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# Sound Absorption Properties of Acoustical Particleboard with Sawdust and Rice Straw

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**Abstract**

Agricultural and industrial waste are typically disposed of by burning. As a result, it would indirectly contribute to the release of carbon dioxide into the atmosphere, further polluting the environment. Previous research has found that these waste materials have the potential to be used in the production of acoustic panel boards. This project investigates the use of agricultural waste rice straw and industrial waste sawdust as basic materials in the production of acoustic panel boards. Both materials would be reinforced with an epoxy resin adhesive. The tests such as water absorption test, bending test and acoustical properties would be carried out and will be compared with the standard for particle board which is JIS A 5908 (2003), ASTM D1037 and ISO 11654 (1997). The sandwich particleboard made from coarse rice straw and sawdust was the best and recommended for the manufacturing process. This sandwich particleboard had a higher sound absorption coefficient than the other sample. The recommended sandwich particle board made from coarse rice straw and sawdust has been defined in terms of its ability to absorb sound, be durable, and can partially or totally replace wood particle board and insulation board in wood construction.

## 1. Introduction

Particleboard is produced by subjecting the wood to heat and pressure along with an adhesive. The demand for particleboard has been consistently increasing worldwide, with a growth rate of 2 to 5 per cent per year, as reported in [1]. Due to the rising demand for wood-based materials and the decline in raw materials, suitable alternatives inevitably need to be found.

Agricultural lignocellulosic fibres, such as rice straw and wheat, can be easily crushed into chips or particles that closely resemble wood fibres. These fibres can serve as substitutes for wood-based raw materials and also contribute to the recycling of agricultural waste. Several studies have successfully developed alternatives to wood particles by utilizing lignocellulosic fibres, aiming to recycle natural resources and meet the demand caused by the diminishing supply of solid wood and wood-based materials. In Malaysia, rice straw is readily available as a by-product of rice harvesting, which is traditionally discarded or burned, causing air pollution and other hazards due to the smoke emitted. Research by [2] focused on using dried rice straw as a fibrous acoustic material in construction. Additionally, [3] combined rice straw with commercial wood particles and a commercial urea-formaldehyde binder to create sound-absorbing insulation material.

Furthermore, researchers have successfully utilized other waste materials in the production of particleboards. [4] investigated the use of sawdust and cassava waste, while [5] utilized sawdust and paper. The results indicated that boards made with sawdust exhibited the best properties. Similarly, [6] explored the utilization of rice husks and sawdust in manufacturing ceiling boards, which were found to meet similar standards as commercially available samples. Sawdust, a by-product of milling processes like cutting, grinding, and sanding boards or planks, is often disposed of in landfills or burned in open areas.

This study focuses on the use of rice straws and sawdust due to their availability. A sandwich-patterned particleboard combining rice straw and sawdust, known as sandwich rice straw–sawdust board (S-RSSB), was manufactured using a method commonly employed in the wood-based panel industry. This study aims to recycle waste products and use them in the production of new, more sustainable materials. Thus, the physical properties (water absorption content), mechanical properties (3-point bending strength), and acoustical properties (sound absorption coefficients) of the S-RSSB were evaluated to assess its potential as an acoustic particleboard. The S-RSSB has the potential to replace traditional particleboard and acoustic boards due to its strength, acoustic qualities, and cost-effectiveness. The properties of the particleboards were determined according to the standards set by JIS A 5908 (2003) and ASTM D1037 for physical and mechanical test while ISO 11654 (1997) for acoustical test.

## 2. Materials and Methods

### 2.1 Materials

Commercial wood particles were used. Rice straw was used as the agricultural lignocellulosic fibre in this study. This acoustical particle board is made in layers using rice straw and sawdust. In this study, two varieties of rice straw will be used: fine rice straw and coarse rice straw. To make the panel, an epoxy resin adhesive was used as a binder, a hardener was applied to strengthen the materials and wood and parquet adhesive was used combined with each layer.

#### 2.1.1 Rice Straw

Rice straw is an environmentally friendly material that can be utilized to manufacture this panel board. It is produced as a by product of rice production at harvest. Rice straw is removed along with the rice grains during harvest and spread out in the field depending on whether it was harvested manually or by machine. The rice straw can be easily crushed to chips or particles, which are similar to wood particle and provide a feasible substitute for wood-based raw materials [3]. In this investigation, the rice straw used in was obtained from a local seller. A grinding machine will be used to grind dried rice straw to get fine rice straw at the Science Technology and Engineering Laboratory while coarse rice straw was cut into small pieces and lengths of 2 to 4 cm with scissors. Fig. 1(a) shows fine and coarse rice straws.

#### 2.1.2 Sawdust

Sawdust is generated as a byproduct of the timber industry, yet it encounters constrained industrial applications. Most of this byproduct is either discarded or burned, leading to environmental issues. To mitigate these issues, particle board mills are predominantly integrated with sawmills, promoting sustainable development through the efficient utilization of wood waste [7]. Nowadays, sawdust is used in many applications, such as building materials, soil mulch, energy production (gasification, incineration, and ethanol production), and low-quality wood pulp. The sawdust used in this study will be obtained from a furniture factory. Fig. 1(b) shows the sawdust that was used in this study.

#### 2.1.3 Polyester Resin and Hardener

In this study, rice straw and sawdust would be combined with polyester resin adhesive and hardener as a binder. Polyester resin is a liquid resin that has a fairly low viscosity and can dry at room temperature when mixed with a harderner. The hardener helps the resin to dry properly. When mixing the resin with the catalyst, it's crucial to make sure the mix is completely even and not too much. If there's too much catalyst in the resin, it can make the material brittle or flammable. A good rule is to add 1% of the volume of resin used for the best results [8]. While wood and parquet adhesive will attach a layer to form the sandwich particleboard. Fig. 1(c) shows the resin used in this study.


**(a)**

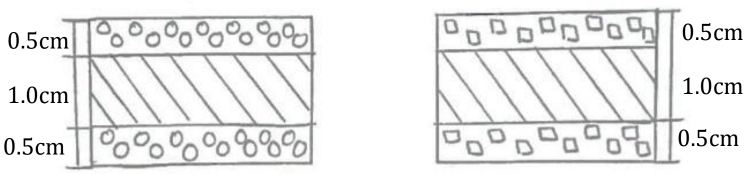
**(b)**

**(c)**

**Fig. 1** *Material (a) Rice straw (b) Sawdust (c) Polyester resin adhesive, wood adhesive and hardener*

## 2.2 Type of Sandwich Particle Board

Sandwich particleboard was created in two (2) forms which is sample A fine rice straw is a surface and bottom layer while sawdust is a middle layer. For sample B, coarse rice straw is the surface layer and bottom layer while sawdust is the middle layer. The sample of sandwich particleboard were shown in Fig. 2 an illustration of sandwich particleboard sample A and sample B.




Sample A                Sample B

**Fig. 2** *Illustration of sandwich particleboard*

## 2.3 Board Fabrication

This acoustical particle board would be manufactured using a 300 x 300 x 10 mm and 300 x 300 x 5 mm mould. The acoustical particle board is made up of three layers and each layer would be compressed using a hot machine. Before being compressed, rice straw or sawdust would be combined with epoxy resin adhesive and a hardener. The target density of this acoustic particleboard is 600 kg/m3 while resin would be used up to 20% of the dry weight of the material and the hardener would be used up to 2% of the weight of the resin. The machine is then hot pressed at a temperature of 1350C and a peak pressure of 10 tans to create a panel board. The time spent pressing is 8 min. After each layer has been made, wood and parquet adhesive would be used to attach each layer. Fig.3 shows the board fabrication process.

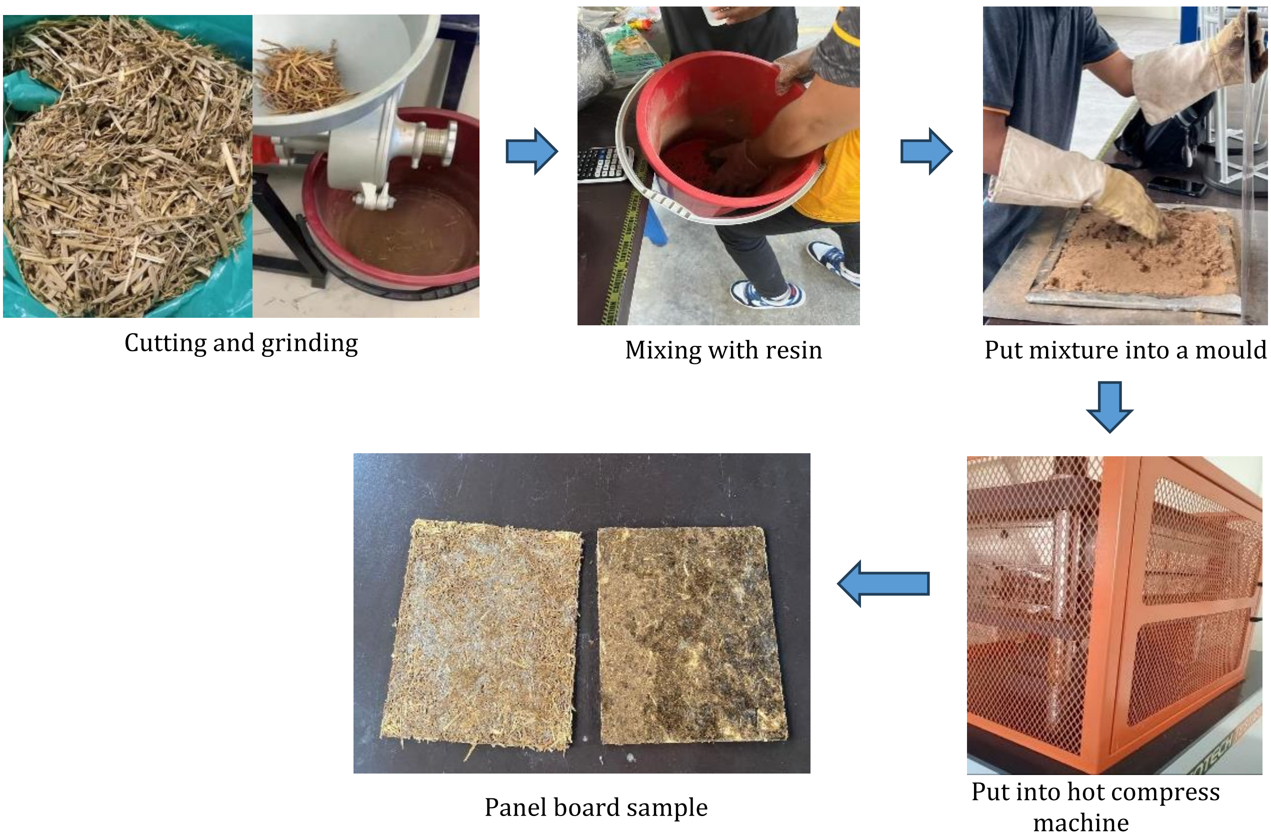



**Fig. 3** *Fabrication process of particleboard*

## 2.4 Board Testing

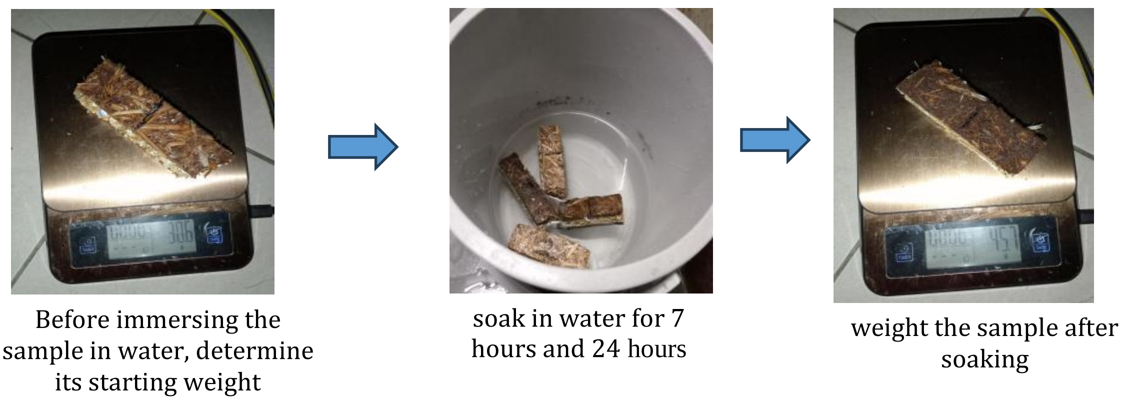
Three tests will be performed to determine whether this particleboard is suitable for use, namely the three-point bending test, water absorption, and sound absorption coefficient.

### 2.4.1 Three-Point Bending Test

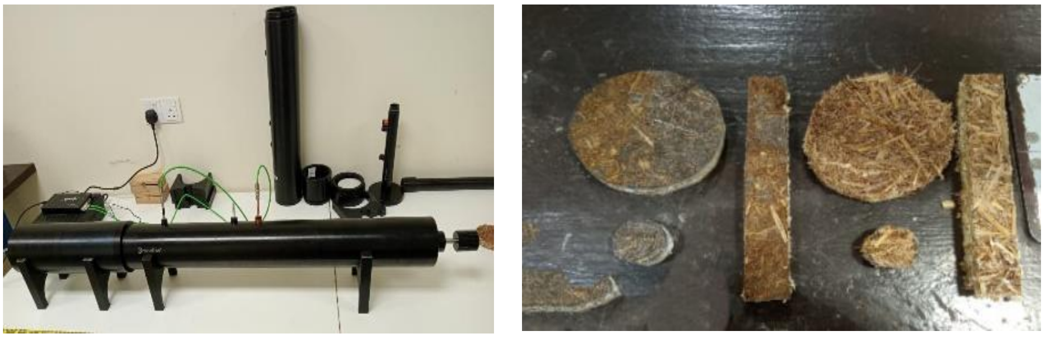
The three-point bending test is to determine the flexural strength of a particleboard. The test was carried out at the automotive engineering technology laboratory. This test used a bending test machine to get the data.

### 2.4.2 Water Absorption Test

The dimensional stability of particleboard and chipboard is determined by the quantity of water absorption (WA). According to the regression model, the water absorption test is affected by relative humidity, resin type, board-specific gravity, as well as the thickness and slenderness ratio of wood furniture. In this study, sample A and sample B would be soaked in water for 7 hours and 24 hours. Fig. 4 shows the flow of the water absorption test.




**(a)**



(b) (c)

**Fig. 4** (a)*The process of water absorption test, acoustical test (b) Impedance tube equipment (c) 28mm and 100mm diameter sample*

### 2.4.3 Acoustical Property

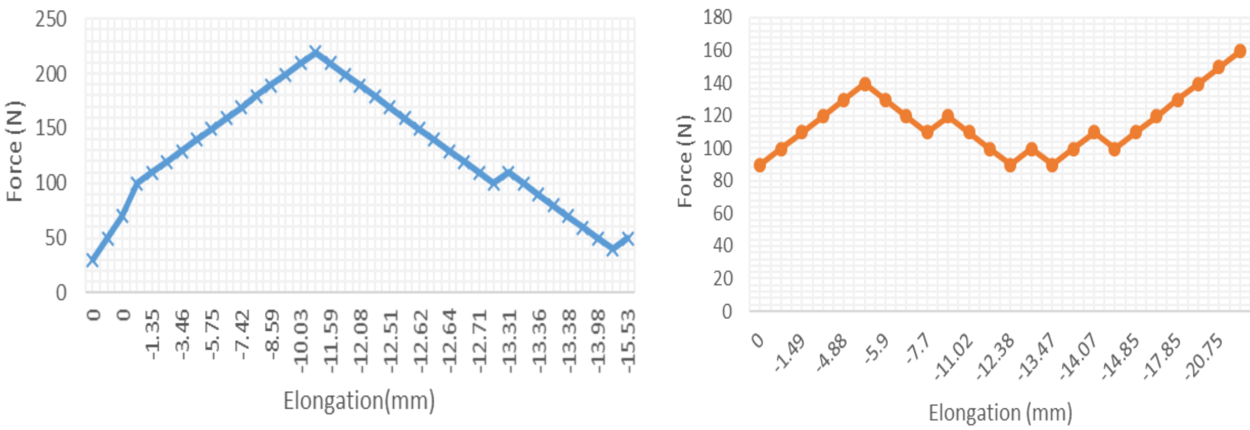
Impedance tube measurements were employed to determine the sound absorption coefficients of the composites as sound absorption boards. Fig. 4(b) shows the impedance tube set up. Fig. 4 (c) shows the samples of the particle board. There are two (2) sizes of samples used which are 28 mm diameter for high frequency and 100 diameters for low frequency. During the test, the sound absorption coefficient was determined. The sound absorption coefficient was obtained by measuring the sound pressure on the material surface and the reflected sound pressure.

## 3. Results and Discussion

### 3.1 Three-Point Bending Test

The three-point bending tests were carried out based on ASTM D1037 to measure the bending strength and failure modes at the ultimate load of the sandwich panel board. The speed of the machine was set up to 15mm per min. The results of the three-point bending test are shown in Fig. 5. This is the result of sample A which is a combination of fine rice straw and sawdust. From the graph, it was found that the maximum load that can be imposed on the panel board is as much as 219.43N before the panel board breaks. This shows that the combination of fine rice straw and sawdust is durable. This panel board can bend up to -10.03 mm before it starts to break.

From the Fig. 5, it was found that the maximum load that can be accommodated by this panel board is 139.58N and this panel board is not broken like sample A. However, this panel board has reached its limit at 139.58N and has a flexibility of -5.78mm. It shows that panelboard sample B is not strong and is not able to withstand high forces.




**(a)** **(b)**

**Fig. 5** *Three points bending test result (a) Sample A, (b) Sample B*

## 3.2 Water Absorption Test

A water absorption (WA) test is used to determine the amount of moisture that may be retained in particle boards with different types of layers and depending on the binder used. Fig. 6 shows the effects of types of particle boards produced with different layers after soaking in water for 7 hours and 24 hours at room temperature. For sample A, the top and bottom layers of particle board use fine rice straw and the middle layer uses sawdust. For sample B on the top and bottom layers use course rice straw and sawdust in the middle layer. Based on both immersion periods, sample B absorbs more percentage water than sample A. The difference in water absorption value may be caused by the type of rice straw size in the manufacture of particle board.

**Fig.6** *Water absorption result*

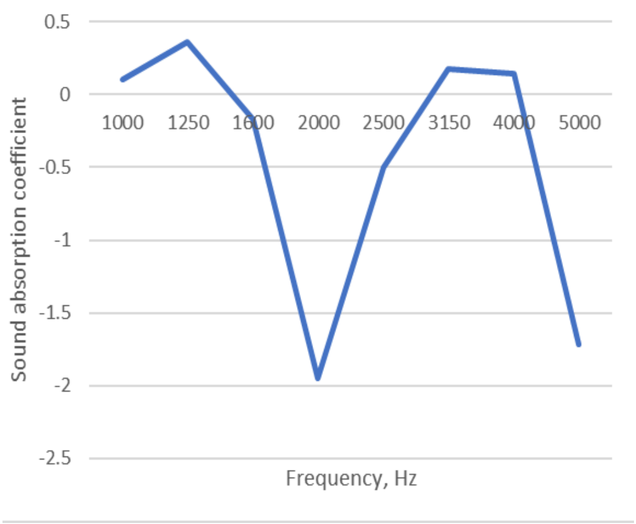
## 3.3 Sound Absorption Coefficient

Sandwich sound absorption coefficient particle board was measured using the impedance tube method (ISO 11654, International standard for sound absorbers used in buildings, 1997) to determine the method for converting the frequency-dependent value of the sound absorption coefficient into a single number. In this investigation, samples A and B were evaluated at low and high frequencies, with a size of 28mm and a diameter of 100mm. The result for samples A and B at low frequency is shown in Fig. 7(a).

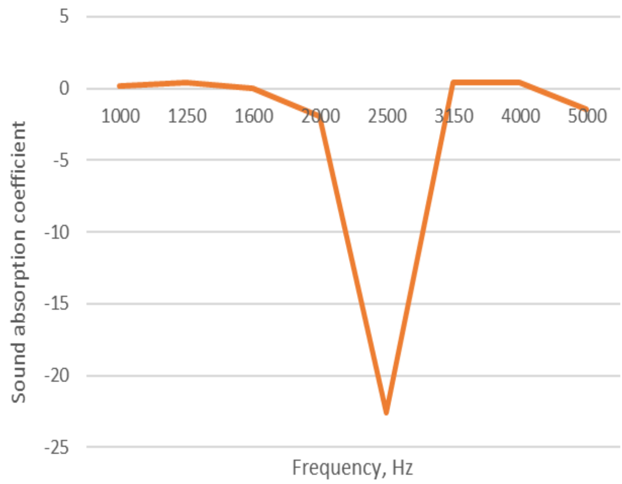
According to the graph, the low-frequency range is 80 Hz to 400 Hz, while the high-frequency range is 1000 Hz to 5000 Hz. Sample A demonstrates ups and downs for the low-frequency test, with coefficients decreasing from 80hz to 100hz and increasing from 100hz to 125hz. When subjected to frequencies, sample A had the largest sound absorption power between 315hz and 400hz. Sample B exhibits a drop in coefficient from 80hz to 100hz and an increase from 100hz to 400hz. This demonstrates that the best sound absorption coefficient is obtained at frequencies ranging from 315hz to 400hz. at low levels of frequency, the sound waves that circulate in the tube have a long wavelength ($\lambda$), hence the reflected wave is larger than the wave absorbed by the material [7].

When undergoing a frequency of 1000hz to 2000hz as shown in Fig. 7(b) and Fig. 7(c), sample A shows decreases, whereas sample B also shows a decrease at 2000hz to 2500hz. However, the received frequency is also quite relevant, as evidenced by the second samples of various types, which show that at high frequencies of 1000 Hz, 2000 Hz, and 2500 Hz, absorption values tend to drop, which can be attributed to faulty manufacturing processes. The graphs for samples a and b for high frequencies show a decrease because this particle board is not suitable for high frequencies.

**(a)**




**(b)**




**(c)**

**Fig.7** *Sound coefficient test (a) Low frequency for sample A & B (b) High frequency Sampel A (c) High frequency Sample B*

## 4. Conclusion

As a result, it has been determined that particle board can be manufactured from a combination of sawdust and rice straw with the addition of epoxy resin adhesive as a binder, producing two types of particle board-based sandwiches that meet three standards: JIS A 5908 (2003), ASTM D1037, and ISO 11654 (1997). Based on the outcomes of research on the sound absorption coefficient of acoustic material made from rice straw and sawdust, this material can absorb sound. This is because the properties of rice straw and sawdust can be employed to replace sound-absorbing materials. The ISO 11654 standard specifies a minimum value of 0.15 for a material to be classified as a sound absorber and included in the quality class E category is shown by the aw value of the absorption coefficient of the sample made. In addition, sample A is more durable than sample B. Overall, sample B is a better sandwich particleboard than sample A due to a better water absorption test and sound absorption coefficient. However, this particleboard sandwich does not reach the entire particleboard standard it should. This particle board needs several improvements and repairs to meet the requirements of JIS A 5908 (2003).

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## Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

## Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design, data collection, draft manuscript:** Ahmad Farhan Bin Mohd Azme, Muhammad Iqbal Hadi Bin Abdul Rohani, Muhammad Shaqeel Bin Sharifuddin; **draft manuscript preparation**: Ahmad Farhan Bin Mohd Azme, Muhammad Iqbal Hadi Bin Abdul Rohani, Muhammad Shaqeel Bin Sharifuddin, Aslila Abd. Kadir. All authors reviewed the results and approved the final version of the manuscript.

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