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AN EXPLORATION OF THE UNIQUE ACOUSTIC CHARACTERISTICS OF MANTUA'S TEATRO BIBIENA

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ABSTRACT

The Teatro Bibiena, known as the Scientific theatre in Mantua, is regarded as the most accomplished example of Rococo theatre construction, inspiring the authors to investigate its unique acoustic characteristics. An acoustic survey was carried out of the stall and some selected boxes according to the requirements of ISO 3382-1 standards. The results show that Mantua's Teatro Bibiena, unlike most Italian theatres, is more suited to musical performance than speech. The Italian opera house is a typical and precious architectural form, and scholars and scientists are responsible for highlighting the worth of cultural heritage. However, as an intangible cultural heritage, acoustics is intrinsically challenging to maintain and readily disregarded. Therefore, its recording, exploration, and transmission should be given equal weight to the historic theatre building itself.

Keywords: *cultural heritage, acoustic measurements, the Teatro Bibiena, acoustic quality.*

1. INTRODUCTION

The acoustic discovery of cultural heritage buildings is of immense value, but their status as intangible culture is fragile and difficult to preserve and pass on. As one of the representatives of a typical European building type, the theatre contains a wealth of acoustic treasures. Therefore, this paper was prompted to carry out this acoustical investigation. There are two principal areas of current research into theatre acoustics: research into the design of theatre acoustics, with O'Keefe EMPLOYING a hybrid computer modelling routine combining image and particle TRACING methods to aid the acoustic design of the new Princess of Wales theatre in 1993 [1]; and the measurement and simulation of acoustic theatre characteristics, as in the study by Chourmouziadou et al. [2].

Impulse responses (IRs) were recorded at various positions throughout the seating area of the Bibiena theatre by acoustic measurements in compliance with ISO 3382-1 [3]. The measurements of the stall and balconies were compared by collecting the main acoustic parameters. This analysis should be considered a preparatory study before acoustic simulations are carried out on the digital model.

2. HISTORICAL BACKGROUND AND ARCHITECTURAL ORGANIZATION

The Teatro Bibiena di Mantova, also known as the Teatro Scientifico, was constructed in the Rococo style by Antonio Galli Bibiena of Parma between 1767 and 1769. Giuseppe Piermarini designed and built the classical façade, which was finished in 1775 [4]. The theatre, created primarily to host scientific conferences but occasionally open for performances and concerts, is regarded as one of Europe's most important architectural schemes at the end of the 18th century.

The Teatro Bibiena is a dominant 17th-century structure rather than a continuation of the Renaissance style. The Teatro Bibiena was officially inaugurated on December 3, 1769, with a bell-shaped plan layout and four balconies, and monochrome figures painted by the architect Bibiena in the various boxes strewn across the balconies. A month later, Wolfgang Amadeus Mozart performed his debut concert in Italy here. The theatre continues to be utilized for high-level conferences and concerts. The view of the theatre hall is shown in Fig. 1 [5].

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Figure 1. The view of the Bibiena theatre hall.

It is a small-volume theatre of approximately 2000 m³ with a maximum capacity of 363 audience members. The stage is 12.9 m wide and 5.7 m deep, and the permanent set consists of a double balcony with a row of columns (Serlians) on each level supporting the arch and a cut-out ceiling, with niches decorated with four statues, as shown in Fig. 2 [4]

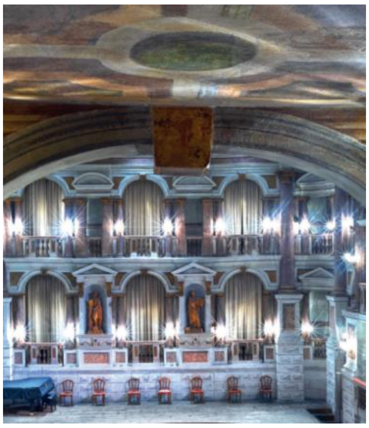

Figure 2. Permanent scenery of the theatre stage.

3. ACOUSTIC MEASUREMENTS

Impulse responses (IR) were measured at various points, including the stall and selected boxes, to investigate the acoustic characteristics of the Bibiena theatre thoroughly. The main acoustic parameters are constructed and compared based on the data collected. The goal is to obtain a better understanding of the acoustic qualities of the theatre. The measurement setup for the acoustic analysis of the Bibiena theatre consisted of placing the sound source 1.4 m above the finished floor whilst the receivers were moved across the stall and selected boxes. A total of 3 measurement points were identified in the stall and 7 on the balconies, which are considered sufficient to understand the acoustic response of the hall due to its axisymmetry. Fig. 3 outlines the location of the sound source and receivers during the survey. The excitation signal was an Exponential Sine Sweep (ESS), which was 15 s long, covering a spectrum bandwidth of 40 Hz to 20 kHz [6-7]. The measurements were conducted under unoccupied conditions using the following equipment [8]:

- The DS3 dodecahedron speaker from NTi Audio.
- A KU100 dummy head made by Neumann.
- The Ambeo B-Format microphone from Sennheiser.
- The Zoom F8 audio interface.

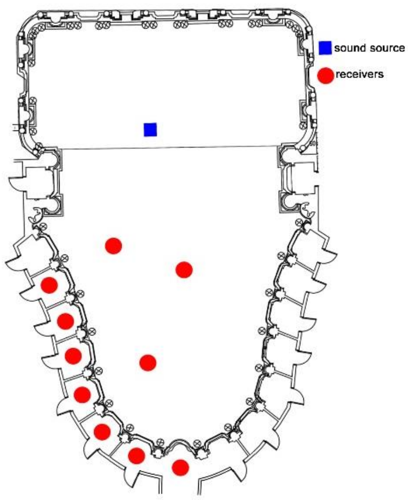

Figure 3. Scheme of the equipment location during the acoustic survey.

4. RESULTS

The main acoustic parameters involved in this investigation are the following: early decay time (EDT), reverberation time (T_{20}, T_{30}), clarity index (C_{80} for music, C_{50} for speech) and definition (D_{50}). The main acoustic parameters for the octave bands between 125 Hz and 4k Hz were gathered from the recorded IRs by the plugin Aurora, which is compatible with Audition 3.0 [9]. The results compare values measured in the stalls and the elevated balconies.

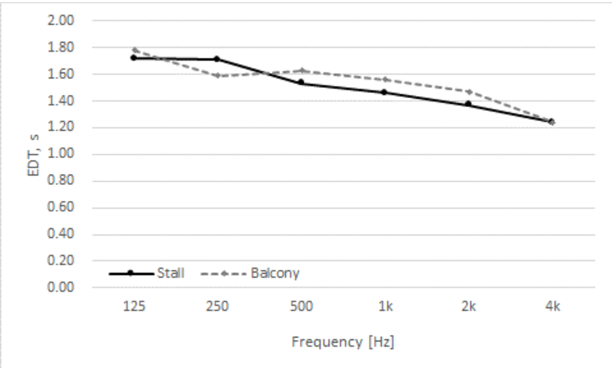

Figure 4. Measured values of early decay time (EDT).

Fig. 4 shows the measured values of early decay time (EDT), found to be similar between stall and balconies. The Early Decay Time (EDT) is in relation to the T_{mid} which is an average of the T_{30} values over 500 Hz, 1k Hz and 2k Hz [3, 10-11], and in our case, the average value of T_{30} is 1.51 s. Given that the optimal values for EDT for opera houses are: $0.75\ T_{mid} < EDT < T_{mid}$, which means, the EDT should be between 1.13 s to 1.51 s. It shows that the EDT (1.53 s) is near the optimal range for music. While it is a bit long for speech ($0.6\ T_{mid} < EDT < 0.75\ T_{mid}$).

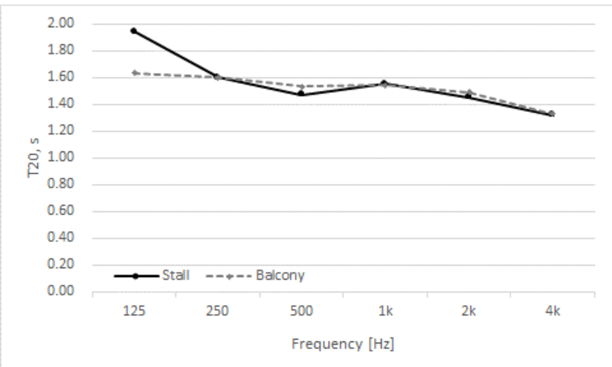

Figure 5. Measured values of reverberation time (T_{20}).

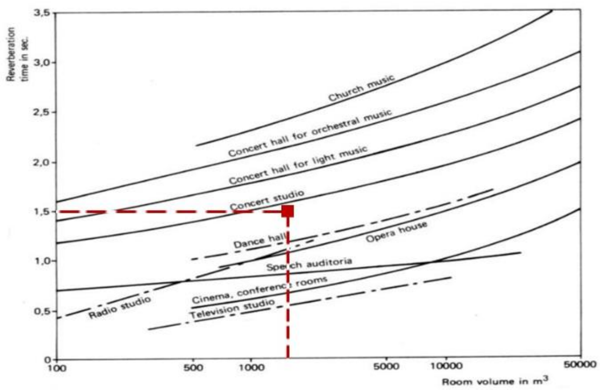

Figure 6. Correlation between reverberation time and volume size of the theatre [10].

The measured reverberation time values indicate (Fig. 5) that the difference between the results obtained in the boxes and the stall is negligible, except for a difference of 0.3 seconds at 125 Hz. As the reverberation time is related to the volume of the room, as shown in Fig. 6, the Bibiena theatre has a mid-frequency value of around 1.5 s, which is slightly higher than the optimum range for an opera theatre [12].

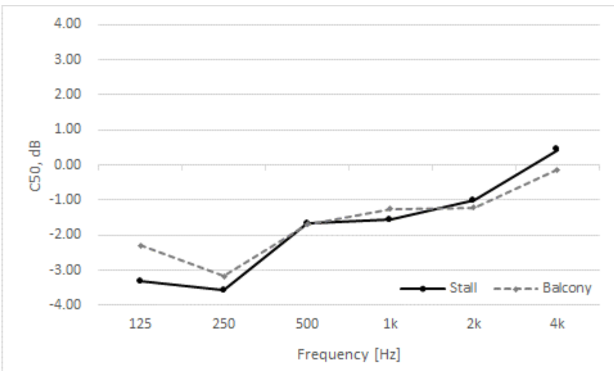

Figure 7. Measured values of clarity index: C_{50}.

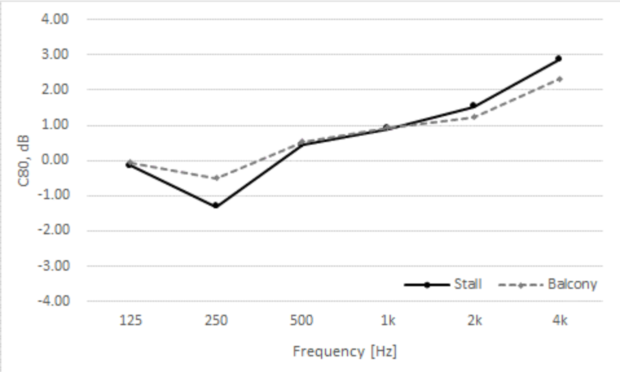

Figure 8. Measured values of clarity index: C_{80}.

Fig. 7 indicates that the C_{50} values for the stall and balconies reach optimum values of -2 dB to +2 dB in the mid and high-frequency bands [13-14], with an increasing trend between -2 dB and +1 dB. From 125 Hz to 250 Hz, the results drop from -2 dB to -3 dB for the balconies and even lower for the stall. In terms of music, as shown in Fig. 8, the values of the clarity index are remarkably similar in the stall and balconies, fluctuating between -2 dB and +3 dB. This results in a lower C_{80} value than the acoustic characteristics of other Italian opera houses of similar volume size. However, the Bibiena theatre is closer to the ideal values for an opera house [15-16].

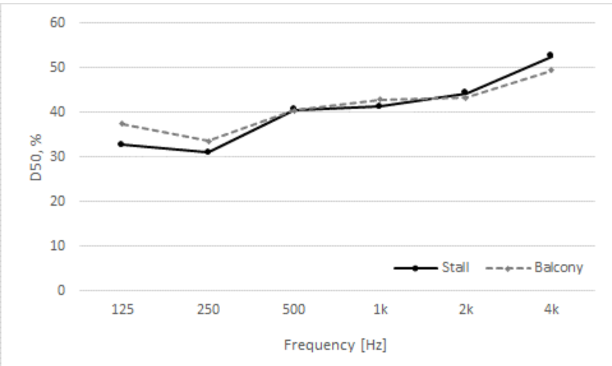

Figure 9. Measured values of definition (D_{50}).

The results related to definition (D_{50}) reveal 40 % in the stall and balconies. The ideal value for music intelligibility should be less than 50%, but good speech intelligibility is defined as having more than 50 % [17-18]. The result of the D_{50} shows that the Bibiena theatre is more suitable for musical performances than speech programmes. This is unlike most Italian theatres, usually suitable for music and speech.

5. CONCLUSION

Evaluating the acoustic measurements taken in the Bibiena theatre summarizes its suitability for musical performances rather than speech. The impulse response in the middle and high-frequency ranges indicates an appropriate response for an opera theatre. In comparison to most Italian theatres, the Bibiena theatre has lower C_{50} and C_{80} values and longer reverberation time, which can be attributed to its interior decoration and material selection, with the absorption coefficients of the various materials being the main influencing factor on the acoustic characteristics of the theatre [19-21]. Future research will concentrate on acoustic simulations of diverse types of scenes and the effect of audience occupancy on the acoustic characteristics of theatres.

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