REMEDIAL ACOUSTICS OF A MONUMENTAL NEOCLASSICAL AUDITORIUM AT TECH. UNIV. ATHENS

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1 INTRODUCTION

This paper refers to the multipurpose auditorium, namely “Kaftantzoglou” hall, of the School of Architecture of the Tech. Univ. Athens. This hall is housed in a monumental neoclassical building, and it is a Europa Nostra award winner[1] of year 2012 (Fig. 1,2, Table 1). The auditorium is mainly used for lectures, as well as for a variety of functions of the School, and is visited every year by wide range of local and international guests, amongst who, academics, architects, engineers etc. Despite splendor, comfort is severely impaired in the auditorium by poor intelligibility of speech; the latter is associated with excessive subjective reverberation, poor loudness of speech signal in the audience area, perception of detrimental echoes, etc. According to a joking comment, the auditorium could be useful, only as a comprehensive educational paradigm of “what not to do”.

This study is part of a research work which aims to remedy the acoustics of the auditorium.

Figure 1 The building façade

Figure 2 Inside view of the auditorium

Date	:	1878
Architect	:	Lyssandros Kaftantzoglou
Volume	:	5800 m^3
Capacity	:	174 persons
Volume per person	:	33.0 m^3/person
Area	:	446.0 m^2
Height (min, max)	:	10.0 m and 17.0 m
Width (max)	:	40.0 m
Depth (max)	:	18.0 m
RT_{mid} (empty hall)	:	3.46 s

Table 1 Basic data of the auditorium

2 PRESENT STATE (BEFORE TREATMENT)

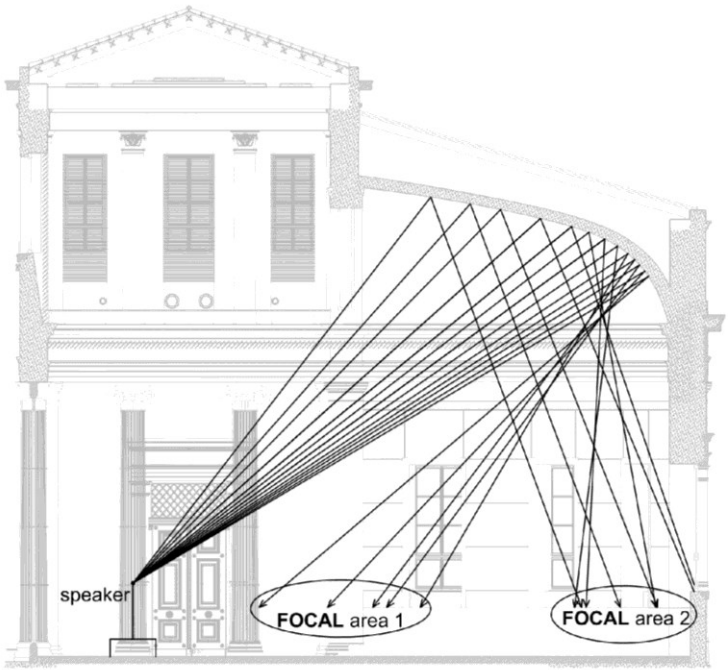
The excessive height and relatively large volume of the auditorium as well as typical neoclassical arrangement in plan and section, combined with hard finishes almost throughout the hall's boundaries, are apparently responsible for a number of acoustic failures; some of these are excessive subjective reverberation, long delayed detrimental echoes, flutter echoes, focusing of sound etc. (Fig. 3).

Measurements of current room acoustic parameters in 17 locations throughout the auditorium were carried out before treatment, in the real and virtual space[2]. This presentation is limited to Reverberation Time results, which are shown in Table 2. Measured values of Reverberation Time, amongst other reasons, justify the need for remedial acoustics.

Noise protection design of the auditorium, is virtually not encountering substantial problems; this is so, thanks to the location of the building relevant to urban noise sources, as well as thanks to the auditorium's careful double glazing, and stone thick walls.

3 PROPOSED ACOUSTIC DESIGN

All wall and ceiling surfaces of the auditorium, are highly decorated according to historic character of the building, and can almost marginally accommodate any acoustic treatment. Preserving the neoclassical character and monumental size of the auditorium, imposes severe limitations to remedial acoustic choices. Under such circumstances, acoustic design was made with care, and was limited in principle, to necessary treatment on room boundaries.



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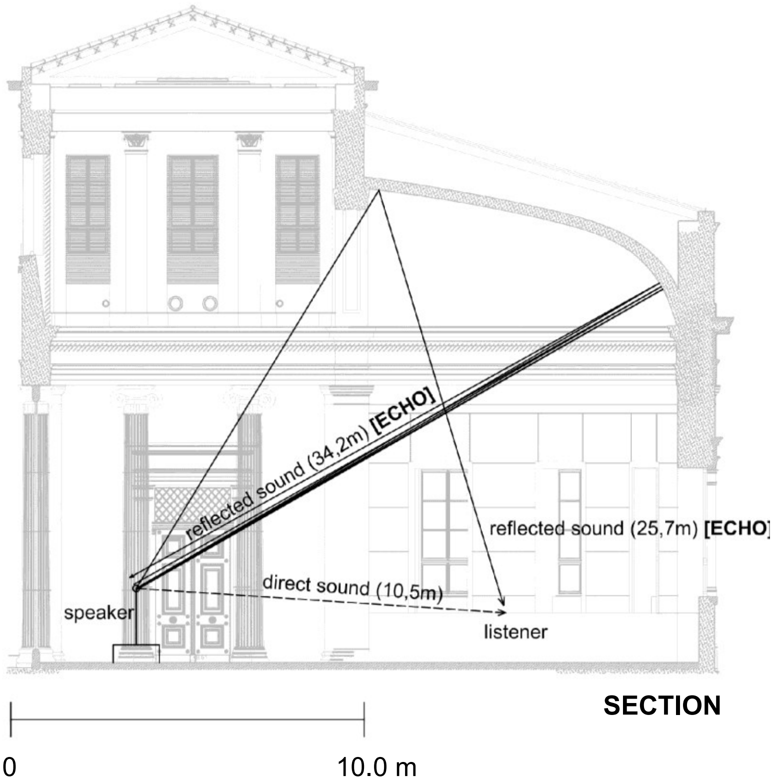

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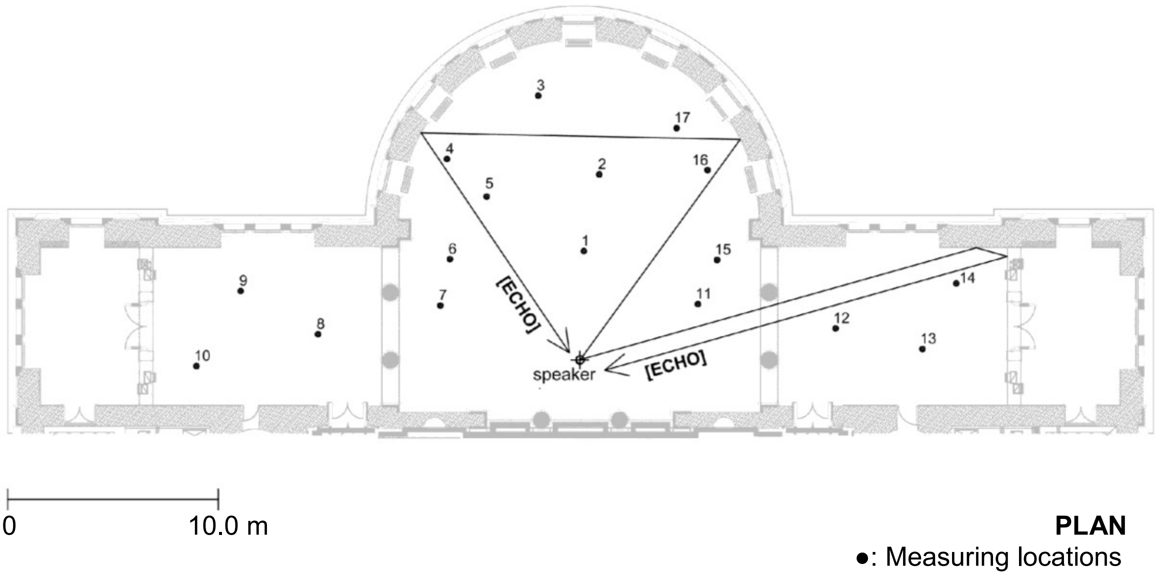


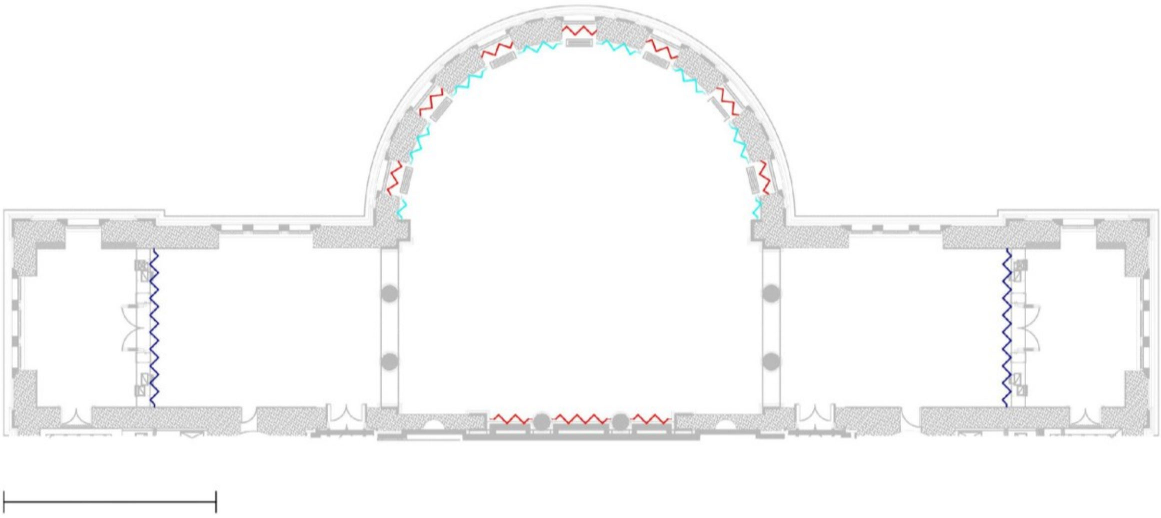
Figure 3 Architectural drawings – Before treatment. Ray tracing demonstrates acoustical faults.

The proposed wall finishes are shown in Fig. 4,5,6,7 and in Table 3. The choice of materials has been a compromise between smart and expensive acoustic treatment such as “Sonacoustic PL” is, and budget-friendly non-proprietary materials. These wall finishes aim at putting right acoustical faults (detrimental echoes, focussing, etc.) as well as at reducing to acceptable levels the Reverberation Time. The target Reverberation Time at mid frequencies was set at 1.5 s in the occupied auditorium. This is a compromise between Cremer’s[3] recommendations and the present architectural limitations.

The reverberation time after treatment, was measured in the simulated sound field using the Odeon software[2]. Also, this parameter was predicted using the classical Sabine’s formula. Results are shown in Table 2. A model of the auditorium in virtual space is shown in Fig. 8.

Moreover, an overhead reflector above the speaker has been designed and is shown in Fig. 9, 10. The sound energy that would be dissipated in the huge volume of the auditorium is directed towards the audience, thanks to this canopy; the latter is virtually the only reflecting surface around the speaker; in this sense, it is of vital importance.

After treatment, sound level in the audience area will possibly need to continue being enhanced electronically, owing to relative shortness in early reflections, and the absorption introduced. Any effort is made that the acoustics after treatment will, at least, offer a suitable background to allow for effective electronic sound reinforcement.



0 10.0 m **PLAN**

0 10.0 m **SECTION**

Figure 4 Architectural drawings – After treatment. /\/\/\/\ *: Sonacoustic PL 45mm,* /\/\/\/\ *: Non proprietary wall finish,* /\/\/\/\ *: StoSilent Top,* /\/\/\/\ *: Thick velvet curtains*

<table>
<tr><th rowspan="2">Octave bands [Hz]</th><th colspan="2">Before Treatment
Reverberation Time [s]
empty hall</th><th colspan="2">After Treatment
Reverberation Time [s]
empty hall</th></tr>
<tr><th>Measured
in situ</th><th>Measured in
simulated sound field</th><th>**Predicted**</th><th>Measured in
simulated sound field</th></tr>
<tr><td>125</td><td rowspan="2">3.16</td><td rowspan="2">3.38</td><td>2.66</td><td>2.44</td></tr>
<tr><td>250</td><td>1.59</td><td>1.95</td></tr>
<tr><td>500</td><td rowspan="2">3.46</td><td rowspan="2">3.48</td><td>1.37</td><td>1.80</td></tr>
<tr><td>1000</td><td>1.42</td><td>1.65</td></tr>
<tr><td>2000</td><td rowspan="2">3.54</td><td rowspan="2">2.74</td><td>1.46</td><td>1.65</td></tr>
<tr><td>4000</td><td>1.33</td><td>1.40</td></tr>
</table>

Table 2 Reverberation Time of the auditorium

No.	**Material**	**Location** *(see Fig. 5)*	**Absorption Coefficients, α** Oct. bands [Hz] 125	250	500	1000	2000	4000
1	Sprayed acoustic plaster, type Sonacoustic PL 45mm *(Fig. 6)*	vaulted ceiling	0.40	0.80	0.95	0.95	0.90	0.90
2	Fiberglass on 3mm plywood, 25mm from solid backing. Finished with open weave fabric (Non-Proprietary) *(Fig. 7)*	semi-circular boundary wall, and coffered ceiling	0.29	0.81	0.98	1.05	1.03	0.99
3	Porous absorptive panel, type StoSilent Top with StoSilent Top finish *(Fig. 8)*	rear wall aisles	0.20	0.40	0.50	0.70	0.65	0.55
4	Thick velvet curtains three-ply fold	windows on semi-circular boundary wall, and on glazing behind speaker	0.30	0.45	0.65	0.56	0.59	0.71

Table 3 Acoustic characteristics of the absorptive finishes

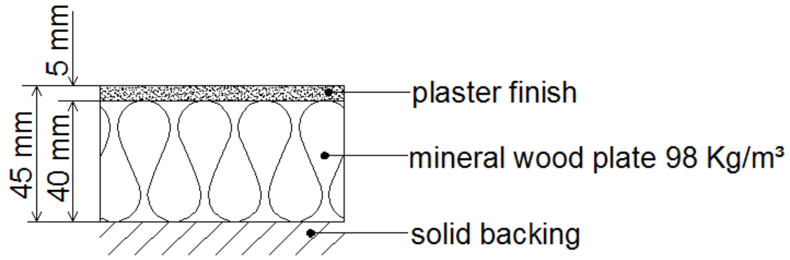


Figure 5 Detail of Sonacoustic PL 45mm [8]

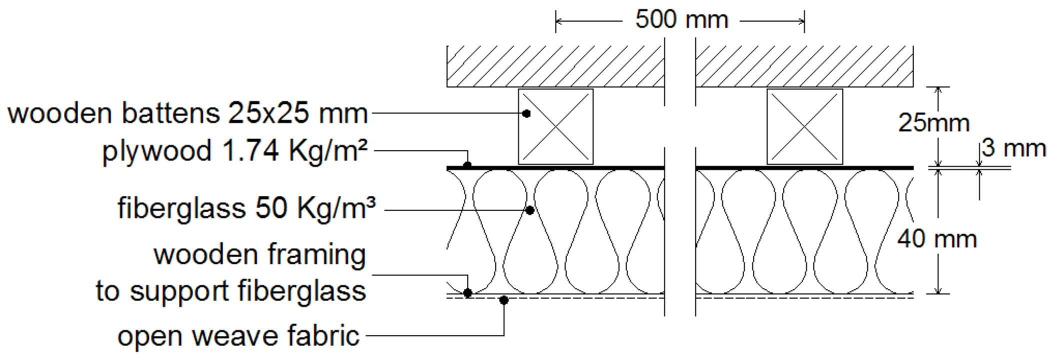


Figure 6 Detail of the non-proprietary acoustic finish [9]

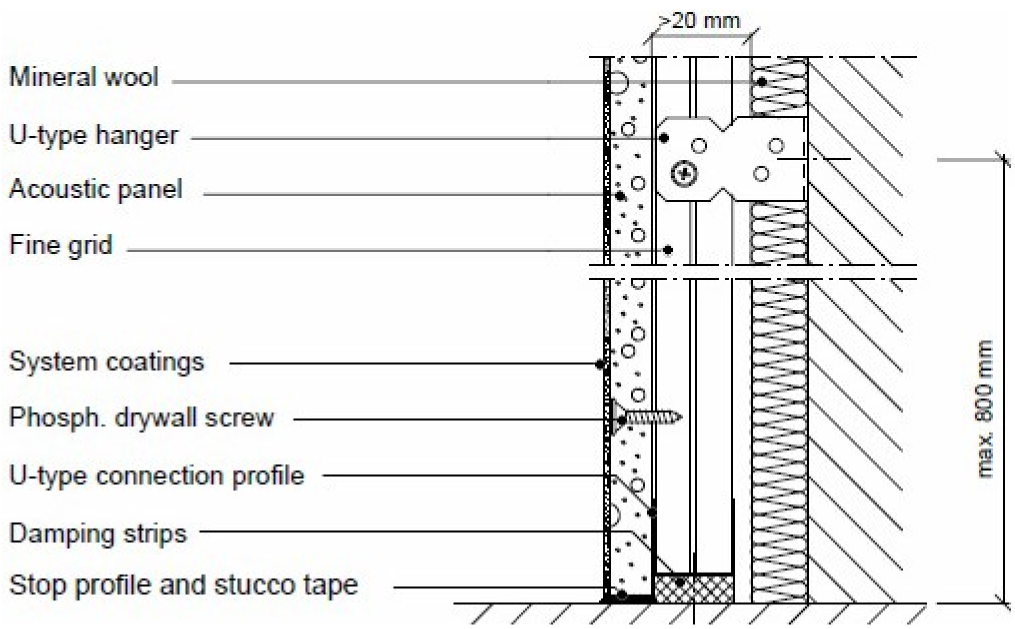


Figure 7 Detail of the StoSilent Top with StoSilent Top finish [10]

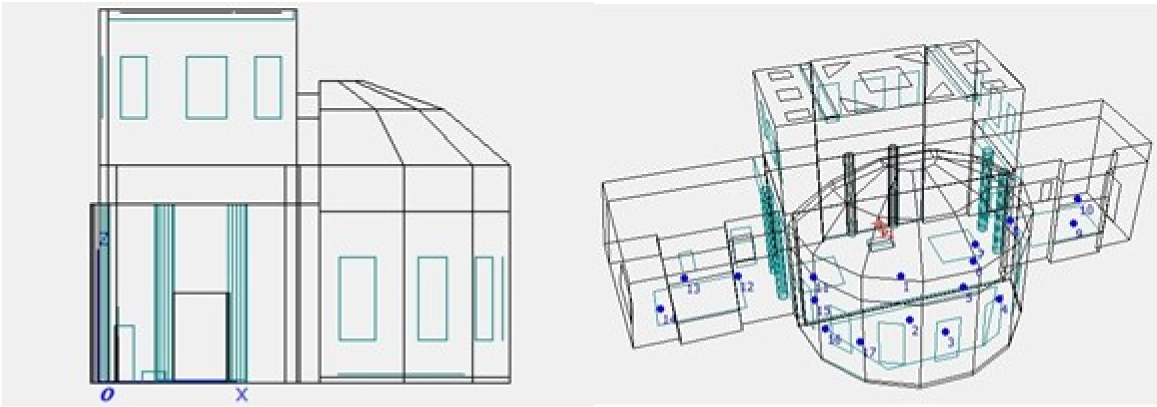


Figure 8 "Odeon" software model of the auditorium

Figure 9 Front view of the auditorium demonstrating proposed overhead reflector; *the latter is of transparent polycarbonate solid panels mounted on a suspended grid*

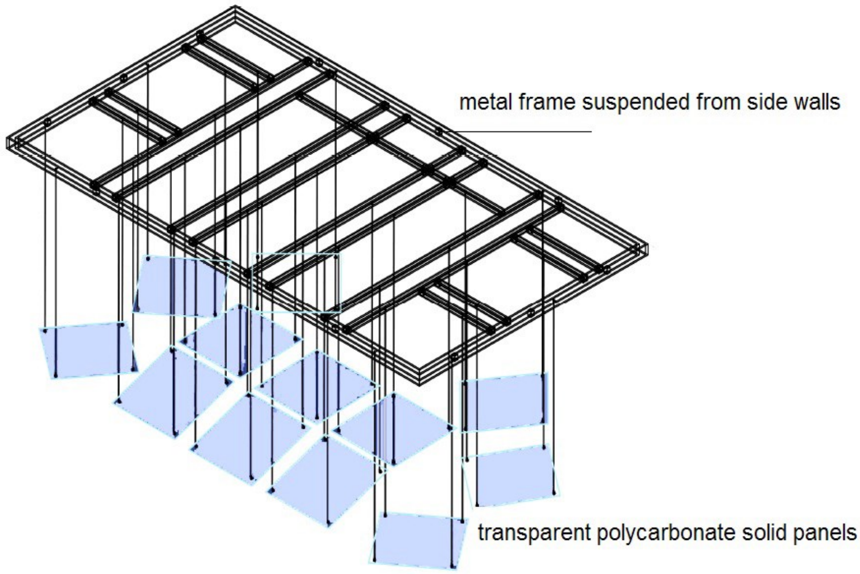


Figure 10 Isometric of suspended overhead reflector

4 DISCUSSION

According to the above results (Table 2), the expected Reverberation Time after treatment, appears to be in fair agreement with target value adopted.
Furthermore, this is a useful exercise which allows for comparison of room acoustic parameters, on the one hand, between virtual and real space measurements, and on the other hand, between measured and predicted values. In particular, measurements of Reverberation Time before treatment, in the real and virtual space respectively, demonstrated good agreement with each other throughout the frequency spectrum. This confirms earlier findings[5, 6, 7] of various authors, and supports the assumption made in this study that the after treatment simulated findings are realistic. Also, comparison of Reverberation Time measurements between virtual space and predictions, demonstrated good agreement throughout the frequency spectrum (Table 2).

5 CONCLUSIONS

Within the limitations imposed to this remedial acoustic design, the proposed solution is expected to meet the requirements of the exercise. This work demonstrates the difficulties associated with acoustic design of preserved monumental buildings, and confirms that acoustics and architecture are capable of coming into terms.

Acknowledgements

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