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Preliminary Study of Ceiling Board from Composite Material of Rice Husk, Rice Husk Ash and Waste Paper

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Abstract: In Malaysia, natural fibre always ended either in trash, burned away or only used for agriculture purposes and it is frequently causing problems in the process of disposal and thus contributing to the pollution environment. This research was aimed at reducing and recycling rice husk, rice husk ash and waste paper from our environment thereby reducing environmental pollution resulting from the disposal of these waste materials. In this research, composite ceiling board materials made from rice husk, rice husk ash and waste paper, as developed at the Universiti Tun Hussein Onn, Pagoh were investigated to determine their suitability for use in low-cost construction work. Four test were conducted to determine the properties of the ceiling board which is density test, moisture content test, water absorption test and sound absorption test. The results obtained showed that the sound absorption ranged between 0.033 α and 0.893 α; water absorption values of between 31.26 % and 102.90 %; moisture content values of between 4.87 % and 9.98 % as well as density values of 0.5071 g/cm^3 and 1.067 g/cm^3. These values obtained were compared with those of the previous study and conventional ceiling boards and it was observed that sample 3 obtained the optimum results

Keywords: Rice husk, Rice husk ash, Waste paper, Ceiling boards, Composite Material

1. Introduction

Malaysia produces many agricultural wastes such as rice husk, sugar cane, palm oil shrubs and so on. This type of material is frequent causing problems in the process of disposal and thus contributing to the pollution environment. Natural fibre that are from plants are being recognize by researchers and manufacturers since the fibre can be obtain with cheap prices, easy to find and importantly, have the strength and other characteristics that can be used and recycle for further usage. These fibre has been used widely due to its biodegradation characteristic which is better than synthetic fibre [1].

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Despite the benefits of synthetic materials that were exposed in construction industry, the material that are usually made for panel is from synthetic fibre such as, glass and mineral that have been used commercially in building has an affect through human health and environment. One of the effect on human health is skin allergies and respiratory system disorders [2].

Therefore, panels that are produce from composite material is one of the manageable ways to counter these problems. The usage of this natural fibre have a good effect on environmental since it follows the 3R concept of reduce, reuse and recycle. It also are much safer to manage since it does not affecting the health of the workers due to less presence of chemical substances when in the process of the material [3].

In Malaysia, these type of natural fibre always ended either in trash, burned away or only used for agriculture purposes and it is frequently causing problems in the process of disposal and thus contributing to the pollution environment. In fact, these natural fibre can be used as an alternative of a material that can absorb sound in a building. This fibre can also be obtain easily and at cheaper than the synthetic fibre. Furthermore, it can be recycled and reuse, thus making it environmental friendly.

2. Literature Review

2.1 Introduction

Ceiling is known as the upper surface that covers the top reaches of a room. It is not generally considered as a structural component, however a completed surface hiding the underside of the rooftop structure or the floor of a story above is needed for beautification. Ceiling is also known to reduce the absorption of heat or cold of the outdoor environment from entering the house through the roof.

Until this era, synthetic fibre that contain glass and minerals which are harmful for human are still being commercialize in the construction industry for making ceiling board but there are still someone who realize about the safety and health of human for this type of materials during its manufacturing and the users. For instance, the effect of glass splinters or minerals when it enters the lungs may jeopardize the owner's [4].

Despite the limitation of composite ceiling board in Malaysia, natural fibre, such as wood, hem, and coconut shell actually hold a great potential to replace expensive synthetic fibres in the manufacture of ceiling boards because of their advantages. Waste materials can be recycled into other materials which can still be useful to man thereby protecting the environment to an extent, from waste disposal challenges [5].

2.2 Ceiling board

In a study, waste paper was used in various mixing proportions with industrial wood particles to develop paper-particle boards using isocyanate as binding agent [5]. The result of this research work showed that boards containing waste paper exhibit excessive thickness swellings and should be restricted to interior use only. In a related research work, ceiling boards have been produced from rice husk with glue as the binder [6]. The results of this research showed that comparable economic boards can be made from rice husk as they can be made from other fibre materials

The physical properties of ceiling boards produced from waste papers using cement as binder were studied as shown in Table 1 and the results revealed that these boards had good hardness property, compressive strength low water absorption which makes them suitable for use in humid environment [8].

Table 1: Some physical properties of other types of ceiling board materials [5]

No.	Properties	Asbestos ceiling board	Fibre cement flat sheets	Trilite board	WP/RH composite ceiling board
1	Composition	Asbestos fibre	Portland cement, cellulose fibre & refined sand	MgO, $CaCO_2$, MgCl, natural silica + non toxic inorganics	Waste paper, rice husk and cassava starch binder
2	Density (kg/m^3)	1500 – 1950	1250 – 1350	1000 – 1050	103 – 201
3	MOE (N/mm^2)	Not available	5000 – 6000	5210 - 7845	1250 – 1320
4	Water absorption (%)	0.5 – 3.0	≤ 35	≤ 35	7.5 – 14.3
5	Flexural strength (N/mm^2)	1.0 – 3.0	3.0 – 7.9	12.1 – 17.1	0.03 – 0.1
6	Thermal conductivity (kW/MK)	0.052 – 0.096	0.015	0.0139	0.07 – 0.082

2.3 Rice husk

The reason of utilizing of RH in the construction industry are due to its high availability, low bulk density (90-150 kg/m^3), strength, grating in nature, protection from weathering and unique composition [6]. The presence of amorphous silica forms the pozzolanic effect of RH where the pozzolanic impact shows cementitious properties that expand the rate at which the material acquires strength. Chemical composition of alumina and silica in the material effect the level of the strength expansion. The differences in the type of paddy, crop year, climatic and geographical conditions, in addition to the sample preparation and method of analysis, could be the reason for the variation of chemical properties [7]. Thus, shows the chemical composition for each country is not the same.

2.4 Rice husk ash

RHA is a source of Silica and Silicon compound it is actually a Super-Pozzolan having about 85.0 % to 90.0 % silica content where the compressive strength of the material can be increased by up to 30.0 %, Water permeability, chloride penetration, and heat of hydration can be reduced by up to 60.0 %, and 25.0 % respectively with 10.0 % replacement of cement in concrete, [8]. The chemical compositions of RHA from various locations are presented in Table 2 which shows that the variation in chemical composition [9].

Table 2: Chemical properties of RHA from various locations [9]

Weight, %			
Constituents	Malaysia	Brazil	Netherlands
SiO_2	93.1	92.9	86.9
Al_2O_3	0.21	0.18	0.84
Fe_2O_3	0.21	0.43	0.73
CaO	0.41	1.03	1.40
MgO	1.59	0.35	0.57
Na_2O	*	0.02	0.11

Note:* not reported

2.4 Testing method

Four tests was conducted which are the density test, moisture content, water absorption test and sound absorption test of. In addition, each testing method follow the American Society for Testing and Material (ASTM) and British Standard (BS) standard of procedure.

i. Density test was done to determine the relative density for the ceiling board. The test was calculated by using calculation below:

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

ii. Moisture content test was done to determine the moisture content for the ceiling board. The test was calculated by using calculation below:

$$\text{Moisture content } (\%) = \frac{\text{Initial mass sample (g)} - \text{Final mass sample (g)}}{\text{Final mass sample (g)}} \times 100\% \qquad \text{Eq. 2}$$

iii. Water absorption test was done to determine the water absorption percentage for the ceiling board. percentage of water absorption was calculated by using equation below:

$$\text{Water absorption } (\%) = \frac{\text{Wet sample mass (g)} - \text{Dry sample mass (g)}}{\text{Dry sample mass (g)}} \times 100\% \qquad \text{Eq. 3}$$

iv. Sound absorption test was done to measurements of impedance events on the ceiling board by using BSWA Technology software.

3. Results and Discussion

The experiment and research were conducted to investigate of the properties of ceiling board from rice husk, rice husk ash and waste paper. Four physical test are conducted for data collection and reviews. Data analysis will be conducted table and graph to organize data collected and to ease for concluding the research that has been conducted. The methodology flow for this research as shown in Figure 1.

3.1 Preparation of material

In this research, the production of ceiling board needed to have some important materials. The materials were rice husk, rice husk ash, waste paper and Urea Formaldehyde glue. The rice husk and the rice husk ash was from from Jelapang Selatan Mill factory at Muar. Next, the waste paper was obtained locally at Pagoh and the Urea Formaldehyde glue were obtained from Evergreen wood factory at Parit Raja. These materials were prepared to ensure the experiment can be carried out based on the objectives stated.

3.2 Mixture proportion

Six binder mixtures were prepared involve a control mix with rice husk and rice husk ash with ratio of 6:0:1, and the others with rice husk ash with ratio of 1 (labelled in the Table 3). The addition of rice husk ash with 10.0 % was based on a study on cement replacement with maximum of 10.0 % RHA that result in strength development comparable to the control specimens [9]. The tests evaluated on 6 specimens of dimensions 400 mm × 400 mm × 13 mm that then will cut to round shape with diammeter of 100 mm and 28 mm. Tests involved determine the density of the material, determination of the moisture content, determination of water absorption values by water curing of specimens at 24 h and determination of sound absorption of 125 Hz to 3000 Hz.

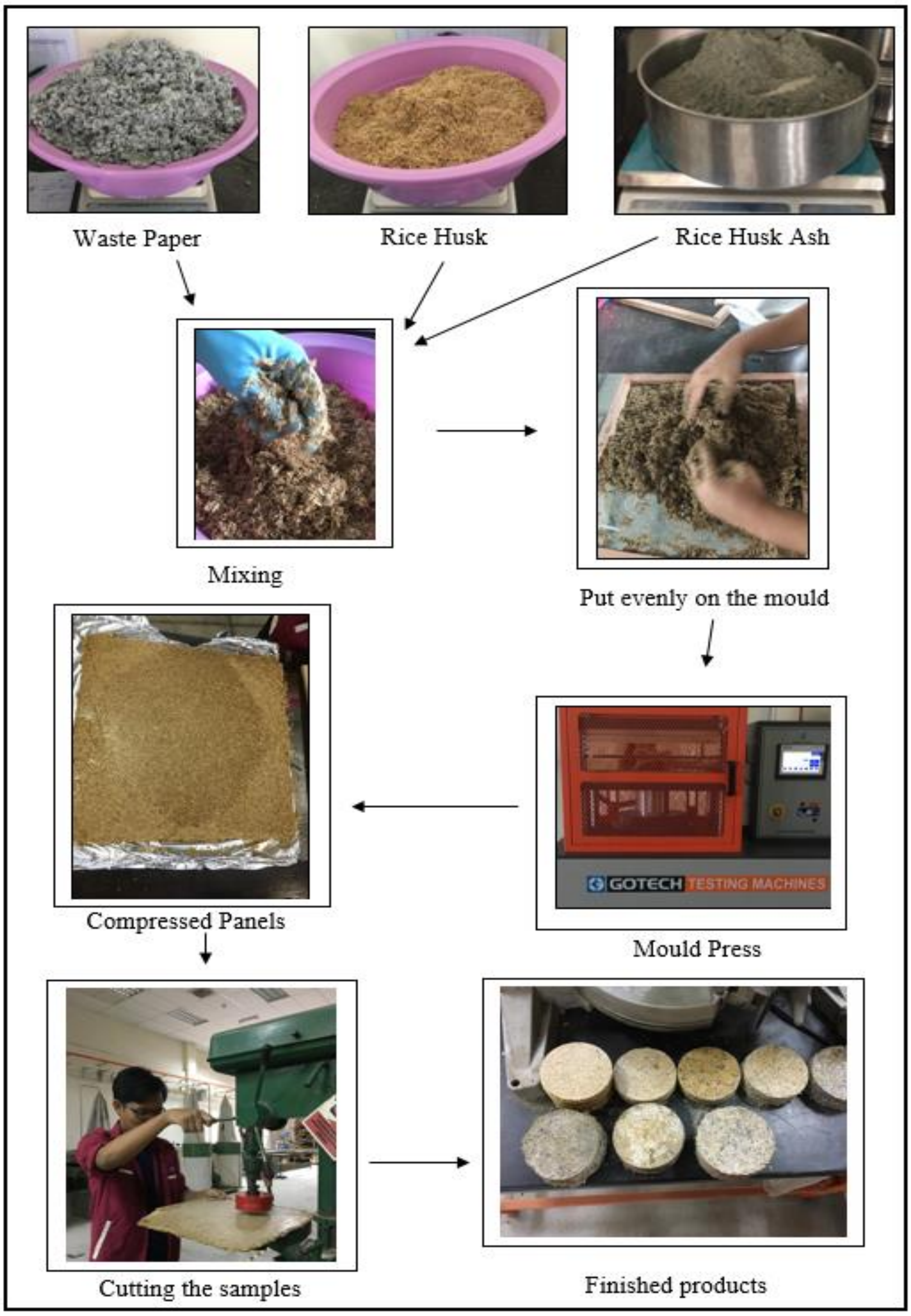

Figure 1: Methodology flowchart

Table 3: Proportion ratio of ceiling board samples

Sample ID	Ratio		
	Waste Paper	Rice Husk	Rice Husk Ash
1	0	6	1
2	1	5	1
3	2	4	1
4	4	2	1
5	5	1	1
6	6	0	1

4. Results and Discussion

To achieve the goals of a research, data collection must be done in order to justify a statement made or a hypothesis on a given case or study. With the data gathered from various method such as interview and lab testing, real situation can be evaluated and integrated with published statement to determine if it complement each other that determine the success of a research. Therefore, it is important to do data collection to have a statement to sort out the outcome of the study.

4.1 Density test

In this section, density of the samples were test based on ASTM D2395. Three round samples with each sides of 100 mm have been weighted and the density have been calculated. Figure 2 illustrated the density value that were obtain. Sample 1 with 100.0 % RH achieved 1.067/cm3. Sample 2 obtained density of 0.859 g/cm3. While sample 3 gain 0.770 g/cm3 and sample number 4 gain 0.708 g/cm3. The second last sample achieved density of 0.6173 g/cm3 and the last sample achieved 0.507 g/cm3. Panel board is accepted when the density value of the samples is either medium or low which is 0.800 g/cm3 or lower [10].

However, the density of the ceiling board from natural fibre, according to Epuknobi [11], has the value of 0.415 g/cm3 to 0.356 g/cm3. From the data that obtained, only 4 samples were fall into the medium and low category which is sample 3, 4, 5 and 6. Even though four of the samples does not fall in the range of standard, the ceiling board still bonded well and achieve a low-medium density.

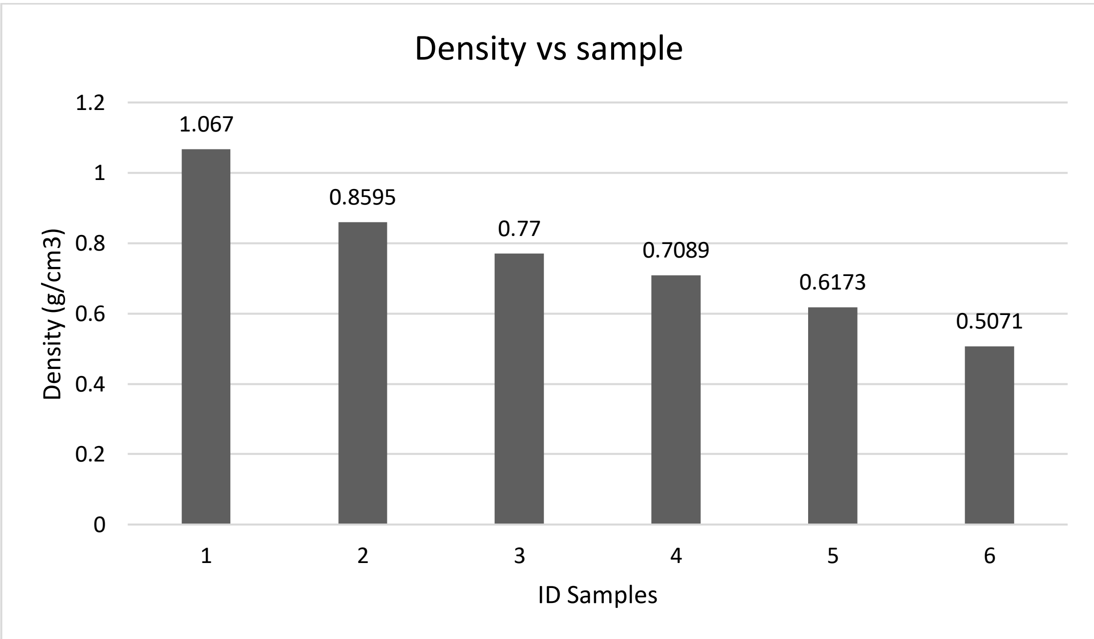

Figure 2: Density graph based on samples

4.2 Moisture content test

In this section, the moisture content was tested on each sample and was calculated through this test. Percentage of moisture content is crucial for testing because the durability of a panels is depending on the moisture content. Moisture content should not exceed 10 % set by the standard ASTM D4442.

From the data as shown in Figure 3 that have been obtained, each type of sample has different moisture content. Sample 1 with 5.47 %. Sample 2 obtained moisture content of 7.99 %. While sample 3 gain the highest which is 4.87 % and sample number 3 gain the lowest which is 5.23 %. The second last sample achieved moisture content of 8.27 % and the last sample achieved 9.98 %. According to

Ajiwe [12], the rice husk panel moisture content were between 27.3 % to 32.3 %c which is much higher and making this test that obtained was much lower and not exceeding 10.0 % of its original mass.

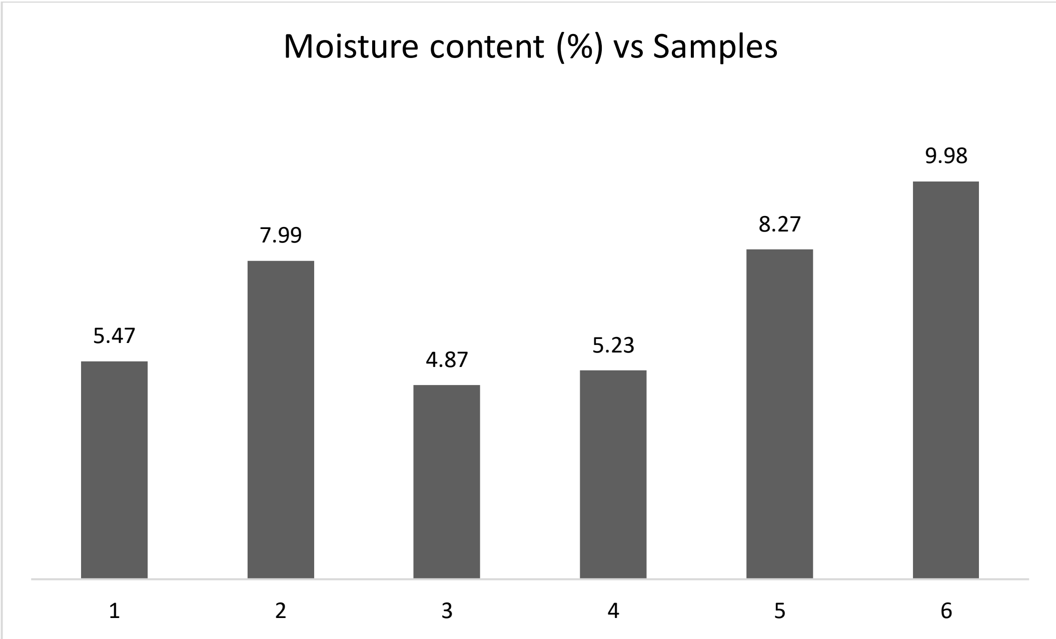

Figure 3: Moisture content based vs samples

4.3 Water absorption test

In this section, the samples undergo water absorption test by following the ASTM D750 standard for 24 hours. From the data shown in Figure 4, it can be analysed that sample 4 obtained the lowest water absorption while sample 6 obtained the highest water absorption of 102.9 %. According to Ataguba [5], the results obtained from this study showed that this composite material of rice husk and waste paper mix obtained the water absorption percentage of 7.5 % to 14.0 % for 24 hours test. The results show that all of the samples is not within the range of 24 hours of water absorption percentage. It is observed, that the sample has tiny size of pores that can be seen from the surface of the ceiling board. Thus, the pores act to absorb and store water in it. From the result, the absorption of water is higher.

Figure 4 depicts that sample 3 and 4 obtained less percentage of water absorption test while sample 6 has higher absorption ability. The water from outside was absorbed in the ceiling board due to the water move through the capillary pores in it. In general, the percentage of water absorption increase with the age of sample. Due to ceiling board is not compact properly, the distance between particles become farther and cause the absorption of water to happen.

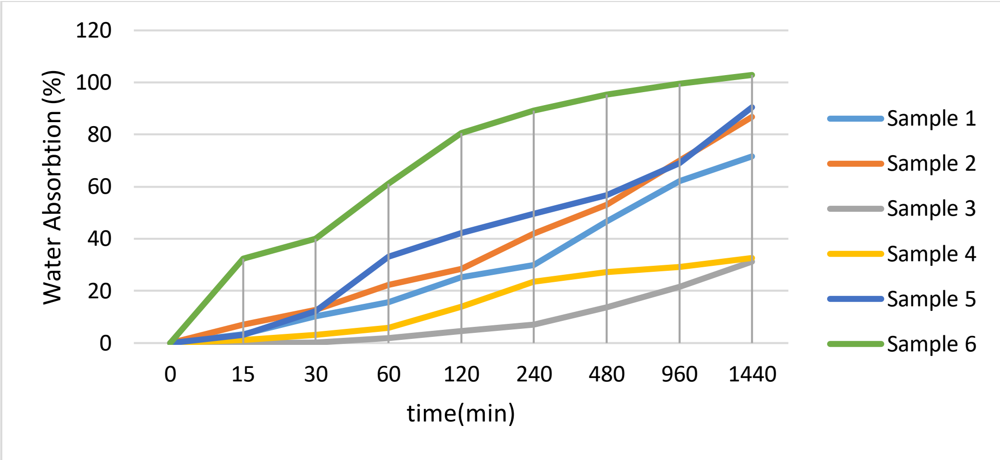

Figure 4: Graph of percentage of water absorption test vs time

4.4 Sound absorption test

In this section, sound absorption test were tested based on BS EN ISO 10534. Three samples of 100 mm diameter have been tested with low frequency which is between 0 to 1500 Hz while three samples of 28 mm diameter is tested with high frequency which is between 1500 Hz to 3000 Hz. Based on the graph that interpreted to Figure 5, it stated that sample 1 gain the maximum coefficient of 0.392. Sample 2 obtain coefficient of 0.78. Sample 3 gain the highest with 0.893 while sample 4 obtain 0.777.Sample 5 and 6 obtain 0.578 and 0.34. Overall, once again sample 3 obtain the highest maximum absorption coefficient than the other samples for high frequency test.

According to Acoustical Society of America [13], the maximum coefficient for market ceiling which is gypsum, plastic, and concrete as shown in Table 4 is 0.25, 0.14 and 0.10. The results show that all of the samples is beyond those ceiling. According to Fouladi [14], by comparing the absorption coefficient of coir, corn and grass which is a natural fibre in various octave bands with common building and acoustic panel materials showed that they are outstanding alternatives as shown in Figure 6.

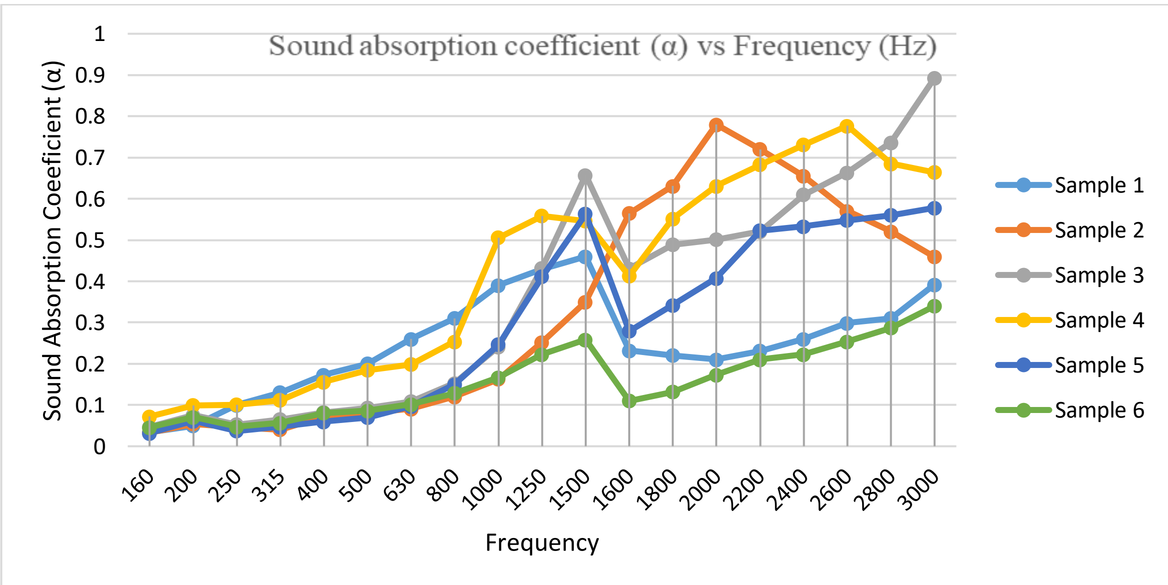

Figure 5: Sound absorption coefficient (α) vs frequency (Hz)

Table 4: Acoustical Society of America coefficient value [13].

Type	Sound Absorption Coefficient (α)					
	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz
Gypsum Board	0.25	0.15	0.08	0.06	0.04	0.04
Plastic wall or ceiling	0.14	0.10	.0.6	0.05	0.04	0.03
Concrete Block	0.10	0.05	0.06	0.07	0.09	0.08

Table 5: Sound absorption coefficient of natural board [14].

Natural fibres	Frequency (Hz)					
	125	250	500	1000	2000	4000
Coir	0.04	0.06	0.12	0.46	0.97	0.78
Corn	0.04	0.06	0.16	0.28	0.81	0.90
Grass	0.11	0.08	0.14	0.45	0.98	0.70
Sugarcane	0.07	0.05	0.13	0.88	0.63	0.78

4.5 Comparison

Figures should be numbered based on the section number and formatted based on the style as presented in the following:

The physical properties and sound absorption properties of ceiling board made by rice husk, rice husk ash and waste paper to other types of ceiling board based on test that has been done by following the standard. For comparison, only the optimum sample which is sample 3 being compared with others.

Table 6: Physical properties of other types of ceiling board materials to be compared

No.	Properties	Asbestos Ceiling Board	Fibre Cement Flat Sheets	Trilite Board	RH/WP /RHA Composite Ceiling Board
1	Composition	Asbestos fibre	Portland cement, cellulose fibre & refined sand	MgO, $CaCO_2$, MgCl, natural silica + non-toxic inorganics	Rice husk, Rice husk ash waste paper and Urea Formaldehyde
2	Density (Kg/m^3)	1500 – 1950	1250 - 1350	1000 – 1050	770
3	Moisture Content (%)	<10	<10	<10	5.23
4	Water Absorption (%)	0.5 – 3.0	≤ 35	≤ 35	31.26

Based on Table 5, the comparison can be observed for the composite panel is 770 kg/m3 which is lesser density compared to asbestos ceiling board, fibre cement flat sheets and trilite board. For the moisture content test, it is shown the sample obtain 5.23 % .For water absorption the values is 31.26 % which is below the standard by fibre cement and trilete board. It is a good result compare fibre cement slat sheet and trilite board. The asbestos contains a lowest percentage for water absorption which is between the range 0.5 – 3.0.

The standards adopted in Malaysia are based on the Acoustical Society of America (ASA). Thus, the data released by the Acoustical Society of America has been the guideline for producing all kinds of panels including composite panels whose effectiveness is achievable and can be classified as acoustic material within the building. Table 6 and Figure 7 below is a table of sound absorption coefficients issued by the Acoustic Society of America.

Table 7: Sound Absorption Coeeficients Issued by the Acoustic Society America

Type	Sound Absorption Coefficient (α)					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	3000 Hz
Glass fibre Ceiling Tiles	0.70	0.85	0.75	0.85	0.90	0.90
Fiberglass Wall Panel – 2 inches thick	0.30	0.50	0.80	0.90	0.80	0.75
Concrete Block, painted	0.10	0.05	0.06	0.07	0.09	0.08
Gypsum Wall Board	0.25	0.15	0.08	0.06	0.04	0.04
Plastics Wall or Ceiling	0.14	0.10	0.06	0.05	0.04	0.03
WP/RH/RHA composite	0.04	0.05	0.09	0.24	0.52	0.89

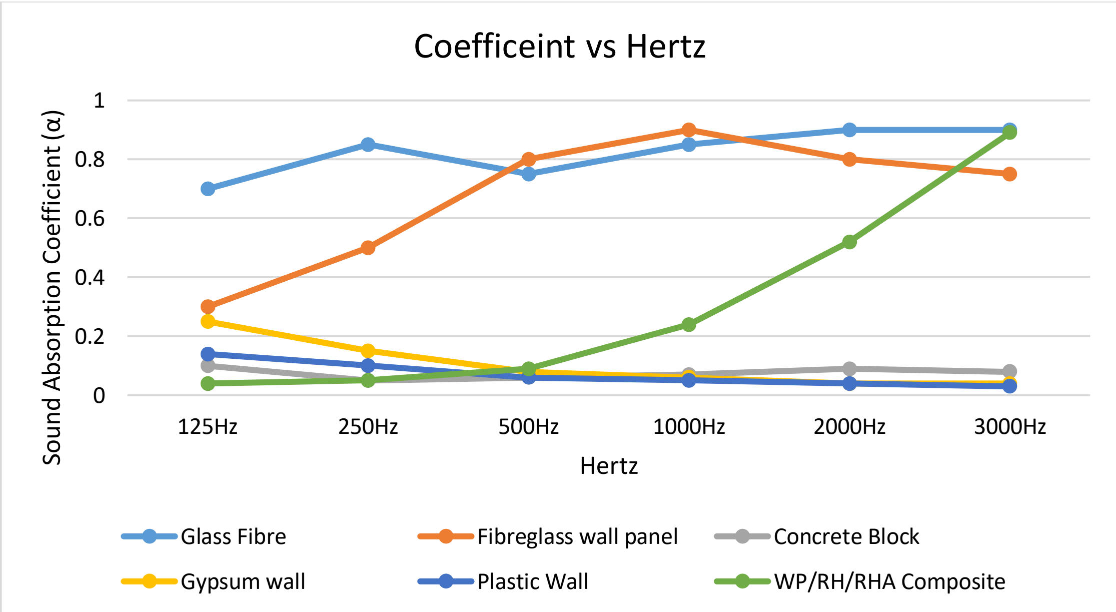

Figure 6: Sound Absorption Coefficients Issued by the Acoustic Society of America

Based on the Acoustical Society of America standard above the low frequency for gypsum board, the maximum noise absorption coefficient is 0.25 at a frequency of only 125 Hz. Meanwhile, for rice husk, rice husk ash and waste paper composite panel is 0.24 at 1000 Hz and 0.89 at optimum frequency 3000 Hz. This proves that the resulting composite panel by rice husk, rice husk ash and waste paper is able to absorb sound better than standard gypsum board at high frequency of 1500 Hz to 3000 Hz. In conclusion, the composite panels of RH/WP/RHA produced have the potential to be used as a building noise absorbing material at high frequency level compared to low frequency.

5. Conclusion

To inculcate, based on the gypsum board standard from the acoustic society of America, the increasing value of frequency, the lower the sound absorption coefficient value. But the coefficient value for rice husk, rice husk ash and waste paper panel shows differently which is better with maximum coefficient value of 0.893 at 3000 Hz which can replace gypsum wall board that has less coefficient value of only 0.04. Not all sample indicate a better value, but sample number 3 which ratio 4:2:1 shows the sample can absorb sound well. Based on sample 3, the three others type of test, it can conclude that the density test reached medium density which can acknowledge as a good ceiling board. Next is moisture content, where it gain value of 5.23 % which is less than 10.00 % stated by the standard ASTM D4442. Finally, the water absorption test for sample 3 obtained the least percentage of 31.65 % than all the other samples.

The first objective is to produce a ceiling board by using composite material varying proportion of rice husk, rice husk ash and waste paper. From the analysis, sample 3 that consist ratio of 4:2:1 is within all the test standard which is the second objective where, density test was based on ASTM D2395, moisture content test was set by the standard ASTM D4442, water absorption test followed the ASTM D750 standard for 24 hours and sound absorption test refers BS EN ISO 10534-2:2001.

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