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THE ROMAN ODEION OF NIKOPOLIS: OBSERVATIONS OF ARCHITECTURAL ELEMENTS AFFECTING ITS ACOUSTICS. MEASUREMENT & CALCULATION OF ACOUSTIC INDICES

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Abstract

This paper investigates the acoustics of the ancient odeion of Nicopolis for the first time. The odeion is examined regarding its architectural characteristics and their effect on acoustics, for hosting musical events in antiquity. The investigation of these buildings and their comparison is multidisciplinary, based on their history, architecture and acoustics. RT, C80, D50 are some of the acoustic qualities and indices studied thoroughly, in order to define the behaviour of sound in both the contemporary open-air and the original roofed conditions of the odeion.

Keywords

Odeion, architecture, acoustics, measurements, Nicopolis.

1. Introduction

This study examines the acoustics of the odeion of Nicopolis. The odeion of Nicopolis was built in the 1st century A.D. and took its final shape and form during the 3rd century A.D. Its architecture is based on the western type of the Roman odeia. The odeion also presents some rare elements of great interest, such as the drop curtain mechanism and the sewage system. There is a lot of evidence found in the odeion, regarding the structure of its roof and its skene building.

The acoustics of the odeion are examined based on measurements, calculation and acoustic simulation methods. This way the acoustic indices are identified.

Measurements of impulse responses and frequency sweeps were carried out during two visits to the odeion of Nicopolis. The traditional methods of pulsive source/gunshots and linear sine sweep method were applied. The results were used to determine some of the basic acoustic indices and qualities; reverberation time, clarity (C80) and definition (D50). During the second visit the level distribution & critical distance of the space were measured. The measurement results were also compared with acoustic simulation results of the present condition of the odeion. This was performed to determine simulation methods and parameters, mainly regarding material properties and mapping. Based on these, the original acoustic condition of the odeion was examined with several roofing and material conditions, combining the image source and the ray tracing methods.

2. Background information

2.1 Architectural characteristics

Nicopolis was a city dedicated on Octavian's victory against Anthony and Cleopatra. Nicopolis is close to the Ionian Sea, at the south of the ancient Greek Kasiopi. Apart from the odeion a Roman theatre was also found in Nicopolis.

The odeion is located in the centre of the ancient city and was used for speech, religious and music contests and theatre performances [1]. Its architecture is based on the western type of the Roman odeia, built on flat ground, with the koilon/cavea (the semicircular structure of the seats) supported by a complex system, which is comprised of semicircular galleries, arcs and domes. In general, its architecture follows the basic principles set by Vitruvius on the architectural design of theatres and odeia [2]. The plan and perspective view of the odeion are presented in figure 1.

Figure 1 – Plan and perspective view of the odeion of Nicopolis

The Roman theatres and odeia present a major construction difference when compared with the ancient Greek; the koilon and the skene building created a uniform architectural whole [1]. Thus, the construction of the odeion does not follow the usual practice where the koilon is inscribed in the rectangular walls of the building, as it happens in the odeia of Pompeii, Epidaurus, Agrippa, Dion, Kos, Rhodes etc. Its plan resembles the odeia of Korinth, and Thessaloniki [3]. Its skene building and proskenion resemble the odeion of Pompeii. The odeion also presents some rare elements of great interest, such as the drop curtain mechanism and the sewage system.

Research has been carried out regarding Greek and Roman odeia, suggesting that they were roofed most probably with a wooden structure. However, since in some cases

the size would not allow such a structure, a fabric/rope construction combination called velarium was probably used [4].

There is a lot of evidence found in the odeion, regarding the structure of its roof and its skene-building [5]. It was probably wooden, supported by wooden columns. Their bases were found at the koilon, while slots for the support of beams were found both at the skene-building and the perimeter at the end of the koilon.

3. Acoustic analysis

The presence of the roof affected the acoustics of the odeia, allowing them to host both speech and music events, which, in previous studies, is verified by acoustic simulation [6]. The methodology that was followed included: on-site measurements and analysis, 3D model reconstruction, verification of simulation parameters and acoustic simulation of possible odeion layouts/conditions in antiquity.

3.1 On- site measurements

Two measurement methods were carried out for the present condition of the odeion: impulse response recording and frequency sweep measurements. The values of the acoustic indices and qualities are used for the verification of simulation parameters of the model. Also, results of the present acoustic condition of the odeion can be extracted.

Both procedures of RT estimation almost agree on a mean RT of 0.5-0.6s in all octave bands for the current condition. A uniform RT of 0.6sec is not satisfying for musical performances, especially at the lower part of the spectrum. Addition of reflectors and orchestra enclosures would certainly enhance sound. Also, audience absorption during the measurements would modify the acoustic conditions in the case of musical events. Similar results of RT can be found at the Odeion of Thessaloniki [7].

Definition is relatively high, at 80-85% at 250, 500 and 1kHz, revealing a high percentage of the sound energy that arrives in the first 50ms. These observations regarding the present condition of the odeion underline its appropriateness for speech/theatre performances. Clarity is similarly high.

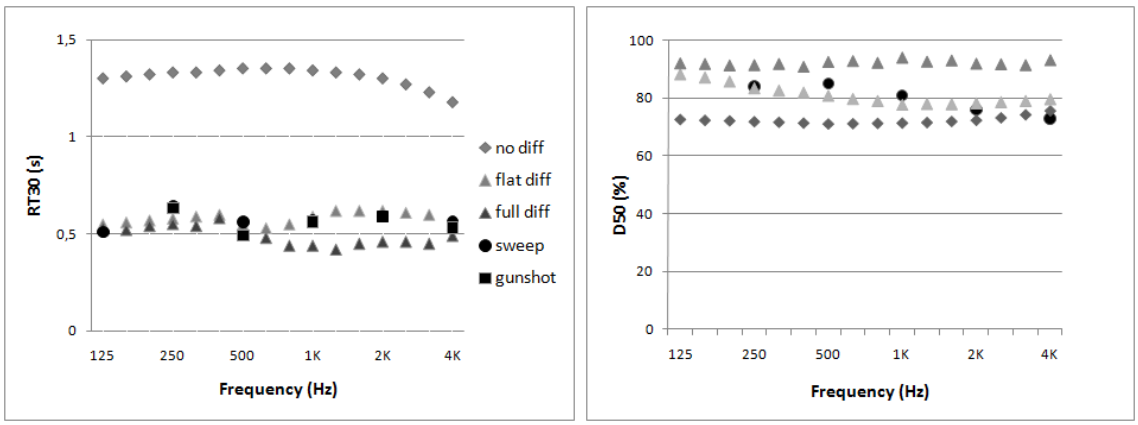
3.2 Acoustic simulation methodology

Based on the architectural drawings provided [1], the model of the odeion was reconstructed in CAAD software Archicad in both the present and the ancient condition. Then acoustic software Raynoise was used for calibrating the odeion's acoustic performance, by comparing acoustic indices with on-site measurements. For the construction of the acoustic model the materials are specified and absorption coefficients are attributed, based on previous studies [8]. The absorption coefficients are presented in table 1.

Table 1 – Absorption coefficients used in the simulation.

Absorption coefficients	125Hz	250Hz	500Hz	1KHz	2KHz	4KHz
Brick	0.09	0.07	0.05	0.05	0.05	0.05
Stone	0.04	0.05	0.06	0.06	0.07	0.09
Wood	0.15	0.11	0.10	0.07	0.06	0.07
Velarium	0.05	0.03	0.35	0.40	0.50	0.50

The diffusion characteristics of the surfaces are defined from the following trials: (i) non diffusive surfaces; only geometrical reflections, (ii) flat panel diffusion and (iii) fully diffusive surfaces. From these trials it is indicated that the model that corresponds to the on-site measurements is the one with the flat panel diffusion. From this procedure, the diffusion of the surfaces is defined. The graphs illustrating the comparison between the measurements and the simulation in order to determine the appropriate material and simulation parameters are shown in figure 2 for RT30 and D50 for the frequency range.



a b

Figure 2 – Comparison between measurement and simulation resutls. a) RT30 (s) and b) D50 (%)

3.3 Acoustic analysis' results

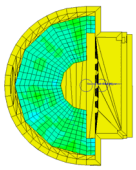
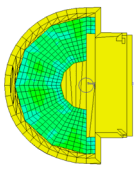
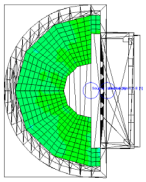
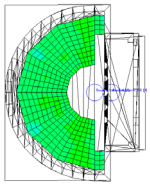
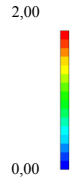
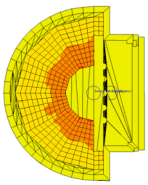
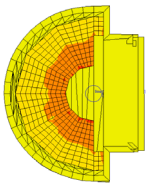
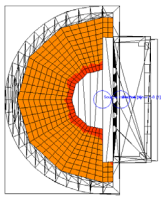
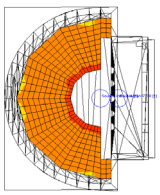
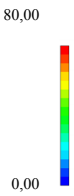
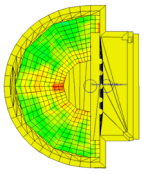
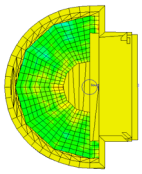
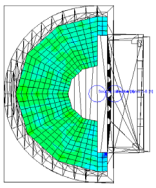
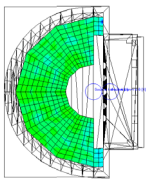
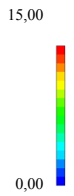
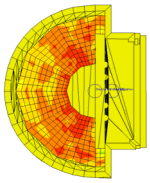
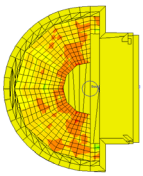
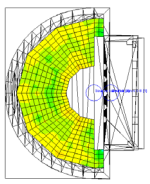
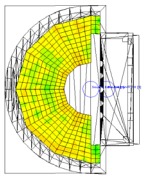
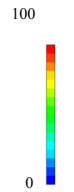
After the definition and verification of the simulation parameters, four configurations of the odeion are investigated. They include the odeion with (i) raised walls/enclosed, (ii) raised walls & roofed skene-building, (iii) fully roofed/wooden roof and (iv) fully roofed/velarium. Table 2 presents the colour maps of the acoustic indices in these configurations.

The existence of a roof over the odeion seems to have almost equal results in both cases of wooden roof or velarium. The case of the velarium seems to be even better than the wooden roof, regarding the uniformity of the acoustic indices. From the analysis it is suggested that the distribution of both SPL and RT30 is even in the odeion. The increase of RT30 and the uniformity of its values, due to the existence of the roof, suggest that the odeion was appropriate for music performances, compared with open theatre conditions. Although the RT30 is not long enough for a symphonic orchestra, the qualities of the ancient Greek & Roman music must be taken into account. Nevertheless, it is possible to partly reconstruct the original condition of the odeion, with the use of lightweight structures, so that other music types would be performed.

The odeion of Nikopolis has a seating capacity of approximately 1000 people and a total volume (including the surrounding walls of the ancient condition) 7200m^3. Its RT, as it results from the model with the wooden roof, is 1,1sec at the unoccupied condition. At the same time Helsinki's Kultuuritalo plan in wide fan shape is similar to ancient odeia with seating capacity of 1500, and a total volume of 10.000m^3 [2]. According to Beranek "it has excellent definition, without audience, and because the shape of the

ceiling provides essential short initial time delay gaps, the hall sounds much better than its low reverberation time and the wide fan shape of its plan would suggest" [9]. Its average RT at 500-1k Hz is 1,05sec for the occupied condition. Although a direct comparison cannot be made Helsinki's Kiltuuritalo can provide some indication on the acoustic qualities of odeia.

Table 2 – Colour maps illustrating the acoustic indices for the four configurations.

	walls/enclosed	**walls & roofed skene**	**fully roofed/wood**	**fully roofed/ velarium**	range
RT30 (s)					
SPL (dB)					
C80 (dB)					
D50(%)					

4. Conclusions

This paper investigated the odeion of Nicopolis based on on-site measurements and acoustic simulation. Both the present and ancient conditions of the odeion have been examined. It was revealed that, based on contemporary criteria, the roofed condition improved the acoustics of the odeion.

All the results of the present condition of the odeion of Nicopolis reveal its appropriateness for speech performances and theatre plays. Certain measures should be taken for music that accompanies plays, since longer reverberation times are required. From the simulation, especially from the covered odeion with velarium, which seems to be the most probable construction, it is suggested that the odeion of Nikopolis would have been adequate for musical performances. The lack of low frequency reverberation is definitely a disadvantage for today's music, but probably it wasn't for Roman music at that time.

The occupied of the odeion, which would modify the acoustic indices, is planned. Nevertheless, the results regarding the acoustic environment of the roofed odeia of antiquity differentiates them from the open-air theatres, revealing the appropriateness of both space types for their use, namely music and theatre performances. Further work should also include interdisciplinary investigation between musicologists, architects and engineers.

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