Architectural Acoustic Assessment Report: the Practice Room in Alison House

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Content

1 Introduction and Background

1.1 Introduction

The acoustic environment is the main task of designing a music rehearsal room, and the successful design of the rehearsal space is conducive to musicians being able to distinguish and listen (Ryherd, 2008). Therefore, it is important to understand the needs of musicians when designing related acoustic environments. Through the study by Grade and Steensgaard (2015) on musicians' perception of indoor acoustic conditions, it can be seen that the duration of reverberation in a performance room will have an impact on the performance of musicians. For example, when reverberation is not obvious enough, musicians often force their performance to affect the generated sound quality, Musicians, although different from acoustic experts who focus more on physics, can establish a good dialogue between the two by observing the acoustic characteristics of the room through their own playing experience. Bottalico *et al*. (2022) pointed out in their study that the different acoustic environments in the performance space can change the way singers perform musical works in singing performances. Singers produce slower tremolo sounds when there is less reverberation and clearer feedback. Having considered all the relevant studies, it is important to measure the acoustic environment of the rehearsal room.

1.2 Background theory

According to the International Organization for Standardization (ISO) (2009, p.2), the key parameters to focus on in room acoustic measurements should be the impulse response, which means "method of observing cavity curves by direct recording of the cavity of sound pressure level after exciting a room with broad or band limited noise". and conversion time, that is, "duration required for the space overaged sound energy density in an enclosure to decrease by 60 dB after the source emission has stopped".

Room impulse response describes the response of a room system to a single excitation signal, which is an application of the Green's function. Under the action of the Dirac function, the solution obtained by the Green's function can be expressed as equation (1), which can reflect how waves propagate in space under a single excitation.

$$G(\mathbf{x}, t, \mathbf{x}') = \frac{1}{4\pi R}\delta(t - R/c), \quad R = |\mathbf{x} - \mathbf{x}'| \tag{1}$$

To obtain the impulse response of a room, two methods can be used: swept sine sweep method and impulsive method. Swept sine sweep method refers to" deploying a sine signal with exponentially variable frequency, it is possible to involve multiple linear impulse responses of the system, and separate impulse responses for each harmonic disturbance order "(Farina, 2000, p. 1). So, after measuring the sweep signal obtained, the impulse response of the room can be obtained by deconvoluting the sweep signal with the original signal. This principle is represented by equation (2), where H represents the room impulse response, Y represents the received signal, and X represents the original signal.

$$H = Y / X \tag{2}$$

When using the impulsive method, clapping hands and exploding balloons are usually used. In measurement, in order to generate sufficient sound pressure levels from the sound source and avoid contamination by background noise, the sound source position is usually located at a typical position of the natural sound source in the room, and the microphone position usually represents the position of the audience.

When a sound source emits sound in a room, the sound is reflected on different surfaces to form a uniform sound field. The Sabine model suggests that the sound field has the same average energy density, which contributes to the calculation and prediction of reverberation time (Pierce, 2019). When sound fluctuates in space, it is reflected and absorbed, and their reflection and absorption coefficients are related to the incident angle. Therefore, when measuring the impact response of a room, different positions of the room should be considered. When there are no relevant external drivers in the room, there are some basic modes of sound vibration, which is also one of the acoustic characteristics of the room.

Based on the basic principles and characteristics of room acoustics and the measured impulse response, the analysis of room acoustic characteristics can be carried out. One method for estimating room reverberation time is Schroeder integration, which can determine the value of RT60 and obtain the corresponding decay curve.

The decibel can be used to describe the average sound intensity (Pierce, 2019). The sound source produces a certain level of sound in a room, and the sound isolation performance of the wall can be determined by measuring the sound pressure level changes inside the sound source room and outside the partition wall. The measurement unit is in decibels.

2 Description of the Studied Space

We chose to measure the practice room in Alison House, which is a roughly square sound isolation booth that provides instruments for band members to practice. A small band often includes the lead vocalist and instrument performers, and the acoustic environment in the rehearsal room often affects the practice of the band members. Bands usually need to rehearse in enclosed spaces, and for large rehearsal spaces, the reverberation time is about 1 second (Ryherd, 2008). In the school teaching building, as a very small music space, the rehearsal room has significant differences in reverberation time. The acoustic environment design of the rehearsal room not only needs to facilitate music communication among band members, but also needs to consider the impact of environmental noise. By measuring the acoustic characteristics of this practice room, it can be determined whether it is conducive to band rehearsal and provide improvement references for some design defects in its acoustic environment, to facilitate subsequent use.

3 Experimental Procedures Used

3.1 Description of the techniques and apparatus employed

We mainly used MixPre-6 II sound devices, AKG-C414B XLS Pair microphones, Genelec speakers, and Lutron Sound Meters to measure the acoustic characteristics of the rehearsal room. MixPre-6 II sound devices enable high-quality capture and control of live and computer sound, resulting in higher quality audio recording and playback. The AKG-C414B XLS Pair microphone is a common low noise microphone that we use to receive sound from the source. The Genelec speaker is a classic speaker device that we use to play sine sweep signals. We use Lutron Sound Meter to measure sound decibels and evaluate the sound isolation performance of the room.

The study by Mleczko and Wszolek (2014) showed that changes in the location of sound sources have a significant impact on the results of acoustic measurements. Therefore, we considered the main purpose of rehearsal rooms and measured three different sets of source and receiver placements. The sound source positions are the positions where the lead singer of the band usually stands, the positions where the guitarist of the band usually stands, and the positions where the drummer is located. The receiver placements and sound source positions correspond one-to-one to the positions of the band guitarist, the band lead singer, and the band keyboardist, respectively. As shown in Figure 1. Considering the performance characteristics of the band, we set the microphone and speaker at a height of 1.5m.

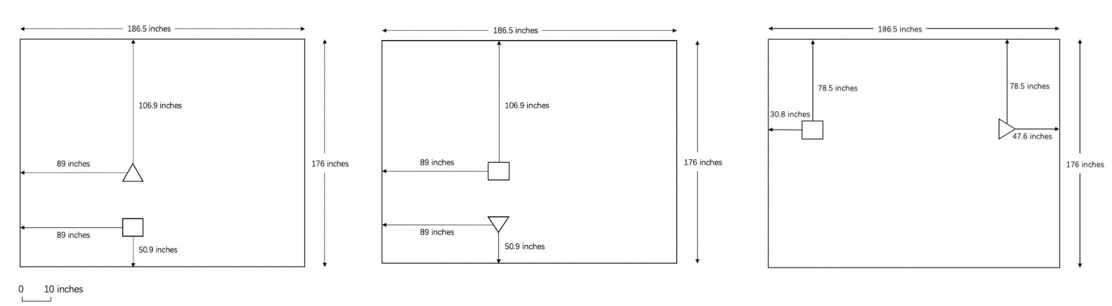

Figure 1: Room geometry, source locations and receiver placements. The microphone is represented by a triangle, and the speaker is represented by a rectangle. In the figure, from left to right are positions 1, 2, and 3, respectively.

By measuring these three sets of source and receiver placements to obtain room impulse responses, it is possible to infer the effects of mutual acceptance and sound propagation among different band members. We used two methods: swept sine sweep method and impulsive method. When using the sine sweep method to obtain room impulse response, we generated and played sine sweep sound waves of 10s and 20s respectively. Generally speaking, longer sweep signals can improve frequency resolution and facilitate more accurate analysis of frequency components, while shorter sweep signals can better capture the room's response to different frequency changes due to their faster frequency change rate. We use microphones to receive sinusoidal sound waves emitted by speakers, and use a computer to save the sound wave signal. We write it into Matlab to obtain the time-domain and frequency-domain signal maps of the room impulse response signal, as well as its energy decay curve, in order to analyze its acoustic characteristics and compare the differences in different sound source positions and sweep times. When using the impulse method to measure room impulse response, we clap our hands and also write the received sound wave signal into Matlab for data analysis. Due to the lower signal-to-noise ratio of impulse response during measurement, it is not possible to conduct more accurate frequency response analysis like sine sweep signals. As the impulse method is only a relatively rough measurement method, it is easier to operate than sine sweep signals and can obtain the acoustic characteristics of the environment more quickly.

3.2 Measurement of noise levels

When measuring the sound isolation characteristics of a room, we played three types of sound: white noise, high-frequency noise, and low-frequency noise. By measuring the difference in decibels between indoor and outdoor sound, we evaluated the sound isolation characteristics of the room for different frequencies of sound.

4 Analysis of Results Obtained

4.1 Analysis of room impulse response

For the three positions shown in Figure 1, the corresponding energy decay curves were obtained by analyzing the 20 second sine sweep signal as shown in Figure 2. The calculated RT60 values for position 1 were 0.0543s, position 2 was 0.0448s, and position 3 was 0.0791s.

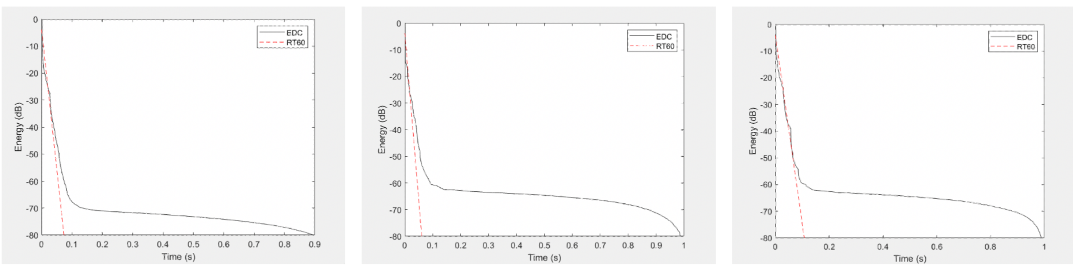

Figure 2: The energy decay curves obtained from the 20s sine sweep signal from left to right are the energy decay curves at positions 1, 2, and 3, respectively.

From Figure 2, it can be seen that the energy decay curves at all three positions do not show linear changes, indicating that sound undergoes multiple decay when reflected by objects inside the room. At the beginning, the sound decay speed is relatively fast, which belongs to the early reflection of sound. However, later on, sound will produce reverberation and undergo multiple reflections with objects on the walls inside the room. From the graph, it can also be seen that in position 1, the decay rate of sound is faster than in positions 2 and 3, indicating that in the middle of the room, sound is least affected by the nonlinear characteristics of the absorbing material. Although the RT60 values of the three positions are very close, there are also slight differences. It is evident that position 3 has the highest RT60 value, indicating that the drummer's sound reverberation is most pronounced at the position where the band keyboardist is located. The RT60 values in all three positions are very small, indicating that the sound can be transmitted very clearly inside the room.

For a 10 second sine sweep signal, the energy decay curves obtained at three positions are shown in Figure 3. The calculated RT60 values for position 1 are 0.0532s, position 2 is 0.0425s, and position 3 is 0.08s.

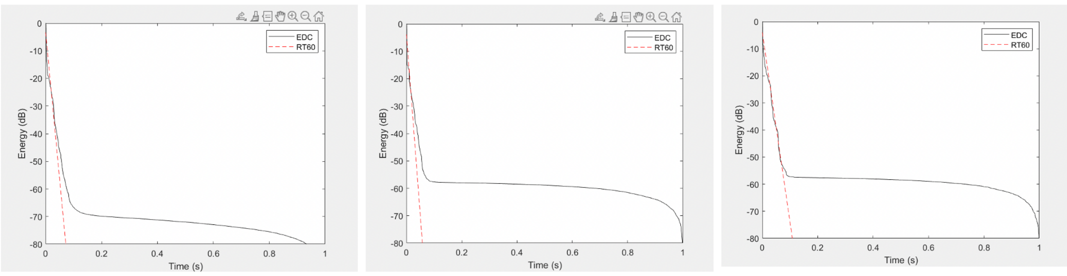

Figure 3: The energy decay curves obtained from a 10 second sine sweep signal, from left to right, are the energy decay curves at positions 1, 2, and 3, respectively.

From Figure 3, it can be seen that the energy decay of position 1 is still the fastest, and the decay characteristics of the three positions are basically consistent with the results measured using a 20 second sine sweep signal. The RT60 value obtained is only slightly different, but also basically consistent. This is because the rehearsal room belongs to a closed environment, and during measurement, the dynamic changes in the environment are relatively small, which will not have a huge impact on the results of long-term frequency sweep signal reception due to environmental changes. This also indicates that the room's response to rapid frequency changes is basically consistent with slightly slower frequency changes.

The energy decay curves of positions 2 and 3 obtained using the impulsive method are shown in Figure 4.

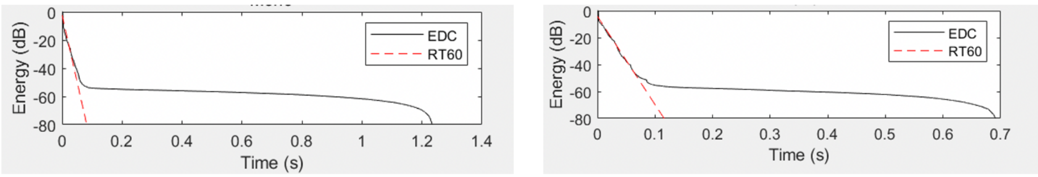

Figure 4: The energy decay curves obtained from the impulsive method, from left to right, are the energy decay curves at positions 2 and 3, respectively.

By comparing the energy decay curves of positions 2 and 3 in Figure 2, it can be seen that the energy decay curve obtained by the impulsive method is not stable. It can be seen that the measurement method of the impulsive method is more susceptible to the influence of other environmental factors. Using clapping hands to create a single impulse often has lower energy, making it susceptible to interference from environmental background noise, low signal-to-noise ratio, and affecting measurement accuracy. However, it can provide an approximate reverberation time.

4.2 Analysis of room sound isolation characteristics

The noise floor indoors was measured to be 28.8 dB, while the noise floor outdoors was 33.7 dB. It can be seen that the rehearsal room has isolated some external sound. In order to more accurately evaluate its isolation characteristics for different frequencies, it was found that in the case of 87.4 dB white noise indoors, the outdoor sound was 62 dB. For high-frequency noise of 82.7 dB, the outdoor measured sound is 42 dB. For low-frequency sound of 76.6 dB, the outdoor measured sound is 33.7 dB. From these three sets of measurement data, it can be seen that low-frequency sound leakage is more severe. This is mainly because low-frequency sound waves have longer wavelengths and are easier to penetrate walls. Therefore, more design considerations are needed to better isolate low-frequency sound.

5 Conclusions and Recommendations

By measuring the impulse response of the room, it can be seen that the reverberation time of this practice room is extremely short, and the sound received by each band member at different positions is basically consistent. This practice room has the advantage of clear sound, avoiding the blurry sound caused by reverberation, which is very helpful for rehearsing music styles that require precise pitch and rhythm. At the same time, there is less reverberation, which facilitates more precise control of the audio system and adjustment of music effects during rehearsals. However, having too little reverberation also has certain drawbacks for music rehearsal rooms. Music rehearsal rooms often require moderate reverberation effects to ensure the richness of the music. Otherwise, for performers, the lack of dynamic sound received will affect the performance effect, especially for bands that often play pop and rock music.

By evaluating the sound isolation performance of the room at different frequencies, it can be found that the sound isolation performance of this room is good. However, due to its location in the music teaching building, the sound of instruments practicing in other rooms often penetrates into the room, and its sound isolation performance needs to be further strengthened. And because the room is used for band rehearsals, drums are one of the essential instruments, and the room has a serious leakage of low-frequency sound, special treatment is needed to strengthen the isolation of low-frequency sound waves.

In order to improve the problem of short room reverberation time, when designing similar extremely small rehearsal rooms, it is possible to consider adding some reflective materials to the walls and reducing some sound-absorbing materials appropriately, but this should also consider the sound insulation performance of the room. It is also possible to install artificial reverberation equipment inside the room, which can directly increase reverberation while avoiding the impact on the sound isolation performance of the room. To enhance the sound insulation performance of a room, it is possible to consider increasing the density and thickness of walls, ceilings, and floors to more effectively prevent the propagation of sound.

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