Sito archeologicodi Basta in Giordania. Individuazione tramite indagine con georadar

Vitruvio
International journal of Architecture Technology and Sustainability
Volume 4 Is 1

Engineering how support of archaeology. Instrumental and safeguard technologies for interdisciplinary integration.

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ABSTRACT

The paper sets in prominence the newfound cooperation between engineering and archaeology. This integration of knowledge is particularly useful in the development of preventive archaeology that allows targeted excavations with a considerable saving of resources and a widening of the possibilities for the protection of the cultural heritage. In many cases, the engineering reading of the ancient buildings reveals surprisingly good construction practices in seismic areas. Particularly, the architectures of archaeological sites shows a series of cases that meet the criteria of seismic assessment by combining the formal and functional aspects of space destruction to the static and dynamic behaviour of the construction.

KEYWORDS
preventive archaeology, engineering approach, non-destructive investigations, anti-seismic technologies

https://doi.org/10.4995/vitruvio-ijats.2019.11817

1. INTRODUCTION

For too long there has not been interdisciplinary cooperation between archaeology and building engineering. It seemed like there was an inviolable barrier that prevented engineers from making their contribution to archaeological science. According to the author, this state of affairs has depended, since the 1960s, on a "formation regression" with an excess of teachings based on numerical calculation that have been produced a cultural isolation of the engineer's figure. In addition, the engineer's training has been focused exclusively on the design of reinforced concrete structures, placing in "a cone of shadow" we can say the knowledge of ancient masonry buildings that had characterized previous teachings in the engineering field.. In this regard, the evaluation of the entire cultural path - from the Middle Ages to the creation of the École des Ponts et Chaussées in the Napoleonic era, passing through Leonardo and Galileo - that have been led to the foundations of the current engineering schools is particularly enlightening. This analysis indicates the great contribution that the engineer field can express for the archaeological sector in order to achieve an integrative approach into the cultural heritage conservation. This paper describes an already started path of cooperation, which includes not destructive investigations with the relative interpretations for targeted excavations. Moreover, the work illustrates another innovative cooperation path, which is the interpretation of classical antiquity buildings as a product of anti-seismic technologies.

2. ENGINEERING FOR PREVENTIVE ARCHAEOLOGY

The first great novelty in the combination of archaeology and engineering is the use of non-destructive investigations. They are non-invasive techniques that do not alter the nature of the buried anthropic deposit, they are able to adapt and investigate in every type of research environment and return very detailed results, reliable and accurate in a short time with a significant "optimization" of energies and budget (Cozzolino, 2009). Their use presupposes a delicate multidisciplinary work, including the integration of humanistic and scientific expertise that demonstrates how it is wrong to consider a culture subdivided into sectors. This is the way to make visible what is submerged.

Preventive archaeology has become a real sector of archaeology. In Italy, it has not yet been configured as a real discipline despite the many important results obtained by synergy between engineers, geophysicists and archaeologists. The path of cooperation is well underway abroad. In France, a public research institute "Institut National de Recherches Archéologiques Préventives (INRAP)" has been found in 2002 by the Ministry of Culture and Communication and the Ministry of Research. Its task is to proceed to the localization and study of the archaeological sites as well as to operate for the diffusion and the valorisation of the archaeology. Similarly, a specific legislation on preventive archaeology has been issued in England, which has resulted in a significant increase in archaeological data included in the Spectrum and MIDAS information systems.

The first geophysical applications go back to the 30s and 40s of the twentieth century, although there are applications starting from the nineteenth century. These investigations are based on the electrical characteristics of the ground. In 1946, Richard Atkinson investigated the neolithic site of Dorchester and John Martin with Anthony Clark the Roman city of Cunetio (Wiltshire). Over the time, the results of such prospections have become increasingly important. In 1954, the Polytechnic of Milan under

the coordination of Richard Linington has founded the Section for Archaeological Exploration of the Lerici Foundation. It is a European reference point for geophysical surveys applied to archaeology. The same foundation in 1966 inaugurated the magazine «Archaeological prospections». Obviously, the great successes achieved in the field are closely linked to the processing of the acquired data, as well as to the innovations of the raw data filtering systems such as that one of Irwin Scollar in 1958. In addition to geoleptric surveys, other methods has been introduced and used from the mid-90s. Martin Aitken and Edward Hall, creators of a prototype proton magnetometer, carried out some tests in the Roman city of Durobrivae (Northamptonshire). Ralph of the University of Pennsylvania experimented the first magnetometer in radiometric configuration near the ancient city of Sibari. John Alldred designs the fluxgate gradiometer. In 1967, John musty established the Geophysics Section of the Ancient Monuments Laboratory focusing on the study of the innovative multi-probe system for geoeleptric surveys and the production of more manageable equipment that required use of a single operator (Boschi, 2009).
From a technical point of view, the methods used aredivided between active and passive investigations. In the latter case, the equipment picks up signals originating from natural sources, including magnetic, gravimetric, thermographic and spontaneous potentials. The active methods, instead, send a signal in the subsoil and evaluate the modifications undergoing during the course. Both the above-mentioned methods are based on the principle that an object present in the subsoil impresses its image, not for itself, but for the effects produced by certain elements that surrounding and hiding it (Bianchini, 2008).

2.1 PRINCIPLES FOR METHODOLOGICAL CHOICE. THE ROLE OF ENGINEERS

All not-destructive investigations are based on the properties of both materials and construction technologies according the methodological approach of the engineers specialized in technical architecture. They interpret the characteristics and properties of the building in function of both the single materials and the construction technologies that assemble materials into a single system. The choice of the most appropriate method requires a sound knowledge of the area in which the presumed archaeological element is buried, as well as factors such as the interference produced by the infrastructure of built-up areas. In the preliminary phase, it is also fundamental the planning of the measures, both from a technical-scientific point of view and logistic, an accurate and careful study of the surveyed maps and bibliographic and archiving investigation on the cultural heritage of the territory.
The active method more suitable for the purposes of Technical architecture is the geoeleptric survey used by the 60's of the last century. Even though it has longer data acquisition times, it provides results that are easy to interpret. Moreover, it is very versatile to variations of soil conditions and allows the detection of even very deep structures. The technique is based on the electrical resistivity that is the resistance that each body opposes to the passage of electric current. The subsoil due to presence of moisture is a good conductor of electricity, while the stone structures (remains of foundations of buildings, walls, streets or voids referred to tombs) have insulating properties. In this way, buried geometries can be easily identified according to the physical parameter that indicates such behaviour (Camarano, Mauriello, Patella, Piro, 1997). The resulting vertical and horizontal sections (topographies) allow the creation of three-dimensional models that facilitate the identification of the location of the main detected anomalies (figure 1,2)[1] collected in time-slice. The low variations of amplitudes, reflected by the ground, indicate the presence of homogeneous material. The high ones, the useful ones, indicate the presence of buried

objects[2]. Variations in amplitude in time-slices are combined with a chromatic scale in shades of grey or colour that makes it easier to read anomalies. These anomalies are "translated" into construction systems by engineers who read the way they are assembled in a preventative and useful way for the investigation of archaeologists.
The seismic method, among the active ones, is decidedly less reliable in the archaeological field for the very limited times of interference between the provoked signal and the anthropic structure. It measures the propagation in the subsoil of artificial seismic waves generated by a source: the perturbation is propagated in the ground with a velocity proportional to its elastic characteristics.The active method most used by archaeologists is the Ground Penetrating Radar (GPR)[3]. It allows mapping accurately the spatial extension of structures and

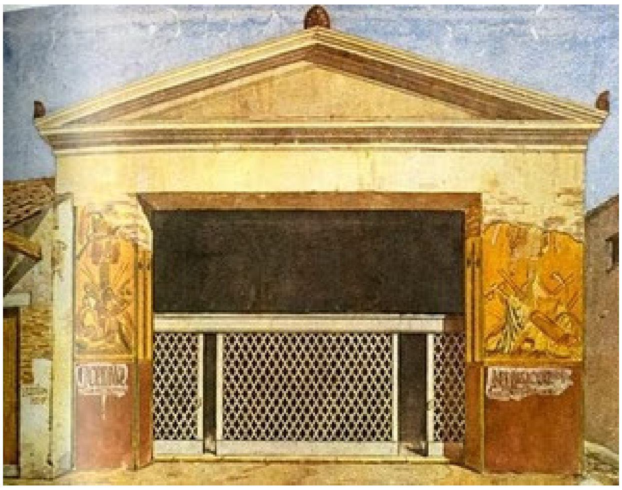

Figure 3.
Archaeological site of Pompei. Schola Armaturarum. Reconstruction.

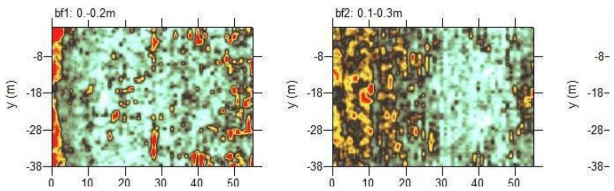

Figure 1.
Time-slices

Figure 4.
Archaeological site of Pompei. Schola Armaturarum after the collapse.

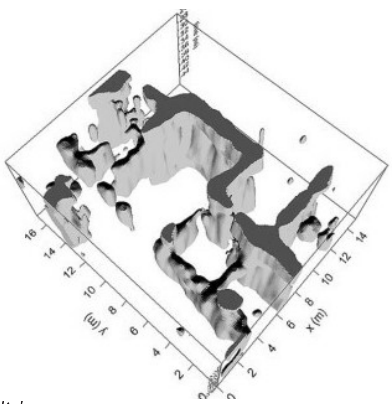

Figure 2.
View of 3D solid

archaeological sites at depths ranging from a few tens of centimetres to a few meters (Goodman, 1994). Moreover, the GPR equipment is easy to carry and easy to handle. The GP system sends electromagnetic pulses in the ground through a transmitting antenna with frequencies between about 10 and 2000 MHz. The frequency of the electromagnetic return signal, captured by a surface receiving antenna, changes according to the different materials present in the subsoil (Conyers, 2004). On the indication of the archaeologist, the frequency of the antenna is varied according to the depth and dimensions of the structure under investigation. There are some important limitations, which can be summarized in the following points:

- the topographical surface of the ground and vegetation;
- the ground moisture;
- the depth of burial of objects and masonry structures.

Figure 5.
Archaeological site of Pompei. Schola armaturarum. Detail of the collapsed masonry.

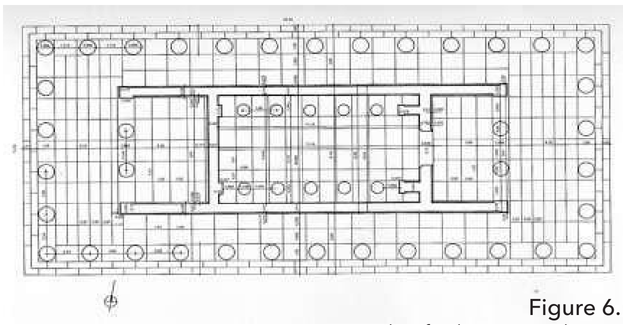

Figure 6.
Temple of Athena in Makistos.

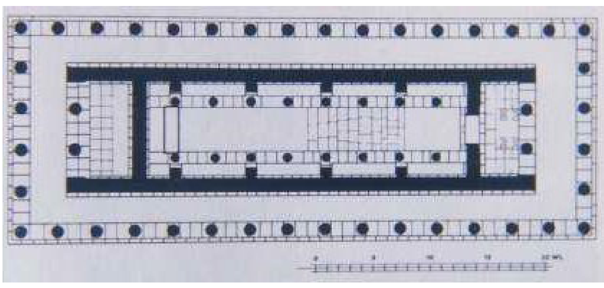

Figure 7.
Temple of Hera in Olimpia.

3. SEISMIC PROTECTION OF ARCHAEOLOGICAL SITES

The seismic risk is defined by factors such as dangerousness, vulnerability and exposure. The first is a technical parameter related to the probability of an earthquake of varying magnitude. The second one evaluates the possibility that a building will be damaged or destroyed. The third factor is linked to the amount and value of cultural heritage that can be lost as a result of an earthquake. The normal interventions that the engineering uses in order to reduce the seismic risk are not able for the conservation of archaeological sites. These interventions provide for the insertion of complex dissipative mechanisms into a sound structural frame. The extreme weakness of the archaeological site masonry would require a pre-consolidation of masonry. Actually, the presence of artistic parts prevents this type of intervention. In the last years, the site of Pompeii is seriously subjected to damaged, testified by the numerous collapses related to the action of both dynamic and static forces. The

Schola Armaturarum has been completely destroyed, also due to a dated, wrong, and invasive consolidation intervention that demonstrates the ineffectiveness of the consolidation methods into archaeological sites (figures 3,4,5).
It must also be said how it is evident the contribution of engineering to archaeology as an essential factor both from the scientific and economic point of view.
The masonry interpretations on the basis of not-destructive surveys and the related engineering considerations clearly indicate the way to be pursued in the field of preventive archaeology.
In addition, their applications can provide interesting explanations about the construction methods in the classical era. The cognitive approach provided by the field of engineering in the study of archaeological constructions shows that some solutions have been adopted with the aim of having a good seismic behaviour of the ancient construction in the Mediterranean geographical areas, frequently affected by earthquakes. The findings of ancient structures have shown masonry having a considerable thickness and wooden panels and beams. In addition, many factors, such as the symmetry of the plan, the presence of foundation grids, the regularity of the structure in elevation with longitudinal and transverse walls, the low eccentricity of the loads, testify an anti-seismic design of the buildings of the classic period that met only functional and compositional criteria. The symmetry in plan, as in the case temple of Athena in Makistos (figure 6), has a decisive role in the response to the dynamic actions of earthquakes.
In the same way, the compactness of the structural organization of the temple of Hera with the cell and the colonnade close together (figure 7) or the presence of transverse walls having a thickness event greater than the longitudinal ones of Temple C of Selinunte (figure 8) are other important testimonies of the anti-seismic design of archaeological sites.
Another technological detail useful to improve the seismic behaviour of ancient constructions is the connection of the stone elements with grips or with refined surfaces technique such as in the shaped blocks detectable in the Valley of the Temples in Agrigento (figure 9).

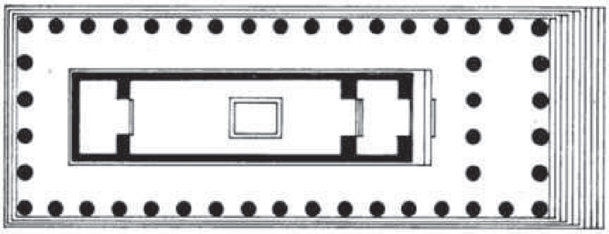

Figure 8.
Temple C in Selinunte.

Figure 9.
Agrigento, Valley of the temples

Figure 10.
Iran. Cyrus the Great's tomb.

Finally, it should be highlighted that the the first seismic isolation technique dates back to 2500 years ago. According to Plinio Il Vecchio, the Temple of Artemis at Ephesus was built on a soft ground that was recovered with a layer of coal and fleeces in order to protect the construction from earthquakes[4]. In the same way, the Greek temple stands can be read as possible insulators separating the foundation soil and elevation structure. This interpretative possibility can be found in another area with very high historical seismicity such as Iran (figure 10).
The innovation in the engineering field has given in recent years a significant contribution to the preservation of the archaeological heritage with the development of satellite monitoring systems and innovative devices for remote control of horizontal and vertical movements of structures.

NOTES

1. The figures are taken from the doctoral thesis "Integration of geophysical surveys, satellite data and 3D survey techniques at the archaeological site of Egnazia (BR)" of which the author has been a tutor. PhD by Vincenzo Gentile.
2. The data obtained by a geoelectric survey are analyzed by mathematical theories related to the physical conditions determining the measured data. To create an Electrical Resistivity Tomography (ERT) it is necessary to have at disposal the greater number of data concerning the apparent resistivity of the subsurface with which is carried out a combined inversion of all the single tests using an algorithm in order to characterize the smallest differences existing in the acquired parameters. A two-dimensional ERT tomography can be obtained from inversion of an apparent resistivity data set. If a set of parallel profiles is assembled, the inversion of the entire apparent resistivity data set provides a 3D ERT.
3. The first applications took place in the study of the lunar ground but later it was used for the localization of cavities, pipes, tunnels, lithological contacts. In 1975, it was tested for the first time in the archaeological field for the purpose of identifying masonry structures located at depths greater than 1,00 m. These studies conducted in the city of Chaco Canyon (New Mexico) were followed by researcher activities of Peter Fisher at the site of Hala Sultan Tekke in Cyprus), Payson Sheets in El Salvador (at the site of Ceren) and Trudy Vaughan in in Canada (in Red Bay Labrador). The most successful exploration was that one of 1993 conducted in Japan by Dean Goodman, who had the intent to map the houses and burial mounds. Obviously, the success of GPR applications is linked to the progressive development of data acquisition and processing techniques. In this regard, we remember the contributions of Lawrence B. Conyers, Jeffrey Lucius and Dean Goodman, thanks to which today we can talk about time-slice and 3D reconstructions of the buried reality.
4. ...*Graece magnificentiae vera admiratio exstat templum Ephesiae Dianae CXX annis factum a tota Asia. in solo id palustri fecere, ne terrae motus sentiret aut hiatus timeret rursus ne in lubrico atque instabili fundamenta tantae molis locarentur, calcatis ea substravere carbonibus, dein velleribus lanae…* (Plinius, Naturalis Historia).

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