

Research Article

Acoustic Quality Analysis Inside the Black Box Theater Room

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Abstract: The acoustic quality of a theatrical or musical room is an important factor in a musical or theater performance because it affects how sound is conveyed from the stage to the audience. In this study, the acoustic quality of a room was evaluated using standard values or recommendation criteria for acoustic parameters for a room Salihara Black Box Theater Room. The response impulse is measured using a balloon popping sound source. The measurement results of the research object show that the space still does not meet the recommendation criteria for reverberation time (T_{30}), early decay time (EDT), clarity (C_{80}), and definition (D_{50}).

Keywords: *Acoustic Measurements, Black Box, Impulse Response, Reverberation Time, Clarity, Definition, Early Decay Time.*

A. INTRODUCTION

The interior design of a theater performance space may be viewed solely as a decoration for visual satisfaction and luxury, or it may be viewed solely for aesthetic purposes (Lau & Choi, 2021; Haselhoff et al., 2022; Hong et al., 2019). This is not entirely incorrect, but the shape of the space and the materials that make up the interior of the room's surface have a significant impact on the acoustic quality or sound distribution of a theatrical or musical performance in a theater room, and these are arranged based on their effect on the acoustic quality of the room (Cabrera et al., 2018; Ding et al., 2021).

Certainly, with current technological advancements, there are already a large number of sound system devices, such as microphones and loudspeakers, that can support the delivery of sound from the sound source on stage to the audience's ears, even if the performance includes both sound and sound system devices (Liu, 2022; Batthyany et al., 2022). Which is not fixed, must be supported by architecture that supports the space's sound system. Layout and design for theater performances must be able to satisfy every audience in various locations so that they can clearly hear the articulation of the actors' conversations and so that the nuances and dramatic effects displayed can be captured and digested by the audience (Indriani et al., 2007; Barsties et al., 2021; Wasmer et al., 2019).

The reverberation time is obtained by definition if 60 dB of sound energy decay is observed, but in practice there is an evaluation to obtain the reverberation time value using a smaller decay interval, which is usually measured from -5 dB to -35 dB for T_{30} or the decay of 30 dB, and from -5 dB to 25 dB for T_{20} or the decay of 20 dB (Gani et al., 2012; Savchenko & Savchenko, 2020). This is due to the possibility of background noise in the room or sound field interfering with the observation of this sound energy decay. The early decay time has an effect on the value of clarity or clarity and clarity of sound. If the early decay time is greater than the reverberation time, it can be interpreted that the initial sound energy and the effect of the initial reflected sound are relatively large and produce better sound clarity, and vice versa (Everetst & Pohlmann, 1993; Tang et al., 2022; Kulak &

ISO 3382-1 recommendations in the range of -5 dB - 5 dB at a frequency of 500 Hz - 1,000 Hz for concert halls or multipurpose rooms with volumes up to 25,000 m³.

2. Research Object

The Salihara Black Box Theater Room, located at Jalan Salihara no.16, Pasar Minggu, is the subject of this investigation. The subject of this study is Indonesia's first black box theater, as well as the country's only one to date. The dimensions of this theater room are 24 m x 13.8 m x 7.5 m. The capacity of this space ranges from 216 to 272 spectators, depending on the format of the stands used. This theater can be used for theatrical performances, musical arts, whether traditional, modern, or contemporary music, as well as other events such as seminars. The Proscenium configuration was used for these acoustic measurements.

3. Measurement Equipment

The equipment used in this study included microphones, sound sources, and data processing tools. The microphone used is a dbx RTA-M, which is an omnidirectional microphone with a flat sensitivity response across nearly the entire audio frequency range and is evenly distributed to all 360° angles. The Audio interface in this study connects the microphone to the laptop, allowing the sound signal captured by the microphone to be transmitted to the laptop.

The balloon was chosen as the sound source because it is the easiest to use compared to the recommended use of other sound sources, as well as due to the limitations of the available tools. The balloon explosion has an impulse sound character that is appropriate for acoustic measurements, but its weakness is that its repetition will not be exactly the same. However not using standard equipment, acoustic measurements using balloon eruptions as a sound source produce quite better results when compared to more standardized equipment.

The use of a laptop in this study stores impulse response data in the form of a recording file; this allows data retrieval to be completed without requiring direct processing first. Data processing is also carried out using laptop software, Audacity, Yoshimasa Real-time Analyzer and Sound Analyzer, and Microsoft Excel.

4. Measurement Conditions

The stage has four curtains on the left side and four curtains on the right side. Three curtains were hung from the top of the room on both the left and right sides, but they were rolled up and placed on the intermediate catwalk. The curtain is placed behind the loudspeaker closest to the audience area, or in other words, behind the SA and SB sound sources. It is installed from the bottom of the intermediate catwalk to the floor. Figure 2 depicts the curtain and grand piano's positions more clearly. However, in that image, the curtain is still fully stretched from top to bottom, whereas when the curtain was measured, it was still attached but rolled up and placed on the intermediate catwalk.



Figure 2. Photos of Room Conditions during Measurement

5. Data Processing

Audacity software is used in data processing in two stages: trimming the recording data and converting the data file format to wav format. The length of the recording time for each data is not made uniform during data retrieval, so each data has a different recording duration, as well as different start and end points. Following the trimming stage, the data is converted into a more common audio file format, namely wav. The use of the Real-time Analyzer is not excessive because much of the processing was previously done on Audacity, but the Real-time Analyzer is still one of the stages that must be passed.

The Sound Analyzer's primary function is to analyze recorded impulse response data and generate values for the impulse response's acoustic characteristics. The data saved by the Real-time Analyzer is opened in the Sound Analyzer, and after selecting the Calculation option and some settings, the Sound Analyzer will perform the calculations itself. The frequency range of 125 - 4,000 Hz in one octave is the minimum requirement for engineering level room acoustic measurements. Microsoft Excel is required to obtain the calculated values from the Sound Analyzer in comma separated value format. It is necessary to use the Excel import data feature in order for the file format to be saved as an Excel file.

C. RESULT AND DISCUSSION

1. Room Overview

The term "black box" refers to the shape and color of the theater space, which is in the shape of a cube or block and has black interior walls. The black bricks that make up this room's wall surface, along with the installation of rotated beams as shown in figure 3, are based on the review's findings. This brick wall is installed for the walls from the ground to the intermediate catwalk, and the bricks are rotated from the ground to the intermediate catwalk. from a height of 1 m above the ground.



Figure 3. Wall Surface Using Rotating Installed Bricks

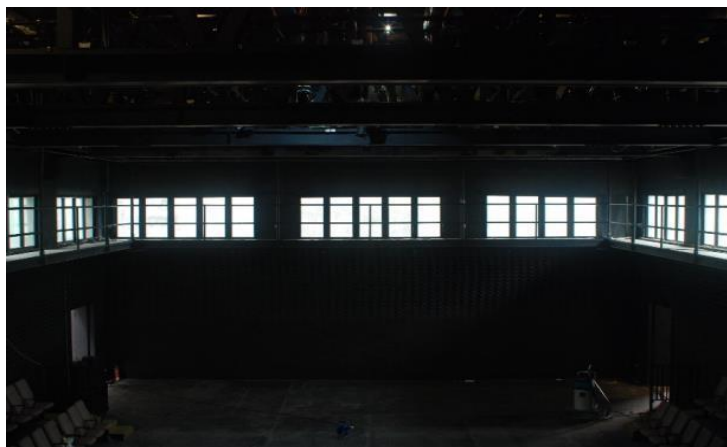


Figure 4. Windows in the Theater Room

Plaster walls and multiplex wood or plywood can be combined for the interior wall surface at the top. Plaster walls and acoustic panels, specifically gypsum perforated boards, are used to cover the room's ceiling. There are five windows for the left and right and three for the front on the wall above the intermediate catwalk. As shown in Figure 4, the window panes provide natural light during the day and are closed with thick black cloth curtains during performances and data collection.

There are six wooden doors in this room: two on the back wall that serve as audience access, two in the stage area that serve as access for performance players, and the remaining two that serve as access doors to the lighting control room and the sound system contained therein. A window pane between the control room and the theater room allows the control room operator to monitor the status of events in the theater room. For the intermediate catwalk with a width of 1.2 m from the iron wall.

2. Results Based on Reverberation Time Receiving Point (T_{30})

There are six wooden doors in this room: two on the back wall that serve as audience access, two in the stage area that serve as access for performance players, and the remaining two that serve as access doors to the lighting control room and the sound system contained therein. A window pane between the control room and the theater room allows the control room operator to monitor the status of events in the theater room. For the intermediate catwalk with a width of 1.2 m from the iron wall.

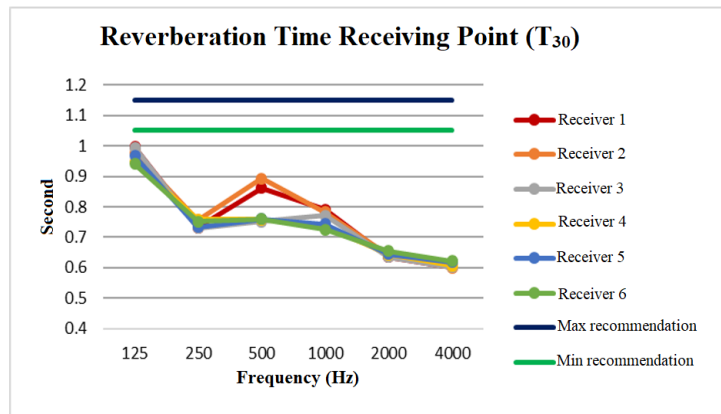


Figure 5. Comparison Graph of Reverberation Time Results

The reverberation time value of each receiving point is nearly uniform with only minor variations and exhibits the same tendency of graph shape. This difference only affects the 500 Hz frequency, and there is a slight difference also at the 1,000 Hz frequency. Overall, the reverberation time obtained from this room did not meet the recommended reverberation time value for a conversation category room with a volume of 2,000 - 3,000 m³.

3. Results Based on Early Decay Time (EDT)

The measurements for the reverberation time are shown in Figure 5, where you can see the differences in the early decay time results. This graph depicts the effect of receiving point positions, particularly for points of similar height or in the same row of spectator seats, namely R1 and R2, R3 and R4, and R5 and R6, each of which has a value that is not significantly different, except for points R5 and R6 at 125 Hz, which have a significant difference.

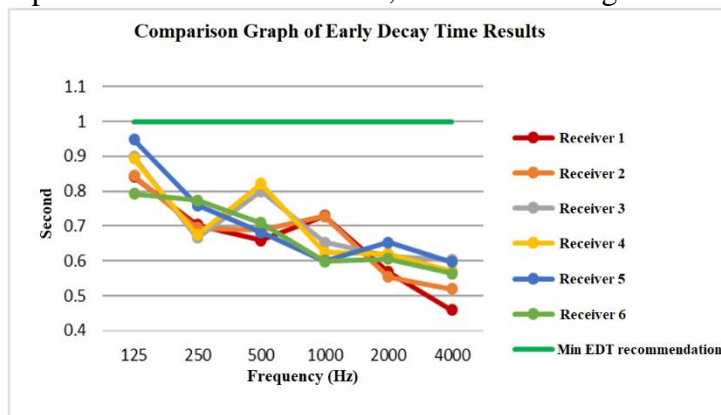


Figure 6. Comparison Graph of Early Decay Time Results

The EDT characteristics for each frequency vary depending on the seat row. For instance, the front row, represented by R1 and R2, has the highest EDT values at 1,000 Hz, but the lowest at 500 Hz, 2,000 Hz, and 4,000 Hz. The fifth row, represented by R3 and R4, has the highest EDT values at 500 Hz frequency but the lowest at 250 Hz. Overall, the EDT value has not yet reached the ISO 3382-1 reference's minimum recommended value.

4. Results Based on Clarity (C₈₀)

According to the graph, each receiving point has a fairly wide range of clarity values for each frequency, with the smallest difference in value seen at 1,000 Hz being only around 1 dB. On the other hand, the receiving point R5 has the lowest value at these three frequencies. The receiver point R1 has the highest clarity value at the frequencies of 125 Hz, 2,000 Hz, and 4,000 Hz.

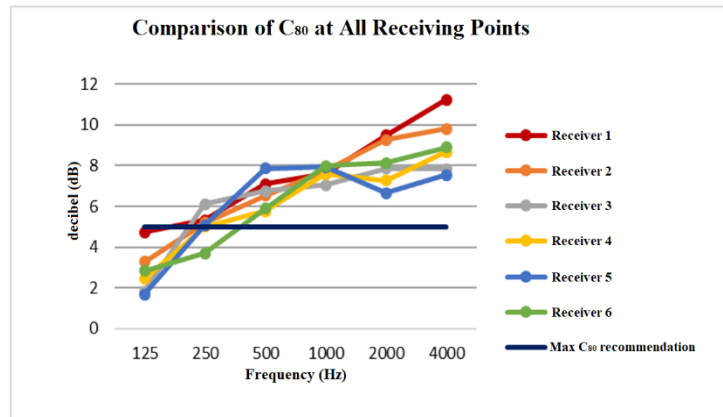


Figure 7. Comparison Graph of Clarity

The effect of receiving point position is visible only for R1 and R2, which have higher values at frequencies of 125 Hz, 2,000 Hz, and 4,000 Hz. The trend of the clarity value results is nearly identical, namely that the value increases with increasing frequency, with the exception of the value at receiving point R5, where the increase is negligible and even decreases after passing 1,000 Hz. Overall, the obtained clarity value exceeds the ISO 3382-1 reference's recommended value range for a concert hall or multifunction room with a volume of up to 25,000 m³.

5. Results Based on Definition (D₅₀)

According to the graph, the definition measurement results follow a trend that is very similar to that of clarity, where the overall definition value rises with increasing frequency and each point has a value difference that is quite large, with the exception of 1,000 Hz, where the difference is the smallest relative to the other points.

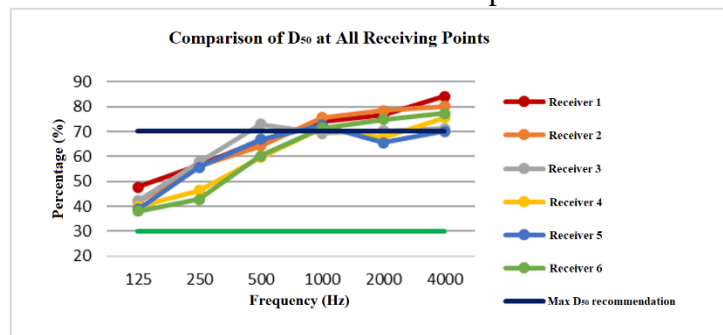


Figure 8. Comparison Result Graph Definition

The highest values are also found at the receiving points R1 and R2 at the frequencies of 1,000 Hz, 2,000 Hz, and 4,000 Hz. Overall, this value is only within the ISO 3382-1 recommended value range at frequencies of 125, 250, and 500 Hz. Even at 500 Hz, the R3 receiving point is above the recommended value. Although the values are still very close to the maximum recommended value, the receiving points R3 and R5 almost meet the recommended values for all test frequencies.

D. CONCLUSION

It can be inferred from each stage of the research that has been done that the method used to obtain the values of the acoustic parameters, namely reverberation time, early decay time, clarity, and definition, has been successful. All parameters are calculated from a comparison of each receiving point and are measured between 125 Hz and 4,000 Hz in frequency. The values range from 1.66 dB to 11.24 dB for clarity. The definition values ranged from 38.09 percent to 84.1 percent. The findings revealed that the values of the acoustic

parameters tested did not meet the recommended criteria in general. The recommended early decay time, according to ISO 3382-1, is between 0.45 and 0.94 seconds at frequencies between 500 and 1,000 Hz, while the measured values fall between those two ranges. To clarify, the ISO 3382-1 recommendations are in the range of -5 dB - 5 dB at a frequency of 500 Hz - 1,000 Hz, while the values obtained range from 1.66 dB-11.24 dB, with 5.7 dB-7.9 dB at 500 Hz-1,000 Hz.

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