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Insulation Panel Using a Combination of Rice Husk and Sugarcane Bagasse for Acoustic and Thermal Properties

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Abstract

Ensuring thermal comfort and mitigating noise pollution have emerged as two of the most critical challenges modern societies have had to confront and address in the design and operation of buildings and infrastructure. Within the past year, the use of agricultural waste as thermal insulation and sound absorption has garnered attention from researchers due to its properties. This study explores the potential of using sugarcane bagasse and rice husk as insulation panels, focusing on their thermal and acoustic properties. Different proportions (25:75, 50:50, 75:25) of each material were made with the thickness 5mm. Insulation panels were produced through a wet mixing process utilizing a hot press machine, during which the thermal properties, sound absorption coefficient, and sound reduction index were thoroughly investigated. The performances of the developed insulation panels were investigated using the thermal conductivity apparatus, SOLTEQ MODEL HE:110, Acoustic box, and Impedance Tube tests, respectively. Thermal conductivity values and sound absorption coefficient were measured and tabulated into graphs. Findings from the study showed that Sample B has the most optimum thermal and acoustic performance, with k value and SAC of 0.0333 W/m°C and 0.101-0.923, respectively. This development highlights the potential of the sample panel made from RH and SCB to replace synthetic panels currently available in the market.

1. Introduction

The building sector is increasingly adopting sustainable practices, particularly through the use of eco-friendly materials like insulation panels, which are essential for enhancing indoor comfort and energy efficiency. Study by [13] told that commercial buildings consume most energy for heating, cooling, and lighting. Thus, implementing these panels help in reducing energy consumption by lessening reliance on heating, ventilation, and air conditioning (HVAC) systems [1][3]. Insulation panel can be applied on building envelope such as wall and ceiling, to serve as effective barriers that enhance both acoustic and thermal properties. The practice of insulation panels in the building envelope can help to lower the environmental damage of construction [15]. This can be further explained if the building envelope materials are well designated, especially in envelope-dominated structures such as residencies. In the case of the building sector, thermal insulation plays a significant role in determining the thermal performance and energy efficiency of the insulation materials According to research by [14], the lower the λ-value, the more effective the thermal insulator, which means higher thermal resistance and greater heat-retardant capacity. While for acoustic properties, sound absorption of building materials plays a significant role, in evaluating the noise inside the building and enhancing the acoustic environment to ensure indoor comfort can be achieved [16].

Research indicates that natural fibers provide effective thermal and acoustic insulation and are environmentally friendly and non-toxic [2][4]. Studies have shown that natural fibers can improve sound absorption and thermal resistance, making them suitable for modern construction [2][9][17][18]. This shift aligns with Sustainable Development Goal 9, which promotes resilient infrastructure and sustainable industrialization, highlighting the importance of using renewable resources in building practices. The development of insulation panels from agricultural waste thus represents a promising innovation that addresses environmental concerns and the need for improved building performance. While traditional insulation materials are often synthetic and harmful to the environment [2], there is a growing interest in natural alternatives derived from agricultural waste, such as rice husk and sugarcane bagasse.

Rice husk is noted for its high silica content and spongy texture that contributes to improvement of sound absorption coefficient [2][9], the presence of air voids inside the structures of rice husk help to enhance the acoustic properties. While sugarcane bagasse features a fibrous structure with rough and grooved surfaces [8]. These structures of sugarcane bagasse are significant factor that influencing thermal conductivity and acoustic properties of the material [8][19][20]. The decision to explore the combination of these two materials is motivated by their abundance, sustainability, and complementary features [2][4][9], which could lead to innovative solutions in waste management and material science. By addressing these aspects, this research aims to contribute to academic discourse while promoting sustainable practices in using agricultural waste. The exploration of these materials not only fills existing gaps in knowledge but also highlights the potential for creating environmentally friendly solutions that leverage agricultural by-products.

This study focuses on developing insulation panels made from agricultural waste materials, specifically rice husk and sugarcane bagasse, combined with tapioca starch as a binder. The research aims to determine the optimal proportions of these materials to enhance their thermal and acoustic properties, critical for improving energy efficiency and occupant comfort in buildings. The panels will be produced using a hot-pressing method, and their performance will be evaluated according to standards for thermal and acoustic properties. By comparing the developed panels with the standard of the gypsum board materials, the study seeks to demonstrate the advantages of using renewable resources in construction, contributing to sustainable development goals, and promoting environmentally friendly building practices.

2. Materials and Methods

To create insulation panels composed of a combination of rice husk and sugarcane bagasse, specific methods were employed, which were detailed in this section.

2.1 Materials

This study used rice husk (RH) and sugarcane bagasse (SCB) in developing sample panel, as shown in Figure 1. Rice husk was sourced from Kilang Jelapang Selatan in Muar, while sugarcane bagasse was obtained from a seller in Kampung Parit Tegak after extracting juice from sugarcane stalks.

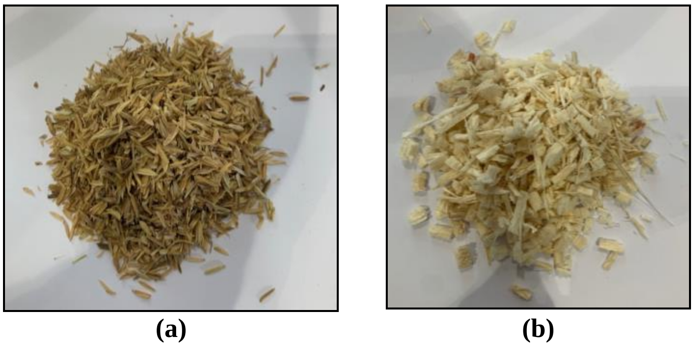

(a) (b)

Fig. 1: Raw material (a) rice husk; (b) sugarcane bagasse

2.2 Methods

2.2.1 Fiber Preparation

Both materials were dried in an oven at 60°C to eliminate excess moisture for proper storage. The sugarcane was manually cut into pieces approximately 1-3 cm long to ensure the fibers were neither too fine nor too thick for the sample panels. For rice husk, it was stored in a controlled environment to maintain its quality and prevent moisture absorption.

2.2.2 Samples Preparation

In order to develop a sample panel, three different sizes of panel were used: 30mm and 100mm diameter, and 300mm × 300mm. This process involved carefully weighing each material to develop the sample panels. Table 1 presents the proportions of rice husk and sugarcane bagasse used in three experimental variations.

Table 1**:** Three proportions of RH and SCB

Samples	**Materials**		**Binder**
	Rice husk (%)	Sugarcane bagasse (%)	Tapioca starch (%)
A	25	75	65
B	50	50	65
C	75	25	65

These three proportions were made to evaluate which developed sample panel exhibited the most optimal properties in acoustic and thermal performance, specifically to investigate whether higher proportions of rice husk, sugarcane bagasse, or equal proportions yield better results. This will help identify each material's optimum proportions for its acoustic and thermal properties.

To develop the sample panels, dried sugarcane bagasse, and rice husk were mixed with a binder in a container until the mixture achieved an even consistency. Fibers were uniformly distributed within the boundaries of the mould. After the mixture was poured into pre-prepared moulds, a GT-7014-H Hydraulic Moulding Press was used to compress the mixture within the mould. After compression, the mould was left to cure, allowing the binder to bond with the fibers. Once cured, the panels were removed, inspected for defects, and adjusted if needed, such as trimming edges or sanding. This process is illustrated in Figure 2.

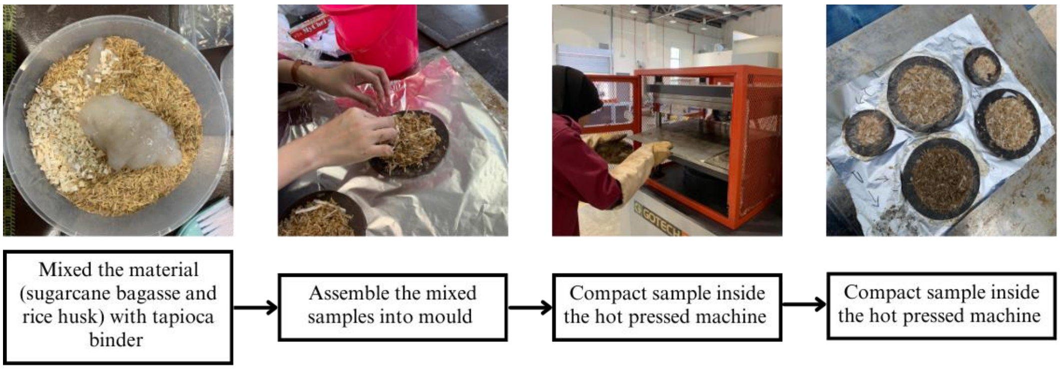


Fig. 2**:** Process samples preparation

2.3 Testing

After the sample panel have been developed, it undergoes several testing to test its properties. This includes physical, acoustic and thermal testing.

2.3.1 Physical Test

Density test was performed on the sample panel after developed. Masses of the sample panel was weighed by digital weighing scale. Each sample's dimensions which are length, thickness, and width was measured using measuring tape. Data of the dimension and mass of each sample panel can be calculated by using equation (1).

$$\frac{\text{Mass of sample,}\ \ m}{\text{Volume of the sample,}\ \ V} \tag{1}$$

2.3.2 Acoustic Testing

To measure acoustic properties of the sample panel, and impedance tube and acoustic box was used to measure the sound absorption coefficient (SAC) and sound reduction index (SRI) of the developed sample panel.

In order to measure the sound absorption coefficient (SAC), an impedance tube (AED 1000-AcoustiTube) was used according to ISO 10534-2 and ASTM E1050-98 for sample sizes of 100 mm and 30 mm diameters, with a thickness 5 mm to measure SAC.

While to measure the sound reduction index (SRI), an acoustic box and sound level meter was used. This measurement is expressed in decibels and adheres to the international standard (ISO 10140), utilizing the equation outlined in ISO 10140-2 (2010).

2.3.3 Thermal Testing

Thermal Conductivity of Building Materials Apparatus MODEL: HE110 was used to measure thermal conductivity value, k for the developed insulation panel. This equipment allows to determine thermal conductivity materials for building apparatus and its thermal resistance. Thermal Conductivity of Building Materials Apparatus MODEL: HE110 consists of clamping devices with heating plates, interchangeable test material, and instruments for temperature measurements. This apparatus required to develop a sample size of 300 mm × 300 mm for testing. All systems are enclosed inside the chamber to minimize heat loss during the testing.

3. Result & Discussion

All data obtained from the experiment will be presented in this section. This serves as a purpose whether the study is successful or not.

3.1 Physical

Density is one of the most important factors in physical properties because it serves as a fundamental characteristic. For the developed sample panel, Table 2 presents the data of each density of the sample panels.

Table 2: Density properties of the tested insulation panel

Sample	Mass (kg)	Volume (m^3)	Density (kg/ m^3)
A	0.1207	0.00045	268.22
B	0.1653	0.00045	367.33
C	0.1400	0.00045	311.11

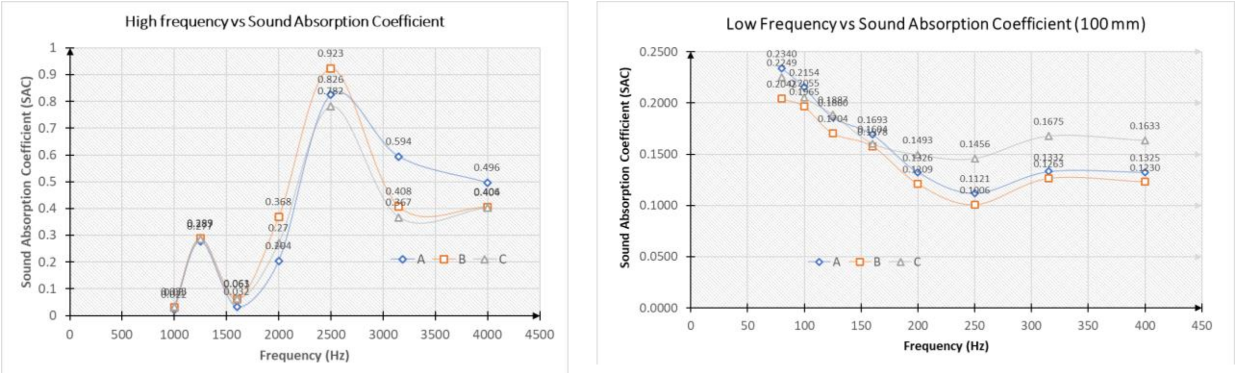
The result revealed that sample B has the highest density, as seen in Table 2. This is due to the higher amount of dense materials, rice husk, and the optimal structural arrangement of both materials, which leads to the higher density value [1]. According to [5], density plays an important role in improving the sound absorption coefficient (SAC). Materials with higher density have more mass per unit volume, which can lead to increased friction and energy loss when sound waves hit them. However, this effect can vary based on material thickness and pore structure [1]. Lower-density materials often absorb sound better because their porous nature allows sound waves to penetrate and dissipate more effectively [1].

3.2 Acoustic

Acoustic properties were tested on the developed insulation panel that consists of sugarcane bagasse and rice husk, determining its Sound Absorption Coefficient (SAC) and Sound Reduction Index (SRI).

3.2.1 Sound Absorption Coefficient

Figure 3 shows the results of sound absorption coefficient for overall samples for both high and low frequencies. From the figure, it can be seen that most curves were identical and consistent in values. Also, note that most samples yield higher values at a frequency of 2500 Hz for high frequencies and 80 Hz at a lower frequencies.



(a) (b)

***Fig. 3*: Sound absorption coefficient graph (a) high frequency; (b) low frequency**

Sample A, made up of 25% rice husk (RH) and 75% sugarcane bagasse (SCB), contains a majority of sugarcane fiber. Research by [2] indicates that SCB has a fibrous structure with a larger lumen diameter, allowing it to absorb more sound than materials with smaller lumen structures. While SCB is known for its high porosity and sound absorption capabilities, excessive porosity without proper structural support can hinder sound dissipation [7]. The addition of RH in Sample A helps balance the porosity of SCB, resulting in improved sound dissipation, especially at high frequencies, as illustrated in Figure 4.1.

In contrast, Sample C, composed of 75% RH and 25% SCB, performs better at low frequencies. This is because RH is effective at absorbing lower frequency sounds due to its granular structure [10]. [7] found that RH's acoustic performance is optimal when mixed in the right proportions, with 75% RH yielding the best results in this study. While Sample C excels in low-frequency sound absorption, it shows reduced effectiveness at high frequencies compared to Sample A and Sample B. The lower SCB content in Sample C limits its high-frequency performance.

Sample B, which contains equal parts RH and SCB (50% each), demonstrates excellent sound absorption at high frequencies due to its balanced composition. The higher porosity of this sample allows sound waves to disperse more effectively, increasing the Sound Absorption Coefficient (SAC) [2]. This happens because the frequency response tends to peak during mid-high frequency (2500 Hz – 4000 Hz) [11]. However, it performs poorly at low frequencies compared to Samples A and C because its equal proportions do not optimize sound absorption in that range. Sample B is best for high-frequency absorption, while Sample C is more effective for low frequencies, highlighting how material composition impacts acoustic properties.

3.2.2 Sound Reduction Index

Sound Reduction Index (SRI), sometimes called transmission loss or sound insulation, is a crucial metric for assessing how well materials reduce sound transmission. It measures the amount of sound energy lost as it travels through objects like doors, windows, or walls [6]. SRI, measured in decibels (dB), is the difference in sound intensity between the incident sound on one side of a material and the transmitted sound on the other.

Figure 4 shows the sound reduction index graph for all samples All samples exhibit a decline in SRI as distance increases, suggesting reduced sound insulation performance at greater distances. Sample C demonstrates superior sound insulation properties, especially at closer ranges, while Sample B provides moderate performance and Sample A the least. The trend of decreasing SRI with increasing distance is consistent across all samples, with Sample C showing a notable decrease in sound levels over distance.

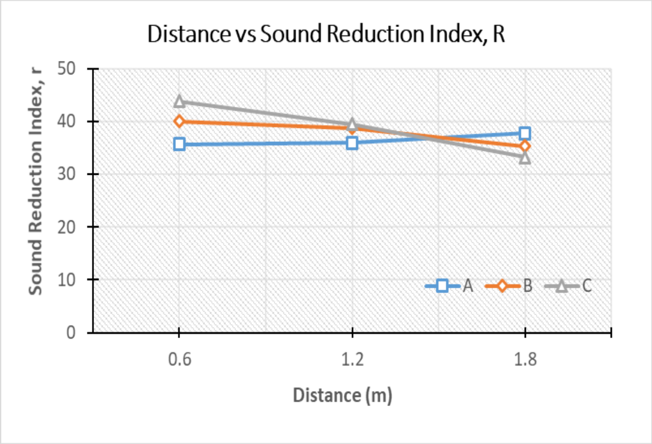


Fig. 4: Sound reduction index graph for all samples

Sample A demonstrates consistent performance in sound reduction across all distances, maintaining a steady Sound Reduction Index (SRI). This reliability suggests that its material composition and structure are well-balanced, making it suitable for applications requiring consistent acoustic insulation. In contrast, Sample B begins with a moderate SRI at 0.6 m but gradually declines as distance increases, indicating reduced effectiveness. The equal proportions of rice husk (RH) and sugarcane bagasse (SCB) may limit its acoustic properties for long-range sound absorption [11].

Sample C initially outperforms both Sample A and Sample B at shorter distances, achieving the highest SRI at 0.6 m. However, its performance significantly drops with increasing distance, eventually falling below Sample A at 1.8 m. This decline suggests that while Sample C is effective for short-range applications, its material composition may not support sustained sound reduction over longer distances. The larger pores in SCB enhance short-distance sound absorption but may weaken long-distance performance [2], while RH contributes to effective sound wave penetration and energy dissipation [11].

Overall, Sample A is more effective for long distances, while Sample C excels in short-distance applications, highlighting the importance of material composition and structure in sound reduction effectiveness.

3.3 Thermal Conductivity

As mentioned previously, all samples' thermal properties were assessed according to their thermal conductivity. The result for all samples were illustrated in Figure 5.

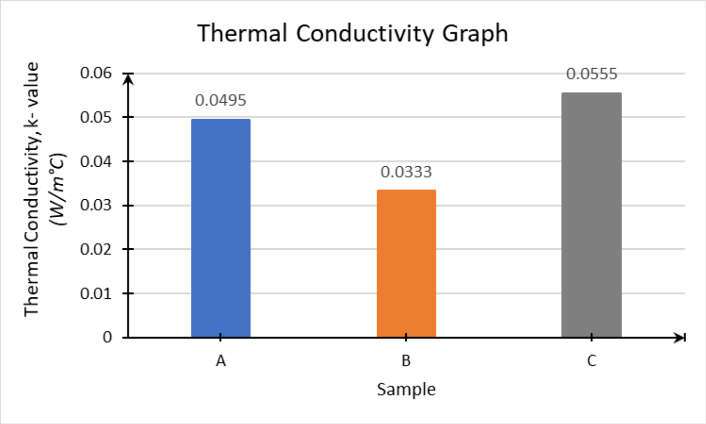


Fig. 5: Thermal conductivity graph for all samples

It is noticed that, the thermal conductivity of the samples varies significantly, with Sample B showing the lowest value at 0.0333 W/m°C, as illustrated in Figure 4.4. Composed of 50% rice husk (RH) and 50% sugarcane bagasse (SCB), Sample B achieves optimal thermal properties among the tested panels. This balanced composition allows for effective insulation, minimizing heat transfer and thereby reducing heat loss or gain [2]. According to [12], density also plays an important role when determining k value. The higher the density volume, the lower the thermal conductivity value [12].

In contrast, Sample C has the highest thermal conductivity at 0.0555 W/m°C, primarily due to its composition of 75% RH and 25% SCB. The porous structure of rice husk contributes to its insulating properties by creating air pockets that enhance sound wave penetration and promote energy dissipation through viscous and thermal losses [2]. While Sample C excels in certain thermal aspects, its higher k-value indicates less effective insulation compared to Sample B.

Sample A, consisting of 25% RH and 75% SCB, exhibits moderate thermal conductivity at 0.0495 W/m°C. The higher fiber content in SCB improves insulation performance, as the rough surfaces of the fibers create microscopic air pockets that enhance thermal insulation. However, Sample B remains the most effective in terms of thermal properties due to its optimal proportions, resulting in higher porosity and lower thermal conductivity. Overall, Sample B stands out as the best performer in thermal insulation among all samples.

3.4 Comparison

Following on the analysis and discussion above Table 3 presents a summary of the properties of the sample panels.

Table 3: Comparison developed sample panel board with standard gypsum board

Parameter / Sample	Thermal conductivity value, k (W/m°C)	Sound Absorption Coefficient, SAC	
		Low	High
Sample A	0.0495	0.112-0.234	0.022-0.826
Sample B	0.0333	0.101-0.204	0.030-0.923
Sample C	0.0555	0.146-0.225	0.033-0.782
Standard Gypsum Board	0.18-0.56 (BS EN 12524:2000)	0.25-0.95 EN ISO 11654:1997	0.60-0.95 EN ISO 11654:1997

According to Table 3, Sample B demonstrates the best thermal insulation performance, featuring the lowest thermal conductivity (k-value) of 0.0333 W/m°C. This value is significantly lower than the thermal conductivity ranges of standard gypsum board, which is between 0.18 and 0.56 W/m°C, indicating that Sample B is highly effective at insulating against heat. In terms of sound absorption, Sample C excels at low frequencies, achieving a Sound Absorption Coefficient (SAC) range of 0.146 to 0.225, which is superior to the other samples. However, all three samples exhibit lower SAC values compared to standard gypsum board, particularly in high-frequency sound absorption. Sample B achieves the highest SAC for high frequencies, ranging from 0.030 to 0.923, yet it still falls short when compared to the SAC values of gypsum board.

In summary, while the samples show strong performance in thermal insulation, they are less effective in sound absorption, especially at high frequencies, compared to standard gypsum board. Overall, Sample B stands out as the most optimal choice for both acoustic performances at high frequencies and thermal properties.

4. Conclusion

This study developed combination of sugarcane bagasse and rice husk as heat and acoustic panel. Acoustic and thermal conductivity value of the developed insulation panel were measured to evaluate their performance. Three samples of each material with different proportions were made, and result reveals Sample B, with 50:50 shows the most optimal performance of acoustic and thermal characteristics. However, in terms of sound absorption coefficient, Sample C excels at low frequencies outperforming other samples. As for thermal properties, it was found that all sample exhibit lower thermal conductivity value, especially Sample B with k value of 0.0333 W/m °C. This happens due to proportions of materials in each samples; rice husk and sugarcane bagasse which have different cellular structure— granular and fibrous structure. These results indicate that there was high potential of the used of combination of sugarcane bagasse and rice husk for use as construction materials for sound absorption and thermal insulation in buildings.

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Conflict of Interest

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

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