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The contribution of diagnostics in architectural survey; case study of combined thermography application.

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Abstract

If up to fairly recent time, the relational system between perception, processing and representation during representation processes was perfected by concluding through natural “intuitus” (physical environment) and human intelligence (perception and processing capacity), the assumption of a dominant role, in terms of methodology and practice, of a third "virtual intelligence", deriving from contemporary developments in technologies such as electronics, information technology and telematics, has transformed the previous method of approach to the environment, natural or built, and to the project.
Applied to the study and investigation of architectural heritage, the contemporary evolution of these technologies of knowledge and simulation, evolve the discipline of representation in the direction of the broader interdisciplinary interdisciplinary perspective, establishing a relational system of methods and information that precede and complement the process of knowledge.
The use of computer systems in the context of visual representation, while being purely a technical/operational aspect that does not conceptually introduce new modus or forms of representation, assumes an even epochal significance by creating a clear separation between pre-and post information.
Useful technologies for the material/formal control intervene in the field of diagnostics and in the behavior of materials by developing measurement, protection and monitoring systems of the performance characteristics.

Keywords: developments, technologies, survey, architectural heritage, diagnostics

1. Evolution of detection techniques

There is no doubt that such technologies supporting representative disciplines have strongly evolved the traditional method of investigation, detection and design, up unto determining an opportunity, if not a necessity, of broad insight in this regard by professionals and researchers.
As noted by Della Vecchia and Mura in the work "Technologies and techniques of graphic representation", in the history of visual representation there has never been such a radical transformation as that in the field of technical representation.
Currently with the development of technology, the acquisition of data is ensured in a more precise, quick and versatile manner. In fact even the same geometrical component of the detection does no longer appear as a simple dimensional measurement. Laser and photogrammetry are part of this innovation, and their integration is able to produce such a large volume of geometrical and material information that alone, already allow an in-depth knowledge of formal, constructional and technological values of the work.
The investigation and representation of degradation or damage can be carried out with tools that can simulate what happens inside the structure; these new opportunities are above all very useful in stratified and complex areas such as restoration work on historic heritage.
To know a building structure, in fact, signifies knowing its history, the natural and urban environment in which it is inserted, the distributional characters, the specific construction techniques, tools and materials used for its construction.

The knowledge of the events, also constructive, regarding the building allows the reconstruction of its evolution and the exact identification of architectural, formal and functional aspects.

2. Diagnostic analysis on architectural heritage

In the context diagnostics occupies a crucial role, or rather the set criteria, procedures and techniques for the identification, investigation and representation of the constituent elements, material and technological aspects and their evolution, which is essential for obtaining a deeper detection of architectural heritage.

The diagnostic action also analyses the changes in the structure and constituent materials of the object, produced by the most various causes, providing information on the composition of the materials used, on the technique of execution, on previous changes or maintenance interventions and on possible changes in the intended use.

The result of the diagnostic knowledge is also indispensable for implementing preventive measures.

The diagnosis for the conservation of artefacts is therefore based on the graphic documentation, which, starting from the autopsic examination includes a scale drawing and mapping of the deterioration. Along with the architectural detection and the mensorial activities, analysis and knowledge of the conservation status of broader area of archaeological and architectural heritage compared to the single artefact determines a regional level mapping that can delineate situations of greater or lesser uncertainty for the exposure to different risk factors.

Today the diagnostic phase tends to confirm its traditional skills, emphasizing the aspects of technical investigation due to the availability of efficient tools and recognized methods; in addition to the shape and architecture, it also investigates the structure with scientific rigor, objectivity and reliability, which is what is expected from a good diagnosis.

The possible progress in this sector today, however, often depends on the development of ever more advanced technologies, such as the use of innovative sensors based on optical fibres and on the miniaturisation of components in their energy autonomy.

The frontier of monitoring, therefore, moves towards the integration of skills and the development of integrated techniques of monitoring; the most frequently used non-destructive type diagnostic investigations are:

The sclerometry analysis, pachometric analysis, magnetometric analysis, sonic analysis, ultrasonic analysis, endoscopic analysis, analysis by X-ray and tomography and thermal and thermography analysis, the latter based on the visualization of thermal differences on the surface of architectural artefacts.

3. Thermography in the architectural survey

Among the non-destructive analysis techniques, thermography certainly represents an important tool of knowledge of architectural heritage and has found in recent years, after some initial setbacks, a wide application in the field of Cultural Heritage.

Thermography is definable as a true measurement procedure that is non-invasive and does not require direct action on the object and is applicable to the diagnosis of dysfunctions and constructive problems of the buildings. In most applications the absolute temperature of the buildings is not as important as the mutual difference that they have. Thermography can be active or passive; active if it detects the energy emitted from the wall, providing the distribution of surface temperature, active if it thermally stimulates the masonry. The thermography camera employed allows to investigate temperatures between - 40°C and 500°C, with a thermal sensitivity of 65mK and an error of ± 2% on the reading or ± 2°C, operating on the wavelength band of the infrared radiation comprised between 8 and 14 μm , which is an interval of the broadest infrared spectrum of the infrared spectrum.

It can be therefore easily understood, which cognitive contribution this technique is able to give in a completely non-invasive manner, providing valuable information relating to the transformations undergone by the architectural system, thanks to shown discontinuity of thermal-physical characteristics of the materials constituting the first deep layer of the wall. The difference in "response" to the thermal stimulation of frequently used materials, such as wood, bricks, stone and mortar between blocks, can therefore be easily visualised by the impression that they project onto the layer of plaster that covers the view. The information obtained and translated into depictions allows us to detect critical situations such as the presence of hidden or detached structural elements, cracks, metal adhesions and everything necessary to determine the historical evolution of the building.

Through the thermography representation of an architectural structure as a whole, and even through the thermogram when the infrared image represents entities that are not otherwise viewable, you effectively obtain the complex of more hidden information regarding the detected object. In this manner it is possible to highlight the quality, the constructive adequacy, highlight architectural structures hidden in the masonry and then buffered, hidden structural defects, rising damp, stagnant water, points of water infiltration, thermal bridges or detect interventions carried out previously.

4. Case study: the bell tower of Sagittarius and the grange of Ventrile

The case study presented in this paper is based on a thesis developed in the degree course in Civil Environmental Engineering, and regards The Grange of Ventrile, a Cistercian complex located in the province of Potenza in the region of the municipality of Chiaromonte.
The complex consists of the remains of the Cistercian monastery of Sagittarius and the defensive grange, a fortified structure with a round tower to the south and a square tower to the north; they are two historical realities, among the most important, especially the Abbey of St. Mary of Sagittarius, that emerges among the ancient monastic one of the county of Chiaromonte and the whole Basilicata.
The case study concerns the detection and combined analysis through the thermography technique carried out on the bell tower of Sagittarius and part of the perimeter walls and the recovery of an area of a structure, the Grange of Ventrile, directed to a bigger recovery action and renovation of the site and nature trail along the valley of the Frido stream.
In the case under examination active thermography was used, where the masonry is thermally stimulated.
On the survey site the radiation was measured with the thermography camera, which had to have the ambient temperature, the emissivity of the material of the object being examined and the distance of the object, set adequately in the instrument as it is influenced by the external environment and also to avoid temperature assessment errors and take into account the parameter of the angle recording, also called angle of incidence, which increases the reflectance of the surface on increasing the angle and decreases the emissivity.
Two thermography recordings were carried out of the constructive wall element with different recording angles, the first with a high angle and the second frontally (angle of incidence close to zero), in order to highlight the different physical characteristics of the material that justify the distribution of temperatures, such as density, the state of inhibition, the surface porosity, alterations and the presence of organic residues.
Infrared analysis were carried out with the Flir, ThermaCam™ P65 model, therefore showing the acquired infrared images and, where needed, the corresponding visible images to better identify the examined area.

Fig. 1: The landscape

Fig. 2: Image of the site

Fig. 3: Ruins of the Grancia

Fig. 4: The village of Sagittario

The structure has been completely abandoned, built of stones and bricks; there are three openings on the west wall, while the openings to the north of the body of the building are narrow slits.
A cognitive thermography investigation was carried out, allowing the present structures such as the masonry work of different periods interfaced by different layers of bricks, contributing to reconstructing the history of the building; it was possible to recognize the bearing wall made from bricks with a regular structure with inclusions of stones and recycled material.
From the point of view of architectural assessment the recognition of the existing architectural structure, of the type of masonry present, its homogeneity and varieties, the regularity of the wall paths, and the size of the masonry unit were important. All this information input is important to correctly perform the structural study whether it is a numerical or analysis of the finished element. In the structural assessment it is important to know the alterations suffered by the building and thermography is a useful tool for investigation in this regard.
Defects of mechanical relevance were detected, such as cracks and crevices, with greater ease and completeness compared to structural and photographic detection. The appearance of the detection of cracks was enhanced in this historic building thanks to image rectification, in this case of thermograms, having a correct spatial restitution of crack distribution on each wall or macro-element.
The structural value of this type of detection lies in being able to locally and globally evaluate the instabilities, deduce the causes and interpret the behaviour of the building: to that end, being an abandoned there are considerable cracks.

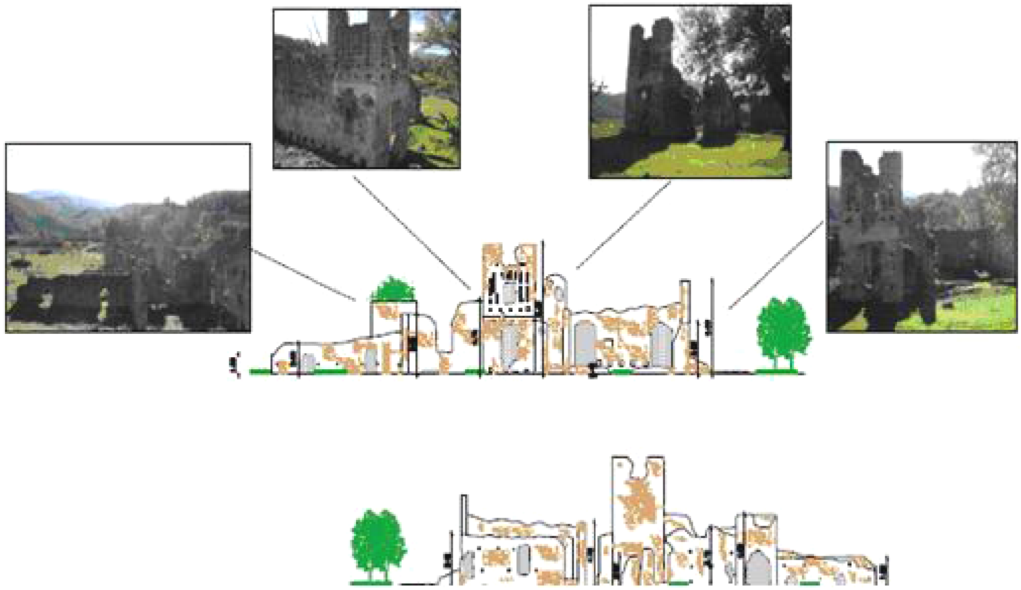


Fig. 5: Details of the Grancia

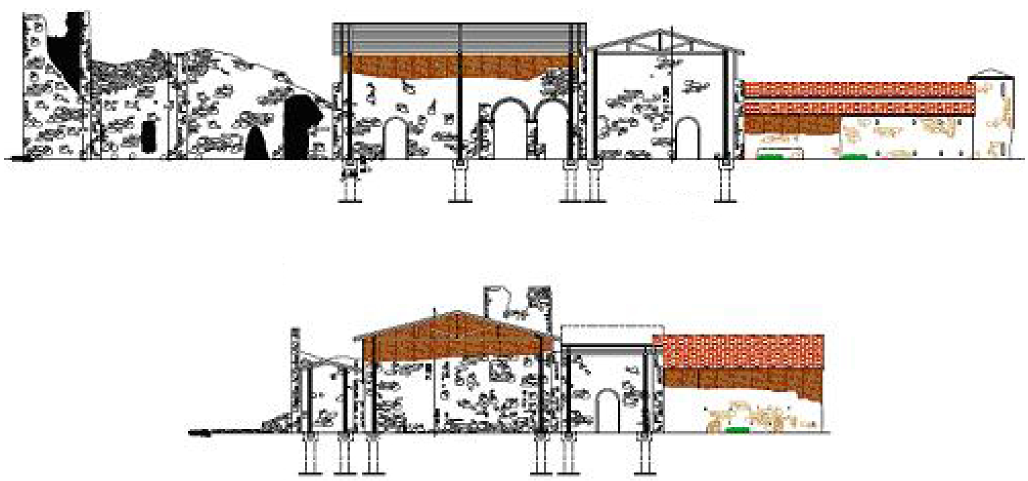
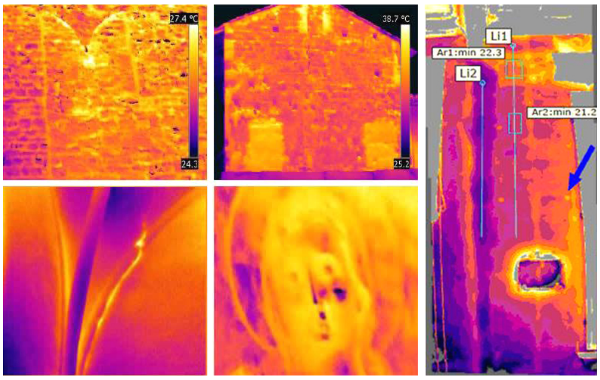


Fig. 6: Sectiones, village of Sagittario

Digital filter were also used to eliminate the influence of objects with temperatures higher or lower than a certain level in order to concentrate the temperature scale only on the masonry and overlooking the constructive element that do not regard the investigation. Advantages can be obtained if the filters are used accurately. You should decide from the moment of the shot what the object of the investigation is and restrict the temperature range used to investigate, in a manner to identify the details of the subject and decide where to shoot a photogram. When a thermogram is shot the element can be "burned" (or over-exposed) which does not apply, gaining on the ease of identifying the thermogram during the re-elaboration phase. In this phase a temperature scale is identified that mostly shows the details of interest of each thermogram, executing the mosaic and applying the filter, a detailed image is obtained in which only the masonry is visible.
With this procedure it is possible to identify even small details such as plug insertion used to support elements that are no longer present, but deducible by the regular distribution of their positioning.
In illustration 7 it can be noticed that the walls are subdivided in two main horizontal thermal layers. The dividing line is at approximately 1.5 metres from the floor and, considering the thermal gradient step which can be observed in passing from one area to another, it can be deduced that it is due to a different wall surface finish. In the high part a warmer area is present which could hide till preserved decorations.



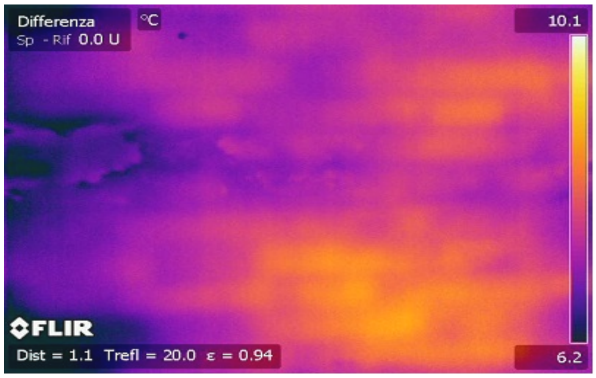


Fig. 7: Thermographic survey on the Grangia

Fig. 8: Texture of the brickwork

Fig. 9: Survey points on the Grangia and on the north tower

Fig. 10: Survey points on the photographic image

From the analysis carried out, the following composition of materials was detected: the wall of the complex of Ventrile and the Abbey of Sagittarius were built with stone blocks of limestone, a material that tends to degrade rapidly, dissolving when attacked by acidic substances in the atmosphere. The masonry was built with stones of the river, partly mixed with flakes of clay and has in most cases, an absence of mortar in the joints. The roughness with the presence of cavities and the emerging on the surface of the concrete stone constitutes the element characterizing the stone surface. In general, the high porosity of the materials used in the two historical complexes, involves a strong sensitivity to the phenomena of frozenness which cause the disintegration of the wall surface. Furthermore, the micro fractures produced by roughing involve an accentuation of the disintegration of the materials, especially as in these cases, if they are in contact with water and exposed to winds, where the material undergoes thermal stress and investment from dust. The analysis of the instabilities and metric degradation, due to the investigation through thermography, led to the evidence of:

- Cracking in the wall and lack of continuity of it;
- Partial loss of bricks;
- Chromatic alteration for oxidation of ferrous substances present in the masonry;
- Efflorescence for crystallisation of salts detectable on blocks of stone due to the capillary rise of water from the soil;
- Progressive flaking of the stones associated to cracks;
- Cracks of mechanical breakage type;
- Patches, with flakes of clay;
- Marks at the edges as a result of the brick arches washing away arches arranged in joints, with an advanced state of internal fracture cracking;
- Internal corrosion phenomena for frozenness;
- Surface break-up and not brick.

Thermography is therefore an essential tool in order to plan with precision and accuracy the works of renewal interventions. Through the thermal image you can check the "health status" of the structure to be renewed. Being a non-destructive control, the thermal image cannot alter the state of the complex to be analysed. The thermography vision of an architectural structure as a whole, allows the quick and effective visualization of any structural defects. In this manner it is possible to highlight the quality and adequate or inadequate execution of work in construction works. Thermography applied to building allows you to highlight architectural structures hidden in the masonry and then tamponed, or go back to maintenance carried out prior to the thermography detection. It is therefore possible to reproduce the detailed account of the work itself, avoiding waste of time and invasive actions to identify areas of possible intervention.

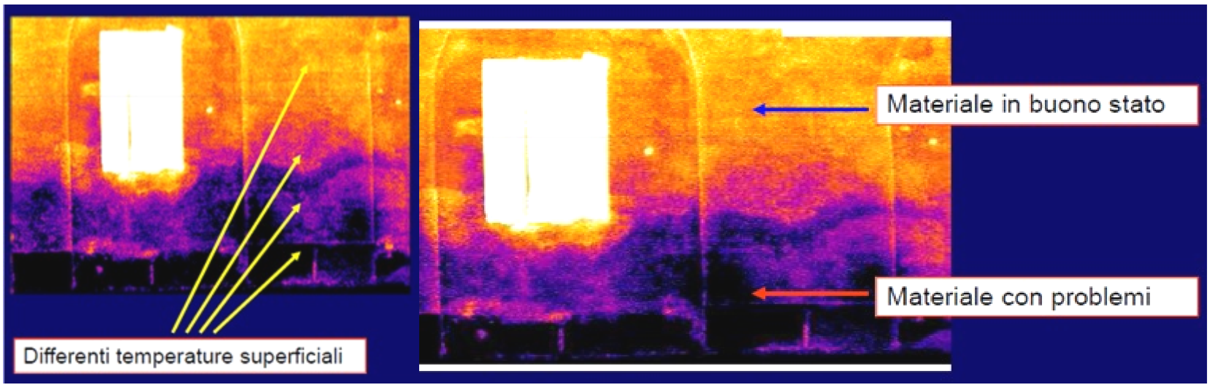


Fig. 11: Thermographic mapping

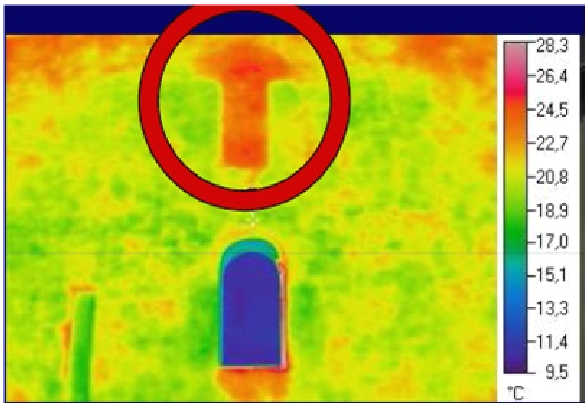


Fig. 12: Visualization of hidden elements

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