Sound Strength G Prediction in Orchestra Pit Based on Barron and Lee "Revised Theory"

Tadeusz KAMISIŃSKI
AGH University of Science and Technology,
kamisins@agh.edu.pl

Krzysztof BRAWATA
AGH University of Science and Technology,
kbrawata@gmail.com

Abstract

Musicians in the orchestra pit often report problems with too high sound levels during performances. At the same time, numerous surveys indicate frequent problems with the mutual hearing of musicians with each other, as well as themselves or a singer from the stage.

The structure of the orchestra pit causes the musicians to be exposed to strong reflections with low delay, which increases the overall sound pressure level. In the literature, one can find recommendations that the space of the orchestra pit should be treated with sound absorbing materials in a wide range and with sound-scattering materials without indicating their quantity or localization.

This paper focuses on the development of tools for assessing and predicting the value of energetic parameters such as sound strength G or clarity C80 in the orchestra pit based on its acoustic absorption and the volume of the hall. The sound propagation model in concert halls proposed by Barron and Lee was adapted for this purpose. The sound strength G can be used to predict the acoustic conditions in the orchestra pit, such as the sound pressure level, the mutual audibility of the musicians, and how the room supports playing musicians. The analysis covers several existing halls of different geometry and size, as well as the design of the barrier of the orchestra pit with the proposed modifications.

Keywords: sound strength, revised theory, orchestra pit

1. Introduction

The most frequently reported by musicians working in orchestral pit is the problem of too high sound levels to which they are exposed. Too high sound levels cause problems with hearing individual groups of instruments, and often yourself. High concentration of music on one's own game causes a decrease in its ability to follow the conductor, which affects the difficulty of maintaining the balance between the soloists on the stage and the musicians in the orchestra pit [1].

Due to the limitations of the available surface, usually absorbing materials of low thickness are used, and thus, with high acoustic absorption for medium and higher frequencies (carpet on the floor [1], curtains hung on the walls [2], overhang treated with mineral wool boards, etc.). This results in a negative change in reverberation characteristics, resulting in some instruments being favoured and another part being masked. An additional difficulty in the correct design of the acoustic adaptation is the fact that the shape, size, height, depth of the orchestra and the various acoustic defects resulting from it are of great diversity.

In the literature it is difficult to find a description of the tools and values of objective parameters that could be used to design and evaluate the quality of the orchestra.

2. Method

To assess the sound level in the room, the sound strength G is used. This parameter, divided into time intervals, is well suited to the assessment of the reverberant noise.

The sound propagation model proposed by Barron and Lee [3] for concert halls was used to predict the value of the sound pressure parameter G with the time distinction between early sound (G_{early}) and late sound (G_{late}). The calculation model is described by equations 1 a-d.

$$d = \frac{100}{r^2} \tag{1a}$$

$$e_r = (31200\,T/V)e^{-0,04r/T}\left(1 - e^{-1,11/T}\right) \tag{1b}$$

$$l = (31200\,T/V)e^{-0,04r/T}e^{-1,11/T} \tag{1c}$$

$$L = 10\log(d + e_r + l)\ [\text{dB}] \tag{1d}$$

where the acoustic energy is divided into three parts:

d – the value of direct sound energy,
e_r – the value of the energy of early reflections,
l – value of late sound energy,
T – reverberation time [s],
V – room air volume [m3],
r – distance between the source and the receiver [m].

Due to the occurrence of phenomena related to coupled rooms, such as double slope of the decay curve, the reverberation time and volume resulting from the separation of the orchestra pit from the room were used to predict the early energy, while reverberation time was used to predict the value of late energy (G_{late}). absorbency of the entire room and its volume.

The influence on the observed parameters of the musicians and equipment present in the orchestra was also examined.

Obtained results from the Barron and Lee model were compared with the results obtained on the measurement path. The measurements were taken in the Krakow Opera.

3. Research

The research was carried out in the orchestra of the opera theater. The table 1 presents a short summary of the most important parameters of the room [4].

Table 1. General parameters value of Opera Krakowska hall

Opera Krakowska	
	
Open	2008
Architect	Romuald Loegler
Seating Capacity	735
Room air volume [m^3]	6504
Stage air volume [m^3]	3933
Reverberation time $T_{500\text{-}1000Hz}$ [s]	1.11
Early Decay time $EDT_{500\text{-}1000Hz}$ [s]	1.09
Sound strength G_{mid} [dB]	3.8
ClarityC_{80} [dB]	3.91

Below (Fig. 1) is a schematic diagram of the measurement points in the orchestra pit, which was used when examining objects for the purpose of this work, meeting the above-mentioned requirements.

Measuring points can be described as:

- P1 – location of the first group of violins,
- P2 – the left back of the orchestra pit,
- P3 – location of the cello / double-bass group.

All points were located at least 1 m from large reflective surfaces. Height of sources and microphones 1 m above the floor surface.

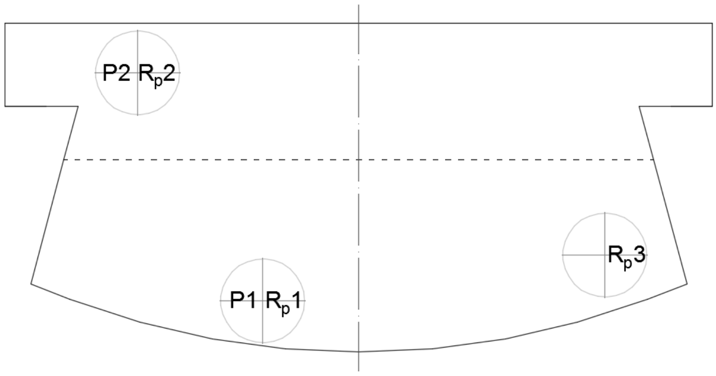

Figure. 1 Measurement layout in orchestra pit: P – source position, R – receiver position; sources and receivers 1 m from reflection surface, and 1 m above floor [5]

To calculate the time of the report with the equipment of the orchestra or with the musicians, the values of the acoustic absorption of individual elements were used based on the results made by J. Rubacha [6]. Values are shown in Table 2.

Table 2. Sound absorption [1m] of empty chairs, and musicians seating on chairs [6]

	1/1 oct [Hz]					
	125	250	500	1000	2000	4000
Empty chairs	0.05	0.15	0.4	0.6	0.9	1
Musician on chair	0.15	0.3	0.8	1.2	1.4	1.5

4. Results

The tables 2-4 listing of the obtained from measurements and model values. The Root Mean Square Deviation (RMSD) was used to assess the quality of predicted values.

Table 2. Values of sound strength G_{mid} derived from measurement (M) and from model (B)

G_{mid} [dB]	**Empty**		**Chairs**		**Musicians**	
	M	**B**	**M**	**B**	**M**	**B**
P1-Rp2	13.7	12.1	9.6	11.9	8.2	10.3
P1-Rp3	10.5	10.8	5.8	7.5	5.0	4.9
P2-Rp1	13.7	12.1	9.6	11.9	8.2	10.3
P2-Rp3	8.7	10.0	9.3	5.1	6.6	2.1
RMSD	**1.35**		**2.77**		**2.71**	

Table 3. Values of early sound strength G_{80_mid} derived from measurement (M) and from model (B)

G_{80_mid} [dB]	Empty		Chairs		Musicians	
	M	**B**	**M**	**M**	**B**	**M**
P1-Rp2	13.7	11.8	11.9	9.4	7.9	10.3
P1-Rp3	10.4	10.1	7.5	4.6	3.5	4.9
P2-Rp1	13.7	11.8	11.9	9.4	7.9	10.3
P2-Rp3	8.6	9.0	5.1	8.5	5.5	2.1
RMSD	**1.36**		**2.84**		**2.49**	

Table 4. Values of late sound strength G_{late_mid} derived from measurement (M) and from model (B)

G_{late_mid} [dB]	Empty		Chairs		Musicians	
	M	**B**	**M**	**M**	**B**	**M**
P1-Rp2	0.2	0.3	-4.3	-0.1	-4.4	-1.1
P1-Rp3	-0.6	2.1	-0.1	-0.9	-0.5	-2.0
P2-Rp1	0.2	0.3	-4.3	-0.1	-4.4	-1.1
P2-Rp3	-1.1	0.4	1.5	-1.4	-0.2	-2.6
RMSD	**1.57**		**3.33**		**2.70**	

5. Conclusions

The article presents the method predicting sound strength G values using computational models based on the Barron and Lee methods.

The method allows you to quickly and easily investigate to what extent sound absorption orchestra pit absorbed influence the value of sound power. In addition, it is possible to examine how much the degree of closure affects the conditions in the orchestra.

The proposed method can also be used to assess the quality of the interior of the orchestra and investigate the impact of other elements of the orchestra and its equipment on the distribution of sound levels in the areas of the audience and the stage.

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