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THE ACOUSTIC DESIGN OF THE MOLINA OF SEGURA THEATER-AUDITORIA

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ABSTRACT
In October of 2005 Molina-Segura's theater-auditoria was inaugurated in Murcia region. Although the format of the the room is not very big the acoustic design was quite complicated due to its complexity shape.
In this communication we will treat aspects of their design and we will establish the initial acoustic goal to get.
We will also expose the results calculated in project and those obtained at the end of the construction.
Now Molina of Segura's people are very happy of the excellent acoustics of this multifunctional hall.
REMARKS: This communication is dedicated to my friend Antonio Perez_Lopez, President of our Spanish Acoustic Society, who was born in Murcia Region, in testimony of our deep friendship and in recognition of its personal effort in benefit of the best improvement of the acoustics in Spain, Europe and in the World.

1. INTRODUCTION

In this report the study of acoustic behaviour of the hall is presented. We have approached the calculation topic from the perspective of several statistical theories and systems of computer simulation. Finally their behaviour is analyzed with relationship to what was desirable to get by acoustic criteria.

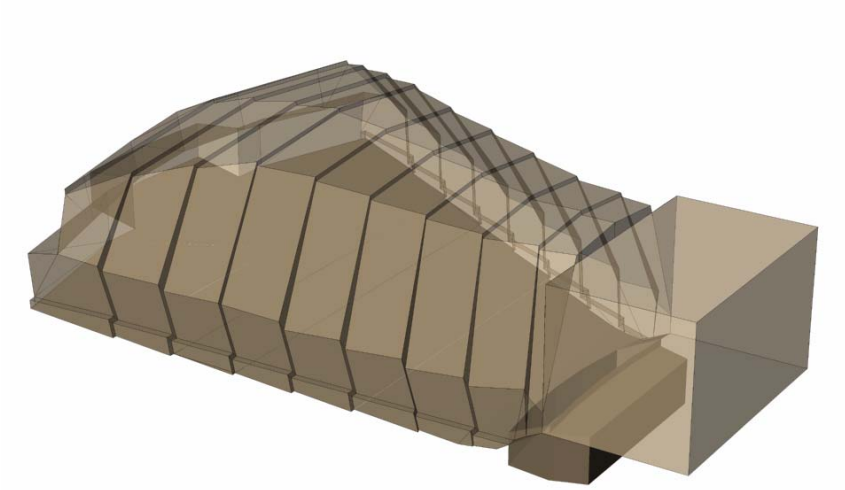

Figure 1.-Multifunctional Auditoria Molina of Segura 3D

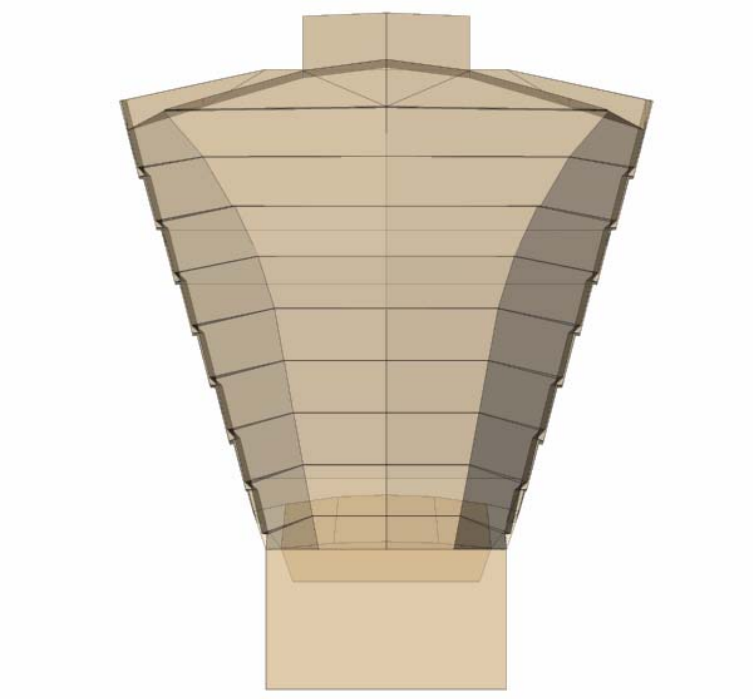

Figure 2.-Multifunctional Auditoria Molina of Segura plan

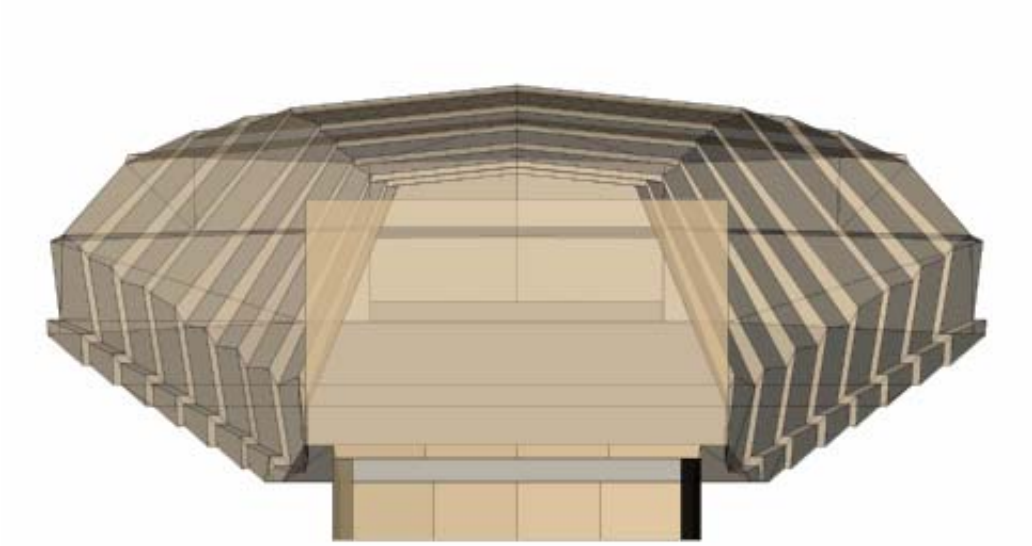

Figure 3.-Multifunctional Auditoria Molina of Segura frontal

2. GEOMETRIC DATA, AREA OCCUPATION AND ACOUSTIC OBJECTIVES TO GET

a) Theatre Configuration

Data of the hall:.
Volume hall (without stage): V = 3200 m3
Seating capacity: N = 562 seats
Audience surface: S_A = 393.4 m2
Relationship V/N = 5.69 m^3/seat.
Relationship V/S_A = 8.13 m

Parameter	Criteria
Reverberation Time RT	$0.81 < T_{MID} < 1.24$ s
EDT	$0.73 < T_{MID} < 1.12$ s
Bass Ratio	$1.1 < I_{warthm} < 1.3$
Brilliance	$I_{brill} > 0.8$
Intelligibility	RASTI $\geq$ 0,6
Definition	$D_{50} > 60$
Clarity C_{80}	$C_{80} > 4$
Lateral Efficiency	LE > 20%
Impulse Response	No undesirable reflections

b) Music Configuration: Chamber hall
Data of the hall:
Volume hall (acoustic shell included): V = 3800 m3 (with acoustical shell included)
Seating capacity: N = 562 seats
Audience surface: S_A = 393.4 m2
Relationship V/N = 6.76 m^3/seat.
Relationship V/S_A = 9.66 m

Parameter	Criteria
Reverberation Time RT	$1.27 < T_{MID} < 1.53$ s
EDT	$0.14 < T_{MID} < 1.37$ s
Bass Ratio	$1.1 < I_{warthm} < 1.3$
Brilliance	$I_{brill} > 0.8$
Clarity C_{80}	$C_{80} > 4$
Lateral Efficiency	LE > 20%
Impulse Response	No undesirable reflections

3. Tmid IN FUNCTION OF DIMENSIONED OF HALL FOR EACH USING

a) Theatre Configuration: Applying of the dimensioned theory of H.Arau [1] is derived that the reverberation time of the hall, for avereged central frequencies, due only to the absorption of the audience it is T_{MID} = **1.18 s**. completes the requirements of reverberation imposed by the acoustic criteria for theater. To see the following graph.

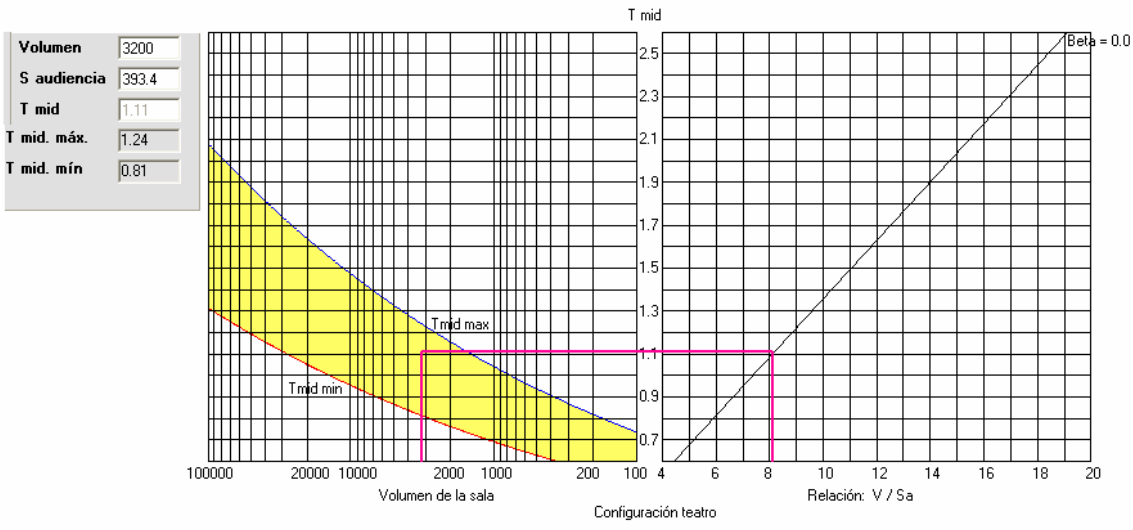

Figure 4.-Tmid for theatre configuration

b) Chamber hall Configuration: Similary for Chamber hall configuration [1] is derived that the reverberation time of the hall, due only to the absorption of the audience it is **T_{MID} = 1.31 s.**

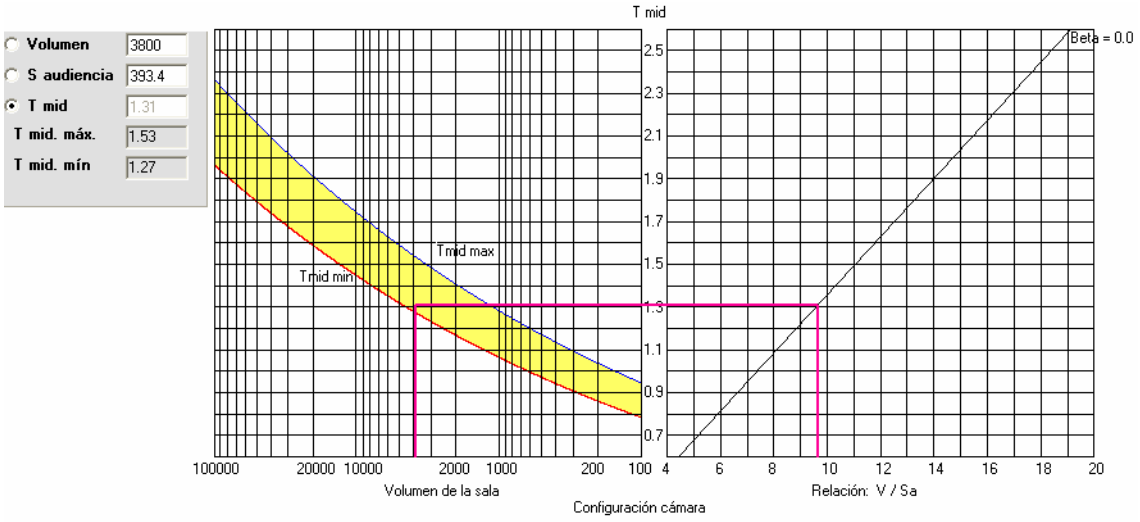

Figure 5.-Tmid for Chamber hall configuration

4. ARCHITECTURAL AND STRUCTURAL DETAILS

Ceiling: 12-mm to 25-mm plywood with airspace behind. *Side, front and rear walls:* 25-mm plywood fixed to wall with a hard and elastic filling up material. *Floor:* Oak parquet fixed over rigid floor. *Carpet:* none. *Stage floor:* 45-mm pine over plywood over deep airspace. *Stage height:* 0.85 m. *Added absorptive material: Seating:* Special designed, rigid seat back, front of seat back upholstered; top of the seat-bottom upholstered; underseat, wood linear perforated Helmholtz resonator.

5. ACOUSTIC RESULTS COMPUTED

Keeping in mind the absorption of the materials of the room, being the black curtains on stage [6], and considering the absorption upholstered seats occupied [7], we have calculated the following values for theatre configuration

a) Theatre configuration

TABLE 1: Acoustic values computed for **Theatre configuration** with occupied audience

Frequency (Hz)	**125**	**250**	**500**	**1000**	**2000**	**4000**	**T_{MID}**	**T_{LOW}**	**T_{HIGH}**
RT_Sabine [2]	1.63	1.37	1.20	0.98	1.02	1.03	1.09	1.50	1.02
RT_Arau- Puchades [3]	1.67	1.35	1.27	1.07	0.95	0.99	1.17	1.51	0.97
RT_Vian [4], (Statist.)	1.60	1.34	1.14	1.00	1.00	1.03	0.96	1.19	0.9
							EDT_{mid}		
EDT Arau [3]	1.35	1.20	1.10	0.93	0.90	0.80	1.01		

Parameter	**CÁLCULATED**	**CRITERIA**
Reverberation Time	Sabine: T_{MID}= 1,09 s Arau: T_{MID}= 1.17 s	0.81 < T_{MID} < 1.24 s
EDT	Arau: EDT = 1.01	0.73 < T_{MID} < 1.12 s
Bass Ratio	I_{warthm} = 1.37 Sabine 1,29 Arau	1,1 < I_{warthm} ≤ 1.3
Brilliance	$I_{brilliance}$ = 0,93 Sabine 0.82 Arau	$I_{brilliance}$ > 0.8
Intelligibility [4], [5]	RASTI > 0,65	RASTI > 0,60
Definition [4], [5]	D_{50} = 63	D_{50} > 60
G Strength [5]	G = 5	G> 0
Lateral Eficiency[4], [5]	LE > 20%	LE > 20%
Impulse response[4], [5]	No undesirable reflections	Don't exist undesirable reflections

a) Chamber hall configuration

TABLE 2: Acoustic values computed for **Chamber hall configuration** with occupied audience

Frequency (Hz)	**125**	**250**	**500**	**1000**	**2000**	**4000**	T_{MID}	T_{LOW}	T_{HIGH}
RT_Sabine	1.52	1.41	1.35	1.20	1.10	1.07	1.27	1.46	1.08
RT_Arau- Puchades	1.71	1.44	1.39	1.25	1.20	1.15	1.32	1.53	1.17
RT_Vian (Statist.)	1.65	1.40	1.27	1.23	1.13	1.05	1.25	1.52	1.09
							EDT_{mid}		
EDT Arau [3]	1.45	1.30	1.30	1.10	1.05	0.90	1.20		

Parameter	**CÁLCULATED**	**CRITERIA**
Reverberation Time	Sabine: T_{MID}= 1,27 s	1.27 < T_{MID} < 1.53 s
	Arau: T_{MID}= 1.32 s	
EDT	Arau: EDT = 1.20 s	1.14 < T_{MID} < 1.37 s
Bass Ratio	I_{warthm} = 1.15 Sabine 1,19 Arau	1,10 < I_{warthm} ≤ 1.20
Brilliance	$I_{brilliance}$ = 0,85 Sabine 0.88 Arau	$I_{brilliance}$ > 0.80
Lateral Eficiency	LE > 20%	LE > 20%
G strength	G = 6	G> 0
Impulse response	No undesirable reflections	Don't exist undesirable reflections

6. ACOUSTIC MEASUREMENTS FOR THEATRE CONFIGURATION

TABLE 3: Acoustic values measured [8], for **theatre configuration** with occupied audience, when the hall was finished

	125	**250**	**500**	**1000**	**2000**	**4000**	T_{mid}	T_{low}	T_{high}
RT	1.57	1.51	1.29	1.07	0.94	0.86	**1.18**	1.50	1.34
							EDT_{mid}		
EDT	1.07	0.89	0.90	0.99	0.92	0.80	**0.95**		
BASS RATIO							**1.31**		
BRILLIANCE							**0.76**		
							$D_{50\ mid}$		
D_{50}	51	56	63	65	66	67	64		
							$C_{80\ mid}$		
C_{80}	3.89	6.46	7.07	7.81	9.24	11.85	7.44		
							G_{mid}		
G	1.34	4.49	6.29	3.81	7.2	5.58	**5.1**		
RASTI							0.78		

Parameter	**MEASURED**	**Criteria**
Reverberation Time RT	T_{MID} = 1.18	0.81 < T_{MID} < 1.24 s
EDT	EDT_{MID}= 0.95	0.75 < T_{MID} < 1.15 s
Bass Ratio	I_{warthm} = 1,31	0.9 < I_{warthm} < 1.45
Brilliance	$I_{brilliance}$ = 0,78	$I_{brilliance}$ > 0.8
Intelligibility	RASTI = 0.76	RASTI ≥ 0,5
Definition	$D_{50\ MID}$= 85.26	D_{50} > 60
Clarity C_{80}	C_{80} = 7.44	C_{80} > 4
G: Strenght dB	G = 5.1	G > 0
Impulse response	No undesirable reflections	No undesirable reflections

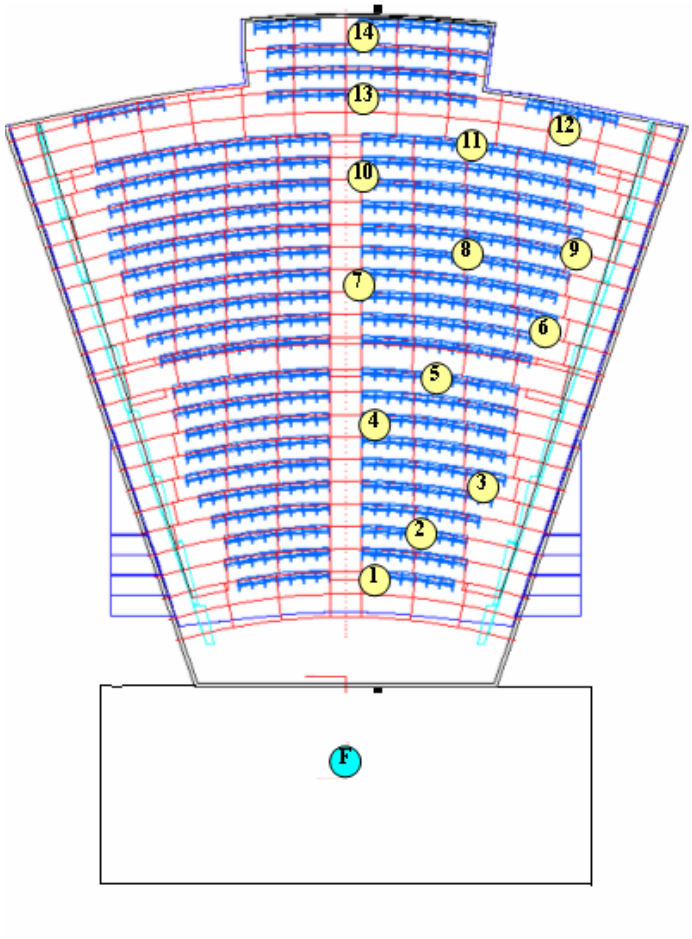

Figure 6.-Measurement points in hall

7. FINAL CONCLUSION: For all that indicated is demonstrated that Molina of Segura Auditoria completes very satisfactorily, with good acoustic quality, in theater configuration, the values of the attributes demanded by the acoustic criteria. Also apparent has a good quality to be used for music, especially when the acoustical shell projected be built, which is nonexistent now, by economic reasons.

References

[1] H. Arau (1997).Variation of the Reverberation Time of places of public assembly with audience size. Building Acoustics, Volume 4 nº 2.

[2] W.C.Sabine (1900) Collected Papers on acoustics. Dover Publications (1922)

[3] H. Arau (1988). An improved Reverberation Formula. Acustica (Hirzel Verlag).Vol 65 nº4, p:163-180.

[4] J.P.Vian-J.Martin-Van Maercke (1993). Binaural simulation of concert halls: New approach for the binaural reverberation process. JASA 94(6). Epidaure

[5] H.Arau (1990-1993). Teoría de diseño informatizado de simulación de salas de audición por trazado de rayos y utilización de la teoría de imágenes especulares para la determinación de: La respuesta impulsional, Trazado de rayos, Tiempos de reverberación y cálculo de las distintas magnitudes energéticas de audibilidad del sonido. Acustic_Sales

[6] V.O.Knudsen-C.M. Harris (1950). Acoustical Designing in Architecture.J. Wiley & Sons Inc.

[7] L.L.Beranek (1969). Audience and Chair absorption in Large Halls II. Journal of the Acoustical Society of America. Vol:45 (nº 6) p: 661-669.

[8] Maximum Length Sequences (MLS). " ISO3382: "*Acoustics – Measurement of the reverberation time of rooms with reference to o*