

In situ test: acoustic performance of eco-absorber panel based albizia wood and sugar palm fiber on meeting room in UNS Inn Hotel

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Abstract. Elimination of echoto improve sound quality is essential term of comfortable function room. This study aims to investigate the enhancing of acoustic quality of a meeting room using eco-absorber panel based sugar palm fiber in UNS Inn Hotel, Surakarta, Indonesia. The panel was made from albizzia wood with sugar palm fiber as acoustic fill covered by sponge and Regency fabric. The reverberation time calculated with theoritical method was to validate thatmeasured with in situ test. The testing was performed using an impulse method by recording handclap sound, and the data was processed using MATLAB software to determine the reverberation time value. The testing of sound pressure level and sound distribution were conducted with two loud speakers placed in front ofthe room for frequency of 250 Hz. The sound pressure was measured at each measurement point using sound level meter. The absorber panels were installed on the back wall of the room varied in 100%, 75%, 50% and 0% of the wall sectional area. The result shows that the increase of installed absorber panels decreases the reverberation time value and it has good correlation with theoritical calculation. According to the test results of sound pressure level and sound distribution, the lowest reverberation time is achieved for 100% of installed absorber panel. The reduction of sound pressure level and sound distribution are up to 18.3 dB and 40-60 dB, respectively.

1.Introduction

The application of sound absorber as wall covering panel to improve sound quality in a function room is seriously needed. There are many absorber products in market and most of them are produced from synthetic materials, such as synthetic foam, polyester fiber, and glass wool. However, it is still limited application of the absorber in many meeting rooms due to its price and on availability in the market. In other hand, the use of natural materials for producing an eco-absorber panel will give better advantages, especially reduce energy consumption and impact on environment [1].

Since ten years ago, researchers studied seriously on natural materials as sound absorber. The multi-layer coir fiber showed good sound absorption coefficient of 0.85 in average from 1 kHzand its performance had been improved at lower frequency using an addition of granular rice-huskgrain in the coir fiber. Oil palm fibers from the empty fruit bunch also have similar sound absorption performance with the coir fibers. The absorber based bagasse fibers



with binder, which has density of 400 kg/m^3 and 500 kg/m^3 , could perform on absorption coefficient greater than 0.5 above 1 kHz. Other natural materials also have good sound absorption performance, such as tea-leaf fibers, paddy fibers, jute fibers, ijuk (*Arenga Pinnata*), kapok fibers, kenaf fibers, sisal-kenaf composite and pineapple-leaf fiber [2].

The absorbent material should be designed according to the function of the absorption mechanism converting sound energy into heat. For example, the presence of pores can convert sound waves energy into heat due to its resonance [2]. Sounds varying over time cause more disruptions [3]. The reverberation can reduce the auditory distraction effect produced by irrelevant speech [4]. It can be recommended that a meeting room or auditorium should have good acoustic quality.

In general, a soft material has a good ability to absorb the sound and an addition of fibrous material as acoustic fill can improve the performance of sound absorption. Albizzia wood (*Paraserianthes Falcataria*), as light weight wood growing in Indonesia, has excellent properties to be used as sound absorber. In 2016, the log production of albizzia reached $2,556,979.59 \text{ m}^3$ or 6.05% of total log production [5]. Besides that, the plantation area of sugar palm (*Arenga Pinnata* Merr) in Indonesia was 60,482 hectares [6]. In Bendo, Tulung, Klaten, Central Java, Indonesia there are many Small and Medium Enterprises (SMEs) producing white noodle from starch of sugar palm, which have waste capacity of 50 tons with 50% of fibers per day. The cellulose content of the waste is 60.61% and enhances up to 72.78% while treatment [7]. Both albizzia wood and sugar palm fiber have good potential to be used as eco-absorber materials.

The basic characteristic of the eco-absorber has been conducted using two impedance tube apparatus. The cover addition on eco-absorber with fabric and vinyl-wall paper can increase the NAC (Noise Absorption Coefficient) in low frequency (100-400 Hz), but it decreases in high frequency (400-1,400 Hz). The hole addition also gives the improvement of NAC [8]. The eco-absorber without cover addition has better performance in NAC compared to the solid absorber based sugarcane bagasse – polyvinyl acetate [8, 9]. The solid absorber has similar characteristic of NAC with the modified absorber based albizzia – sugar palm fiber. However, the use of sugar palm fiber as panel absorber applied in a meeting room is not yet known. Therefore, the study of eco-absorber application to improve the acoustic performance on a function room is important to be published.

2. Experimental method

2.1. Preparation of eco-absorber panels

The eco-absorber panels were produced based on previous research, especially for unmodified absorber (50 x 50 x 5 cm) [8]. The absorber panel was produced from albizzia wood as frame and sugar palm fiber as acoustic fill. The front side was covered with sponge of 1 cm in thickness and regency interior fabric. The panels were assembled on a knock-down steel frame and placed on back wall of the testing room.

2.2. Acoustic Testing

A function room (meeting room) in UNS Inn Hotel was used as test room which was equipped with two loud speakers on each corner in front of the room (figure 1). The room dimension was 8.09 x 7.05 x 3.17 m and its capacity was 18 audiences and 4 speakers. The first testing was the measuring of the reverberation time using hand clapping method and the measurement was conducted using a sound level meter on a tripod holder that was placed in the center of the room. The sound level meter had same high with the ear of audiences. The

clapping person was in front of the room at the speaker position. After that, the sound distribution from the loud speakers was filtered for frequency 250 Hz and maintained to have same amplitude on all frequency spectrum. The chosen frequency (250 Hz) was based on standard stimulus due to fundamental frequency. The data, which was collected from the measuring points (P1 up to P9), was measured using the sound level meter. Then, the installed absorber panels were reduced and re-tested. The installed absorber panels were varied in 100%, 75%, 50% and 0% of the backwall surface.

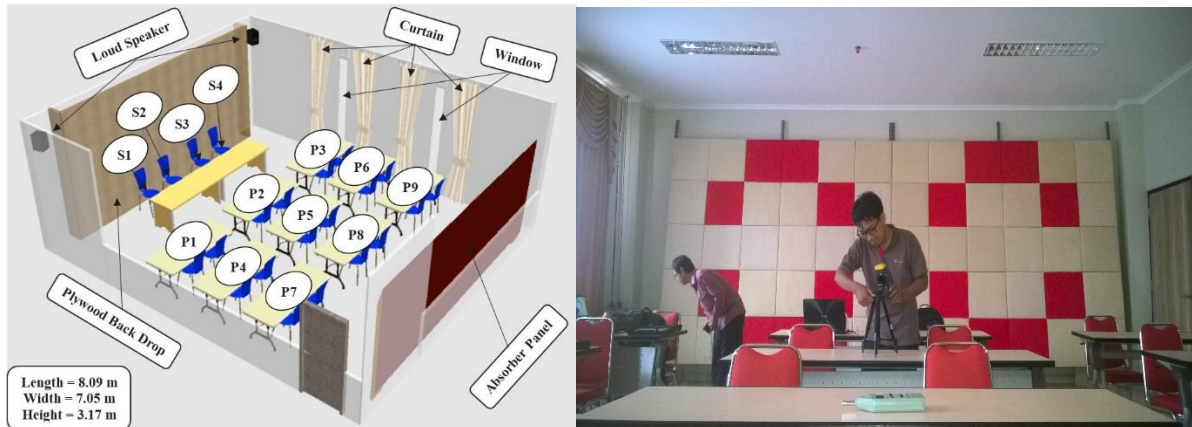


FIGURE 1. Design of function room for testing and application of eco-absorber for testing

2.3. Theoretical Analysis

The theoretical analysis of reverberation time was conducted using Sabine equations for the meeting room as shown in figure 1. In the test room, the reverberation time, as an objective-based measurement, was considered as the most important criteria to determine the quality of audibility [10]. The calculation of reverberation time (RT60) based on the Sabine equation is an predicting experiment to give an estimation on room acoustic quality. The equation is as follows [11]:

$$RT = \frac{0,161.V}{A} \quad (1)$$

The total absorption of indoor sounds (A) is represented from the sum of the surface area (S) multiplied by the absorption coefficient (α), then [11]:

$$A = \sum_i S_i \cdot \alpha_i \quad (2)$$

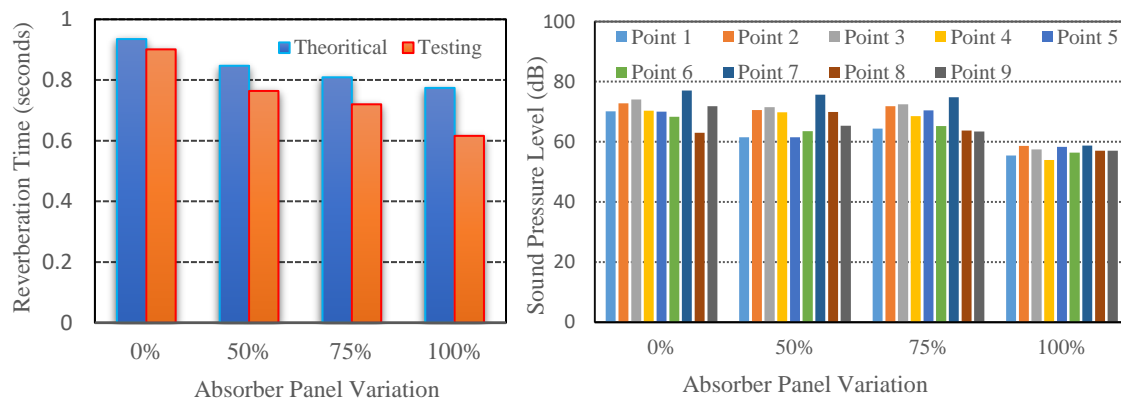
The Sabine equation assumes that the absorption was evenly distributed on all surfaces and the sound field was diffused. It means that each point in the room has the same energy density and equal probability of sound propagation in all directions.

3. Result and Discussion

For experiment and theoretical calculations, the reverberation time decreases proportionally with the addition of absorber panel (figure 2a). According the data, the testing results have better reverberation time than theoretical results. This is in accordance with previous research conducted by Carvalho [12] with an average yield of 16%. For this experiment, the reverberation time with absorber panels of 100% has a decrease by 0.285 seconds compared that of 0%, while the theoretical analysis decreases the reverberation time

of 0.161 seconds. The result shows that the acoustic control treatment in the meeting room is able to reduce the sound reflection (echo). The shorter reverberation time can be obtained by addition of eco-absorber panel (fig. 2a) and the results can be validated by theoretical analysis.

The reduction effect of reverberation time is a decrease of sound pressure level that is too noisy in the room due to excessive echoes [13]. By using of absorber panels (50% and 75%), the sound pressure level can be reduced below 70 dB at almost each measurement point. The greater of absorber panel application, the lower of sound pressure level, the smaller of the difference in sound pressure level. Especially for 100% of absorber, the panel works most effectively because the difference in sound pressure level is not greater than 6 dB. This experimental result indicates that sound pressure level not exceeding 60 dB (the room acoustic comfort) [14]. As well as reducing of sound pressure level at this frequency for the same measurement, the best result is 18.3 dB at point 7 (between 0 - 100% of absorber panel). The sound distribution at each measurement point was filtered for frequency 250 Hz (Figure 2b).



a. Comparison of experimental and theoretical results b. Sound distribution at frequency 250 Hz

Figure 2. Comparison results and sound distribution

The sound distribution at 250 Hz with 100% of absorber panel has a sound deviation that meets the comfort terms limit of 4.8 dB between point 7 and point 4 [14]. The use of 75% absorber panel has a larger deviation of 11.4 dB (at point 7 and point 9), while the use of 50% absorber panel has larger deviation of 14.2 dB (at point 7 to point 1 and 5). The largest deviation, which was occurred in the variation of 0% absorber panel, is 14.1 dB (at point 7 and point 8). The sound levels in this variation are also quite noisy and there are 2 points which have values below 70 dB (points 6 and point 8). High sound pressure level at point 7 was started from 0-100% of absorber panel installation due to its position is closed to the left and rear wall. The point 7 was closed with wall concrete blocks and ceiling concrete that has very low sound absorption coefficient at a frequency of 250 Hz (0.05 and 0.01, respectively), so that the sound from the loud speaker was much reflected. However, overall of sound distribution with 100% of absorber panel is the most effective due to the plywood material that covers almost all the front wall of the room and the door at the back of the room has the best absorption coefficient at the frequency of 250 Hz that is 0.22 and 0.21 [15]. The remnants of the sound reflection in the room can be absorbed well. The sound pressure level in this variation has also reached the ideal limit of 40-60 dB (14).

At certain frequencies, the factors of material also affect on the sound distribution in the room. The measured sound detected the sound level meter in the room not only comes from the sound source, but also comes from reflective sounds. This sound is influenced by many things, such as spatial material, the shape and volume of space, and position of the loud speaker sound source. On other hand, the sound distribution is also influenced by many factor, such as loudness difference of loud speaker, bulge on the left and right walls, wall materials (curtain), and furniture layout. Therefore, measurement points which have longer distance from the sound source will have a smaller different of sound pressure level compared to which shorter distance of sound source. As consequence, there is a lot of reflected sound even though the direct sound is reduced, so that the sound pressure level can remain high at that point.

4. Conclusion

The different effect of absorber panels installation in meeting room on acoustical characteristics has been investigated. Terms of room acoustical comfort at a meeting room in UNS Inn Hotel based on the reverberation time has been achieved at 0.774 seconds by theoretical calculations on absorber panels installation of 100%, while the reverberation room based experimental result is of 0.616 seconds. Absorber panel installation of 100% can reduce sound pressure level below 70 dB at each measurement point. The use of 100% absorber panel is the most effective on sound distribution the meeting room. The sound distribution of eco-absorber panel based albizzia wood with acoustic fill of sugar palm fiber is better than glass wool-based absorber panel, so that it has good potential to be commercialized.

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