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Assessment of fractures in some columns inside the crypt of the Cattedrale di Otranto using integrated geophysical methods

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Abstract

We investigate the problem of internal fracturing of the columns of a building of cultural importance (the Crypt of the ''Cattedrale di Otranto'', Apulia, Italy), using a multi-disciplinary approach, integrating different non-destructive techniques (Microclimatic and Geophysical). In fact historic buildings, over centuries, may accumulate a high concentration of water and/or moisture that increases significantly the deterioration rate, diminishing the mechanical resistance.

It is well known that the distribution of moisture within stone strongly depends on ambient conditions, i.e. temperature and relative humidity. No suitable environmental condition in the Crypt and the presence of wet buried structures in the ground involved in the process of deterioration have been indeed assessed in previous surveys.

Actually we perform a ground penetrating radar (GPR) investigation, in reflection mode, in order to reveal the existence of fractures inside the columns, because of the important rising of water from pavement.

The reconstruction of the fracture distribution is fundamental to plan the safeguard and the restoration of the columns themselves and also the stability of the Crypt and of the uppermost Cathedral. Such survey was performed on seven columns using GPR technique. Moreover the electrical resistivity tomography (ERT) and GPR traveltime tomography (TT) methods were applied on the most damaged column.

The results obtained with these different methodologies are in good agreement, however, the 2D electrical resistivity tomography seems to be less resolutive than GPR. While the GPR traveltime tomography is more time expensive than GPR reflection mode method. The GPR method, in reflection mode, allows to reconstruct the main fractures inside the columns also in virtue of its penetration power.

We think that the joining of different methodologies permits to better understand the complex physical mechanisms in the phenomenon of deterioration of the cultural heritage, in order to achieve useful information for possible, future, restoration works.

Keywords: Deterioration of cultural heritage; Fractures; GPR and ERT survey; Microclimatic investigation

1. Introduction

In the last few decades, the deterioration of stone buildings has particularly drawn the attention of scientists due to the need for protection, especially in polluted environments. Numerous studies have shown the complexity of relationship between different agents (biological, chemical and physical) of degradation, pointing out the issue of a necessary interaction among the various disciplines involved [1,3,4].

Some causes of the phenomenon of deterioration of the stone were studied with previous different, non-destructive biological and physical researches [6,18] in the Crypt of the ''Cattedrale di Otranto'' (Apulia, Italy) (Fig. 1). First of all, no suitable microclimatic conditions in the Crypt were evidenced. Furthermore the presence was argued of buried wet structures that could be involved in the process of deterioration, and then a localisation of some discontinuities was performed.

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Fig. 1. Localisation of the Crypt of ‘‘Cattedrale di Otranto’’.

Following the results and the suggestions of the above researches, we conducted other geophysical investigations for detecting and imaging fractures, voids, etc., in order to determine their influence on the structure stability, as described by many authors [2,25,15,12,5,7,22,17].

The methodologies adopted to estimate the integrity degree of the columns were as follows:

- the back-scattered energy in GPR survey;
- the electromagnetic (EM) wave velocity by GPR travel-time tomography (TT);
- the resistivity values from 2D electrical resistivity tomography (ERT).

Comparing the results of geophysical survey to microclimatic survey, we draw a more realistic scenario of the deterioration inside the Crypt.

This common approach produces a meaningful map of the condition of the cultural heritage, making possible more effective suggestions in order to obtain suitable conditions for the conservation of works of art.

2. The columns of the crypt of the “Cattedrale di Otranto”

The Crypt (Fig. 1) of the ‘‘Cattedrale di Otranto’’ is an hypogeum structure, founded in 1080, built in the middle of XII century, partially rebuilt in 1481. It contains 42 columns within the interior, different for size of diameters; of various materials such as polychromatic different marbles, granite and breccias. These rocks do not outcrop in the Apulia region. When the Crypt was built, it was common to reemploy materials coming from preceding structures, destroyed for carelessness or for natural or war events.

The columns exhibit specific peculiarities; they are crowned by capitals of historical and geographical different origin (from the Classical Age to the Romanesque one), with a discard in the date of their construction of about 10 centuries.

Due to their different origin, epoch and material, they present different problems derived by the structural chemical and physical origin and by the constructive and traumatic events that characterised the Crypt.