support diagnoses with a higher level of precision. The simulation of the solar chart and the respective shading, caused by obstacles (modeling of masses in the surrounding area) reproduces the effects caused by the rotation and translation movements of the Earth, at the proposed latitude. In this direction, it becomes possible to mitigate subjectivity in the interpretation of thermal images, especially those caused by light reflection.

The building examined during the winter solstice in the southern hemisphere presented ideal thermal contrast, significantly, after sunset (5:28 pm). For this reason, it was observed that the effects generated by shading did not contribute to the interpretation of the collected records. However, the integration of expert records into the BIM system promotes a State of the Art approach, whether thermographic or photographic, as well as any other type of information that is relevant to the multidisciplinary design process. Using the As-is model, a consistent database is formatted for the other project teams.

In the expert study object, thermography effectively assisted in the reverse process of the structural typology, it was characterized in reinforced concrete (beams and pillars) and the ribbed type slabs (Figure 4(a))

The vertical sealing system was documented using the thermographic technique, consisting of a ceramic brick core, covered by layers of mortar. The detection of a large concentration of pillars on the west facade, acting as concentrated forces at the end of the structure, also recorded by infrared, was extremely important to highlight the need for preliminary studies specific to the discipline of structures and foundations. This diagnosis was inspired by the thermographic record presented in Figure 4(b).

It is worth noting that, traditionally, engineering reports only use 2D geometry to represent the examined objects. In this study, the As-is model of the inspected building adds a different value to the conventional work process. In addition to enabling 3D visualization of the asset's State of the Art, it represents a valuable tool for the management team, allowing access to updated information, with agility and precision.

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