Study on Sound Absorption Properties of Coconut Coir Fibre Reinforced Composite with Added Recycled Rubber

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Abstract

Sound pollutions have become worsen and creating concerns for many peoples. Conventionally, expensive sound absorption materials are employed to control noise disturbances. However, recent developments on natural fibres have created interest for researchers especially for acoustics application purposes. This paper investigates the viability of coconut coir added with recycled rubber to be implemented as sound absorption panel. The composite is constructed at prescribed percentages of fillers and polyurethane as resin. The two-microphone method was applied to obtain the acoustic properties of the samples. The samples were also tested for physical properties such as density and porosity, as well as the microstructures. The results demonstrate good acoustics performances and highlight the potential of the coconut coir reinforced with recycled rubber as the sound absorption panel.

Keywords: Sound Absorption Coefficient, Coconut coir, Recycled Rubber, Polyurethane.

1. INTRODUCTION

Noise pollution has become a common major problem to various developing nations [1]. Such uncontrolled pollution has always contributed to various levels of discomfort and uneasy feelings to many people [2 – 4]. Exposure to a very loud noise for a specific duration can lead to hearing impairment; of which sometime to be permanent. Here lies the importance of noise control, which tries to reduce the direct contact of noise to human. Various techniques have been implemented to reduce noise pollution, e.g. wearing hearing protection, installation of sound barrier and implementing sound absorption panel. This paper is more interested in the sound absorption panel rather than any other techniques available.

Various product of sound absorption panels have been commercialised in open market. Practically, these sound absorption materials are applied as interior lining for apartments, automotives, aircrafts, ducts, enclosures, sub-flooring and interior surface for wall which can help to reduce the reverberant noise. However, conventional sound absorption panels utilised fibre glass, mineral wool blanket, open cell foams and acoustics tiles; which is sometimes expensive. Recent developments have seen the implementation of natural fibres as the potential replacement for synthetic fibre products. Traditionally, these natural fibres are often disposed through open burning which creates another issue of environmental pollutions.

Due to this problem, and abundance of natural fibres, several researchers have initiated to explore the potential of natural fibres [5 – 8]. Ersoy and Kucuk [9] have investigated the potential of tea leaf fibres for sound absorption application. Here, the comparison has been done for three different configuration of tea-leaf fibre with and without backing provided by a single layer of woven textile cloth. The potential of rice-wood straw also has been investigated [10]. It was found that rice-wood straw capable to absorb sound with higher absorption coefficient compared to any other wood-based materials. Yang et.al [11] also has investigated the sound absorption performance using recycled tyre particle and rice straw. The results show water proof, flexibility and flexural properties of the composite are superior to those of wood particleboard.

This paper investigates the viability of composites from coconut coir added with recycled tube tyre particles for sound absorption material. The effect of adding recycled rubber particles and the influence of polyurethane are investigated as the potential replacement of synthetic and mineral fibres.

2. MATERIALS AND METHODS

The study used coconut coir as the main raw material and recycled rubber as the secondary material. Before being used, both materials have to undergo several processes. The coconut coir has to undergo several pre-treatment processes. Initially, it was crushed to obtain small grain, soaked in water, washed and dried before it was ready to be used. The processed coconut coir was added with recycled rubber particles and evenly mixed together using polyurethane as the binder, prescribed as in Table 1 and 2. Here, the percentage of polyurethane varies in order to investigate the influence of resin on the performance of coconut coir composites. The composite boards were prepared in two diameters, e.g. 100 mm for low frequency and 28 mm for high frequency. The samples were compacted by hot press machine to produce the composite fiber boards.

Table 2: Composition of coconut coir, recycled rubber with 25 percents of polyurethane

Sample	**Coconut Coir (%)**	**Recycled rubber (%)**
1	0	100
2	10	90
3	20	80
4	30	70
5	40	60

Table 2: Composition of coconut coir, recycled rubber with 35 percents of polyurethane

Sample	**Coconut Coir (%)**	**Recycled rubber (%)**
1	0	100
2	10	90
3	20	80
4	30	70
5	40	60

Sound absorption of a material is defined as the ability of the material to absorb sound energy and convert it into other forms of energy. It is always indicated by the sound absorption coefficient ranging in between zero to one; i.e. zero mean total reflection and one means total absorption. Here, the sound absorption coefficients of the composite were determined using the impedance tube that employs the two-microphone method, following the ASTM E1050-98 and ISO10534-2 international standards [12]. Figure 1 illustrates the schematic diagram for acoustics measurement.

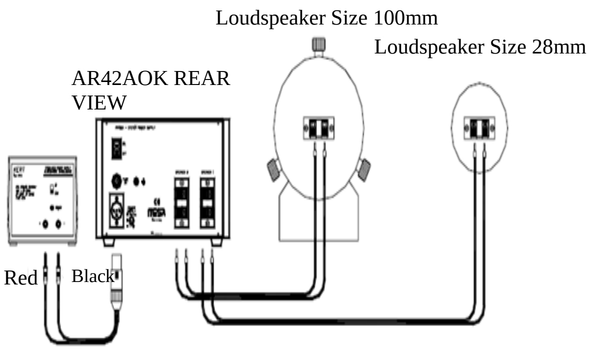

Fig. 1 Schematic diagram of impedance tube for acoustics measurement

Another experiments tested on the composites fibre board were porosity and density tests. Porosity test is a measurement of void spaces in a material, defined as a fraction of void volumes over total volume. It is indicated as percentages between zeros to hundred percents. Porosity can be a relic of deposition (primary porosity, i.e. space between grains that were not compacted together completely) or can be developed through alteration of the rock (secondary porosity, i.e. when feldspar grains or fossils are preferentially dissolved from sandstones).

Density is a physical property of matters, as each element and compound has a unique density associated with it. Density is defined in a qualitative manner as the measure of the relative "heaviness" of objects with a constant volume. Density is an important indicator of a composite's performance. It virtually affects all properties of the material. Another important consideration in this investigation is about the morphology of the composite's mixture. Characteristic of fillers (coir and rubber) and the resin is determined using scanning electron microscopy (SEM). Information about porosity, void spaces between fillers and resin, as well as surface texture of the composite could be identified.

3. RESULTS AND DISCUSSION

3.1 Acoustics Properties

All samples with different percentages of polyurethane have been tested for sound absorption coefficient. Figure 2 and 3 demonstrate the results for samples with 25 percents and 35 percents of polyurethane respectively. In general, both types of sample demonstrated higher absorption coefficients for middle to high frequency range (1400 - 6300 Hz). This wider range of frequencies highlights the potential of coconut coir composites for sound absorbent material. However, samples with 25 percents PU demonstrate superior performance to its counterpart, which most samples produced the absorption coefficient above 0.5 in wider frequency range.

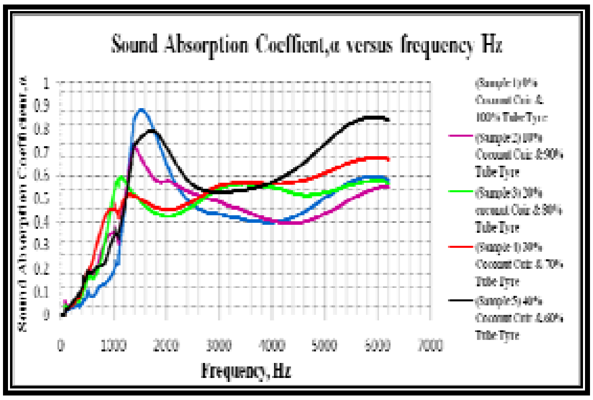

Fig. 2 Sound absorption coefficient for various compositions with 25 percents of Polyurethane

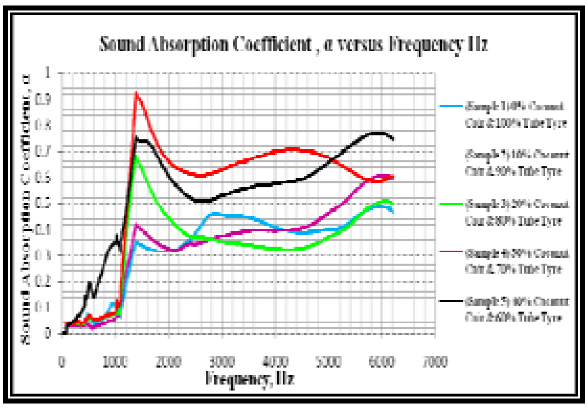

Fig. 3 Sound absorption coefficient for various compositions with 35 percents of Polyurethane

Considering the performance of both types of samples, the optimum composition of filler – resin were obtained for sample 5 with 40 percents coconut coir added with 60 percents of recycled rubber. As a comparison, both optimum composition were plotted together and shown in Figure 4. Though both samples work well in wider frequency range, sample 5 of 25 percents polyurethane obtained a higher absorption coefficient. Further analysis has been made by calculating the Noise Reduction Coefficient (NRC) values.

NRC is a scalar representation of the amount of sound energy absorbed upon striking a particular surface. Theoretically, it was calculated as average arithmetic value of sound absorption coefficients at four frequencies of 250, 500, 1000 and 2000 Hz indicating a material's ability to absorb sound. The coefficient range was in between zero to one; i.e. zero mean total reflection and one indicates total absorption. Figure 5 shows the results of NRC values obtained for both types and samples. It was found that NRC values obtained for 25 percents of PU content always produced higher values compared to samples of 35 percents PU. The values recorded were within 0.24 to 0.32. On the other hand, NRC values calculated for 35 percents of PU content yield the values from 0.1 to 0.29. The result was expected as the performance of 25 percents PU obtained the highest sound absorption coefficients. Less polyurethane contents give higher coefficients to the coconut coir composites.

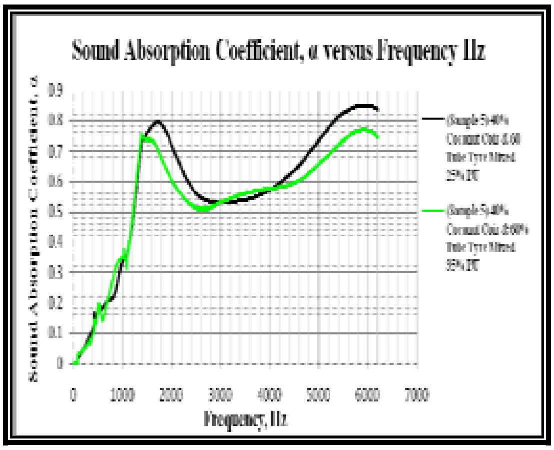

Fig. 4 Comparison between two optimum compositions of 25 and 35 percents of polyurethane

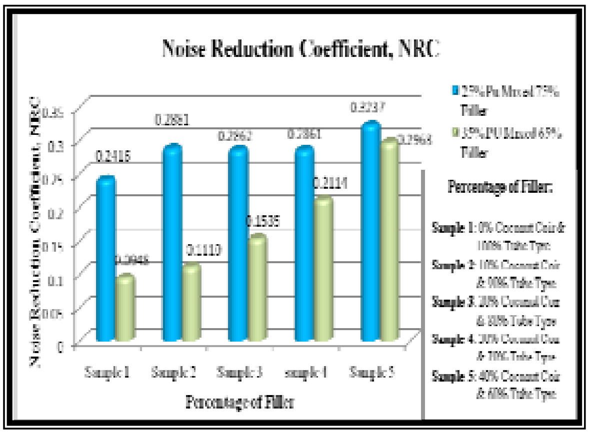

Fig. 5 Noise reduction coefficient for various compositions of fillers and resin

3.2 Physical properties

Variations of densities were recorded for different samples. Figure 6 demonstrates the comparative values of densities for 25 and 35 percents of polyurethane samples for different compositions of fillers. In general, the down slope trend was observed, with 25 percents yielded the lower values for all samples. Lower percentages of polyurethane influenced the density values; of which less polyurethane produced less foam of pores, an important parameter for sound absorber. The results also indicated that density values of fibreboard are related to the percentage content of fillers. The density values are gradually decreased as the percentage of recycled rubber is decreased or percentage of coconut coir is increased. It was anticipated that the increased in recycled rubber percentages is reducing the pores in the samples.

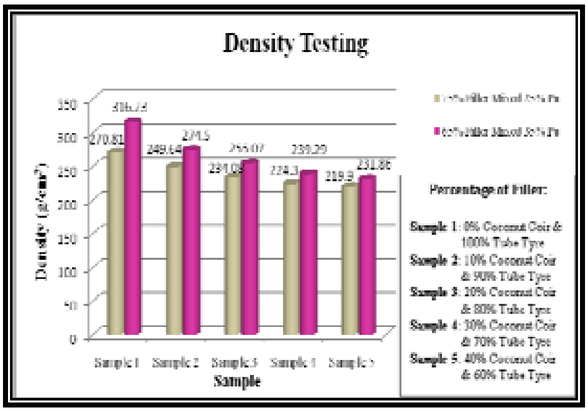

Fig. 6 Values of density for various percentages of coconut coir and recycled rubber

Figure 7 demonstrates the results of porosity test for the samples. It was found that porosity characteristics were inversely related to density characteristics. The upward trend was identified for all samples with 25 percents of polyurethane perform better. This result was expected since the 25 percents produced lower density compared to 35 percents of polyurethane. Again, sample 5 which contains less recycled rubber (60 percents) yielded the highest porosity value of 98.62 percents. Sample 1 that contains 100 percents recycled rubber was the least porous with 86.59 percents of values recorded. This is in agreement to the fact that higher content of recycled rubber fills up more voids, thus increasing the density and lowering the porosity of the samples.

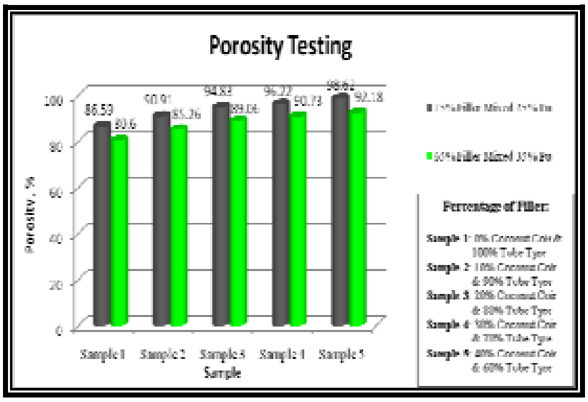

Fig. 7 Values of porosity for various percentages of coconut coir and recycled rubber

The density and porosity properties of the composite fibre boards were controlled by the gas quantity released during the isocyanate reaction. This affects the number of cells and their sizes. Figures 8 and 9 compare the surface structure between composites with 25 and 35 percents of PU content, respectively. It was observed that more pores have occurred in the sample with 25 percents PU with larger pore size. The recorded pore size obtained was between 129µm to 179µm. On contrary, composite boards with 35 percents PU and 65 percents fillers produced less pores and smaller pore sizes. The measured size recorded was in between 99µm to 110µm. The microstructure of composite fiberboards justifies the results obtained in density and porosity analysis, and reflecting into the acoustics properties of coconut coir composite boards.

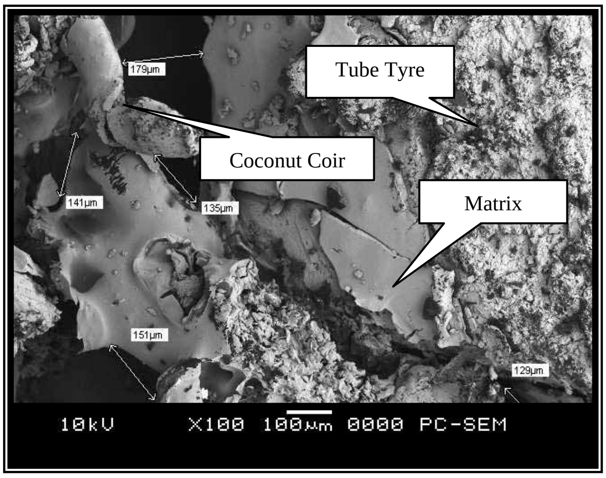

Fig. 8 Microscopic view for composite board with 25 percents of polyurethane

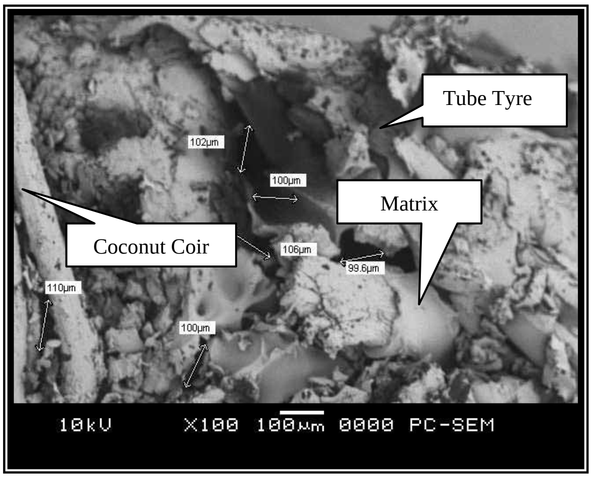

Fig. 9 Microscopic view for composite board with 35 percents of polyurethane

4. CONCLUSION

As a conclusion, the potential of composite boards made of coconut coir and recycled rubber for sound absorbent material has been identified. By considering the performance of acoustics and physical properties, the composition of composite boards with 25 percents polyurethane and 75 percents fillers is recommended for sound absorption applications. More specifically, the optimum composition of 40 percents coconut coir and 60 percents recycled rubber is of interest. The superior performance that is high absorption coefficient and wider frequency range enables this composite board to be employed in various sound absorption applications. Additionally, the utilisation of recycled rubber and coconut coir can also helps to reduce sound and air pollutions.

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