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ANALYSIS OF SOUND ABSORPTION OF ACOUSTIC BOARDS MADE FROM HEMP FIBER (*BOEHMERIA NIVEA L. GAUD*) AND EPOXY RESIN

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Abstract

This study aims to determine the effect of thickness on the absorption coefficient of hemp fiber acoustic boards with epoxy resin adhesives. The method used in this study was to analyze composite samples with 3 different compositions, namely by the ratio of hemp fiber 12 grams, 8 grams and 4 grams with the same epoxy resin for each sample, namely 80 grams. The absorption coefficient test was carried out using a glass designed as a test chamber and a Sound Level Meter as a detector. The frequency values that are used are 250 Hz, 500 Hz, 800 Hz and 1000 Hz. Based on the results of the study, it was found that of the three compositions, the highest value was obtained in composition III with 12 grams of hemp fiber, 80 grams of epoxy resin and 40 grams of the catalyst with a density value of 1.116 gr/cm^3 and a thickness of 1.178 cm. The composition of the sample is capable of producing a sound absorption coefficient of 0.120 cm^{-1} at a frequency of 250 Hz, 0.055 cm^{-1} at a frequency of 500 Hz, 0.051 cm^{-1} at a frequency of 800 Hz, and 0.073 cm^{-1} at a frequency of 1000 Hz. So the addition of hemp fiber and the epoxy resin is directly proportional to the absorption coefficient. The greater the concentration of the hemp or resin used, the greater the absorption coefficient.

Keywords: *absorption coefficient; acoustic board; epoxy resins; hemp fiber*

Abstrak

Penelitian ini bertujuan untuk mengetahui pengaruh ketebalan terhadap koefisien absorpsi papan akustik dari serat rami dengan perekat resin epoxy. Metode yang digunakan pada penelitian adalah menganalisis sampel komposit dengan 3 komposisi yang berbeda yaitu dengan perbandingan serat rami 12 gram, 8 gram dan 4 gram dengan resin epoxy yang sama setiap sampel yaitu 80 gram. Dilakukan pengujian koefisien absorpsi menggunakan kaca yang didesain sebagai ruang uji dan Sound Level Meter sebagai detektor. Nilai frekuensi yang digunakan adalah 250 Hz, 500 Hz, 800 Hz dan 1000 Hz. Berdasarkan hasil penelitian diperoleh bahwa dari ketiga komposisi, nilai tertinggi diperoleh pada komposisi III yaitu dengan 12 gram serat rami, 80 gram resin epoxy dan katalis 40 gram dengan nilai densitas yaitu 1,116 gr/cm^3 dan ketebalan 1,178 cm. Komposisi sampel tersebut mampu menghasilkan koefisien absorpsi suara sebesar 0,120 cm^{-1} pada frekuensi 250 Hz, 0,055 cm^{-1} pada frekuensi 500 Hz, 0,051 cm^{-1} pada frekuensi 800 Hz, dan 0,073 cm^{-1} pada frekuensi 1000 Hz. Sehingga penambahan serat rami dan resin epoxy berbanding lurus dengan koefisien absorpsi. Semakin besar konsentrasi rami atau resin yang digunakan, maka semakin besar pula nilai koefisien absorpsinya.

Kata Kunci: *koefisien absorpsi; papan akustik; serat rami*

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INTRODUCTION

One of the methods to reduce noise is to use shields from acoustic materials that absorb or muffle sound (Ardan et al., 2020). The acoustic board is a material that absorbs sound or sound in many types, both high frequency, medium frequency and low frequency. Acoustic absorption is the loss of energy that occurs when sound waves impact and are reflected from the surface of a particular object or material (Khotimah et al., 2015). Making an acoustic board must be done by combining two materials, which is often called a composite. Composite is a material formed from a combination of two or more inhomogeneous materials where the two forming materials have different mechanical properties (Phiri, 2024).

The fiber and matrix are the two main elements in most composites. Fibers are usually elastic and have good tensile strength, but they cannot be used at high temperatures, while the matrix is usually ductile, soft, and binds when frozen. These two ingredients with different properties are mixed to form a new material (composite) with properties different from those of the constituent particles (Arulprasanna & Omkumar, 2024). A composite reinforced with natural fibers can help the environment by reducing the use of synthetic fibers and resins. Since the natural fibers have more porosity and amorphous structure than synthetic fibers, they have the capacity to dampen sound and control noise. The finding revealed that coconut (Taiwo et al., 2019) and hemp fibers can effectively absorb sound at high frequencies (Zhang et al., 2022).

The natural fibers generally have the ability to absorb sound, especially in controlling noise, for example in vehicles, offices and factories. However, due to differences in cellulose content, the physical properties of natural fibers are quite varied. The hemp fiber content is 75% cellulose and 16% hemicellulose (Promhuad et al., 2022). The cellulose is often known as fiber which is an organic substance and is present in about 33% of all component materials in plants. The plants that include cellulose have various advantages, including the capacity to minimize sound or noise, temperature insulation, low density, and good mechanical ability, making it ideal for industrial applications (Sozcu et al., 2023). Hemp as a natural fiber is biodegradable, therefore this composite with hemp fiber is believed to be a material for noise created by increasing human technology and industry. In the manufacturing of composites in addition to reinforcement, other materials are also needed as a binder (Huang et al., 2023).

The composite binder has a function, namely to bind the fibers into a single unit with the structure. They can protect the fiber from damage caused by the environment (Chaudhary et al., 2024), and distribute the load to the reinforcement and provide stiffness (Hamzat et al., 2025), resilience and resistance properties (Olanrewaju et al., 2025). The epoxy resin is a thermoset material with excellent chemical resistance. They are durable, flexible and strong (Albadrani & Almutairi, 2024). They are also suitable for use as protective coatings. The reaction between epichlorohydrin and bisphenol-A produces most epoxy resins. The epoxy resin is often used in the production of primers, coatings, varnishes, and adhesives, as well as rim materials for cans, drums, tank pipes, and tank cars.

This research aims to determine the effect of thickness and frequency on the absorption coefficient of acoustic boards from hemp fiber with epoxy resin adhesive. This research is therefore carried out with a combination method between the two materials and is expected to be the latest innovation to create sound absorbers and be able to overcome noise problems.

METHODS

The sample base materials used were hemp fiber, epoxy resin and catalyst. This research uses three variations of sample composition. In each composition, three times were made so that nine samples would be obtained. The measurement results of each sample of the same composition will be averaged to determine the result value of each sample. The compositions I, II, III use the ratio of epoxy resin: catalyst: hemp fiber respectively, I = 80 gr: 40 gr: 4 gr; II = 80 gr: 40 gr: 8 gr: III = 80 gr: 40 gr: 12 g. Epoxy resins have a number of advantages, including corrosion and acid-base resistance. Epoxy has the strongest mechanical strength and can resist water absorption (adhesion) quite well (Siregar et al., 2013). The density value obtained in composition I, II, III, IV, V, and VI are 1.101 gr/cm^3; 1.109 gr/cm^3; 1.116 gr/cm^3; 1.106 gr/cm^3; 1.115 gr/cm^3, and 1.120 g/cm^3 respectively. The hemp fiber used in compositions I and IV is the same: four gams. Designs II and V also use the same mass of hemp fiber, namely eight grams; likewise, compositions III and VI use the same group of hemp fiber, namely 12 grams. The lead acetate used for each sample is the same at 2.5 grams (Jusli et al., 2023). Weighing the ingredients according to the predetermined composition of the ratio of the number of these compositions which can be described in table 1.

Table 1. Composition of various epoxy resins, catalysts and hemp fibers

Compositions	Epoxy Resin		Catalysts		Hemp Fibers	
	(%)	(gr)	(%)	(gr)	(%)	(gr)
I	63.24	80	31.62	40	3.16	4
II	61.30	80	30.65	80	6.13	8
III	59.48	80	29.74	40	8.92	12

The hemp fiber to be used is cut into pieces with a maximum length of 1 cm. The mold is also prepared by placing aluminum foil in it so that the sample does not come into direct contact with the mold so that it is easier when released from the mold. Samples are made by mixing the three ingredients that have been weighed according to the composition into one plastic cup that has been prepared. The epoxy resin was mixed with the catalyst in a glass beaker placed on a magnetic stirrer. The first material entered is the resin then added with catalyst and lead acetate. After all three ingredients are stirred until evenly distributed, hemp fiber is added and then stirred again until homogeneous and then put into the sample mold. After that, pour the mixture of materials into the sample mold that has been prepared. Then, it is put into a fume hood (room temperature) and left for 5-24 hours until the sample hardens by its own.

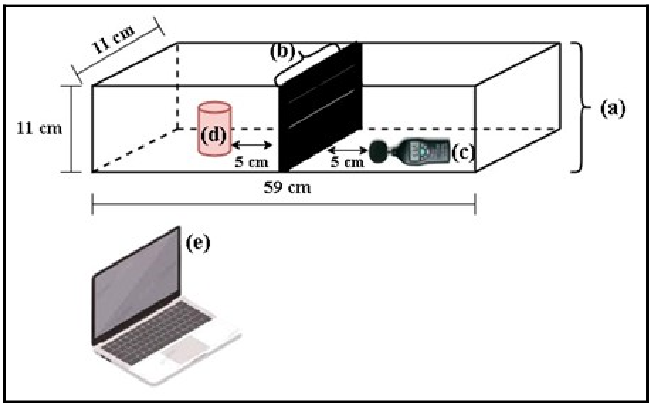

Figure 1. Design of the sound absorption coefficient test

Figure 2. Method of taking sound intensity data at different frequencies

The equipments used in the research are glass cutter, sound level meter (Exctech Instruments, Lo: 35-100 dB and Hi: 65-30 dB), bluetooth speaker (JBl Go 2), laptop with true tone software installed. The Materials used in this study are clear glass with a thickness of 3 mm, glass glue, acoustic board composite. The research testing room manufacturing methodology is to prepare tools and materials, namely glass, glass cutter and glass glue. The cutting of the glass, then designing the testing room with a length of 59 cm, a height of 11 cm and a width of 11 in Figure 4 and Figure 5 are the measurement methods for data collection. a (glass box), b (acoustic board), c (sound level meter), d (bluetooth speaker), and d (laptop).

The coefficient of absorption of the sample is measured after testing the sound intensity of the sample through the process of transmitting audio to the sample. The tools used are JBL Speakers using a Sound Level Meter detector. The samples tested in this study have 3 thickness variations, namely 1.11 cm; 1.145 cm and 1.178 cm. Testing was carried out using 4 frequency variations namely 250 Hz, 500 Hz, 800 Hz and 1000 Hz and test tone generatore software. In this test, the intensity of the source sound and the intensity of the sound after passing through the sample are known. The value of the sound intensity that has been obtained is used to find the absorption coefficient of the sample. The data obtained after testing using a Sound level Meter (SLM), after which the data is analyzed. Densities (ρ) are quantities in the ratio between the mass and volume of an object and (V) is the volume of the object. The mass (m) value is the mass of an object which is a measure of the amount of substance contained in an object. Densities are calculated using equation (1).

$$\rho = \frac{m}{V} \tag{1}$$

$$\alpha = \frac{\text{Ln } I_0 - \text{Ln } I_1}{x} \tag{2}$$

The calculated value is the measurement data of sound intensity before passing through the sample (I_0) and sound intensity after passing through the sample (I_1) obtained, can determine the value of the sound absorption coefficient using equation (2). The coefficient of sound absorption is α, I_0 is the intensity of sound before passing through the medium (dB), then I_1 is the intensity of sound after passing through the medium (dB) and x is the thickness of the absorbing medium (cm).

RESULTS AND DISCUSSION

The thickness of each sample occurs due to differences in concentration and addition of hemp fiber, epoxy resin and catalyst used. Calculating the volume of an object depends on the shape of the object for objects with simple shapes such as cubes. Objects with irregular shapes, volume can be measured using the grouping method. In this research, we did a simple measurement to determine the thickness of each sample by using a ruler. It can be seen that the thickness of the samples based on different material mixtures after synthesizing are in Figure 3 (x = 1.11 cm), Figure 4 (x = 1.145 cm) and Figure 5 (x = 1.178 cm). The epoxy resin is 80 grams for the composition of samples I (63.24%), II (61.30%) and III (59.48%). catalyst as much as 40 grams of sample I (31.62%), sample II 80 grams (30.65%) and sample III 40 grams (29.74%). The hemp fiber of 4 g, 8 g and 12 g in sample I (3.16%), II (6.13%) and III (8.92%), respectively.

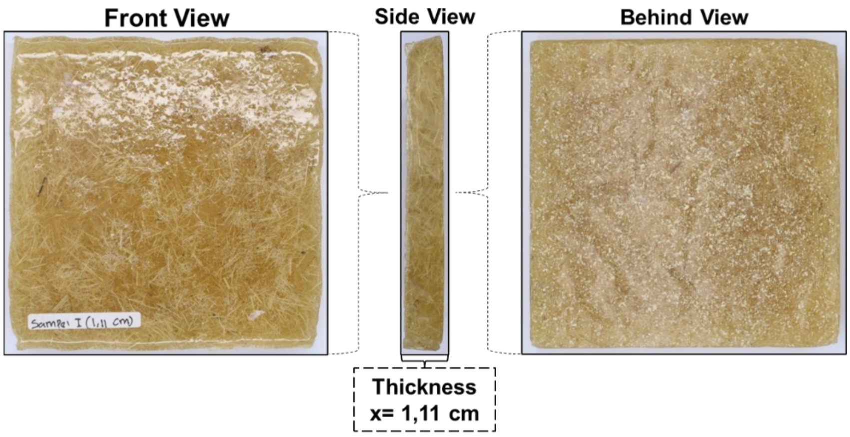

Figure 3. Acoustic board sample (I) with hemp fiber mass of 4 g and 80 g epoxy resin

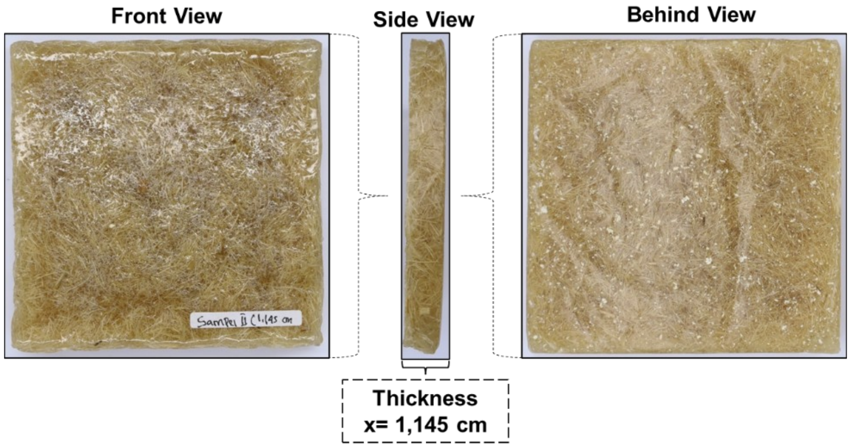

Figure 4. Acoustic board sample (II) with hemp fiber mass of 8 g and 80 g epoxy resin

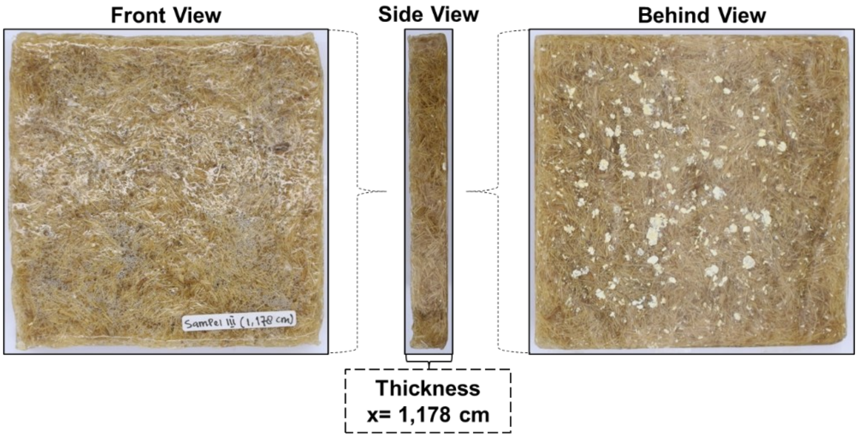

Figure 5. Acoustic board sample (III) with hemp fiber mass of 20 g and 80 g epoxy resin

The variation in composition and density of the material causes differences in density in each sample. Densities were found using equation (1). The value of density of the samples in composition I, II and III are 1.101 gr/cm^3 (Figure 3), 1.108 gr/cm^3 (Figure 4), and 1.116 gr/cm^3 (Figure 5), respectively. The hemp fibers used in compositions I, II and III are 4 g, 8 g and 12 g respectively. The more hemp fiber used, the greater the density of a sample. In more detail, the density (ρ) of each sample can be seen in Table 2.

Table 2. The density measurement results of the samples

Compositions	Mass (gr)	Volume (cm^3)	Density (gr/cm^3)
I	122.26	111.03	1.101
II	126.94	114.50	1.108
III	131.47	117.76	1.116

The absorption coefficient of a sample depends on the energy and material type of electromagnetic waves absorbed by the sample. In this research, 3 different types of composite thickness were used, namely 1.11 cm (Figure 3), 1.145 cm (Figure 4) and 1.178 cm (Figure 5) with each density value successively being 1.101 gr/cm^3; 1.109 gr/cm^3; 1.116 gr/cm^3. The sample absorption coefficient measurement is carried out to determine how much sound can be absorbed by the samples. Measurement of the absorption coefficient was carried out after testing the sound intensity using glass designed as a testing room with a length of 59 cm, width of 11 cm and height of 11 cm with 4 different frequency variations of 250 Hz, 500 Hz, 800 Hz and 1000 Hz. The value of the absorption coefficient is influenced by the thickness and density of the material. The absorption coefficient value is obtained using equation (2). The results of testing sound intensity and absorption coefficient with each frequency are shown in table 3 (250 Hz), table 4 (500 Hz), table 5 (800 Hz) and table 6 (1000 Hz).

Table 3. The measurement results of average sound intensity and absorption coefficient at a frequency of 250 Hz

Sample codes	Frequency (Hz)	I_0 (dB)	x (cm)	I (dB)			I_r (dB)	A (cm^{-1})	α_r (cm^{-1})
				I_1	I_2	I_3			
I	250	69.7	1.11	64.8	64.9	64.8	64.83	0.065	0.066
				64.2	64.2	64.1	64.17	0.075	
				65.2	65.2	65.3	65.23	0.060	
II			1.145	62.4	62.5	62.3	62.40	0.097	0.087

				63.8	63.8	63.7	63.77	0,078	
				63.1	63.1	63.1	63.10	0.087	
III			1.178	60.5	60.5	60.7	60.57	0.119	0.120
				60.7	60.8	60.8	60.77	0.116	
				60.2	60.2	60.2	60.20	0,124	

Table 4. The measurement results of average sound intensity and absorption coefficient at a frequency of 500 Hz

Sample codes	**Frequency (Hz)**	**I_0 (dB)**	**x (cm)**	**I (dB)**			**I_r (dB)**	**A (cm^{-1})**	**α_r (cm^{-1})**
				I_1	I_2	I_3			
I	500	74.2	1.11	71.4	71.4	71.1	71.30	0.036	0.036
				71.2	71.3	71.2	71.23	0.037	
				71.3	71.2	71.3	71.27	0.036	
II			1.145	70.2	70.3	70.1	70.20	0.048	0,047
				70.5	70.5	70.5	70.50	0.045	
				70.3	70.4	70.3	70.33	0.047	
III			1.178	69.3	69.1	69.3	69.23	0.059	0.055
				69.9	69.9	69.8	69.87	0.051	
				69.5	69.5	69.5	69.50	0.056	

Table 5. The measurement results of average sound intensity and absorption coefficient at a frequency of 800 Hz

Sample codes	**Frequency (Hz)**	**I_0 (dB)**	**x (cm)**	**I (dB)**			**I_r (dB)**	**A (cm^{-1})**	**α_r (cm^{-1})**
				I_1	I_2	I_3			
I	800	81.1	1.11	78.2	78.2	78.2	78.20	0.033	0.030
				78.7	78.8	78.7	78.73	0.027	
				78.5	78.5	78.5	78.50	0.029	
II			1.145	77.3	77.4	77.3	77.33	0.042	0.040
				77.4	77.2	77.3	77.30	0.042	
				77.6	77.8	77.7	77.70	0.037	
III			1.178	76.1	76.1	76.2	76.13	0.054	0.053
				76.5	76.6	76.4	76.50	0.053	
				76.4	76.5	76.4	76.43	0.053	

Table 6. The measurement results of average sound intensity and absorption coefficient at a frequency of 1000 Hz

Sample codes	**Frequency** (Hz)	**I_0 (dB)**	**x (cm)**	I (dB)			I_r (dB)	A (cm^{-1})	α_r (cm^{-1})
				I_1	I_2	I_3			
I	1000	107.	1.11	101.8	101.8	101.8	101.	0.047	0.047

						80		
			101.7	101.8	101.6	101.70	0.047	
			101.7	101.7	101.9	101.77	0.047	
II	2	1.145	99.5	99.6	99.5	99.53	0.065	0.068
			98.9	98.9	98.9	98.90	0.070	
			99.1	99.2	99.1	99.13	0.068	
III		1.178	98.3	98.2	98.1	98.20	0.074	0.073
			98.2	98.1	98.2	98.17	0.075	
			98.6	98.5	98.6	98.57	0.071	

The original sound intensity (I_0) at frequencies of 250 Hz, 500 Hz, 800 Hz and 1000 Hz is 69.7 dB, 74.2 dB, 81.1 dB and 107.2 dB. The sound intensity of the samples (I_r) obtained in compositions I, II and III can be seen in tables 3, 4, 5 and 6, respectively. Table 3 is the sound intensity of the sample (Ir) obtained successively for a frequency of 250 Hz is 71.267 dB; 70.344 dB and 69.533 dB. The Table is the result of measuring the average intensity (I_r) of sound absorption measurement and sound absorption coefficient of 0.066 cm^{-1}, 0.087 cm^{-1} and 0.120 cm^{-1}.

Table 4 shows the sound intensity (I_r) obtained successively for a frequency of 500 Hz is 71.267 dB; 70.344 dB and 69.533 dB. The values of absorption coefficient (α_r) in the above table are 0.036 cm^{-1}, 0.047 cm^{-1} and 0.055 cm^{-1}. Table 4 shows that the greater the mass of hemp in a sample, the smaller the sound intensity that penetrates the sample. Table 5 presents the sound intensity of the sample (Ir) obtained as 71.267 dB, 70.344 dB and 69.533 dB for a frequency of 800 Hz, respectively. The coefficient of absorption successively obtained values of 0.036 cm^{-1} 0.047 cm^{-1} and 0.055 cm^{-1} shown in Table 5. In addition, the table shows that the thicker the sample used, the greater the absorption coefficient or it can be said that the absorption coefficient is directly proportional to the thickness of the sample.

Table 6 shows the sample sound intensity (I_r) obtained in compositions I, II and III are 101.756 dB, 99.189 dB and 98.311 dB, respectively. The table shows that the greater the mass of hemp in a sample, the smaller the sound intensity that penetrates the sample. The coefficient of absorption successively obtained a value of 0.047 cm^{-1}, 0.068 cm^{-1} and 0.73 cm^{-1}. The result of the measurement is the average value based on the pattern of equation (2). Figure 6 shows that the higher the frequency used for each sample used, the coefficient of absorption (α) will also be greater or it can be said that the coefficient of absorption is directly proportional to the thickness of the sample from the value of the absorption coefficient obtained, it can be concluded that at a frequency of 250 Hz, 500 Hz, 800 Hz and 1000 Hz all variations in thickness.

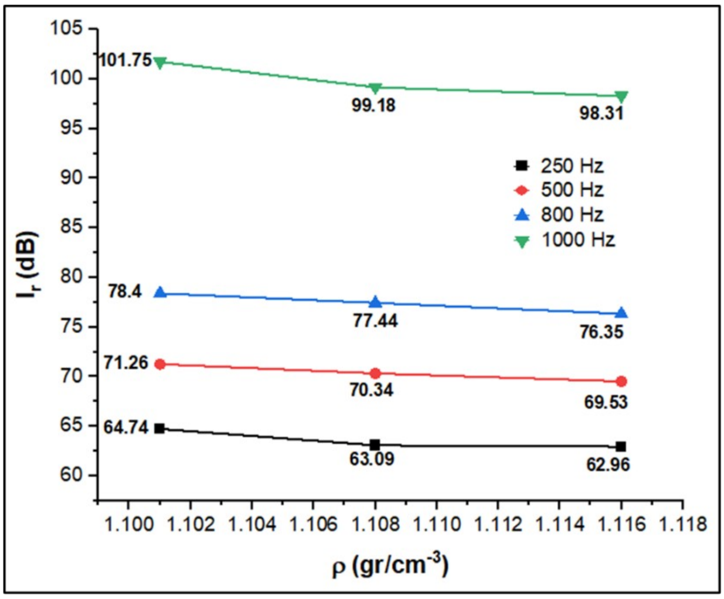

Figure 6. Graph of the relationship between density (ρ) and the average intensity of sound at different frequencies

Figure 6 shows the average value of sound intensity by each different density. The frequency of the sound wave has an effect on each different density. As the frequency of the sound used increases, the intensity of the sound increases and the higher the density, the lower the frequency value. Figure 6 shows that the greater the mass of hemp in a sample, the smaller the intensity of sound that penetrates the sample.

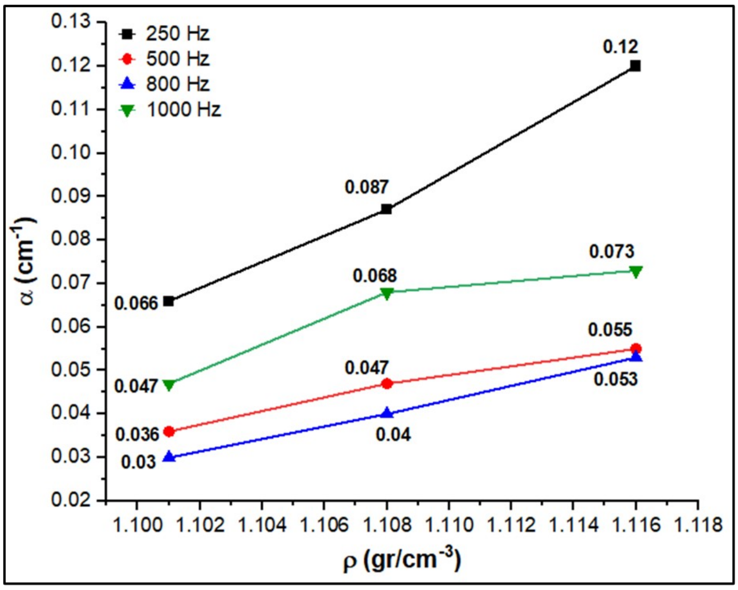

Figure 7. Graph of the relationship between density (ρ) and sound absorption coefficient at different frequencies.

Figure 7 shows that none of the samples meet the ISO 11654 standard, where the ISO 11654 standard states that a material is said to absorb sound well when the absorption coefficient value is greater than 0.15 ($\alpha > 0.15$). It was explained by (Gumanová et al., 2022) in his research that the greater the value of α, the better the sound absorption and attenuation. The values of α range from 0 to 1. If α is 0, it means that the sound is not absorbed. If the value of α is more than 0 but less than 1, it means that some of the sound is absorbed and some is reflected or forwarded. When α is 1, the sound is completely absorbed.

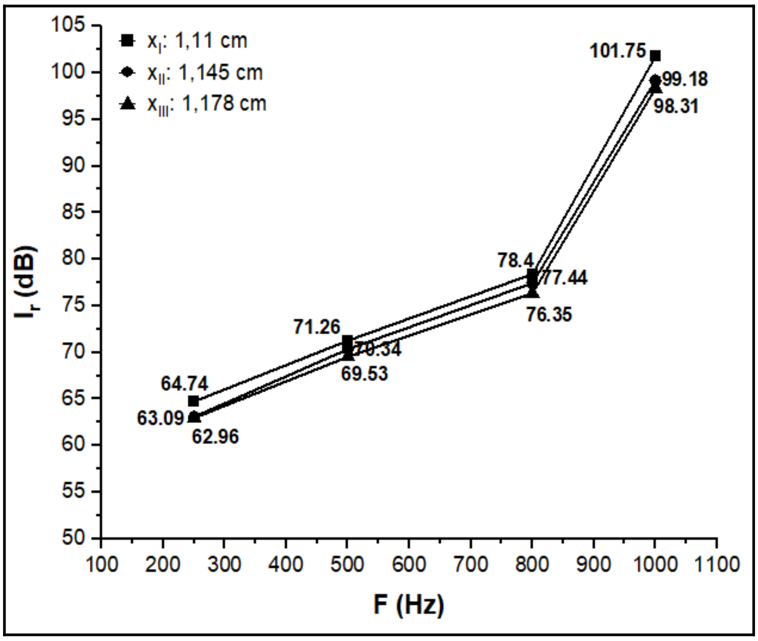

Figure 8. Graph of the effect of frequency on sound intensity at all thicknesses

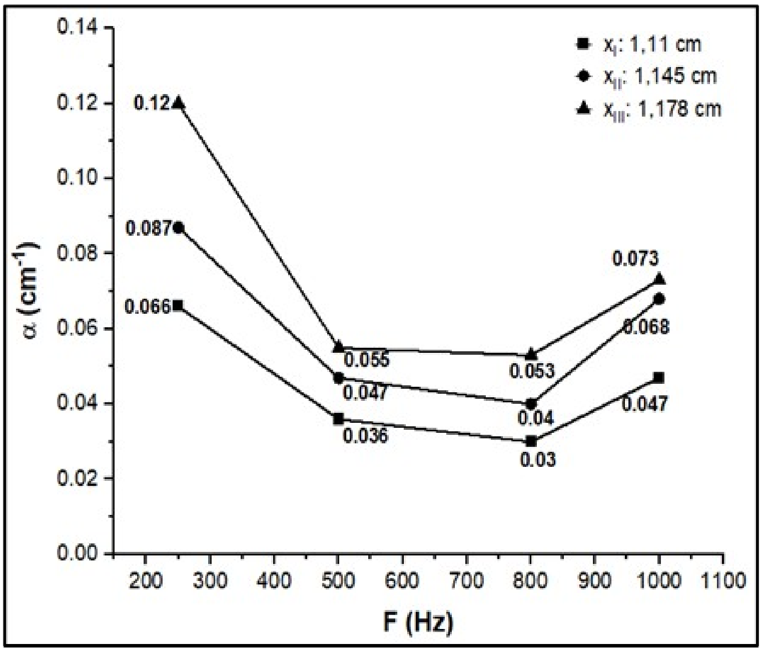

Figure 9. Graph of the effect of frequency on the absorption coefficient at all thicknesses

Figure 8 shows the value of frequency against the intensity of the sound produced based on the overall thickness of the sample. Research similar to that by (Putra, 2020). In his research using palm trunk waste as a base material for sound absorbing boards using 4 thickness variations, namely 3 mm, 6 mm, 9 mm and 15 mm. The sound absorbing test results at a frequency of 500 Hz increased as the thickness of the sample increased. The increasing coefficient is caused by sound vibrations entering the thicker sample so that the absorption is greater.

Figure 9 shows the relationship graph of all data at each frequency and thickness. The graph shows the same thing where every increase in thickness will increase the absorption coefficient. The graphic also shows that the highest absorption coefficient is obtained at a frequency of 250 Hz and the lowest absorption coefficient is obtained at a frequency of 800 Hz. The overall measurement data of the absorption coefficient of the sample shows that the addition of jute fiber will increase the absorption coefficient of the sample. The increase of hemp fiber and epoxy resin is directly proportional to the absorption coefficient. All of the existing compositions with the highest absorption coefficient at each frequency are in composition III with a density of 1.116 gr/cm^3. The absorption coefficients at frequencies of 250 Hz, 500 Hz, 800 Hz and 1000 Hz are 0.12 cm^{-1}, 0.055 cm^{-1}, 0.053 cm^{-1} and 0.073 cm^{-1} respectively. Of the four frequencies, the highest absorption coefficient is obtained at a frequency of 250 Hz.

According to the provisions of ISO 11654 in 1997 on sound absorption rating standards to be used has six categories A, B, C, D, E and unclassified. The A category has an absorption coefficient of (0.90-1.00) cm^{-1}, B (0.80-0.85) cm^{-1}, C (0.60-0.75) cm^{-1}, D (0.30-0.50) cm^{-1}, E (0.15-0.25) cm^{-1} and the unclassified category <0.15. When the material has a sound absorption coefficient of 0.15, it can be said that the material is a sound-absorbing material. Among the three sample compositions that have been tested, composition III is the most optimal sample in absorbing sound. However, based on the provisions of ISO 11654 in 1997 regarding the standard sound absorption rating, it is known that no one has met the standard.

CONCLUSION

The most optimum composition of the absorber sample with hemp fiber and epoxy resin is composition III, which uses 12 grams of hemp fiber, 80 grams of epoxy resin, 40 grams of catalyst with a sample thickness of 1.178 cm because the composition has the highest density and thickness. The samples with this composition are able to absorb sound intensity of 0.12 dB at a frequency of 250 Hz, absorb sound intensity of 0.05 dB at a frequency of 500 Hz. At the frequency of 800 Hz and 0.07 dB sound is absorbed at a frequency of 1000 Hz. Hemp fiber and epoxy resin based composites are less than optimal in absorbing sound so that composites with these materials cannot be used as acoustic boards.

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