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ACOUSTICS OF THE MIRA TEATRO DE POZUELO DE ALARCÓN, MADRID

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ABSTRACT

The Mira theatre is a multipurpose hall which is part of the City Hall Cultural Center of Pozuelo de Alarcón, Madrid, Spain; were both musical and theatrical representations are presented. The hall project begins with an atypical rectangular ground plan and a very high air volume per seat/listener. The acoustic project included unusual edges because of the building characteristics and the formal requests of the projectors. The acoustic project design of the concert hall, in use since 2005, is completely presented in this article beginning from the estimated acoustic parameters, the acoustic modeling on a simulation software, the proposed constructive techniques and the ones carried out, and the measures taken once built the hall, from which are presented conclusions which evaluation offers several points of interest.

THE ARCHITECTURAL PROJECT.

The Mira theatre is part of the City Hall Cultural Center of Pozuelo de Alarcón, Madrid, Spain. The project corresponds to the architect Antonio Moneo. The hall is to be used for all kinds of events, both musical and theatrical representations. It has an approximate volume of 5,426 m^3 and a capacity of 600 people, which gives a volume per seat of approximately 9 m3. This relation is very high for the hall to be used for making a speech, and it comes closer to the needed volume for perform lyrical music. It was considered that a volume reduction will improve the hall condition referring to speech conditions but it will produce an important loss when performing non-amplified music. Attending to this characteristics, and according to the recommendation of [Recuero et al 91] and [Ahnert 93] the reverberation time was established to be around 1.3 seconds, for correct speech intelligibility to be achieved, with the use of a public address system; granting adequate conditions to listen to music interpreted by acoustic instruments or amplified music. For the allowed noise levels it has been chosen an NR 30 profile. If in the ground plan in figure 1 is analyzed the relation between the spaces it can be perceived the hall wide special feature in relation with the length.

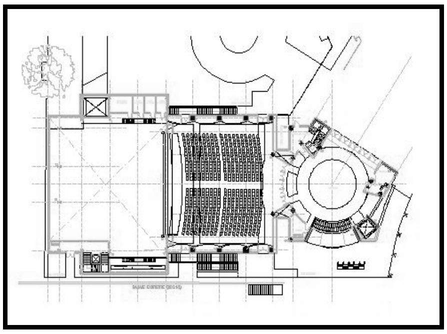


Figure 1.- Hall plan.

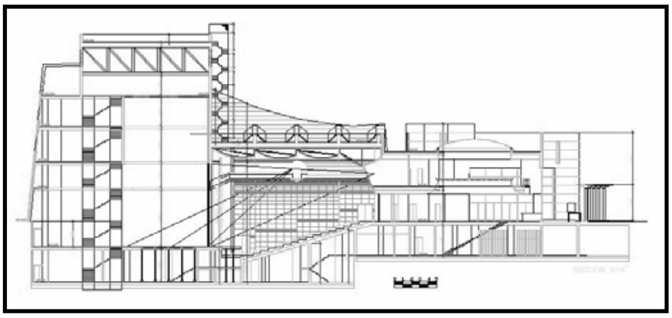


Figure 2.- Building cross-section

The cross-section presented in figure 2, previous the intervention of the acoustic consultants, confirms this idea and shows the projector's intentions to present a roomy access and staying zone for audience after and before the play/concert. The theatre width will have strong influence in the characteristics of this concert hall while analyzing it by means the geometrical acoustic as it will be seen, since in the seats in the central area will show a slight temporary gap on the reflections. It is worth reminding Beranek conclusions in [Beranek 62] on expressing that the width of a hall is an objective parameter of close correlative with subjective parameters. This idea is also mentioned in [Schroeder 74] who express that “the greater correlation between subjective preferences and geometric parameters is the hall width; as narrow is the hall, greater the preference and vice versa”. The same matter is discussed by Gade in [Gade 85] who says that “in relation to a hall geometry, the statistical analysis has shown the hall width significance in the spatial impression. Beranek deeply analyze this matter from the point of view of his ITDG, suggesting the fits of suspended panels from the ceiling in order to keep the volume for not altering the reverberation time and also provide with necessary initial reflections for a correct intimacy, very important factor in his acoustic outline conception. Something similar has been done in this case and no matter of this “temporary gap” of the central seats the sound is close, intimate.

Figure 3.- Stalls view from the stage.

ACOUSTIC INSULATION.

Due to the peculiar building location it was estimated that a 55 dBA insulation will be enough based on the that could be generated in the inside, in order of 90 dBA, also reasonable to insulate the hall from the exterior noise which is a very low level because the theatre is away from the routes/streets. The forecasts of the design, suggested a double compressed concrete bricks wall of 20 cm thickness in the hall perimeter and in the stage, whit a mass in order of 180 kg/m^2 per sheet, being this set superior to the estimated 55 dBA, reason why nothing has been done about this factor. On the other hand it was pointed to take precautions on the assumption that the stage cover consists in plate. In order to accomplish to the estimated NR 30 profile, several fixes were pointed in the air conditioning system, such as air speed injection, acoustic filters placement, vibration isolation holders and other recommendations.

ACOUSTIC PROCESSING AND THE ESTIMATED ACOUSTIC PARAMETERS.

In concept, it has been working trying to reduce the reflections arrival time to the stalls. To achieve that it has been placed suspended panels from the ceiling that supplies a useful reflection surfaces. In figure 4 you can see the panels distribution. As for their constitution we are talking about a curve surface and extended between the exterior limit of the footbridges. They are built in 15 mm thickness gypsum boards with a rear structure each 48 cm that makes them strongly rigid in order to avoid undesirables resonances. In the back part this panels have the 50% of the surface cover with a 25mm thick and 35 Kg/m^3 density fiberglass layer, protected by non-organic and non-textile cloth in order to avoid particles dispersion.

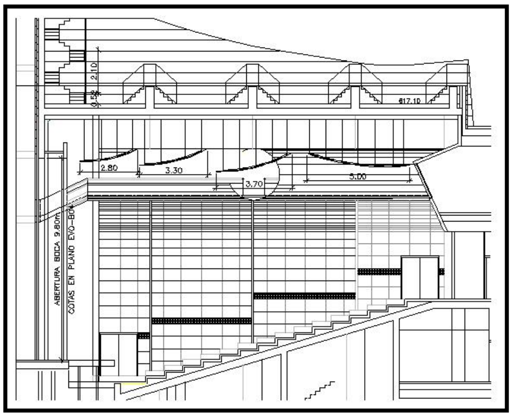


Figure 4.- Storey cross-section with panels.

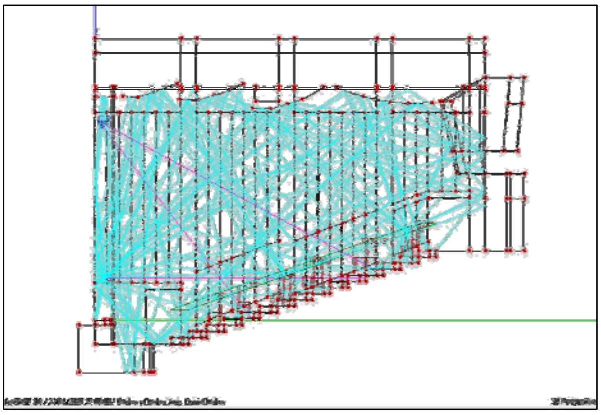


Figure 5.- Reflections with panels.

To get this panels curvature it have been working in consideration of the reflections from the stage and drawing sketches, although when the model was built a few simulations were carried out to verify the estimated geometry fulfillment. This panels also have an aesthetics function covering the lighting area and they also allow to place lights and the lighting projection. The objective to get was to arrive with the reflections in first or second order to the seats in the center of the hall an more or less on the same distance from the side walls since as it was seen there were some inconvenient with the side reflections due to the hall width.

The formal repertoire proposed by the work designer included images of the plating in all its variants. It was thought that mixing different kind of drilled plate, with several drills and different air chamber depths will obtain a uniform absorption. At the same time a “fold” in the plate will avoid undesirables echoes. However for some reason unconnected to those who advised on acoustics, some of the specifications were changed, some of them after a query others unilaterally. Even so, the results were high quality agreeing almost to everything planed. On the other hand, the color and glamour image obtained by the designer “hides” some inconvenience shown during the measurements which have origin in this changes.

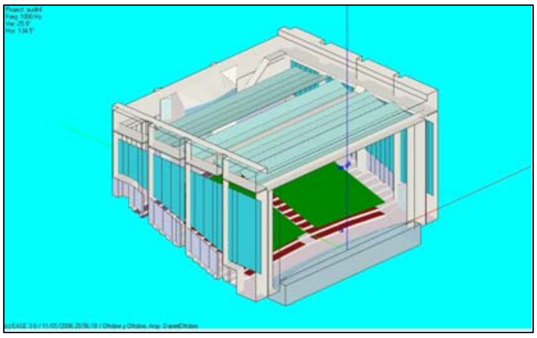


Figure 6.- EASE model.

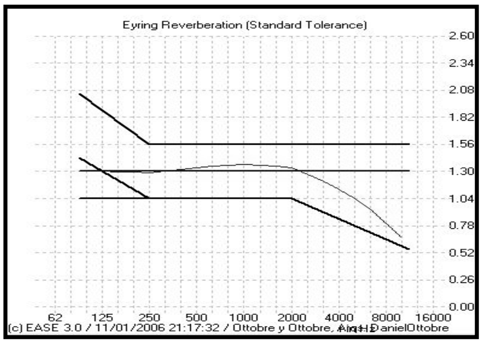
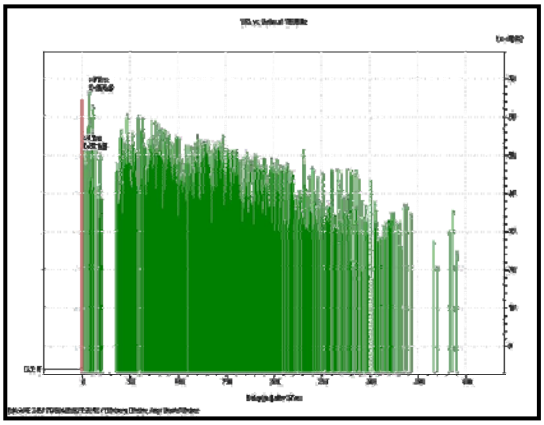


Figure 7.- Estimated reverberation time.

The model on the EASE software was built respecting each material surfaces and it layout in the hall; at the same time, the absorption coefficients were taken from the software data base which adapted very well to the estimated materials. For simulations an speakers cluster was placed over the stage entrance. Others parameters obtained in the simulation phase are:

- Center free way: 5,41 m
- Seats draft surface: 225 m^2
- Area per person: 0,37 m^2
- Volume per person: 9,04 m^3

Figure 7 shows the obtained reverberation time and in the graphic has been added two "tolerance" strips following an evaluation provided by the EASE software. We can see an important fall in very high frequencies over the 4 KHz, which is directly connected to the air absorption due to this hall volume. Now it is evaluated the ITDG, is to say, the arrival interval of the first reflection. To the ITDG evaluation and other parameters, it has been done a 100.000 rays reflection design from each speaker. To analyze the first interval reflection arrival has been used a reflectogram produced by this design for each seat shown in figure 89.
In this case, as it is a central seat, the absence of reflections in that time interval is appreciated. This because of the hall width and the cluster location, factors that produces an 18 ms gap in the reflections arrival. An IDTG summary fot several seats may be seen in figure 9. (First number shows the row an the second one the seat).



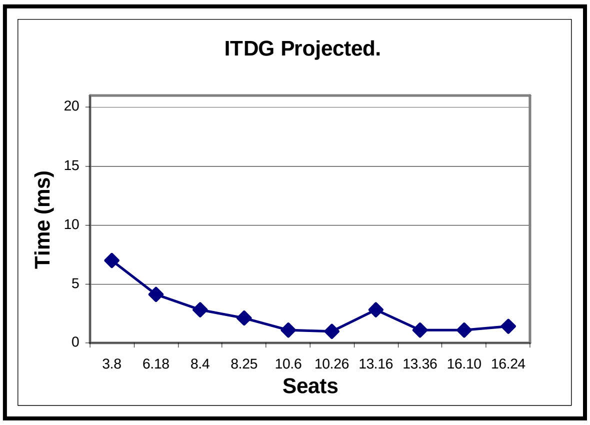
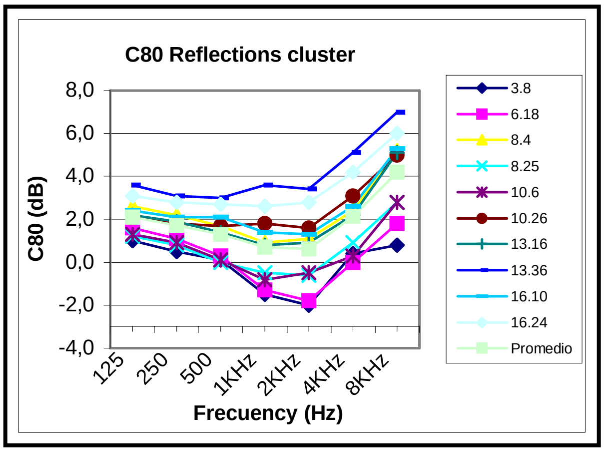


Figure 8.-.Reflections to a seat.

Figure 9.-ITDG

Subsequently departing from the reflectogram per each evaluated seat, to obtain the C80 index information of which summary per frequency and seat is represented in figure 10.



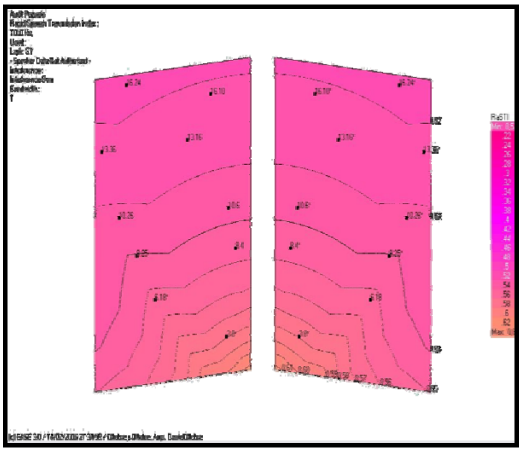


Figure 10.- C80 Index.

Figure 11.- RASTI Simulated over listeners area.

Hereafter C50, Rasti and ALCons intelligibility parameters are evaluated to 1KHz frequency departing of an speaker emission over the stage emulating a man voice. The C50 index locates on top of –5 dB for all rows which implies a good intelligibility a little bit more reverberant that ones seen before. The Rasti and ALCons indices for the last rows are in the limit zone of good intelligibility. In this case, due to the hall reverberation time, for the ALCons, it was used the Peutz formula which adds the reverberation time and the background noise establishing up to 11% as a good intelligibility. It is obvious that the hall great volume per seat exerts influence over the definition indices.

MEASSURED ACUSTIC PARAMETERS.

On measurement time, the works was done in what refers to roofs, floors and panelling. The seats were placed and in the pictures, if they are compared with the design ones, is noticeable that the central corridor is gone, adding two lateral corridors. There was also the firewall curtain which was closed during the measurement to avoid the stage great sound box influence over the hall, except for the background noise measures carried out with the curtain open. Measurements were carried out using a Symphonie system and impulsive noise. The forecasts of obtaining an NR 30 profile were clearly improved obtaining an NR 25 profile. However, during the first measurements appear some differences of the building with the design:

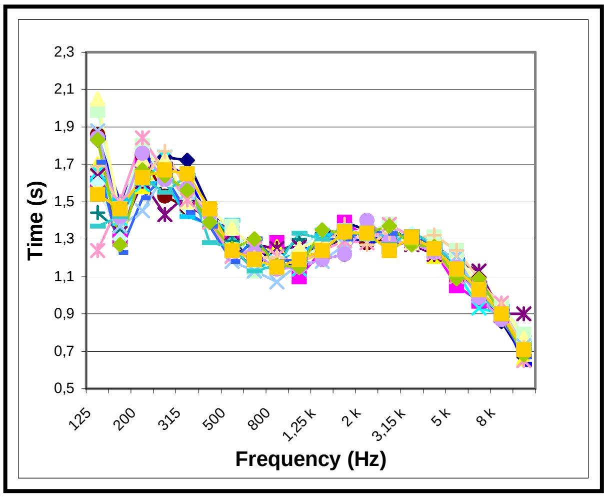
- The drilled plate chosen was only one kind, contrarily to the designed, of two different characteristics. The plates fastening was not correct so it vibrated.
- The bended frames for plate paneling were gone, leaving trimmed panels with no sloping in relation to the walls.
- The plate type chosen by the designers was different to the one chosen in the acoustic design.
- The materials surfaces did not fulfill with the values planned in the acoustic design.

Due to this circumstances, a first report was made were certain adjusts were recommended over the hall, proposing a new measurement once finished the repairs. In subsequent measurements, although the situation was remarkably better referring to vibrations, though diminished was still there a 160 Hz strip gap on reverberation time. In order to analyze it, the mainly used material, is to say drilled plate, was measured and checked it's installation, air chamber, filler material etc. To clarify this matter a little more, it is good to say that though the analysis range of the acoustic design departed of a 125 Hz frequency, one of the plate resonator have it's resonance frequency one octave lower, around 53 Hz. The objective was to avoid the unpleasant effect produced by excessive reverberation in very low frequencies, in particular if there is an amplifying system. The fiberglass filler suggested will “bell-shape” the material absorption curve, reducing the peak absorption effect produced by non muffled Hemlholz resonator, as the one in the drilled plate. However, this was not actually done for motives not involved with the acoustic design, the plate was replaced and the filer withdrawal. The table 1 analyzes the results obtained and the suggested ones departing from the resonance evaluation for the drilled plate estimated and the one measured in the building site. Comparison shows the estimated resonance frequency seeing clearly were both type of resonator resonance falls. To this effect should be added the absence of muffle.

Drilled Resonators	Estimated	Measured
Plate drilling diameter (mm)	1,00	4,00
Plate thick (mm)	2,00	1,00
Holes separation (mm)	3,78	5,00
Neck section (mm^2)	0,79	12,57
Neck conductivity (mm)	0,28	2,99
Air chamber (mm)	200,00	150,00
Resonator volume (mm^3)	2857,68	3750,00
Resonance frequency (Hz)	53,50	152,53

Table I.- Resonators comparison.

Figure 12 shows an obtained reverberation time summary were around 160Hz a valley can be seen, prompted by the mentioned factors. The EDT (Early Decay Time) was evaluated departing from an impulsive noise. Figure 13 shows a summary of the EDT and T30 values measured and estimated. It is interesting to check although the estimated and measured reverberation time are correlatives, EDT raises considerably to the lower frequencies. However, it is good to say that in lower frequencies there is a dispersion which is not always easy to handle.



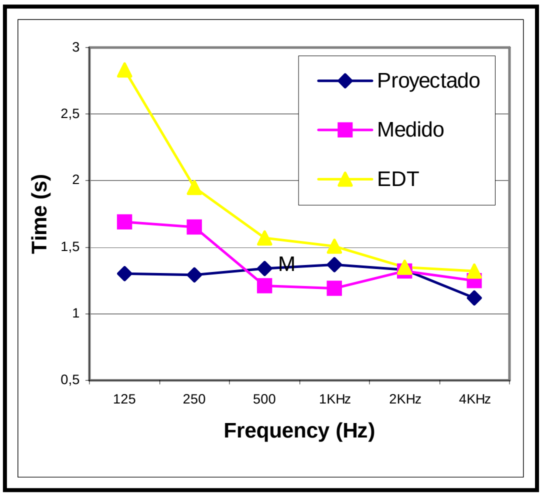


Figure 12.- Reverberation time. Figure 13.- Reverberation time comparison

On figure 14 we can se a C80 measured and evaluated index summary. For lower frequencies, the measured C80 presents the bigger disagreements, adjusting to the estimated values for the middle and higher frequencies. Iintelligibility has been evaluated using the RASTI index, obtaining a 0,56 average which is inside the good intelligibility limit (0,6).

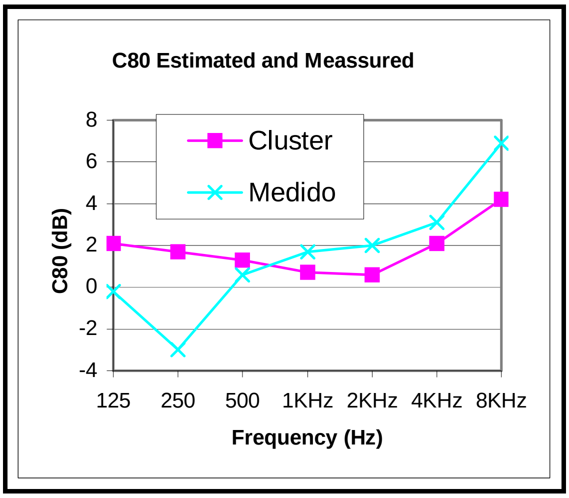


Figure 14.- C80 Estimated and measured

CONCLUSIONS.

The developed research shows the need for an acoustic adviser from the first architectural suggests carried out for a concert hall; and the request of an interactive task between designers an acoustics specialists. For example, an on time intervention would avoid. Although in this case the results were finally successful, the non-query interventions since formal requirements can take results to a spectacular failure.

References: [Ahnert 93] "EASE 30 Reference Manual"; ADA Acoustic Design Ahnert, Pág 302-304; Germany; 2000; [Beranek 62] "Music, Acoustics and Architecture"; L.L. Beranek; Wiley, New York; 1962 Pág. 417-425; 1962; [Gade 85] "Objective measurements in Danish Concert Halls"; A. C. Gade; Proc. Institut of Acoustics 7, Pág. 9-16; 1985; [Recuero et al 1991] "Acústica Arquitectónica" Manuel Recuero López, Constantino Gil González; UPM; Pág. 9.40; Madrid; 1991; [Schroeder 74] "Comparative study of European Concert Halls: correlation of subjective preference with geometric and acoustic parameters"; M.R. Schroeder, D. Gottlob y K.F. Siebrasse; JASA Vol. 56 Pág. 1995; 1974.