

# A multidisciplinary approach to the safety assessment of the archaeological site of Pietrabbondante

Evelina Volpe<sup>1</sup>, Adriana Marra<sup>2</sup>, Adriano La Regina<sup>3</sup>, Giovanni Fabbrocino<sup>1</sup>

<sup>1</sup> *Dipartimento di Bioscienze e Territorio - Università degli Studi del Molise, Via F. De Sanctis-86100 Campobasso (CB), [e.volpe@studenti.unimol.it](mailto:e.volpe@studenti.unimol.it), [giovanni.fabbrocino@unimol.it](mailto:giovanni.fabbrocino@unimol.it)*

<sup>2</sup> *Consiglio Nazionale delle Ricerche, Istituto per le Tecnologie della Costruzione, Via G. Carducci, 32 – 67100 L'Aquila (AQ), [adrianamarra.am@gmail.com](mailto:adrianamarra.am@gmail.com)*

<sup>3</sup> *Istituto Nazionale di Archeologia e Storia dell'Arte, [adrianolaregina@gmail.com](mailto:adrianolaregina@gmail.com)*

**Abstract** – In recent decades, the need of preserving the cultural heritage is becoming very relevant due to an increase in frequency and in intensity of extreme natural events, which have recalled major attention by the Authorities on natural hazards associated.

An important role, in the field of safeguard cultural heritage, is developed by structural and materials engineering. These disciplines conduct an essential role in the definition of risk and in the identification of interventions and technologies that can be used respecting the cultural value of asset. However, archaeological assets are constantly exposed to natural deterioration, human impact and a lot of different agents able to compromise their preservation. The cultural heritage, and the archaeological site are exposed to multiple types of vulnerabilities that involve different disciplines. For this reason, to ensure the preservation of cultural heritage in the time, an interdisciplinary approach is required.

In this paper, a multidisciplinary engineering approach is used for the archaeological site of Pietrabbondante; the issue of preservation of cultural heritage will be examined with reference to the environmental context where the site is located.

## I. INTRODUCTION

Italy represents a country characterized by an extensive presence of cultural heritage made of different types of assets. In fact, in according to data published by UNESCO, the 70% of cultural universal heritage is located in Italian country [1].

However, cultural assets, and in particular archaeological sites, are constantly exposed to agents able to compromise their preservation; a lot of Italian archaeological sites are subjected to geological and geomorphological issues.

Natural hazards represent today, an important problem which requires an improvement in the adaptation strategies and in the mitigation of risk for all vulnerable elements through a multidisciplinary approach [2].

Similar methodologies, validated at National and International level, are used not only in the restoration field [3] but also in the seismic vulnerability assessment of historical buildings [4].

In the following, some aspects related to the safety and preservation of archaeological assets are reviewed in order to point out the need of an effective and reliable assessment process based on the connected action of different skills. An overview of established National and International rules and guidelines is provided and discussed in the light of preliminary outcomes of the study conducted for the Sannitic Archeological area of Pietrabbondante, a country located in Molise Region (Figure 1).

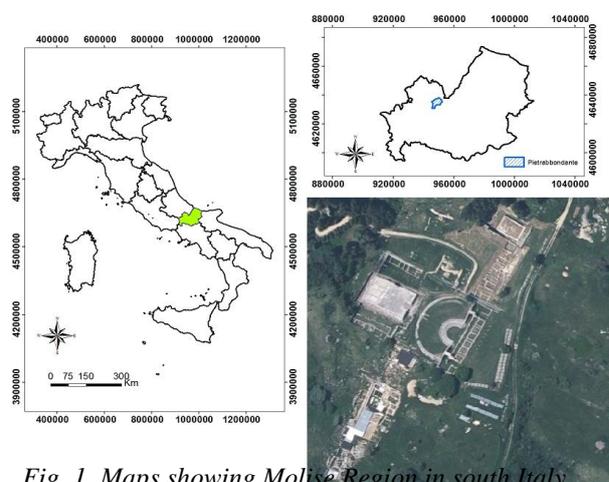


Fig. 1. Maps showing Molise Region in south Italy and the location of study area.

With reference to Sannitic Sanctuary of Pietrabbondante, the role of geotechnical and structural engineering is highlighted in relationship to conservation and safeguard of this historic site.

## II. SAFETY AND PRESERVATION OF HERITAGE ASSETS, AN OVERVIEW

The cultural heritage is represented by movable and immovable assets, characterized by an artistic, historical, archaeological interest, or in other word from all those assets that are proof with value of civilization. In particular, archaeological assets are all artefacts realized “at a certain stage historically completed of human civilization” [5] undergone processes of alteration and fragmentation processes. Due to the time they appear modified respect their original conformation.

The archaeological heritage, as well as the cultural heritage in general, must be protected and enhanced in order to preserve the memory of the national community and to promote the development of culture [6]. However, theirs conservation isn't an elementary activity; the correct protection of cultural heritage requires the realization of complex and specialized projects that involved different knowledge.

In the past, the methodological contrast between historical and technical requirements has led to the realization of improper interventions, as constructions of structures or use of materials, not respectful of assets value. In order to protect the cultural heritage from destruction and alteration, principles and prescriptions have been elaborated, codified and incorporated into a series of documents aimed at guiding the interventions and the methodological approach to be followed for these artefacts.

The interest in archaeological assets is already evident in the Athens Charter (1931) that can be defined as the first restoration Charter. From a technical point of view, the use of modern materials for consolidation, particularly that of reinforced concrete, is admissible, while in the case of archaeological restoration only anastylosis is allowed. “[...] when it comes to ruins, but scrupulous conservation is necessary, and when conditions allow it, is well-chosen to replace the original found elements (anastylosis); and the new materials needed for this purpose must always be recognizable. When, however, the preservation of ruins brought to light in the course of excavations was recognized as impossible, it would be advisable, instead of destroying them, to bury again, afterwards, obviously, to have taken specific surveys. It is clear that the technique of excavation and the preservation of the ruins impose close collaboration between the archaeologist and the architect. As for the other monuments, the experts, acknowledging that each case presents a special character, agreed to advise, prior to any consolidation or

*partial restoration, a scrupulous investigation of the damages that need to be repaired*”, point IV of the Athens Charter.

In the following years, the scientific community continued to research the correct practices for the restoration and in 1964 the Venice Charter have been elaborated. It summarizes the principles that can be considered immutable in the methodology of restoration. The fundamental point of the paper is the second Article where, for the first time, the interdisciplinarity of the restoration project is affirmed: “*The conservation and restoration of monuments must have recourse to all the sciences and techniques which can contribute to the study and safeguarding of the architectural heritage*”.

For archaeological heritage, only the reconstruction of dismembered parts (anastylosis) is considered acceptable; the integration elements are minimized in order to make them recognizable. “*The excavation work is to be performed in accordance with scientific standards and the ‘Recommendations that defines the international principles to be applied in the field of archaeological excavations’, adopted by UNESCO in 1956. It will be ensured the use of the ruins and the measures necessary for the conservation and the stable protection of architectural artefacts and objects found. All initiatives that can facilitate the understanding of the monument discovered will also be taken, without ever distorting their meanings. It should be excluded a priori any reconstruction work, while it is only to be considered acceptable anastylosis, i.e. the reassembling of existing but dismembered parts. The elements of integration should always be recognizable, and limited to the minimum that will be necessary to ensure the conservation of the monument and restore the continuity of its forms*”, Venice Charter, article 15.

The interdisciplinary approach, therefore, begins to be contemplated in the context of restoration and conservation, but too often this method has been disregarded, especially when the other variables that make the historical heritage vulnerable are considered. In the field of the protection and safeguarding of cultural heritage to reducing the seismic risk, the task of scientific community has not been negligible. The technical-scientific community and the technical regulations have tried to promote the correct actions for the protection of historical built.

Following the seismic events of the 1970s and 1980s, the National Committee for the Prevention of Cultural Heritage from Seismic Risk, established by the Ministry for Cultural and Environmental Heritage and the Department for Civil Protection, a new cultural approach has promoted. It is explained with the definition of the: “Recommendations for interventions on the monumental heritage of a specialist type in seismic zones” (1986), and in 1989, the “Guidelines for the drafting and execution of restoration projects involving anti-seismic improvement

and maintenance in the architectural complexes with historical-artistic value". In these first notes, the insufficient of proper normative and methodological reference for the historical heritage are underlined. Anti-seismic improvement is seen as the aim to be pursued, in fact the interventions "*must be characterized by an increase in security against seismic actions without, however, rigidly respect the assessment against seismic project actions planned for new buildings*" [7]. In the 1989 Directive a complete paragraph is dedicated to interventions concerning the archaeological heritage, as these have particular aspects that distinguish them from the interventions on built heritage in general. In the same paragraph, it is also underlined that the levels of exposure of users to the risk are much lower. Actually, although the seismic risk of this type of assets is limited compared to people, the vulnerability of archaeological heritage is significant if all the structural and natural factors involved in the damage to the artefacts are considered.

The application of these recommendations has often been disregarded and new and efficient documents were drawn up only in 2007 with the publication of the "Guidelines for the assessment and reduction of seismic risk of the cultural heritage". No explicit reference to the archaeological assets are contained in this work; for this reason, in 2010, along with the update of the aforementioned Guidelines, the "Guidelines for the preservation of the archaeological heritage" have been issued. This document is a methodological guideline for the design and execution of structural intervention for the archaeological heritage.

It underlines the need to protect archaeological artefacts not only against seismic risk, but also from all the other risk factors derived from material degradation, hydrological phenomena, meteorological and climatic conditions and degradation factor caused by man.

The multidisciplinary approach is required, different knowledges are involved to ensure the survival of cultural heritage over the time.

The basis of any choice to be made must be the knowledge of the structure. The causes that led the artefact to assume its current configuration must be known.

Very important is the knowledge of the properties of the structures and the causes that led the artefacts to assume the actual conformation. The archaeological artefacts must be known from all points of view, both from a morphological-dimensional, without neglecting the forms of previous damage and the transformations that have contributed to modify the stress state, both from the material point of view, to determine correctly the resistance of the materials, using in situ or laboratory tests, preferring weak-destructive testing.

No less important results the knowledge about the site where the artefact is located. Geological and geomorphological characteristics of the area induce,

through superficial or deep movements, the structure deformations. It is also important to know the frequency and magnitude of natural events which have occurred in the past; the acquisition of this information allows to evaluate the degree of exposure of cultural heritage by natural hazards.

In order to define a multidisciplinary approach that is able to protect and safeguard the cultural heritage, increasing the security of users and decreasing the deterioration of the monuments, it is necessary that all information acquired and all the scientific experiences conducted are shared.

In this paper, an interdisciplinary and engineering approach is used for the archaeological site of Pietrabbondante; the issue of preservation of cultural heritage will be examined with reference to the environmental context where the site is located.

### III. ARCHAEOLOGICAL SITE OF PIETRABBONDANTE

The archaeological site of Pietrabbondante represents an important evidence of the people and culture of Sanniti and their ability to build monumental architecture [8]; the site is located 1000 m above sea level in the present Pietrabbondante municipality in South Italy.

The development of the site covers a long period ranging from the 4th up to the beginning of the 1st century B.C.

In the 2nd century A.C., the alluvial soils covered completely the monument [9]; excavation activities, conducted in different phases, allow today to admire important structures out-of-ground, located in an extensive sacred area of seven hectares (Figure 2).

The interest for this magnificent archaeological site was confirmed in the nineteenth century by the Bourbon excavation campaigns; from which an important theatre and a temple (called A), the minor one, were discovered. Only with the investigations started in 1959, which led to discovery of the great temple (called B), the historical events related to the site could be understood, as well as the importance of this site from its construction to its decadence (the decline began in the Augustan era).

Between 4th and the 1st century B.C. the Sanctuary of Pietrabbondante represented the main centre of public religiosity for the Sanniti Pentri [10]. Destroyed during the war against Annibale, the recovery of building activities began at the end of Second Punic War with temple A construction (2nd century B.C) and temple-theatre construction (at the end of the 2nd century).

New excavation campaigns, conducted since 2002 allowed to identify the *domus publica* construction [11], a building destined to sacerdotal activity.

Wonderful discoveries continue to be done, revealing a "place of mind and soul" much wider than previously estimated [12].

In the following paragraph, for the most important structures of Pietrabbondante site, a more detailed description will be provided.



Fig. 2. Archaeological site of Pietrabbondante

#### A Current configuration and state of the monuments

Numerous and different objects have been found in the archaeological area, as sacred statues, coins, religious inscriptions; however the most important structures of the monumental complex, result: i) Theater and Temple B, located in the center of the archaeological site; ii) Temple A, located on the north side of area; iii) the *domus publica*, located in southwest area of the complex Theatre and Great Temple B.

The Theater structure (Figure 3) uses the natural incline of the slope and it presents obvious affinities with Pompeii's Great Theater [13] for the planimetry layout, and with the *odeon* construction, for plastic and architectural decoration. An external polygonal wall, composed by large blocks, encloses the cavea; it is constituted, at the top, by six sections with a double row of seats, while at the bottom, three rows of stone seats are present.

The classic Hellenistic planimetry, characterized by a rectilinear facade and a division of the building into six environments with a perimetric corridor, is visible in the proscenium.

Temple A, built on a monumental terrace, stands on a podium with four frontal columns and a single inner chamber; the maximum size of the area 27,5m x 18m. The Temple A evolves on a podium, composed by a unique cell with pronaos. An *ambulacro*, located into a polygonal wall, surrounded the construction.

Insufficient information are available to define the monument era; the inscriptions discovered date back to the end of social war. The typology of this construction is reflected in the Sannita environment of the I century BC.

Temple B evolves on a tall podium constituted by triple cell. Inside, a rectangular enclosure, bounded by porticoes and preceded by the terrace with the altars are located. A stairway, erected into the podium, allows the access to the monument. The discovery of citation, in osca language, suggested that the monument was

dedicated to Vittoria. Different elements of Doric frieze are present.

The *domus publica*, realized at the end of 2nd century B.C. and at the beginning of 1st century BC, is located on a large terrace, where a lot of ruins are presented. The building had the function of hosting priests, judges and ambassadors and constitutes an example of house model at atrium and impluvium, extends over an area of 45.75 to 20.45 m.

The *domus* is constituted by the presence of a linear porch, with two aisles for votive offerings (*stoa*) and for the priestly curia, a large room used as a place for meetings and banquet hall.

The outer nave, made up of 8 columns, opens onto a still little explored space [14]; at the center of the colonnade, a reservoir is presented; its ritual function is still uncertain. After the abandonment of the sanctuary, in the Augustan era, the construction was assigned to the *Socellia* community, who settled in the *domus*, adapting it to their needs, by creating, for example, a bath (*thermae*) and an outdoor area facility, the latter dedicated to manufacturing as evidenced by the presence of furnaces and workshops for the melting of metals. The use of this area is documented until the first half of the fourth century A.D [15].



Fig. 3. Theater of Pietrabbondante

#### B Preliminary geotechnical and structural analysis

The Sanctuary of Pietrabbondante is located on an extremely vulnerable area. In according to the classification provided by OPCM n. 3274/2003, updated with the Resolution of the Regional Council of Molise of 2 August 2006 n. 1171, the area is classified as zone 2. The area was damage by a violent earthquake, probably in 346 A.C., after which many buildings were destroyed, and the area was abandoned. However, in the actual state, the historiography argues that the phenomenon of hydrogeological instability represent the principal cause of site deterioration. Conditions of instability, implicated by low mechanical properties of the soils, are aggravated by presence of runoff phenomena (see Figure 4); the erosive actions are triggered by intense and prolonged

rainfall events.

The geotechnical site excavation campaigns [16], conducted in 2007, confirmed the presence of fine grained superficial soil, side-by-side with deposits of limestone characterized by a thick of 10 cm. The soil cover type is constituted mainly by silt and clay, characterized by low values of strength parameters (cohesion  $c'$  and friction angle  $\phi'$ ).

In addition, the area is characterized by copious events in the winter-spring semester, and in relation to the high elevation on the sea level, it undergoes to long snowy periods.



Fig. 4. View of the archaeological site in 1873 [17].

Tangible signs of alteration are visible in the historic constructions; in particular on the *domus* colonnade (see Figure 5). The columns of central nave have lost their original alignment due to ground surface movements and differential land subsidence phenomenon at the base of the pillars. In this area, subjected by new excavation campaign in 2006, a continuous visco-plastic deformation is in progress; it involving considerable soil thicknesses; the deformation movement showed a greater activity, a lot of deformation have been observed in excavation faces and in the archaeological remains.

In addition, the natural conformation of the Theatre seats is threatened by not insignificant soil pressure, as can be seen from the Figure 6 a, a lot of instability phenomena are visible in the area.

For example, Figure 6 b shows the actual state of a stone wall located in the northern part of archeological site.

Hydrogeological instability phenomenon, characterized by slow movements, have created considerable deformations in the *domus* areas and in the Sanctuary.



Fig. 5. Current state of colonnade, located in front of *Domus Publica* construction



Fig. 6. Current state of cavea seats (a); Stone wall located in the northern part of the archaeological complex (b)

#### IV. DISCUSSION AND FINAL REMARKS

The cultural heritage, in addition to symbolize the identity and history of an area or community, represents a significant economic resource for the tourism industry [18] based on a unique artistic heritage and a characteristic landscape.

In addition to natural deterioration and human impact, natural hazards represent a strong threat to historical heritage.

In recent decades, the need of preserving the cultural heritage is becoming very relevant due to an increase in frequency and in intensity of extreme events, which have recalled major attention by Authorities on natural hazards associated. Specialists from different disciplines are involved in the process of analysis and knowledge of historical artefacts, offering their contribution to define a correct method able to protect and safeguard the cultural heritage.

Pietrabbondante Sanctuary represents a special case where very important historical and cultural assets are fully embedded and integrated with a landscape of great value.

The presence of the Archaeological site, State Nature Preserve (called Collemeluccio [19]), *tratturi* tracks (itinerary used by shepherds during transhumance), a

rugged, wild and mostly beautiful landscape, make this archaeological site very particular, mainly due to very complex geological and geotechnical characteristics of the area.

Preliminary outcomes of a collaborative study between archeologists, architects, structural and geotechnical engineers indicate that geotechnical issues are significant factors in view of the preservation of the area and of the assets. This circumstance appears to be much more relevant if the extension of the investigated areas is expected to shade more light on the Sanniti people and culture.

As earthquake hazards is concerned, it is observed that both the overall stability of the area and the structural performance of rebuilt architectural assets need to be assessed. This is the reason why a multidisciplinary and shared approach to define the correct methodologies able to preserve, safeguard, protect and requalify a site of undeniable cultural value.

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