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Development of A Biodegradable Panel using Rice Straw and Saw Dust for An Acoustic and Thermal Properties

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Abstract: The expanding use of acoustic panels in industry, particularly for the acoustics of buildings, has increased demand for them. However, the synthetics used in most of the commercial acoustics product cannot be disposed of in nature as solid waste or burned in industry, moreover, have an effect on human health. Therefore, this study was conducted to develop a biodegradable panel using rice straw, saw dust and corn starch to obtain sound absorption and thermal conductivity properties. The samples are divided into three, with separate proportions 70.00 %, 50.00 %, 30.00 % of rice straw and saw dust respectively, with corn starch as binder. The objectives of this study are to identify suitable proportion of rice straw, saw dust and corn starch for biodegradable panel, to measure physical, acoustic and thermal properties of the panel and to compare with previous acoustics panels and gypsum board. The mixture is then set in a mould and ready press with the hot press at 105 °C for 15 minutes with pressure 1.0 tonne. Three types of testing were tested physically, acoustical and thermal conductivity. Saw dust (70.00 %) and rice straw (30.00 %) showed the maximum sound absorption coefficients at low and high frequencies, respectively. It's 241.9 kg/m^3 dense. Rice straw (70.00 %) and sawdust (30.00 %) have the highest heat conductivity. This sample is denser, at 255.56 kg/m^3. Thermal conductivity, sound absorption, and density are interrelated. Sound absorption reduces density. Density raises thermal conductivity. Compared to gypsum board, acoustics panel has 0.07 low frequency sound absorption coefficient at 400 Hz. At 4000 Hz, gypsum board sound absorption is 0.11 and acoustics panel is 0.9. Gypsum board and acoustic panel are alike. Saw dust (70.00 %) and rice straw (30.00 %) can replace the use of gypsum board.

Keywords: Biodegradable Panel, Sound Absorption, Density, Rice Straw, Saw Dust

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1. Introduction

Alternative materials capable of reducing noise levels over a number of frequency ranges are in high demand due to noise pollution in our surroundings. Acoustical panels were used in studies of composite materials and natural fibres. Typical acoustical panels are made of synthetic fibres, which are harmful to human health and the environment and are prohibitively expensive for small-scale use. To echo-free rooms, acoustical absorption panels can be applied. Panels packed with a porous layer of material capable of managing echoes and background noise are commonly used [1]. The sound energy of the event turns to heat and vibration of the fiber, and eventually disappears [2].

Natural fibres, such as palm, kenaf, and coconut coir, have also been studied for their potential as a raw material for acoustical panels and have been reported on numerous occasions. With its high flexibility and hollow area, paddy straw has been claimed to be ideal for acoustic panels [3-4]. The optimal sound absorption coefficient in the high frequency band was found for a rice husk reinforced sodium silicate single-layer acoustic panel [5]. Both coconut coir fibres and oil palm fibres provide good sound absorption at higher frequencies, but not as much at lower frequencies. As a result of its increased density [6-8], oil palm has a higher noise absorption capacity. The waste material made from industrial tea-leaf fibres also offers high-frequency sound absorption capabilities [9]. Therefore, natural fibres have a lot of potential as raw materials for sound absorption materials, according to these findings.

However, in this research, the acoustic panel from agro and industrial waste used to against the problems. The objectives of this study are:

i. To identify suitable proportion of rice straw, saw dust and corn starch for biodegradable panel.
ii. To measure physical, acoustic and thermal properties of the panel.
iii. To compare with previous acoustics panels and gypsum board.

2. Materials and Methods

Materials, methods, testing and procedures to prepare the acoustic panel to achieve the objectives of this study were explained in detailed. There are three basic materials were used to develop the biodegradable panel such as rice straw, saw dust and corn starch.

2.1 Rice straw

Figure 1: Raw rice straw

A bag of 1 kg rice straw as shows in Figure 1 was purchased through online shopping. Then, the top 10 cm of the rice straw was cut into three sections top, center and bottom, the rice straw particle was prepared by cutting each of the sections of the rice straw into 2 to 4 cm length as shown in Figure 2.

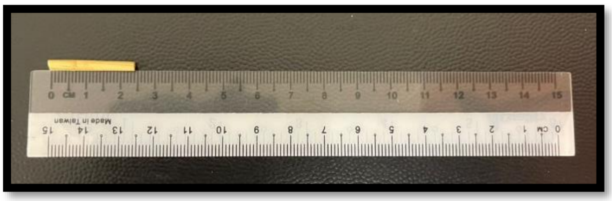

Figure 2: Dried rice straw length

2.2 Sawdust

Saw dust was taken from wood lab in UTHM Pagoh Campus. After the saw dust was taken, it must sieve with 0.02 cm sieve to remove fine sawdust that is not suitable for making panels. The saw dust used was approximately 1cm, it is a coarse size as in Figure 3.

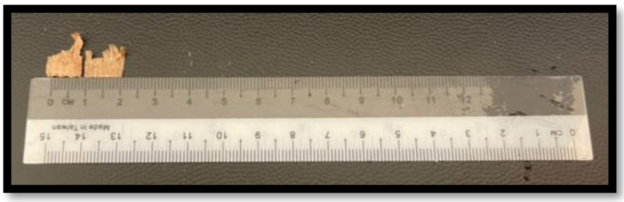

Figure 3: Saw dust size

2.3 Binder

After rice straw and sawdust were provided, a binder was used to mix them. This acoustic panel's binder is natural starch. Binder was 10 g cornstarch powder and 500 ml water. Mix as in Figure 4 until the corn flour is lump-free.

Figure 4: Corn starch and water were mixed well

2.4 Formation of the panel

The biodegradable sample panel was made using a steel mould with measurements of 100 mm, 28 mm in diameter, and 300 mm by 300 mm with a 10 mm thickness. The ratio was used to find the ideal amount of material. The selected ratios were determined previously, and the corn starch ratio was fixed 500ml for all the samples the chosen ratios:

Sample A :70 % saw dust : 30 % rice straw : 500 ml corn starch
Sample B :50 % saw dust : 50 % rice straw : 500 ml corn starch
Sample C: 30 % saw dust : 70 % rice straw : 500 ml corn starch

Combination of the composite samples were uniformly distributed within the boundaries of the mould. Then, the samples were compacted using Gotech Testing Machine Hot Press Machine at 105 °C with pressure 1 tonne and then, were dried using an oven at also at temperature of 105 °C for 15 minutes.

2.5 Testing

There are four testing was conducted at the laboratory such as density, water absorption sound absorption and thermal conductivity.

2.5.1 Density

The samples with 100 mm and 28 mm diameter were weighted. A few observations were taken for each sample and expressed in kg/cm³ the test was calculated by using calculation below:

$$\text{Density (g /cm}^3\text{) = Mass of the test piece (g) /Volume of the test piece (cm}^3\text{)} \qquad \textit{Eq. } 1$$

2.5.2 Water absorption test

The samples were then completely immersed in distilled water for up to 2 hours, then the sample was removed from water and dried with a cloth as quickly as possible until all free air was drained from the surface. Once again, each sample was weighed, and the final weight was recorded. The water absorption of the acoustic panel was calculated by using:

$$\text{Percentage of absorption water (\%)} = (Wet\ weight - Dry\ weight)/ \text{ Wet Weight x 100} \qquad \textit{Eq. } 2$$

2.5.3 Sound Absorption Coefficient (α) testing

This testing was conducted in accordance with the international standard, ASTM E 1050-98. The diameter of the test sample was 100 mm for low frequency and 28 mm for high frequency. Acoustic Tube (AED 1000-Impedance Tube) was used.

2.5.4 Thermal conductivity test

Thermal conductivity was running to determine whether the panel is suitable used as heat insulator. This testing was used Thermal Conductivity of Building Material (Solteq HE: 110). Thermal conductivity can be determined by using this formula:

$$k = qx / A\Delta T \qquad \textit{Eq. } 3$$

where, k is thermal conductivity, q is the amount of heat transferred, x is thickness of sample, A is area of sample and ΔT is temperature difference.

3. Results and Discussion

After conducting tests, the results of density, water absorption, sound absorption coefficient, and thermal conductivity were obtained and recorded.

3.1 Density

Three samples of varying densities were prepared to examine the relationship between density and thermal conductivity. All three specimens were weighed on a digital scale with an accuracy of 0.01 g, and the findings were graphed and analyzed in Figure 5.

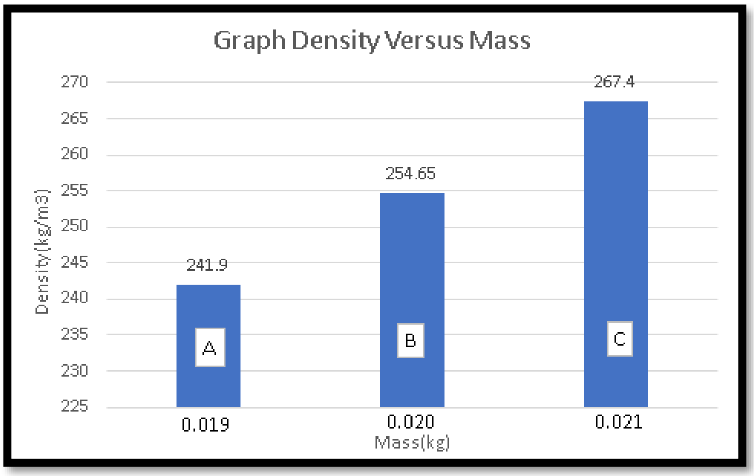

Figure 5: Graph density versus mass

Figure 5 illustrates that when sample mass decreases, the density also decreases. This indicates that density and mass are directly related. The maximum density is 267.4 kg/m^3 for Sample C, while the minimum is 241.9 kg/m^3 samples' fibres and binder were determined.

3.2 Thermal conductivity (k-Value)

Using the Thermal Conductivity of Building Materials Apparatus (Model: HE110), thermal conductivity was measured. The thermal conductivity result presented in a bar chart form with density value in Figure 6 is as follow.

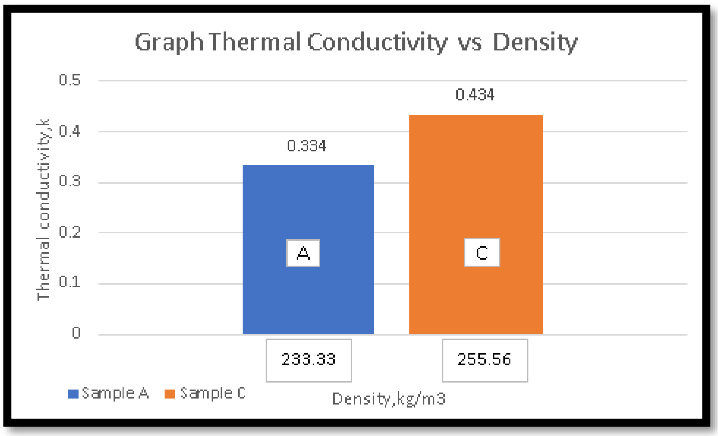

Figure 6: Graph of density versus thermal conductivity

Density affects heat conductivity as in Figure 6 Sample A's thermal conductivity at 233.33 kg/m^3 is 0.334 W/mK. Sample C is 255.56 kg/m^3 and 0.434W/mK. Less dense acoustic panels have less thermal conductivity. Air gaps within fibres affect thermal conductivity [10]. Due to, too much rice straw touches a hot plate, the densest sample has the highest thermal conductivity, showing that air spaces are insufficient to transfer heat. The lowest density sample had the lowest thermal conductivity because the air spaces in the rice straw and sawdust fell. Smaller air spaces reduce heat transfer by convection in a sample. Sample A can be utilized as an excellent insulator because low thermal conductivity materials restrict heat transmission, maximize material capacity and operating costs, and reduce energy consumption. Denser wheat straw boards can be used as heat sinks, while lower density boards can be used as thermal insulation [11].

3.3 Water absorption

In this work, ability of the sample to maintain its density when soaked in water for 2 hours and the mass was checked for every 5 minutes was measured as in Figure 7, there were 24 data recorded.

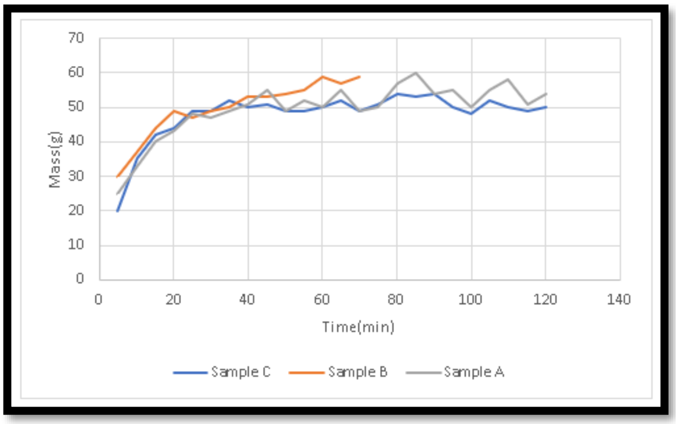

Figure 7: Graph of mass versus time for every 5 minutes

Sample A had the maximum water absorption while Sample C had the lowest, Sample B disintegrated and separated after 70 minutes. Starch adhesive increases water absorption. Starch films absorb water and become soft and flexible at high humidity, causing moisture content [12]. Sample A had more hydroxyl groups from sawdust, which improved water absorption. Due to their hydrophilic hydroxyl groups, cellulose and hemicelluloses in sawdust have the maximum water absorption of natural fibres [13]. Water permeated the samples easily. This study's porous and hygroscopic acoustic panel explains its highest water absorption.

3.4 Sound Absorption Coefficient (α)

Two measurements were performed for each sample, so that which the value can be determined by the software. The absorption coefficient values were read from the graphs at Figure 8 and Figure 9 each frequency for individual sample. Rice straw and saw dust absorb sound at lower frequencies, mostly from 80 Hz to 400 Hz meanwhile, the samples absorb sound from 1000 to 5000Hz at high frequency.

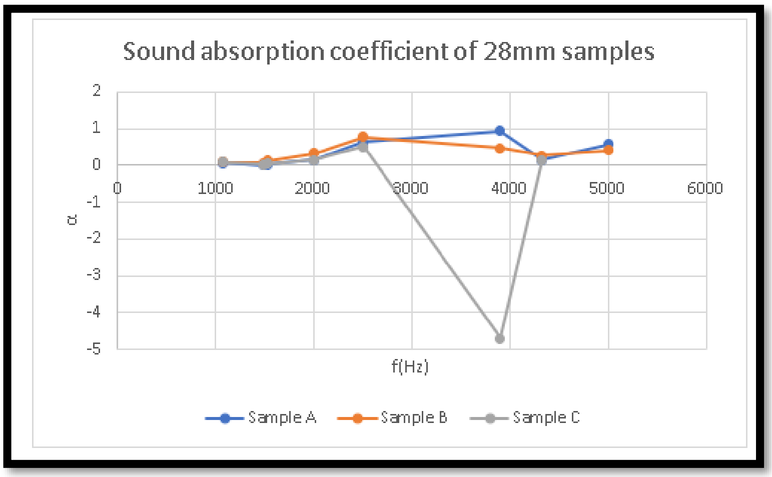

Figure 8: Sound absorption coefficient of 28 mm samples at high frequency

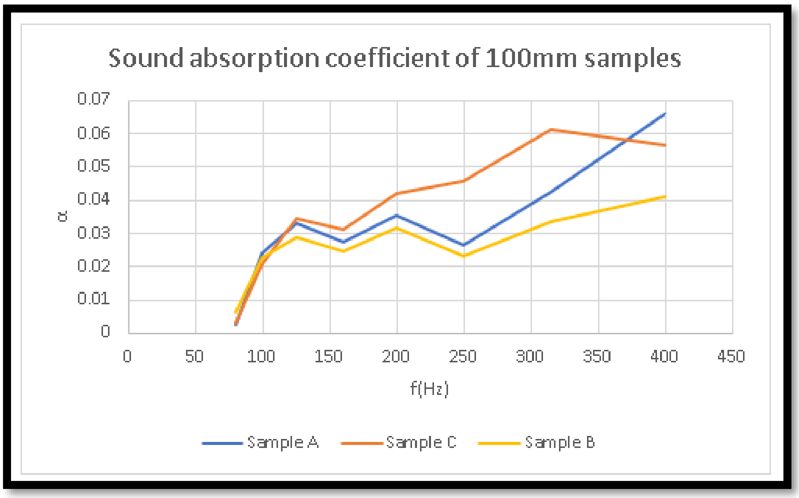

Figure 9: Sound absorption coefficient of 100 mm samples at low frequency

Figure 8 shows that Sample A and B's sound absorption increases with frequency. It nearly hit 0.9 at 2500 Hz to 3900 Hz. Sample C sound absorption decreases from 2500 Hz to 4200 Hz. Sample C is denser than others. Increased board density reduces sound absorption. As sample density increases, so do natural fibres per unit area [14].

Sample A has a high sound absorption coefficient of 0.07, as shown in Figure 9. The sound absorption coefficients of materials effectively increase with increasing density at lower frequencies (500 Hz) but tend to decrease for denser samples at higher frequencies (>2000 Hz). The coefficients of sound absorption are greater for less dense samples than for denser samples. As a result of their high porosity [15].

4. Conclusion

This research succeeded in creating biodegradable acoustic panel using the rice straw and saw dust reinforced corn starch mix proportion. Sample A with 70.00 % saw dust and 30.00 % rice straw is the best proportion for the biodegradable panel.

Then Sample A has the lowest density and C the greatest. Sample A's significant water absorption influences the acoustics panel's density. Sound absorption and thermal conductivity are affected by density. Sample A's high-frequency sound absorption coefficient is 0.9 and low-frequency is 0.07. Higher sound absorption coefficient effects lower in acoustic panel density. Sample C has the highest thermal conductivity at 0.434 W/mK, but it also has the largest density. The panel's thermal conductivity increases with density. In summary, the objectives of this study have been accomplished.

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