THE ACOUSTIC DESIGN OF AMPHITHEATRE "IOANNIS DESPOTOPOULOS" IN ATHENS CONSERVATOIRE, ATHENS, GREECE

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1 INTRODUCTION

The Athens Conservatoire is an emblematic and prestigious Bauhaus building located in the main cultural axis of Athens. It is a successful, sustainable and internationally recognized School of Performing Arts, an educational and cultural center for music, dance and theatre, a lively hub for young artists of international calibre and a point of reference in the city life. The building was originally built in the period between 1969-1976 and it was designed by the famous Greek architect John Despotopoulos (Jon Despo 1903-1992) and constitutes an important example of modern Greek architecture. Athens Conservatoire, is the country's oldest non-profit educational organization for Music and Theatre, with almost 150-year history and active contribution in the field of performing arts. Some of the famous graduates of Athens Conservatoire are: Maria Kallas, Mikis Theodorakis, Manos Chatzidakis, Nikos Skalkotas, Dimitris Sgouros and many more.

During the last few years, the building has been undergoing a process of gradual transformation and renovation. The architects in charge of the refurbishment works are Thymio Papayannis Architects (TPA). Part of this work is the renovation of its main auditorium, the **Amphitheatre "Ioannis Despotopoulos"** which is an underground, modern, elegant and of stunning aesthetics multipurpose auditorium of 606-seating capacity ideal for chamber orchestras and sinfoniettas. The amphitheatre forms part of the new "Athens Conservatoire Art Centre" complex which also includes a multi-purpose experimental "black-box" stage of a 200-seating capacity, spaces for conferences, exhibitions, a recording studio complex, an Arts Foyer and a Café/restaurant.

2 THE BUILDING

The Athens Conservatoire is a 160m long, concrete frame building and it has been developed in four storeys. Two of these storeys (i.e. Ground and 1st Level) are above ground floor level and two below ground. Prior to the development of the "Athens Conservatoire Art Centre" complex, the majority of Athens Conservatoire teaching, practice, performance and administration facilities were located at Ground and First Floor levels.

Figures 1 and 2 show the Athens Conservatoire building and the location of the Amphitheatre "Ioannis Despotopoulos" (referred to as the "Auditorium" for the rest of this paper).

Figure 1: The Athens Conservatoire – Site Location

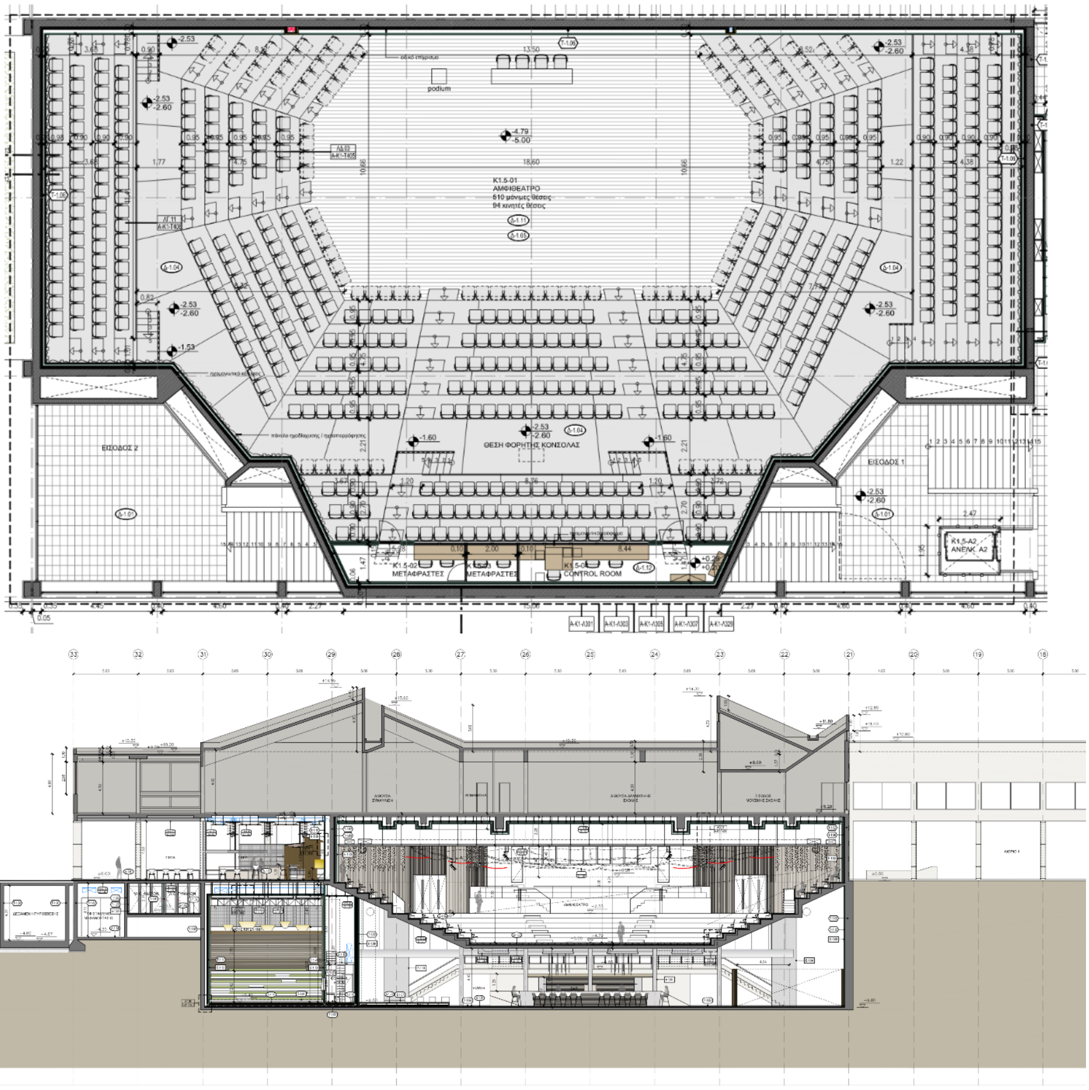

Figure 2: Plan and Section of the Amphitheater “Ioannis Despotopoulos”.

The plan form of the auditorium is that of an amphitheatre (or 180° fan), occupying the first basement and ground floor levels of the western part of the building. Some useful constructional information of the auditorium is presented below:

Date (Construction/Refurb):	1971 / 2022
Seating Capacity:	606
Auditorium Volume (m^3):	4,700
Volume per seat (m3/seat):	7.75
Seating rake (degrees):	~ 22
Distance from the back of the thrust stage to farthest seat:	22.3m
Height:	9.5m at the stage, reduced to 5m at the most remote seat
Stage width (m):	18
Stage Depth (m):	11
Stage area (m^2):	182
Reflector height:	Approximately at 6m from local FFL
Building Frame:	Reinforced concrete

Table 1: Auditorium Constructional Information

The auditorium includes a control room and two translation booths.

3 THE BRIEF

Uses and room acoustics

The initial brief for the auditorium was to be designed as a multi-purpose hall with a primary use that of a speech auditorium for conferences and lectures. Other uses include theatre and dance performances and musical events of unamplified and amplified music. In the auditorium there is a permanent installation of a sound reinforcement system to support lectures and musical events, as required. Nonetheless, the aim of the acoustic design was to support unamplified speech and music from a speaker/source on the stage. During the design process, Athens Conservatoire expressed the desire of investigating further the feasibility to effectively support the use of the auditorium hosting classical music events, acknowledging the limitations imposed by the conflicting acoustic design requirements of speech and classical music. This was in line with the original design aspirations for the auditorium by the architect John Despotopoulos.

Sound Insulation

The auditorium and its operation should be “acoustically independent” from its surrounding areas, which include practice rooms, another auditorium above it and the Drama Room.

4 THE ACOUSTIC DESIGN AND THE CHALLENGES ENCOUNTERED

In order to fulfil this brief, we have visited the auditorium and carried out a number of acoustic measurements to establish its existing acoustic performance. The measurement results were used as a benchmark for any proposed acoustic design recommendations. The testing included:

- the measurement of the sound insulation between the auditorium and its surrounding areas (where possible, because the state of the existing construction was poor).

- The measurement of rooms acoustics, ground borne vibration and road traffic noise.

The following presents briefly a list of the acoustic design challenges encountered:

- The physical limitations and constraints imposed by the existing structure.
  As this was an existing building, the physical constraints and limitations imposed by the existing structure, did dictate the acoustic design provisions on several occasions.

- The proposed uses of the auditorium.
  The conflicting acoustic requirements of its proposed multi-purpose uses.

- The "acoustically independent" operation of the auditorium, considering the adjacencies above and below.

  All areas surrounding the auditorium, including the auditorium itself, have "very high" activity noise level as sources and "very low" tolerance to extraneous noise, as receivers. In more detail;

  - Areas located directly above the auditorium are some of the 1st floor practice rooms, the Drama Room and the 200-seat capacity "Aris Garoufalis" Auditorium.
  - Areas directly below the auditorium include part of the "New Stage" auditorium which a multi-purpose experimental "black-box" stage of a 200-seating capacity and the Arts Lounge. The Arts Lounge is situated right outside the "New Stage" at Level B2 of the building. It is a flexible, open space, used for commercial and trade fairs, art exhibitions, receptions and cocktail parties and also corporate and social events.

  - The auditorium also shares a party wall with the Café located at ground floor level. Please to Figure 2.

The adjacencies above and below the auditorium and the briefing requirement for its "acoustically independent" operation, imposed very high sound insulation requirements for the auditorium building envelope which could only be achieved by using a "box in a box" construction. The existing heavy reinforced concrete structure comprised the "outer shell" of the box. The "inner shell" comprised structurally independent drylining walls, a mass barrier ceiling suspended on springs and a floating concrete floor laid on top of a resilient layer. Unfortunately, structural limitations of the existing structure did not allow for a properly isolated floating floor on springs and on that respect our "box in a box" construction had to be compromised to some extent. Nevertheless, the sound insulation between the auditorium and the 1st floor practice rooms and the 200-seat capacity "Aris Garoufalis" Auditorium was found to be in the order of 78-80 dB D_w.

Other constructional features and ancillary spaces of the auditorium are: A massive grille platform suspended on springs from the concrete roof of the auditorium. This is used to support the sound system, building services, lighting installations etc. The stage is made of timber with a provision of a specialist removable sprung floor for dance performances. The ancillary accommodation includes an interconnecting space behind the stage leading to dressing rooms and storage areas via lobbied acoustic doorsets. The auditorium also includes a control room and two translation booths.

This paper is limited to the room acoustics design of the auditorium. Issues associated with sound insulation are beyond the scope of this paper and are limited to the information provided above.

5 OBJECTIVE ROOM ACOUSTICS ASSESSMENT

As can be seen in Figure 3 (left), the auditorium when we first visited the building, was just an empty shell made of reinforced concrete. Not surprisingly, the measured mid frequency (500Hz – 2kHz) reverberation time was found to be in the order of 7.0 sec.

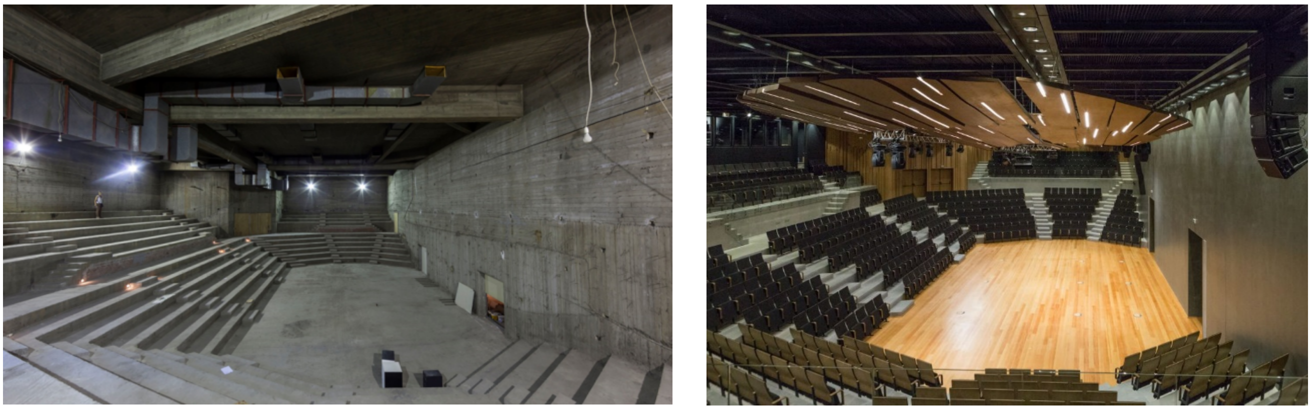

Figure 3: The amphitheater "Ioannis Despotopoulos" before the commencement of works (left) and after its completion (right).

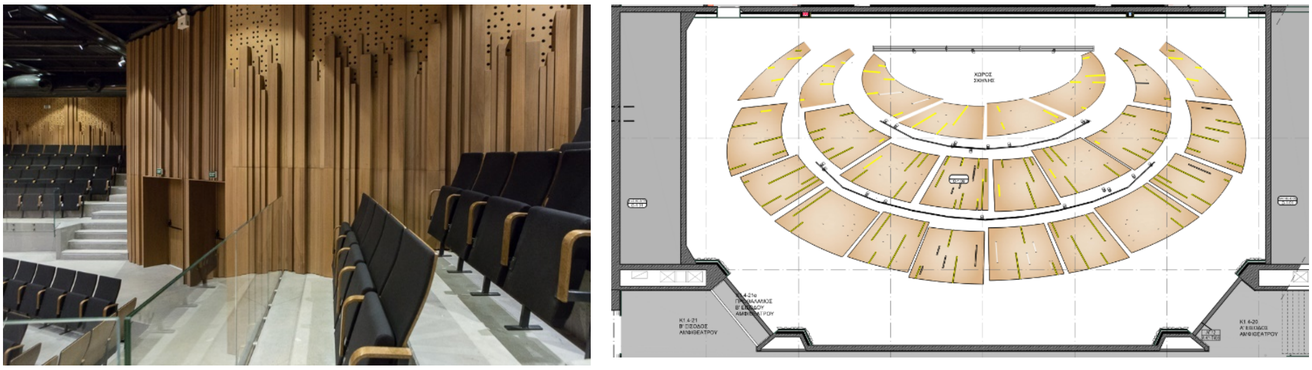

Figure 4: Sound diffuser and absorption wall treatment (Left) and plan of the suspended reflector/diffuser.

The internal volume of the auditorium was excessive for speech. The calculated volume per seat was found to be 7.7m^3/seat. This lies within the recommended [1] range for opera (7-9m^3/seat) but is higher than the recommended value for Drama/Speech (4m^3/seat). This means that achieving the required reverberation time values for speech, in addition to the sound absorption provided by the seating, it would require an additional significant amount of absorption to be introduced into the room. Based on guidance provided in DIN 1841[2], the recommended reverberation time values for a room of this volume for speech and music use, are shown in Figure 5. Ideally, an acoustically acceptable compromise for achieving the briefing requirements would be aiming for a reverberation time at the low end of the recommended music range and at the upper end of the recommended speech range.

The acoustic treatment for achieving the acoustic requirements was as follows:

- Medium upholstered seating, to minimize variation between its unoccupied and occupied configurations. The seats have a timber back.

- With the exception of the front wall which was kept flat and reflective and the backwall (occupied by the control room and translation booths windows), all other walls of the auditorium were acoustically treated with a combination of sound diffusers and sound absorbers. The diffusers were an optimized version of a Schroeder diffuser, without the fins[3] to be developed within the limited depth available imposed by the project constraints. The diffuser developed[4] has a scattering coefficient higher than 0.5 for frequencies above 1000Hz but its performance gets lower with decreasing frequencies. Some additional absorption was located above the diffusers in the form of Helmholtz resonators with a tuned frequency of 1000Hz.

- A sound reflector/diffusor in the form of three concentric rings, as shown in Figure 4 (right), was installed at a height of 6m from FFL. The reflector was made from polyester resin layers, incorporating slots for LED lighting. Each of the reflector panels has been developed incorporating "bumps" and "valleys", forming essentially an overhead diffuser.

The measured reverberation time in the unoccupied room was found to be as shown below. The graph includes the recommended range for speech and music for a room of this volume and also the predicted values of reverberation time in the occupied auditorium.

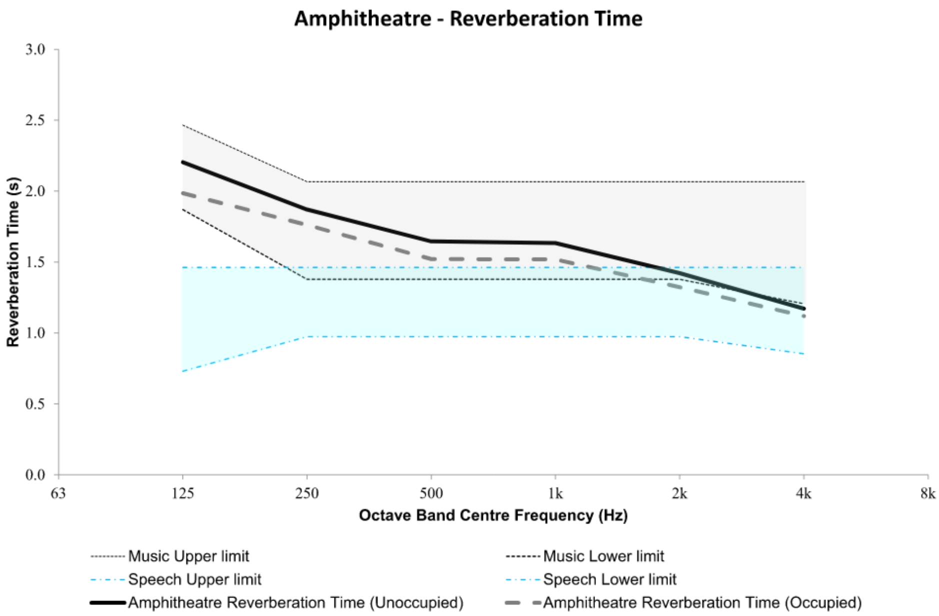

Figure 5: Measured reverberation time in the complete, unoccupied auditorium. The recommended ranges for music and speech uses are shown.

As can be seen, the measured and predicted reverberation times confirmed achieving the desired compromise in reverberation time.

With the seating and all other proposed acoustic treatment installed, we invited the architects, conductors, the sound engineer and the president of Athens Conservatoire to subjectively assess the room acoustic performance of the auditorium. The presentation involved the reproduction of anechoically recorded classical music and speech from a full range portable sound system located in the centre of the stage. The sound levels adjusted to realistically represent an orchestra or a talker on the stage. The panel, including the author, unanimously agreed that there is no need for additional sound absorption, as per the original sound absorption allowance made during the early stages of the design for a speech auditorium.

The auditorium resembles the design of an "enclosed" Ancient Greek Theatre or "Odeon" with a stage large enough to be considered as the "orchestra" and a rear stage wall.

Typically, the arrangement of the audience around a thrust stage in an amphitheatre-type space offers the advantage of having many of the audience closer to the stage and for a hall of this size, this can offer an "intimate" experience for the listeners. On the other hand, depending on its size, imposes certain challenges such as central areas of the hall receiving few early sound reflections which can be perceived as a lack of sound clarity. In this particular case however, centrally located listeners receive, in addition to the direct sound, a strong early reflection from the wall behind the stage, a reflection off the stage floor and a reflection (diffused) from the suspended reflectors/diffusers. In addition to these, all remaining sound energy directed to the suspended reflectors/diffusers is redirected towards the diffused side walls returning attenuated from lateral directions to the audience enhancing the sense of envelopment. This has been objectively measured and subjectively confirmed, as can be seen below.

The measured values of, Early Decay Time (EDT), Objective Clarity C80, Objective Source Broadening, STI and sound pressure level distribution, are presented below:

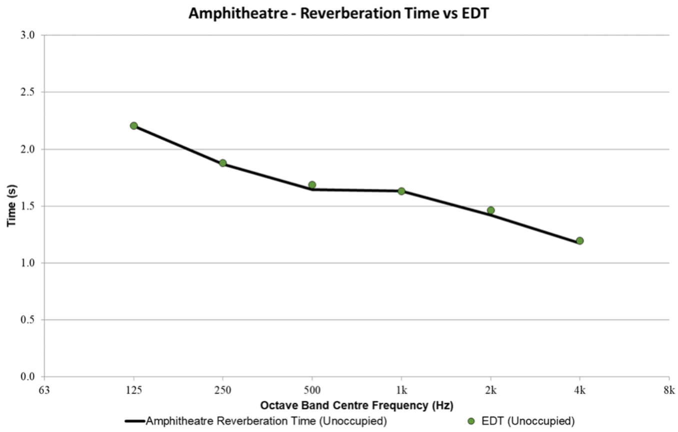

Figure 6: Reverberation Time vs Early Decay Time (averaged over 48 positions)

It is well documented[1], that in a highly diffuse space, the two quantities, RT and EDT, would be identical. As can be seen above, the values of RT and EDT are almost identical and as such, this is an indication of a diffused sound field.

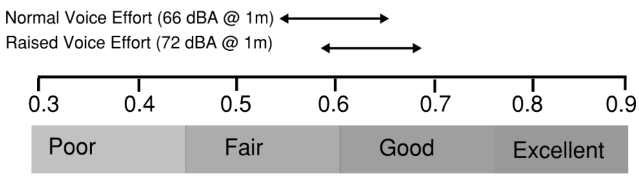

Figure 7: *Speech Intelligibility (STI) measured according to* IEC-60268-16[5] *using a small loudspeaker (6") facing the receiver at 9 no rec positions across half of the seating area (other half is a mirror image).*

Speech intelligibility from a talker on stage with normal voice effort, facing the receiver varies from 0.55 – 0.65 "Fair" to "Good". With a raised voice effort, speech intelligibility is improved further to "Good". Background noise level: NR25.

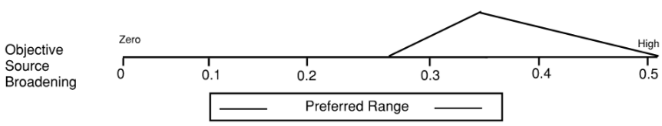

Figure 8: Objective source broadening measured at 9 no rec positions across half of the seating area *(other half is a mirror image).*

The objective source broadening is shown as a triangular pediment with the range of measured values and the apex at the mean value. The mean value over four octaves (125-1000Hz) is used. The preferred range [5] is also shown. Although typically, fan-shaped halls exhibit a limited degree of source broadening, in this particular case, source broadening is high at all positions.

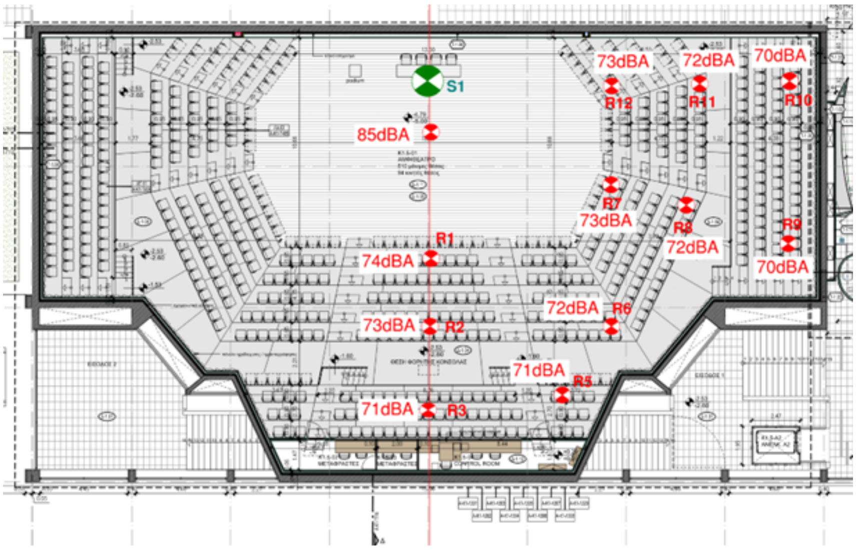

Figure 9: Sound pressure level spatial distribution in the audience, from an omni source on stage

Measurements of Strength (G) were not undertaken, as measurements of the omni-speaker in free field or anechoic chamber were not available. Alternatively, the spatial distribution of sound pressure level from a pink noise stimulus emitted from an omnidirectional source on the stage, was measured in the audience area. As can be seen above, the variation of sound pressure level in the audience area, is within 3dB. This is another positive indication of the diffusivity of the sound field in the auditorium as well as an indication of its loudness.

6 SUBJECTIVE ROOM ACOUSTICS ASSESSMENT

Since its official opening in a glittering ceremony, in the presence of the President of the Hellenic Republic, Mrs. Katerina Sakellaropoulou, on December 2022, the Amphitheatre "Ioannis Despotopoulos has hosted a number of events, including performances from chamber orchestras and sinfoniettas, small ensembles, electronic music, dance performances, TED talks and conferences.

The hall has received very positive reviews overall for its acoustics and architecture by both audience, critics, conductors and performers. It is characterised as an intimate hall with a loud, clean, warm and rich, well-balanced sound, offering close contact between performers and audience. It is a very "reactive" space to the various orchestral dynamics behaving almost like an "instrument" itself bringing the listeners to their feet following a *fortissimo* conclusion while providing intimate sound for smaller ensembles – an advantage of a smaller concert hall compared to larger halls. Its sound gives the impression of a much larger hall. Subjectively, it could be considered by some as being more reverberant that it actually is. The EDT is more closely related to the subjective impression of reverberance [1] but in this particular case, is almost identical with the reverberation time, so the explanation does not lie there. This is a mixed-geometry auditorium of a fairly massive construction and a high degree of scattering surfaces (walls and ceiling/reflector) around it. The soundfield here is well-diffused which may also contribute to the sense of reverberance. Also, the auditorium has a shorter reverberation time in the mid-frequencies and a longer reverberation time in the low frequencies. This leads to the idea that the bass must also be contributing to the sense of reverberation [1]. The longer reverberation time in the low frequencies (2.2sec at 125Hz unoccupied) is welcome by musicians and conductors and the author himself, as it seems to blend nicely with the higher frequencies, providing useful harmonics to the sonic content enhancing the acoustic experience.

Excessive levels near tympani or in front of the highly directive brass sections may occur and due to the proximity of the stage to the audience may occasionally become prominent and mask other sounds in the orchestra. Typically, the location of these instruments is against the rear stage wall which adds further to the output of these instruments. By adjusting the orchestra layout or the dynamics level for these instruments, a conductor can greatly influence the blend of these into the mix.

The diffuse sound field in the auditorium also proves to be a very welcome and supporting feature for the recording of classical orchestra performances.

7 ACHNOWLEDGEMENTS

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8 REFERENCES

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