A Multidisciplinary Study on the Roman Amphitheatre of Lecce, Southern Italy

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***Abstract*—In this contribution, a multidisciplinary investigation regarding the Roman Amphitheatre in Lecce, southern Italy, is be proposed. In particular, GPR prospecting combined to passive seismic measurements and with a virtual reconstruction of the monument allows deducing some important features of the monument, unknown before. In particular, this is a monument only partially brought to light, and part of it lies under the current Saint Oronzo's Square. We have investigated about the part still undiscovered of the amphitheatre.**

Keywords—GPR, Passive Seismic, Cultural Heritage

I. Introduction

The Roman amphitheatre in Lecce, southern Italy, dating back to the first or maybe the second century A.D., was a monument whose memory had been lost up to the beginning of the 20th century. Some work for the foundations of a building aimed to host an office of the National Bank of Italy brought casually to its discovery.

However, the town was already developed at the time of this discovery, and many buildings in the area of the amphitheatre were historical in their turn (some dating back to the renaissance and the baroque period) and could not be removed. So, it was decided to discover only part of the amphitheatre and to leave underground the remaining part. This can be well appreciated from figure 1, where an aerial vision of the monument is shown. In particular, under the steps, the *ambulacrum*, i.e. a corridor all around the area, was present. The ambulacrum was typical of any Roman amphitheatre (indeed the *ambulacra* could be even more than one). In the case of the amphitheatre of Lecce, nowadays an ambulacrum remains, partially developing under the steps and partially under the current Saint Oronzo's Square. Nowadays it is not any longer possible to run around the entire ring of the arena, because the ambulacrum is walled at a certain point. Consequently, a question arises whether under the square this ancient Roman corridor is still present or not.

In order to answer this question, we have conducted GPR investigations [1] in several places of the square and have compared them with a reconstruction of the map of the amphitheatre (and in particular of the ambulacrum) implemented through a three-dimensional virtual reconstruction achieved from laser scanner data. Then, we have taken also passive seismic measurements in several points were GPR investigations had been performed. On the base of the data, we deem probable that the ambulacrum partially continues beyond the part known to date, even if it is not much probable that the entire ancient ring is still today available.

II. 3D Survey of the Amphitheatre of Lecce

The town of Lecce represents an emblematic case of architectural stratification, because in its urban centre it hosts the remains of the monumental Roman amphitheatre, embedded in the urban tissue and only partially visible.

In spite of the evidences brought to light, it is impossible for the visitor or the tourist, to perceive the real size of the ancient building, both with regard to its map and its height. No didactic panel or didactical tool exist, to our knowledge, enabling at the moment the comprehension of the asset of this monument to the large public. The work done by IBAM-CNR allows, at least partially, to sill this gap. The survey performed within this study have enlightened not only structure in itself but also the ancient contest wherein the amphitheatre was inserted. The reconstructive proposal (partially illustrated in figure 2), based on laser scanner measurements and on photogrammetric image-based methodologies, has been aimed to create several outputs aimed to help the in situ visit and provide to the final user different possibility of reading both on-line and off-line. In particular, semi-AR device and stereoscopic narratives allow nowadays understanding the constructive-architectural characteristics not easy to understand from a direct visit, and above all, they allow to read the reconstructions of ancient contexts within current urban tissues. The laser scanning was made with a time-of-flight scanner Leica P20, with about 4 mm of mesh resolution. The photogrammetric restitution provided an extremely photorealistic representation, thanks to which it has been possible to study in detail the colour of the external surfaces (cracks, humidity, constructive details, etc.).

This work has also put into evidence the exigency of further investigations, only partially started, aimed to sustainable tourism and social inclusion issues. Future works will allow, among other things:

1. To track the complete morphology of the building contextualizing it within the ancient settlement;
2. To investigate the possible presence of any hydric leaks;

3. To map and record to conservation state of the structure;

These activities will be hopefully inserted within a wider multidisciplinary scientific project, that will also include study of the stone materials and archive investigations, aimed to address properly restoration works in view of an enhanced and better-devised exploitation of the monument. The integrated approach between the different disciplines will allow to study the monument both in the visible morphological aspects and in the parts hidden under the surface.

III. GPR Data

GPR data were taken in several places in the square. Here, we will show only those gathered on a rectangular area placed just beyond the visible part of the arena, as shown in figure 3. The image is superposed to the virtual reconstruction of the amphitheatre in order to allow a comparison (even if some small imprecision about the relative hanging of the two images is possible). The data were taken along parallel profiles each of which about 30 meters long, with a transect of 50 cm. The system exploited was a RIS-HI mode manufactured by IDS and equipped with a dual antenna at 200 and 600 MHz. Here, we will focus on the data at 200 MHz. The data have been processed [2] with zero timing, background removal, gain vs. depth, 1D filtering and migration in time domain. From the diffraction hyperbolas, the propagation velocity of the electromagnetic waves in the soil resulted to be about equal 0.07m/ns. Time slices have been gathered with an interval of 10 ns. In figure 3, the level of major interest for this paper is shown were the ambulacrum, if any, should be seen in the slice. This amount to 40 ns, about corresponding to 140 cm.

From figure 3, we appreciate that some spot is seen on the lower part of the image, were we know that the ambulacrum prolongs below the square. On the other hand, also some similar feature is visible on the opposite side, along the ideal elliptic prolongation of the ambulacrum beyond the accessible part. This makes us think of the possibility of the presence of a further piece of ambulacrum under the square. On the other hand, we do not perceive (either from the slices or from the B-scan) any clear evidence of a continuous anomaly suggesting the "closure of the ring". Therefore, we cannot infer the current completeness of the underlying ambulacrum, which is instead quite improbable. An anomaly similar to the lateral niches of the ambulacrum is seen too put into evidence with a dashed bent line. We interpret it of course as a further niche. Finally, two stronger anomalies appears too, put into evidence with two ellipses. It is difficult to clue what they could be precisely, even if it is possible that they are still structures related to the ancient amphitheatre.

IV. Passive Seismic Data

The use of passive seismic data and the HVSR method are common tools used for investigating geological structure in a non-invasive manner. They are also used to evaluate site effect investigations. The HVSR method is based on the ratio of the horizontal to vertical components of ground motion. It uses ambient noise vibrations and the ambient noise wavefield is the result of the combination of unknown fractions of both body and surface waves

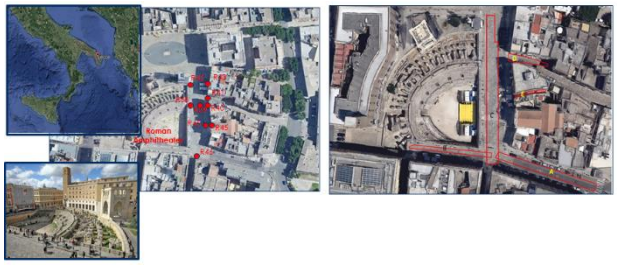

Figure 1: Location of the study area and location of the single station (HVSR) measurements for HVSR analysis (left) and Ground Penetrating Radar prospections

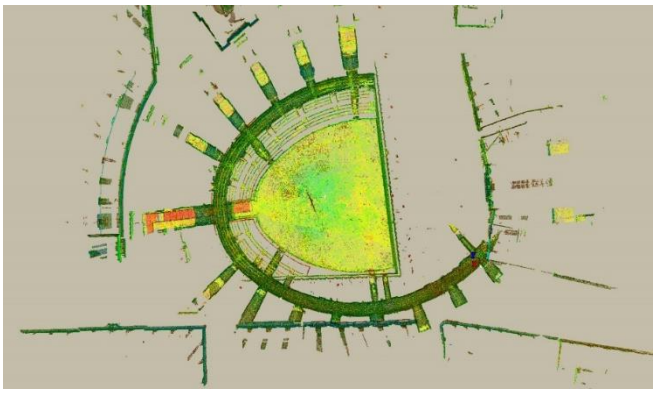

Figure 2: virtual reconstruction of the amphitheatre, ambulacrum included.

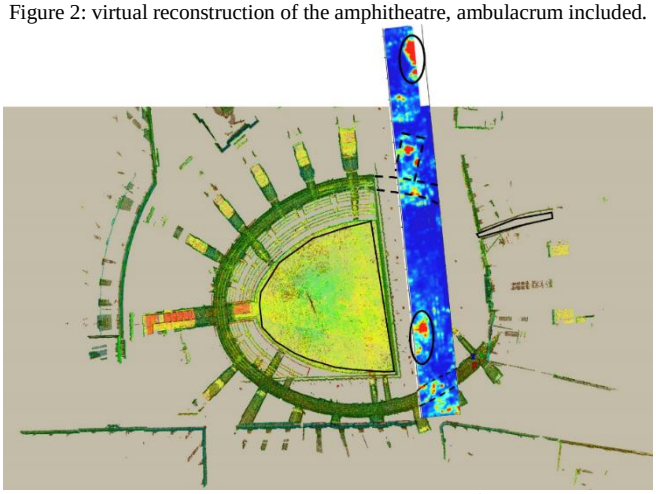

Figure 3: GPR data beyond the visible part of the arena

If the first are prevailing, the ratio is mainly induced by SH resonance in the superficial layers whereas; if Rayleigh surface waves predominate, the theoretical ellipticity dictates the observed curves. Although experimental data peaks usually fit quite well the resonance frequency of the theoretical curves, they are less reliable as regards their amplitude. Nevertheless, the HVSR curve contains valuable information about the underlying structures. We recorded ambient noise at several sites sites (Fig. 1) using a 3-component seismometer (Tromino, www.tromino.eu). Time series of ambient noise, having a length of 20 min, were recorded with a sampling rate of 256 Hz and, following the guidelines suggested by the SESAME project (2004), they were divided in different time windows of 20 s each not overlapping each other. A 5% cosine taper was applied to each window and the Fourier spectra were calculated. The spectra of each window were smoothed using a Konno–Ohmachi window [3] fixing the parameter b to 40. Finally, the resulting HVSR, in the frequency range 0.5–64.0 Hz, was

computed by estimating the logarithmic average of the spectral ratio obtained for each time window, selecting only the most stationary and excluding transients associated to very close sources. Preliminary results seem to agree with GPR anomalies and the high frequency peaks suggest the potential presence of buried structures which could be associated with the amphitheatre. The peaks at lower frequency could be associated with deep geological features. The results are to be considered preliminary and further investigation as well as numerical modelling are necessary.

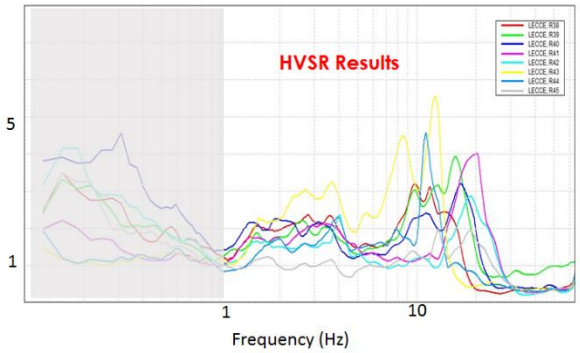

Figure 4; HVSR curves recorded near by the Roman Amphitheatre of Lecce

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