Advanced Materials Research Vols. 133-134 (2010) pp 1015-1020
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doi:10.4028/www.scientific.net/AMR.133-134.1015

Preservation, Safeguard and Valorization of Masonry Decorations in the Architectural Historical Heritage of Piedmont (Italy)

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Abstract In the present paper, a project for integrated investigation is described, using noninvasive methods, specially designed for dealing with the highly diversified historic heritage of Piedmont (Italy). The stability of the decorated surfaces will be investigated by innovative Acoustic Emission (AE) and ultrasonic methods already experimentally tested in the field of artistic and monumental cultural heritage in Italy. The ultrasonic investigation techniques allow assessing separations, defects and damage phenomena that can regard the decorated surfaces and the masonry supports. Innovative acoustic methods will allow distinguishing a well-preserved artwork in comparison to a damaged one providing a quantitative criterion for the definition of intervention priority.

Keywords: Non-destructive techniques, acoustic emissions, cultural heritage, frescos.

Introduction

Public awareness of the need to preserve, protect and enhance the historic heritage of Piedmont (Italy), on account of its intrinsic cultural value and its relevance to environmental concerns, is a well-established fact.

While the devastating, irreversible damage wrought by inappropriate intervention methods are right under everybody's eyes, the experience acquired in over a quarter of a century of strengthening and restoration works has led to the following conclusions:

(a) Repair and restoration interventions must be conducted on the basis of careful investigations into the composition of the materials, construction history, and deterioration mechanisms.

(b) The investigation must focus on the relationships and interactions between the decorative apparatus and the supporting masonry, the microclimate and the soil in direct contact with the structure.

(c) In Piedmont (Italy), as anywhere, it is possible to identify a multiplicity of local practices in terms of masonry construction, finishing and decoration methods that are able to make use of local materials and resources.

(d) Each local technique gives rise to special problems of compatibility with some of the integration and bonding systems to be adopted.

(e) In designing rehabilitation and restoration works it is necessary to resort to systems that have been specifically tested for compatibility, durability, and, possibly, reversibility.

The partners laboratories of the Politecnico di Torino and the National Research Institute of Metrology (INRiM) are developing a fine-tuned integrated investigation, using noninvasive methods, specially designed for dealing with the highly diversified historic heritage of Piedmont, with the aim to remedy current shortcomings in the identification of effective and compatible restoration and maintenance techniques. The project, named RE-FRESCOS, is funded by the Piedmont Region.

The physical-chemical decay and the damage evolution of materials constituting the decorated surfaces and the support can be caused by infiltrations of water, thermo-elastic stresses, or seismic and environmental vibrations. The physical-chemical degradation (Fig. 1a) has to be dealt with Materials Science and Chemical Engineering techniques (Fig. 1b, De Filippis et al. 2005).

On the other hand, the stability of the decorated surfaces can be investigated by innovative Acoustic Emission (AE) and ultrasonic methods already experimentally tested in the field of artistic

and monumental cultural heritage in Italy. The ultrasonic investigation techniques allow to assess separations, defects and damage phenomena that can regard the decorated surfaces and the masonry supports. Innovative acoustic methods will allow to distinguish a well preserved artwork in comparison to a damaged one.

The stability and the dynamic behavior, induced also by seismic and environmental vibrations, will be monitored by the AE technique using wireless transmission systems to control continuously and simultaneously decorated surfaces, situated in different sites of Piedmont.

The data collected during the experimental tests conducted in situ can be interpreted with Fracture Mechanics models and methodologies.

The design of the most appropriate technique turns out to be crucial as well as the selection of the most suitable repair products in terms of durability and compatibility. Therefore, innovative laboratory methodology must be adopted for material prequalification based on uni-axial static and tri-axial fatigue tests.

The Sacri Monti of Piedmont (belonging to the UNESCO World Heritage List since 2003) provided different case histories where the application of the proposed analysis assumes a fundamental role for preservation and maintenance of these monuments.

(a) (b)

Figure 1: Degradation by meteorological events (a); details of the plasters sampling (b) (De Filippis et al. 2005)

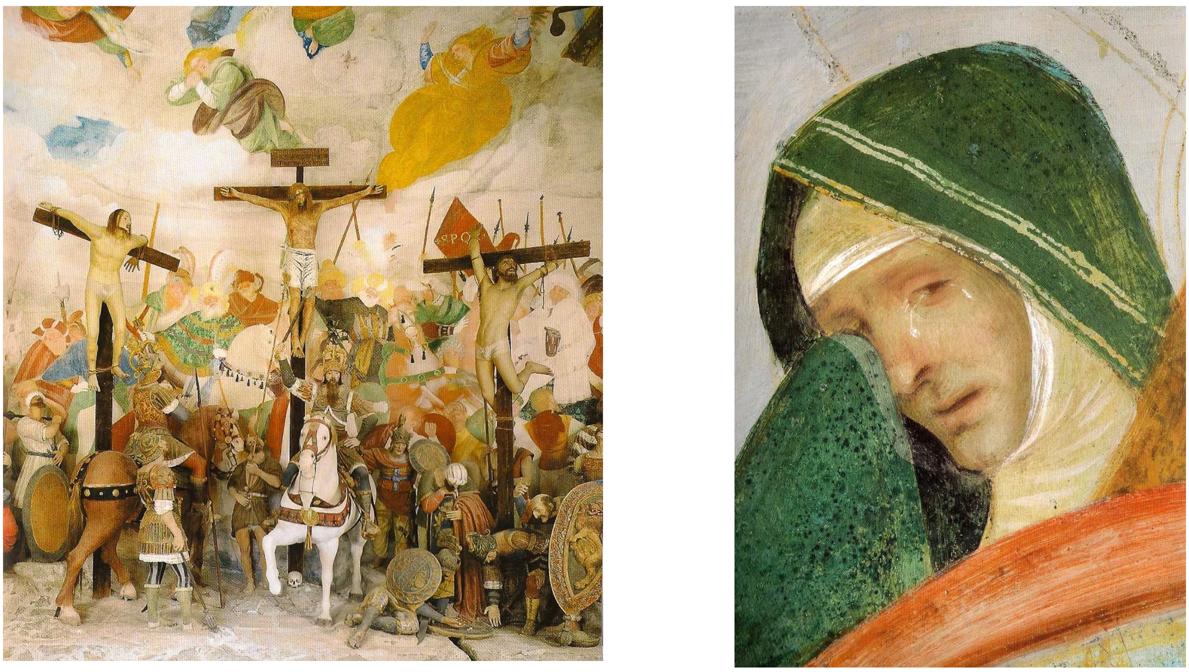
The Sacred Mount of Varallo

The most Ancient Sacro Monte of Piedmont and Lombardy is situated among the green of the forests at the top of a rocky spur right above the city of Varallo. It consists in 45 Chapels (Fig. 2a), some of which are isolated, while others are part of monumental groups. They contain over 800 life-size wooden and multicoloured terracotta statues, which represent the Life, the Passion and the Death of Christ. From this natural terrace (Fig. 2b), visitors can enjoy a view of the whole area, from the lower valley of Valsesia to the Mt. Fenera. In the North-West it is possible to see in the background the massif of Mt. Rosa.

(a) (b)

Figure 2: Plan of the Sacred Mount complex (a); aerial view of the Temple square (b).

Brief History The Sacro Monte of Varallo is the work of two great churchmen and of a number of artists headed by Gaudenzio Ferrari. The two churchmen are: the Franciscan friar, Blessed Bernardino Caimi and St. Charles Borromeo Archbishop of Milan. At Varallo, Fra Bernardino Caimi put into practice the idea that he had been turning over in his mind during his stay in the Holy Land. His aim was to erect buildings that would recall the "Holy Places" of Palestine. Those places evoke the characteristic monuments of Christ's stay on earth (the Stable at Bethlehem, the House in Nazareth, the Last Supper, Calvary and the Holy Sepulcher). He began his work in 1491 and carried on with it as long as he lived (until the end of 1499), assisted by Gaudenzio Ferrari who continued the idea and decorated a number of chapels with frescos and statues in wood and terracotta (e.g. Fig. 3).



(a) (b)

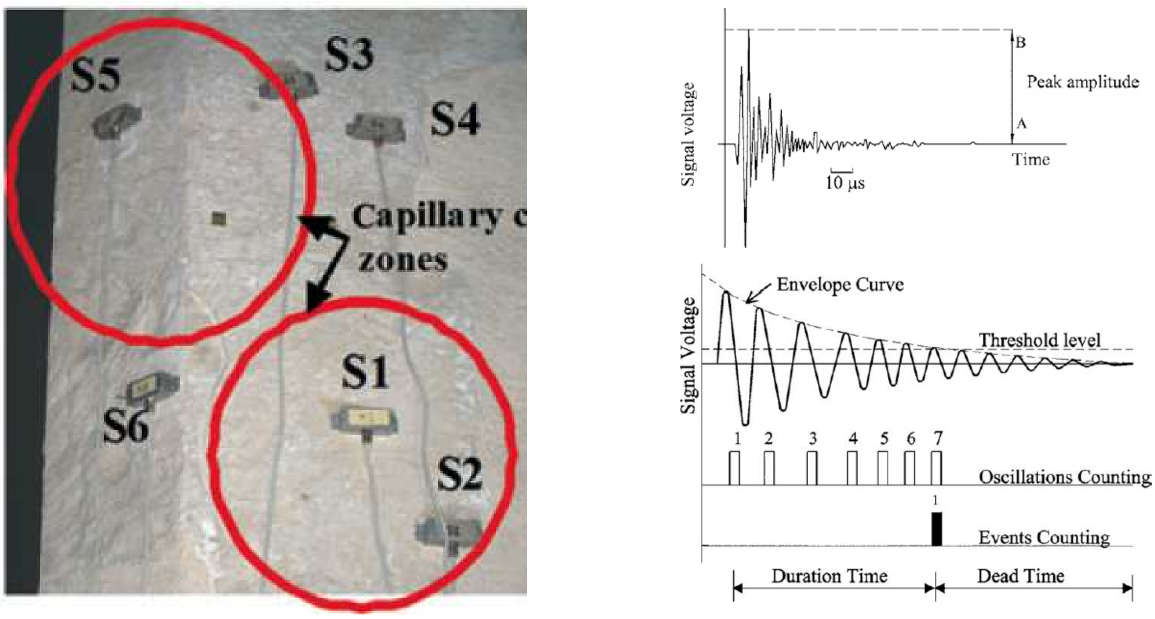
Figure 3: Chapel of the crucifixion (a); Gaudenzio Ferrari, detail of the pietas (b) (De Filippis 2009)

St. Charles Borromeo appreciated the work already done when he paid a visit to the Sacro Monte in 1578 and, giving the place the appropriate name of "New Jerusalem", made it more widely known among his contemporaries. Returning there at the end of October 1584, he decided to develop the original idea by building new chapels, which would illustrate the life of Jesus more completely.

For the great Bishop of Milan it was an effective mean of his time, giving the population greater religious fervor and protecting them from the heresies that threatened Northern Italy. He utilized the project for the rearrangement of the Sacro Monte drawn up by Arch. Galeazzo Alessi in 1592 and, adapting it to his own plans, gave instructions for the resumption of work.

The work continued until 1765. During the eighteenth century a half dozen new artists added their names to Gaudenzio Ferrari's: Morazzone, Tanzio, the Fiammighini and the Danedi in panting frescos; Giovanni d'Enrico and Tabacchetti for sculpture, to mention only the most well-known of them. St. Charles Borromeo's idea and efforts made the Sacro Monte of Varallo the prototype of few other Sacri Monti that arose in the area during the XVII Century. In total, nine sites were built, the most important being Sacri Monti of Orta, Varese, Oropa, Crea and Locarno.

Today the Sacro Monte of Varallo continues to be a school of Christian truth and life, while at the same time it is the most precious treasury of art in the Valsesia valley.



(a) (b)

Figure 4: Acoustic Emission sensors (a); AE signal and events counting definition (b) (Carpinteri et al. 2009).

Damage Analysis of Decorated Surface Structural Support by the AE Technique

The preservation of mural painting heritage is a complex problem that requires the use of innovative non-destructive investigation methodologies to assess the integrity of decorated artworks without altering their state of conservation. A complete diagnosis of crack pattern regarding not only the external decorated surface but also the internal support is of great importance due to the criticality of internal defects and damage phenomena, which may suddenly degenerate into irreversible failures (Carpinteri et al. 2009, Anzani et al. 2007).

A great deal of NDT techniques work by introducing some type of energy into the system to be analyzed. On the contrary, in AE tests, the input is the mechanical energy release generated by the material itself during the damage evolution, so that no perturbation is induced and the integrity of the system may be guaranteed. By monitoring the support of a decorated surface by means of the AE technique, it becomes possible to detect the occurrence and evolution of surface vs. support separation and of stress-induced cracks.

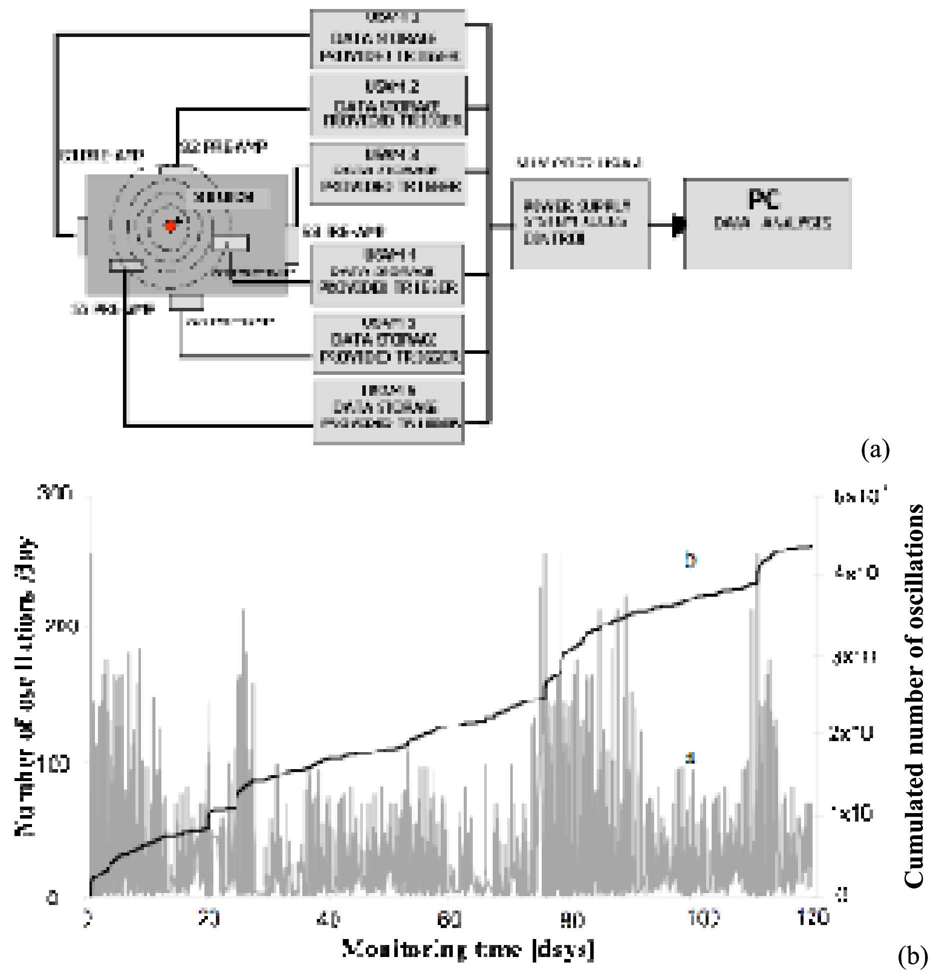


Figure 5: Scheme for the AE localization (a); AE sample acquisition (b) (Anzani et al. 2007)

Cracking, in fact, is accompanied by the emission of elastic waves, which propagate through the bulk of the material. These waves can be received and recorded by piezoelectric (PZT) transducers applied to the external surface of the artwork support.

Fig. 4a shows the AE sensors used for the signal counting and localization. Fig. 4b shows an example of AE signal and the scheme for identification of the event.

Objective of the research is to use the AE technique to assess the support of the decorated mural surfaces in Piedmont, developing the application aspects of this technique, which has been widely studied from a theoretical and experimental point of view by the authors in the safeguard of civil and historical buildings (Carpinteri et al. 2008, Carpinteri et al. 2007, Anzani et al. 2010). In a first stage, it will be essential to recognize the artwork to be monitored, its conservation state and the severity of its conditions at the beginning of the monitoring and restoration processes. The AE technique makes it also possible to predict and localize the presence of cracks and analyze the damage evolution in supports such as decorated masonry walls and vaults (Carpinteri 2007).

The research activity will focus on methods aimed at the localization and quantification of acoustic emission sources in the support of decorated surfaces. These highly advanced procedures, called Localization and Moment Tensor Analysis (MTA), are already used in seismology, where the seismic moment is a parameter directly correlated with fracture problems in the Earth's crust. To this purpose a computer-based procedure including the AE source location algorithm and the MTA is adopted. The procedure can perform automatic AE data processing, by means of dedicated software. The scheme of the localization procedure is shown in Fig. 5a. Fig. 5b shows an example of typical AE acquisition in terms of cumulated or density of events versus time. The final output of the code returns a complete description of the decorated surface preservation state, giving precise information about the damage characterization and evolution of the support stability. In addition, during the research

activity in the most critical cases, or in some cases requiring prolonged in situ observation periods, the AE monitoring method can be fine tuned for the use of an automated working procedure.

In a common case, a huge structure can be monitored by means of sensors of a new type, using wireless transmission systems and efficient algorithms for processing large amounts of data. Thus, it is possible to use a centralized station to control continuously, simultaneously, and in real time, individual decorated surfaces, possibly situated in different locations.

A correlation exists between the regional seismic activity and the AE signals collected during structural monitoring. Therefore, the Acoustic Emission technique can be also used for the preservation of decorated artworks from the seismic risk. In this framework, the AE collected on sensor networks installed during the project activity in different monitored sites, will be directly connected to the "Piedmont center for the environmental forecast and monitoring" ARPA (2010).

Conclusions

The paper synthesizes the main lines of an ongoing research program directed to the preservation, safeguard and valorization of masonry decorations in the architectural historical heritage of Piedmont (Italy). An innovative technique, based on the AE monitoring, is described, which is able to provide information about the progress of frescoes detachment from the masonry support. The proposed approach allows for determining damage propagation quantitatively, and is thus useful to derive the optimal priority for interventions.

Acknowledgements

The financial support provided by the Piedmont Region (Italy) to the Project ''Preservation, Safeguard and Valorisation of Masonry Decorations in the Architectural Historical Heritage of Piedmont" (RE-FRESCOS) is gratefully acknowledged.

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