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The Cathedral of SS Annunziata in Castro (Lecce, Southern Italy): Structural - Diagnostic surveys

Giovanni Leucci, Giovanni Quarta
Istituto per i Beni Archeologici e Monumentali
Consiglio Nazionale delle Ricerche
Lecce, Italy
g.leucci@ibam.cnr.it

Abstract

Within the project restoration regarding the static improvement of the northern façade of the S.S. Annunziata Cathedral in Castro (Lecce), integrated geological and geophysical investigations were undertaken. The aims of the survey were to define the model of the local geological stratigraphy and to evaluate the geotechnical characteristics of the ground hosting the foundation of Cathedral.

Geophysical survey was performed used Ground Penetrating Radar integrated with seismic refraction tomography. Moreover both a direct investigation using continuous core boring and a hand excavation were performed in correspondence of the building foundations.

The obtained results have allowed determining the typology of foundation and its depth with respect the living surface. In addition, the model of the local geo-stratigraphy was reconstructed, as well as, the geo-mechanical parameters of the litho-types conditioning the foundations structures were determined. Doubts remain on the direct correlation with to crack pattern observed on the Northern façade of the Cathedral.

Keywords- *GPR, Cultural Heritage, Structural analysis, seismic refraction tomography*

I. Introduction

Castro is a village located few kilometres southeast of Lecce (Italy). The Cathedral of Castro (Fig. 1) is a remarkable example of Romanesque architecture in the Salento region. It was built in 1171, probably on the ruins of a Greek temple and it is characterized by a Latin cross plan. It is composed of only aisle that terminates in three apses. The continuous interventions and remaking during the centuries have sensitively altered the native structure in Romanesque style. The Cathedral is divided into two zones: an anterior part, rebuilt many times until to the substitution of its roof in wood in 1670; a back part, where are located the central altar, in Baroque style, and the two lateral chapels. In this area, the façade is affected by fissures relating to a structural damage witch has allowed to define a specific intervention of restoration. Analyses concerning the strengths acting on this part of monument, together with investigations on the subsoil under/near the artefact were performed. This latter investigation is taken into account in this work with particular attention to define the physical-mechanical characteristics of the geological materials of the subsoil nearest the church. In addition, existence of ancient structures will be evaluated.

II. Geological Setting

The studied area is located in the central part of historic centre of Castro. The geological setting is similar to that of salentine Peninsula which is characterized by a base carbonate rocks constituted by a calcareous-dolomite formation dating to the superior Cretaceous. This formation has been successively covered by deposits belonging to the various sedimentary cycles, happened between the Paleocene and the Pleistocene periods. During these periods, tectonic events folded the structure of carbonate formations displacing, in some cases, the blocks at different heights. In the Paleogene one of these areas was still submerged allowing the deposition of the Castro Limestone that is the litotype outcropping in the studied area. This latter, as well as, the majority of carbonaceous rocks, is affected by karstic features characterized by a network of fractures and/or sinkholes full of “terra rossa”, made of silty-argillaceous sand enriched in iron oxides

III. Material and Methods

Ground-penetrating radar (GPR) is a fast and cost-effective electromagnetic (EM) method, which in favourable conditions, i.e. mainly resistive non-magnetic environments, can provide valuable information on the shallow subsurface. Over the last few years GPR has been successfully used in the study of shallow structure and stratigraphy of sedimentary rocks [1, 2].

Seismic refraction tomography provides information on the P-wave velocity distribution. It helps to calibrate the GPR data, and provides additional information about bedrock depths and on its physical-mechanical features [3, 4, 5].

For the GPR survey a Mala Geoscience GPR instruments (RAMAC) with a 250MHz shielded antenna (centre frequency) was used. The data were acquired using 512 samples per scan, 8 bit data word length, and a recording time window of 130ns. Furthermore, data were collected by means of a monostatic configuration in continuous mode. GPR profiles location is show n in Fig. 3.

The 2D seismic P-wave velocity distribution was obtained on the base of the geometry shown in figure 4 using 12 vertical geophones (4.5Hz), spaced 2m apart and 14 shot-points. The seismic data were collected by means of a seismograph (GEOMETRICS model GEODE) with 12 active channels. The first step in the refraction tomography survey consists of measuring the travel-times of seismic wave first arrivals related to source–receiver distances located along the set profile.

IV. GPR DATA ANALYSIS

The quality of the raw data did not require advanced process-ing techniques. However, appropriate processing was performed for easier interpretation. The most important steps of this post-processing can be summarized as follows:

1 Background removal: the filter is a simple arithmetic process that sums all the amplitudes of reflections that were recorded at the same time along a profile and divides the sum by the number of traces summed. The resulting composite digital wave, which is an average of all background noise, is then subtracted from the data set.

2 Kirchhoff 2D velocity migration: a time migration of a 2D profile is performed on the basis of a 2D velocity distribution, obtained from the interactive velocity adaptation of a diffrac-tion or reflection hyperbola by calculating a hyperbola of defined velocity and width.

Figure 5 shows the reflection profiles acquired in the study area after the above-described processing. A general characteristic of the surveyed area is the good penetration, about 110 ns, of the electromagnetic energy, corresponding to a depth of about 4.4 m if the mean EM-wave velocity is 0.08 m/ns. This is essentially due to the physical properties of the subsurface material which low dissipates the electromagnetic energy. In the uppermost metre of ground surrounding the church several anomalies (S) are present. They are related to the subsurface pipes network. Two radar facies types can be distinguished at two different depths. The first radar facies, (labelled B), is slightly dip is located between 2 and 2.4m in depth. It is probably related to the more fractured calcareous bedrock.

The second radar facies, (also labelled B), is more dipping than the first and it is located between 3 and 5m in depth. It is probably related to the more compacted calcareous bedrock.

Some vertically and horizontally reflections (labelled F) can be seen within the two facies. They are probably related to the presence of several fractures.

V. SEISMIC REFRACTION TOMOGRAPHY DATA ANALYSIS

Figure 6 shows the seismic P-wave velocities model in the first meters of the subsoil. It is possible to note two seismic velocity areas, labeled H and L respectively (Fig 6a). The Vp values ranging from about 1200ms^{-1} to about 1700ms^{-1} (areas labeled L) could be related to fractured or calcareous bed rock. The Vp values ranging from about 1900ms^{-1} to about 2800 ms^{-1} (areas labeled H) could be related to more compact calcareous bedrock.

VI. CONCLUSIONS

The integrated geological and geophysical surveys have allowed to reconstruct the geological model of the surveyed area.

GPR and seismic refraction tomography datasets have been compared to integrate the results and to eliminate the intrinsic ambiguity of each method. Combining different data sets minimizes the ambiguities in the interpretation and allows esteeming bedrock depth and quality.

Particularly seismic refraction tomography pointed out problems related to the spatial resolution and therefore it doesn't allow evidencing the single anomalies related to the fractures. Moreover, in this study the seismic refraction methodology was used under not standard conditions and it had allowed reconstructing the subsoil condition related to the N-W side of the cathedral. In fact in the investigated area the results revealed a bedrock constituted by a one type of calcareous with varying mechanical characteristics. Particularly the mechanical characteristics improve with the depth, according to the increase of the P-waves velocity. The GPR results allowed, with higher spatial resolution than seismic measurements, to underline variations of the physical state of the subsoil with the depth.

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Figures

Figure 1. The Cathedral of SS Annunziata in Castro (Lecce, Italy)

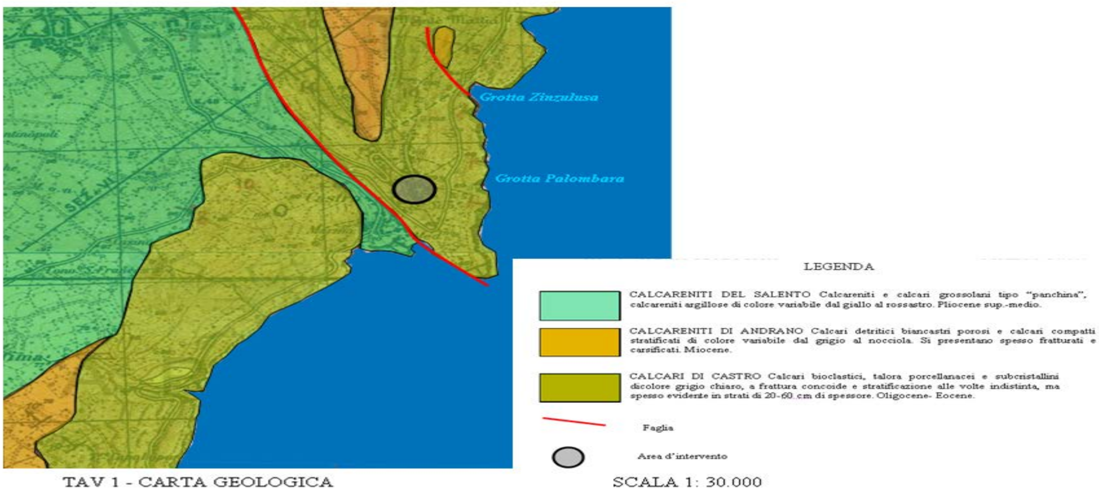

Fig. 2: The geological map

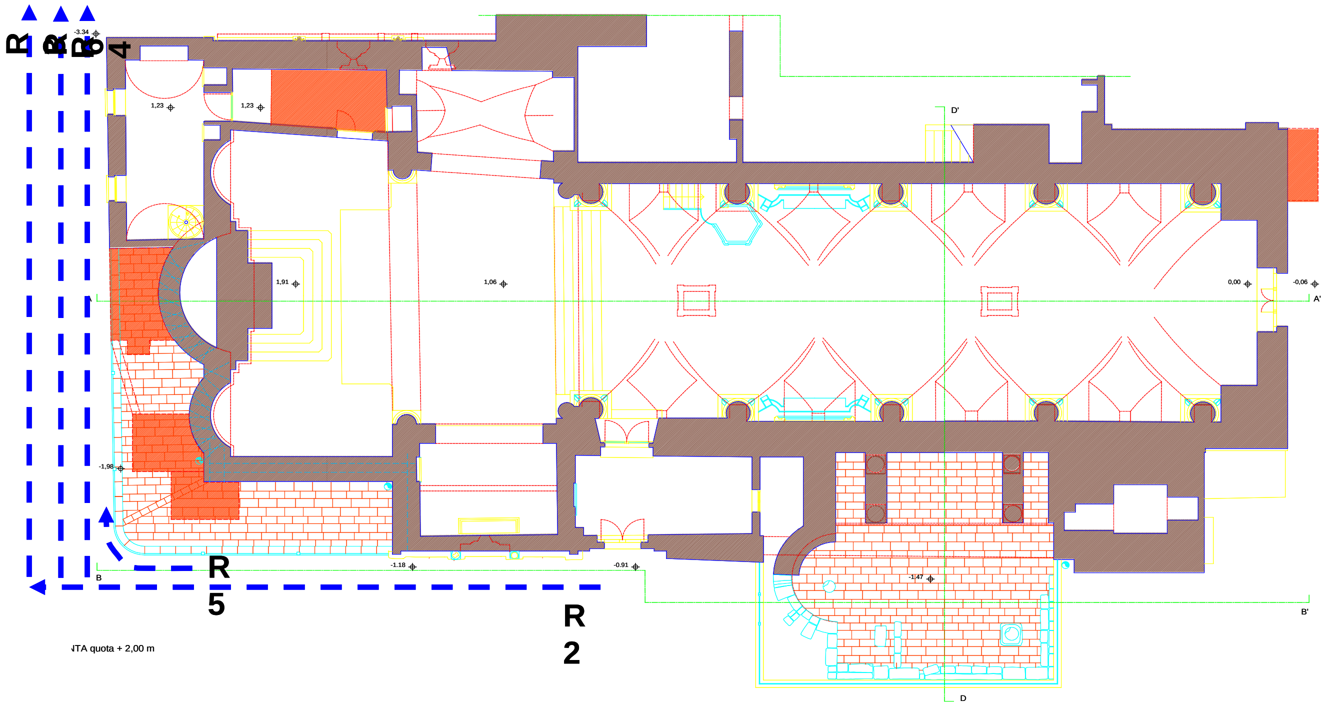

Figure 3. GPR profiles location

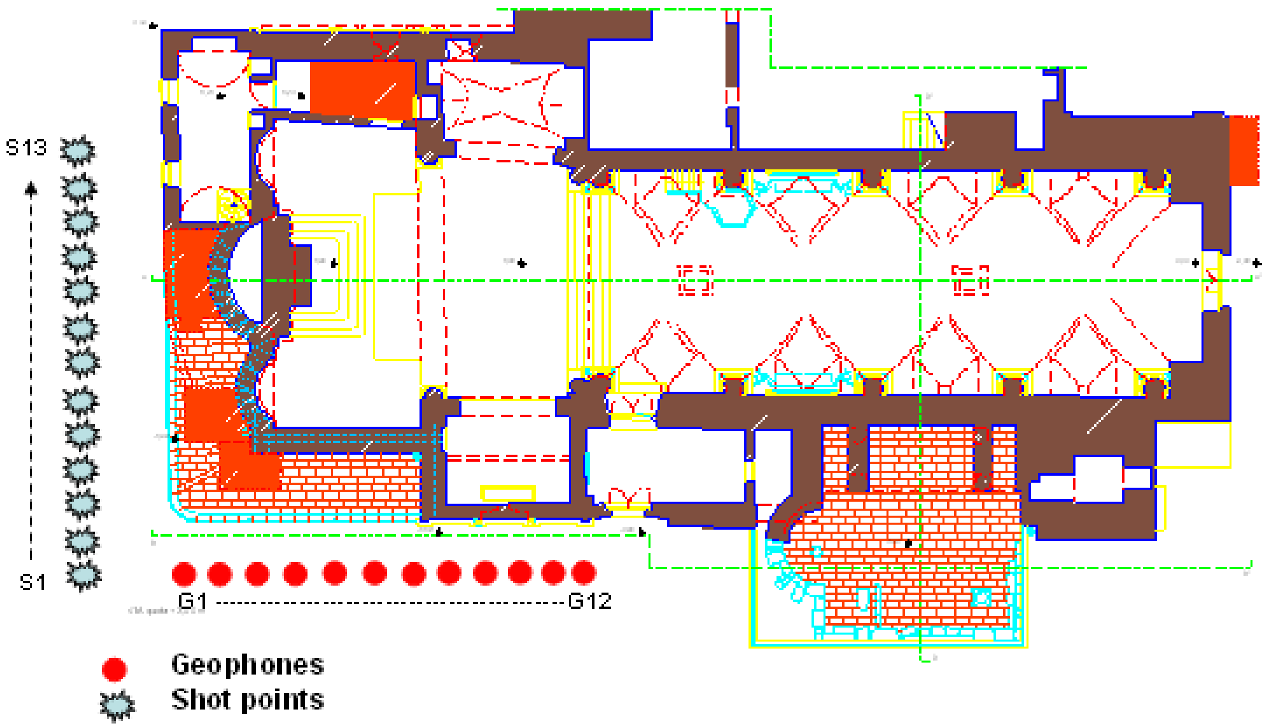

Figure 4. Seismic refraction tomography acquisition geometry

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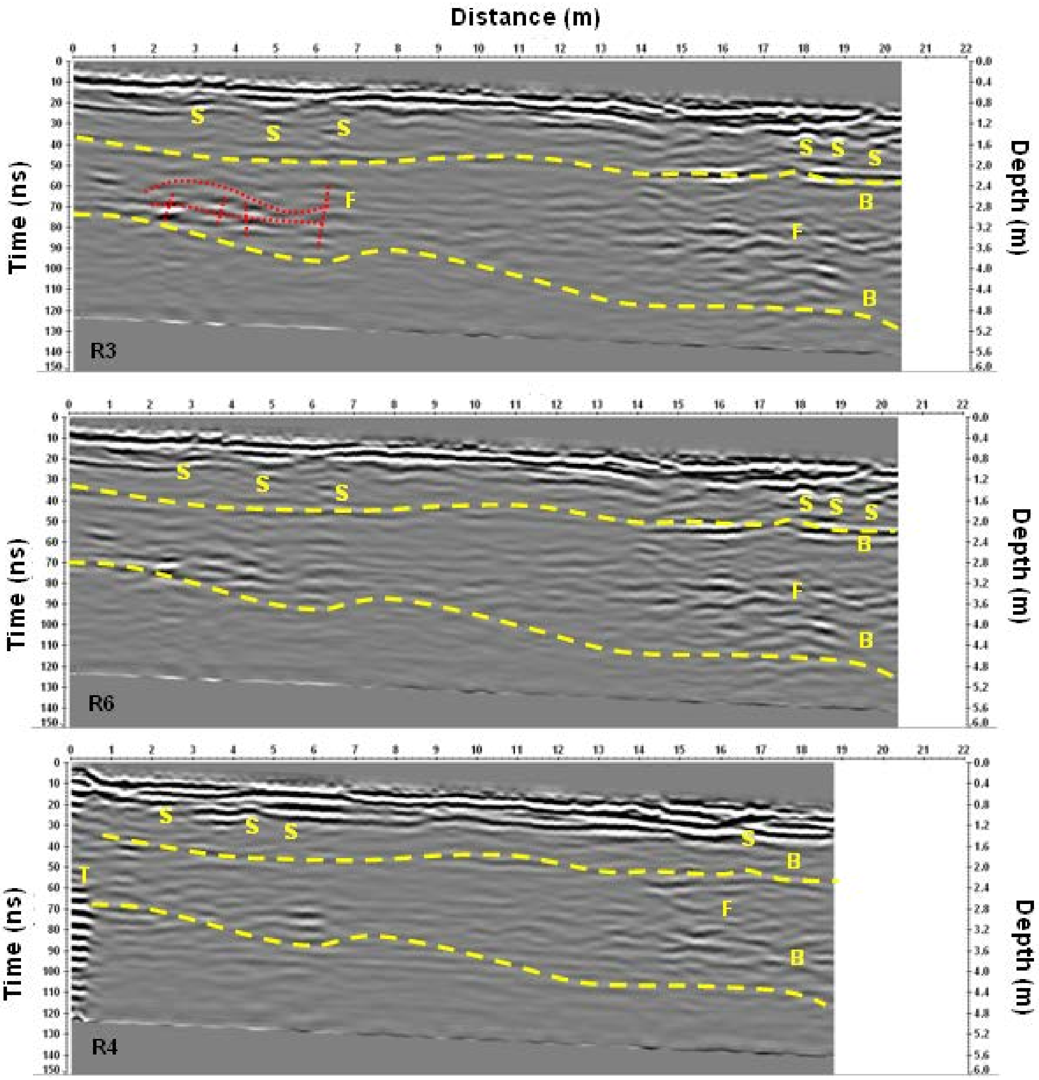

Figure 5. The processed radar sections related to the profiles named R3, R6 and R4

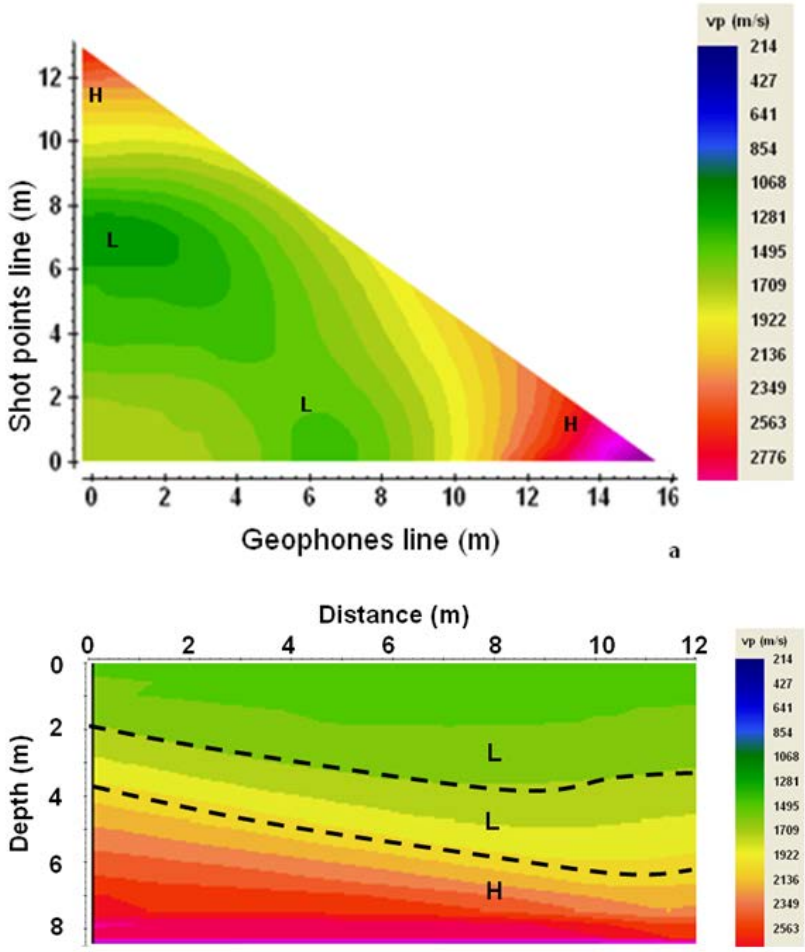

Figure 6. Vp distribution model: a) in the surveyed area; b) at the shot point line