OPEN-AIR AMPHITHEATER IN ANDROS

K. Dadiotis EAGROUP - ACC Acoustics Consultancy Company, Greece
A. Galatas EAGROUP - ACC Acoustics Consultancy Company, Greece
K. Kondylatou K. Kondylatou – K. Loukos and partners Architects, Greece
K. Loukos K. Kondylatou – K. Loukos and partners Architects, Greece

1 INTRODUCTION

Open-air amphitheaters are part of the cultural background of Greece since ancient times, with evolving performances, from the first ancient theater plays to the modern electro-acoustically amplified theater and music performances.

A local benefactor, Mr. Alkiviadis Tattos, wished to provide the citizens of Andros with an open-air amphitheater that would be a cultural hub for the city and the island.

The aim of this project was for the amphitheater to blend in with the landscape, providing the maximum integration, while at the same time ensuring that it had the minimum impact to the urban soundscape.

This paper presents the Acoustic and Architectural design process of the open-air amphitheater of Andros that was built in 2015 and houses the International Festival of Andros since then. The sound uniformity in the spectator area is calculated, during strong northern winds, with the use of acoustic 3D modelling and the noise exposure of the Amphitheater is investigated though field measurements and noise propagation predictions.

2 PROJECT AREA

2.1 Location

The location chosen is close to center of the city of Andros, next to the town hall. The land was owned by the Municipality.

The plot of land was selected as it combined easy access/parking and it had the required topographic characteristics. It had a naturally occurring slope, with the Typical Cycladic terraces and an inclination of 20^{o}. The slope would minimize the required excavations and the resulting height of construction, as the Amphitheatre would be embedded in the hillside, similarly to the Ancient Greek Theaters.

The slope was facing Southeast, so the spectators would be protected from the strong Northern Summer winds “Meltemia”, that occur in the Region of Central Aegean, as the hillside and the town itself would act as wind barrier.

The city of Andros extends to the North, Northeast and West of the Amphitheater, so the stage while oriented toward the city, will be at the lowest possible height compared to the sensitive receiver in the region.
The only exception is the school on the Southeast, which is not in operation during the cultural events (typically 8:00-11:00pm) in the Amphitheater (Figure 1).

Figure 1. Project Area

2.2 The Theater

The amphitheater is open-air, with 15 rows and a capacity of approximately 900 spectators. The stage is at a level of +31.70 m and the highest platform at a level of +42.70 m, at a horizontal distance of about 20 m from the back of the stage (Figure 2).

Behind the stage a building is erected that houses auxiliary uses, provides early reflection for sound amplification towards the spectators and acts as a noise barrier from the public parking to the South.

To the West of the amphitheater, a multi-story closed Cultural Center will be built what will also act as a sound barrier for the houses on that side of the Amphitheater.

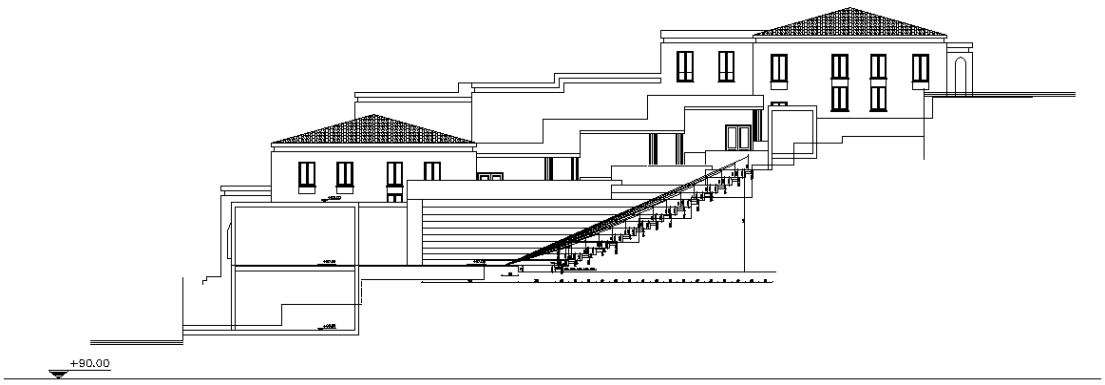


Figure 2, Cross-Section of Open-Air Amphitheater with the Cultural Center on the background

Note: The Cultural Center has not been built yet but is has been considered in the study.

3 SOUND PROPAGATION MODELLING

The noise mapping and noise propagation software that was used in this study was IMMI by Woelfel (License No. S72/354)[1].

It is a special sound propagation prediction and noise mapping software. This software calculates and predicts noise emissions in the external environment with modules for industrial, road, railway, aviation noise, but also any other noise. Its calculations are based on the ray tracing method.

In the calculations of the present study, based on the directive of the Atmospheric Pollution and Noise Control Directorate of the Ministry of Environment, Energy and Climate Change, the contribution of up to third (3rd) order reflections are calculated used. The results of the calculations can be presented as noise maps with equalized noise curves in plan view or in section.

In the specific project under study for noise propagation it is assumed that:

- all sources related to electromechanical equipment and sources of outdoor events have been considered as point sources of noise and are calculated based on the ISO 9613-2[2] calculation method.
- all road traffic noise sources are calculated based on the calculation method XP S 31-133 (NMPB)[3].

Both calculation methods are the provisional calculation methods for Strategic Noise Mapping by the European Commission DIRECTIVE 2002/49/EC[4] at the time of the project development (2013).

For the construction of the three-dimensional model of noise propagation, topographic diagrams, impressions of the elevational relief and footprints of the buildings in the area and the architectural plans of the amphitheater were used. All building surfaces were considered reflective.

The model for the investigation of sound propagation during events in the amphitheater under study is presented on the next page (Figure 3).

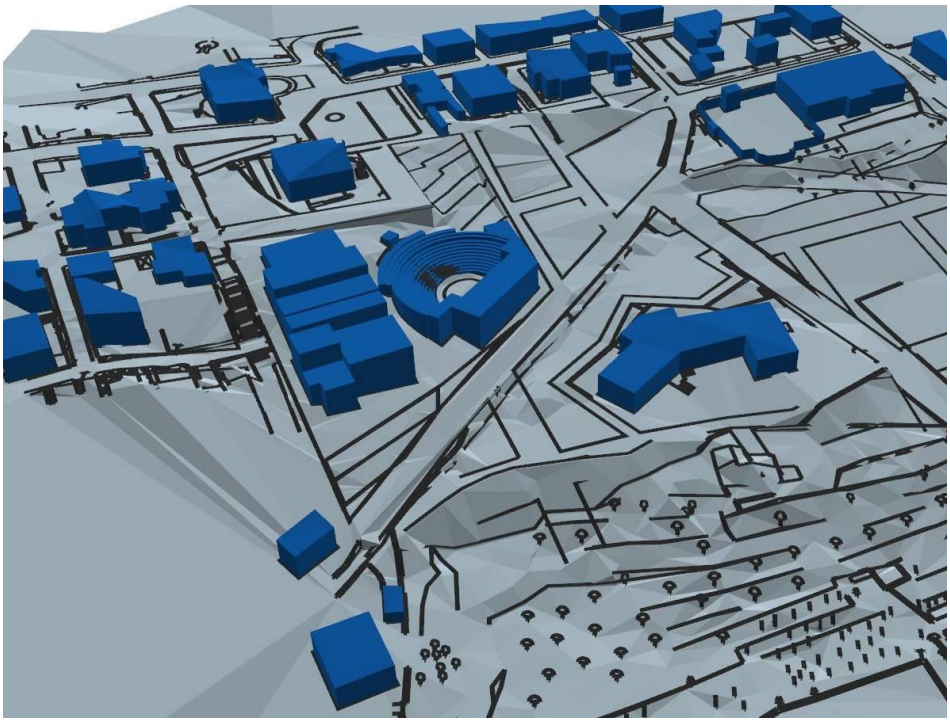


Figure 3. 3D model view (view from southwest)

4 AMPHITHEATER ORIENTATION

In the island of Andros there are strong Northern winds, especially in the summer months when the Amphitheatre will be used more often.

The choice of the direction of the main axis of outdoor theatres does not follow any orientation, but in terms of acoustics it should take into account that the concave relief favours the propagation of direct sound due to geometry and temperature gradient, while the direction of the wind also plays an important role.

Therefore, the ideal orientation of the Amphitheatre based on the topographic relief would be towards the North, while based on the wind, for events that do not have electro-acoustic amplification (e.g. theatrical performances), it would be towards the South, i.e. the stage should face the stands to the South. In the later case the wind will be directed from the stage towards the spectators helping the propagation of the sound wave and requiring less source intensity.

The fact that the orientation is skewed compared to the North axis also presents the potential for unevenness in the sound level that will reach spectators directly to the North of the stage compared to those on the West.

The propagation of the acoustic wave, from two static sound sources positioned on either end of the stage, was investigated with the orientation defined by the slope of the ground combined with the boundaries of the plot, considering a North wind with a speed of 90 km/h. The results of the sound propagation are presented n

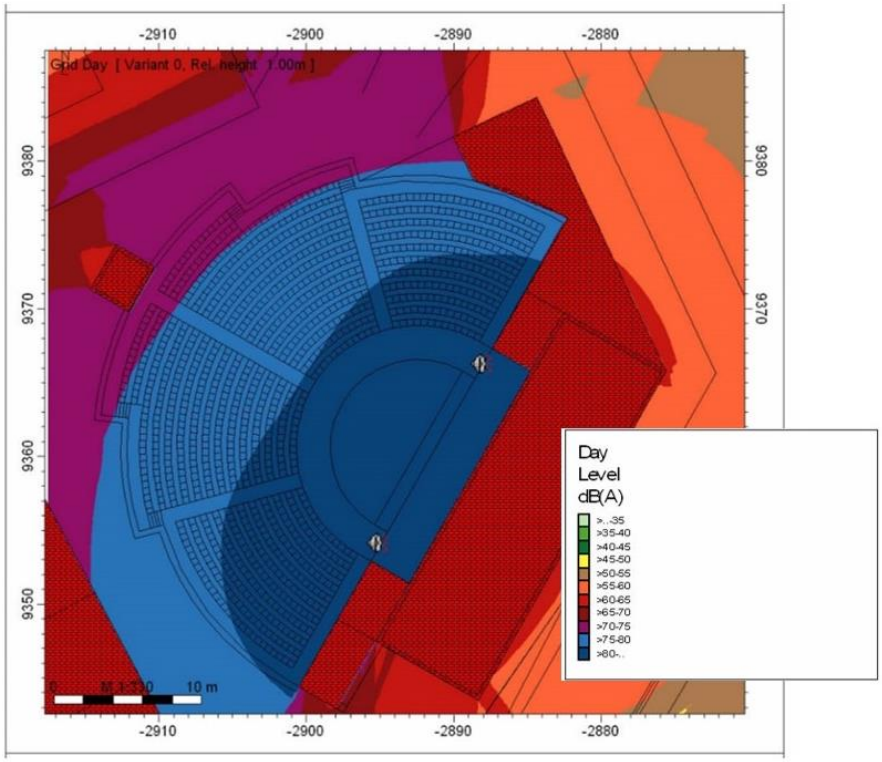


Figure 4.

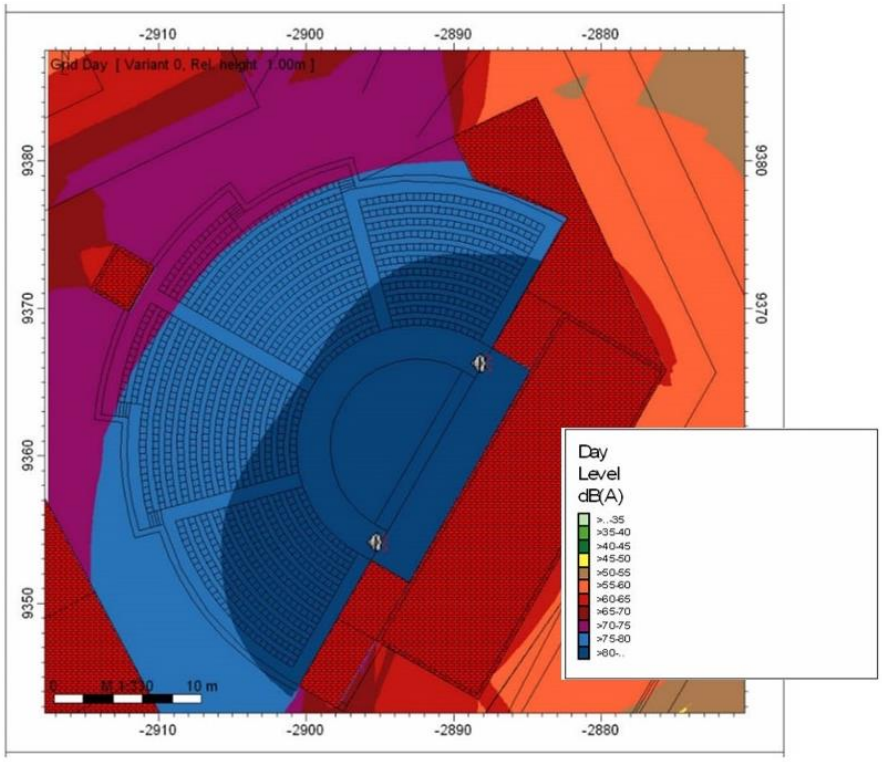


Figure 4. Investigation of sound propagation inside the Amphitheatre with a strong North wind.

The isonoise curves show no substantial unevenness in the sound levels reaching the viewers as the maximum difference observed in the same row of viewers is 2 dB and a difference between the first and the last row is less than 10 dB. At the same time the sound attenuation between the center of the stage and the last row is 15 dB.

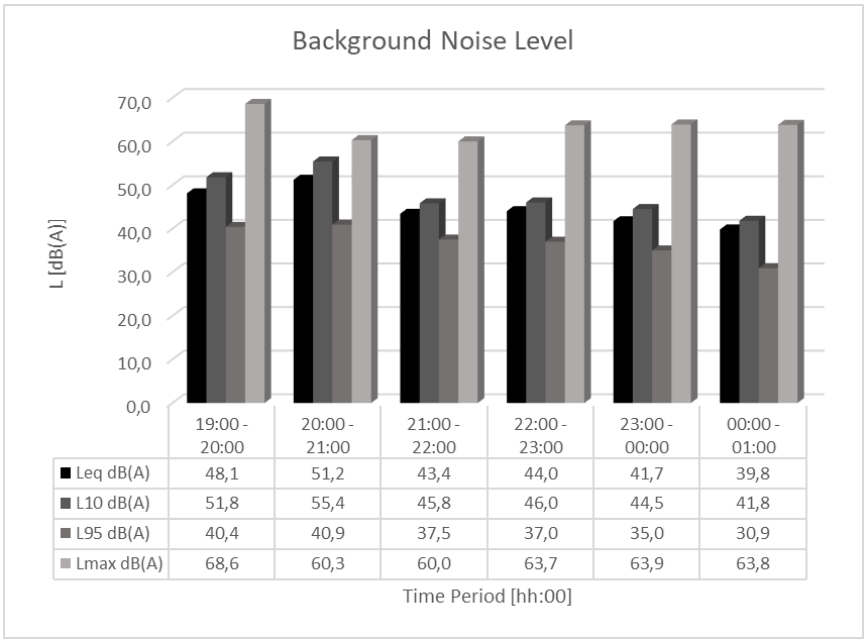
Based on the simulations above, the events in the Amphitheater, will not be substantially affected by the climate conditions in the region.

5 NOISE PROTECTION OF THE AMPHITHEATER

The Amphitheatre being adjacent to an urban area would need to be protected from external noise sources such as the roads, the Public Parking and the Open-air Cinema situated at the Northeast.

5.1 Background Noise Measurements

To establish the Background Noise Levels in the region noise measurements were made during the hours of Amphitheatres typical operation (08:00-11:00pm) with the Open-air Cinema in operation.



	19:00 - 20:00	20:00 - 21:00	21:00 - 22:00	22:00 - 23:00	23:00 - 00:00	00:00 - 01:00
Leq dB(A)	48,1	51,2	43,4	44,0	41,7	39,8
L10 dB(A)	51,8	55,4	45,8	46,0	44,5	41,8
L95 dB(A)	40,4	40,9	37,5	37,0	35,0	30,9
Lmax dB(A)	68,6	60,3	60,0	63,7	63,9	63,8

Figure 5. Background Noise Measurements (August 1st, 2013)

The measurements indicated a low background noise level which does not exceed 45 dB(A) in the time period of 09:00-11:00 pm (typical operation time).

The measurements indicate that the amphitheater is not exposed to high levels of urban noise while the sound from the operation of the Open-Air Cinema is not detectable above the background noise.

5.2 Signal-to-Noise Ratio

Given that the noise attenuation between the stage and the last row has been established to be in the order of 15 dB and the background level has been measured at 45 dB(A), in order to achieve a signal to noise ration above 25 dB, the sound source must achieve a sound pressure level, on stage, on the stage must be in the order of 85 dB.

This level can be achieved with the human voice[5] which makes the venue acceptable even for theatrical performances even without electroacoustic amplification.

5.3 Effect of the other buildings/structures of the plot on the acoustics of the theater

The study showed that due to the gradation of the ground, the adjacent building of the cultural center does not affect the acoustics of the amphitheater through reflections and therefore no sound-absorbing treatment is needed for the facade of the building towards the theater.

On the contrary, the building placed at the back of the stage should have flat and reflective surfaces as it is required to act as an amplifier for the sound of the stage.

The stage should not be elevated in relation to the access aisle of the front seats and its final surface should be of sound-reflecting materials to achieve high acoustic comfort for the front spectators.

The final configuration of the canopies to the left and right of the stage between the stands and auxiliary building were designed to provide optimal visual and acoustic comfort for the spectators who will be at the ends of the stands.

6 NOISE EXPOSURE OF ADJACENT SENSITIVE RECEIVERS

The sound propagation from the stage when the event creates a sound pressure level of 85 dB(A) in presented in Figure 6.

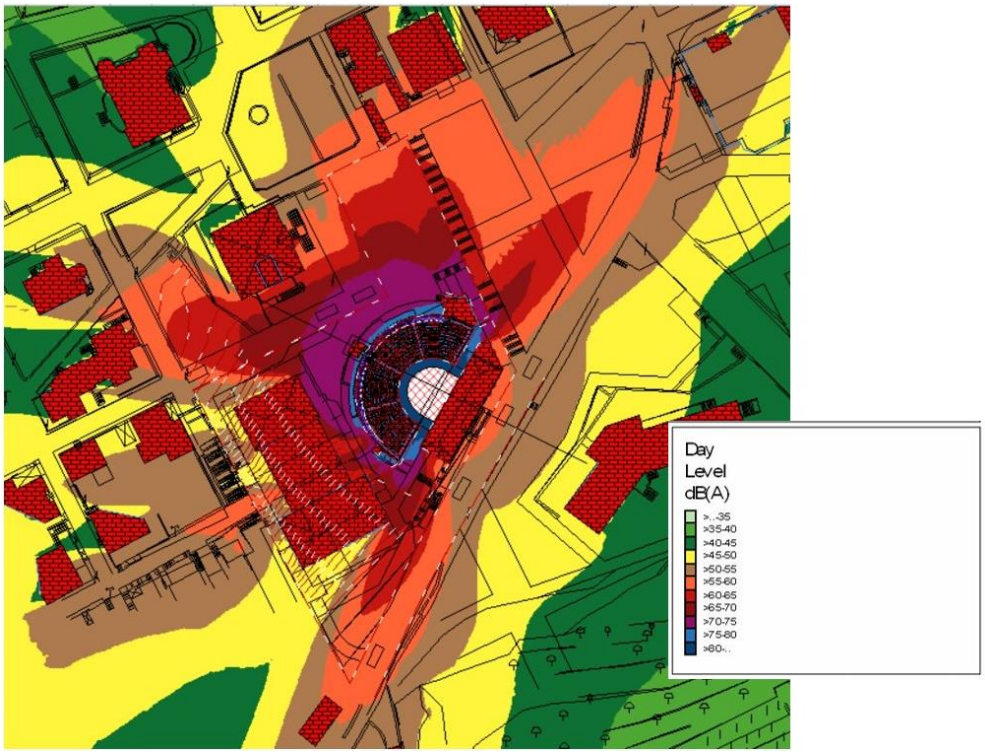


Figure 6. Investigation of sound propagation during event in the amphitheatre.

From the level of the stage there is no visual contact with other buildings except for part of the top floor of the town hall, as the cultural center building and the building at the back of the stage acts as a sound barrier.

The North wind creates an acoustic shadow on the residences North of the theater due to the uplift of the sound waves when directed downwind, while to the South, where the sound waves curve downwards limiting the acoustic shadow provided by the theater's outbuilding as a sound barrier, the density of houses and other sensitive receiver is very low (it is considered that the use of the theater will take place in the evening hours when the adjacent school is not expected to operate).

The sound from the venue that reaches the closed housed to the North and West of the Amphitheater has a sound pressure level of 55 dB(A) which exceeds the background noise level measured, 45 dB(A), by more than 10 dB and it is therefore expected to be distinct.

7 SUMMARY

The paper presented an overview of the design considerations of the Open-Air Amphitheatre of Andros. The aspects that were taken into account for the choice of location were presented and the main Acoustic measured taken to protect ensure that the venue could operated in the given urban environment under the specific climate conditions of the region.

The strong North Winds of region were proved to not substantially effect the sound inside the Amphitheatre, while the urban background noise does not interfere with the events even without electroacoustic amplification. The noise exposure of the region from the Amphitheater was established.

The Amphitheater has been in operation since 2015 hosting the International Festival of Andros under the direction of Pantelis Voulgaris.

8 REFERENCES

1. IMMI, Noise Mapping Software - https://immi.woelfel.de/en
2. ISO 9613-2: Acoustics – Attenuation of sound during propagation outdoors including car park study (normal case)
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4. DIRECTIVE 2002/49/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 June 2002 relating to the assessment and management of environmental noise
5. J. Melton, Z. Bradford, J. Lee, 'Acoustic Characteristics of Vocal Sounds Used by Professional Actors Performing Classical Material Without Microphones in Outdoor Theatre', Journal of Voice, Volume 36, Issue 5, Pages 733.e23-733.e29 (September 2022)
6. International Festival of Andros - https://www.festivalandros.gr/en/