

Coconut Leaf Midribs as an Acoustical Panel – Feasibility Study through Impedance Tube Method

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Coconut Leaf Midribs as an Acoustical Panel – Feasibility Study through Impedance Tube Method

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Abstract. This research aims to determine sound absorption coefficients of absorber materials making from coconut leaf midribs. Absorber material has been made with different arrangement and thickness. Nine samples have been made which consists of 3 configurations and each configuration consists of 3 thicknesses. Absorption coefficients were measured by using impedance tube method. The experiment results show that coconut leaf midrib is up to standard for absorber material according to ISO 11654 with α over 0.15. The absorption coefficient obtained by the whole sample is in the range 0.02 to 0.65. Fluctuating values are affected by differences forms and thicknesses. Absorber materials that have been made are also compatible with marketed products.

1. Introduction

Research on sound absorbers made from acoustic materials is generally distinguished in natural materials and recycled materials. Some of them are like rice straw [1], sugar cane [2], sago midribs [3]. Fibrous sound absorbers are characterized by the presence of pores, where sound absorption is expressed in the coefficient of sound absorption as one of the characteristics in the design of acoustic materials. Porous sound absorbers can be produced by utilizing natural fiber waste into composite boards [4], where the sound absorption of the material depends on variable thickness, density, and fiber orientation.

In this study, the natural material chosen was midribs of coconut leaf, because there are still limited research references that choose the material as the object of research, especially acoustic material. Its hard porous outer texture allows this material to be used as an acoustic board material by measuring the absorption coefficient of sound so that it can be as a soundproofing material. The configurations and thickness of the material are used as research variables.

2. Research Method

The study uses an experimental methodology approach (experimental research) which will be divided into four stages of implementation. These stages are the process of getting raw materials, sample making, testing of sample characteristics and analysis of test results to the conclusion of the study.

Material Making:

- 1) Coconut leaves are separated using a knife
- 2) The material is then dried in direct sunlight



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Figure 1. Separation of leaves and midrib using a knife



Figure 2. Coconut leaf midribs are dried for approximately four days

The sample making procedure conducted as follow:

- 1) Making an impedance tube pattern with a diameter of 10 cm to be used as a template for specimen raw material.
- 2) Raw materials are glued using PVAc adhesives according to templates with thicknesses varying from 25-50 to 75 mm.

Testing the characteristics of the next sample through the impedance tube method to get the absorption coefficient (α) of the sample with a variation of the configuration and thickness that have been determined.



Figure 3. Coconut leaf midribs are glued together one by one using PVAc adhesives

The last method is a standard method commonly carried out by researchers or acousticians to get the absorption coefficient including the tube's sensor [5]-[9] This tube is intended to measure acoustic parameters by using a small sample placed on one end of the tube. A sound source emitted by a computer speaker is amplified and then forwarded into the impedance tube which is then captured by the two microphones. Results are recorded and processed using the PULSE labshop software version 16.1. Data of recorded sound waves in impedance tubes will produce absorption coefficient at frequencies from 100 Hz to 1600 Hz. The records then processed by *KaleidaGraph* and displayed in curves.

3. Measurement Setup



Figure 4. Samples of coconut leaf midribs



Figure 5. Measurement set up



Figure 6. Sample of coconut leaf midribs and acoustical gypsum with variety of thickness and configurations

Three types of coconut leaf midribs in the form of composite board thickness of 25-50-75 mm were measured. Composite board materials were cut in a circular shape with a diameter of 10 cm as the sample for measurement of absorption coefficient, see Figure 4. Similar measurements of acoustical gypsums with similar thickness are also performed for comparison purposes. Sample of coconut leaf midribs and acoustical gypsum with all variety of thickness and configurations that used in this study can be seen in Figure 6. The absorption coefficient of the coconut leaf midrib composite board is measured by the two microphone methods on impedance tube as shown in Figure 5.

4. Results and Discussions

The following figures of absorption coefficients according to configuration and thickness:

- 1) Parallel (A)
- 2) Cross (B)
- 3) Star (C)

As mentioned in the previous section, the normal sound absorption coefficients of the prepared Coconut leaf midribs (CM) for 25 mm 50 mm and 75 mm thick samples were measured in the impedance tube. Figures 7, 8 and 9 respectively show the measured results of CM with various configurations i.e. parallel, cross, and star, as well as 25 mm, 50 mm and 75 mm thicknesses. The curves in Figure 7 indicate the values of all CM samples of the same configurations (indicated as CM A is parallel) with different thickness (indicated as two numbers following the CM A such as 25, 50 and 75).

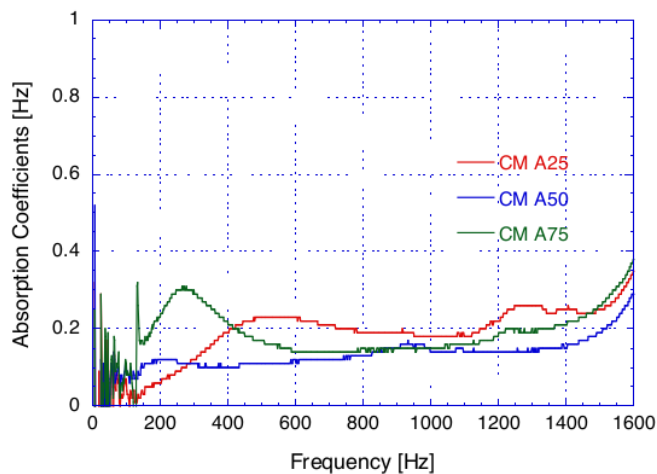


Figure 7. Absorption coefficients by variety of thicknesses of coconut midribs (CM) with parallel configurations

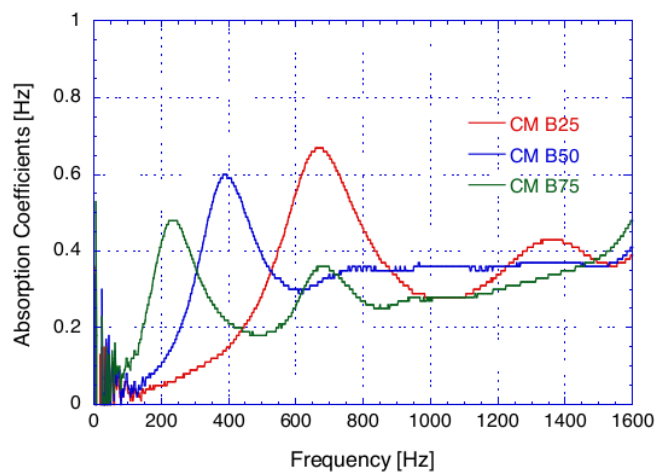


Figure 8. Absorption coefficients by variety of thicknesses of coconut midribs (CM) with cross configurations

In the Figure appears that all α of CM A25, 50 and 75 generally fluctuates below 0.4 with maximum value at frequency 1600 Hz. The curves quite stable at a middle frequency from about 500 Hz to 1000 Hz. Figure 8 shows all absorption coefficients of CM with cross configuration and thicknesses of 25 mm, 50 mm and 75 mm. All CM samples with cross configurations show the high fluctuation of absorption coefficient from low frequencies to frequencies of 1000 Hz, while absorption coefficients at high frequencies that are above 1000 Hz to 1600 are more stable. Similarities in tendency in Figure 8 also occur in CM with the star configuration shown in Figure 9, where absorption coefficient fluctuations occur at frequencies below 1000 Hz and are more stable at frequencies above 1000 Hz.

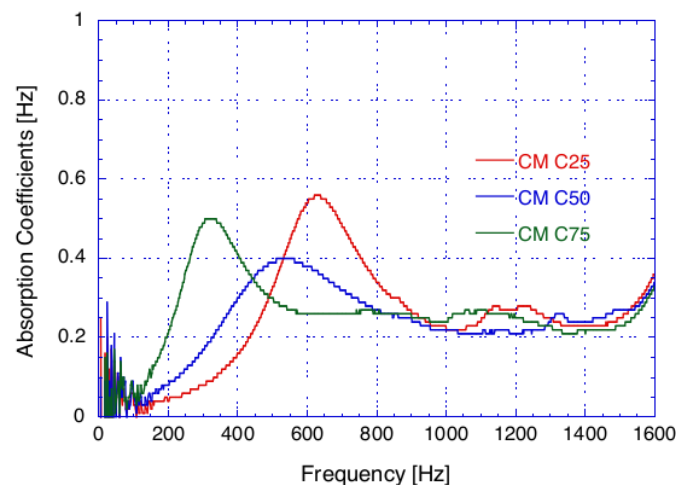


Figure 9. Absorption coefficients by variety of thicknesses of coconut midribs (CM) with cross configurations

From the overall graph presented it can be seen that the thicker the sample, the maximum sound absorption coefficient ($\alpha = 0.67$) shifts to a lower frequency. This is because porous material can provide greater sound absorption when it is in a position where the sound wave particle velocity will reach a maximum value at a distance of $\lambda/4$, $3/4 \lambda$ and so on. The absorption coefficient has a slight decrease in the distance $\lambda/2$, λ and so on. The thicker the sample, the absorbed waves are waves that have a greater wavelength. Based on the theory in the following equation:

$$\alpha = \frac{\ln I_0 - \ln I}{x}$$

The relationship between the thickness and the coefficient of sound absorption is that the greater the thickness of the absorbent medium, the value of the sound absorption coefficient gets smaller, and vice versa [1]. This theory is only fulfilled in samples with the form of configuration B which is evident in the comparison Graphs on Fig 7, where the sample with a thickness of 25 mm absorbs the most optimal sound followed by a sample with a thickness of 50 mm and the last is a sample with a thickness of 75 mm.

The same thing also happened in the sample configuration C wherein Fig. 8, the most optimal sound absorption sample sequence from the high to low-frequency range, which is 25 mm then 50 mm and the last is 75 mm. For the form of configuration A this theory is not fulfilled in the graph of Fig. 6

explaining sample A. Samples with a thickness of 25 mm of the most optimal sound absorption are in the highest frequency range but are followed by samples with a thickness of 75 mm and finally on a sample thickness of 50 mm.

For the form of configuration A, this theory is not fulfilled because it sees that thickness of 75 mm which absorbs optimally. The thickness of 75 mm is the greatest thickness in this study. Followed by a thickness of 25 mm and 50 mm. The form of configuration C also does not meet the existing theory. The results shown in the graphs show fluctuating values for the three graphs presented. On the whole graph that has been described, it can be seen that in configuration B at a thickness of 25 mm the optimal sound absorption coefficient is at the middle frequency as well as being the most optimal form of absorption coefficient compared to the other arrangement. As for the thickness of 50 mm and 75 mm the optimal noise absorption coefficient is at low frequency. So it can be confirmed that all forms of configuration (A, B and C) are suitable treatments because they meet the sound absorption standards that are good for use depending on the absorption coefficient desired.

The minimum absorption value of sound dampening material according to ISO (International Organization for Standardization) 11654 is 0.150. From the value of sound absorption coefficient based on thickness variation, it is obtained that the value of sound absorption coefficient is the largest and meets the standard that is at 25 mm thickness, whereas for variations in the composition of the material it is found that the crossing configuration with the highest sound absorption coefficient value.

Comparison with Gypsum Acoustic Materials

The following graph of Figures 10, 11 and 12 are the coconut leaf midribs samples compared with commercial gypsum acoustic boards according to midribs configuration.

Figure 10 shows the absorption coefficient of CM with variations in parallel configurations (A), cross (B) and star (C) and acoustic gypsum with 25 mm thickness. From the obtained graphic data of acoustic gypsum experimentations and the tested material with similar thicknesses, there were far differences of the resulted sound absorption values. Observation on both graphs showed that the sample of CM A25, CM B25 and CM C25 have increased in the middle frequencies while GA25 increased in high frequency ranges. The highest coefficient value achieved by the coconut midribs is 0.67 at a frequency of 650 Hz. For GA samples, the highest sound absorption coefficient achieved is 0.36 at frequency 1200 Hz. The difference between the highest absorption coefficient values of the two samples were 0.31.

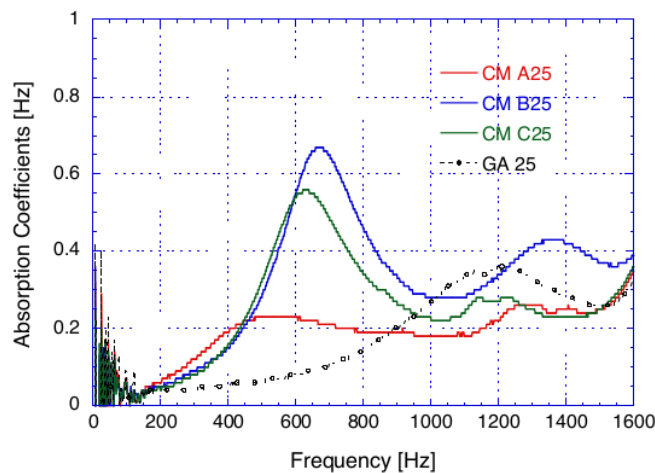


Figure 10. Comparison of absorption coefficients between coconut leaves midribs (CM) with variety of configurations and acoustica gypsum (GA) 25 mm thickness

The measurement results as seen in Figure 11 showed that the acoustic samples of gypsum material (GA50) and the tested material (CM A50, CM B50 and CM C50) with same thicknesses had difference of sound absorption coefficient values. Observation on both form of graphs, showed that the coconut midribs with configuration of A, B and C experience a fluctuated absorption coefficient values along the frequencies, while for GA50 tend to be stable and have an increasing tendency during high frequency ranges. The highest coefficient value achieved of the coconut midribs with all variety is 0.60 at a frequency of 40 Hz. While for GA50 samples the highest sound absorption coefficient achieved was 0.18 at 920 Hz frequency. The difference between the highest absorption values of the two samples was 0.42.

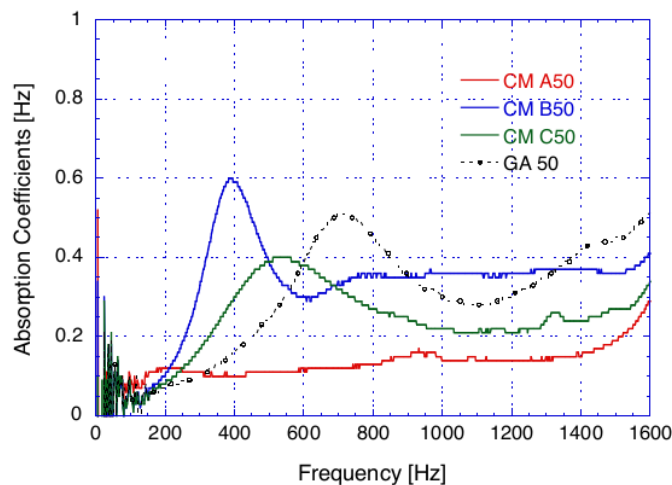


Figure 11. Comparison of absorption coefficients between coconut leaves midribs (CM) with variety of configurations and acoustical gypsum (GA) 50 mm thickness

Figure 12 shows the absorption coefficient of CM with variations in parallel configurations (A), cross (B) and star (C) and acoustic gypsum with 75 mm thickness. The test results showed that the acoustic samples of gypsum material and the tested material with same thicknesses had significance differences of sound absorption values. Observation on both form of graphs, showed that the coconut midribs samples of CM A75, CM B75 and CM C75 experience a fluctuated absorption coefficient values along the frequencies, while for GA75 tend to be stable and have an increasing tendency during high frequency ranges. The highest coefficient value achieved of the coconut midribs material is 0.49 at frequency 300 Hz. While for GA samples the highest sound absorption coefficient achieved was 0.29 at frequency 400 Hz. The difference between the highest absorption coefficient values of the two samples were 0.20.

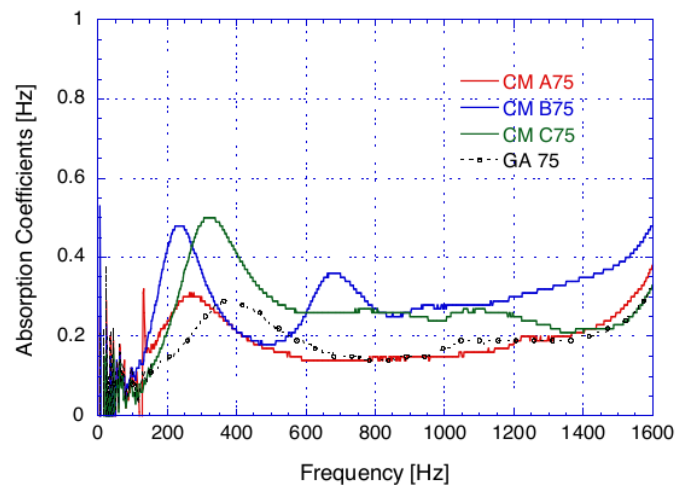


Figure 12. Comparison of absorption coefficients between coconut leaves midribs (CM) with variety of configurations and acoustical gypsum (GA) 75 mm thickness

5. Conclusions

The acoustic material from the coconut leaf midrib used in this study can be categorized as a good sound absorber because it has an absorption coefficient value that is better than the ISO 11654 standard, which is a minimum of 0.15. Based on the optimum absorption coefficient at each frequency (0 - 1600 Hz) with a frequency interval of 100 Hz at low-frequency intervals (0 - 500 Hz) the best results come from samples of crossing configurations of 50 mm and 75 mm thick. For intermediate frequency intervals (500 - 1000 Hz) the best results are obtained by crossing configurations of 25 mm thick. Whereas at high-frequency intervals (1000 - 1600 Hz) the best results from the crossing configurations sample are 50 mm. From the whole frequency interval, the cross-sample is the best sample compared to the other two forms. Sound absorption coefficient value based on variations in the thickness of acoustic material is obtained that the value of the greatest sound absorption coefficient and meets the standard that is at a thickness of 25 mm. The sound absorption coefficient value obtained by the whole sample is in the range of 0.02 to 0.65. This fluctuating value is obtained because of the influence of the midrib configuration and thickness of the test sample. Based on the value of the sound absorption coefficient obtained, the sample acoustic material from midrib coconut leaf material with PVAc adhesives is feasible to be an alternative acoustic material.

Acknowledgment

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