

THE ACOUSTICS DESIGN OF THE EUSKALDUNA PALACE

Pacs reference SS-RBA-01

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ABSTRACT:

The Euskalduna Palace of Bilbao was inaugurated in 1999.

The main hall of 2200 seats is used for opera, symphonic music and for conventions.

Designing this hall a lot of the rules for to opera houses have been violated which shows that some of this rules are not so important as it seems because the acoustic of the hall has been very well acclaimed by its excellent acoustic.

In this paper we will do a short exposition about the shape and materials used for this hall and an analysis of the acoustical magnitudes obtained.

1. INTRODUCTION

The main hall of the Euskalduna has been designed to be used both for symphonic music, opera house and conventions. Here, we present the acoustical view of the opera configuration.

This hall will have 2200 seats. The hall has a maximum longitude 47.5-m from mouth stage and a width of nearly 34-m between sidewalls. We regard that the longitude is greatest than distance allowable for opera of according criteria. The main stall is placed in front of the stage. The main stall is softly raked and there is a multitude of terraces of audience. This idea of terraces is repeated in the amphitheatres. There are two elevated amphitheatres, steeply raked. The walls are disposed following as a great ship with certain additional reflectors at the sidewalls.

A complex ceiling have was carefully analysed to provide exact reflections over all audience area.

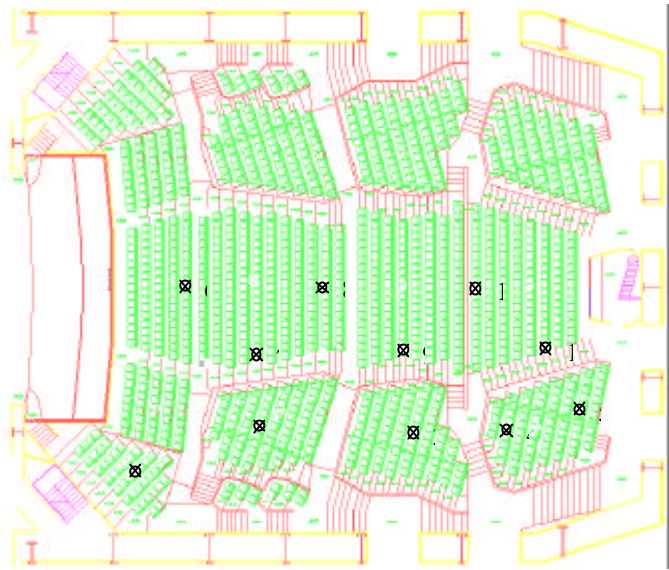


Figure 1: Euskalduna Stalls

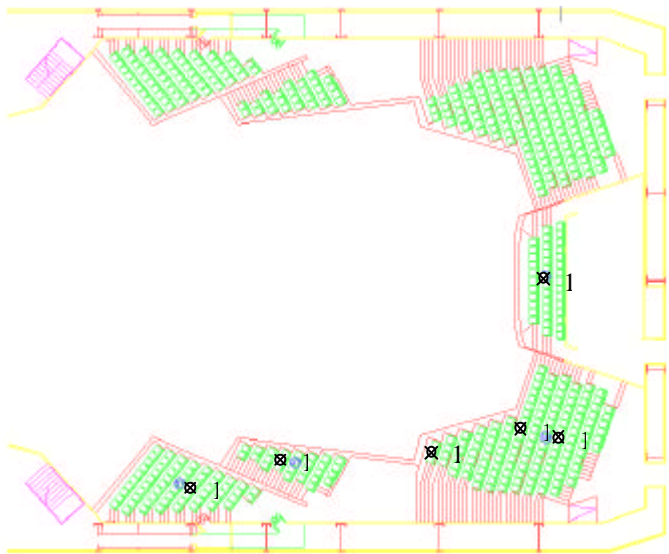


Figure 2: Euskalduna Amphitheatre 1

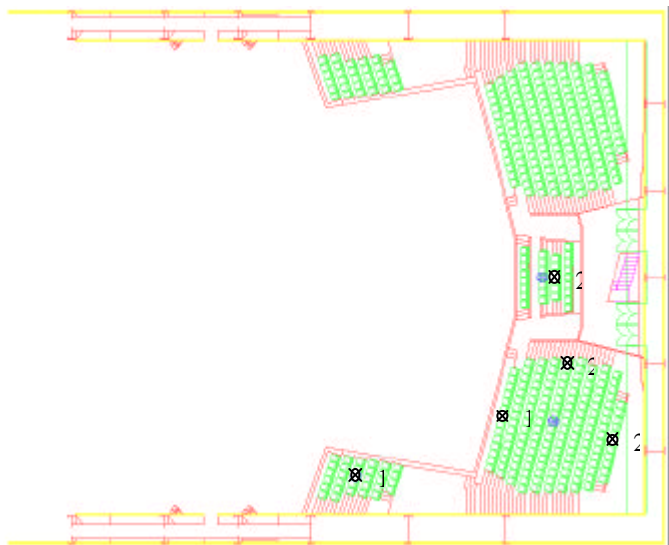
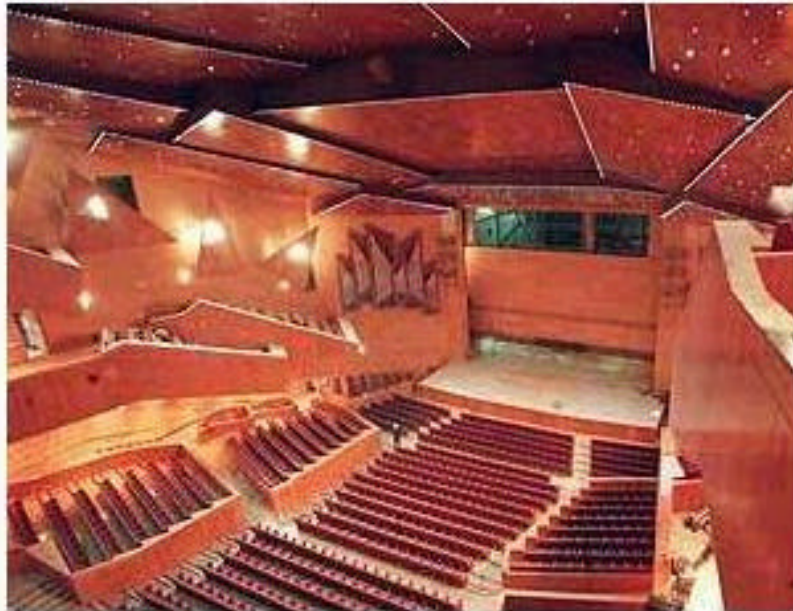


Figure 2: Euskalduna Amphitheatre 1
Figure 3: Euskalduna Amphitheatre 2



PALACIO DE CONGRESOS Y DE LA MUSICA
EUSKALDUNA de BILBAO, of 2200 seats
 Concert Hall, Opera House, Congress

Figure 4: Euskalduna Palace

2. ARCHITECTURAL AND TECHNICAL DETAILS

Usage: Symphonic music, opera, reinforced music, conferences. *Ceiling:* 15 mm to 25-mm plywood with airspace behind; moreover there is a circular resonators in certain side and rear parts of ceiling. *Side, front and rear walls:* 20 mm plywood + gypsum board fixed to wall with a hard and elastic fill up material, except in certain areas of rear wall in where there are circular resonators of wood. *Floor:* Oak parquet fixed over rigid floor. *Carpet:* none. *Stage enclosure:* Yes. *Stage floor:* 40-mm pine over deep airspace (and 15 mm of oak wood placed above pine only for symphonic music). *Stage height:* 1.20m. *Seating:* Special Poltrona Frau seats
Architects: Federico Soriano - M^a Dolores Palacios. *Acoustical Consultant:* Higini Arau..

Acoustical and technical details*

Opera house

$V = 23645 \text{ m}^3$	$S_A = 1534.4 \text{ m}^2$	$S_o \text{ (pit)} = 150 \text{ m}^2$
$S_T = 1684 \text{ m}^2$	$N = 2200$	$V/S_T = 10.67 \text{ m}$
$V/S_A = 15.41 \text{ m}$	$V/N = 10.75 \text{ m}^3/\text{seat}$	$S_A/N = 0.70 \text{ m}^2$
$T_{MID} = 1.70 \text{ s (occ.)}$	$EDT_{MID} = 1.30 \text{ s (occ.)}$	$BR(\text{occ.}) = 1.25$
$C_{80 MID} = 4 \text{ dB (occ.)}$	$RASTI = 0.6 \text{ (occ.)}$	

Concert hall

$V = 25029 \text{ m}^3$	$S_A = 1534.4 \text{ m}^2$	$S_o = 251 \text{ m}^2$
$S_T = 1785 \text{ m}^2$	$N = 2200$	
$T_{MID} = 1.85 \text{ s (occ.)}$	$EDT_{MID} = 1.65 \text{ s (occ.)}$	$BR(\text{occ.}) = 1.11$
$C_{80 MID} = 2.5 \text{ dB (occ.)}$		

3. EXPERIMENTAL ANALYSIS

Following we expose the values measured, with MLS of according ISO 3382, in the Kursaal for unoccupied and occupied seats, and moreover we realise a comparison with the best halls considered, [1], [4].

- **RT REVERBERATION TIME**

	125	250	500	1000	2000	4000	T _{low}	T _{mid}	T _{high}
Stalls	1,83	1,75	1,65	1,69	1,7	1,61	1,8	1,7	1,7
Amphitheatre 1	1,94	1,76	1,76	1,73	1,7	1,57	1,9	1,7	1,6
Amphitheatre 2	1,68	1,63	1,66	1,68	1,67	1,52	1,7	1,7	1,6
Average value	1,83	1,73	1,68	1,7	1,69	1,58	1,8	1,7	1,6

Table 3: Reverberation Time for occupied seats

The occupied RT values have been obtained from the expression given by [3], using the experimental test values obtained in a reverberant.

The incremental absorption values α among occupied and unoccupied seats were:

	125	250	500	1000	2000	4000
Incremental absorption $\Delta\alpha$	0.04	0.03	0.07	0.25	0.38	0.40

Table 4: Table of the incremental absorption values $\Delta\alpha$ among occupied and unoccupied seats.

NOTE: These values will be used with the expressions [4], proposed by Bradley, to obtain the energetic magnitudes for occupied condition.

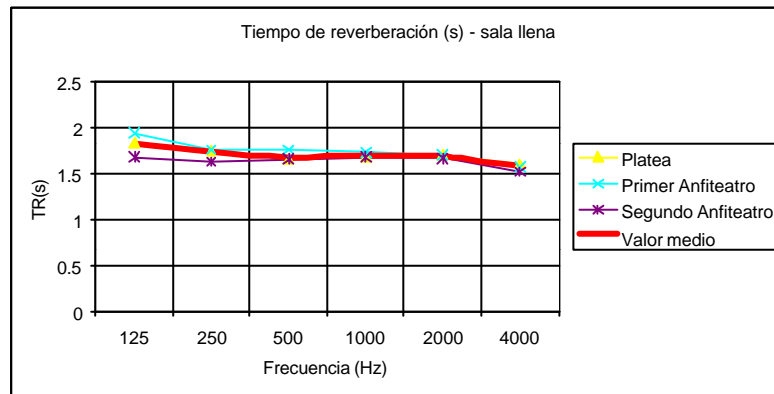


Figure 5: Reverberation Time hall occupied

- **WARMTH AND BRIGHTNESS INDEX**

Averaged values (occupied)	Warmth (T _{low} / T _{mid})	Brightness (T _{high} / T _{mid})
Euskalduna	1.06	0.94

Table 5: Warmth and brightness for occupied state

- **EDT EARLY DECAY TIME**

	125	250	500	1000	2000	4000	EDT _{low}	EDT _{mid}	EDT _{high}
Stalls	1,56	1,46	1,49	1,37	1,5	1,28	1,5	1,4	1,4
Amphitheatre 1	1,52	1,32	1,22	1,17	1,27	1,1	1,4	1,2	1,2
Amphitheatre 2	1,64	1,16	1,15	1,32	1,38	1,16	1,4	1,2	1,3
Average Value	1,57	1,35	1,34	1,3	1,41	1,21	1,5	1,3	1,3

Table 6: EDT (occ.)

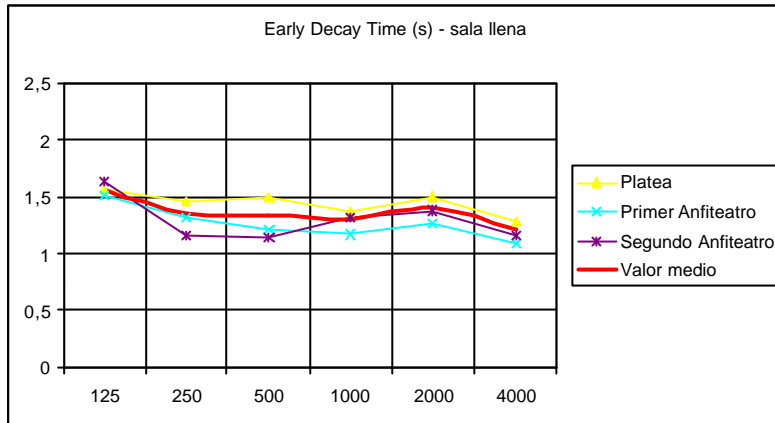


Figure 6: measured EDT (occ.)

• CLARITY INDEX C_{80}

	125	250	500	1000	2000	4000	C_{80low}	C_{80mid}	C_{80high}
Stalls	2,15	2,55	2,27	3,63	2,35	3,67	2,4	3	3
Amphitheatre 1	2,07	3,8	4,98	5,43	5	5,75	2,9	5,2	5,4
Amphitheatre 2	1,1	4,46	4,32	3,46	3,34	4,34	2,8	3,9	3,8
Valor medio	1,9	3,3	3,5	4,1	3,3	4,3	2,6	3,8	3,8

Table 7: C_{80} occupied

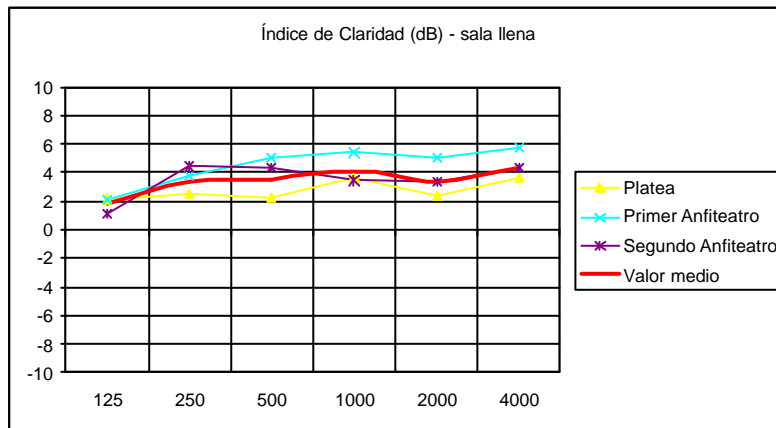


Figure 7: measured C_{80} (occ.)

• DEFINITION INDEX

	125	250	500	1000	2000	4000	D_{50low}	D_{50mid}	D_{50high}
Stalls	44,12	49,9	53,25	63,48	54,1	63,69	47	58,4	58,9
Amphitheatre 1	48,85	56,72	70,35	81,65	83,55	86,82	52,8	76	85,2
Amphitheatre 2	43,04	61,54	63,28	62,16	64,44	71,22	52,3	62,7	67,8
Average Value	45,1	54,4	60,2	68,1	64,4	71,8	49,8	64,2	68,1

Table 8: Experimental D occupied

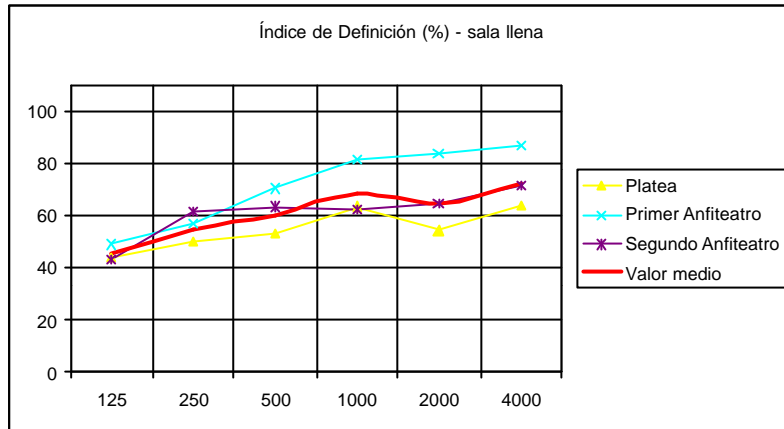


Figure 8: measured D (occ.)

• **INTELLIGIBILITY INDEX**

	RASTI	STI
Stalls	0,54	0,58
Amphitheatre 1	0,65	0,64
Amphitheatre 2	0,61	0,61
Average Value	0,59	0,6

Table 9: Intelligibility occupied

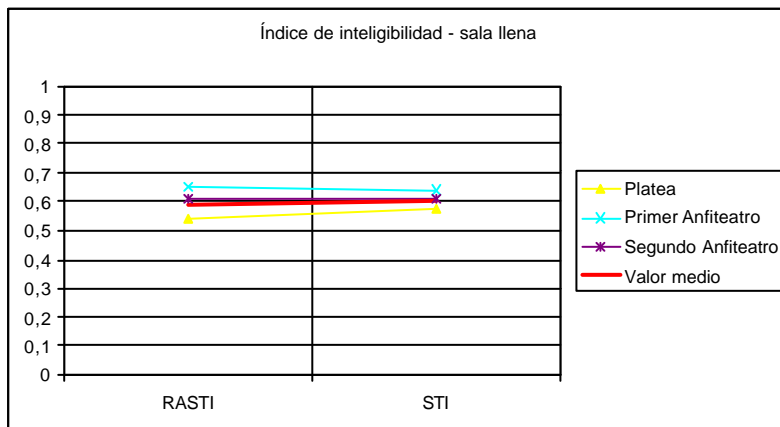


Figure 9: measured Intelligibility (occ.)

4. CONCLUSIONS

The main hall of the Euskalduna Palace, in opera configuration, is a very fine hall, as it is easy to derive it from of data supplied in our analysis. However the importance of this hall is that its acoustics is variable being also an excellent symphonic hall and a good congress hall.

5. REFERENCES

- [1] L.Beranek (1996) How They Sound Concert and Opera Halls. Ed. Acoustical Society of America.
- [2] Higin Arau (1997) Variation of the Reverberation Time of places of public assembly with audience size. Building Acoustics, Volume 4 n° 2.
- [3] Higin Arau (1999) ABC de la Acustica Arquitectonica. Ed. CEAC.
- [4] J.S.Bradley (1991) A comparison of three classical concert. J.A.S.A. Vol 89 n°3- March.