Role of diagnostic surveys in the conservation of the former mother-church of Santa Margherita di Belice in Sicily: preliminary tests and restoration site checks
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The paper presents the results of a campaign of non-destructive and minimally invasive tests that were conducted in the former mother church of Santa Margherita di Belice (Agrigento, Sicily), damaged during the earthquake in 1968 and now re-used as a “Museum of Memory”. It includes a summary of the reflections that arose during the preliminary surveys and instrumental tests, and reasons that supported the choice of investigations to be performed and methods to be specifically applied for the conservation of the architectural heritage.

An innovative method designed to produce an effective diagnosis for the localization of defects and the choice of restoration techniques has been applied: its goal is to achieve a synergy between photogrammetric survey and diagnostic graphs. The elaboration of the project will be implemented with the support of scientific diagnostic tools this way, in addition to the sensory evaluations already carried out. The unification of photogrammetric images, ultrasonic tomography, thermograms and radar maps produces the metric layer on which the thematic graphs have been drawn. The final charts are the simultaneous representation of multiple levels; each level contains specific data that can be filtered using experimental software.

The paper introduces the result of investigations made during the conservation works in progress. The diagnostic checks have been carried out at the points where the defects were diagnosed earlier, to verify the quality of the interventions and, therefore, raise the quality levels of preservation yard.

One of the main aspects in the restoration of the former Mother Church of
Santa Margherita di Belice was the consolidation of the stucco that line the inner surfaces of the two walls not collapsed during the earthquake of 1968. The restoration has been difficult due to exposure of the interior finish surfaces to the elements for more than forty years. The condition of degradation reached in the years and the need to assess the state of conservation of the stucco and the level of adhesion to masonry required a careful investigation campaign. After the earthquake, in fact, the church (built in the late seventeenth century) remained without coverage in ruins, until the recent construction of new roofs with a project funded by the City of Santa Margherita1. We must remember that many kind of diagnostic surveys today employed in the field of restoration and maintenance were born and developed in other sectors of the applied research and industry. In recent times, some diagnostic tools also found interesting applications in the conservation of cultural heritage field too; this evolution, today in progress, evidently implies a lot of difficulties that plainly became obvious more and more.

It’s impossible to import methods and diagnostic techniques, already encoded for other work of research and with a different character from the Italian restoration discipline, in the field of restoration of the architectural and environmental heritage. The diagnostic instruments and methods to support a restoration site are to be specifically chosen and planned to reach the purpose of conservation. Many researchers are noticeably attracted by the renewed interest for the restoration and diagnostic tests, but they don’t possess a suitable cultural education and experience to take part efficiently in the methodological knowledge works that anticipate and support the elaboration of a restoration plan. Specific analytical methodology and software for architectural diagnosis are conceived to introduce and permeate the results into the conservation project and applied during the non-destructing testing in the remains of the ancient church. The diagnostic instrumental investigations can certainly localize every defect that architectural structures and finishes reveal and support the maintenance of the material document. The adhesion decreasing of stucco and plaster and their discontinuities are made evident by superficial maps and tomographic sections that return density of materials and internal anomalies. Thermography, radar and ultrasonic test, in synergy with other diagnostic surveys, have given many essential information about structures and coating materials status that once was possible to reach only through direct investigation, altering the integrity of layers: it is possible to study the degradation entity in those superficial portions or thickness to be consolidated, or verify the result of the conservative treatments already carried out in the restoration site. The investigations systems reached high sensibility nowadays and software can support data editing for every single survey to obtain scientific evaluations. But the value of the investigations is subsequently increased by the comparative analysis of all the diagnostic information and it’s important for the different data to interact.

The T.R.U.E. (Thermography, Radar, Ultrasonic survey, Endoscopy) Methodology is characterized by the consequent implementation of non-destructive diagnostic surveys and endoscopic observations (respecting a specific sequence) and pursues the finality to elaborate the conservation project of
plasters and other kind of architectural finishes, in the full respect of the authenticity of monuments and their historical stratification.

The thermographic survey was carried out with the “active method” on the side and apsidal walls. The achievement of adequate thermal levels has been possible with the use of two convectors, who sent a stream of hot air on the surfaces in a uniform manner. Meanwhile, activating the thermal camera and measuring the superficial temperature of the stucco, the thermal state was continuously monitored. Reached the optimal temperature levels, the filmmaking process started; the thermograms were recorded along regular routes until covering the areas to be investigated. To simplify the graphic processing of thermal maps, the large wall surfaces of the former mother church were divided into sectors.

During the visual study it was possible to detect defects, lesions and assume
adherence loss of plaster; however the extend under and between the layers cannot be observed. Improvements, which have been made with another type of plaster, like cement, can be seen in small areas because of the consolidation of masonry already carried out in a past intervention.

The thermal investigation offers a model of interpretation of the degradation state that is based on the evaluation of the distributive geography of the temperatures on the deteriorated surface; in fact, the presence of lesions or adherence loss between superficial layers can influence the emissivity levels and determine anomalous thermal distributions. But every single thermal image contains the measure of the temperatures in a small area and it’s characterized by a perspective deformation that prevents the effective location of the areas to be restored. For such a reason, the result of the investigation is not diagnosis yet: it is simply a data set of mere measurements that doesn’t determine a cognitive close examination that results specific for the planning and the execution of a restoration.

The computer processing of the thermal IR images has been developed in the laboratory and it was composed by some different phases, from the setting right of the infrared images to the elaboration of the thematic maps directly on the thermal mosaic of images. The result of the investigation achieves therefore a global character and becomes a thermal and metric image (in reduced proportions and measurable). From this phase the “measure” can be unified with the architectural mapping and acquire the potentiality to be integrated to the project too.

In order to limit the separation from the material reality of the architectural surface, the diagnostic analytical methodology foresees the processing of the IR images to glimpse the underlying wooden ceiling.

Ideally, in orthogonal sight, are present two (or more) overlapped plans: the first one is opaque and contains the metric image of the surface to be restored, and the second, overlapped, is partially opaque (with transparency level to be set out according to the results the planner wants to get) and contains the metric thermal IR mosaic or the tomography offered by other diagnostic surveys.

The goal of this iconographic elaboration of the diagnosis is the integration of the additional diagnostic information to the maps of the project: to get such a result it is possible to modify the levels that compose the histogram of the maps and change the method of representation. It is in fact evident that colours are automatically associated to the temperatures on the painted wooden ceiling.

The graphic choices are determined by the results of the sensorial exploration and by the restoration technique the architect wants to introduce in the project. The gotten graphs are to be considered as specific project maps and underline, with metric precision, the degradation of materials and the areas to be treated during the restoration yard. The maps can be elaborated in c.a.d. software as raster images to estimate the costs of the conservative treatments. The synergy between photogrammetric and thermographic survey and the fusion of their corresponding maps supported the clear demarcation of the detached superficial areas where consolidation was to be carefully accomplished.
The thermal images were assembled or completely collaged upon the metric visible image in order to get the thermal (and simultaneously metric) maps of the stucco façades. The final result of the computer processing phases is a system of overlapped images, perfectly corresponding and without distortions. The iconographic elaboration of the diagnosis resulted to be well target for the restoration project, with positive effects on the correlated site while works in progress, and a consequent positive economic outcome too. The thermograms evidenced balanced temperatures in the areas where superficial parts are still intact. Cavities and non-adherent plaster are made evident in the hot parts, which can be seen in the thermographic and metric maps. Discontinuity and cavities act as thermal barriers; these non-intact areas are like failings, which have a lower thermal conductivity under the surface area. This is the reason why the cavities above these areas keeps warmer longer, which can be seen in the thermal graphs in the warmest colours and higher temperatures. The applications of radar played a crucial role in early stage and during interventional diagnostics too. The radar made possible to highlight anomalies inside the investigated sections, under the stucco layer, and verify the effectiveness of the consolidation techniques applied in the restoration site. The research group carried out the electromagnetic radiation acting on the plank of the site’s scaffolding in order to investigate the walls up to greater heights. To get more information about the status of plasters and masonry and test the potential combination of both methods, the radar survey was applied to the internal facades, which had already been investigated before by IRT. A high-resolution radar instrument with the two ranges of 600 and 1600 MHz frequency antennas was used for the measurement. The complex system of final two and three dimensions radar maps demonstrates different signal-reflexes in the form of parabolic curves, present above all in the areas where the electromagnetic contrast was sign of clear degradation phenomena. It was possible to measure the dimensions of layers and walls of the ancient construction, which is composed of compact masonry. All the radar signals emerged in maps where put in relationship with some specific defects to intervene on. The survey was also carried out using a controller unit with vibrational pulse probes in the field of ultrasonic frequencies. The investigation is based upon the propagation of vibrations and was useful for detecting the speed of propagation of the pulses in the stucco and, therefore, to indirectly derive the homogeneity and compactness of the material. Tests were made using the superficial propagation mode, that is by placing the transducers on a regular plane. The finish layer’s inhomogeneities altered the propagation speed, reflecting and refracting waves, partially absorbing and attenuating in some directions. The evaluations were carried out with ultrasound on smooth surfaces to promote contact between the probes and the plaster and to convey impulses properly. They had an important role to evaluate the re-establishment of the continuity and compactness in the areas where speed had been low because of the presence of discontinuities below the surface. In addition, observations with fiberoptic flexible endoscope have affected the walls in order to assess the continuity and compactness levels of internal structures. Observations shown that blocks of yellow limestone compose the...
masonry, that is typical of the Valle del Belice traditional architecture. The material appeared very compact, and only in rare situations the presence of microcracks emerged, but above all at superficial level due to the effects of drilling.

The monitoring of moisture levels coming up from the lower parts of walls was also useful for assessing the risk of degradation of plaster and stucco coatings. The probes with electrode needles were applied according to regular acquisition grids developed along the inner walls. The water percentage present in the surface layers has been recorded in a punctual manner but at various altitudes from the lower.

It is important to underline that the second phase of investigations was made when conservation works were still in progress. The diagnostic checks have been carried out at the points where the defects were diagnosed earlier, to verify the quality of the interventions and, therefore, raise the quality levels of
The case study demonstrates that the application of preliminary studies by non-destructive investigation in combination with the visual study generated some very interesting and utilizable results in the determination of the status and damage of finishing materials and architectural structures. It must be underlined that the results given by the innovative diagnostic method of the Laboratorio di Indagini e Restauro dei Beni Architettonici can get a basis for the future procedures for later maintenance; and non-destructive or minimally invasive diagnostic tests can be helpful to raise this aim. The non-destructiveness, in particular, represents a great advantage in the preservation of monuments by getting useful results of the preliminary testing.
of architectural heritage. We also have to critically consider the considerable amount of effort like the technical tools, cost and time as well as the efficiency of the diagnostic findings.

It is clear that future experience will emphasize the relationships between analysis and elaboration of the project. Also if instruments like thermocameras, radar or ultrasonic units become more and more sophisticated, it clearly appears that a real positive evolution can be determined only if the dialogue between architects and other discipline specialists is increased.

We can today purchase very sophisticated and expensive tools of recent evolution, but it is still difficult to note the contemporary evolution of the application methods. It may be wrong to set too many possibility of regulation in the tools because they became difficult to be used and, accordingly, expensive. The Software are often lacking and cannot support the processing of the final diagnosis: images are limited and distorted.

The most interesting developments in the works of applied research are probably the ones characterized by the synergic use of photogrammetric survey, non-destructive tests and laser scanner: this integration produces the metric precision that is requested for the restoration planning.

The conservative maturation of the restoration discipline tends to increase the range of application of the diagnostic technology more and more and maximizes the interaction among different disciplines.

Notes
1 The project of the new roof and re-use as a Museum of Memory is elaborated by Alfonzo Cimino and supported by the City of Santa Margherita di Belice with funds from the European Community.

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