ACOUSTICS AND THEATER REHABILITATION IN ANDALUSIA

43.55.GX STUDIES OF EXISTING AUDITORIA AND ENCLOSURES

León Rodríguez, A.L.; Navarro Casas, J.; Sendra Salas, J.J.; Zamarreño, T.
Instituto Universitario de Ciencias de la Construcción (I.U.C.C.). Universidad de Sevilla.
Escuela Técnica Superior de Arquitectura. Av. Reina Mercedes, 2. 41012 Sevilla. Spain
Tel: +34 954556595 Fax: +34 954557024 E-mail: leonr@us.es

ABSTRACT

The present communication summarizes the acoustic conditions of a sample of 18 Andalusian theaters that have been recently rehabilitated. They are the most representative in the Andalusian Public Theater Rehabilitation Program in which our team has participated as acoustic consultants since 1988.

These theaters, from small to medium size, are part of the Andalusian architectural heritage and their rehabilitation seeks their acoustic conditioning as multipurpose spaces in order to adapt them to the cultural offer and demand of each town.

Starting from in situ measurements together with those obtained by means of computer simulations important conclusions have been elaborated to evaluate the acoustics of these spaces so that they could be extrapolated to spaces of similar kind and sizes, those most frequently found in the Spanish theatre heritage.

1. INTRODUCTION

Within our country's cultural scene, theater activities count for an outstanding position. Besides, in Andalusia there is a rich and varied architectural heritage mainly devoted to shelter this type of artistic manifestation, as well as other cultural activities, specially related to music playing.

Two main aims are pursued with this research work: to advance in the knowledge of theater architecture within the Andalusian architectural heritage, and to introduce and spread the importance of acoustic quality in these buildings, with regard to their functional adaptation, which implies to learn the procedures that will lead to their appreciation and their inclusion in the corresponding theatre rehabilitation projects.

In this work some conclusions of general character on acoustic global performance of a wide range of important Andalusian theaters are presented. In León *et al* (2000)[1] an advance of this work was presented in relation to a sample of 4 theaters. The results shown in this work correspond to a sample of 18 theaters (table 1). The methodology and measuring procedures to be used have already been described in León *et al.* (2000).

Nº	THEATER	Locality	Year of construc.	Year of rehabilit.	Hall Volume[2] (m^3)	Capa-city
1	TEATRO APOLO	Almería	1882	1993	1393	368
2	TEATRO SAAVEDRA	Cantoria. Almería	1926	1989	785	190
3	TEATRO VILLAESPESA	Sorbas. Almería	1900	1997	1062	273
4	TEATRO FALLA	Cádiz	1905	1985	8114	1038
5	TEATRO OLIVARES-VEAS	Arcos de la F[ra]. Cádiz	1910	1993	790	221
6	TEATRO VILLAMARTA	Jerez de la F[ra]. Cádiz	1928	1993	7988	1221
7	TEATRO PRINCIPAL	Puerto Real. Cádiz	1859	1993	2214	444
8	TEATRO DE LAS CORTES	San Fernando. Cádiz	1804	1999	2492	360
9	GRAN TEATRO DE CÓRDOBA	Córdoba	1873	1986	6071	946
10	TEATRO GARNELO	Montilla. Córdoba	1917	1995	2062	333
11	TEATRO-CINE VICTORIA	Priego de Córdoba	1961	1992	4232	539
12	TEATRO ISABEL LA CATÓLICA	Granada	1950	1993	5035	689
13	TEATRO-CINE IDEAL	Baza. Granada	1920	2001	1694	299
14	GRAN TEATRO DE HUELVA	Huelva	1923	1990	4800	672
15	TEATRO CAPITOL	Cortegana. Huelva	1957	1999	2999	515
16	TEATRO DARYMELIA	Jaén	1927	1987	1888	417
17	TEATRO LOPE DE VEGA	Sevilla	1929	1983	5902	815
18	TEATRO GUTIÉRREZ DE ALBA	Alcalá de Guadaira. Sevilla	1931	1986	2251	395

Table 1. Sample of the Andalusian case-study theaters

Fig.1 Lope de Vega Theater. Seville

Fig.2 Falla Theater. Cádiz

2. REVERBERATION

In figures 3 and 4 the values corresponding to average reverberation times (RT_{mid} 500-1000 Hz) are shown, measured in empty halls, as well as those obtained for a 100% occupancy simulation. The latter have been determined by means of computer simulation models.

Results are shown for three different conditions: [1] original condition, previous to rehabilitation intervention; [2] after architectural and acoustic rehabilitation; and [3], after installing an acoustic shell on the stage in those theaters which, after rehabilitation, have been fitted with that equipment. The values measured in situ and those simulated have been compared to those given by Beranek[3] for a sample of 14 Opera Houses with good acoustics.

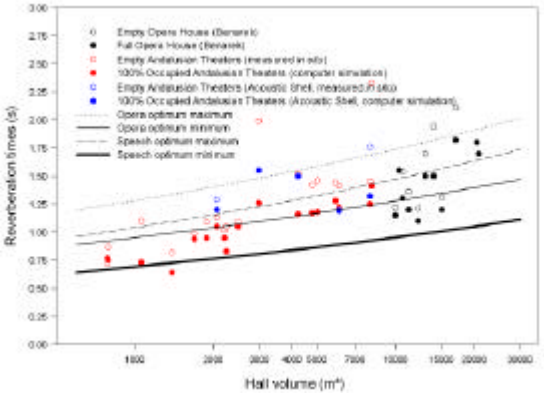

Fig.3 RT_{mid}, measured *in situ* and simulated. ORIGINAL CONDITION [1]

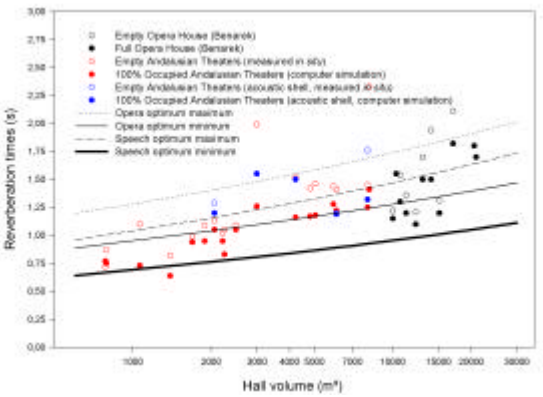

Fig.4 RT_{mid}, measured *in situ* and simulated. AFTER REHABILITATION [2] and [3]

Conclusions:

- The absorbing surfaces that do have more influence on reverberation times are the audience areas and the decoration and stage machinery of the stage boxes, since both sum up more than 75% of the total theater's absorption (hall+stage). Absorption of stages, not only in theaters with "Italian" typology but also in those with "Movie-theater" typology, is usually around 40%, while in audience areas they have an average repercussion of 35% of total absorption. According to the aforementioned, intervention on the sound absorption of the rest of the hall's coatings and linings (excluding the stage), which suppose 25% of total absorption, will be of use to qualify its acoustics: Theater or Concert-Hall.

- After using absorption coefficients from different authors with regard to audience areas, it has been possible to verify that those proposed by Beranek[4] for the various types of stalls allows us to estimate adequately the reverberation times of halls corresponding to the typologies and sizes of halls present in Andalusian theaters. Thus, the use of these absorption coefficients, in simulation models, is valid to estimate reverberation times of theaters in the presence of spectators.

- The range of values for low, mid and high frequencies of reverberation times in Andalusian theaters[5], in the case of empty halls (in situ measuring) and of fully occupied halls (simulation models) are shown in table 2.

REVERBERATION TIMES IN ANDALUSIAN THEATERS (Hall volume: from 800 to 8000 m^3, approx)			
FINAL CONDITION	**FREQUENCIES**		
	Low	Mid	High
Empty halls (measured)	0.63 a 1.96 s	0.72 a 1.52 s	0.68 a 1.38 s
Occupied halls (simulation)	0.59 a 1.62 s	0.64 a 1.28 s	0.52 a 1.15 s

Table 2. Reverberation times in Andalusian theaters.

- According to our approach and with regard to main optimum reverberation time formulations, those proposed by L. Cremer[6] are the ones which better adjust to Andalusian theaters acoustic performance. These optimum reverberation times, taken as a reference for acoustic corrections, have proved to be adequate to obtain good results in multifunctional halls. This adequacy has subsequently been contrasted with the results attained, not only with traditional parameters but also with the use of the most recent acustic qualification rates.

3. SOUND DISTRIBUTION

In León *et al.* (2000) the data intake system for sound distribution was presented. Figure 5 is included as an abstract of the study, in which the measured sound field (with and without acoustic shell) in 3 representative theaters (of increasing volume) is compared with the classical theory and Barron and Lee's[7] theory.

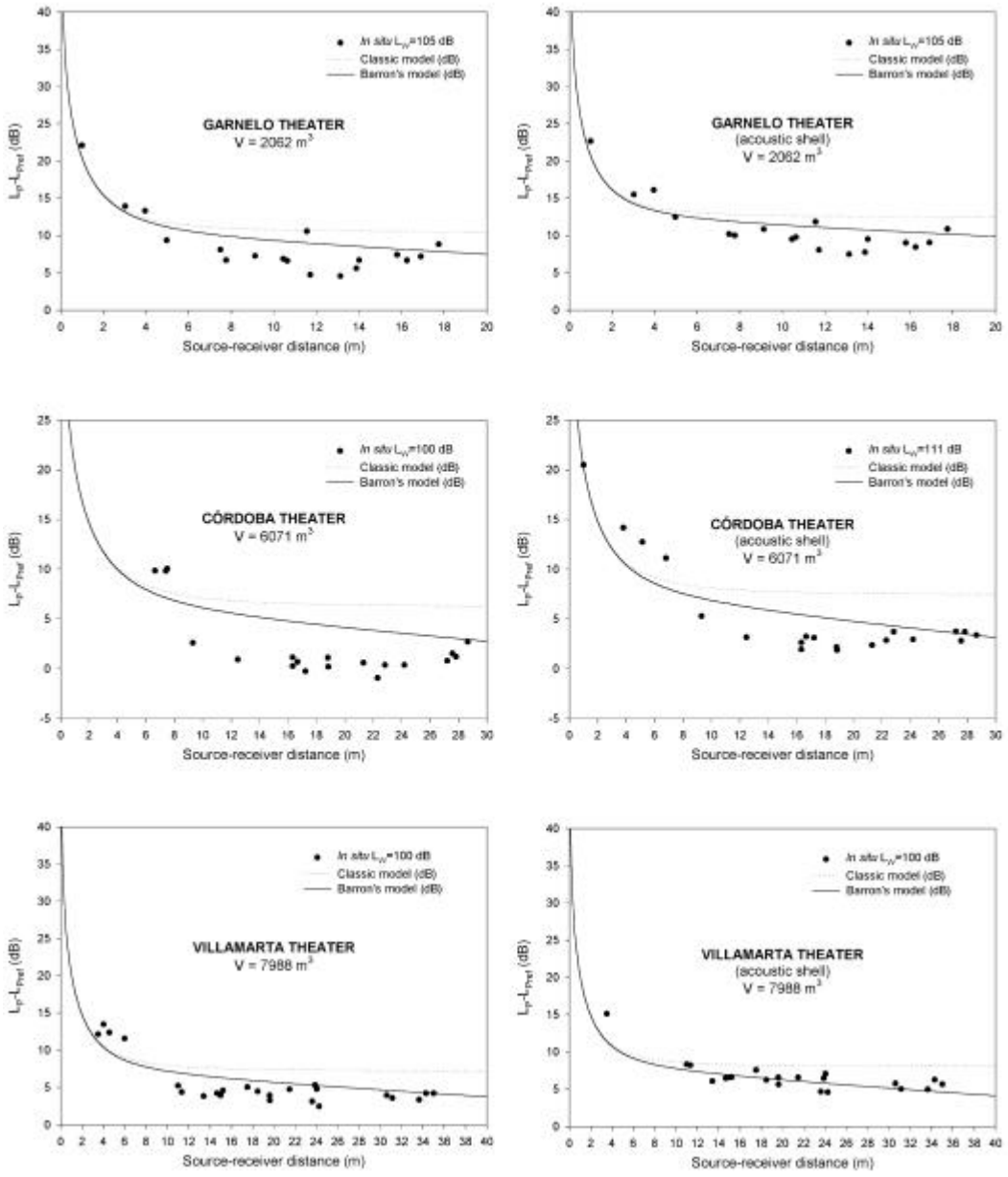

Fig.5 Sound distribution WITH and WITHOUT acoustic shell. Global levels.

Conclusions:

- It is verified the validity of the affirmation that, to attain homogeneity in the sound field, the audience areas in this kind of theaters should be distributed as homogeneously as possible, since they constitute the areas with higher relative absorption in the halls[8], taking into account that they suppose an average 60% of total absorption. This characteristic is common to both typologies approached: "Italian" theaters and Movie-theaters.

- The detailed analysys of the ecograms obtained by means of simulation models show that, in order of importance, the walls that do have more influence on sound reflections whithin the halls are the following: [1] Ceilings: They are the surfaces with higher repercussion with regard to reflection of sound waves. Regardless of the theater typology, ceilings receive an average 25% of the total hall reflections, mainly ceilings on top of stall pits. [2] Side walls: they have an average 20% incidence. In traditional theaters, with an “Italian” arrangement, side walls reflect 15% of sound waves, while in the “Movie-theater” typology higher results are obtained (23%).

- In both analyzed typologies, bottom walls have an average 6% repercussion on total reflections produced inside the halls.

- Acoustic shells increase the number of reflections within the halls an average 35%, since they considerably reduce those lost within the stage space.

- Barron and Lee’s revised sound field theory happens to be more appropiate than the classical prediction model of sound level in this kind of halls. Anyway, even values measured in situ tend to be below those obtained by means of their algorithm.

4. INTELLIGIBILITY

To analyze intelligibility RASTI index has been represented in all theaters, not only in their original condition but also after rehabilitation. Both existing typologies in the sample have been distinguished: “Italian” theaters (with a bell-shape or horseshoe layout) and “Movie-theaters”.

In the same way, and with the purpose to study in depth the influence of the spectator position and with regard to the capability of understanding speech delivered from the stage, an average of measuring spots in each of the following 6 areas has been made: [1] Stall Pit (fig.6), [2] 1st Level Amphitheaters, [3] 2nd Level Amphitheaters, [4] Ground Floor Side Pits, [5] 1st Level Boxes (fig.7), and [6] 2nd Level Boxes.

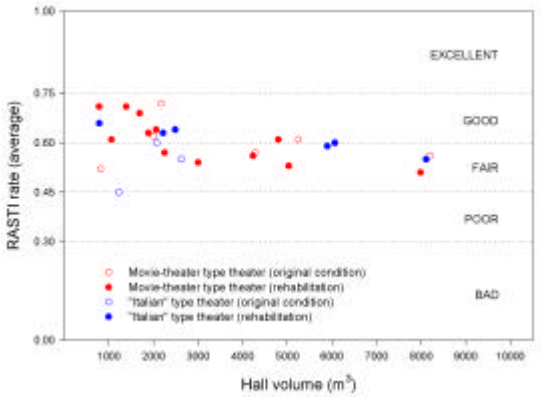

Fig.6 RASTI index. Empty Halls. Stall pit.

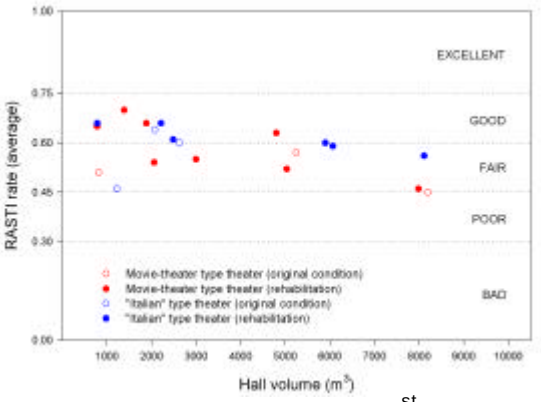

Fig.7 RASTI index. Empty Halls. 1st Lev. boxes

Conclusions:

- Comparison of intelligibility values[9] measured in situ and by means of computer simulation do not show great differences, even though those measured in situ tend to be 3% higher than the latter.

- Intelligibility values estimated when halls were full with spectators are slightly superior (3.5%) to those simulated in empty halls, and very close to those measured in situ when empty. That is: the influence of spectators on the speech intelligibility is minimum, assuming acceptable conditions of background noise.

- The range of values within RASTI index measured in situ and by computer simulation in the different areas of Andalusian theaters have been the following (table 3):

THEATER AREA	THEATERS WITHOUT ACOUSTIC SHELL						THEATERS WITH ACOUSTIC SHELL		
	TYPOLOGY								
	"ITALIAN"			*MOVIE-THEATER*					
	Measu-red (empty)	Simulation		Measu-red (empty)	Simulation		Measu-red (empty)	Simulation	
		Empty	Occup.		Empty	Occup.		Empty	Occup.
Stall Pit	0.61	0.55	0.57	0.61	0.58	0.60	0.56	0.47	0.50
Amphi-theaters 1	0.62	0.62	0.64	0.66	0.59	0.62	0.54	0.48	0.52
Amphi-theaters 2	0.56	0.52	0.54	0.56	0.52	0.55	0.53	0.46	0.52
Ground Floor Side Pits	0.59	0.60	0.62	0.62	0.56	0.57	0.55	0.47	0.50
Boxes 1	0.59	0.57	0.59	0.61	0.57	0.58	0.55	0.45	0.49
Boxes 2	0.54	0.55	0.57	0.59	0.55	0.58	-	0.44	0.49
QUALIFICATION				Good			Fair		

Table 3. Range of values (RASTI index) measured in situ and by computer simulation.

- As it can be noticed in the preceding table, both theater typologies object of this study show a very close intelligibility of speech, since the rates measured in both of them do not differ more than 3-4%, being the same for certain areas. With empty halls, the evaluation of intelligibility in the different areas of the theaters tends to be qualified as "good" or at least "fair". Theaters with hall volumes inferior to 3000 m^3 do show better results, while lowest rates are recorded in amphitheaters and boxes in the last levels, as contrasted with experience.

REFERENCES

[1] **León, A.L. *et al*. (2000).** *La valoración acústica en los proyectos de rehabilitación de teatros. El ejemplo andaluz*. Proceedings of Congreso Iberoamericano de Acústica [CD Rom]. Madrid, October 16-20.

[2] The volume shown does not include the volume of the stage box.

[3] **Beranek, L.L. (1996).** *Concert and opera halls: how they sound*. Nueva York: Acoustical Society of America. p.p. 593-617.

[4] **Beranek, L.L. (1960).** Audience and seat absortion in large halls. *The Journal of the Acoustical Society of America*, 32, p.p. 661-670.

[5] From this range of RT values those from Capitol de Cortegana and Falla de Cádiz Theaters have been excluded due to their singular performance.

[6] **Cremer, L. *et al*. (1982).** *Principles and applications of room acoustics*. Volumen 1. Londres: Applied Science Publishers. (German original edition. Stuttgart: Hirzel, 1978).

[7] **Barron, M. and Lee, L-J. (1998).** Energy Relations in Concert Auditoriums.I. *The Journal of the Acoustical Society of America*, 84 (2), p.p. 618-628.

[8] Within this percentage the absorption made by stage space is excluded.

[9] Average space values in each area of the hall.