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Original Article

Development and Characterization of Mechanical and Acoustic Properties of a Corn Husk/Fly Ash Hybrid Composite Board

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Abstract *- This study focuses on the development of an acoustic hybrid composite that will be used as a sound absorber using corn husks obtained from maize, fly ash from coal and polyester resin. Corn husks were pre-treated using 5% hydroxide before being used in the fabrication of the composite, and fly ash was only moistened using distilled water. The fabrication of the composite was carried out using the hand-laying method. Three different samples were fabricated, with sample A having 30% corn husks, 20% fly ash, and 50% polyester resin, sample B with an equal ratio of corn husk and fly ash of 25% and polyester being 50%. Sample C has 20% corn husks, 30% fly ash, and 50% polyester resins. These percentages were in terms of mass fractions. Different tests were carried out, including sound absorption test, compression strength test, flexural strength test and water absorption test. Both the fabricated samples showed good sound absorbance, with good results obtained from the one with a high mass fraction of corn husk.*

Keywords *- Composite, Corn husk, Fly ash, Mechanical strength, Flexural Strength.*

1. Introduction

In many parts of the country, especially in urban areas, corn husks are either left to rot or burn. The problem with burning corn husks is that they pose health and environmental hazards [1]. The smoke from corn husks irritates the eyes, and the smell of burned corn husks induces breathing difficulties. When dumped along roads, heaps of corn husks become eye sores. These heaps of corn husks would be there for a long time as they decompose very slowly. Furthermore, the high rate of deforestation in recent years has motivated research into alternative sources of raw materials for the manufacture of boards [2]. Utilization of natural agricultural by-products in composite materials can minimize adverse environmental impacts [3,4,5]. The use of natural fibres has the advantages of low cost, low density, recyclability and good processability [6, 7]. Fly ash is a coal combustion residue after burning pulverized coal at elevated temperatures [8]. Fly ash is a heterogeneous material that consists of amorphous alumina silicate spheres, trace amounts of iron-rich spheres, crystalline phases, and small quantities of unburned carbon [9]. About 900 million tonnes of fly ash are produced around the globe, with a small fraction of about 30 to 40% of them being used for value-added products [10]. Humans face the following potential risks from an increase of fly ash exposure and if improper disposal of fly ash waste continues. Cancer risks are due to arsenic exposure from contaminated drinking water, genetic damage due to high exposure to fly ash, and respiratory and cardiovascular health effects due to prolonged exposure to fly ash [11, 12]. Composite materials manufactured from corn fibre have gained increased attention from researchers [13]. Some researchers have established that corn husk fibre composites with polymer matrix composites have an absorption coefficient of 0.8-0.9 at a frequency of 2 kHz [14]. The fibrous sound absorbing materials have been extensively investigated. Veerakumar and Selvakumar studied the properties of composite made from kapok fibre with polypropylene fibre, which were found to demonstrate good sound absorption behaviour in the frequency range 250 – 2000Hz. Zulkiflii (2010) [13] investigated the effect of the porous layer backing and a perforated panel on the sound absorption coefficient of coconut fibre. They indicated that increasing the thickness material of the panel will improve the sound absorption ability, especially in the low-frequency range of 600 – 2400Hz [15] . These previous studies showed that a better understanding of the microstructure and physical properties of corn husk material could help develop high-performance acoustic materials [16]. This study aims to develop a hybrid composite for absorption and mitigation of noise. Compared with conventional sound absorber materials, the developed sound absorber is made from corn husk and fly ash. Corn husk and fly ash are part of industrial waste materials; thus, they provide a cheap source of raw materials. In addition, the effects of fibre and particle content on the tensile, flexural and compression have been analyzed. The results of this study could contribute to engineering applications, especially as sound absorbers.

2. Materials and Methodology

2.1. Research Framework

The methodology of this study involved the extraction of corn husk fibres and chemical treatment with NaOH. Chemical treatment has been shown to increase the mechanical properties of cellulose based fibres [17, 18]. After that, a composite was fabricated from the corn husk, fly ash and polyester resin according to the experimental design. The fabricated composite material was then characterized with a focus on the mechanical and sound absorbance properties. Figure 1 below shows the research framework that was followed.

2.2. Raw Materials

Corn husk is the main material used in the study. The corn husk fibre contains cellulose, hemicellulose, and lignin. Prior to use, corn husk was treated with 5% sodium hydroxide (NaOH) for 2 hours to remove the impurities on the fibre surface. The corn husk fibres were then rinsed thoroughly with distilled water. The fibres were then dried in an oven at 40 ℃ to remove residual moisture and preserved them in preparation for composite fabrication.

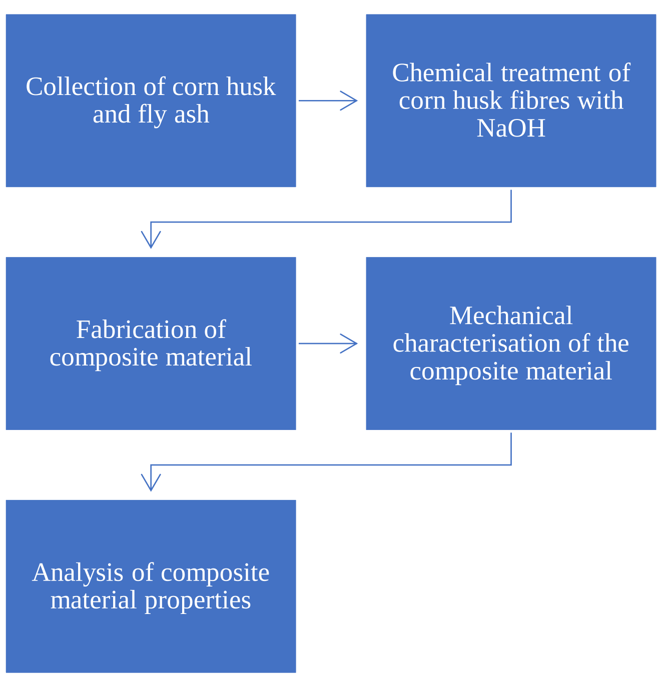

Fig. 1 Research framework followed in the study

2.3. Composite Fabrication

A mould made from a galvanized iron sheet of 200 mm in length and 200 mm was used for composite fabrication. A release film was applied to aid in the demoulding process. The general-purpose polyester resin and catalyst were then mixed in a ratio of 100:1. The composite was then fabricated using the hand lay-up method according to the experimental design shown in Table 1. The composite was allowed to cure for 24 hours before demoulding. The experiment was repeated 3 times for each design. Figure 2 shows some of the samples of the fabricated composites.

Table 1. The experimental design followed

Sample	Corn Husk Fibre (M_f %)	Fly Ash (M_f %)	Polyester Resin (M_f %)
A	30	20	50
B	25	25	50
C	20	30	50

Fig. 2 Three fabricated samples

2.4. Mechanical Characterization

Mechanical characterization of the composite was carried out. This included water absorption, flexural, compression strength, and sound absorbance. The methodology followed is outlined in the subsequent subsections.

2.4.1. Water Absorption Test

Water absorption tests were carried out according to ASTM D570 by immersing the composite in a deionized water bath at 25 ℃. Firstly, the composite was weighed before immersion. After immersion for 48 hours, the specimens were taken out from the water and all surface water was removed using a clean, dry cloth. The specimens were reweighed to the nearest 0.1 mg within 1 minute of removing them from the water, and the results were noted.

2.4.2. Flexural Strength Test

Flexural tests were carried out using the three-point loading method. The flexural strength was calculated using Equation 1.

$$F_{ct} = \frac{PL}{bd^2} \qquad (1)$$

Where F_{ct} is the flexural strength, P is the breaking load, L is the space between supports, b is the beam width, and d is the beam depth. The results were calculated and recorded as the flexural strength of the test sample to the nearest 0.05MPa. The results were considered valid if the difference between the highest and lowest did not exceed 15% of the average.

2.4.3. Compression Test

Compression strength was carried out in accordance with ASTM D6641 using a Combined Loading Compression (CLC). The loading rate of the machine was calculated for each sample by multiplying the sample depth by the length of the sample and by 18, which was the MPa factor of the machine. The compression force was recorded from the machine, and compression strength was calculated using Equation 2.

$$Compression\ strength\ (MPa) = \frac{compression\ force\ (KN)}{correction\ factor} \qquad (2)$$

Where the correction factor of the machine was 1.4

2.4.4. Sound Absorbance Test

The sound absorbance test was carried out by producing a constant pitch sound of 440Hz. The sound was channelled through an impedance tube, as shown in Figure 3.

The samples were then placed in front of the impedance tube. A microphone was placed in front of the sample to take readings of the signal passing through the sample. The microphone was connected to the oscilloscope, which transforms the signal into a sign wave graph.

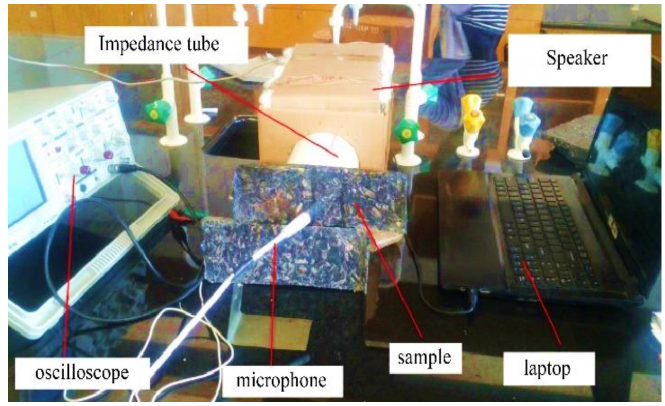

Fig. 3 The set up of sound absorbance test

The microphone was moved throughout the sample, noting the behaviour of the composite in different places. The results were obtained in the form of sine wave graphs where the x-axis was time and the y-axis was voltage. The speaker was enclosed in a box covered with cotton to reduce sound lost into the air. Therefore, the sound was directed straight to the impedance without much sound lost.

3. Results and Discussion

3.1. Water Absorption

The results obtained from the water absorption test are shown in Table 2. The tabulated values of water absorption indicate that the effect of the mass fraction of corn husks drastically reduces the percentage of water absorbed by the composite. It can also be seen that the composite with a low mass fraction of corn husks has lower water absorption than that with a high mass fraction of corn husks.

This may be due to the hydrophilic nature of corn husks. The sample with many corn husks will have a high hydrophilic coefficient, implying it absorbs more than the one with a few corn husks. Therefore, these results showed that sample A has higher water absorbance, followed by sample B and sample C.

3.2. Flexural Strength

Flexural strength results were calculated and recorded, as shown in Table 3.

Table 2. Water absorption results

Samples	M_f corn husks (%)	M_f Fly ash (%)	M_f Polyester (%)	% Water Absorption
A	30	20	50	4.17
B	25	25	50	2.97
C	20	30	50	1.81

Table 3. The Results for flexural strength

Sample	Breaking load (N)	Flexural strength (MPa)
A	280	0.73
B	297	3.10
C	306	0.80

The samples did not flex significantly. They behaved more like brittle materials. In brittle materials, the outer layers are extended, and the inner layers are compressed, but the plane in the centre, known as the neutral plane, will remain unchanged. The fracture can be brittle if it follows a common fracture break of glass fibres. The fracture growth begins with an elastic crack and can, therefore, be referred to as elastic-crack-growth fracture. The composite containing 25% corn husk and 25% fly ash had the highest flexural strength. This finding is consistent with results by Boynard et al. (2003), who reported a high flexural strength with samples containing a high percentage of corn husk fibre [19].

3.3. Compression Strength

The results of the compression strength test are shown in Table 4. It was observed that with an increase in the percentage mass fraction of fly ash from 20% to 25% and from 25% to 30%, the compression strength increased. It increased sharply with approximately a percentage of 6.7% from 25% to 25% and a rapid increase of 27% from 25% to 30%. The compression strength in the study increased with the mass fraction of fly ash. Overall, sample A has higher compression strength, followed by sample B and then sample C. The Increase in the thickness also results in high compressional strength, thereby providing better absorption of the wave and reflecting less energy.

Table 4. The results for compression strength

Sample	M_f cornhusk (%)	M_f fly ash (%)	M_f polyester (%)	Force (KN)	Compression (MPa)
A	30	20	50	193.7	140.9
B	25	25	50	210.6	150.4
C	20	30	50	269.4	192.0

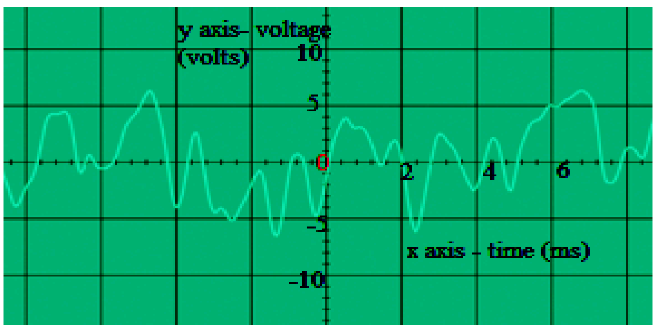

Fig. 4 The sound absorption graph for sample A

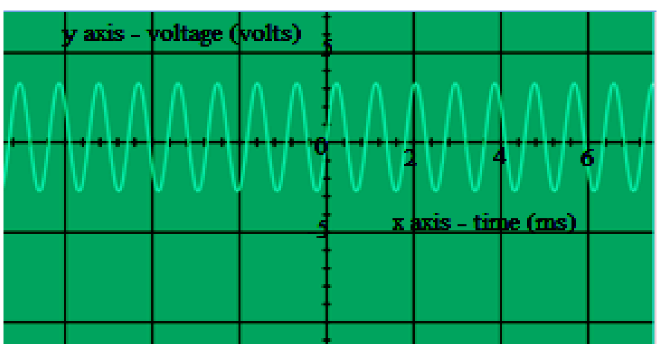

Fig. 5 The sound absorption graph for sample B

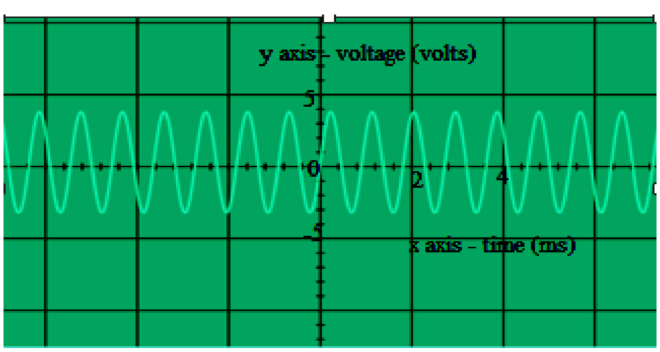

Fig. 6 The sound absorption graph for sample C

3.4. Sound Absorbance

The results for sound absorbance of Samples A, B, and C are shown in Figures 4, 5 and 6, respectively. The graph shows that as the microphone was moved all over the sample, there were parts which passed the 5 volt mark showing good absorbance. At some points, the volts were close to zero, showing total reflection of sound at some points. The diagram shows that the composite has the same behaviour at all points on the composite. The composite has poor reflection, but it exhibits better sound absorption since the sound wave was close to the 5 volts mark. Sample C shows good sound absorption and bad sound reflection. Sound absorption was almost near the amplitude value of 5 volts.

3.4.1. Sound Absorption Coefficient of the Samples

The sound absorption coefficients were calculated using a voltage without the sample being 2 volts. This was the voltage which was set on the oscilloscope. The velocity of sound at room temperature was 346 m/s (temperature 25℃). The sound absorption of the sample was found to be as shown below in Table 5. Both the samples exhibited good sound absorbance properties regarding the frequency of 440Hz, which was used. Comparing the sound coefficients of two different composites, one made of urea formaldehyde reinforced with kenaf natural fibre and the other made of polypropylene reinforced with kenaf natural fibre, the composite of corn husk and fly ash showed positive results [20].

Table 5. Sound absorption coefficients of samples at a frequency of 440Hz

Sample	Sound Absorption Coefficient (α)
Sample A	0.007
Sample B	0.004
Sample C	0.003

Table 6. Sound absorption coefficients of urea-formaldehyde and polypropylene composites reinforced with kenaf [20-22]

Frequency	Urea-formaldehyde reinforced with kenaf	Polypropylene reinforced with kenaf
300	0.009	0.0028
400	0.011	0.0046
500	0.013	0.0048
600	0.021	0.0058
700	0.019	0.0055
800	0.025	0.0258

These results show that the composite demonstrated a good sound absorption coefficient at the frequency of 440 Hz. This is because of the lumen inside the corn husk fibre bundle, which increases the amount of fibre, which results in a high absorption coefficient. The additional thermal energy was dissipated more rapidly due to the increased frictional surface area.

The sound absorption coefficient of sample A is, therefore, correspondingly higher than those of the other samples. The sound waves propagate vibration energy through the air spaces in the individual lumina inside the corn husk fibre. A part of this sound energy is converted into heat in the lumina, which is then absorbed by the surrounding walls. The results also showed that sample A has high sound absorbance, followed by B and lastly, C. This is because of the corn husk fraction in the composite. The composite with a huge amount of corn husks showed good sound absorbance compared to the rest. This is because of the lumens inside the corn husk fibres, which results in a high absorption coefficient. The sound waves propagate vibration energy through the air spaces in the individual lumina inside fibres. Therefore, the composite suits are to be used as a sound absorber.

4. Conclusion and Recommendations

From the results, all samples that were fabricated were able to absorb sound significantly. Samples with a high mass fraction of corn husks, which was sample A, are able to absorb more than the others. Sound absorption at lower frequencies is desirable for automotive applications because of this frequency range, which is based on noise from the wind, engine running, tires, road, and conversation, thereby making the composite a promising candidate for automotive interior sound absorption.

Compressional strength and flexural strength happen to increase with an increase in the mass fraction of fly ash. Overall, all samples showed good flexural and compressional strength. In terms of water absorption, the sample with a huge mass fraction of corn husks absorbs more water than the other with a low mass fraction of corn husks.

There is little literature available which indicates the physical and chemical properties of both corn husk and fly ash. Therefore, it is suggested that investigations be carried out to establish other mechanical properties of corn husks and fly ash composites. Also, the size of fly ash might need to be varied to find the effect of particle size on the composite.

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