THE MYCENAEAN TOMB ‘TREASURY OF MINYAS’: CONSERVATION PROBLEMS AND EVALUATION OF THE DETERIORATION PHENOMENA

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Keywords: Minyas treasury, tholos tomb, deterioration phenomena, evaluation, conservation

Thematic Area: No1. Historical and structural aspects of monuments

ABSTRACT

The excavations at Orchomenos in Boeotia by H. Schliemann in 1880-1 and in 1886, among else resumed work, brought to the light the important Mycenaean tholos tomb known as the ‘Treasury of Minyas’. The carved ceiling of the side chamber of the tomb is of great historic and artistic importance due to its uniqueness as a monumental remain of the Mycenaean period, surviving up to the present day. In 1914 the architect and archaeologist A. Orlandos partially restored the side chamber aiming to prevent the deterioration phenomena. In 1995-1996 a complex program of works was implemented by the Ministry of Culture of Greece. However, the last macroscopic observations on the monument in 2009 showed that a serious damage has been undertaken mainly above the side chamber since its last restoration.

The aim of this work is the study of the decay patterns carried out in the reliefs of the side chamber of the tomb. For this reason, mapping and evaluation, non destructive testing was performed in situ by means of Ultrasonics, IR Thermography and Ground Penetrating Radar techniques. Taking into account the bad condition of the monument described above, the need for the prompt protection of the carved ceiling of the tomb’s side chamber is crucial and urgent, as its decay is difficult to be prevented in situ. Therefore, the replacement of the ceiling by a copy and the exhibition of the original in a museum’s environment must be under serious consideration.

INTRODUCTION

Historical Notes

The archaeological research at Orchomenos has already completed more than a century and has offered plenty of evidence for the prehistoric settlements at this site. In the Neolithic period, a type of house consisting in a species of circular hut was used, while in the Early Bronze Age (2800-1900 B.C.), the houses of the settlement were mostly apsidal. The excavated remains of a palatial complex and the great royal tholos tomb, known by ancient writers as the “Treasury of Minyas”, show the great power of Orchomenos in the Mycenaean Palatial period (c. 1400 BC–1200 BC). The power and richness of Boeotian Orchomenos was mentioned, by the ‘Catalogue of the Ships’ in Homer’s Iliad (B 511-16), as it was among the cities which sent ships to engage in the Trojan War. Later, during the Archaic and the Classical period, Orchomenos was in a constant rivalry to Thebes and although it has built commanding fortifications it have been destroyed two times during the 4th
cent. BC. In Mycenaean times the city employed a complex hydraulic system which drained the neighbouring marshes of the lake Copais in order to reclaim more fertile land. The inhabitants of Orchomenos worshipped the Charites, or Graces, to whom a sanctuary was dedicated in historical times. The Charities festival, with its competitions in poem and music, was held in the city to honour the Charites, as was the Agrioneia a festival in honour of Dionysos. The town was equally important during the Hellenistic times when the fortification walls, preserved and visible still today on its citadel, were constructed. Today, the archaeological site of Orchomenos comprises except from the imposing walls of its fortified acropolis, the Mycenaean tholos tomb said the Treasury of Minyas, the Hellenistic theatre, and the early medieval church of Panaghia Skripou, built almost entirely of re-used classical blocks [1]. In the Fig. 1(a,b) a plant of the archaeological site of Orchomenos and an aerial photo of the monumental tholos tomb are shown.

Figure 1: (a) Plant of the archeological side of Orchomenos, (b) aero photo of the Minyas tomb (IXth E.P.C.A)

The tholos tomb known as the ‘Treasury of Minyas’

According to the founding myth of Orchomenos, its royal dynasty had been established by the Minyans, who had followed their eponymous leader Minyas from coastal Thessaly to settle the site. In Greek mythology, Minyas (Greek: Μινύας) was the son of King Chryses, the son of Chrysogenia and god Poseidon. Minyas was a very wealthy king and the first who had built a treasury to deposit his treasures (Iliad I, 381) [2]. Homer first mentioned (Iliad I, 379-382) the treasures of King Minyas and the royal family at Orchomenos in Boeotia. At the 2nd century AD, the traveller Pausanias, admired and described the tholos tomb in detail by believing that it was the treasury of Minyas (Pausanias, Boeotica IX, 38) [2].

The tomb of Minyas, a schematic representation and a view of the tholos shown in Fig 2(a,b) respectively, stands at the eastern side of the Akontion hill and the western end of the city of Orchomenos and it was probably built for the members of the royal family of Orchomenos about 1250 BC. The tomb was a famous landmark until at least the second century AD, when Pausanias admired its construction (Pausanias, Boeotica IX, 38). It stood on ground level and had a path of thirty metres long, its entrance - 5.46 metres high, 2.70 metres wide at the lower end and 2.43 metres wide at the upper end - was built of dark grey marble and had a wooden door. The lintel was six metres long and weighs several tons. The circular chamber was fourteen metres in diameter and it was built according to the beehive system, with stones to equal structure lines and originally
decorated with bronze attachments. On the northeast side of the chamber a small side chamber was found, accessed by a door - 2.12 metres high, 1.44 metres wide at the lower end and 1.21 metres wide at the upper end [2,4]. A similar side room appeared only in two other royal graves: the Tomb of Atreus at Mycenae, which was contemporary with the tomb of Minyas, and the tholos Tomb A at Archanes, Crete. The main chamber was decorated with bronze rosettes as shown by the attachment holes on the walls, while the ceiling of its lateral room consisted of four limestone slabs with relief spirals, rosettes and papyrus flowers (Fig.3) [2,5]. Pausanias refers to that the tholos was built in the load displacing technique with a keystone at the very top to hold it together [2].

Figure 2: (a) Plant of the archeological side of Orchomenos (Photo from the Internet), (b) aero photo of the Minyas tomb (IXth E.P.C.A)

Figure 3: Drawing of the carved ceiling of the side chamber (Photo from ref. 5).

In early 19th century some travellers, namely Clarke, Dodwell, Leake and Cockerell, report that the tholos was destroyed and the only visible part was the upper end of the lintel (5 x 2.22 m). The monument was first excavated in 1880-81, as well as in 1886 by the pioneer archaeologist Heinrich Schliemann, his wife Sofia and the Professor A. H. Sayce. They had many difficulties during the excavation process as the upper part of the tomb had been collapsed. The same difficulties disinclined its looted by the men of lord Elgin, in the early of the same century. Schliemann began the excavation from the interior of the tomb until he brought to the light the grate facade of the entrance [2]
The grave had been looted since antiquity therefore the amount of the finds was not corresponding to the expectations of the excavator. In contradiction his attention was centred at the marble pedestal, 5.73 metres long, which placed in the Hellenistic period in the centre of the chamber in order to hold dedicatory statues of gods or kings. Moreover, he observed holes with bronze remains of nails which fastened the bronze decoration on the walls of the inter side of the entrance. Same decoration appeared also to have applied to the entrance which leads to the side chamber of the tomb.

In 1881, H. Schliemann, his wife Sofia, Professor Sayce and the general curator of antiquities Panagiotis Eustratiadis, brought to the light the side chamber of the tomb which was also decorated with bronze rosettes, as shown by the attachment holes on the walls, while its ceiling consisted of four limestone slabs with relief spirals, rosettes and papyrus flowers [5]. This finding awarded Schliemann’s efforts as it was a unique remain of such a kind from the Mycenaean period.

**Figure 4:** View of the tholos tomb of Minyas, after Schliemann’s excavation (Photo from ref. 5).

**Past restoration works - side chamber**

The side chamber of dimensions 2.75 x 3.79 m and 2.40 m of height was constructed with walls 1.50 m of thickness. The embossing roof is placed on four well-jointed fine grained slate boards. The height of these four boards is varied from 0.20 to 0.46 m. In 1914, during consolidation and restoration works by Orlandos, the roof boards were mounted using “I” profile iron bars and “Π” profile iron plates. A non-reinforced board of concrete was placed all over the whole chamber for sealing reasons [6].

In 1995-1996 a global program of works aiming to the conservation and restoration of the monument, was implemented by the Ministry of Culture of Greece. The technical report referred to that the roots of the trees and the plants growth in the gradient above the tomb caused static weakening of the structural material. The construction of an inappropriate water canal made with cement along the extent stonework of the circular chamber, as well as the formation of an open ditch in the east side of the side chamber, caused water accumulation inside the tomb and consequently, stone weathering due to the water action. Therefore, the consolidation of the monument was of crucial importance for its preservation.

The conservation interventions carried out are summarized as follows [7]:

- Consolidation of the gradient with launching concrete on stainless grid which was set with grapnels and epoxy resin. Construction of an open water gutter (30 x 20 cm wide) along the extend stonework of the circular chamber.
- Reinforcement of the masonry with cement grouting, epoxy resins injections and fabricated
limestones, where it was necessary.

- A new board of reinforced concrete (with stainless steel) was constructed, due to Orlandos concrete board corrosion. This board was connected to the old one with the use of pins and weld emulsion. A special asphalt based seal was applied. The new board was expanded 50 cm out of the borders of the side chamber in order to prevent water accumulation between the surface of the stonework and the ground. Moreover an air pipe was constructed, at the end of right wall of the side chamber, for water evaporation. For the abduction of the rainwater from the upper side of the tomb roof the constructed channel by Orlandos was cleaned and cement pipes of 0.50 m diameter were installed for a length of 28 meters.

Although the mechanical properties of the materials used are acceptable, by means of the reinforcement of the monument, they lead to a solid construction with materials of incompatible physicochemical properties compared with the historical stone. In Fig. 5(a) a view of the entrance of the side chamber after Orlandos conservation works, while in Fig. 5(b) a view of the entrance of the side chamber after the conservation works carried out by the Ministry of Culture in 1995 showing the reinforced concrete board.

Figure 5: (a) View of the entrance of the side chamber after Orlando’s conservation works (Photo from ref. 6), (b) View of the entrance of the side chamber after the conservation works carried out by the Ministry of Culture in 1995 (Photo IXth E.P.C.A 2009).

EXPERIMENTAL

The present view of the carved ceiling – In situ macroscopic observations

The deterioration of the monuments is depending on various natural and anthropogenic factors. For instance, the action of water, provided by rainfalls, or by capillary rise from the ground, as well as environmental factors such as frosts, winds, temperature variations, relative humidity, which are responsible for the ageing of the structural materials. The maintenance of these factors inside the side chamber of the tomb is extremely difficult as it is exposed to the climatic data of the broad area. The principal agents responsible for the deterioration of the carved ceiling are mainly moisture flows associated with absorption and evaporation, as well as cumulative thermo-
hygrometric effects that may induce condensation and in some cases ice formation. Moreover, the relive decoration of the side chamber shows extreme salt contamination which, combined with the humidity action, is resulting in the extreme stone weathering (Fig. 7). Comparing the old photographs of the ceiling, shown in Fig. 6, with the recent ones, presented in Fig. 7, it is obvious that the deterioration process develops rabidly and the depth of the relief is reducing, consequently it will be eliminated in the following years. The deterioration phenomena are more aggressive along the joints of the boards where the humidity accumulation occurred due to past water penetration, as well as along the areas which abut on the side walls of the tomb. The physicochemical attack of the structural material is obvious in the whole surface of the monument as well. In contradiction, the mechanical behavior of the structure is acceptable.

**Figure 6:** View of the centre of the carved ceiling as it was five years ago (Photo IXth E.P.C.A 2005)

**Figure 7:** View of the carved ceiling of the tomb as it is today. The deterioration phenomena are visible with naked eye (Photo IXth E.P.C.A 2010).

**Non Destructive Techniques**

*In situ* non destructive testing was performed by means of Ultrasonics, IR Thermography and Ground Penetrating Radar aiming to the decay patterns detection and evaluation. Passive infrared thermography was employed, with the use of a ThermaCAM™ SC640 long wave thermography
system (7.5 – 13.5 µm) of FPA type with image resolution 640 x 680 pixels (0.65m rad) and thermal sensitivity 60 Mk at 30°C, for the in situ investigation of the tomb side chamber. The ultrasonic measurements were performed with the use of a V-Meter MK III system, working on the frequency range 250 kHz to 1 MHz. For the radar investigations the commercial SIR 3000 radar system from GSSI was used. The bow tie antenna from the same manufacturer having nominal frequency 1.5 GHz and depth of viewing window approximately 0.50 m was applied. For the recording of the antenna position, a survey wheel FGMOD615 was used.

RESULTS AND DISCUSSION

IR Thermography results

Since a moist porous material presents emittance variations, as well as brightness variations, moisture detection and assessment in porous stone masonries by means of infrared thermography is feasible.

In Fig. 8a the interior left side of the chamber roof examined is presented and in Fig. 8b the respective thermal image obtained with the use of the passive thermography approach. Temperature variations were observed on the carved ceiling and the stone masonry surfaces (Table 1). In particular, the temperatures of the selected measuring spots and the area (AR01) ranges from 14.5 – 17.0 °C as presented in Table 1. These surface temperature variations indicate probably the presence of moisture.

![Figure 8: (a) View and (b) Thermal image of the interior left side of the chamber roof investigated.](image)

**Table 1:** Temperatures of the selected measuring spots and the selected area
(Analysis by the ThermaCAM Researcher Pro 2.8)

<table>
<thead>
<tr>
<th>Label</th>
<th>Value [°C]</th>
<th>Min</th>
<th>Max</th>
<th>Max - Min</th>
<th>Avg</th>
<th>Stdev</th>
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<tr>
<td>SP01</td>
<td>16.6</td>
<td>14.5</td>
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However, in terms of a more extensive and complete research concerning the moisture detection and assessment, the performance of measurements with the application of active thermography approach using external energy sources is considered to be essential.

**Ultrasonic Results**

The ultrasonic measurements were performed on the frequency of 250 KHz, to bruit ultrasound waves in maximum depth aiming to trace the stratigraphy of the ceiling. In Fig. 9(a) the investigated area of the ceiling is presented in a distance of 40 cm, while in Fig. 9(b) a graphic representation of a set of measurements on the ceiling of the chamber is shown. The modification of the graphic line shows three different ranges where the line gradient changes due to the change of the ultra sonic speed during its penetration through the material of different composition. Namely, in the first range, the relief area of the ceiling, the ultra sonic speed is 1017 m/sec (blue line) and the change of the gradient is attributed to the presence of materials of different composition. In the second part, the substrate, the ultra sonic speed is 1420 m/sec (yellow line). The lowest speed of 830 m/sec (green line) which is observed in the third range, where the gradient is more increased, it probably reveals decay or detachment of layers of the material.

![Figure 9](image-url)

**Figure 9:** (a) The distance of the surface area of the carved ceiling of the chamber examined by Ultrasonic technique, (b) graphic representation of the measurements, Area 1 (Blue line) 0-16 cm, Area 2 (Yellow line) 16-27 cm, Area 3 (Green line) 27-34 cm.

However, since the lower frequency used is 250 KHz a part of the board appears on the graphic. It should be of a great advantage to perform the same measurements with different ultra sonic frequencies to reach in deeper sections providing thus, a more complete "picture" of the hidden substrates.

Therefore, interest was focused on the depth of the first change of the gradient (blue-yellow line) which probably reveals a differentiation of the material composition and texture and thus, it may show the thickness of the carved part of the ceiling. This depth was calculated and found, $a = 3.2$ cm, by using the following equation:

$$a = \frac{l_o}{2} \left( \frac{V_S - V_D}{V_S + V_D} \right)^{0.5}$$
Where $V_S$, $V_D$ the velocities at the lower and upper of the line respectively, and $l_o$ the distance of the gradient change.

**Ground Penetrating Radar results**

Intra-wall radar inspection offers a unique non-invasive means for the diagnosis of buildings, where the assessment of the structural safety and durability needs information on the internal structure and on the localization and size of reinforcement bars, voids and defects [8]. Penetrating radar is being used increasingly for the appraisal of structural safety and durability of historical buildings [9] and large structures such as road pavements [10] and bridges [11]. Recent results from the European Research Project “On-site investigation techniques for the structural evaluation of historic masonry buildings” (ONSITEFORMASONRY) have shown that radar (Ground Penetrating Radar-GPR) as well as acoustic methods are very well suited to detecting structural inhomogenities in brick and stone masonry [12].

![Figure 10: Patterns from the GPR technique (cross-section, surface vs. depth), (a) applied to the new board of reinforced concrete, outside, over the chamber’s roof (with stainless steel), (b) applied inside on the ceiling, to the four fine grained slate boards.](image)

The first set of measurements was performed outside, over the chamber’s roof, where the new board of reinforced concrete was constructed, a representative GPR pattern is presented in Fig.10(a). The thickness of the board is varied from 0.30 to 0.60 m, according to reference data from previous restoration works [7]. As it is shown in the GPR pattern (Fig.10(a)), irregularities of the board appeared which cause sifting of entire segments of traces, over the depth of 0.35 m. For the specific cross-sections these irregularities are probably attributed to the stainless steel reinforcement had been used for the new board along with the interface of the two boards (applied from the two different restoration works).

The second set of measurements was performed inside, directly on the ceiling of the chamber, a representative GPR pattern is presented in Fig.10(b). The purpose was to investigate the condition of the first restoration work curried out by Orlando [6]. The irregularities shown in Fig 10(b) at the range of depth between 0.15 to 0.45 m may be attributed to the iron presence and it is a serious indication that during past restoration works iron bars and/or iron plates had been used to mount the four fine grained slate ancient boards in the correct position. However, since the maximum depth of viewing for the antenna used is approximately 0.50 m, a
part only of the board appears on the GPR patterns. It should be of a great interest, the same measurements to be performed by means of a different antenna type to reach in deeper sections and with the better resolution provided so as a more complete view of the hidden substrates will be revealed.

CONCLUSIONS

The observations arised from the in situ macroscopic inspection of the tomb side chamber and the ceiling, as well as the results derived from the in situ investigations by means of the non destructive techniques of Ultrasonics, IR Thermography and Ground Penetrating Radar lead to the following conclusions:

- The physicochemical attack of the structural material is obvious in the whole surface of the monument. The deterioration phenomena are more aggressive along the joints of the boards where the humidity accumulation occurred due to past water penetration, as well as along the areas which abut on the side walls of the tomb. Moreover, the extreme salt contamination combined with the humidity action has resulted in the extreme stone weathering. In contradiction, the mechanical behavior of the structure is acceptable.
- The thermal images obtained reveal the presence of moisture on the carved ceiling and the stone masonry surfaces.
- The ultrasonic results show the presence of materials with different composition and texture within the first depth of 3.2 cm from the surface of the ceiling. Going deeper through the ceiling they reveal decay and/or detachment of the material layers.
- GPR patterns show the presence of different material over the depth of 0.35 m from the top of the roof, these probably attributed to the stainless steel reinforcement that had been used for the new board along with the interface of the two boards (applied from the two different restoration works). The same differentiation is observed inside within a depth between 0.15 to 0.45 m at the ceiling surface which may be attributed to the iron presence and it is a serious indication that during past restoration works iron bars and/or iron plates had been used to mount the four fine grained slate ancient boards in the correct position.
- Macroscopic observations on the curved ceiling combined with the results obtained by the applied of the non-destructive techniques give some indications that the sculptured surface and the substrate of the ceiling are not of the same composition. However, more extensive research is required in combination with the non-destructive techniques used to be documented this assumption. Namely samples must be taken from the ceiling to be analysed by means of advanced methods analysis such as Scanning Electron Microscope (SEM), X Ray Diffraction (XRD) ect.

Taking into account the extremely deteriorated condition of the monument described above, the need for the prompt protection of the carved ceiling of the tomb side chamber is crucial and urgent, as its decay is difficult to be prevented in situ. Therefore, the replacement of the ceiling by a copy and the exhibition of the original in the Museum environment might be seriously taken into account.

REFERENCES