APPLICATIONS OF THE INFRARED THERMOGRAPHY TO THE ASSESSMENT OF HISTORIC BUILDINGS: A CASE STUDY IN PISA

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Measuring the thermal response of materials in building assessment has a wide range of applications concerning not only the thermophysical aspects, but also the structural ones. The last topic is particularly interesting in the context of historic buildings, where the modern tools for surface temperature measurement are capable of providing many useful information: the masonry texture and the materials detection under the plaster are the fundamentals for the evaluation of the structural behavior and for the selection of the strengthening and restoration criteria. In this regard, the full-field, contactless and real time investigation makes the infrared thermography indispensable. The thermographic technique is taken here into consideration in an emblematic case study.

Introduction

In the context of historic buildings, information on distributive and structural schemes is essential for the safety evaluation and for the identification of conservation criteria. This is achieved by the joint use of data from historical analysis, detailed geometric survey and non-destructive or minor-destructive investigations. The infrared thermography has clear advantages for the amount of the information provided and for its non-invasive nature which makes the technique particularly suitable to the assessment of historic and artistic buildings.

As demonstrated in [1] and [2], the ability of the technique to read the different thermal images released on the surfaces by different materials under the plaster is related to the percentage difference of the thermal diffusivity of the blocks to that of the mortar joints. This is reflected in the survey campaign herein presented, which is an emblematic case in the restoration field.

Franchetti Palace in Pisa

Franchetti Palace is a “U”-shaped masonry building located in the historic center of Pisa and is currently the seat of the Reclamation Consortium. It is composed by a three story main body of 22 m x 38 m, which is part of the aggregate of via San Martino, with two lower wings fronting the Arno river (Fig.1).

Fig. 1. Franchetti palace.

As many buildings of the historic center, the palace has undergone an articulated evolution. The first phase takes place in the Middle Age

(XII-XIII century) with a group of tower-houses separated by alleyways. These common medieval buildings were erected by powerful families and are characterized by the main facade made up of Verrucano (sedimentary siliceous-clastic rock) blocks and monoliths [3], with wide openings and arches in the upper part.
In the late Renaissance phase, the ancient constructions are to form two adjacent buildings (Fig.2).

Fig. 2. The facade on via San Martino.

The third phase, which provides the current configuration, was fulfilled under the Jewish Franchetti family, which brought together the fractional ownership and operated the restructuring at the end of the XIX.
While the nineteenth century configuration is well known from historical documents, the evolution from the original situation is not so clear. In this context, thermographic survey has provided a significant contribution.

The thermographic survey

The survey has been performed between March and June 2012, by means of a fully radiometric IR camera AVIO TVS 500 EX, with long-wave microbolometer FPA sensor (320x240), having thermal sensitivity of 0.05 °C and geometric resolution of 1.3 mrad. The camera high performances allowed obtaining high definition images. Furthermore, in order to optimize thermal image, the measurement campaign of the weather conditions and environmental hygrothermometric quantities (ambient temperature and relative humidity) was carried out by using a psychrometric probe with forced ventilation. The value of the emissivity parameter ε of the target object has been evaluated through the "Contact Thermometer Method" procedure [4], by means of temperature probes. Furthermore, in order to obtain measurable temperature differences on the surface of the observed elements, a previous heating of the surface was often necessary.
The acquisition of the IR images of the external surfaces was performed in passive mode, under normal environmental conditions. Instead, the internal surfaces were heated by using a LPG powered convector with 37 kcal maximum power; the measurements presented here were performed during both the heat absorption and the cooling down process.
The technique has provided information about:
_ different masonry textures;
_ ancient architectural details within the masonry walls;
_ cracking on walls and frescoed vaults;
_ anomalies like hidden chimneys and voids.
The IR images of the south west facade on via San Martino reveal the hidden structures of the ancient tower-houses made up of square stone blocks (Fig.3).
The higher thermal conductivity and a generally lower volumetric heat capacity of the stones in comparison with clay bricks and lime mortar produced a strong thermal contrast (T = 5° C) between the different materials. Six piles was detected, four of them corresponding to the transversal walls of the palace (Fig.3). In Fig.4 one can distinctly observe two central arches in the upper part of the façade, with the typical cantonal on the right side. This observation confirms the historical information of the existence of an adjacent alley. On the left side, however, the interruption of the structure at the arch springing is clearly visible. Putlog holes for the wooden beams of the medieval balconies are clearly visible at the top of the stone structure and at the underlying floor. The IR images taken from inside, showing the single stone blocks of the arches and piles, confirm the presence of the old structures on the entire wall thickness (Fig.5).
In this case, the materials under the plaster have been clearly detected, thanks to the 50% percentage variation between the thermal

diffusivity of white-pink quartzite (Verrucano) ($\alpha s \approx$ 10-6 m2 s-1) compared to the limestone mortar ($\alpha m \approx$ 5•10-7 m2 s-1), [1] and [5].

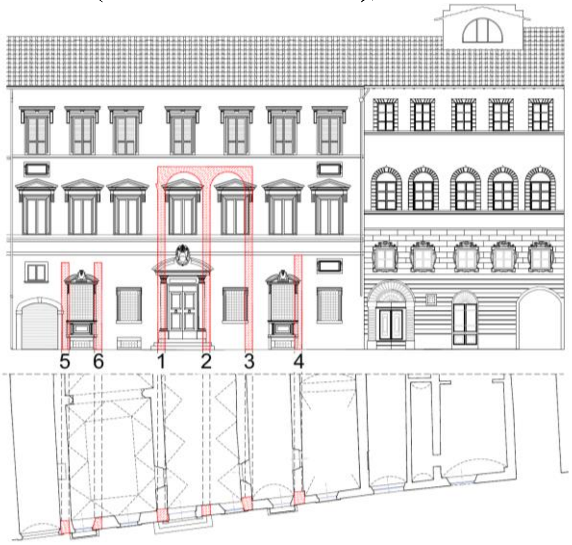

Fig. 3. The hidden structures on the facade along San Martino street with a part of the plan view.

Various types of infill walls between the masonry piers have been detected: those which are made up of clay brick masonry have been quite clearly identified, since they are characterized by a noticeable thermal uniformity, due to the low difference (not more than 10%) between the diffusivity value of the mortar and that of the clay bricks. However, there are also areas with chaotic texture, with irregular stone elements, as on the left of the pile 4 seen from inside (Fig.5).

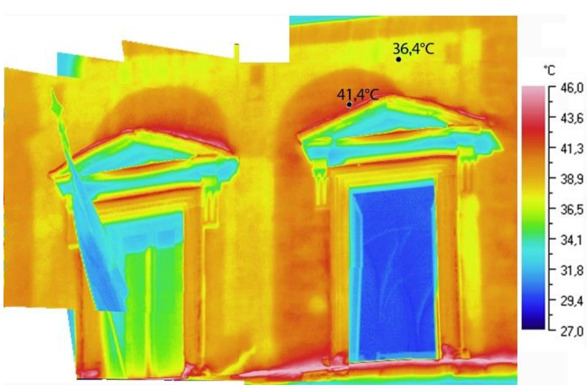

Fig. 4. Detail of the upper part of the facade on San Martino street.

From Fig.5, taken from the inside, the protrusion of pile 4 is recognizable from its surface temperature which reveals the presence of stone blocks. This discontinuity demonstrates that the walls incorporating the pile 4 are not in phase with it.

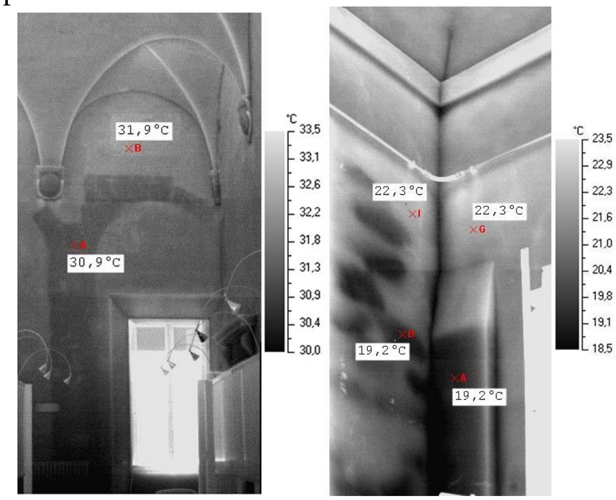

Fig. 5. Views from the inside: the image of the arches and the protrusion of the pillar 4.

The IR image of the facade towards the Arno highlights the Renaissance structure with three stone arches (Fig.6) which are currently filled with clay brick masonry. A vertical crack, which runs over the entire height of the palace, marks the change of masonry texture, which is characterized by stone elements on the left side (Fig.7). This discontinuity is located in correspondence of the transversal wall including the pile 4 (Fig.3 and Fig.6).

Fig. 6. Superposition of IR and visible images of the facade fronting the Arno river.

A mosaicing of thermal images of the interior spaces is shown in Fig.8. One can observe the typical texture of in folio vaults, the trace of the brick ribs on the extrados and the level of the extrados filling. The wall with chaotic texture, that is characterized by stone elements, is crossed by a chimney and is lined with in folio bricks at the lower part.

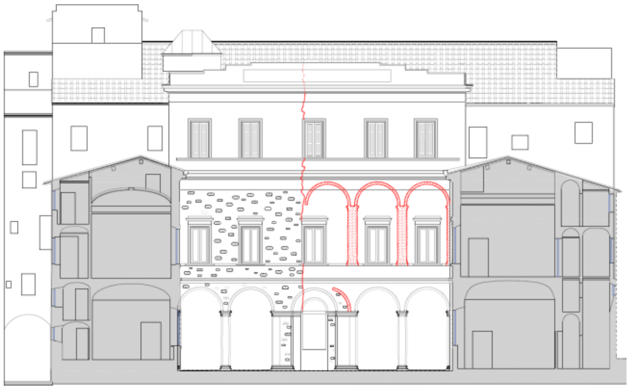

Fig. 7. The hidden texture on the facade fronting the Arno river.

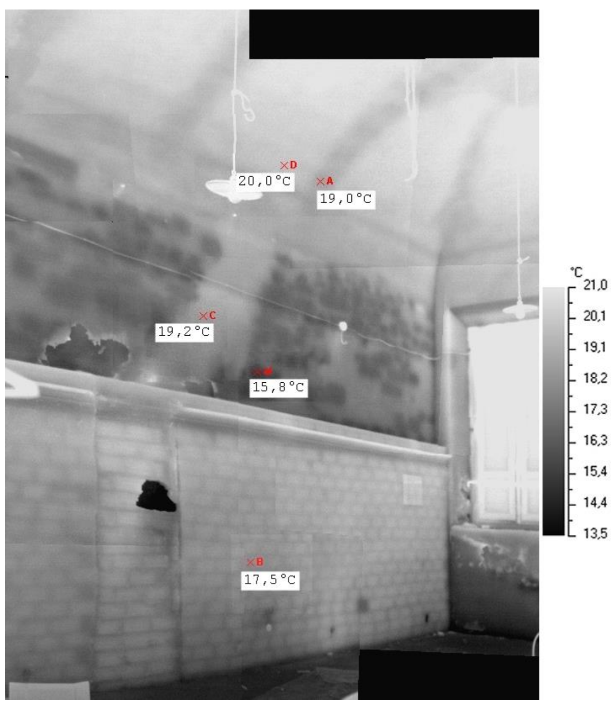

Fig. 8. Mosaic IR images of the internal surfaces of a room at the ground floor.

Results of the survey

The ability of infrared thermography to detect the masonry texture under the plaster is related to the different thermal properties of the blocks compared to the surrounding mortar: the best images have been obtained when the percentage variation of the thermal characteristics between nearby materials was higher than 50%.

In this emblematic case, the survey provides information that offer interesting insights regarding the building construction phases. A first synthesis of the construction periods for the different parts of the structure is shown in Fig.9.

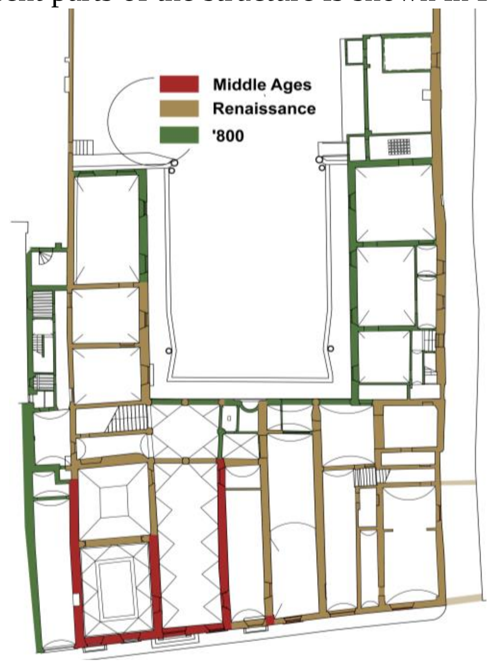

Fig. 9. Dating of current masonry structures.

Conclusion

The IR thermograpy may provide an important contribution to the knowledge of the structural schemes and the construction phases of historical buildings. This paper presents an example of its potential in this regard.

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