

Geophysical data acquisition for a non-invasive diagnosis at the Convitto Palmieri in Lecce

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Abstract – **The church of San Francesco della Scarpa is a church in the historic center of Lecce (south Italy) located inside at the Convitto Palmieri. The church has had static stability problems in recent years. In order to understand the causes, a series of findings have been undertaken with the use of integrated non destructive methodologies. Ground Penetrating Radar (GPR), seismic tomography (ST), were used. Results reveals the structural problems of the church.**

I. INTRODUCTION

Restoration is a multidisciplinary method aimed at preserving works of human creativity of recognised cultural value, including historical and aesthetic one, so as to extend its life. It must be rooted as much in historical research as in traditional maintenance practices, and consequently based on complete fusion of historical and technical-scientific expertise [1]. As regards architectural and built heritage, the restoration cannot be separated from the knowledge, conservation of the structural components in order to produce an accurate preventive diagnosis of static problems and, consequently, to suggest reinforcement interventions. These interventions must be designed to act on the causes of the problem and not only on the effects. Moreover, they must be not only effective but also compatible and, 'quite' reversible. To this aim non-invasive geophysical measurements were undertaken. With particular reference to the need to image cracks, deformations, structural failures, there are several applications and approaches published mostly in Europe. We cite for sake brevity only [2], who integrated microvawe tomography, GPR and seismic tomography with some direct data, provided by coring and endoscopic inspection, to detect, map and interpret cracks affecting the pillars of a church; [3]

studied a medieval rose window threatened by an out of plane instability phenomenon, detecting by GPR cracks and metallic connecting elements of the rose window construction elements; the integration of seismic tomography and GPR for the analysis of structural behaviour of the Cathedral of Mallorca by [4].

Despite the rich literature on non-invasive investigation methods applied to the study of static problems, there are few contributions aimed at characterizing these problems with an investigation strategy aimed at identifying the cause-effect mechanisms. This is the case of the baroque Church of S. Francesco della Scarpa in Lecce, affected by widespread cracking phenomena, not serious but difficult to understand from the point of view of the causes due to the lack of strongly connoted degradation patterns that generally help to identify the type of structural failure (crushing, push failure, foundation subsidence).

Therefore an integrated multi-imaging approach including (seismic tomography, GPR survey) has been adopted with the twofold aim: i) to characterize the structural alteration and degradation; ii) and to identify the cause-effect relationship.

II. STUDY AREA

The church, located in the historical centre of Lecce (Souther Italy) Fig. 1), was founded in the 12th century on the site of a noble palace, as attested by some epigraphs. It was rebuilt assuming the current Greek cross plan between the end of the 17th century and the first two decades of the 18th century. In the 19th century some works made in the colonnade of an adjacent building incorporated the main facade of the church into the new structures.



Figure 1: The San Francesco della Scarpa church

The Greek cross plant (probably originally was a Latin cross) is oriented along the NE-SW (main entrance axis) and NO-SE directions. The four arms of the cross (NE, SO, NO, SE) are characterized and embellished by two orders of Corinthian and Tuscan style pilasters and by four altars. Originally there were six other altars, then removed and placed in another church.

Between the years 2000 and 2005, the church underwent restoration interventions on both structural and historical-artistic aspects. After a few years some

problems of structural degradation have arisen, consisting of a widespread crack pattern on a load-bearing element placed at the intersection of the SO and SE arms of the Greek cross. The cracks that are found are 0.5-3.5 mm wide, mainly vertical and sub-vertical direction and 10-30 cm long which affect the base and the stone cladding of the pillar (Fig. 2).

The aim of the investigations was to make a diagnosis by identifying the causes of this failure and providing any indications on the methods of restorative intervention.

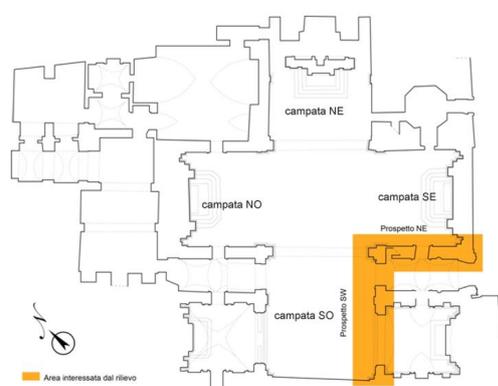


Figure 2. The area interested by structural problems

II. METHODOLOGICAL APPROACH

The objectives which the investigation methodology was based on, were the following:

- a) to detect, map and analyze deformations and cracks, in order to characterize and quantify the effects of the failure
- b) multitemporal monitoring of the cracks aimed at understanding if the failure was still active and to what extent or if it tended to achieve a balanced condition
- c) the geophysical exploration of the shallow subsoil and foundations to identify the possible presence of subsidence of foundations as the cause of the failure

To achieve these objectives, the following investigations were conducted :

1) Detection of inner cracks, characterization of building characteristics the right side of the former church affected by the structural instability, by means of georadar prospections performed with IDS pulsed GPR equipped with low frequency (200-600 MHz) and high frequency (900 MHz - 2 antennas) GHz).

2) Analysis of the stiffness characteristics and the state of degradation, detection of inhomogeneity and internal cracks in one of the pillars affected by fracturing phenomena, by means of ultrasonic speed measurements using multi-channel instrument for sonic and ultrasonic

measurements "TDAS" (frequency used 55 KHz).

3) Multitemporal monitoring of cracks and deformations through the installation of centesimal electronic crack meter

III RESULTS AND DISCUSSION

Integrated non invasive un situ investigations have been performed in order to characterize and identify the causes of a crack picture that mainly affects the southeast of the church and in particular a pillar located at the intersection of the South East and South West spans adjacent to a rampant staircase.

Starting from the visual informations, the geophysical prospections have been aimed at exploring and investigating 1 to 2 m of the subsoil order to detect the causes of the static instability. The radar profiles showed in the first meter the presence of significant disturbances to be related, probably, to structures of anthropogenic origin and linked to the renovation of the pavement. The distribution of the propagation speed of the electromagnetic wave was estimated on all the georadar profiles created inside the former church and, subsequently, through the use of the empirical relationship, the distribution of the volumetric content was estimated in water (Fig. 3).

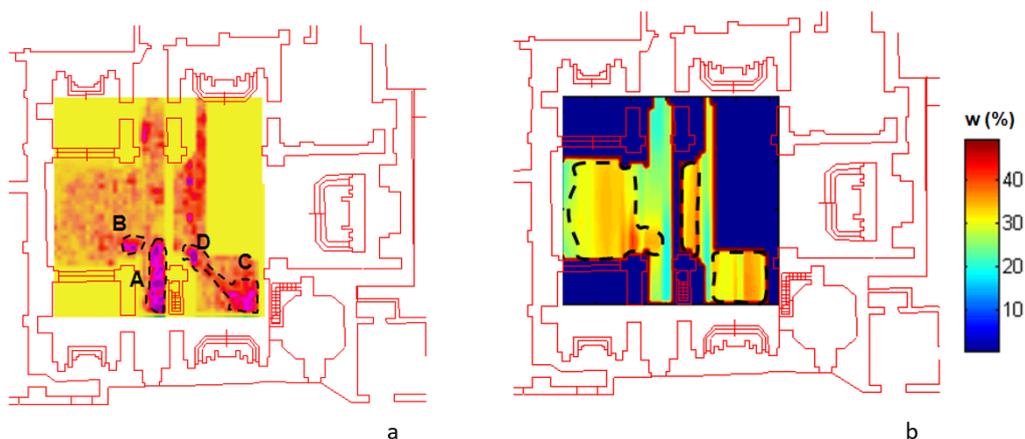


Figure 3 a) depth slice; b) volumetric water content map

From about 1.4m to over 2m radar profiles and time slices image the presence of cavities (fig. 3a), some of them close to the structure affected by instability phenomena. In correspondence with these cavities, the distribution of the volumetric content in water variable from 30 to 40% in the subsoil was estimated (fig. 3b). Seismic tomography prospectings, applied to the structures revealed the distribution of the seismic velocity

and allow to evidence the presence of weakened points. In the same structures, vertical seismic refraction tomography (fig. 4) detects very low speed values ($800 < V_p < 950$ m /) for thicknesses ranging from 25 to 40 cm. This suggests that the lesions, although characterized by small amplitudes, are not superficial but affect the entire coating and probably the interface between the coating and the bearing core of the pillar.

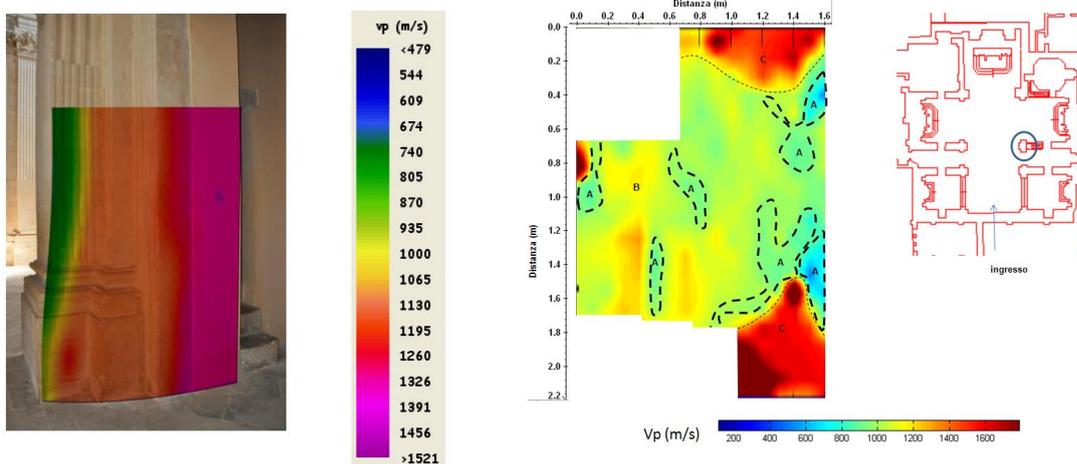


Figure 4. seismic tomography results

The anomaly in the dynamic behavior detected in the wall of the south east arm can be due to two possible causes: i) one is the presence of the rampart staircase which causes a drastic decrease in stiffness in the middle-

basal part of the wall, ii) the second is a non-uniform soil-structure interaction, as is observed by 3d seismic tomography (fig. 5) which highlights a non-homogeneous distribution of the propagation velocities of the P waves.

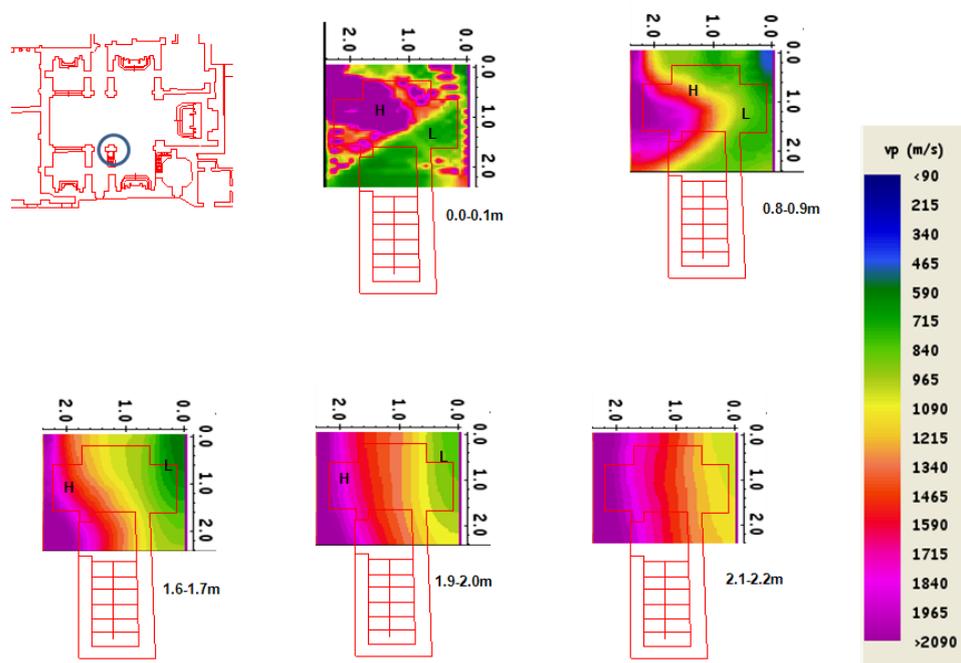


Figure 5. seismic wave velocity distribution at several depths

IV CONCLUSIONS

In relation to the results of the relevant campaigns carried out, it is possible to establish that the crack pattern mainly affects the pillar coating but also begins to extend towards the bearing core.

The presence near the pillar of cavities, of which a small part was known and in the remaining part was detected by the georadar (figure 3, in particular see anomalies A and D) may have played a decisive role in reversing the behavior dynamic of the masonry structure and in determining the anomalous distribution of the P waves in the foundation, from which, reasonably, the phenomenon of instability manifested itself with the cracking pictures of the pillar, placed at the intersection between the SE and SO arms of the Greek cross plant

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