

The Teatro Colón in Buenos Aires. Preservation of acoustic quality during the latest restoration work.

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ABSTRACT

Between 2006 and 2010 an extensive restoration of the Teatro Colón in Buenos Aires was carried out. One of the main concerns related to the works was the preservation of the excellent acoustic quality of the theatre. To do so, a specific methodology was chosen that included acoustic measurements made at different stages of the works. This paper describes the applied methodology and some of the results of the measurements made.

Keywords: Teatro Colón in Buenos Aires, acoustic restoration.

1. INTRODUCTION

The construction of the Teatro Colón began in 1889 as an original project of the architect Francisco Tamburini, who died before finishing the work. He was succeeded by his collaborator Victor Meano and, on his death in 1904, the Belgian architect Jules Dormal completed the work. The Teatro Colón in Buenos Aires was finally inaugurated on May 25, 1908.

The hall meets the general characteristics of a classical Italian horseshoe-type theatre. It has a total capacity of 2,360 seats, with standing room for an additional 500 people. The stalls are 29.25 m wide and 32.65 m long, and the ceiling is 28 m high. The main floor, which has a gentle slope, is surrounded by seven levels: three levels of French-style open boxes and, above them, the levels of Cazuela, Tertulia, Galleria and Paradiso.

The stagehouse is 35.25 m wide, 34.50 m deep and 48 m high. Its floor has an inclination of three centimeters per meter and it has a rotating disc of 20.30 m that allows scenes to be changed quickly. The orchestra pit, framed by the boxes of the proscenium arch, has the capacity for 120 musicians.

Restoration work began in 2002, comprising three well-defined areas: the historic building, the main hall and the stagehouse. One of the main objectives of the works was to preserve the well-known acoustic quality of the Teatro Colón [1], [2]. Rafael Sánchez Quintana and the author acted as Acoustics Consultants for the Government of the City of Buenos Aires and Alberto Haedo for the companies contracted to carry out the work.

The purpose of this article is to describe the methodology developed to preserve the original acoustic quality of the Theatre.

2. PRELIMINARY DECISIONS

After an exhaustive analysis of many precedents of acoustic preservation works, it was concluded that none

of the previous methodologies were suitable for the particular case of the Teatro Colón.

The acoustic parameters defined by ISO 3382:1997 were used as a starting point [3]. To overcome the limitations of the standard, it was decided to make broadband recordings using a large number of source-receiver pairs, in which the impulse responses were completely preserved. This database was used to calculate the ISO parameters, which are average values limited to the octave bands between 125 and 4000 Hz, and which would be used for future analysis.

The general approach adopted for the acoustic restoration was described by Javier Fazio, structural consultant of the works: "A building that is considered to have a high heritage value is subject to conservative restoration actions due to its uniqueness, which excludes it from the field of application of the standards" [4].

Taking into account the above statement, the technical objective was to keep the differences of the ISO 3382 standard's parameters, measured before and after the works, below the errors admitted by the standard, which correspond approximately to the acoustic limits of each parameter.

2.1 Acoustic model to preserve

Choosing the historic moment to use as a reference point presented certain problems. The Teatro Colón had undergone modifications throughout its history. For example, until the 1930s, when the final curtains were installed, its acoustics was considered from regular to poor, and in the late 1960s a new air conditioning system that reused the original ventilation ducts of the building was installed.

Another problem with the choice of the reference point is that previous measurements, at least until the 1990s, were scarce and limited. Those of Leo Beranek, mentioned in his 1962's book, and of Federico Malvarez, recorded in 1971, were incomplete and would not

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have served as a valid reference.

To solve this dilemma, we turned to heritage consultants, who suggested applying the principle that states that in the restoration of a historical monument, most recent significant historical event that occurred should be considered. If all the performances of operas and concerts are considered significant historical events, it is therefore possible to use the artistic performances and measurements of the year before the closure as valid reference points: it was decided that the "acoustic photograph" taken in 2006 should be replicated at the end of the restoration work.

2.2 Intervention criteria

The general principle that defined the intervention was that any modification that could affect the acoustics of the hall should be potentially reversible.

Four possible scenarios were foreseen:

1. It was technically possible to demonstrate that the change proposed by the team of architects would affect, if carried out, the acoustic quality of the hall. In those cases, the modification was rejected. Examples of this situation include the proposals to reduce two internal walls on the stage or the replacement of the ventilation grilles in the stall's floor.

2. It was determined that the proposed change would not affect the acoustic quality of the hall. Therefore, it was accepted. For example, the installation of air conditioning through floor ducts in the upper levels

3. It was not possible to determine with certainty that the proposed change would be acoustically innocuous. In these cases, an extremely conservative approach was adopted and the proposals were rejected. This included the intention to create new access doors to the orchestra pit.

4. The last possible scenario was, perhaps, the most problematical: the modifications had the capacity to affect the acoustics of the hall, but they had to be made to increase the theatre's resistance to fire. The example here is obvious: the complete textile material, responsible for much of the interior acoustic absorption and the spectral balance of the theatre, would be replaced.

3. IMPLEMENTED METHODOLOGY

The methodology adopted to achieve the goal of preserving the acoustic quality of the Teatro Colón can be divided into the following stages [5]:

1. Diagnosis of the acoustic state prior to the beginning of the restoration tasks. The measurements were made in 2006 based on the ISO-3382 standard.

2. Development of a digital acoustic model to control the hall's disassembly-assembly process.

3. Acoustic measurements of the hall at specific stages in the disassembly.

4. Laboratory measurement of the acoustic characteristics of the components and materials removed from the hall.

5. Laboratory measurements of the acoustic characteristics of the components and materials to be

incorporated into the restored hall.

6. Acoustic measurements of the hall at specific stages in the reassembly.

7. Final measurement with the hall restored and fully equipped. This was done in 2010 based on the ISO-3382 standard.

8. Comparison of the measurements mentioned in stage 1 (initial condition) and in stage 7 (final condition).

What follows will briefly describe what was done based on this methodology.

3.1 Acoustic measurements of the hall

The measurements in the hall were carried out by the Argentine Institute of Acoustics, Electroacoustics and Related Areas and certified by the Argentine Institute of Standardization and Certification IRAM -ISO representative in Argentina-. A normalized omnidirectional source (dodecahedron), excited with logarithmic sinusoidal sweeps of 5.5 s duration, was used. It was located in 8 different positions, half of them with the pit in the low position and the other half with the pit at the stage level. Measurement microphones were placed at 21 different positions around the hall. Broadband impulse responses were recorded on all emitter-receiver pairs and parameters defined by ISO-3382:1997 were measured.

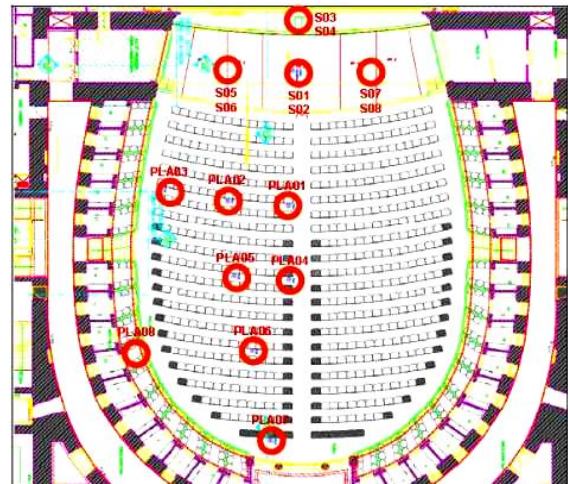


Figure 1 – Positions of the omnidirectional source, on the stage and in the pit, and measurement points in the stalls (After [6])

During the measurements prior to the works, carried out in November and December 2006, and during those carried out after its completion in March 2010, the textile curtain was used to decouple the main hall from the stagehouse. Throughout the intermediate measurements, the fire curtain made of iron was used for the same purpose.

Table 1 – Values of the ISO-3382 parameters measured in December 2006 [3], [6]

PARAM	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
EDT [s]	2.46	2.24	2.05	1.68	1.55	1.10
T10 [s]	2.37	2.24	2.02	1.81	1.61	1.32
T20 [s]	2.34	2.27	1.99	1.75	1.59	1.35
T30 [s]	2.37	2.25	1.99	1.75	1.61	1.37
C80 [dB]	-1.9	-1.5	0.8	2.9	2.6	5.3
G [dB]	1.1	1.7	3.5	3.7	3.1	2.8
Ts [ms]	167	159	113	80	81	53
LF	0,31	0,24	0,14	0,10	0,12	0,12

Intermediate measurements were made, during the staggered disassembly of the hall, in the following sequence:

- After the removal of the seats from the stalls
- After the removal of the stall's carpets
- After the removal of the upper-level seats
- After the removal of the chairs and stools from the boxes
- After the removal of the curtains from the boxes
- After the removal of the carpets from the boxes
- After the removal of the curtains covering the exits
- After the removal of the carpets from the Paradiso level



Figure 2 – Measurements in the hall after the removal of the stalls carpets

During the staggered reassembly of the hall, a reverse sequence was followed. Thus, the last measurement in the disassembling and the first measurement in the assembling were carried out with the hall completely devoid of textiles. In this way, the results of the equivalent stages -the ones with the original materials and the ones with the replacement materials- were able to be compared. The objective was to detect any deviation and correct it immediately if necessary.



Figure 3 – The hall before putting the seats on the main floor during its reassembly

3.2 Laboratory measurements

Samples of the original elements - curtains, seats, draperies, carpets, etc. - and their replacements were measured at the *Laboratorio de Acústica y Lumineotecnica* (LAL-CIC) of the Province of Buenos Aires.



Figure 4 – Laboratory measurement of the hall curtains



Figure 5 – Kundt tube measurement of the carpets for the Paradiso level

In almost all cases, the acoustic absorption was measured in a reverberant chamber following the ISO-

354 standard. In some cases, the standing wave tube method -Kundt tube- was used to carry out preliminary measurements. By way of illustration, the replacement fabric for the upholstery of the seats was finally resolved having discarded the first seven samples that did not meet the required acoustic absorption values.

3.3 Development of a digital model

Simultaneously with the measurements in the hall, a digital acoustic model was developed using the *CATT-Acoustic* software. It was adjusted with the values of the on-site measurements until the errors were similar to those established by the ISO-3382 standard. The model was widely used throughout the process and was very useful for making critical decisions, such as extrapolating the measurements of the absorption of the seats made in the reverberant chamber to the particular acoustics of the theatre.

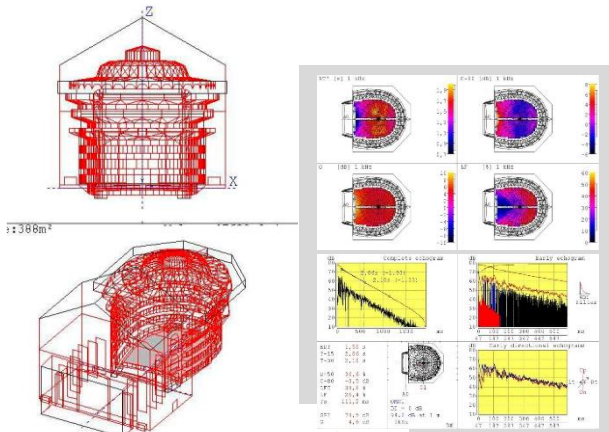


Figure 6 – Views and some predictions of the digital model of the Teatro Colón (*Catt-Acoustic* software)

4. RESULTS AND CONCLUSION

The comparison between the results of the measurements carried out before and after the restoration work showed that there were no deviations above the margin of error allowed by the standards. For example, Figure 7 shows the global T30 values, with the two curves practically superimposed. The rest of the global ISO-3382 parameters showed a similar agreement.

The methodology used proved to be effective in preserving the original acoustic quality of the hall. A methodology that, although designed *ad-hoc* for the specific case of the Teatro Colón, it would be possible to be adapted in the restoration of other halls of great heritage value

TC - Comparación mediciones T30

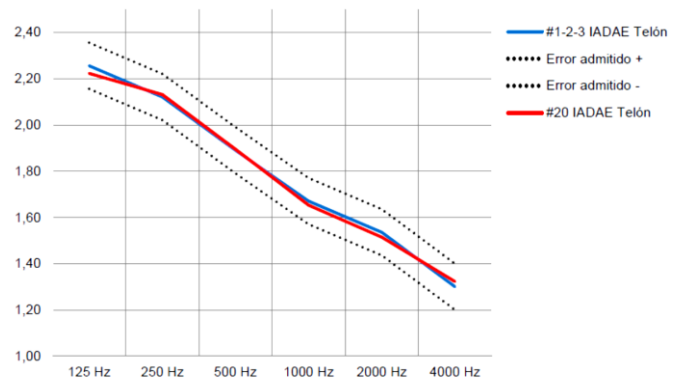


Figure 7 – Comparison of the initial (blue curve) and the final (red curve) T30 measurements in the empty hall. Dotted lines represent the error allowed [6]

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