

DOCUMENTATION OF THE GEOMETRY AND EARLIER INTERVENTIONS OF THE ANCIENT THEATER OF DODONA

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KEY WORDS: Dodona, ancient theater, restoration, laser scanning, Digital Terrain Model

ABSTRACT:

The implementation of the Digital Terrain Model which was produced after Laser Scanning of the theatre of Dodona resulted in numerous valuable information about the architecture and the history as well, of the ancient monument. The most important feature was the geometry of the cave which was recorded in details since the DTM provided an accuracy of 1cm. All the remains situated at their original position contributed to that and among other issues it was definitely determined the original number of seat rows at the Epitheatron. The accuracy of the DTM helped also to the geometry of the detailed architectural sections. Moreover the data of the DTM also contributed thoroughly to the recording of the interventions of 1960. The variations in the original geometry were identified as well as the variations at the level of the seats and the diazomas. In addition to that some of the numerous miss positioned parts can be identified more easily from the DTM data than from the ortho-photo. Besides all the above, the quality of the DTM was the essential tool to record issues as the identification of the original position of the rows on the epitheatron, the inclination of the retaining walls, of the wall of the arena, and the modification of the floors of Parodoi. Finally the experimental recording of the degree of decay of the limestone revealed another aspect of use for the DTM.

1. INTRODUCTION

1.1 General information

Even though it is totally excavated since 1959 (Fig. 2), and was restored and partially reconstructed in 1960, (Dakaris, 1960, p.17) the ancient theatre of Dodona had up to 2006 minimal architectural and topographical documentation and recording, except from parts of the retaining walls and the scene. The project for the Study for the Restoration of the Ancient Theater of Dodona was commissioned to our study group in November 2004, by the Committee for the Protection and Restoration of the monuments of Dodona.

Except from all the remedies for the restoration, it also included the orthophotographic recording of the monument. Besides that, it was asked by the Study group to record and document the original geometry of the cave. Furthermore it was also included the documentation of the intervention of the 1960 and the identification of the miss positioned parts.



Figure 1. General view of the Theatre of Dodona



Figure 2. The Theatre at the end of 1959 (Dakaris, 1960)

1.2 Digital Terrain Model and Architectural results

The Geomet Ltd. i. e. the surveyors of the study group who were responsible for the orthophotographic recording, produced a very detailed Digital Terrain Model (DTM) by Laser scanning of the monument (Vozikis E., 2005 p.20), as a tool element for the orthorectification of the theatre photos (Vozikis G. 2006). Because of the high precision of the DTM, it was also used as a remarkable tool for architectural results and conclusions on the features and the construction of the theatre. That aim was supported by numerous architectural recordings, observations and remarks, made mostly with conventional techniques.

The results given by the use of the accurate DTM would require otherwise thousands measurements taken by conventional topographical or architectural techniques. Moreover the coverage of all the theatre by the DTM provided the ability for examination of every part of the monument.

Even though the results for the original geometry, the earlier interventions and the decay were presented on ground plan

drawings, the calculation was made on and through detailed section drawings of the cave and long sections of the diazoma. The original DTM was used for the production of these drawings. It was inserted in Autodesk Autocad 2004 software (registered to the author). The possibility to work on a Triangulated Irregular Network (TIN) was rejected since the accuracy provided was less than that of the DTM.

2. THE GEOMETRY OF THE THEATRE

2.1 Basic issues – Loss of the stone mass

The only relevant to the authentic geometry element required by the study was the 3D model of the original layout of the theater, made by the topographers of the study group. Despite being part of the preliminary partial study, that result was achieved after critical architectural recording and remarks on the parts of the theatre which had been preserved in their original position. In addition to that all the reliable clues on the cave have been embodied, so the result would be as accurate to the original geometry as possible.

Moreover the precision of ~1cm that the D.T.M. provided, resulted in the recording at the critical for the authentic geometry places, of the well known loss of the mass of the limestone at the surfaces exposed to rainfall. That factor was calculated mainly for the precision of the height of the seats, but also for their width. It was considered not only at the dimensions of individual edolia, the theatre seats, but also at the edolia curved on the natural rock and other in situ parts of the construction.

These critical spots on the cave, such as seats and steps curved on the natural rock etc, were used also as verification check points on the detailed sections, through the precision of the D.T.M.

2.2 The curved edges of the edolia rows

The only curved edges of the edolia which preserve their original position are those of the few in situ rows at the lower part of the cave. (Fig. 3) These edges were the guidelines for the original geometry of the cave. They have been considered as parts of a circle and the calculation made by Geomet Ltd resulted in an ellipse axis ratio more than 0,995 (Vozikis, 2005, p 23) which is nearly a circle.



Figure 3. In situ parts of the theatre

The outer parts of the rows have almost linear edges according to the surviving pieces and steps. Therefore the original geometry should have followed those edges.

For the exact original width of the rows were considered two elements. The first is the average width of the in situ rows and the second the position of the in situ parts of the small krepis on diazoma A. All of them were recorded with significant precision from the DTM data. The original width of the slabs on diazoma A was recorded conventionally, after the surviving ones.

Similarly the DTM was used also at the second zone of the cave. There, the detailed recording of the capital stones of the wall of the diazoma A (Fig. 4), determined the position of the first row of that zone. The architectural recording of the surviving slabs of diazoma B resulted in the width of that diazoma.

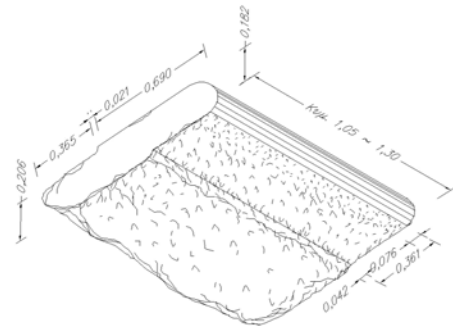


Figure 4. The capital stone of the wall of diazoma A

The case of the rows of the epitheatron was recorded in more details due to the doubts about their number (Dakaris, 1960, p.22)

2.3 The number of the seat rows at Epitheatron

The detailed section made after the DTM with the contribution of limited architectural recordings, resulted in the original number of the seat rows in the epithetro. For that conclusion, it was necessary to be cleared up the form of the retaining wall of the diazoma B as it is described below at 2.4.

Since that form was given, the presence of the edolia curved on the natural rock and the in situ parts of the krepis of the retaining wall on peridromos, indicate the original number of the rows in epithetro. The precision of the DTM data in the detailed section, (Fig. 5) eliminates the chances for a mistake.

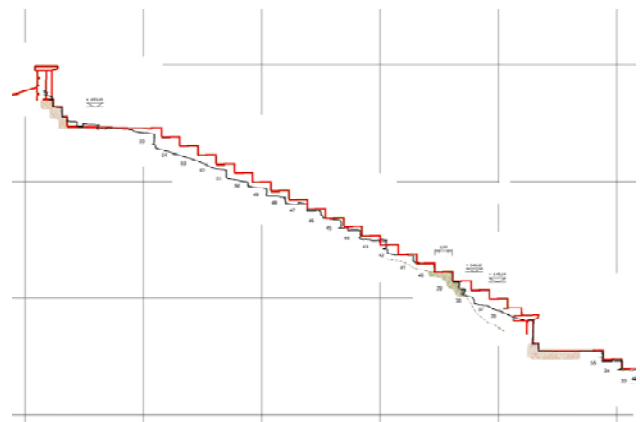


Figure 5. Detailed section of the epitheatron

For that calculation were drawn several alternative cases with the width and height of the rows that varied. The section that was adjusting better to all the above critical spots, is that

proposed as the one of the original layout. (Fig. 5, in red) As it derives from that geometry it varies slightly in the width of the rows from the lower parts of the theatre and little more in height. Thus, the height of the rows in the epithetron is nearly half centimetre more than in the lower part of the monument.

According to that and to the assorted architectural and constructional details, it could be testified that the epitheatron was built later than the lower zones A and B, but it had been planned from the beginning.

2.4 The form of the retaining wall at diazoma B

In addition to that, the precision given by the DTM along with the architectural remarks and comparison with similar monuments documented the most probable shape of the retaining wall at diazoma B. The form that occurred (Fig. 6) is the result of testing the four most possible arrangements on the section of the DTM with the undoubtable check points i.e. the seats curved on the rock and the in situ krepis of peridromos. The similarity of that form with the equivalent construction at the stadium of Delphoi is evident. (Fig. 7)

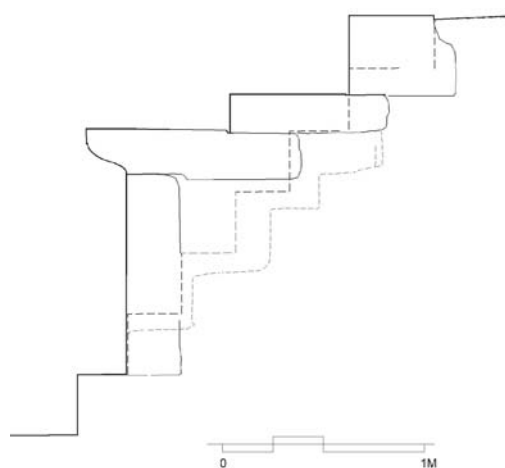


Figure 6. Formation of the retaining wall at diazoma B



Figure 7. Formation of the retaining wall at Stadium in Delphoi

2.5 Recording the inclination of the sloping retaining walls

The different inclinations measured on various architectural stones of the monument resulted in the detailed examination of the inclination which has the triangular retaining to the south side. The examination was applied through a strip section of the point cloud on the lower parts of the inclined retaining walls. There, the only in situ ancient stone blocks which incorporate the original inclination are being preserved.



Figure 8. Section of the Eastern edge of the retaining wall

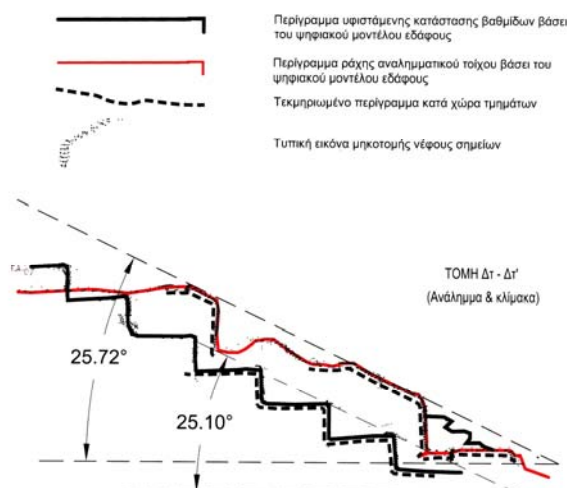


Figure 9. Section of the Western edge of the retaining wall

The results indicated a different inclination between the east wall, in which is $\sim 26, 81^\circ$ and the west one in which is $25, 72^\circ$. (Fig. 7, Fig. 8) In addition to that was measured as well the inclination of the stairs adjusted on these walls. The detailed measurements showed also the difference between the inclination of the wall and the stair. That difference has already been recorded by V. Harisis in 1960, not only at the walls but also at the external staircases.

The most significant result of these detailed measurements through the point cloud, was the identification of the original position of the parapet stone No ΔM03 (Drawing. 20 Harisis) to the west wall, instead to the east one, where it was attributed in the past. The inclination of that stone was measured 25.74° (Fig. 15), which is more resembling to the one of the west wall ($25,72^\circ$, Fig 14). Because of the condition of the stone the measurements of inclination were taken at three places $-25.84, 25.47, 25.93$ respectively- for a more accurate result. Multiple measurements have been taken for the inclination of the retaining walls as well.

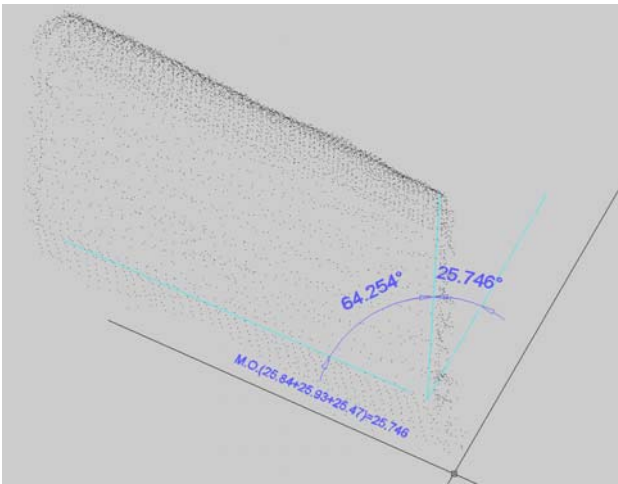


Figure 10. 3D detailed view of the parapet stone

3. RECORDING THE RESULTS OF THE EARLIER INTERVENTIONS AND DECAY

3.1 The Intervention of 1960

The intervention of 1960, due to its extensive scale and the lack of proper documentation, resulted in numerous variations of the authentic geometry and form. The short period in which it was taken place contributed to that result. Prof. S. Dakaris who was in charge of that intervention noted that the way it was applied provides the possibility to rearrange any mispositionings made. (Dakaris, 1960, p17. Dakaris 1992, p.3).

Some of these variations had been recorded officially, since 1960, (Mpouras, 1960 p.1) and the official guidelines for the Study for the Restoration of the Ancient Theatre of Dodona refer to them as well. (Committee of Dodona. 2003 p. 20-22)

3.1.1 Variations of the original geometry (2D) made due to that intervention: They refer mostly to the differences between the geometrical layout and the layout of the rows resulted after that intervention. The detailed DTM testifies the distance between the present position and the authentic one which is given by the plan of the original geometry. (Fig.11)

These variations can be adjusted to the authentic layout more easily than the variations of the height of the seats and the level of the diazomas. That adjustment through the rearrangement of the edolia was proposed by the study group (Antoniou, 2005, p. 12, 19, 31).

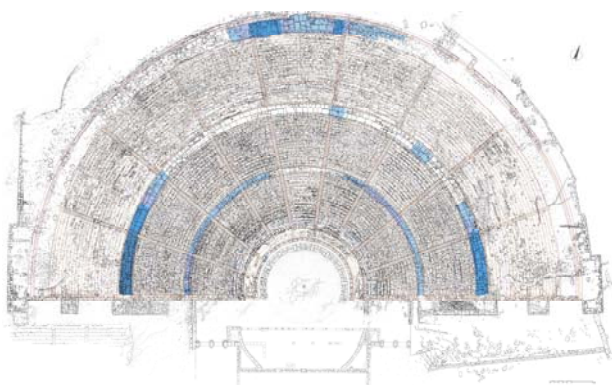


Figure 10. Ground plan indicating the variations from the original levels

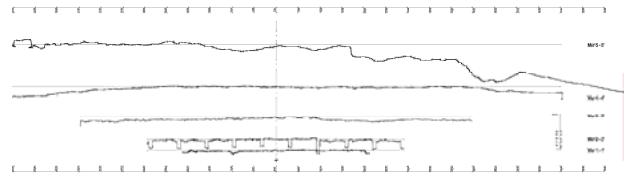


Figure 11. Long sections of the diazoma a, b and c

3.1.2 Variations of the height of the seats and the Diazomas: Due to the precision of the DTM it is recorded vividly the shorter than the original height (outline in red) of the most repositioned rows of edolia. (Fig. 12)

Moreover, through long sections on the Diazomas have been recorded, their irregular inclination outwards, which occurred after the intervention of 1960, in comparison with the levelled position that the original construction should have. (Fig.10, 11)

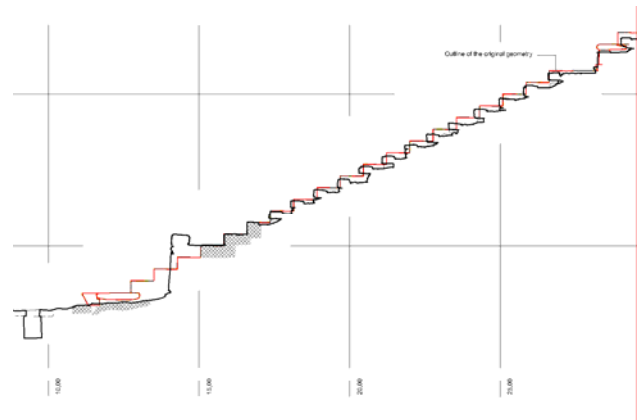


Figure 12. Detail of section indicating variations of levels

3.1.3 Misspositioned parts: Because of the significant differences of some misspositioned parts, they can be testified from the DTM, easier than from the ortho-photo. This is a secondary contribution of the DTM. Actually its accuracy, provides the differences of these stones which otherwise should have been measured using conventional methods.

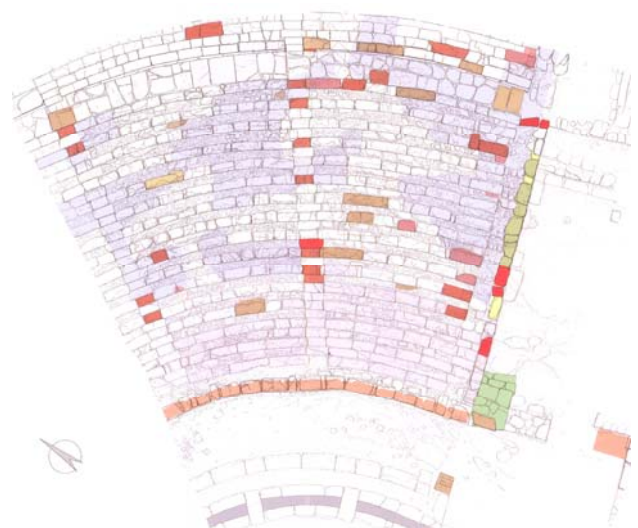


Figure 11. Partial ground plan indicating miss positioned parts

3.2 Decay and Other Interventions-Modifications

Identification of the original position of the rows on the epitheatron. It has been already recorded that their position varies from the original geometry. On some parts of the epitheatron is almost 1m out of the original geometry (Vozikis 2005, p. 24) That has happened because most of the rows have slide downwards, due to decay of their understructure combined to the decay of their limestone. After the comparison with the original geometry of the cave and especially that of the epitheatron (2.3 and Fig. 5), their authentic position can be easily testified.

The doubts concerning the original number of the rows in the epitheatro (2.3, Dakaris 1960, p.22) occurred because of the displacement of these rows of edolia and the difficulties of that time -1960- for a detailed recording and documentation of that part of the theatre.

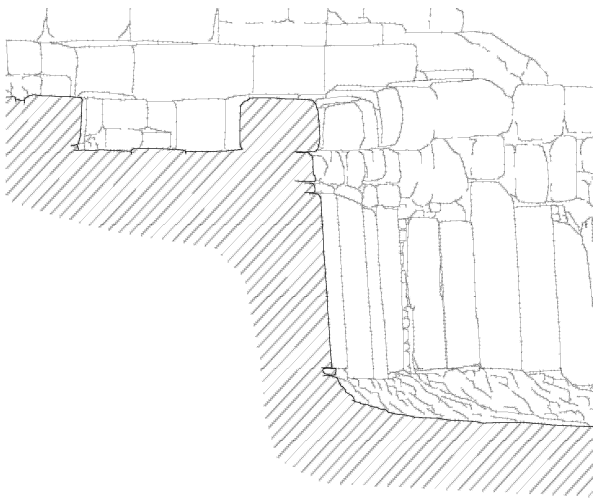


Figure 12. Section of the wall of arena traced out of the DTM

Inclination of the wall of the arena. It has happened probably after damages of the rock edge on which the reused slabs of the wall were based. The DTM quality describes that inclination easily and its variations are also well recorded. In addition to that it can be evaluated where the pressure from the soil and materials behind the wall contribute to that inclination.

The ability that DTM provides, which is to draw many detailed sections, helps to identify the most deteriorated areas. Therefore it is easier and more accurate to propose the best techniques for its preservation.

Modification of the floor of Parodoi. Probably parodoi were modified at least two times during the lifetime of the monument in the antiquity, as it can be concluded after surviving constructional traces. The detailed recording of the DTM makes easier the comparison between the levels of the door steps and the surface of the orchestra.

The results help to testify the possible layout of the Parodoi and the entrances at the previous phases of the monument. Also we can evaluate much better the traces of the edges of the large external staircases which were originally based on parodoi. (Dakaris, 1960, p30)

3.3 Experimental recording of the decay of the limestone

Despite of the difficulties in recording the curvature of the edolia, the precision of the DTM makes it possible to record the amount of the decay and the loss of the stone mass as well, not only on the top of the seat stone blocks –edolia- but also on their face. In most cases that reduction of the stone because of the fact that the mass loss is more than 1cm, which is the average precision of the DTM, it can be recorded.

More over the loss of the stone mass at the bottom of the edolia can be easily calculated. So it can be estimated more precisely the necessary volume of stone -natural or artificial- for the supplement of the missing part of each stone block. During the final stage of the study, the DTM provided by Geomet Ltd was used for that purpose as well.

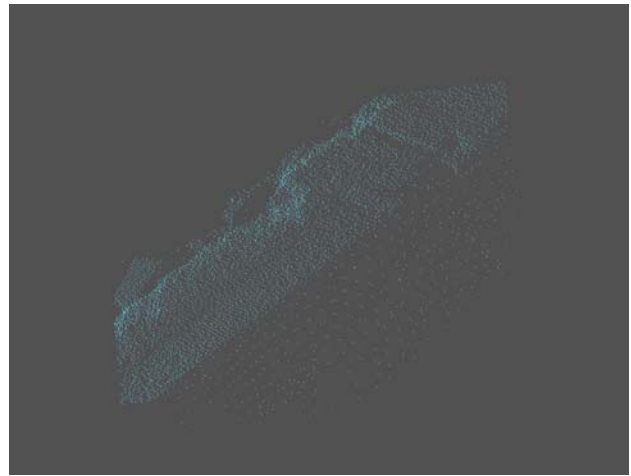


Figure 16. 3D detailed view of an edolium (from DTM)

The results on the seat stones which have been laser scanned from over than two positions are also well visibly presented in a 3D model. In many cases the scanning reached even the bottom side of the edolia, which have been based on impromptu brackets after the intervention of 1960, due to the loss of their lower part.

4. CONCLUSION

The main result of the described work on the DTM of the Dodona Theater is the ability to use the products or side products of a detailed recording in documenting constructions and forms which have lost most of their evidences. Also it becomes easier and more accurate to identify the parts which were miss positioned because of human interventions or dispositioned after natural decay. The last benefit is possible because of the testified authentic geometry of the theatre. At the end, the most important feature of a building like that is its geometry, since there were not constructed many morphological elements.

The ability provided to measure, in three dimensions, almost every part of the monument with satisfying accuracy, is a unique tool not only for the restoration of the monument but also for the study of its architecture and construction as well. In

addition to that, the contemporary CAD software provide the capability to draw out of the DTM quite detailed 3D and 2D drawings for most parts of the monument.

In addition to that, in similar cases, it could be applied a more detailed laser scanning on areas of increased significance for constructional or morphological reasons. Therefore it would be possible to obtain more accurate results.

Finally small scale laser scanning can also contribute in a better and faster result of the restoration works, providing precise surface model for the supplements of the stone blocks. Afterwards that surface could be produced mechanically through the appropriate software and hardware.

ACKNOWLEDGEMENTS

The author would like to thank the President of the Committee for the Protection and Restoration of the monuments of Dodone for the approval to use elements and data of the Study for the Restoration of the ancient theatre of Dodona in scientific presentations and publications. Also I would like to thank Geomet Ltd and its staff for their support on handling the DTM data and V. Charisis, the first architect involved with the restoration of the theatre, for his help on archival data.

Besides, I would like to thank Prof. A. Georgopoulos and especially G. Makris for their help and support during all the years I practise photogrammetrical techniques for the projects of my architectural office.

Finally, many thanks have to be granted to the colleagues in my architectural office for their help on this presentation.

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