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Study the conservation state of the façade of the Basilica of Santa Croce (Lecce- Italy) using ground-penetrating radar

Carrozzo[2] A. R., Comisi[3] F., De Giorgi[1] L., Leucci[1*] G., Longhitano[3] L., Torre[3] C.

[1]*Institute of Heritage Sciences, National Research Council, 73100 Lecce*
[2]*University of Urbino, 61029 Urbino*
[3]*University of Catania, 95124 Catania*
[*]*corresponding author, giovanni.leucci@cnr.it*

***Abstract* – The basilica of Santa Croce in Lecce is a baroque church internationally well known; the starting point for this research was the evidence that some structures of the façade are more damaged and present signs of subsidence. The possible causes of damages can be: i) buried structures or subsurface anomalies; ii) not suitable microclimatic conditions; iii) deposition of pollutants. In order to study the first cause of damage geophysical survey, using ground-penetrating radar (GPR) was performed. This allow to obtain information on buried structures or to locate and identify anomalies related to a restoration intervention carried out in the 80s.**

I. INTRODUCTION

The *Basilica di Santa Croce* (Fig. 1) was built in two phases: the first, by the architect Gabriele Riccardi, from 1549 to 1590 and concerned the construction of the lower area of the facade up to the balcony under the current rose window, adorned with figures depicting men and animals, as well as the dome, completed in 1590. One second phase developed from 1606 to 1649, during which the three decorated portals were added to the facade and the church was completed. In these years, the architect Francesco Antonio Zimbalo first worked on the project and then Cesare Penna and Giuseppe Zimbalo (perhaps the most important architect-sculptor of the Lecce Baroque). The famous decorated rose window, with the two statues of St. Benedict and Pope on the sides, is from this second period, which is the strictly Baroque one. Celestino V, and again on the sides of the balustrade two colossal female statues, representing the Faith and the Fortress. The façade was recently hit by some collapse events that caused some pieces to detach from the decorative complex of the façade itself, with particular deterioration of the tympanum. As part of the diagnostic project concerning the problems of instability / deterioration present both on the facade and columns of the Basilica di Santa Croce in Lecce, the Institute of Cultural Heritage Sciences (ISPC-CNR) was commissioned to carry out some geophysical surveys, using the ground penetrating radar (GPR) method, in order to: i) identify armed drilling e filled with cement grout performed following the structural recovery intervention carried out in the 80's; ii) obtain information on the state of conservation of the wall faces and columns.

Fig. 1. The Basilica di Santa Croce (Lecce, south Italy)

The geophysical investigation of monuments is a topic of great interest worldwide [4, 5, 6, 7], because it allows the collection of information regarding the preservation state of walls, pillars, columns, ceilings and foundations. Geophysical prospecting also makes it possible to identify fractures, metal hinges embedded in the historical structures, either initially put in them or added during subsequent restoration works [8]; raising or spreading humidity [9, 10, 11], or even voids ascribable in some cases to walled windows, doors, ciboria, and more [2].

In this work, the results of GPR prospection carried out on the façade and columns are presented.

II. THE GROUND PENETRATING RADAR SURVEY

The GPR survey was performed using a RIS MF Hi Mod by IDS GeoRadar and deploying antennas of 900MHz and 2000 MHz centre frequency (Fig. 2). 150 georadar profiles were performed, 99 of which with a 900 MHz antenna and 51 with a 2000 MHz antenna. The location of the profiles is shown in fig. 3. All profiles were acquired with 512 samples per trace. The other acquisition parameters have been optimized on site. The quality of the campaign data, despite the poor operating conditions was acceptable. However, to mitigate the effect of noise (inevitably present in the data of a geophysical survey), and to allow for a simpler interpretation of the data, a processing of which has been carried out steps are listed below:

1) removal of the average trace
2) migration
3) envelope of the tracks (Hilbert transform)

Fig. 2. Phase of the GPR data acquisition. On the right side of the photo, a detail of the status of conservation

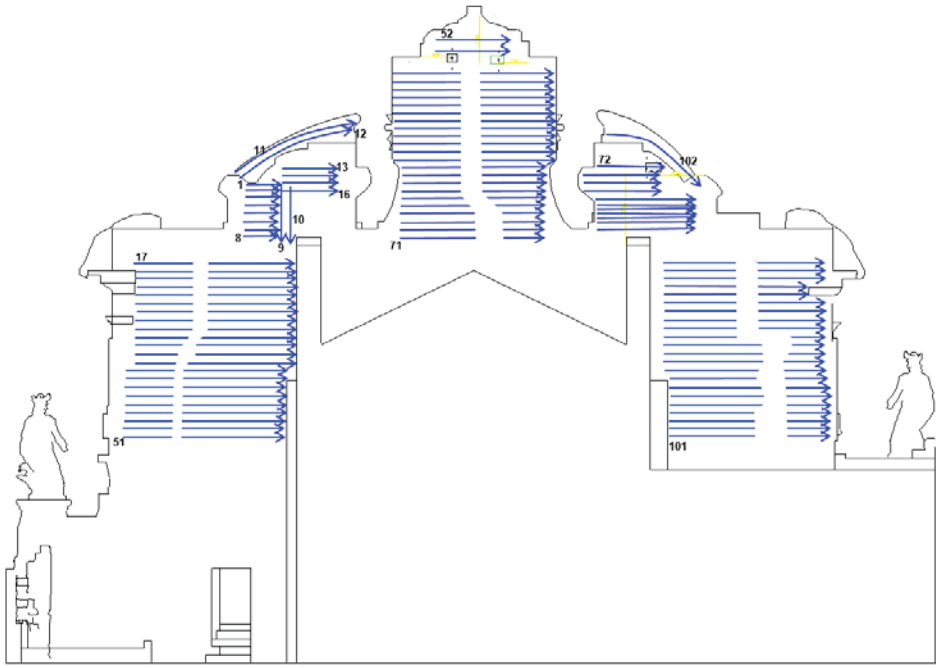

Fig. 3. location of GPR profiles

An example of the processing data result is shown in fig. 4.

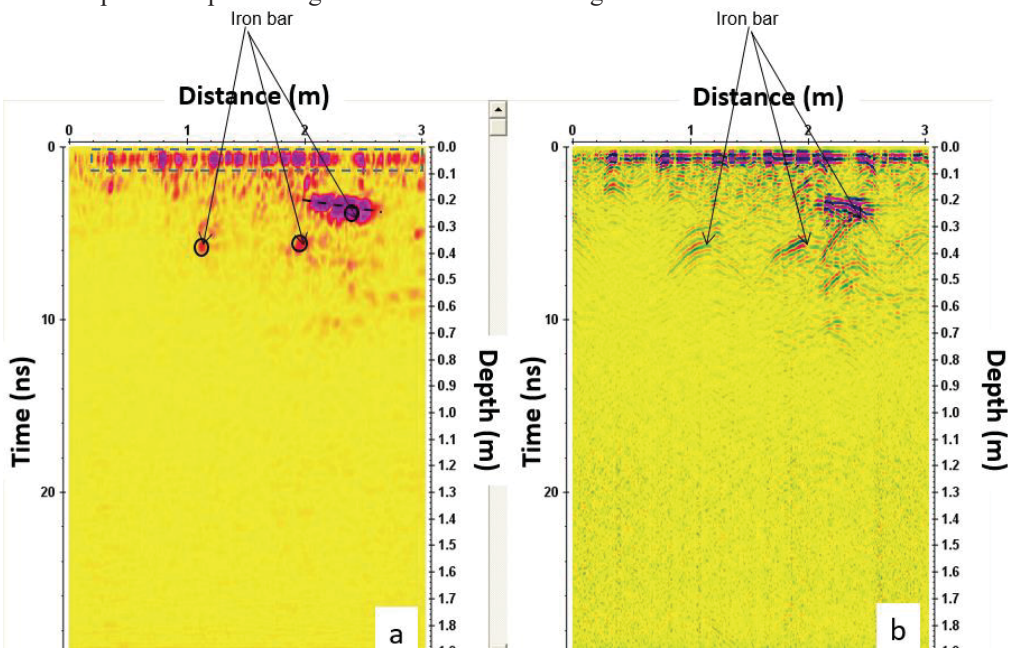

Fig. 4. the processed radar sections a) traces envelop; b) migrate

The data analysis (Fig. 5a) has evidenced the presence of some reflection events (inside the circle) related to the iron bars. The analysis by time slice shows the distribution of the iron bars (Fig. 5).

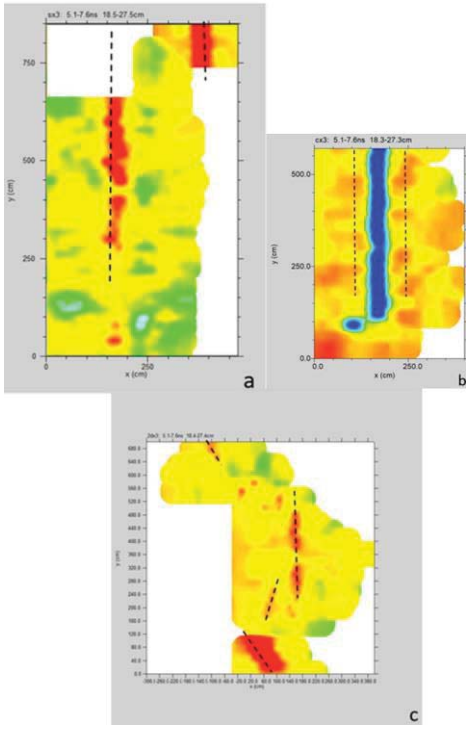

Fig. 5. Time slices 18-27cm: a) left side; b) central side; c) right side

Figure 5 evidence the iron bar positions (dark dashed lines). Particularly the Figure 5b clear evidence a low

amplitude (blue) anomaly, probably related to a fracture inside the wall. For the central side the iso volume analysis (Fig. 6) well evidence the two iron bars.

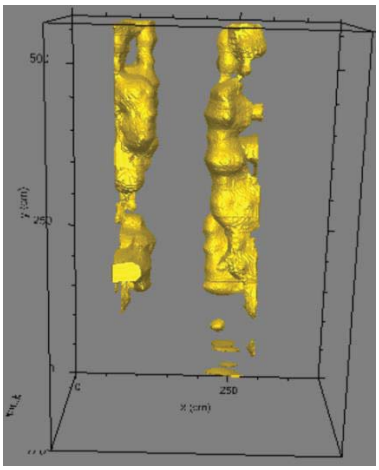

Fig. 6. The iso-surface amplitude visualization

Despite having used antennas with frequencies between 900 and 2000 MHz the spatial resolution was not always able to discriminate the presence or absence of iron bars inside the perforations. The density contrast existing between the different materials, such as stone, concrete / resin, iron, and the net of voids is not always sufficient to discriminate in the field the presence of voids, perforations with cement grout, or iron bars. The post-acquisition data processing was therefore fundamental, which allowed us to obtain satisfactory and useful results for the intended purpose. From these results and the direct observations (Fig. 7) it is clear that the declared location of the irons inserted in the structure, in the intervention carried out in the 80's, differs from the one actually found, not so much for the spatial distribution of the reinforcements as for their length.

Fig. 7. Photos of the excavation done after the results of geophysics

III. CONCLUSIONS

The GPR survey was used to reconstruct the presence of the iron bars inside the façade and to study its conservation state. GPR survey pointed out the presence of some anomalous zones that could be related with iron bars and highlight the poor state of conservation of some elements of the facade with the presence of gaps and fractures.

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