



**STUDY OF THE ITALIAN STYLE THEATRE'S ACOUSTIC PERFORMANCE  
THROUGHOUT THE RESEARCH JOB CARRIED OUT IN THE  
" TEATRO PRINCIPAL" OF VALENCIA**

PACS: 43.55.Ka

Barba Sevillano, Arturo; Giménez Pérez, Alicia; Cibrián Ortiz de Anda, Rosa M<sup>a</sup>; Cerdá Jordá, Salvador; Romero Faus, José; Lacatis, Radu George  
Grupo de Acústica Arquitectónica Ambiental e Industrial, Universidad Politécnica de Valencia, Spain; [arbarse@doctor.upv.es](mailto:arbarse@doctor.upv.es)

**ABSTRACT**

This paper describes the study of an architectural typology widely extended in Europe during the 18<sup>th</sup> and 19<sup>th</sup> centuries: the Italian Style Theatre.

The "Teatro Principal" of Valencia -Spain- was built following the project developed by the Italian architect Felipe Fontana in 1.774. It is one of Spain's first horseshoe shaped theatres.

The technique used for obtaining the acoustic measures, has been the "impulse response". Next parameters we have calculated: TR, BR, Br, EDT, Tc, C80, C50, IACC, G mid, LF and LFC.

After the values of the acoustic parameters from the experimental tests knowing, a system of acoustic simulation to predict the theatre's acoustic field's behaviour we used, considering any changes that could take place in the hall's shape. The plans were digitized and a three-dimensional geometric model with AutoCAD software was created. Later into the CATT-Acoustic program it was imported.

Then, three-dimensional geometric models of previous documented states of the theatre are made, to verify the incidences in the acoustic field that different architectonic interventions caused in the "Teatro Principal". This is done to draw general conclusions on the resulting acoustic impact that architectonic interventions into Italian Style Theatres have, applicable to other rehabilitations.

**INTRODUCTION**

The current study is being developed as a part of I+D+i coordinated project, BIA2003-09306-C04-01 with the title: "*Establishment of objective acoustic parameters qualifying the concert hall quality. Application to new buildings and rehabilitation projects*". This project is developed by four research groups from the Universidad Politécnica de Cataluña, Universidad de Sevilla, Universidad Pública de Navarra and Universidad Politécnica de Valencia. The project is coordinated by the group of Valencia.

In the specific case of the "Comunidad Valenciana", one of city's most emblematic hall is the Teatro Principal of Valencia. It has been unquestionably the musical and theatre reference point in the region for more than 150 years, this is, from its inauguration in 1.832 until the appearance in 1.987 of the "Palau de la Música de Valencia", designed and built by architect *J. M<sup>a</sup> García de Paredes*.

The acoustic study of the theatre shows the undoubted interest that supposes to collect data from one of Spain's first horseshoe shaped theatres (We shall remember that the "Teatro Real" of Madrid was inaugurated in 1.850 and the "Gran Teatre del Liceu" of Barcelona in 1.847). In addition to this, the main hall of the Teatro Principal of Valencia has remained until nowadays without any important changes in its structure. This brings us closer to the study of an architectural typology widely extended in Europe during the 19th century. All this reasons, but mainly the fact that the study of acoustic conditions of this theatre has never been undertaken before, and the 175 anniversary of the inauguration that we have this year in July, lead us to carry out a deep study of the Teatro Principal of Valencia.

## TYOLOGYCAL DEFINITION

Although the beginning of the architectural typology of the Italian Style Theatre (Theatre with a horseshoe, oval or ellipse shaped ground floor plan, and theatre boxes around it) goes back to the baroque period, it will not be until the 18th and mainly 19th centuries when it reaches its apogee, due to a greater demand from the mighty European bourgeoisie. From their birth, these halls changed very little because there was an objective limit on its dimensions: which was the limit of demanding an acceptable hearing and visibility. The most important aim since the middle of the 18th century, was to approach the suitable plan design so that the stage could be entirely seen by the important people, but then also by the rest of the people. This task was demonstrated impossible from the beginning.

Another essential characteristic of these theatres that distinguish them from the previous Renaissance theatres is the presence of a stage box of greater width and depth than previous ones in the Renaissance theatre typologies.

As main examples of Italian Style Theatres we mention the Theatre alla Scala of Milan (1.778), the Fenice of Venecia (1.792) and the Opera of Paris (1.875).

## TEATRO PRINCIPAL OF VALENCIA: CHARACTERISTICS

The Teatro Principal of Valencia was built following the project developed by the Italian architect Felipe Fontana in 1.774, and it was inaugurated on 24 of July 1.832. The theatre comprises a seating capacity of 1.226 localities distributed in stalls, two tiers of boxes and two upper galleries.

The theatre has a “stage box” of 8.202 m<sup>3</sup>, 24.60 m. of width, 17.55 m. of depth and 19.00 m. of height, facing a horseshoe shaped capacity area of 6.570 m<sup>3</sup>, 21.80 m. of length and a maximum height of 15.95 m. The theatre has two lower floors underneath the stage, and an orchestra pit. Under this orchestra pit and probably in order to reinforce the sound of the orchestra, an air chamber was made in the 19<sup>th</sup> century (the specializing bibliography alludes to this type of artifices) in which there are located invested perforated vessels of an approximate height of 40 cm. whose possible acoustic function has not been studied yet.

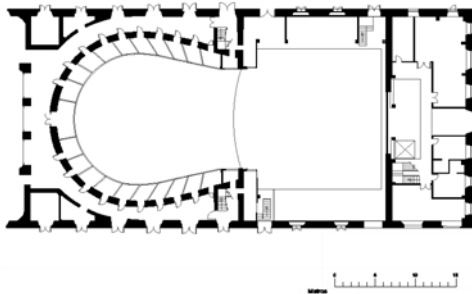


Figure 1- First floor: Theatre boxes

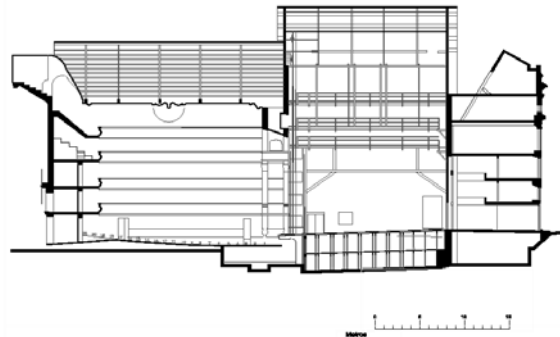


Figure 2- Cross-Section

## PROTOCOL OF MEASURES; PARAMETERS AND THEIR EVALUATION

The technique used for obtaining the acoustic measures, has been the most widespread nowadays: the “impulse response”, which completely characterizes the concert hall from the acoustic point of view. The signal used is a Sinusoidal Sweep, sine whose frequency is a function of the time (the sine begins at 20 Hertz, and is increasing the frequency with the time until reaching the 20 kHz, scanning all the rank of audio frequencies). This system is the adopted one by unanimous agreement in all the acoustic measures carried out by the members of the four Universities belonging to the investigation project in which this study fits in.

The hall is excited by means of a broadcasting system formed by PC, professional sound card, high power amplifier by channel (500W) and dodecahedric source (omnidirectional). The emitted signal, is registered in great number of audience points of the hall (exceeding the number of points demanded by ISO 3382 norm by far) by a receiving system formed by a PC, professional sound card, omnidirectional and directional (multipattern) microphones, and artificial head (binaural head). In the ground floor, the symmetry of the theatre is ignored and

measurements are taken in 36 points (fig 3) to avoid initial hypotheses that later could induce us to mistakes. The *Winmls* software run on the PC, allows us to obtain the acoustic parameters of the responses to the impulses according to recent norm ISO 3382 and other parameters not included in the norm, like LG, LFC or measures of strength (G) using the direct sound as reference.

The calculated parameters have been: TR, BR, Br, EDT, Tc, C80, C50, IACC, Gmid, LF and LFC.

ground floor: rows	ground floor boxes	first floor boxes	second floor boxes	third floor gallery	fourth floor gallery
36	6	11	11	15	15

Table I- distribution of measurement points

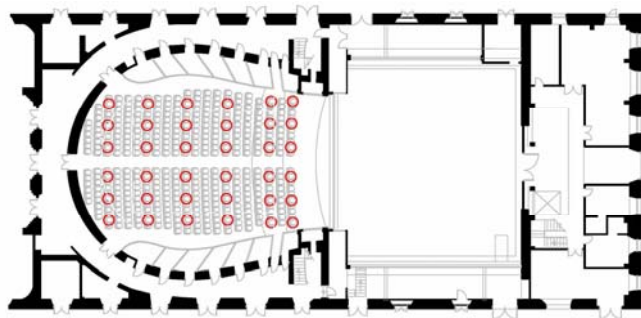


Figure 3- Ground floor: measurement points

### ACOUSTIC SIMULATION OF THE THEATRE; VALIDATION AND ADJUSTMENT

After knowing the values of the acoustic parameters from the experimental tests, we used a system of acoustic simulation to predict the theatre's acoustic field's behaviour considering any changes that could take place in the hall's shape. The work that it implies is quite complex, mainly due to the elaboration of the geometric model. The plans were digitized and a three-dimensional model was created with AutoCAD software (composed by 1.470 surfaces), and later imported into the CATT-Acoustic program. Coefficients of absorption and diffusion (obtained of specialized bibliography) depending on the frequency are assigned to every surface.

In order to adjust the geometric model, the carried out simulation uses a calibration process that is not possible to implement when applied on new buildings. It is based on an adjustment of the values of the coefficients of absorption and diffusion for the materials that do not appear in bibliography and whose testing is excessively complex in the laboratory. This process is carried out through an iterative procedure that seeks that the simulated times of reverberation does not differ more than 10% of the values measured "in situ" in the theatre. The high number of measurement points (Table I, Fig 3) has allowed a very exact adjustment between the geometric model and the real theatre (36 in the ground floor, and 58 in theatre boxes and upper galleries). Another parameter used for the geometric model's adjustment especially with the materials of the theatre boxes, has been G mid (strength).

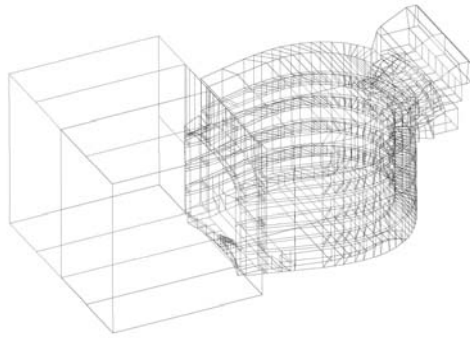


Figure 4- 3D Geometric model (AutoCAD)



Figure 5, 6-Tiers of boxes, stalls and stage

### ACOUSTIC SIMULATION OF PREVIOUS STATES OF THE THEATRE AND DISCUSSION ON THE RESULTS OBTAINED

Once the simulation of the present state of the theatre was validated, the three-dimensional geometric models of the previous states of the theatre -documented graphically throughout its history- are made to verify the incidences in the acoustic field that different architectonic interventions caused in the Teatro Principal. To carry out this one, we consult all the texts and graphical documentation in the files of the "Diputación Provincial de Valencia". There are enough documents of 19<sup>th</sup> century, but some graphical documentation (decoration planes of theatre boxes, which do not contribute for a formal simulation of the theatre). The first existing architectonic plane is a longitudinal section of the theatre (in 1.928 year). From this date, the next architectonic interventions in the theatre are perfectly documented. In this way, for the two first simulated situations of the theatre we have left from the 1928 planes and we have been undoing the most important reforms described in the written documentation consulted.

The simulated architectonic stages have been:

**I- 1.832** - The theatre is built according to the initial project of the Italian architect Felipe Fontana, reducing very much its original size for lack of money. The theatre was inaugurated with one top gallery less than nowadays (considerable change of volume); in addition, the theatre boxes on the ground floor around the stalls were complete and both the fronts of the theatre boxes and the interior roof of the theatre were smooth, without plaster decoration. Because of it the diffusion to high frequencies was initially lower than the present one (Fig.7)

**II- 1.834-** In view of the success of the first functions, the seating capacity is extended: the existing roof was elevated by means of hydraulic machinery, and a gallery was constructed on top (fourth floor). Due to the existence of a loggia in the third floor gallery (Initially the last one), the fourth floor was built incomplete in its central part (hypothesis). (Fig. 8)

**III- 1.964** – Throughout the 19<sup>th</sup> century the interior decoration of the theatre was completed. In 1.964 the architect Luis Albert suppresses six central theatre boxes in the ground floor, in order to increase the seating capacity. In addition to this, dressing rooms on the sides of the stage were constructed, which diminishes considerably the volume of the stage box and changes its absorption and diffusion. (Fig. 9)

**IV- 1.989** - Present state: the architect Guillermo Stuyck completes the horseshoe form of the fourth floor gallery eliminating part of the third floor loggia looking for a formal clarity which the theatre was lacking; besides it, the dressing rooms on the sides of the stage were suppressed recovering the stage box volume previous to 1964; the orchestra pit was extended considerably. In this intervention there takes place the find of the invested perforated vessels of the 19<sup>th</sup> century under the wood pavement of the orchestra pit. The persons in charge of the restoration with absolute historical respect decided to preserve them in their original location. In 1991 a new reform is made to install conditioned air inside the theatre. (Fig. 10, 11)

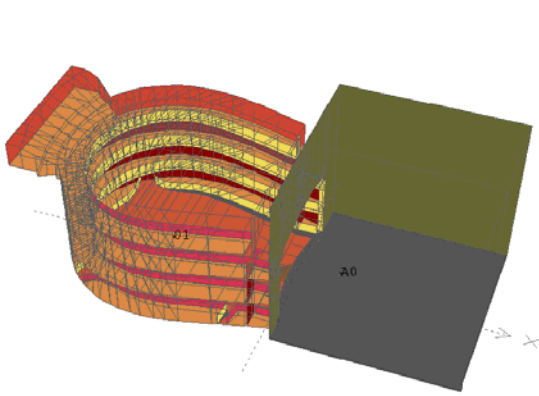


Figure 7- 1832- 3D Geometric model (CATT)

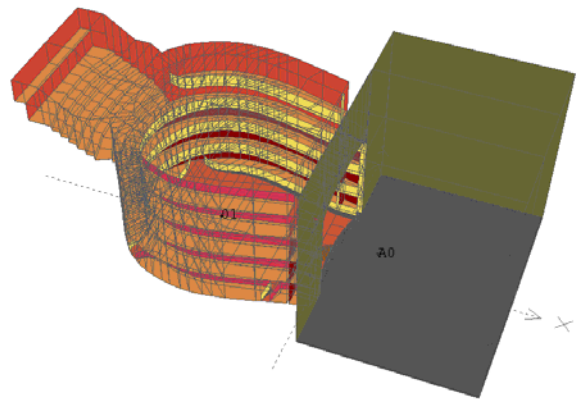


Figure 8- 1834- 3D Geometric model (CATT)

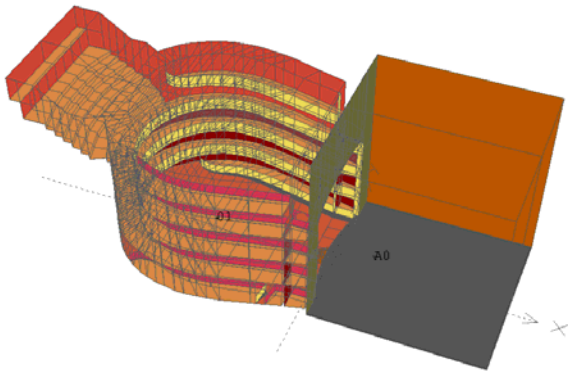


Figure 9- 1964- 3D Geometric model (CATT)

Year	Hall volume (m <sup>3</sup> )	Stage box volume (m <sup>3</sup> )
1.832	4777,2	5048,8
1.834	6841,8	8202,2
1.964	6542,5	5634,5
1.989	6569,8	8202,2

Table II.

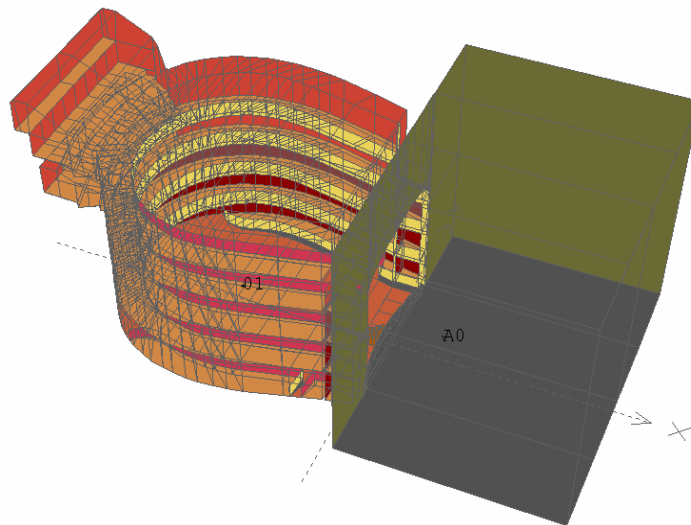


Figure 10- Present State - 3D Geometric model (CATT)

## RESULTS, ANALYSIS AND DISCUSSION

Though the reverberation time is not independent of the receiver position, the variations that it experiments on the different measured points do not overcome 10 % of RT's average value in the theatre. This way, we are comparing the RT<sub>30</sub> depending on the frequencies in different situations of the hall along its history. The tonal curve (RT / frequency) of the Teatro Principal of Valencia nowadays comes closer a descending straight line centred around 1.5 seconds, with higher values in low frequencies and lower values in high ones. This does not change very much with the formal changes of the theatre with the exception of the initial situation, (less volume) when the tonal curve was approximately two tenths lower than the current one. As the seating capacity of the theatre was the same that at present time (the fourth floor is closed to the public from the last architectonic intervention) the relation "volume of air / person" is higher than 175 years ago.

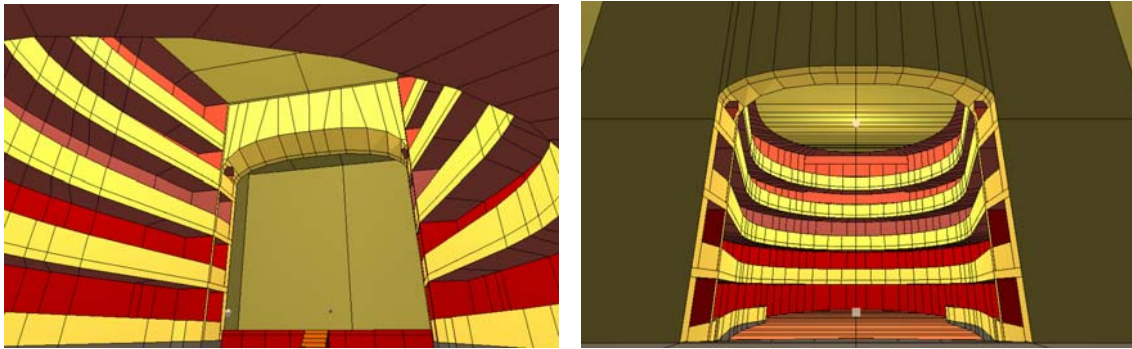


Figure 11.- Present state - 3D Geometric model (CATT)

We have also studied the variation of G strength with the frequency in every simulation, and they have been compared among them. G is a parameter very dependent on the situation of the receiver, by what several curves have been obtained in every case. The curve corresponding to a central point of the ground floor begins with high values to low frequencies (around 4 db) and it descends progressively becoming stable in the high ones without going down of 1.5 db in no moment. These are reasonable values, if we thought that all the walls of the Teatro Principal are made of plastering painted (whose absorption to low frequencies is little) and not of wood with air chamber like many of the Italian Style Theatres. The variation of G with the frequency in the same point in previous situations of the theatre is parallel to the described one but lightly higher. The curves obtained in the theatre boxes draw a slope similar to previously described, but they reach values very lower than those, placing in medium and high frequencies in negative values; reasonable also due to the attenuation of the signal with the distance (we have taken points to 21.5 m. of distance of the source) and to being surrounded with very near absorbent materials.

## CONCLUSIONS

With this work we think to have contributed to extend understanding of the Italian Style Theatre's acoustic performance throughout the exhaustive research job carried out in the Theatre Principal of Valencia. By the computer simulations we will be able to recreate and perceive the acoustic behaviour of this theatre, not only in the in the past configurations, but also the current ones.

The simulations by means of CATT-Acoustic have allowed us to evaluate, in an efficient way, the effects on the acoustic spaces behaviour of a series of architectonic interventions. These simulations will have great value when approaching future reform projects, rehabilitation, maintenance or preparing the theatre for temporary specific uses.

In this work we have been taken as acoustic parameters the Reverberation Time and Strength and have been settled down the bases for a detailed scientific study. The great number of measurements points, allows us to analyze their dependency and variation, with the different studied typologies.

## BIBLIOGRAPHY

- [1] M. Forsyth: Buildings for music. Cambridge: Cambridge University Press, (1985), p. 95
- [2] A. L. León Rodríguez, J. J. Sendra Salas, J. Navarro Casas, T. Zamarreño García: Acústica y rehabilitación en teatros de Andalucía. Secretariado de publicaciones Universidad de Sevilla (2007)
- [3] L. Beranek: Concert halls and opera houses. Acoustical Society of America (1996)
- [4] M. Recuero: Acústica arquitectónica. Soluciones practicas. Editorial Paraninfo (1992)

## ACKNOWLEDGEMENTS

This study was subsidized by the FEDER and the Ministry of Education and Science in the Plan Nacional I+D within the coordinated research project, reference BIA2003-09306-C04.

We thank the *Diputación de Valencia* and "*Teatros de la Generalitat Valenciana*", for their constant support in letting us use their Theatre in order to carry out our study.