DAMAGE ASSESSMENT TO THE MACEDONIAN “TOMB OF MACRIDY BEY”
AT DERVENI, THESSALONIKI

Alexios Papasotiriou,
Civil Engineer (MSc)
24, Ptolemaion str., 57010 Pefka - Thessaloniki, Greece

Fani Athanasiou (MSc), Venetia Malama, Maria Miza, Maria Sarantidou
Architects,
16th Ephorate of Prehistoric and Classical Antiquities,
Hellenic Ministry of Culture
Avenue Megalou Alexandrou / opposite “Poseidonion”/ 54646 Thessaloniki, Greece

Keywords: Macedonian Tomb, Damage, Arch, Soil thrust, Conservation

ABSTRACT

The Macedonian “Tomb of Lagadas”, also known as the “Tomb of Macridy Bey”, is situated on the eastern edge of the cemetery of ancient Liti at Derveni in the Prefecture of Thessaloniki. It is a monumental grave edifice constructed at the end of the 4th cent. BC. The tomb was discovered and excavated in 1910 by the archaeologist Theodore Macridy. Excavations were recommenced in 1993. The monument is in a bad state of preservation and has suffered extensive structural damage, caused by the tumulus load and the compressive failure mechanisms that were activated during the excavation works. The aims of the present study are to: analyse the structural behaviour of the monument, examine the processes which caused the observable damages, assess the monument’s strength and stability, and determine the measures to be taken for the tomb’s restoration.

INTRODUCTION

The Macedonian “Tomb of Lagadas”, also known as the “Tomb of Macridy Bey”, is situated on the eastern edge of the cemetery of ancient Liti at Derveni in the Prefecture of Thessaloniki. This monumental grave edifice was constructed at the end of the 4th cent. BC., for the burial of a prominent man. The tomb in antiquity was covered by an artificial tumulus (fig.1), whose diameter and height were 75m and 19m, respectively. The tumulus was comprised of successive horizontal layers reaching up to 50cm in thickness and its earth material was of different composition. [1]

The structure has two barrel vaulted chambers whose foundations are on stable ground. It is built of brick-shaped stone made of local brownish limestone according to a “pseudo isodomsystem”. [2]
Figure 1: Tumulus of “Tomb of Macridy Bey” during the 1993 archaeological excavation.

The dimensions of the burial chamber are 4.07m x 5.08m. (fig.2) The sarcophagus is located at the back of the chamber (eastern wall); while in the dividing wall (western) there is a 3.06m-high trapezoidal opening, which had a marble door now found in the Archaeological Museum of Istanbul. (fig.3) The chamber walls are 3.35m high, built of brick-shaped stone 1m long, 0.60m thick and 0.40m wide in nine courses. The cross-section of the chamber arch is semicircular and sits on the impost that protrudes by 2.5cm. The longitudinal walls are bonded with the perpendicular ones, while the arch sits on the rabbet of the brick-shaped stones of each tympanum.

The dimensions of the antechamber are 5.40m x 2.60m. Its walls, which are 3.90m high, are also made of brick-shaped stone, ranging in height from 0.33m - 0.55m, and which are placed in nine courses.

Figure 2: The “Tomb of Macridy Bey”. Plan.
The arch has a semicircular cross-section and is situated on the first course above the lintel of the doorway. On the upper part of the brick-shaped stone of this course there is a band 17cm wide which protrudes by 2cm. The longitudinal walls of the antechamber are bonded with the dividing wall and the façade, which has been wholly destroyed. In accordance with the study of the graphical representation based on the in situ archaeological data, the architectural design of the façade resembled that of a temple of Ionic Order. In the centre there were two engaged half columns, while in the outer face of the wall there were two ante with engaged quarter-columns. The columns were crowned by an entablature and pediment. A road, whose length and mean width were 14.70m and 3.05m, respectively, led to the tomb’s doorway between the two half-columns. There were mud brick walls along the side of the road (to the north and south of the structure) leading to the façade of the antechamber allowing the doorway to be visible. Both the façade and the interior were covered in colored plaster.

The structure was discovered in February 1910, due to a hole that had opened up in the northwestern side of the tumulus following an earthquake. In 1911, Theodore Macridy, a high-ranking official of the Ottoman Empire, excavated the monument. The main objective of the initial archaeological excavation was to uncover the interior of the tomb and thus a section of the ancient fill was removed. As Macridy noted, the monument was in a bad state of preservation: the structure leaned NW; the western wall of the chamber was cracked; while the façade had collapsed in a southwest direction destroying the lintel as well as one of the door leaves, both of which were of marble.

Publication of the findings aroused the interest of both Greek and foreign researchers who highlighted the significance of the structure and the necessity for immediate action to ensure its protection. Unfortunately, unanticipated circumstances, such as the two World Wars resulted in the tomb’s neglect. In spite of the fact that for decades the bad state of the monument concerned the Archaeological Ephorate, work only recommenced as late as 1993 largely due to lack of funds.

During this long period of inactivity the tomb was buried and the tumulus was covered over with thick vegetation. Works involved having to once more remove the fill from the interior of the structure, as well as carrying out excavations on a section of the ancient road in front of the tomb entrance. At the same time, during these excavations (1995-96) the monument, and in particular the antechamber, presented certain static problems, which resulted in some of the remaining brick-shaped stones of the façade being dismantled and the ancient fill that covered the structure to be removed up until the springing line of the arches. At this stage, despite the fact that some rudimentary preservation measures had been instigated (supports - overhead shelter) and damage assessment to the structure had commenced, regrettably it was not completed and the monument was again abandoned.

In 2008 the Archaeological Service designed a study for the structural restoration and the reconstruction of the façade with the express aim of incorporating the monument into the National Strategic Reference Framework (NSRF).
STATE OF MONUMENT PRESERVATION

The damages to the tomb are many and of a significant extent and intensity. They have largely been caused by the excessive load of the tumulus, whose thickness was 12m above the roof of the burial chamber. They consist of the structure’s deformation, extensive cracking, local compression failures, and the collapse of the façade of the antechamber. The majority of these damages appear to have occurred over a relatively short period of time subsequent to the construction of the tumulus. The likely exception to this is the collapse of the façade.

More specifically, the deformations involve: the walls lean, the outer walls have bent inwards, and there has been a significant alteration in the curvature of the arches. This has resulted in the structure’s overall deformation. The monument presents the most intense deformation in its two arches. There has been a discernable reduction in the height of the arches in both the burial- and the ante- chambers by 22cm and 43cm respectively, due to the load of the tumulus. This has caused the original round arches to become three centered. The magnitude of the deformation of the arches changes along their axes because the tympanum of the side walls constrains the radial displacement on the arch faces. The result is that the deformed arches have an anticlastic shape. (fig.4)
Despite the intense deformation of the arches, their span remained practically unchanged. This fact, in conjunction with the existing excavation data, shows that the fill that surrounded the monument up to the springing line of the arch had acquired a sufficient bearing capacity even prior to the construction of the tumulus.

The monument’s outer walls bend inwards revealing the deformation as would happen in a two-way slab. The deflection reaches its highest value in the middle of the surface; this value depends on the dimensions of the walls. The deflection is about 5cm on the longitudinal (north and south) walls and 3cm on the lateral (eastern) wall of the burial chamber. Correspondingly, the longitudinal walls of the antechamber have a deflection of about 2cm.

The tomb’s façade (west wall) presented the biggest deformation since it was the weakest wall of the structure due to a number of factors: its large span, its architectural design; and its doorway. Furthermore, in contrast to the structure’s other walls, the façade was filled in at the same time as the tumulus was being constructed and therefore, it supported soil that was loose. From the little that remains of the façade, it is estimated that its deformation was about 50cm, a fact which greatly contributed to its collapse.
Besides the deformations presented above, there is extensive cracking of the brick-shaped stones. A dense network of cracks whose thickness ranges from a few millimeters to 10cm runs through the entire structure. (fig.5)

The main cracks of the arches are transverse and are associated to the deflection of the courses along the monument’s axis. Although these are clearly visible in the intrados of the arches, many of them are difficult to discern in the extrados. They are widest at the crown and taper at the arch’s springing line. In addition, the extensive separation between the successive string courses, resulting from the changes in the arches curvature, has formed longitudinal cracks.

In the burial chamber the width and length of the transversal cracks vary significantly. The largest such crack, 9cm wide at the crown, can be seen 1.15m from the dividing wall and runs along the entire width of the intrados. In addition, three large cracks, the biggest being 10cm wide, completely divide the antechamber arch into four separate arches.

Vertical cracks have appeared in the structure’s outer walls, caused mainly by the walls’ bending which is due to the soil forces. The cracks of the brick-shaped stones are primarily due to the lateral bending - and are also possibly due to the twist of the courses. Some cracks are also associated to the intense in plane compressive stress of the wall. Cracks of this type exist in those stones found above and below the holes in the walls of the burial chamber that in the past were opened by grave robbers to raid the monument. The horizontal joints of certain courses in the chamber have also opened due to the lateral bend of the walls.
A large diagonal crack in the antechamber’s south wall presents particular interest. (fig.6) This is actually a continuation of the main transverse crack of the arch. It begins in the middle of the south impost and ends in the western edge of the second course of the wall. It severs a large triangular section of the masonry; it has tilted to the right and slid downwards along the crack by about 7cm. The distortion of the masonry around the area of the crack, the numerous smaller cracks, the severe spalling, and the local compressive failures are factors that indicate the magnitude of the loads that have developed in that area.

Compressive failures occur in places where the stresses attain the compressive strength of the brick-shaped stone due to the high local eccentricity. These failures appear in the form of spalling and occurred at the haunch of the arch, in the zone where the thrust line approaches the intrados. (fig.7) In certain brick-shaped stones of the antechamber, whose mass contains layers with high porosity and discontinuities, the compressive failure has spread across their entire width, a factor indicating the severe compressive stress that has developed.
DAMAGE ASSESSMENT AND ANALYSIS

The damages which the monument has suffered are extremely severe, degrading its structural cohesion and drastically reducing its load-carrying ability.

A new survey was designed for the in-depth study of the damages caused to the structure, using Geodetical and photogrammetric methods. Simultaneously, in collaboration with the relevant Departments of the School of Civil Engineering at the Aristotle University of Thessaloniki, laboratory tests were conducted on the mechanical properties of the stones [3] and geotechnical research [4] was carried out in order to determine the mechanical properties of the soil that surrounds the tomb from the foundation level up to the springing line of the antechamber arch. The findings show that the main fill material is composed of well compressed silty sand containing a small proportion of gravel.

A comparison of the new data with that from the earlier excavations revealed that during the period 1995-2008 the span of the antechamber arch increased by about 15cm, while at the same time there was deformation of the longitudinal walls.

The activation of a deformation mechanism has been known since 1995 and was attributed to the
removal (until the third course of the antechamber arch) of the tumulus soil. Measurements of the arch span during the former geotechnical research showed that the outer walls of both chambers shifted inwardly with a decreasing rate due to residual soil stresses surrounding the tomb. Nevertheless, the findings showed that this deformation lasted a few months.

Consequently, the change in the span of the antechamber arch, observed in the most recent topographical survey (2008), suggested the existence of some other failure mechanism. Naturally, an in-depth understanding of this mechanism plays a determining factor in the measures needed for the monument’s preservation. In order to investigate this phenomenon a manual deformation monitoring system with two dial gauges was placed in the west extremity of the arch, where due to the collapse of the antechamber’s western wall any suspected lateral deflection would be readily detected.

The measurements (begun in October 2008) showed that over the initial six-month period (until March 2009) the overall span hardly changed at all; however, the span changes that did occur were no greater than 2.5mm. (fig.8) Following a period of prolonged rainfall at the end of March a shortening of the span by 4.5mm was recorded. This deformation continued, reaching the highest value of 7.7mm in April. During the summer months the phenomenon was reversed, where the span of the arch began to increase until the end of autumn. Within fourteen months the increase in the span came to 7mm, whereas the greatest annual change, which took place within a period of six months, was 14.65mm.

Figure 8: “Tomb of Macridy Bey”. Data of monitoring system
The extent of the deformations made it necessary to incorporate three additional monitoring instruments as well as to upgrade to an automatic digital recording system. The new instruments monitor the angular deformation of the antechamber and the rise of its arch, as well as the span of the burial chamber arch. (fig.9) Measurements are recorded every six hours and comprise a systematic data base for a detailed analysis of the monument’s structural behaviour.

Additional measures were taken in order to make the arch more stable. It was decided that the optimal solution was to modify the thrust line pattern by applying lateral loads to the arch; namely, by placing sand bags in the extrados. This particular measure was chosen since not only was it easy to implement but it is also non-destructive and reversible. It was carried out in three stages some days apart, simultaneously recording the corresponding deformations to the arch. The intervention, among other things, provided valuable data concerning the arch’s structural behaviour. The association of load - deflection, at every stage, on the one hand, confirmed the arch’s critical condition and on the other, the main postulations concerning the boundary conditions of the arch.

Data collection analysis revealed independent failure mechanisms of the monument related to three distinct periods prior and following its excavation. The bulk of the damage was caused by the load of the tumulus during antiquity. Despite the extent of the damage an overall equilibrium was established between the tumulus and the structure leading to a long period of stability, during which the tumulus functioned as a form of protection for the tomb.
Following the unloading of the arches during the removal of the tumulus in 1995, the equilibrium that had been established was again disturbed and the strong lateral soil thrust caused the outer walls to bend inwards. Then a new damage mechanism was activated, which is due to the recurrent expansion and contraction of the ground caused by the seasonal fluctuations in the soil moisture content [6]. More specifically, the soil after each cycle of expansion-contraction does not return fully to its initial state due to the fact that the degree of contraction is greater than that of expansion. The result of this is that with the passing of time there is a significant increase in the residual deformation, causing a gradual lateral yield of the abutments of the antechamber arch.

CONCLUSIONS

There are three main types of damages to the monument. The first which comprises the most serious problem is the progressive deformation of the antechamber, which as the findings clearly show, is caused by the alternating expansion-contraction of the ground. In order for this problem to be solved it is imperative that the ground moisture content be kept stable and generally that the earth surrounding the tomb is protected from adverse weather conditions.

Another significant problem concerns the stability of the arch which is at a critical point. This is not as one would expect due to the strength of the brick-shaped stones, but has arisen because of the arch’s deformation in conjunction with the extensive lowering of the tumulus to the extrados. The arch’s stability can be reinstated externally by the addition of lateral buttresses, constraining the radial deformation of the arch haunches. This intervention has the potential to be reversible.

Finally, the damage to the brick-shaped stones (cracking, compressive failures etc), although it contributes to the structure’s bad condition, is not a main factor in the preservation of the monument. Certain serious cracks which greatly weaken the structure can be encountered with local interventions, consisting of grout with dowels. More generally, the brick-shaped stones have sufficient strength and the monument can carry the dead load with a high capacity ratio.

In conclusion, the high precision topographical survey, the geotechnical research, the evaluation of the materials’ mechanical properties, and the monitoring of the deformations have contributed significantly to the assessment of the monument’s state of preservation and the examination of its damage mechanisms. Furthermore, the static analysis played a major role in determining which failure mechanisms were involved to the exclusion of others, as well as assessing the severity of the damage. On the whole, the study of the Macedonian “Tomb of Macridy Bey” highlights the fact that restoration works must begin immediately to ensure the preservation of the monument in the future.

REFERENCES

[3] Study of the building material from Macedonian Tomb in Derveni, Thessalonik and evaluation of the results. (Unpublished). Aristotle University of Thessaloniki, Civil Engineering Department, Division of Structural Engineering, Laboratory of Building Materials Scientist responsible: Professor I. Papayianni
