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Acoustic study of the Compañía de Jesús church. Characterization by means of objective and subjective parameters

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ABSTRACT

This work shows the objective results of the acoustic quality of the Compañia de Jesús Church in Cordoba, Argentina. The acoustics of this Temple, built by the Orden Jesuita (Jesuit Order) two centuries ago and declared a World Heritage Site by UNESCO in 2000, is currently considered optimal by musicians as well as general public. In the second half of XVI century, with the Catholic reform, the need for improved speech intelligibility was given priority, being the Jesuit one of the orders that gave most importance to the construction of their temples. This church has constructive and spatial characteristics consistent with those needs. With the purpose of carrying out the acoustic assessment of the precincts, a work methodology that allowed comparing the results obtained from objective measures was developed by means of implementation of field measurements and space modeling, with subjective appreciation results, by developing surveys, with the aim of characterizing acoustically the sound space. This paper shows the comparison between the subjective results and objective criteria, which allowed important conclusions on the acoustic behavior of the temple to be obtained. In this way interesting data were obtained in relation to the subjective response of the acoustics of the church.

INTRODUCTION

For the Jesuit order, colonization in America was a big challenge, which allowed the European formation of the Jesuit order to move to all manifestations of life, not only to culture but also to customs. European Baroque influence is evident in the architecture, as well as in literature, music and philosophy. With regard to architecture, the formation of the Jesuits played a significant role in the constructions, with the contribution of the local workforce who left their mark on the characteristics of building and decorative type. The best example of the Jesuit legacy is reflected in their temples with "Latin cross" plant, with a single nave, barrel-vaulted covers and a dome in the crossing.

Of all the religious orders, the Jesuits were the ones who had greater concern for their churches' acoustics, building their temples with a single nave and replacing vaulted large areas with wooden ceilings. [1]

Through this research we present the characterization of the acoustic quality of the Compañia de Jesús Church in the city of Cordoba, Argentina, from the subjective point of view, with the implementation of surveys, and objective point of view, by obtaining results of acoustic parameters. This study allowed the correlation of the opinions with the acoustic quality of the Temple.

ANTECEDENTS

The acoustic characteristics of the religious precintcs are conditioned by their architectural form, which in turn is determined by the time and place they were built in, as well as by the religion they belong to.

The Paleochristian churches had a longitudinal cross-shaped plant with wooden roof and lintel structural system, where the only vaulted part was the apse. The ceilings, which were not very high, and the large blank walls, behaved better acoustically than medieval churches. In the Romanesque period domed surfaces were used, which generated focalized surfaces. The wooden buildings were replaced by stone surfaces, more resistant to fire. [2]

In Gothic cathedrals, the locations of major proportions and heights, as well as the use of vaulted surfaces, generated significant reverberation times and sound focalization. With the addition of side chapels, the absorption of low frequency sound was favored. The important decoration of such chapels favored the dissemination of sound.

The Renaissance churches improved acoustics, since they present better proportions than Gothic cathedrals do, using wood in the roof surfaces without the presence of large reflective surfaces and a vault in the lateral chapels and dome.

In the Baroque churches the important ornamentation their surface present favors the dissemination of sound. This

ornamentation is present in most of the elements component of the architecture such as pilasters, lintels, steeples, etc. [2]

In the second half of the sixteenth century, with the Concilio de Trento/Council of Trent, the preaching at the service of the Counter Reformation was given importance, which generated a significant change in relation to the acoustics of the churches. Of all the religious orders, the Jesuits were the ones who gave most importance to the acoustics of the churches, adopting a single nave plant that allowed a better relationship between the preacher and the parishioners and the use of wooden roofs in replacement of the large vaulted surfaces. The Compañia de Jesús Church has architectural features in accordance with the need to improve the acoustic conditions of this type of areas. It thus raises the possibility or need to verify whether the architectural features of this church respond to the changes arosen in the sixteenth century after the Celebration of the Council of Trent. [1]

Compañía de Jesús Church

The deep knowledge that the Jesuits had on structural and language solutions is reflected in the architecture developed by the order in America.

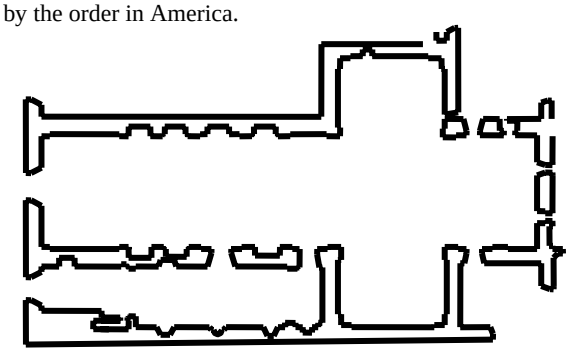

Figure 1. Plant of the Compañía de Jesús church

A clear example of such knowledge is the Compañía de Jesús Church, which has an unusual feature in Latin America: total wooden vaulting. Started between 1645 and 1654, it is a church of large dimensions, but with a simple configuration, with a Latin cross plant, a single nave, a shallow chancel and chapels in the transept of shallow depth. [1]

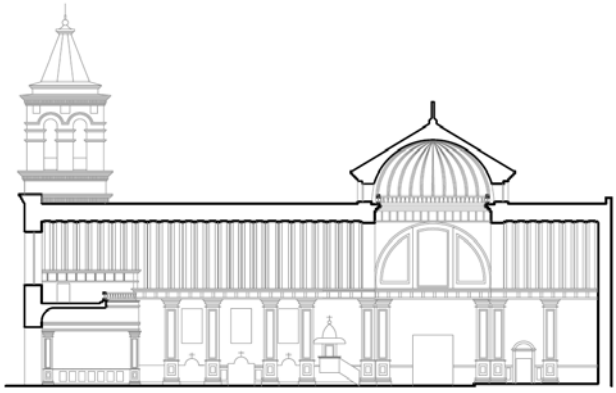

Figure 2. Church's longitudinal section

The dome is composed of a semicircle of wooden beams, joining several sections by pegs. Joining these beams longitudinally with joists or crossbars, or diagonally with stringpieces, forms a non deformable structure resulting in excellent spatial solution. Figures 1 and 2 show the plant and longitudinal section and Figure 3 shows the interior of the Church.

Figure 3. Interior of the Church

METHODOLOGY

For the quantitative evaluation, parameters that allowed to link the subjective aspects of the premises with the objective ones were relieved, for the purpose of seeking the correlation between them. The parameters surveyed are those that relate to subjectivity: EDT (Early Decay Time) [3] warmth or tone, brightness, energetic parameters such as D50 Definition, Clarity C80.

To measure the reverberation time, the impulsive method was used. We worked with the implementation of an acoustic pulse of sufficient intensity to excite the site. Six measurements were carried out distributed through all the area of interest.

Quality parameters were also obtained by using automated computer programs, modeling or acoustic simulation. The modeling at the same time allowed predicting the behavior of the Church against the use of various sound sources. It was also used as a tool for assessing the church's acoustics in situations that could not be met during the measurement.

For the subjective assessment a survey based on the ones conducted by M. Barron [4] in Great Britain was implemented. With the premises fully occupied, approximately 50 surveys were distributed. With regard to the conditions of occupation, the benches were fully occupied as well as the hallways and atrium, thus a large number of people were standing. The main church door was wide open, so that the people located in the atrium could hear the concert. We proceeded to deliver the survey before the program began with a general explanation in relation to the objective and how the questions should be answered.

The surveys were made choosing people from the audience at random, and basically people who were standing for practical reasons. Importantly, the surveyed audience was the one inside the temple, and not those in the atrium, as our interest was to evaluate the response of those who were inside the precincts, for the purpose of obtaining more accurate information.

Seven subjective parameters were considered: vividness, loudness, clarity, warmth, brightness, privacy and specialty. In the structure of the survey each of these parameters were defined, with the object of their being interpreted by the audience surveyed, and a verbal scale was implemented with four response alternatives for each parameter. [6]

RESULTS OBTAINED

Objective Parameters

Figure 4 shows the average values of EDT (Early Decay Time) of the six measured points corresponding to the empty church.

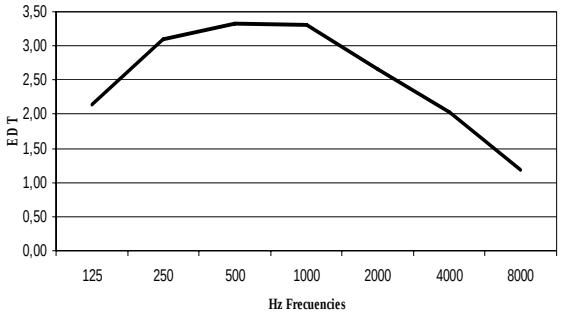

Figure 4. EDT average values

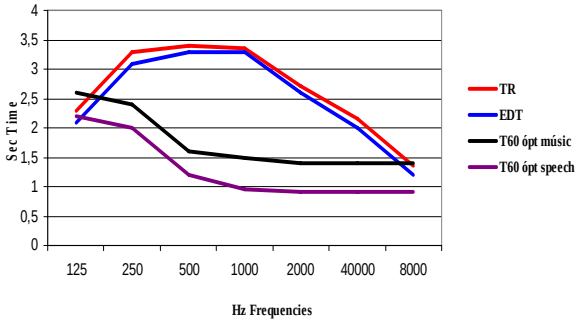

Figure 5. EDT, TR and Optimun T comparison

Figure 5 shows the comparison among the EDT, the Reverberation Time (T_{60}) and the values considered optimal for music and speech. The behavior shows the presence of a significant sound absorption in the bands between 125 and 400 Hz, the values for all the frequencies are close to the Reverberation Time, but they are far from the values considered optimal for both the music and speech.

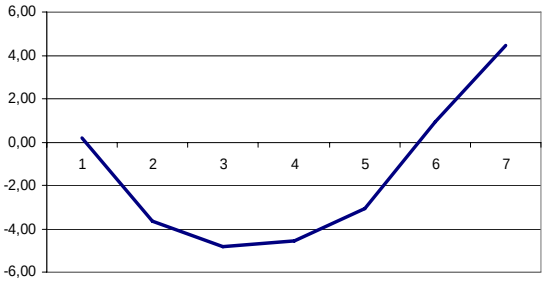

Figure 6. C_{80} Clarity Index

Figures 6 and 7 respectively show musical clarity (C80) and the definition (D50) according to the frequency.

With respect to the Index of Clarity C80, the values are found in low and middle frequencies within the range recommended by Beranek for an empty room [5] but not for high frequencies.

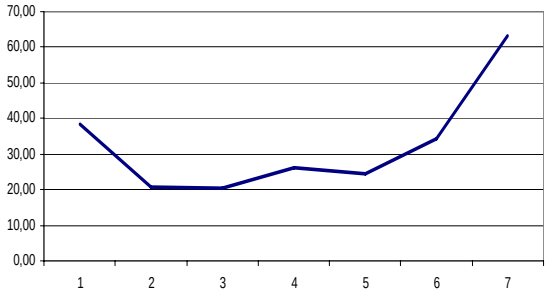

Figure 7. D_{50} Definition Index

In relation to the Index of Definition (D50) in the analysis of the measured points it can be seen that in all the points in the low, medium and high frequencies (except for 8000 Hz), the values are below 50%, which implies that the precincts have, from the theoretical point of view, little privacy.

Acoustic Simulation

Based on the hypothesis that this church has very good acoustics for the interpretation of any kind of music, especially choirs and considering that, in highly reverberant precincts of important volume, the absorption introduced substantially affects reverberation times, the simulation was performed with the presence of parishioners for the purpose of verifying the acoustic parameters and thus the quality parameters of the precincts.

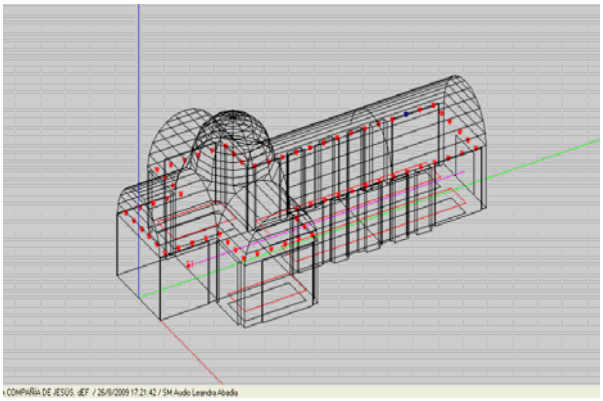

Figure 8. Church digital model

Figure 8 shows the model of Compañía de Jesús church and Figures 9 and 10 show EDT values (Early Decay Time) simulated with and without an audience. In Fig 11 the comparison of the results obtained are shown.

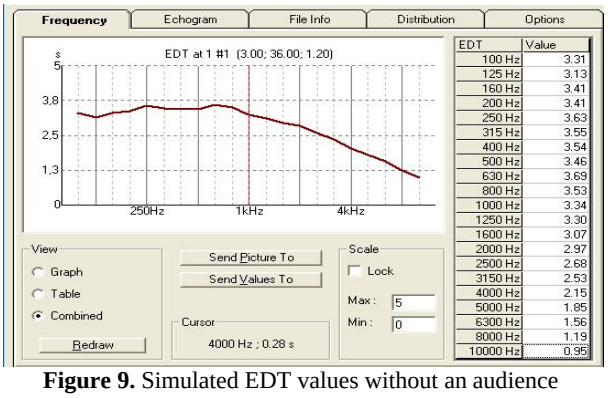

Figure 9. Simulated EDT values without an audience

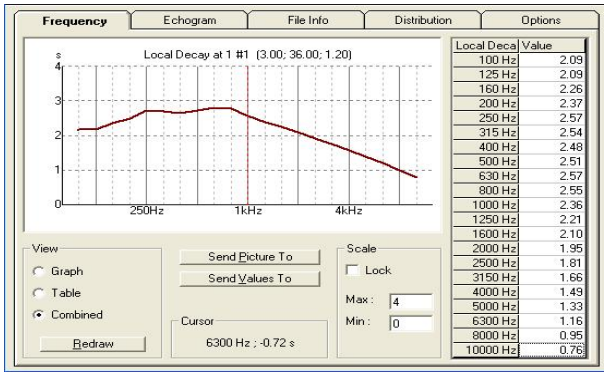

Figure 10. Simulated EDT values with an audience

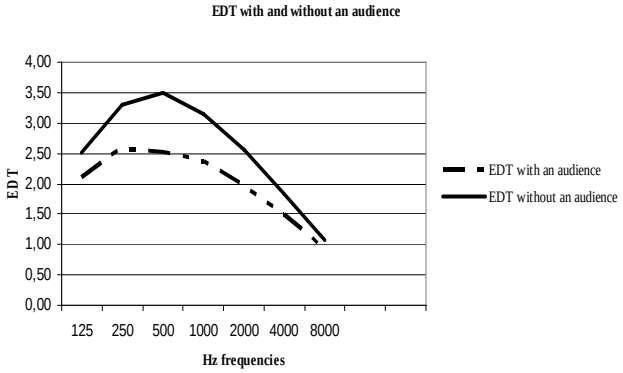

Figure 11. EDT values with and without an audience

Subjective Study

Through the implementation of the surveys, the audience subjective assessment could be evaluated with respect to the acoustics of the church. Fig 12 shows a summary of the responses of individuals to the questions asked and a comparison between objective and subjective results.

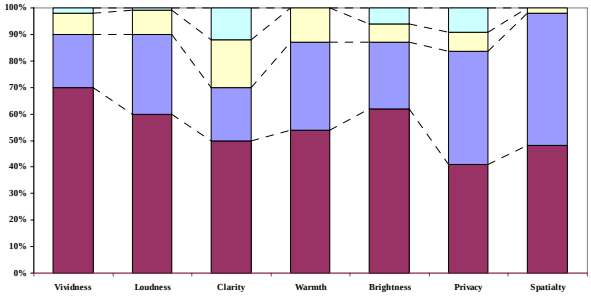

Figure 12. Summary of the survey. Comparison between objective and subjective results

The results of some of the subjective parameters assessed by the survey are shown, in which the positive response of the audience is verified with respect to the acoustic behavior of the church in general.

CONCLUSIONS

The real acoustic performance of the prescints without an audience was assessed with these measurements and it was verified that the reverberation time is high in mid frequencies for the use of the site. Moreover, the tone curve shows that in low frequencies the wood used on the surface of the roof, of important dimensions, gives absorption to those frequencies, for which reason the reverberation time decreases considerably.

Through the evaluation of the surveys, a positive assessment of the audience in relation to the acoustics of the Church was proved. The results in this investigation indicate that the statistical relations constitute a significant opinion of analysis for this type of precincts.

The important adjustment between the subjective responses and the objective analysis on issues such as brightness and warmth must be highlighted. On the contrary there is no tight relationship for privacy.

The simulation allowed verifying the acoustic behavior of the church attended by parishioners, a situation that could not be considered in the measurement. It could thus be proved that the presence of parishoners inside the prescincts significantly affects reverberation times.

REFERENCES

1 Navarro, J; Sendra, JJ “El Concilio de Trento y las condiciones acústicas en las iglesias” *Actas del Primer Congreso Nacional de Historia de la Construcción*. Madrid 19 – 21. Setiembre, 1996

2 Sendra, Juan; Navarro, Jaime. “Análisis acústico de los tipos eclesiales”. *SEA.* Madrid, España, 1993

3 UNE-EN ISO 3382:2001. Medición del tiempo de reverberación de recintos con referencia a otros parámetros acústicos.

4 Barron, M. “Subjetive Study of British Symphony Concert Hall”; *Acústica Vol. 66 Nº* 1; 1988.

5 Beranek, Leo. (2003). “Concert Halls and Opera Houses: Music, Acoustics, and Architecture”. *Ed. Springer-Verlag, New York, USA.*

6 Ottobre, Daniel. “Base de datos para el análisis y comparación de parámetros acústicos y psicoacústicos en teatros y salas de concierto”. *Tesis Doctoral. Universidad Politécnica de Madrid*, 2006