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The Effect Of Epoxy Resin Ratio And Sugar Cane Bagasse Particle Dimensions On The Effectiveness Of Noise-Reducing Materials

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Abstract: Noise pollution adversely affects human health and the environment. Bagasse waste has the potential to be developed as an environmentally friendly sound-absorbing material. This study investigated the effects of epoxy resin content and bagasse particle size on the acoustic performance of bagasse-based composites. The composites were fabricated using epoxy resin-to-bagasse ratios of 10:40, 10:50, and 10:60 g, with particle sizes of 16, 20, and 30 mesh. Sound absorption was evaluated using a PVC impedance tube (100 cm long, 15 cm in diameter) at frequencies ranging from 50 to 1000 Hz, with specimens positioned 50 cm and 75 cm from the sound source. The results indicate that both resin ratio and particle size significantly influence composite density and sound absorption performance. The highest density (0.78 g/cm³) was obtained with the 10:60 g composition at 20 mesh, while the lowest density (0.54 g/cm³) was recorded for the 10:40 g composition at 16 mesh. The best acoustic performance was achieved by the 10:60 g composite with 30-mesh particles, exhibiting a sound absorption effectiveness of 10% at a distance of 50 cm from the sound source.

Keywords: Noise, bagasse, composite, epoxy resin, acoustic materials.

Introduction

Noise is an environmental problem that is often overlooked. Several studies have shown that noise can affect an individual's quality of life. Prolonged exposure to high-intensity noise can cause various negative impacts, especially on health [1] [2]. A number of large cities have made noise an environmental issue that is significantly related to increased human activities such as motorized vehicle traffic, construction projects, industrial activities, and crowds in entertainment centers [3] [4]. Noise is the occurrence of unwanted sound that is disturbing and dangerous to health [5]. Noise is expressed in a logarithm, namely decibels (dB), where sound intensity is used as a parameter in determining whether a sound is categorized as noise or not. Noise occurs at a sound intensity of around 85 dB. Meanwhile, humans have a hearing limit in the range of up to 140 dB, more than that will cause damage to the organs in the eardrum [6]. The higher the frequency, the more sound waves occur in a unit of time and the sound tone is heard higher [3]. Discomfort in the sense of hearing due to high frequency or sound intensity can damage hearing and psychological functions in humans such as decreased comfort, concentration, and stress on the heart's working system [7].

One way to reduce noise is by using sound-absorbing materials, also known as acoustic materials [8]. In industrial applications, a number of materials are widely used for noise control, such as glasswool, rockwool, and so on. These materials are suspected of having drawbacks, such as a high carbon footprint, operational hazards such as allergies, or the potential to trigger respiratory disorders [9]. Based on this, various studies have been conducted to create alternative noise control materials that are more environmentally friendly and biodegradable [10]. In addition to ecological benefits, the use of natural fibers is based on the permeability of porous materials with strong

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lignocellulose content and resistance to decay. For this reason, the use of natural fibers is chosen as a substitute for synthetic materials for noise control. As is widely known, bagasse is a waste product from the sugar processing process, the utilization of which is less than optimal. Sugar production is abundant each year, so approximately 35–40% of the total weight of milled sugar cane can be recovered. The selection of bagasse as an alternative noise-dampening material is based on its beneficial characteristics. Bagasse contains 90% carbon and 10% silica, resulting in the carbon chains that form cellulose fibers, which play a crucial role in sound absorption [11] [12].

Composites are materials composed of two main elements: a matrix and a filler. The matrix acts as a binder and the filler acts as a filler, enabling it to function effectively against various forces. One type of matrix commonly used in composites is natural fibers, with epoxy resin as a filler [13]. Research on composite materials as noise dampers has been conducted, but acoustic panel samples were made from meranti wood fibers with variations in sheets and fiber lengths. The results showed that the highest sound absorption coefficient value was 0.95 at a frequency of 1000 Hz with a width and length of 0.5 cm and 2 cm. The highest acoustic impedance value was 1.79 at a frequency of 1000 Hz with a small width of 0.5 cm. Research on materials as noise dampers is often carried out by varying the length and width of the fibers to be tested, while this research was conducted by varying the density of the bagasse samples, because the sound absorption coefficient of the material can be increased with different densities. The research will be conducted by varying the density, namely 0.38 g/cm³, 0.44 g/cm³, 0.57 g/cm³, and 0.62 g/cm³. The method used in this research is the tube method [14]. Based on the description above, it is necessary to conduct research on noise-reducing composite materials using bagasse waste with variable compositions between bagasse particles and epoxy resin.

Method

Framework of Thought

The framework of this research is shown in the following figure:

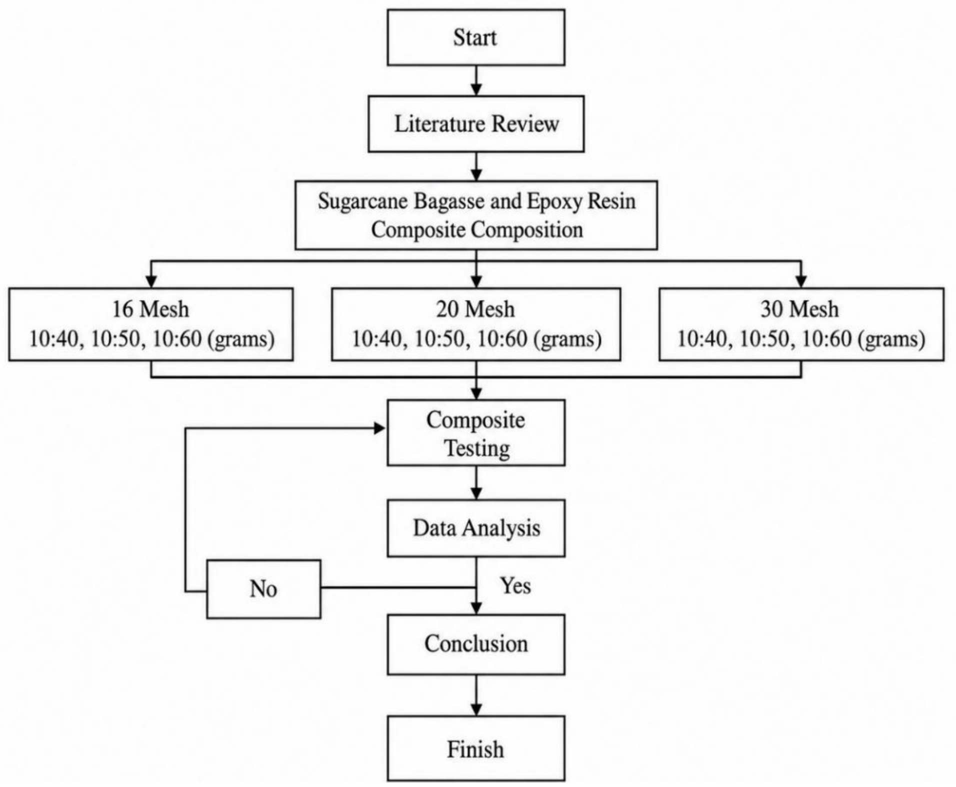

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Figure 1. Research framework

The research phase began with a literature review of research journals and books, both online and offline. This was followed by media preparation and the creation of a sound-damping composite using an epoxy resin mix ratio. The variations used were mesh sizes of 16, 20, and 30, with mix ratios of 10:40, 10:50, and 10:60 grams. The prepared sound-damping media was then tested on a laboratory scale to determine the noise reduction data.

Composite Manufacturing Procedure

1.Preparation of tools and materials for collecting bagasse.
2. The bagasse was sorted to select even, intact pieces, then washed with water until clean. Then, it was soaked in HCl (7 liters of water to 50 ml of HCl) for 2 hours, then rinsed with water and dried in the sun.
3.Once dry, the bagasse was chopped, blended, and meshed.
4. The composite specimen volume was measured using the ratio of resin to bagasse fiber in grams to determine the mass of the bagasse particles based on the specimen volume, using the following equation:
5. $V = \pi \times r \wedge 2 \times t$

Where:
V = cylinder volume (cm3)
π = pi constant (3.14)
r = radius of the base of the cylinder (half the diameter)
t = height of the cylinder

6. The mass-weight ratio between bagasse particles, epoxy resin, and hardener was measured using a scale for each composition variation.
7. Before mixing with the bagasse, the epoxy resin and hardener were mixed in a 1:1 ratio and then stirred thoroughly.
8. The composite manufacturing process uses the hand lay-up method, where bagasse particles are mixed with resin and hardener, manually stirred using a spoon until evenly distributed in the container.
9. After the mixing process is complete, the composite composition is weighed again to determine the weight of each component.
10.Before the composite molding process, the composite mold is lubricated with wax.
11. The composite is then removed from the mold and allowed to dry for 24 hours.
12.After 24 hours, the composite's weight and thickness are measured.
13 Before testing, the composite is adjusted to fit a 15 cm diameter PVC pipe. After that, the specimen can be tested.

Sound Absorption Test Equipment Schematic

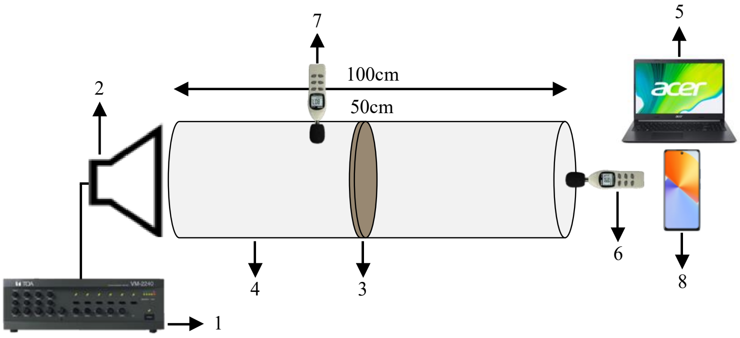

Figure 2. Sound absorption test equipment schematic

The tools used in this study include 1. An amplifier functions as a sound amplifier with a capacity of up to 90 dB and is used to operate 6, 8, 10, and 12-inch speakers. 2. The speakers used are 6 inches in size with a sensitivity

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level of 89 dB. 3. The specimen is a circular sound-absorbing composite with a diameter of 15 cm and a thickness of 0.5 cm. 4. An impedance tube made of PVC material and used as a sound absorption test tool with a length of 100 cm, an inner diameter of 15 cm, and a wall thickness of 5 mm. 5. A laptop is used as a video player from the YouTube platform that produces sound frequencies in the range of 50 Hz to 1000 Hz. 6. A sound level meter is used to measure the intensity of transmitted and reflected sound, with a measurement range of 30–130 dB, and is placed at a distance of 10 cm from the specimen during the testing process. 7. The recording camera uses the Infinix Note 30 smartphone camera to document the testing process while recording sound intensity measurement data.

Morphological Test Tool Scheme

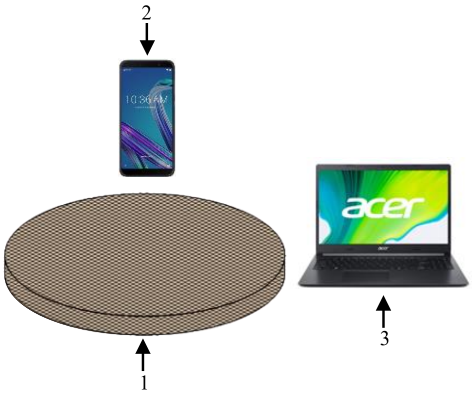

Figure 3. Schematic of morphological test equipment

The morphology image capture scheme of the bagasse particle composite surface is shown in Figure 3, where 1 shows the test specimen in the form of a bagasse particle composite used as a test object. 2. A mobile phone is used as a camera to document and take pictures of the composite surface after the testing process. 3 A laptop is used to analyze the composite photo results using ImageJ software to obtain the necessary data according to the testing parameters.

Visualization of Specimen Morphology by Light Scattering Method

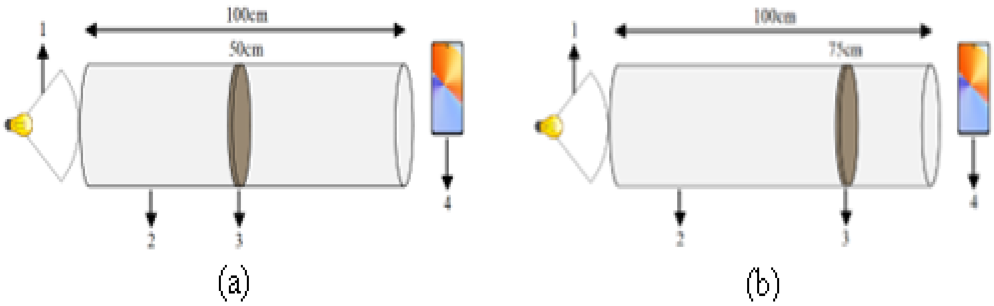

Figure 4. Schematic visualization of specimen morphology using the light scattering method: a) specimen at a distance of 50 cm, and b) specimen at a distance of 75 cm.

The schematic of the gap image capture on the noise-dampening composite specimen is shown in Figure 4. The test was conducted using a 10 Watt LED lamp (950 lumens) as a light source mounted on one end of the impedance tube. The composite specimen with a diameter of 15 cm and a thickness of 0.5 cm was mounted on the impedance tube, then the presence of gaps in the specimen was observed based on the light that passed through the joint side. The entire process was documented using the Infinix Note 30 smartphone camera as data for further analysis.

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Results And Discussion

The following are the results of the composite fabrication in this study, which will then be used as test specimens to evaluate their physical and acoustic characteristics. Next, the specimens will undergo a series of tests, including sound absorption coefficient testing using an impedance tube, surface morphology observation using ImageJ software, and gap observation in the specimens. The results of the composite fabrication used as test specimens are shown in Figure 4.

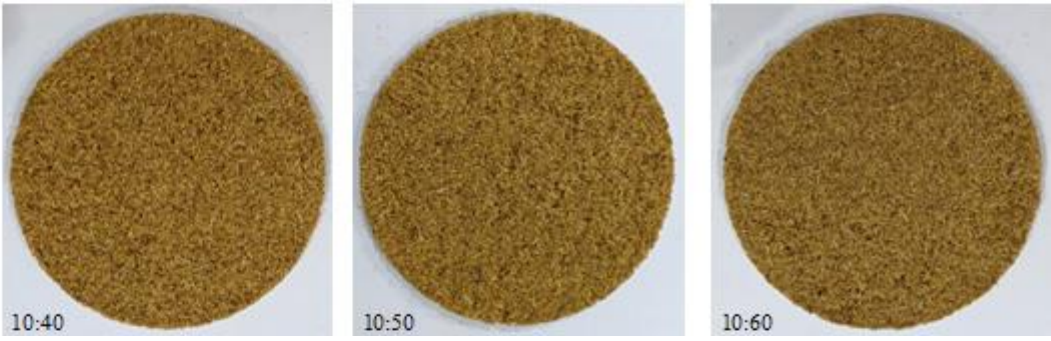

Figure 5. Physical Form of Composite

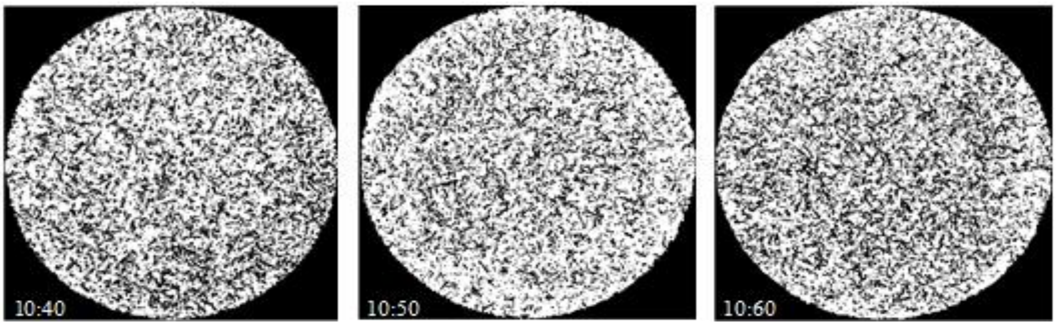

Figure 6. Test results of composite mesh 16

Visually in Figure 5, with the use of an increasing epoxy resin mixture ratio, the bagasse particle size appears smaller. So the addition of epoxy resin makes the composite have a smaller average pore size value. In addition, differences in mesh size also affect the density of the material, the larger the powder size, the lower the density, this is in accordance with Table 1, the results of surface morphology processing.

Table 1. Data from composite morphology processing results using image-J software.

Mesh	Rasio ampas tebu dan resin *epoxy* (g)	Total area (mm)	Average size (mm)
	10:40	2071,76	2449,40
16	10:50	1863,54	2469,96
	10:60	1978,08	2454,25
20	10:40	2050,26	2461,94

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	10:50	1882,73	2491,87
	10:60	1943,20	2484,00
	10:40	1915,26	2487,14
30	10:50	1987,19	2497,53
	10:60	1937,69	2480,43

Sound Absorption Coefficient Graph (Specimen Distance: 50 cm)

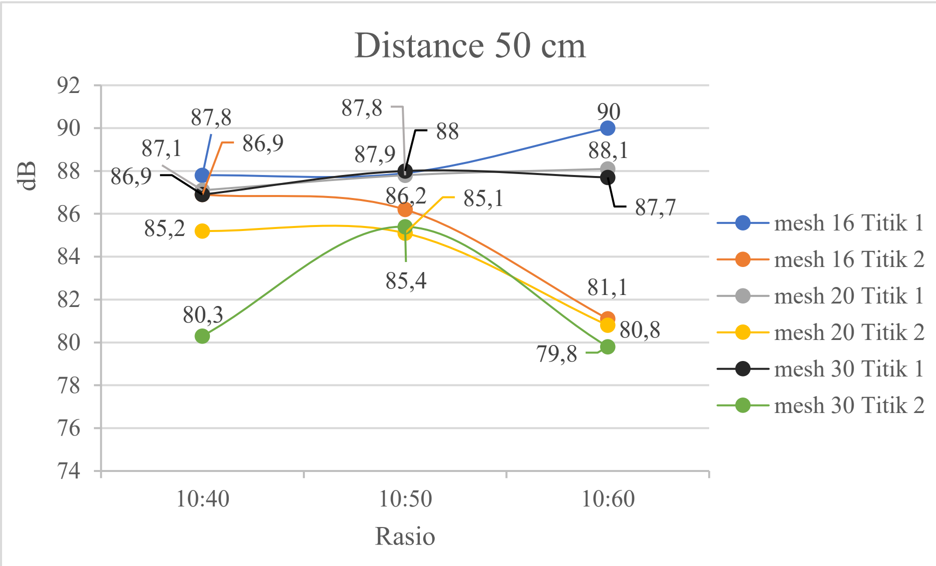

Figure 7. Graph of sound absorption coefficient at a specimen distance of 50 cm.

The graph above shows the sound absorption coefficient of a bagasse and epoxy resin composite at a distance of 50 cm with varying mesh sizes (16, 20, and 30) and mix ratios (10:40, 10:50, and 10:60). Point 1 shows the reflected sound, while point 2 shows the transmitted sound. At mesh 16, the 10:60 ratio produces a reflection of 90 dB and a transmission of 88.1 dB, indicating an increase in sound absorption with increasing resin content. Mesh 20 shows a similar trend, but with slightly lower absorption values. Meanwhile, mesh 30 at a 10:60 ratio provides the best results with the lowest transmission value of 79.8 dB and a reflection of 87.7 dB, indicating that finer particles can improve the composite's sound absorption capacity.

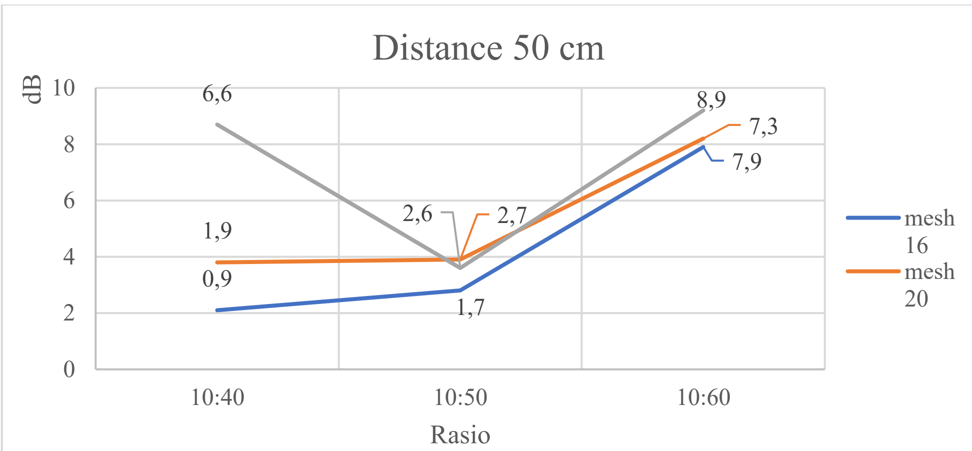

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Figure 8. Graph of average sound absorption coefficients for composition variations at a distance of 50 cm.

The graph above illustrates the average sound absorption values across varying mixture ratios (10:40, 10:50, and 10:60) and sugarcane bagasse particle sizes (16, 20, and 30 mesh) at a distance of 50 cm from the sound source. For the 16-mesh size, the sound absorption value rose from 0.9 dB (10:40) to 1.7 dB (10:50), then increased significantly to 7.9 dB (10:60). A similar pattern was observed for the 20-mesh size—with values of 1.9 dB, 2.7 dB, and 7.3 dB—indicating that increasing the epoxy resin content enhances sound absorption capability. For the 30-mesh size, the sound absorption value was 6.6 dB (10:40), dropped to 2.6 dB (10:50), and subsequently rose to 8.9 dB (10:60). The decrease observed at the 10:50 ratio indicates that the relationship between resin content and sound absorption capability is not always linear. This phenomenon is attributed to non-homogeneous resin distribution, which caused some pores to become blocked, thereby reducing the effectiveness of sound energy dissipation. At the 10:60 ratio, the resin distribution became more uniform, resulting in a more homogeneous composite structure and improved sound absorption capability.

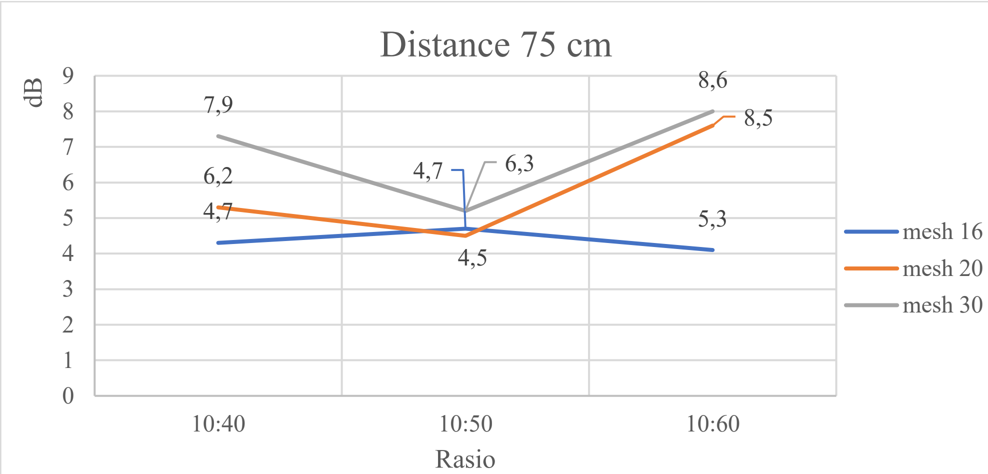

Figure 9. Graph of the average value of the sound absorption coefficient of composition variations at a distance of 75 cm.

The graph above shows the average sound absorption coefficient at various mixture ratios (10:40, 10:50, and 10:60) and bagasse particle mesh sizes (mesh 16, 20, and 30) at a distance of 75 cm from the sound source. At mesh 16, the sound absorption value is relatively low and stable, namely 4.7 dB (10:40 and 10:50) and increases to 5.3 dB (10:60), which indicates that the sound absorption capacity is still limited. At mesh 20, the sound absorption value increases from 6.2 dB (10:40) to 8.5 dB (10:60), although it drops to 4.5 dB at a ratio of 10:50. Meanwhile, mesh 30 provides the best performance with absorption values of 7.9 dB (10:40), 6.3 dB (10:50), and reaches 8.6 dB (10:60). These results show that the finer the particle size and the higher the resin ratio, the better the composite's ability to absorb sound waves.

Conclusions

Based on the results of this study, increasing the epoxy resin content in the composites led to an increase in density values. A mixture composition of 10:60 grams across mesh sizes 16, 20, and 30 yielded relatively uniform density values, whereas the lowest density (0.54 g/cm³) was observed with mesh size 16 and a 10:40 gram composition. This indicates that higher epoxy resin ratios and finer particle sizes tend to increase composite density. Furthermore, acoustic testing at a distance of 50 cm revealed that increasing the epoxy resin ratio to 10:60 enhanced sound absorption capacity, with the best performance achieved at mesh size 30. These findings suggest that finer particle sizes and higher resin content provide greater effectiveness in absorbing sound waves. Meanwhile, in tests conducted at a distance of 75 cm, mesh size 16 exhibited the highest absorption coefficient at a 10:50 ratio, whereas

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mesh sizes 20 and 30 achieved optimal performance at a 10:60 ratio. These results demonstrate that the use of finer particle sizes and higher epoxy resin ratios contributes to an increased sound absorption coefficient by reducing

transmitted sound intensity. This study was limited to specific variations in particle size, mixture ratios, and testing distances. Therefore, future research should evaluate a broader frequency range, varying composite thicknesses, and different types of matrices or binders, as well as conduct microstructural characterization using SEM to gain a more comprehensive understanding of the sound absorption mechanisms in sugarcane bagasse-based composites.

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