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Study of a brittle and precious medieval rose-window by means of the integration of GPR, stress wave tests and infrared thermography

L. Nuzzo (1), N. Masini (2), and E. Rizzo (3)

(1) Research Institute for the Environment, Physical Sciences and Applied Mathematics, EPSAM, Keele University, Keele, Staffordshire, ST5 5BG, U.K. (l.nuzzo@esci.keele.ac.uk), (2) Istituto Beni Archeologici e Monumentali, IBAM-CNR, C.da S. Loja, 85050 Tito Scalo (PZ), Italy (n.masini@ibam.cnr.it), (3) Istituto di Metodologie per l'Analisi Ambientale, IMAA-CNR, C.da S. Loja, 85050 Tito Scalo (PZ), Italy (rizzo@imaa.cnr.it)

The correct management and restoration of architectural monuments of high cultural interest requires a comprehensive understanding of their status of preservation, the detection of the building features, the localization of damages and possibly the identification of their causes, nature and extent. To this aim, in recent times there is a growing interest on non-destructive and non-invasive geophysical methods as an invaluable tool for correlating spatially the information gained through destructive tests, which are restricted to a few locations of the investigated structure, and to optimize the choice of their position in order to minimize their impact on the monument structural stability. Moreover, the integration of the classical geophysical techniques with emerging surface and subsurface sensing techniques (acoustics, thermography) provides a suitable methodology for a multi-scale assessment of the monument state of preservation and its material and building components, which is vital for addressing maintenance and restoration issues.

The present case study focuses on the application of Ground Penetrating Radar (GPR), infrared thermography (IRT), sonic and ultrasonic tests to analyze a 13th century precious rose window in Southern Italy, affected by widespread decay and instability problems. The Cathedral of Troia (Apulia, Italy) is the masterpiece of the Apulian Romanesque architecture. Its façade is adorned with an astonishing 6 m diameter rose window consisting of 11 twin columns, in various stone and reused marbles, connected to a central oculus and to a ring of trapezoidal elements decorated with arched ribworks. Between the twin columns there are 11 triangular carved panels with different and strongly symbolic geometrical patterns. According to visual inspection, mineralogical and petrographic studies, different materials have been used for the different architectural elements: fine grained limestone for the central oculus, medium-fine grained calcarenite for the carved panels and coarse grained calcarenite for the elements with arched ribworks. The various elements are supposedly joined together by iron bolts and melted lead, as exposed at the base of a damaged column.

As a consequence of the 1731 earthquake, the upper part of the façade underwent rotational strains which induced severe out-of-plane deformation in the rose window and caused disconnection and rotation of the capitals, compression failures, cracks and detachments in various architectural elements. Despite the 19th century consolidation works, the progressing of strains caused by the recent seismic activity made necessary further structural rehabilitation to preserve the historical rose window.

The geometrical and structural complexity of the monument and the multiplicity of issues to be addressed required an integrated approach using various Non-Destructive Testing (NDT) techniques to complement the laboratory analyses for the material characterization. Being based on different theoretical principles, the NDT techniques are sensitive to different physical parameters of the structure, which are in turn interpreted in terms of its engineering properties based on some calibrations or assumptions. Therefore, especially in case of monuments having exceptional artistic value or structural complexity, the integration of several methods becomes mandatory in order to compensate the limitations of each single method thus reducing interpretation ambiguities and the risk of failure in detecting structural defects. In our case the combination of GPR, IRT and sonic/ultrasonic tests was deemed the best strategy to obtain information on different physical parameter and to achieve different depths of penetration and resolution capabilities. A multi-scale integrated approach was necessary since the aspects to be investigated were themselves of different scales, ranging from the sub-centimeter size of small metallic joints, narrow fractures and thin mortar fillings up to the decimeter-meter scale of the masonry structure of the circular ashlar curb link-

ing the rose window to the façade. This multi-technique NDT approach provided a wide amount of high-resolution complementary information on the internal and surface characteristics, materials, state of conservation and building techniques, which were essential for the design of an effective restoration strategy.