The Amintore Galli Theatre in Rimini: A Dataset of Building Simulation Tools for its Acoustic Design

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Abstract

The Amintore Galli theater in Rimini re-opened in 2018, after more than 60 years of inactivity. Its acoustics have been studied in depth, starting in 2009 until the re-opening of the theater. This paper analyses the following different steps of the acoustic design of the Opera House: the analysis of the acoustics of similar other theaters, the design of the acoustics of the new main hall, the analysis of the acoustic characteristics of the diffusing panels in the theater, and the acoustic design of other rooms, including the rehearsal room. Moreover, this paper reports some of the most relevant results of the acoustic surveys conducted after the re-opening, comparing the values of some acoustic parameters obtained after the simulation processes, and the values of the same parameters during the final validation of the theater.

1. Introduction

The acoustic studies of Italian opera theater houses have been improved in their accuracy by the development of new generation technology (Farina et al., 1998; Tronchin, 2005 and 2021; Tronchin & Bevilacqua, 2021 and 2022; Tronchin & Knight, 2016; Tronchin et al., 2020a, 2020b, 2021a and 2021b). An acoustic survey was undertaken inside Galli theater of Rimini in order to show the acoustic parameters as required by the regulations (ISO 3382-1). Furthermore, a multichannel spherical array microphone was employed to add value to this acoustic investigation by illustrating the impulse response (IR) through an overlay video. The outcomes of this additional provision were recorded with some snaps related to different moments of the IR decay. The authors of this paper also outline a brief history of Galli theater of Rimini, including a description of the architectural features that characterize this important opera house.

2. Historical Background

The theater was originally named "Teatro Nuovo" (The New Theater), and the project began in 1841, overseen by architect Luigi Poletti. The theater distinguished itself from other theaters in the same period, showing the innovative style of memorial architecture of classical architecture (Toyota, 2020).
The theater was built between 1843 and 1856, and the project was delivered to Pietro Bellini, the Rimini contractor. The cost of the theater was mostly covered by the aristocracy. The theater officially opened in 1857. It was renamed Teatro Vittorio Emanuele II in 1859 (Toyota, 2020).
In 1916-1923, the ceiling of the theater was damaged and cracked in an earthquake. In addition to the necessary repair of the historical structure, it was also equipped with an electrical system (Toyota, 2020). Subsequently, the architect Gaspare Rastelli completed the Ridotto and upper Gallery of the theater with neoclassical elements different from Poletti (Toyota, 2020).
In 1943, the theater was almost completely destroyed by bombing during World War II. At the same time, the theater was looted after becoming a military camp, and the best furniture in the theater was robbed. In 1947, it was officially renamed with its current name in memory of the great composer, Amintore Galli.

Part of
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Since 1948, any decision on the restoration of the theater was repeatedly postponed because Rimini, a town of Roman origin, contained a lot of Roman relics. Part of the reconstruction of Amintore Galli theater began in 1997, and, in 2010, under the auspices of the municipal authorities, adhering to the concept of being as faithful to the original design as possible while respecting the safety rules, the theater began to be fully rebuilt. After a long period of restoration work, Amintore Galli theater reopened in 2018.

Fig. 1 − Internal view of the Galli theater of Rimini

The main hall of Galli theater could host more than 700 people. All these seats are distributed as 268 seats in the stalls, and 324 seats on the three orders of boxes and 108 seats in the gallery. The dimensions of the main axes of the horseshoe shape plan are 22 m and 16 m [L, W,], which are crowned by three orders of balconies, surmounted by a gallery having a capacity of 108 seats. The total height of the main hall is 20 m. The floor of the stalls is composed of oak planks, slightly inclined (2 %) towards the stage.
The restoration works in Galli theater had previously also included the restoration of the main foyer of the theater, and also other rooms, including the "ballet room", located just beyond the roof, on top of the foyer.

3. Architectural Organization

The main hall of Amintore Galli theater, completed in 1856, is a traditional horseshoe plan, with a total capacity of 700 seats, of which 268 seats are distributed in the stalls, 324 seats are distributed in the elevated box, and 108 seats in the gallery. The main hall is 22 m, 16 m and 20 m [L, W, H], crowned by a three-order balcony, with a gallery at the top that can accommodate 108 seats. The floor of the stalls is slightly inclined towards the stage, composed of oak planks, as shown in Fig. 2.

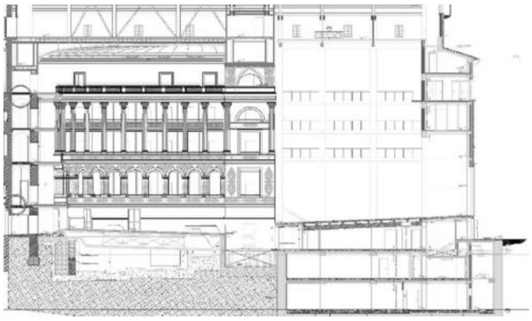

Fig. 2 − Longitudinal section of Amintore Galli Theater

After a period of long repair, the main hall still retains the original historical appearance dominated by ivory and gold. The floor and ceiling have been reinforced, and the decorations and painting have been restored (Toyota, 2020), as shown in Fig. 3. Further, pomegranate red has been used on seats and for the upholstery of the boxes.

Fig. 3 − Reliefs have been restored

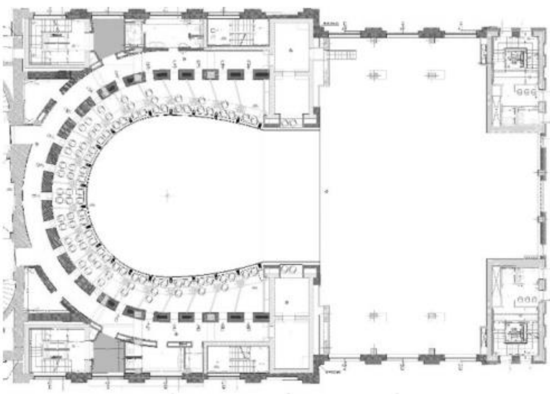

Fig. 4 − Plan layout of the main hall

The total area of the stage is 358 m² and the proscenium arch is 13 m large and 17 m high, the stage inclined by 2 %. The orchestra pit is 5.5 m deep and 12 m wide. Fig. 4 shows the horseshoe-shaped layout of the main hall.
Table 1 summarizes the architectural features of Amintore Galli theater.

Table 1 - Architectural characteristics of Amintore Galli theater

Description	Features
Type of plan layout	Horseshoe box
Total volume (m^3)	14420
Total capacity (no. of seats)	700
Stage dimension (m) [L × W]	30 × 16
Inclination of stage floor (%)	2 %
Inclination of stalls area (%)	2 %
Volume of the flytower (m^3)	8640
Volume of the main hall (m^3)	5780

Fig. 5 − View of the main hall of Teatro Galli of Rimini

Elaborate decoration is installed all around the main hall, with floor finishings , seats, upholstery and the walls of the boxes. having a pomegranate red color. Other dominant colors are ivory and gold, used on the wooden decorations.
The acoustics of Teatro Galli have been studied since 2010, when a specific 3D model was created in order to determine the future sound distribution in the main hall. Fig. 6 reports the numeric model of the theater.

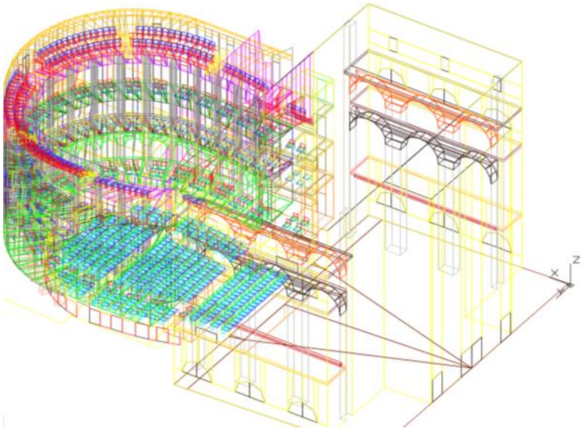

Fig. 6 − 3D numeric model of Teatro Galli

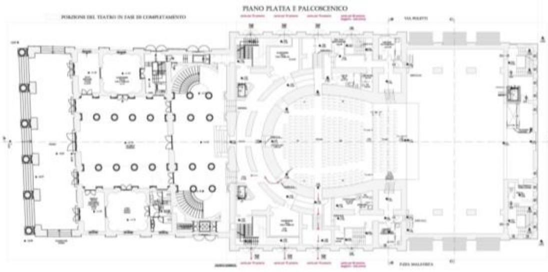

Fig. 7 − Plan layout of Teatro Galli of Rimini

4. Acoustic Surveys

Inside Galli theater, several acoustic measurements were taken during different steps of the reconstruction of the theater, and compared with the simulation conducted during the acoustic design. At the same time, thermo-hygrometric parameters were also taken into consideration, since the variation of the acoustic parameters with thermo-hygrometric conditions are relevant. The acoustic survey was carried out with the following equipment:

1. Equalised omnidirectional loudspeaker (Look Line);
2. Binaural dummy head (Neumann KU-100);
3. B-Format (Sennheiser Ambeo);
4. Omnidirectional microphone (Bruel&Kjaer);
5. 32-channel spherical array (Mh Acoustic em32 Eigenmike®);
6. Ricoh Theta V 360 camera
7. Personal Computer connected to the loudspeaker and all the receivers.

Fig. 8 reports a screenshot of two impulse responses, measured in the stalls and in the box.

Fig. 8 − Impulse responses measured in the stalls (n 2) and box (2nd order (n 12))

Fig. 9 reposts the comparison for reverberation time T30 obtained after reconstruction with the same parameter simulated in 2010.

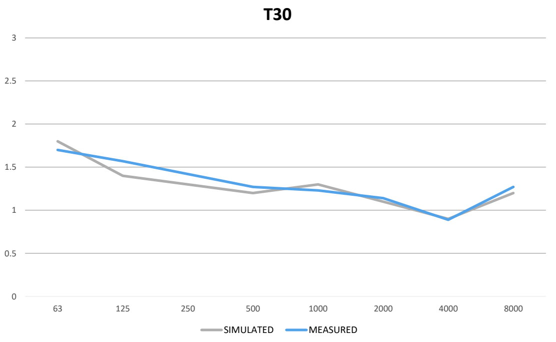

Fig. 9 − Reverberation time measured after reconstruction compared with the values obtained during the acoustic design in 2010

The sound source was located 1.4 m from the stage floor, while the receivers were positioned at a height of 1.2 m on stalls and boxes. The excitation signal emitted by the sound source was the Exponential Sine Sweep (ESS), having a duration of 15 s at a uniform sound pressure level for the between 40 Hz and 20 kHz range. The measurements were undertaken in unoccupied conditions and without any scenery or acoustic chamber mounted. Fig. 10 and Fig. 11 show the measurement positions of sound source and receivers placed across the sitting areas.

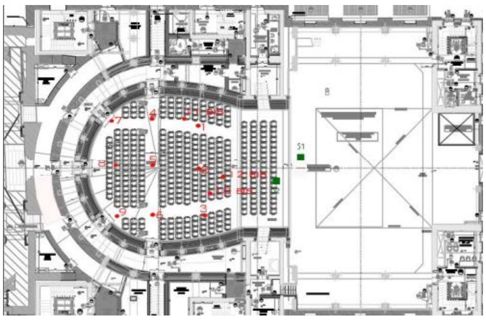

Fig. 10 − Scheme of the equipment location during the acoustic measurements in the stalls of Teatro Galli of Rimini

Fig. 11 − One of the surveys conducted in Teatro Galli in Rimini

5. Results

5.1 Traditional Parameters

The recorded ESS signals were processed by using the Aurora plugin suitable for Audition 3.0. Different acoustic parameters defined by the international standards ISO 3382-1 were analyzed and commented on.To be included are reverberation time (T_{20}), early decay time (EDT), clarity indexes (C_{80} and C_{50}), definition (D_{50}) and strength (G). The main acoustic parameters are reported in the octave bands between 125 Hz and 4 kHz, considered as the average results of all the measurement positions.

Fig. 12 and Fig. 14 show the graphs of the measurements of the main acoustic parameters. Fig. 13 shows the frequency response of the EDT and T_{20} parameters. If optimal values of EDT for concert halls are considered to range between 1.8 and 2.6 s, as defined by the literature, this target was not achieved by the measured values related to the selected bandwidth. However, if compared with several other opera houses, the results for Teatro Galli are much better than the others.

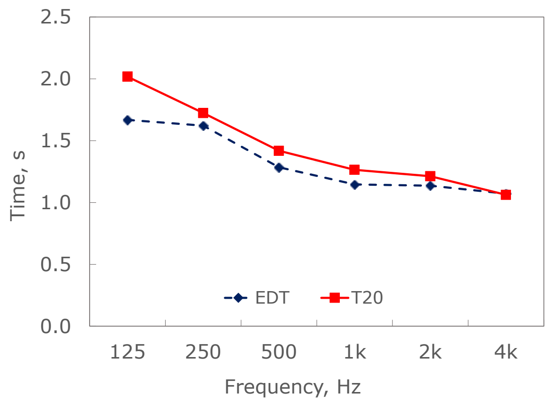

Fig. 12 – Measured results of clarity indexes (C50 and C80)

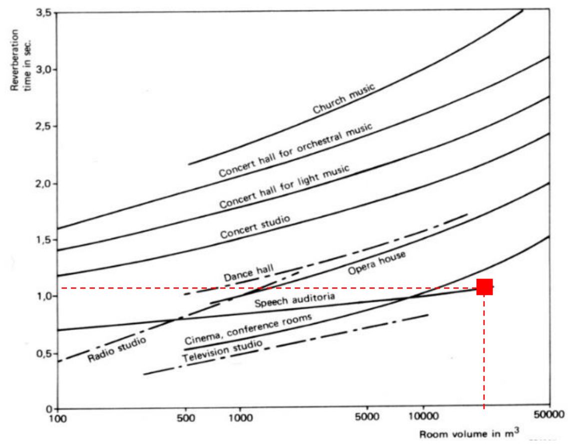

Fig. 13 – Optimum reverberation time values in function of room volume

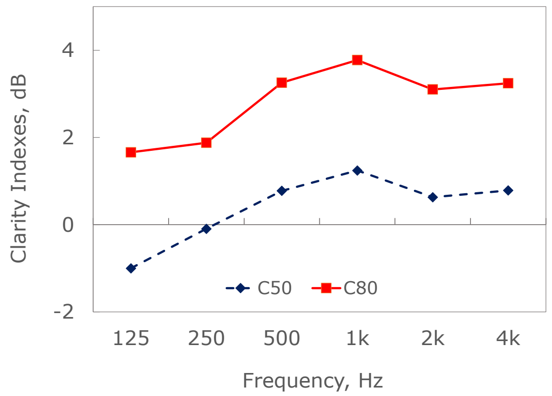

Fig. 14 – Measured results of clarity indexes (C50 and C80)

Following the research studies by Reichardt, the optimum values for the speech clarity index (C_{50}) would be ≥ 0 dB. In Teatro Galli, this parameter floats between +1 and +4 dB, at low and high frequency bands, respectively. Based on the results of Fig. 14, the good response of C_{50} was achieved at frequencies higher than 500 Hz. However, the shortfall at low frequencies found to be slightly below the lowest range limit is not to be interpreted as a negative result.

5.2 Acoustic Analysis of 3D Sound Maps

The employment of the spherical array microphone (i.e., em32 Eigenmike®) allowed the authors to elaborate sound maps obtained for each source-receiver combination. These maps were created by a video-overlay that reproduces the recorded IR.

This different data analysis is obtained by a combination of the omnidirectional sound source, the multichannel microphone (i.e., em32 Eigenmike®) and the panoramic camera (i.e., Rico Teta V, capturing a 360° image herein represented in an equirectangular view). The 32 microphone signals were processed by extracting 122 high-directivity virtual microphones (with 8^{th} order cardioid setup) with the addition of the Spatial PCM Sampling (SPS). By using this methodology, it was possible to encode the direction of arrival of all the sound rays, including the direct sound and the reflections occurring after hitting any surface.

The colors shown in the map overlay range between red tinge (indicating the high level of sound energy) and blue-violet shades (representing a poor energy sound wave). Fig. 15 shows an illustration of the outcomes.

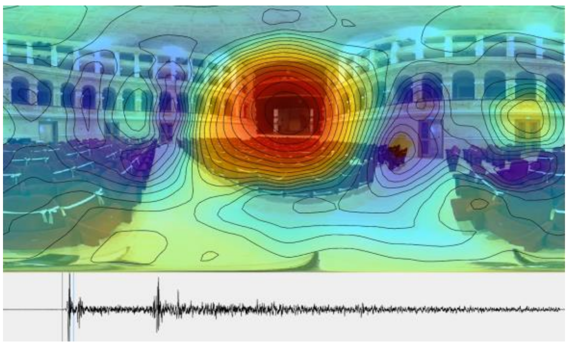

Fig. 15 – Acoustic map showing direct sound arriving to the receiver placed in the stalls

Fig. 15 shows the late reflections hitting the ceiling surface area. As per the above discussion, the overlay videoclip allows the surface areas that contribute toward creating the early and late reflections to be visualized. The bar at the bottom of the image indicates the flow time of the IR.

6. Conclusions

This paper deals with the representation of the acoustic results obtained by the survey undertaken in the Teatro Galli in Rimini Measurements were conducted by using an omnidirectional sound source and four types of microphones.

Overall, the results obtained from the measurement campaign showed that the theater has a good response for speech performance, with some difficulties at low frequencies in terms of strength, which requires the singers to put more effort into the bass tones. In terms of music, the theater turns out to be slightly dry compared to opera houses of similar volume size.

This acoustic study was extended to analyze the specific trajectory of the sound waves during the IR. The capabilities of the multi-channel spherical microphone (i.e., em32 Eigenmike®) allowed the authors to render 3D sound maps, obtained for each source-receiver combination. Such maps indicate the direction of arrival of the sound rays and their intensity, contributing to understanding the specific role of the specific construction elements interacting with the sound waves.

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