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Infrared thermal imaging to inspect pathologies on façades of historical buildings: A case study on the Municipal Market of São Paulo, Brazil

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ABSTRACT

Cultural assets are historical buildings that combine formal and technical elements with an immaterial dimension with great significance and value for the population. These buildings may present several pathologies, since they were constructed with outdated systems and techniques and are subject to weathering. 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. The objective of this paper is to evaluate the presence of pathologies on the façades of the Municipal Market of São Paulo using infrared thermal imaging. Results indicated several damages that present risks to the integrity of the building, such as the presence of moisture, cracks, and regions with a detachment of the rendering mortar. Based on the results obtained, a proposal for intervention in the building was elaborated to reduce the damages that compromise its service life and maintain its original characteristics.

1. Introduction

Until the mid-eighteenth century, it was common to adapt cultural assets to desired needs or even demolish them, with no restrictions. This conduct was taken because constructions were considered perennially updatable, disregarding differences between past and present [1]. The recognition of the value attributed to 'knowledge-rich constructions' was the primary motivation to create a disciplinary field to promote debates and proposals in favor of their preservation, focusing on their importance to future generations. This theoretical consideration, accompanied by the restoration practice, has developed since the 19th century due to the arbitrary destruction of heritage monuments [2].

The values attributed to cultural assets comprise their condition of 'social fact', associated with the rights to use and enjoy them. All cultural assets are supported by material vectors and an immaterial dimension of meaning and value [3]. Cultural assets are meant to be recognized to express their value and assess social practices.

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Currently discussed interventions, such as renovation, rehabilitation, requalification, and revitalization, involve substantial changes to a specific construction. Restoration consists of a strict procedure that establishes precise limits and general principles for the transformation and conservation practices of cultural assets, respecting their authenticity and integrity [4]. In addition, it corresponds to a particular process within a wide range of legal and physical protection actions, expressed by several intervention modalities that vary from identification, research, documentation, and inspection to maintenance, damage recovery, and adaptation to new uses. Finally, the restoration concept is consolidated by recognizing and respecting the value of historical and aesthetic components that cultural assets carry [2].

In scientific investigations conducted on the preservation of cultural assets and their architectural restoration, an intimate relationship between a theoretical preparation based on a historical-critical approach and a consistent knowledge of construction processes and techniques is crucial [4–7]. Historical investigations linked to architectural examination, detailed photographic records, and careful observation of the conservation state of the building not only offer elements to recognize cultural values but also provide evidence of its structural condition and detailed information on the construction design. Thus, it is possible to comprehend the main technical characteristics of a cultural asset, its construction process, and pathologies, which allow the proposal of intervention measures and restoration stages.

This operation sequence should be guided by the coherence between the theoretical and the technical-methodological procedures, consistent with a rigorous scientific preparation [7]. The evaluation of pathologies and structural damages and the restoration project should be in line with the theoretical basis guided by the critical understanding of the building subject to intervention, considering its cultural value. To accurately assess these practices, the intellectual and operational tasks present in the various stages of the work must be concatenated.

To evaluate damages in cultural assets, it is essential to employ non-destructive tests, which consist of inspection techniques that do not cause damage or interference on the physical-mechanical characteristics of the building [8]. The most common non-destructive tests applied to inspect cultural assets are visual inspection, infrared thermal imaging [9], ultrasound wave propagation velocity [10], acoustic emission [11], and electrical resistivity [12]. The definition of which test to use depends on the pathology type and the material to be inspected.

Fig. 1. Cultural assets that underwent restoration from 1983 to 1998: the Olinda Cathedral, Olinda - Pernambuco (a) [16]; the Model Market, Salvador - Bahia (b) [17]; the Imperial Palace, Rio de Janeiro, Rio de Janeiro (c) [18]; the Pinacotheca, São Paulo, São Paulo (d) [19].

In this context, this study aims to evaluate the presence of pathologies on the façades of the Municipal Market of São Paulo, which is officially recognized as a cultural asset of the city and state jurisdictions [13,14], using infrared thermal imaging. By doing so, pathologies may be identified and monitored to maximize the service life of the building and keep its original historical characteristics.

2. Background and context: an overview on the preservation of cultural assets in Brazil

At the end of the 1930 s, several laws were established to protect the national historical and artistic heritage due to the creation of the IPHAN (National Historical and Artistic Heritage Service of Brazil) and the decree nº 25/1937. Such laws were based on several criteria to identify assets worthy of preservation, supported by the idea of national identity recognized in material production. Scholars refer to the valorization of "stone and lime" to refer to listed goods representative of colonial architecture, especially the Baroque style, as a translation of the genuine spirit of national creativity [15].

Although the notion of contemporary cultural heritage has expanded since the 1960 s, in concomitance with the debates held in Europe, its principles are present in Brazil due to the protection laws and the treatment given to the objects of intervention. It is also important to emphasize that no united thinking exists, as the Heritage Charters may suggest, even considering that the country was among the signatories of the Venice Charter (1964). Moreover, certain difficulties persist in establishing consensual institutional practices, especially regarding the urban dimension of heritage. Urban spaces involve a complex system of relationships between people and situations in continuous transformation.

From the 1970 s on, with the challenge of accelerated urbanization, "heritage protection services focus primarily on the preservation of large deteriorated urban sectors and threatened natural sites" [16]. Such perspective prevailed in the main meetings and documents produced at that time, such as the Brasília Commitment (1970), the Salvador Commitment (1972), and the Pelotas Charter from the International Council of Monuments and Sites in Brazil (1987). Restoration actions were developed several historical buildings in the following decades, such as the Olinda Cathedral (1983 - Fig. 1.a), the Model Market in Salvador (1984 - Fig. 1.b), the Imperial Palace in Rio de Janeiro (1985 - Fig. 1.c) and the Pinacotheca of the State of São Paulo (1998 - Fig. 1.d). Nevertheless, it was difficult to obtain detailed information on the interventions performed because only a few actions encourage the creation of a critical framework for the practice of conservation in Brazil.

In the 1980 s, only a few specialists worked in the field of Conservation-Restoration of architectural assets, and the number of specialized professionals dedicated to the conservation of cultural assets was even smaller. When not held abroad, their technical training was obtained by short courses promoted by heritage protection agencies, by collegiate institutions such as the Architects Institute of Brazil (IAB), and some associations of restorers. Therefore, restoration projects conducted in the first half of the 20th century were not as detailed as nowadays [20].

Several factors contributed to changing this scenario, such as the recognition of Brazilian cultural assets as world heritage by UNESCO between the 1980 s and 1990 s, which favored the formulation of public policies for the conservation of architectural complexes and Historical Centers and the celebration of partnerships between public universities, UNESCO and IPHAN. In addition,

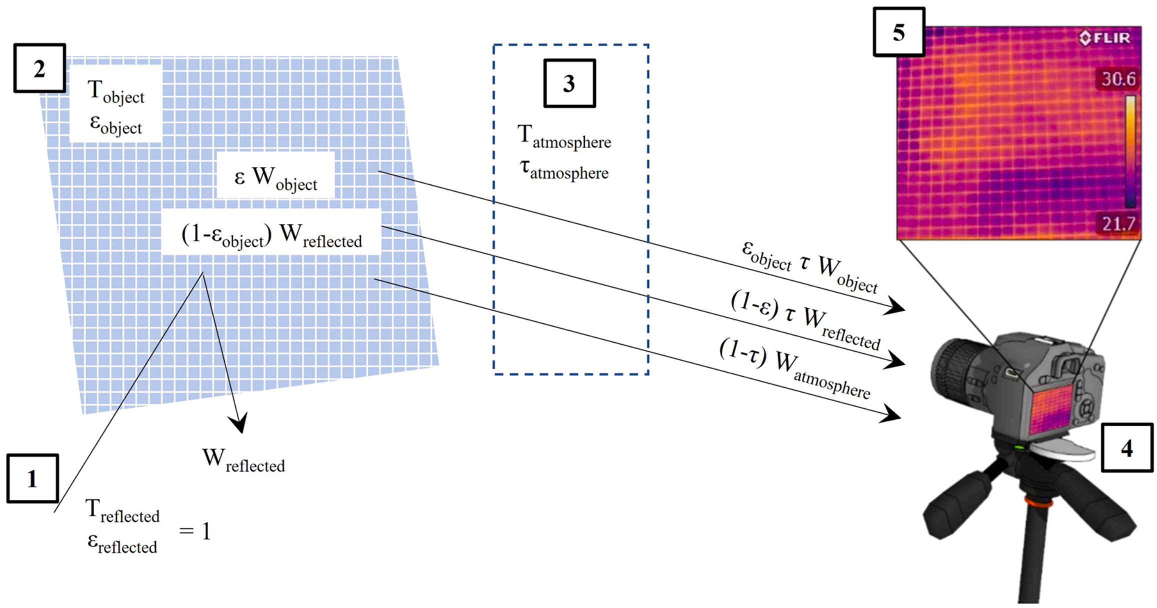

Fig. 2. Schematic representation of the infrared radiation measurement process by thermal imaging cameras. Infrared radiation is emitted by the adjacent medium (1), the object (2), and the atmosphere (3).
The thermal camera (4) captures the resultant radiation from the object and provides the thermogram of the object's surface (5) (adapted from Andrade [23]).

post-graduate courses in public and private institutions expanded from the 1990 s on, which contributed significantly to disseminating research in this area. As a result, critical thinking on procedures and intervention methods was developed, overcoming a dichotomous view between theory and practice [15,16,20].

In recent years, the choices that shaped the heritage corpus and their intervention process have been subjected to a more severe critical analysis, spreading the perspective of academic studies in the professional field. This way, the comprehension of intervention processes in cultural assets was consolidated as a social construction, especially due to the articulation conducted in government association. As a result, the articulation between public policies and intervention practices is favored [21].

3. Methodology

3.1. Principles of infrared thermal imaging

Infrared thermal imaging is a non-destructive technique employed to analyze pathologies in concrete structures. It is based on the principle that defects under the material surface affect its heat flow transfer and generate differences in surface temperature. These temperature differences help detect anomalies on the material surface, such as cracks, moisture, heterogeneities, and the detachment of the rendering mortar. Such irregularities are identified by generating thermal resistances, translated as either cooled or warm regions [22].

A camera coupled with thermal sensors (infrared camera) collects infrared radiation emitted by the surface. Then, the radiation is converted into electrical signals that enable the creation of a thermal image (Fig. 2). By doing so, the heat distribution on the material surface is obtained using a detailed visual image of temperature profiles (radiometric image) and its graphical representation (thermogram) [22].

Thermograms may be analyzed both qualitatively and quantitatively. In the first case, thermograms are interpreted visually depending on the technician's knowledge of the target object's properties. Then, thermograms are compared with thermal patterns of intact surfaces to search for abnormalities in the profiles analyzed and describe the detrimental processes occurring in that object.

In quantitative analyses, some parameters must be determined to ensure accuracy during the measurement. The main parameters required are the emissivity of the object under investigation (ε), the radiation transmittance of the object (τ), the radiation power (W), the reflected temperature (T_{refl}), the distance from the camera to the target object (d), the atmospheric temperature (T_{atm}) and the relative humidity (RH). Results obtained help determine the criteria to rate the damage extension and define the repair conduct.

Evaluating the variables that influence the thermograms for an accurate measurement process is necessary. The main parameters to be considered are the characteristics of the thermal camera (thermal resolution; the analysis angle related to the camera lens; the geometric resolution of the instantaneous field of view - IFOV), the characteristics of the object analyzed (emissivity; distance from the camera to the object; reflection) and variables related to the environment (temperature; relative humidity). All these variables affect the accuracy of the results and their interpretation, and it is fundamental to know or measure them before inspection [24].

Regarding the characteristics of the thermal camera, the thermal resolution and sharpness of the thermogram are directly proportional to the number of sensors of infrared radiation (microbolometers) the camera contains. Thermal resolutions for commercially available cameras range from 160 × 120–1024 × 768 pixels. In addition, the greater the analysis angle of the camera lens, which can vary from 7 to 80 degrees, the lower the thermogram resolution [23].

The IFOV defines the smallest object that may be analyzed according to the sensor-target distance. IFOV values vary between 0.6 and 3.7 mrad, and the higher the IFOV, the lower the thermogram resolution [23]. Therefore, the object under analysis must be smaller than 3xIFOV to ensure that it falls within the sensor limits and that at least one of the sensors is entirely covered by the receiving radiation.

Concerning the characteristics of the object analyzed, its emissivity is related to its ability to emit electromagnetic radiation, which can vary from 0 to 1. It is calculated by the ratio between the energy radiated by the object surface and the energy released by a theoretical blackbody at the same temperature, considering the same wavelength. Most civil construction materials present emissivity values above 0.8 [25].

It is essential to conduct measurements at maximum distances of 1 m from the object, mainly when low thermal resolution cameras are used (the larger the measurement distance, the lower the thermogram resolution). Since part of the radiation emitted by the object is attenuated by the atmosphere, by the presence of water vapor and temperature variation, variables related to the environment must be controlled. The higher the ambient temperature, the greater its radiation emission, influencing the actual measurement of the object temperature.

3.2. Application of infrared thermal imaging to inspect cultural assets

Infrared thermal imaging may be applied to inspect historical buildings with different ages, construction characteristics, and materials and presents several advantages over traditional techniques [26]. For example, infrared thermal imaging makes it possible to identify materials and components in the construction system, such as wood and steel reinforcements in masonry elements, the distance between beams on a roof, slab thickness, and column dimensions. In addition, previous restorations may be identified since layers composed of varied materials provide differences in thermograms. Infrared thermal imaging may also be employed to monitor crack propagation, detachments, and surface changes caused by moisture and mold in structural elements.

Fig. 3 illustrates possible applications of infrared thermal imaging to inspect historical buildings. By comparing conventional and infrared thermal images, it is possible to map the occurrence of building pathologies. Moreover, combining conventional and infrared data denotes a fruitful analysis based on multispectral imaging techniques in the infrared range [26].

Several works have already been published on the inspection and monitorization of the conservation of historical buildings by infrared thermal imaging, which reinforces the potential of this technique. For example, Paoletti et al. [27] employed this technique to assess the risks of ruining historical buildings in Italian cities after the earthquakes in 2009. Their analysis was based on comparing thermograms obtained before and after the earthquakes.

Kordatos et al. [9] used infrared thermal imaging to evaluate the damage to the murals and masonry of the Monastery of Molybdoskepastos in Greece. The analysis conducted characterized the degradation of the masonry murals caused by cracks and detachment of the rendering mortar. Cortizo [28] evaluated the structure of the Chapel São Sebastião de Águas Claras in Nova Lima, Minas Gerais, Brazil. Thermograms showed discontinuities on the walls, representing wooden beams used for wind protection. This analysis contributed to elucidating how the chapel structure was designed and identifying the critical points for its reparation.

3.3. Target object: the Municipal Market of São Paulo, Brazil

The target object of this study was the Municipal Market of São Paulo (known colloquially as 'Mercadão', Fig. 4). The project of this building was developed by the Brazilian engineer and architect Francisco Ramos de Azevedo to combine the most modern concepts of hygiene and functional organization in the center of São Paulo [29]. Located on Cantareira Street, it was strategically designed close to the railway network and the Tamanduateí river to facilitate the loading and unloading of goods.

Its construction began in 1928, and the market was inaugurated on January 25th, 1933, after the Constitutionalist Revolution. With

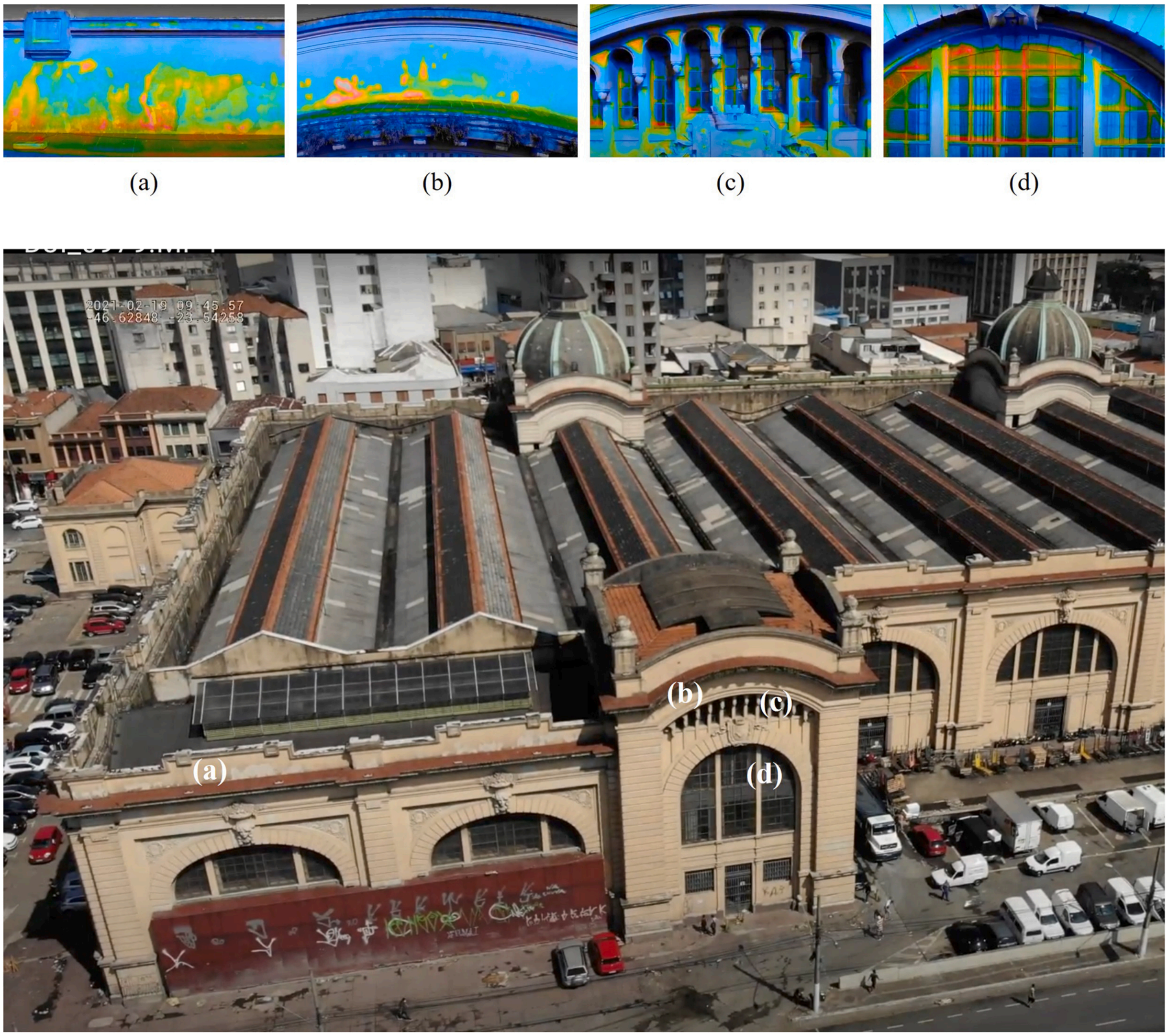

Fig. 3. Examples of building pathologies identified in cultural assets by infrared thermal imaging: detachment of the rendering mortar (a); the presence of mold (b); loss of adherence of the paint (c); corrosion in metallic elements (d).

Fig. 4. The Municipal Market of São Paulo ('Mercadão').

12,600 m^2 of built-up area and 16 m of height, it is considered one of the most important tourist attractions in the city [29]. In 1998, the Municipal Market of São Paulo was approved as a listed building by the Council for the Defense of the Historical, Archaeological, Artistic, and Touristic Heritage [13]. According to the resolutions of the city protection agencies, this building is officially recognized as a cultural asset of the city and state jurisdictions [13,14]. It is one of Brazil's most important touristic sites and contains innumerable formal, cognitive, and affective values.

In 2004, a partial restoration was performed in the building, respecting the premises of interventions in listed properties. During this restoration, infrastructure, drainage, electrical and hydraulic installations were revised. Besides, an area for restrooms, changing rooms, and a cafeteria for employees was constructed in the basement, and a mezzanine for restaurants was built. Currently, the Municipal Market of São Paulo suffers from a lack of maintenance operations. As a result, many building pathologies may be found, such as infiltration stains, mold, and detachment of the rendering mortar and painting of the façades.

3.4. Inspection of the building façades

The façades of the Municipal Market of São Paulo were inspected visually and by infrared thermal imaging. The study was conducted as a qualitative thermographic analysis, focusing on examining thermal patterns and damages. The qualitative analysis comprises the comparison of thermogram standards, that is, the absolute values of temperature measurements were not considered.

Passive infrared thermography was used and no artificial heating sources were used. The natural excitation of the surface by sunlight and the shading effects of the building's façade components were considered. To do so, the building was divided into four wings (east, north, west, and south - Fig. 5), considering the facility's location and the incidence of solar radiation. The inspection was conducted counterclockwise, starting with the east façade, between 8 and 11 AM, when the ambient temperature ranged from 18 to 26 °C.

A portable thermal camera (model: Flir One; thermal resolution: 160 ×120 pixels; HFOV: 57º; opening: f/1.1) was used to inspect the façade from the floor up to a height of 1.5 m. For the analysis of the remaining façade, a Mavic Enterprise Dual drone coupled with a camera containing a three-axis stabilizer was used. The camera had a 4 K RGB sensor (resolution: 4056 ×2280 pixels) to capture visible light and a micro thermal camera (model: FLIR Lepton; thermal resolution: 160 ×120 pixels; HFOV: 57º; opening: f/1.1). The cameras were positioned 1 m distant from the façade. The color/temperature configuration of both cameras is presented in Fig. 6.

The emissivity factor of the façade was corrected using a piece of black tape 10 cm long, whose emissivity was 0.90. Under

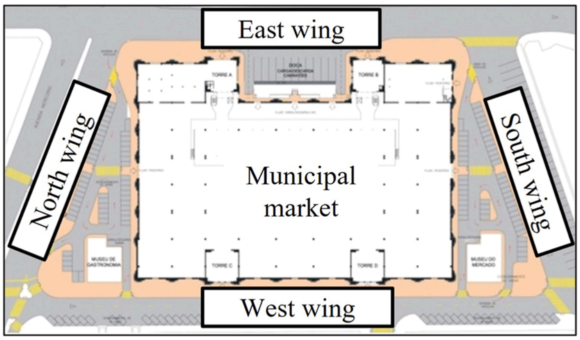

Fig. 5. Division of the façades into wings.

equilibrium conditions, the temperature of the tape glued to the façade is equal to that of the façade itself. Then, the temperature of both surfaces was adjusted to obtain the actual emissivity of the façade, which was equal to 0.86. Finally, this result was input to the thermal camera to correct the temperature as a function of the emissivity of the façade, ensuring a reliable measurement of the temperature values shown in the thermograms.

4. Results and discussion

4.1. Mapping and description of the pathologies observed

The mapping of the pathologies present on the façades of the Municipal Market of São Paulo is shown in Fig. 7. The identification of each damage is presented in Table 1. The central anomalies found were the detachment of the rendering mortar, cracks, blisters, mold, biological growth, paint disintegration, damage to door and window frames, and the presence of dirt. Remarkably, the damage degree is more easily observed in the thermograms than in conventional images, which show only minor differences between intact and damaged areas.

In general, few regions with cracks and blisters were found. The detachment of the rendering mortar occurs at the bottom part of the façades due to mechanical actions and impacts caused by the transportation of goods. Furthermore, such manifestation occurs in the corner regions and protruding elements of the façades.

Mold may be found on the upper part of the façades, near flashings, gutters, and piping for rainwater. This indicates the possibility of water infiltration in these regions, leaving them with greater humidity and favoring the formation of biofilms. Some parts containing biological growths were also found.

The disintegration of the paint is observed in the upper part of the door cornices. The south façade is the most affected by this damage due to the lower incidence of sunlight, which leads to greater humidity in the coating and favors dust formation. In addition, the door frames, originally made of cast iron, were oxidized at the bottom parts close to the ground due to the action of urine and washing water.

Fig. 8 shows in greater detail the damages observed on the building's façades. The damages identified occur due to moisture from the runoff of rainwater. Thus, thermal anomalies are observed in regions close to cornices, frames, and projections. For example, Fig. 8.a shows the disintegration of paint, identified in the thermogram by areas with higher surface temperature (yellow color) in relation to intact areas (blue color). In addition, an accumulation of dirt and detachment of the rendering mortar on the cornices, identified as thermal anomalies in the thermogram by higher surface temperatures (red color), may be found.

In Fig. 8.b, the thermogram indicates the total detachment of the rendering mortar in a humid region (purple color), represented by a surface with a lower temperature than the intact area (orange color). The detached region presents a higher surface temperature since the air pockets inhibit heat propagation to the substrate. Fig. 8.c shows areas with biological growth and loss of adherence of the paint, which causes air pockets and inhibits heat transfer to the substrate. Therefore, these regions present a higher surface temperature (red color) than the intact part (blue color). Similarly, Fig. 8.d also shows regions with loss of adherence of the paint, identified by the red areas in the thermogram.

4.2. Intervention proposals

The deterioration of the building's façades compromises the integrity of the decorative elements that give the building its historical character. In addition, the constant presence of moisture associated with the absence of a maintenance program (cleaning the façades, repairing cracks, and repainting) enhances the development of damages, such as mold growth, vesicle formation, paint disintegration, frame corrosion, and detachment of the rendering mortar. Therefore, it is essential to establish a strategy to repair the damage caused to the building and increase its service life.

Since the Municipal Market of São Paulo is a listed building, the reparation of damages identified on its façades must be conducted following the guidelines of the agencies in charge of preservation at the municipal and state levels [13,14]. Therefore, it is fundamental to maintain the originality and physical characteristics of the building, respecting the construction techniques and materials used at the time of its construction to avoid incompatibilities. Based on that, the intervention proposals to repair the damages found are presented in Sections 4.2.1 to 4.2.5.

4.2.1. Development of an inspection program

Since the absence of a maintenance program is one of the causes of the degradation of the Municipal Market of São Paulo, regular inspections must be conducted to keep the façades in good condition. Furthermore, after major repairs are performed, annual inspections and monitoring should be performed to identify defects and anomalies that may compromise the service life of the building. By doing so, data may be obtained to establish preventive measures to preserve such historical asset.

Inspections using a high-resolution infrared camera (resolution $> 640 \times 512$ pixels) are recommended. Such inspection needs to be performed in similar environmental (temperature and incidence of solar radiation) and experimental conditions (distance from target

Fig. 6. Color/temperature configuration of the infrared thermal cameras.

Fig. 7. Mapping of damages on the façades: east (a); west (b); north (c); south (d).

object and observation angle). The thermal inspection should be conducted at a maximum distance of 5 m from the façade. The façade should receive solar radiation for 1.5–3 h to provide adequate heat/temperature conditions to analyze thermal defects. The inspection should start at the east façade, followed by the north, west, and south façades.

4.2.2. Damages caused by humidity

It is necessary to take urgent actions related to waterproofing the roof and draining the rainwater. To install a new waterproofing system, the mechanical protection, the existing waterproofing system, and the rendering mortar must be removed from the façades. In addition, a new project for the roof must be elaborated, including flashings, gutters, and dimensioning of the rainwater drainage ducts, for subsequent execution. The primary sources of moisture that damage the façade components will be eliminated by performing these

Table 1
Identification of pathologies on the façades of the Municipal Market of São Paulo.

Pathology	Identification	Pathology	Identification
Detachment of the rendering mortar	(red)	Biological growth	(dark blue)
Cracks	(orange)	Loss of adherence of the paint	(blue)
Vesicles	(green)	Damages on the door and window frames	(yellow)
Mold	(brown)	Presence of dirt	(magenta)

actions.

In the case of moisture penetrating from capillary pores at the base of the facades, as a palliative measure that will delay this problem, the entire rendering mortar of the façade (approximately 1.0 m high) must be removed. Then, three layers of a polymeric mortar must be applied, followed by applying a new layer of a rendering mortar and a mineral paint system. By doing so, moisture will be blocked from penetrating the capillary pores.

4.2.3. Repair of the façades

The repair procedure should be determined in a small area of the façade for validation of the process. Next, it is recommended to wash the façades for a further evaluation of the adherence of the paint and rendering mortar, which may be performed by infrared thermal imaging using a high-resolution camera (1024 ×768 pixels) or percussion tests. The washing of the facade should be conducted using a water jet under pressure with a fan-type nozzle (opening at 45º), neutral detergent, and a soft brush. In regions where graffiti is present, an organic solvent should be used to remove stains before washing.

Areas with adherence problems must be removed by sawing, followed by cleaning and preparation to receive the new rendering mortar. After at least 72 h, a new layer of rendering mortar should be applied. Finally, the materials used to fabricate the original rendering mortar must be evaluated to produce a cementitious matrix with equivalent properties to repair the detached areas [30,31].

During the mortar application, it is essential to observe and adjust its workability, water retention, and the proper times to sand and finish the surface. Subsequently, the occurrence of cracks, the quality of the finishing surface, and the adhesion strength must be evaluated. If all these requirements are approved, the mortar and the repair procedure are accepted. However, if the quality standards are not fulfilled, a new mortar dosage and/or a new recovery procedure must be developed.

4.2.4. Treatment of cracks

The treatment of cracks may be performed concomitantly to the repair of detached areas. First, cracks must be widened by sawing, followed by vacuum cleaning. Then, cracks must be filled with epoxy mortar of low hardness (30–40 shore A) to absorb the deformation stresses occurring on the façade, with no generation of new cracks. A polyester mesh may also be installed in this step to avoid cracks.

4.2.5. Painting

After repairing the damaged areas, the façades must be rewashed and repainted. To do so, the properties of the original paint must be evaluated concerning the permeability to water vapor, which directly interferes in the moisture diffusion by the coating. A mineral paint must be applied 14 days after the surface is finished. Such paint has a greater permeability to water vapor and avoids the occurrence of pathologies related to the penetration of moisture from capillary pores.

5. Final considerations

From the results obtained by the inspection of the façades of the Municipal Market of São Paulo by infrared thermal imaging, the following considerations were drawn:

- Infrared thermal imaging is a non-destructive technique that may be potentially used to evaluate building pathologies in cultural assets.
- Infrared thermal imaging may be applied to monitor cultural asset conservation by comparing thermograms obtained at various times. Alterations in the thermogram pattern indicate changes in the behavior of the construction component, enabling the decision-making process on maintenance operations.
- Thermograms allowed the identification of damaged regions more efficiently than conventional images. Thus, structural damages could be evaluated by infrared thermal imaging since they are hardly detected by visual analysis.
- The qualitative evaluation of thermograms allowed the identification of damages in the façades, such as moisture, detachment of the rendering mortar, mold growth, and crack formation. Furthermore, building elements composed of different materials could be identified.
- The inspection of façades by infrared thermal imaging should be performed with high-resolution cameras. Then, high-definition thermograms may be obtained, which facilitates the detection of microcracks in less superficial regions.

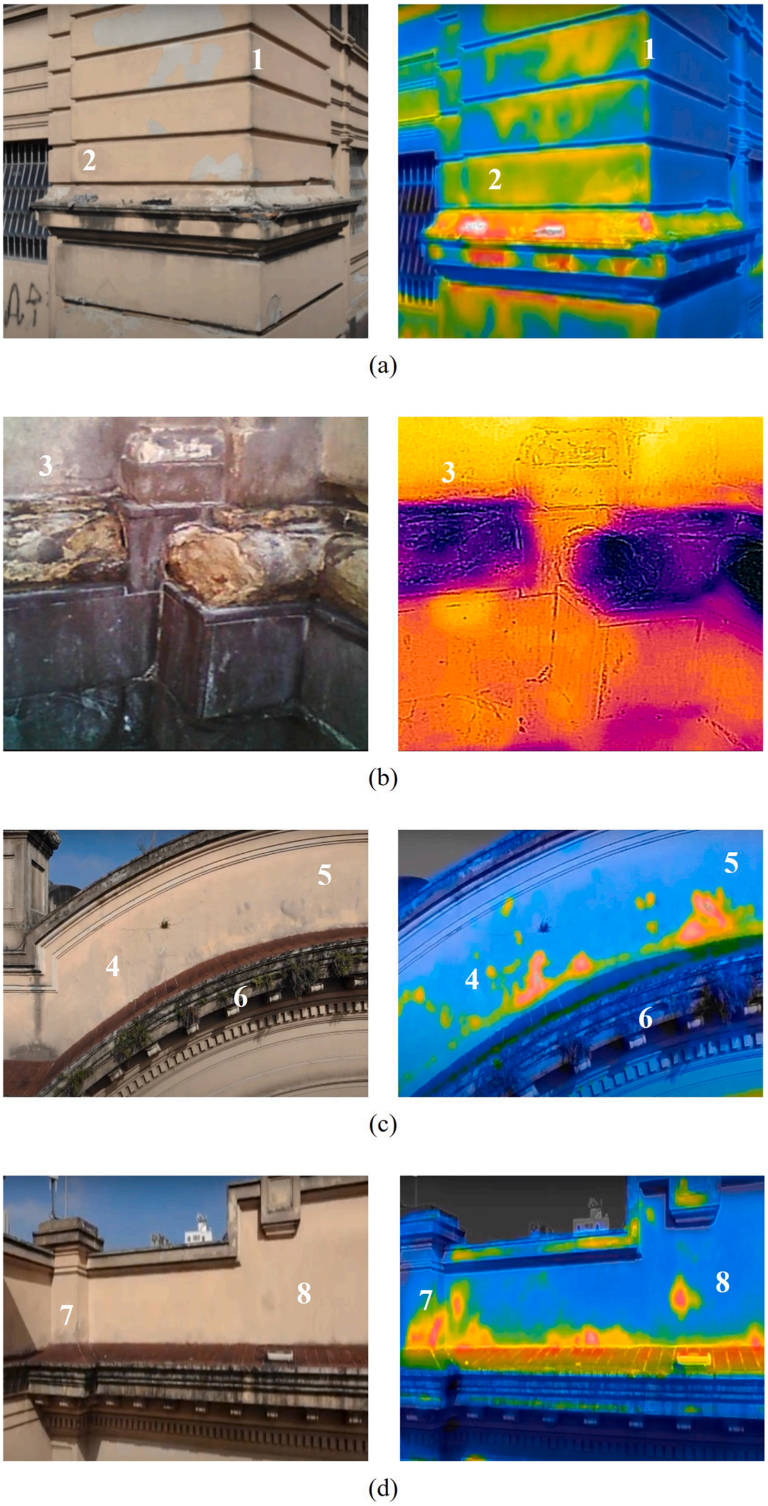

Fig. 8. Conventional images (left) and equivalent thermograms (right) of the main damages identified on the façades of the Municipal Market of São Paulo: (a) loss of adherence of the paint (1) and accumulation of dirt and detachment of the rendering mortar on the cornices (2); (b) detachment of the rendering mortar (3); (c) loss of adherence of the paint (4 and 5) and mold (6); (d) detachment of the rendering mortar (7 and 8).

- Restoration processes must consider the principles of minimal intervention in the reconstitution of missing elements that present aesthetic and documentary relevance.
- After major repairs are performed, annual inspections and monitoring should be performed to identify defects and anomalies that may compromise the service life of the building. By doing so, data may be obtained to establish preventive measures to preserve such historical asset.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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