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THE ERATO PROJECT AND ITS CONTRIBUTION TO OUR UNDERSTANDING OF THE ACOUSTICS OF ANCIENT THEATRES

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Abstract

The ERATO project (2003-2006, Contract Number ICA3-CT-2002-10031), was a three-year research project financed by the European Commission under the Fifth Framework INCO – MED Program. The ancient Greek and Roman theatres are famous for the excellent acoustics. However, it is not generally well known that different kinds of theatres were built, for different purposes and with different acoustical conditions. One of the aims in the ERATO project has been to investigate the acoustics of the open air theatre and compare to the smaller, originally roofed theatre, also called odeum (from Greek: Odeion, a hall for song and declamation with music). The method has been to make computer models of the spaces, first as they exist today, and adjust the acoustical data for surface materials by comparison to acoustical measurements from some of the best preserved examples, namely the Aspendos theatre in Turkey and the South theatre in Jerash, Jordan. Next step was to complete the computer models in accordance with archaeological information, to make virtual reconstructions of the spaces. The acoustical simulations have given a lot of interesting information about the acoustical qualities, mainly in the Roman theatres, but the earlier Greek theatre has also been studied in one case (Syracusa in Italy). It is found that the Roman open-air theatres had very high clarity of sound, but the sound strength was quite low. In contrast, the odea had reverberation time like a concert hall, relatively low clarity, and high sound strength. Thus, the acoustical properties reflect the original different purposes of the buildings, the theatre intended mainly for plays (speech) and the odeum mainly for song and music.

Keywords

Ancient theatre, odeon, computer models, virtual reconstruction.

1. Introduction

The main objectives of this research are identification, virtual restoration and revival of the acoustical heritage in a few, selected examples of the theatre and the roofed odeum in a 3D virtual environment. The amphitheatres with their clearly different purpose were included in this project. The virtual restitution integrates the visual and acoustical simulations, and is based on the most recent results of research in archaeology, theatre history, clothing, theatre performance and early music.

This paper will focus on the acoustical results. The acoustical simulations were made with the room acoustic software ODEON ver. 7.0, developed at the Technical University of Denmark.

2. The selected theatres and odea

Five spaces have been selected for virtual reconstruction in the ERATO project: Three theatres, see Fig. 1, and two odea, see Fig. 2. Acoustical measurements were made in the best preserved theatres in Aspendos and Jerash. In the theatre of Syracuse and the two odea the state of preservation was not sufficient to make acoustical measurements meaningful.

The Odeon in Aosta was selected because this is the only known example where some of the outer walls still exist in full height. The Odeon in Aphrodisias was selected because there was very good and detailed information available from the archaeological excavations, and many of the interior details like statues and marble floor in the orchestra still exist.

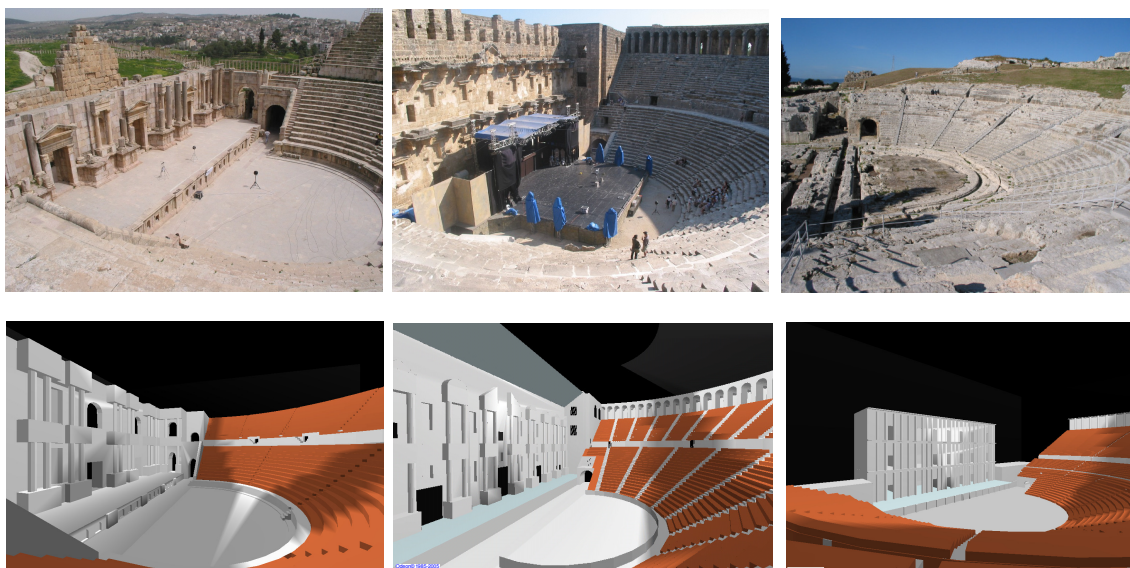


Figure 1 - Above: Photos from the three selected theatres, below: View from computer models, reconstructed for the Roman period. Left: Jerash, Middle: Aspendos, Right: Syracuse.



Figure 2 - Above: Photos from the two selected odea, below: View from computer models, reconstructed for the Roman period. Left: Aosta, Right: Aphrodisia.

3. Acoustical results from virtual reconstructions

3.1 The theatres in Aspendos, Jerash and Syracuse

These three theatres differ in shape and size as well as in cavea slope. In the Roman time, the Aspendos and Syracuse theatres had a colonnade behind the last rows of the cavea and the Aspendos theatre had a Velum (sunscreen over the audience area) made of wool like a sail. Probably the Jerash theatre also had a colonnade, but there are no remains left from that. In table 1 are shown the acoustical parameters for the three theatres in their different configurations and the cavea diameter to get an idea of the size of each theatre.

Table 1 - Calculated parameters in different configurations of the theatres (empty and fully occupied) and their cavea diameter. The parameter values are averaged over all source-receiver positions and over mid-frequencies 500-1000 Hz in 1/1-octave bands

	T30 (s)		G (dB)		C80 (dB)		STI		Cavea Diameter (m)
	Empty	Full	Empty	Full	Empty	Full	Empty	Full	
Aspendos Roman	1,95	1,59	-2,34	-4,36	1,17	4,08	0,53	0,61	95,5
Aspendos Present	1,89	1,53	-4,37	-6,09	2,68	6,53	0,60	0,70	95,5
Aspendos Present (Stage)	1,77	1,43	-4,49	-6,05	4,42	8,27	0,63	0,71	95,5
Jerash Roman	1,54	1,06	-0,72	-3,05	3,46	6,88	0,62	0,70	87,8
Jerash Present	1,21	0,86	-1,18	-3,29	5,98	9,85	0,67	0,75	87,8
Syracuse Roman	1,81	1,67	-6,69	-8,24	4,07	8,25	0,62	0,70	138,6
Syracuse Present	1,25	0,97	-10,60	-11,61	12,88	18,12	0,88	0,93	138,6

The table 1 shows that the difference in reverberation time between empty and full is about 0,3 - 0,4 s generally in all theatres, Jerash having a slightly bigger difference. The reverberation time when full seems to be more adequate in the roman reconstructions than in the present models.

The overall strength is the highest in Jerash and lowest in Syracuse, partly due to the different slopes and the great difference in cavea diameter.

The clarity is exceptionally high in all the theatres despite the levels of reverberation, and this is due to the lack of roof that make the field more like a free field than a diffuse field. As a consequence of this, the STI values are also remarkably high in theory if we neglect the background noise.

For the Aspendos theatre in present state, the modern stage provides a decrease of reverberation time at mid-frequencies, and in the case of the Roman reconstruction (with added velum and stage canopy) there is only minor difference in reverberation.

From Table 1 it is seen that in Jerash theatre the reconstruction of mainly the frons scaenea results in an increase of the reverberation time of around 0,3 s. It is also seen that the Syracuse theatre in the Roman era had around 0,6 s longer reverberation than in the present stage. This is mainly due to the frons scaenae but also the colonnade provided some reverberation.

3.2 The odea in Aosta and Aphrodisias

This type of theatre has the property of being a closed room with wooden roof structures used for more intimate music and theatre plays and often only for an exclusive audience. They have been made of hard materials as stone or marble and they are assumed to have had open windows to the outside for daylight and ventilation. The open windows and the audience seated in the cavea have provided the main acoustical absorption in these buildings. These rooms have thus been over-reverberant from an acoustical point of view if we compare them to the standards of today.

The Aosta and Aphrodisias odea differ both in their volume and in their shape. The outer walls of the Aosta odeon follow a rectangular shape whereas in Aphrodisias odeon the shape is semicircular following the seating area.

The Aosta odeon had a volume that was almost twice that of Aphrodisias odeon as reconstructed, mainly due to the difference in ceiling height.

Table 2 - Calculated parameters in different configurations (empty and fully occupied) of each odeon, and cavea diameter. The parameter values are averaged over all source-receiver positions and over mid-frequencies 500-1000 Hz in 1/1-octave bands.

	T30 (s)		G (dB)		C80 (dB)		STI		Cavea Diameter (m)
	Empty	Full	Empty	Full	Empty	Full	Empty	Full	
Aosta Roman	5,97	3,49	7,14	4,26	-5,28	-2,41	0,36	0,43	59,6
Aphrodisias Roman	4,02	1,62	10,45	5,45	-4,21	1,86	0,38	0,55	45,6
Aphrodisias Present	0,37	0,24	6,42	3,95	15,19	23,21	0,85	0,90	22,5

By comparing the reverberation times of the two odea in Roman time it is seen that Aosta has a longer reverberation time, mainly caused because of the greater volume.

The ruins of the Aphrodisias odeon in the present have too little surfaces to provide a reverberant field for satisfactory acoustics as it is seen from the table. Aosta odeon has not been reconstructed in its present state since there is only one wall standing.

In the reconstructed models of the Roman era both odea are over reverberant when they are empty. The Aphrodisias odeon has a reverberation time T_{30} when full, which is comparable to the optimum for modern concert halls of similar volume. The Aosta odeon seems to be over reverberant even when full.

The strength G of both odea is seen to have optimum values both when empty and full. The clarity C_{80} of Aosta odeon is too low mainly because of its high reverberation whereas Aphrodisias has an adequate clarity. The STI values show that the Aphrodisias odeon is satisfactory for speech when full whereas the Aosta odeon is just bearable. It has to be mentioned that the background noise level of the audience is not known and has probably caused lower speech intelligibility.

Overall, the calculation results of the reconstructed model of Aphrodisias odeon have shown an excellent acoustic ambience comparable to modern halls. It is a hall that mainly has been optimal for music but also good enough for theatre plays and chorus.

The Aosta odeon is less adequate for spoken performances but still acceptable for music.

3.3 Acoustical scale model investigations

From scale model investigations it is found that the different architectural layout of the theatre in the Greek and Roman periods indeed has an influence on the acoustical parameters, and the reverberation time was longer in the Roman theatre.

4. Reconstruction of musical instruments, music, song, clothes and style of performance

The musical instruments that have been reconstructed are Kithara, Aulos, Tympanon, and Scabellum. Three pieces of music in the antic style have been composed for the instruments and recorded in anechoic environment.

A database on virtual humans has been created, based on historical descriptions of clothes, shoes and hairstyle. The database consists of twelve virtual actors from the Roman period, three actors from the Greek period and a set of virtual musicians. For the virtual audience a crowd rendering and animation machine has been developed. The method allows real-time rendering of thousands of animated virtual humans.

Visual VR reconstructions in computer models have been made for the Aspendos theatre and the Aphrodisias odeon. The models include details like columns and statues, texture to represent the building materials, the coffered ceiling in the odeon and the velarium for sun shielding over the open air theatre. A collection is made with over 150 different textures that represent different surfaces in the buildings. The light conditions can be controlled using a virtual light probe to simulate any position of the sun and condition of the sky.

The visual simulations have been integrated with the acoustical simulations and a number of animated scenarios have been produced, including sounds from the audience.

5. About restoration works on ancient theatres

New information has been provided concerning the acoustical importance of different parts of the ancient theatres and odea. In the Roman theatre the height of the scene building and the decoration with columns and statues are particularly important, but also the colonnade behind the audience is acoustically important. In the odeon the roof and the open windows are acoustically most important; however, it is not very likely that any odeon will be fully restored with a new roof.

6. Modern use of ancient theatres

A report on the modern use of ancient theatres has been prepared. The report deals with problems related to festivals and deteriorations and threats due to improper uses of ancient theatres. It also refers to the relevant charters and guidelines like the ICOMOS Charter for the protection and management of archaeological heritage and the Verona Charter on the use of ancient theatres.

7. Conclusion

The results of the acoustical simulations in the reconstructed theatres and odea confirm the assumption, that they were dedicated for different purposes. The theatres with very high clarity of sound were excellent for plays (speech), whereas the odea with a higher sound strength and more reverberant sound were excellent for song and music from weaker instruments like the lyre or chitare.

More information can be found in the final project report [1] and in the proceedings of the ERATO project symposium [2]. Detailed studies on the acoustics of ancient theatres are described in a PhD thesis [3].

8. Acknowledgement

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