



## **Integration of terrestrial laser scanner, ultrasonic and petrographical data in the diagnostic process on stone building materials**

Giuseppe Casula (2), Silvana Fais (1), Maria Giovanna Bianchi (2), Francesco Cuccuru (1), and Paola Ligas ()

(1) University of Cagliari, DICAAR, Department of Civil and Environmental Engineering and Architecture (DICAAR), Cagliari, Italy (sfais@unica.it), (2) Istituto Nazionale di Geofisica e Vulcanologia (INGV) – Sezione di Bologna, Via Donato Creti 12, 40128 Bologna, Italy

The Terrestrial Laser Scanner (TLS) is a modern contactless non-destructive technique (NDT) useful to 3D-model complex-shaped objects with a few hours' field survey. A TLS survey produces very dense point clouds made up of coordinates of point and radiometric information given by the reflectivity parameter i.e. the ratio between the amount of energy emitted by the sensor and the energy reflected by the target object.

Modern TLSs used in architecture are phase instruments where the phase difference obtained by comparing the emitted laser pulse with the reflected one is proportional to the sensor-target distance expressed as an integer multiple of the half laser wavelength.

TLS data are processed by registering point clouds i.e. by referring them to the same reference frame and by aggregation after a fine registration procedure. The resulting aggregate point cloud can be compared with graphic primitives as single or multiple planes, cylinders or spheres, and the resulting residuals give a morphological map that affords information about the state of conservation of the building materials used in historical or modern buildings, in particular when compared with other NDT techniques.

In spite of its great productivity, the TLS technique is limited in that it is unable to penetrate the investigated materials. For this reason both the 3D residuals map and the reflectivity map need to be correlated with the results of other NDT techniques such as the ultrasonic method, and a complex study of the composition of building materials is also necessary.

The application of a methodology useful to evaluate the quality of stone building materials and locate altered or damaged zones is presented in this study based on the integrated application of three independent techniques, two non destructive such as the TLS and the ultrasonic techniques in the 24-54 kHz range, and a third to analyze the petrographical characteristics of the stone materials, mainly the texture, with optical and scanning electronic microscopy (SEM). A very interesting case study is presented on a carbonate stone door of great architectural and historical interest, well suited to a high definition survey . This architectural element is inside the “Palazzo di Città” museum in the historical center of the Town of Cagliari, Sardinia (Italy). The integrated application of TLS and in situ and laboratory ultrasonic techniques, enhanced by the knowledge of the petrographic characteristics of the rocks, improves the diagnostic process and affords reliable information on the state of conservation of the stones used to build it. The integrated use of the above non destructive techniques also provides suitable data for a possible restoration and future preservation.

**Acknowledgments:** This work was financially supported by Sardinian Local Administration (RAS – LR 7, August 2007, n.7, Promotion of Scientific Research and Innovation in Sardinia - Italy, Responsible Scientist: S.Fais).