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Investigation on Sound Absorption of Rice-Husk Reinforced Composite

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Abstract— Natural fibres have become an important element in producing alternative fibre-reinforced composites. The use of natural fibre for sound absorber material has recently investigated. This study investigates the use of rice-husk waste as the potential element for sound absorption material of rice-husk reinforced composite. The rice husk is initially cleaned and dried up at room temperature (25 - 30 ºC). The dried rice husk is then mixed together with Polyurethane (PU) foam as a binder to produce the rice husk reinforced composite. Six different samples have been produced according to the percentage of rice husk. The specimens were tested using an impedance tube. The result found that the best percentage of rice husk was obtained at 25 percents. The sound absorption coefficient obtained demonstrated that the mixture produced the best performance at low frequency region. The results also demonstrated that the rice husk reinforced composite have a better sound coefficient compared to other natural materials, hence promising a great potential for commercialisation.

Keywords: composite sound absorber, natural fibre, rice husk, sound absorption coefficient.

I. INTRODUCTION

THE sound which is not desired is called noise. Noise may consist of a single pure tone but most cases consist of many tones at different frequencies and intensities. Noise pollutant has created concerns among people. Noise effects are including sleep disturbance, stress and speech interferences. These concerns have led to various investigations regarding to noise control and sound absorptions [1]-[4].

Noise control and its principles play an important role in creating an acoustically pleasing environment. This can be achieved when the intensity of sound is brought down to a level that is not harmful to human ears. The demand for a better environment and more diversified life style are increased. Achieving a pleasing environment can be obtained using various techniques that employ different materials. One such technique is by absorbing the sound and converting it to thermal energy. Sound absorbent materials are used within rooms or enclosed working areas to reduce reflection and thereby reduced the noise levels in the room. Therefore, the thin, lightweight and low-cost materials that can absorb sound waves in wider frequency regions are strongly desired.

Sound is “absorbed” by energy conversion into heat in the material. Conventional materials such as glass fibres, open cell foams, and acoustic tiles are often used as the sound absorbent materials. These materials are called dissipative or porous materials due to the sound energy are dissipated in the interstices of the fibres. Their maximum efficiency occurs at the typical thickness of these materials. Recently, several investigations have implemented natural mineral as the filler material of the sound absorbent such as wood, rubber and tea leaf [5]-[7]. Natural fibres have many advantages compare to synthetic fibres, for example low weight, low density, low cost, acceptable specific properties and recyclable or biodegradable. These materials have demonstrated good distinctive features from the both of aspect of sound qualities and mechanical. This shows that mineral fibres have the potential as filler material of sound absorbent material.

Paddy has been identified as a major source of crop, mostly cultivated by Malaysian society. Paddy produces rice, a main source in Malaysian food chain system. Once the paddy has been utilized, the rice hulls are burned, causing the air pollution. Therefore, it is important to recycle the rice husk into a beneficial thing. The objective of this research is to identify the ability of rice husk as an absorbent material by find the sound absorption coefficient. The research is also investigates the behavior of polyurethane as an additive or binder to rice husk and observe the effect of increment in rice husk percentage of the absorber.

II. LITERATURE STUDY

The sound absorption material can be applied to the ceiling, floor and walls to remove as much reflected sound as possible or desirable so that the room appears to be like a free space. There are two types of the acoustical materials which are porous material and panel absorber. Porous acoustic possess a cellular structure of interlocking pores. It is within these interconnected open cells that the sound energy is converted into thermal energy. Common porous

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absorption materials are made from vegetable and mineral fibers and elastomeric foams, and come in various forms. For panel absorbers, a sound wave that strikes a panel causes the panel to vibrate at either the fundamental or a harmonic frequency of the incident wave. Owing to the inherent damping of the panel, an energy loss occurs and hence some sound absorption takes place. A low frequency incident wave is much more effective in causing the panel to flex than a high frequency one. The absorption coefficient as a function of frequency is dependent upon the mass and stiffness of the panel and therefore is determined by the specific design configuration. In general, the absorption coefficients for a basic panel are greater at low frequencies than they are at high frequencies. Typical values of sound absorption coefficient, α for 125 Hz are 0.2 to 0.5 [8].

Materials such as glass fibre or mineral wool blankets, open cell foams and acoustic tiles are called dissipative or porous absorbers because the sound energy is dissipated in the interstices of the fibres. Meanwhile, membrane or panel absorbers convert the sound energy into heat as a result of bending deformations associated with the typical thickness of these materials that are used in practice. Cavity or Helmholtz resonator absorbers provide a very high absorption coefficient but over a very narrow band of frequencies. It is used for industrial applications where it is necessary to reduce the effect of pure tones [1].

Previous researches have showed that many recycled or waste materials were sound absorbent, for example recycled rubber and woods. According to Yang et al [5], the recycled rubber in particles shaped ranging in 150-840μm was built in within the composite. One of the composite that have been tested was layer structured, with the top was recycled rubber particles and next layer was polyurethane as a porous foam material. The result demonstrated that sound absorption functional region shifts to the high-frequency side as the PU foam layer becomes thicker and the sound absorption in higher frequency region was relatively low. It is clear that the improvement on sound absorption of the rubber particles layer due to the PU foam is limited [5]. Meanwhile, Wassilieff [3] has investigated about sound absorption of wood-based materials. In this research, it used the particle board made of compressed wood shavings. The result showed that it wood absorbed the sound at the low frequency region.

The rice husks are unique in nature. They contain approximately 20% opaline silica in combination with a large amount of the phenyl propanoid structural polymer called lignin. This abundant agricultural waste has all of the properties one could ever expect of some of the best insulating materials. The rice hulls do not flame or smolder very easily. It is highly resistant to moisture penetration and fungal decomposition, do not transfer heat very well, do not smell or emit gases, and they are not corrosive with respect to aluminum, copper or steel. In their raw and unprocessed state, rice hulls constitute a Class A or Class I insulation material, and therefore, they can be used very economically to insulate the wall, floor and roof cavities of a super-insulated Rice Hull House [9].

Polyurethanes can be designed to be either a solid or foam. Creating foam with polyurethane involves adding a blowing agent to the polyol component, which activates when the polyol reacts with the isocyanate. Typical wall thickness for un-reinforced polyurethane structural foam is 9.5mm. The flexural modulus of polyurethane structural foams increases as the density increases [10].

The absorbed energy is usually being converted into another form of mechanical energy which is generally heat. The sound absorption coefficient of a material is the fraction of the randomly incident sound energy that is absorbed or otherwise not reflected by the material. It is defined as the ratio of the sound energy absorbed by the surface to the sound incident upon the surface. It is also a measure of the sound-absorptive property of the material.

Sound Absorption Coefficient, α: The sound absorption coefficient for every material varies with frequency. It is a common practice to list the coefficient of a material at frequencies of 125, 250, 500, 1000, 2000, and 4000 Hz the sound absorption coefficient is donated by α. The higher the coefficient number, the better is the absorption. In general, the coefficient number can be obtained using the following equation.

$$\alpha = 1 - \left|R^2\right| = 1 - R_r^2 - R_i^2$$

(1)

where, R = complex sound reflection coefficient, r and i represent incident sound and absorbed sound, respectively.

Noise Reduction Coefficient, NRC: Another term employed to describe the absorption properties of a material is Noise Reduction Coefficient. The NRC of a material is the average value of the absorption coefficient of the material at the frequencies of 250, 500, 1000, and 2000 Hz. It rounded off to the nearest multiple of 0.05. It is normally used as a simplified descriptor for convenience. The noise reduction coefficient, NRC is more convenient to be used because it is a single number than using several of data depending on the frequency.

$$\text{NRC} = \frac{\alpha_{250} + \alpha_{500} + \alpha_{1000} + \alpha_{2000}}{4}$$

(2)

III. MATERIAL AND METHODS

This investigation used rice husk as the filler material whereas the Polyurethane foam was selected as the binder.

Preparation of rice-husk samples: The rice-husk was initially underwent a treatment process in order to strengthen the sample structure. The treatment was also done to obtain the cleanest appearance to the rice husk. Initially, the rice husk was exposed to the heat in order to isolate it from impurity that present in the raw rice husk. Then, the rice husk was immersed with the 95% mixture of Natrium Hydroxide (NaOH) and 5% of water. This immersion process took time up to 24 hours. Next, the immersed rice husk was washed with water and then exposed to the heat of the sun for about 24 hours. In order to ensure the rice husk was totally clean and strong, the rice husk was dried in the oven with 80ºC for about 12 hours. Finally, the rice husk was blended by using Variable Rotor

Mill machine to get a powder particle.

Preparation of mold: The samples were prepared in two different sizes. The first dimension was 100-mm in diameter and 25-mm thickness, whereas the second dimension was 28-mm in diameter and 25-mm thickness. The material used for mould is a rectangular shape mild steel plate. The round shape mould is produced using the CNC machine. Finally, the mould underwent surface finish in order to obtain good and smooth surface finish.

Fabrication of rice-husk reinforced polyurethane: In order to produce polyurethane foam, two types of liquid were used, namely polyol blend Maskimi foam 788B/9/45 and isocynate Maskimi 80. The ratio between the polyol and isocynate was 100:110 or 10:11. The cleaned rice husk was mixed with this PU mixture. This mixture was calculated based on mass and density of mold. The density of the mold was 100kg/m^3 and the mass was 21.65grams. This mixture of rice-husk and polyurethane was poured into mould and left for 2 hours under room temperature. Overall, there were six samples of rice-husk added polyurethane were prepared. The sample has been produced based on the percentages of rice husk.

Experimental works: All the experiments were conducted in Vibration Laboratory, Universiti Tun Hussein Onn Malaysia (UTHM). The main purpose of the testing was to obtain the sound absorption coefficient, α of the foams. For the experiment, the standard test procedure used was based on ASTM E1050-98. The experiment setup used the Two-microphone Transfer-function Method [11]. A sound source (loudspeaker) was mounted at one end of the impedance tube and a sample of the material was placed at the other end. The loudspeaker generates broadband, stationary random sound waves. These propagate as plane waves in the tube, hit the sample and are reflected. By measuring the sound pressure at two fixed locations and calculating the complex transfer function using a two-channel digital frequency analyzer, it is possible to determine the complex reflection coefficient, the sound absorption coefficient and the normal acoustic impedance of the material. The usable frequency range depends on the diameter of the tube and the spacing between the microphone positions [11].

IV. RESULT AND DISCUSSIONS

Sound Absorption Coefficient: Figure 1 shows the results of sound absorption coefficient for overall samples. It shows that although there was inconsistencies in values, the pattern of most curves were identical to the membrane type of curve absorber. It can be seen that most samples yield a higher values at frequency of 250 Hz. The highest sound absorption coefficient number obtained for 25 percents rice husk added with polyurethane. The lowest sound absorption coefficient was obtained for 15 percents of rice husk added with PU.

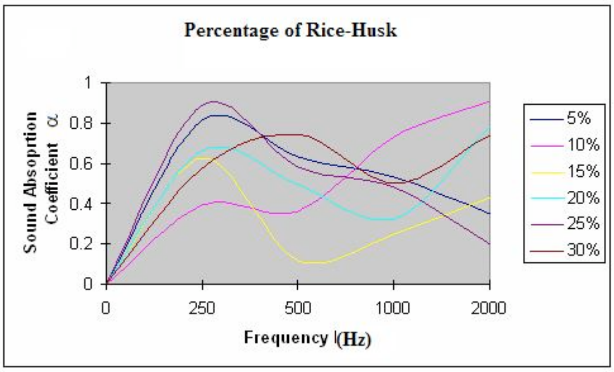

Figure 1: Sound absorption coefficients for all samples.

Comparisons between PU mix with rice husk and Virgin PU: Figure 2 demonstrates the comparison between the virgin PU and the 25 percents of rice husk added with PU. The result shows that the patterns of both curves were different. At low frequency, 0 – 500Hz, sound absorption of rice husk was higher than virgin PU with the value of 0.899 at 250Hz. whereas, the virgin PU recorded higher absorption at a higher frequency, 2000Hz with a value of 0.679.

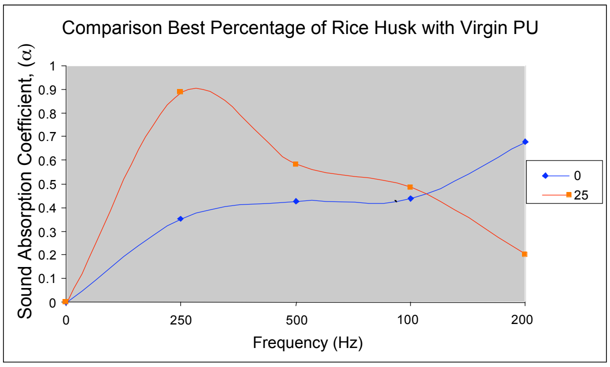

Figure 2: Comparison between 25 percents of rice husk with the virgin polyurethane.

Noise Reduction Coefficient, R: Based on (2), the noise reduction coefficient, R values were calculated for all samples. Figure 3 shows the result of NRC obtained. It shows that the highest NRC value was obtained for 30 percents of rice husk.

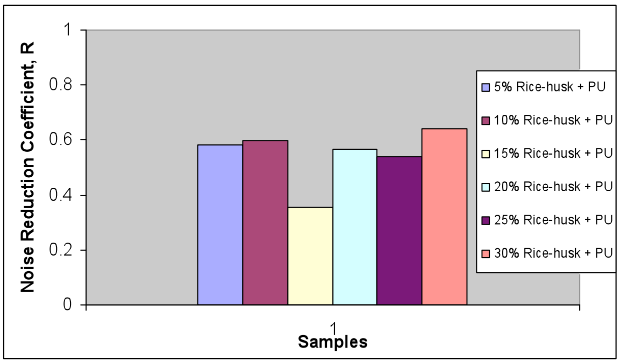

Figure 3: Noise reduction coefficient values for all samples.

Comparison between other waste materials: The previous result has demonstrated that rice husk has the potential for sound absorbent material especially for lower frequency region. It was indicated that the rice husk is a useable material and has its own value. However, in order to validate this research, a comparison has been made with other natural materials obtained from [3] and [6]. This is done in order to find out how far sounds absorption effectiveness of rice husk compared to these materials. The 25% of rice husk is compared with recycled rubber with laminated PU on the top of the double layer structure and compressed woods shaved. The result demonstrated that rice husk was superior to rubber particles and wood shaved, as shown in figure 4. At 250Hz, the recorded sound absorption coefficient for rice husk was 0.889, whereas for rubber particles and wood shaved, the coefficients were 0.583 and 0.484, respectively. The result also shows that both rice husk and rubber particles yield the maximum absorption coefficient at 250Hz, whereas for wood shaved at 1000Hz.

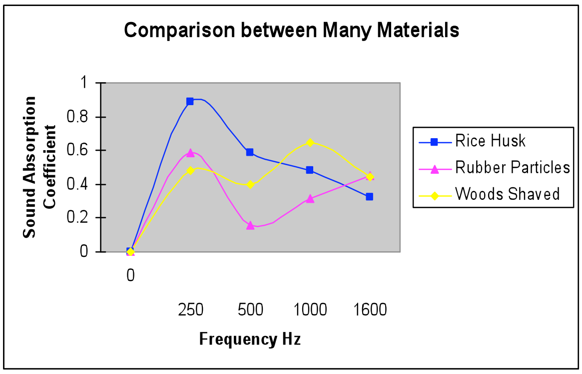

Figure 4: Comparison on sound absorption coefficient for rice husk with rubber and wood.

V. CONCLUSION

The study of rice husk waste material for sound absorption purposes has been reported. The optimum percentage of rice husk was obtained at 25%. The pattern obtained for rice husk was similar to membrane absorber curves which are predominant at the lower frequencies. Furthermore the peaks α value was obtained at 250Hz. Comparison between virgin PU and the optimum percentage rice husk (25%) indicated that α value of mixture is higher than virgin PU at low frequency whereas for high frequency the virgin PU is higher. The comparison between other natural materials also has been done for recycled rubber and wood shavings. The result demonstrates that rice husk is superior to both materials for range 0-500Hz. Since, rice husk is available in large amount, the potential for commercialization, especially for low frequency sound absorbent material is possible.

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