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Acoustic Properties of Multi-Layer Coir Fibres Sound Absorption Panel

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Abstract: A comparison between acoustic sound absorption coefficient and transmission loss index of absorption panel using natural organic multi-layer coir fibre as the filler with and without perforated panels were studied this research. Experimental data obtained using reverberation room test method were compared with data from numerical simulation. The innovative sound absorption panel was developed and fabricated using treated coir fibre layers as sound absorption materials. The outer layer of the panel was fabricated from natural fibre/polyester composite panel. This innovative acoustic panel was tested at acoustic lab, faculty of engineering, Universiti Kebangsaan Malaysia using ISO 354 (1985) standard for noise absorption coefficient and ISO 717-1 standard for the transmission lost index. Simulation study was also conducted for the sound absorption panel using the Win FLAG™ software. For the sound absorption coefficient, the experiment gives the value between 0.70 and 0.80 for the frequency range of 1000 to 1800 Hz while the sound absorption coefficient obtained from simulation gives 0.7 to 0.85 for the frequency range of 500 to 2500 Hz. Transmission lost index gives an average of 20 dB for the panel. The results showed that the sound absorption coefficient obtained through both the experimental and simulation methods were comparable to those use commercially in the market such as rock wool and synthetic fibres.

Key words: Acoustic materials, coir fibre, sound absorption coefficient, transmission lost index, reverberation room

INTRODUCTION

Currently, commercially available sound absorption materials for acoustic treatment used in the building construction industry consisted of glass-or mineral-fibre materials. However, they are growing concern in health and safety related issue due to the potential health risks associated to these fibres when exposed to human such as the effect from fibre shedding from glass-or mineral fibre materials to human lungs and eyes. These issues provide an opportunity for an alternative materials from organic fibres to be developed as a replacement materials. In Malaysia, agricultural waste such as coir fibres (*Cocos nucifera*), rice fibre (*Oryza sativa*) and oil palm frond fibre (*Elaeis guinnesis*) are abundance and usually burnt or used as an agricultural by-products. Recently, natural fibres from agriculture are increasingly being investigated for various usage in many structural and non-structural applications such as a substitute for synthetic fibres in composite materials and lining for automotive components. However, natural fibres such as coir fibre are also suitable as a substitute to synthetic fibres and wood-based materials for acoustic absorption purposes. These fibres have many advantages because they are cheaper, renewable and abundance, non-abrasive and does not give rise to health and safety issue during processing and handling (Jinkyo and Swenson, 1992; Wambua *et al*., 2003; Joshi *et al*., 2004; Khedari *et al*., 2003).

Khedari *et al*. (2004) has developed particle composite boards from agricultural waste products using combinations of durian peel and coir fibre straw particles instead of wood as an insulation board in wooden construction industry. Yang *et al*. (2003) study the acoustic properties of rice straw-wood particle composite boards and found that the sound absorption coefficient in the frequency range of 500 to 8000 Hz is higher than other wood-based materials which is due to the low specific gravity of the composite boards.

To improve the acoustic properties further, perforated plate design is used in the construction of the panels. Davern (1977) studied the effect of the perforated plate,

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airspace layers and porosity on the acoustic properties of materials. He found that the porosity of the perforated plate and the density of the porous material would significantly affected the acoustic impedance and sound absorption coefficient of the panel in which case the frequency b and near the resonance frequency achieved high acoustic absorption. Lee and Chen (2001) reported that the acoustic absorption of multi-layer materials is better with perforated plate backed with airspaces.

The main parameter that is critical in the determination of the acoustic properties is the acoustic absorption coefficient properties and transmission loss index. These parameters were determined using the tests carried out in the reverberation room and anechoic chamber at the Acoustic Laboratory, Universiti Kebangsaan Malaysia. Computer simulation using the dBBAT132 program was carried out to determine the reference acoustic parameters. The acoustic properties of the rock wool materials were also determined as a comparison. The fibres arrangements in the plate were studied using the scanning electron microscope. Latex were used to provide the necessary cohesion between the coir fibres so that its arrangement can be moulded into square layers for the acoustic testing purposes. The latex was shown to have no influence on the sound absorption properties due to the small influence on the fibres physical characteristics. Other usage of natural fibre is in applications to reduce sound propagation in automotive interior spaces or to improve the control of outdoor noise propagation (Larbig *et al*., 1998).

The aim of this research was to study the potential use of the multi-layer coir fibres as a sound absorption material to replace synthetic materials such as glass, mineral wool, felts or polyester fibre in commercial applications. This study investigated the sound absorption properties of the coir fibres together with the characteristics of the coir fibres and its fibre arrangement as the data were important to optimize the acoustic properties of the panel. The characteristics and arrangement of the fibre were found to influence the acoustic properties of the panel (Ono *et al*., 2002). The use of natural fibres as sound absorption materials will be good for environment as it is biodegradable and exposed no potential health risk.

MATERIALS AND METHODS

There are two main parts in carrying out this research. The first is to fabricate the composite panel box using coir/polyester composites and the second is to use treated coir fiber as the absorption materials. The combination of high quality natural fiber/polyester composite and coir fiber as the absorption material gives the panel a good absorption characteristic. The outer layer of the sound absorption panel is fabricated with polyester resin reinforced with coir fiber to make the composite strong and stiff. Perforated panel design requires holes to be drilled on the panels surface in order to give more advantages in acoustic part by decreasing the optimum absorption coefficient to the lower frequency (Wang and Torng, 2001).

Some of the experimental equipments used in the setup were calibrator 94.0 dB, 100 Hz (Cal 21 01 dB), microphones (GRAS 26 AK), speaker, amplifier and symphonie (Dual-Channel Real Time Acquisition Unit). The test was also simulated using DBBATI32 software.

Testing

Noise absorption coefficient

- **Experiments using reverberation room:** Experiments using the reverberation room have been performed to calculate the noise reduction coefficient (NRC). The test was performed using ISO 354 (1985) standard for noise absorption coefficient. The required inputs are reverberation time for empty room, RT0 and reverberation time for room with sample, RTm. Parameter needed for the experiment are volume for an empty reverberation room and testing area for the sample. Figure 1 shows the schematic drawing of the experimental setup and (Fig. 2) shows the sound absorption perforated panel using coir fibre as the absorption material. The tests were carried out at the Acoustic Laboratory in the Department of Mechanical and Materials Engineering, Universiti Kebangsaan Malaysia between January and March 2008.

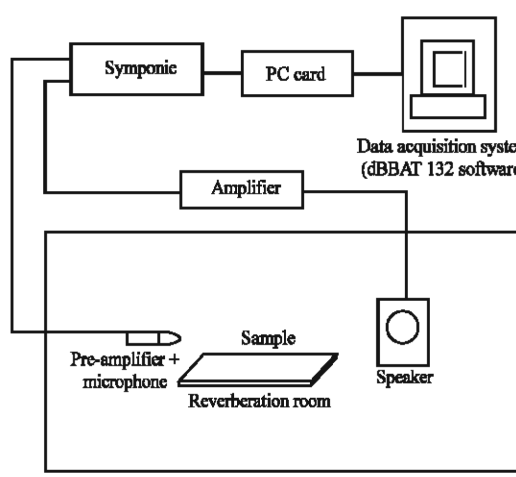

Fig. 1: Schematic configuration absorption coefficient test in the reverberation room

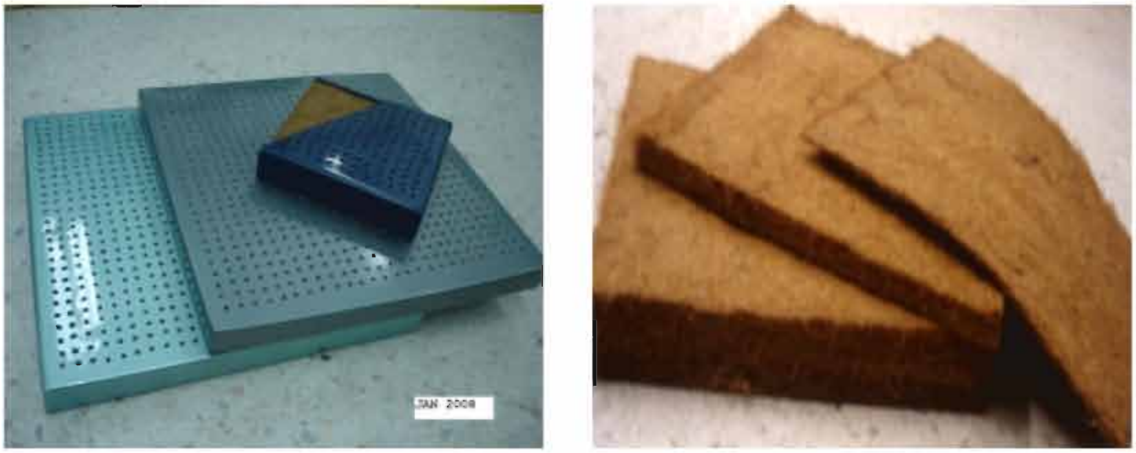

Fig. 2: Sound absorption perforated panel using coir fibre as an absorption material

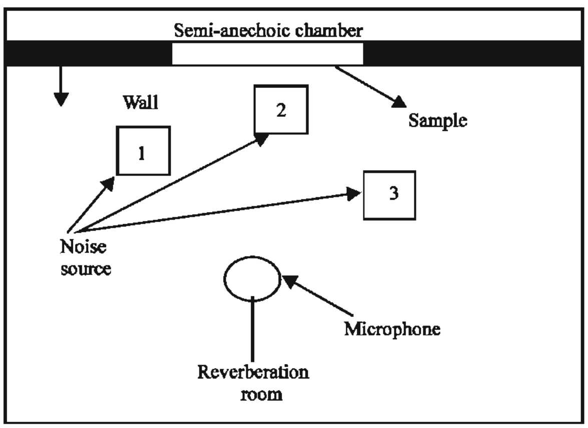

Fig. 3: Location of the sample between the reverberation room and the semi-anechoic chamber for the transmission loss index test

Fig. 4: Equipments for the transmission loss index test

- **Simulation by WinFLAG™ program:** For the simulation works, absorption coefficients of panels were calculated by the computer WinFLAG™, developed at NTNU (Vigran, 2003). This program implements the transfer matrix method for a number of materials, including porous material and perforated plates (slotted, with circular holes etc.). The program calculates the absorption coefficient, impedance and sound reduction index. Calculation can be performed at single frequencies or as mean values in 1/3 octave b and. WinFLAG™ has also been used to estimate the acoustic performance of materials with and without airspaces (Mohd Nor *et al*., 2004).

Transmission loss index: Experiments for the transmission lost have been conducted at acoustic lab, Universiti Kebangsaan Malaysia which consisted of reverberation room and semi anechoic chamber using the ISO 717-1 standard (Lee and Chen, 2001). The composite panel was placed between the two rooms and a noise source was given from the reverberation room.

One microphone was placed at semi anechoic chamber to receive the sound that has been transmitted. The data was analyzed to determine the transmission loss value. Figure 3 and 4 show the setup for the transmission loss index test.

RESULTS AND DISCUSSION

Noise absorption: Simulations works have been conducted in order to predict the sound absorption coefficient of the panel before the experimental tests were conducted. The simulation for the noise absorption

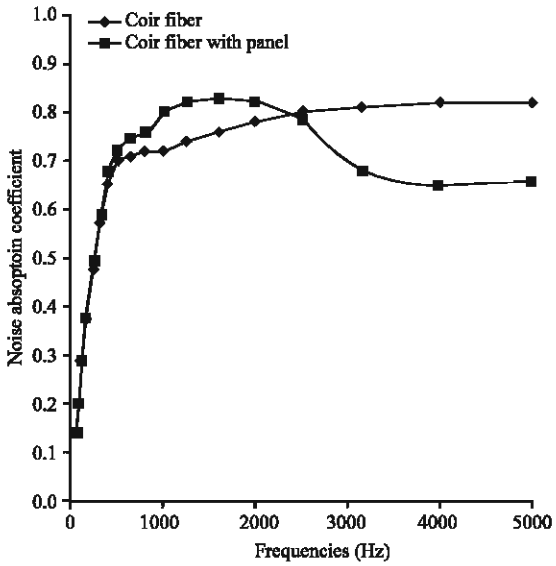

Fig. 5: Comparison of simulation results for noise absorption coefficient between coir fibre with and without composite perforated panel

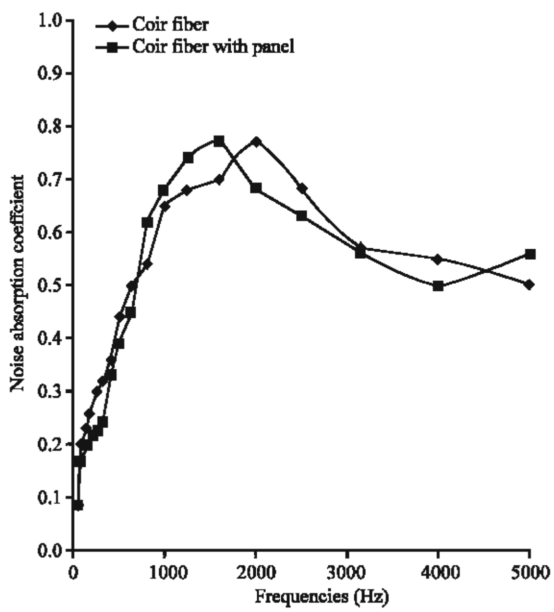

Fig. 6: Comparison of experimental results for noise absorption coefficients between coir fibre with and without composite perforated panel

coefficient of the plain coir fiber and coir fiber with perforated panel were calculated using computer program WinFLAG^{TM}. In the simulation works, absorption coefficients of the panels were calculated by the computer program WinFLAGTM, developed at NTNU (Vigran, 2003). This program also had been used for simulations to estimate the acoustic performance of constructions combining different material layers by other researchers This program implements the transfer matrix method for a number of materials, including porous materials and perforated plates (slotted, with circular holes or microperforated etc.). WinFLAGTM does the job of calculating absorption coefficient, impedance and sound reduction index for such constructions. Calculations may be performed at single frequencies or as mean values in 1/3-octave bands, in both cases for a free field sound incidence as well as in diffuse field. Figure 5 shows the result obtained for the noise absorption coefficient for multi-layer coir fibre with and without composite perforated panel. The coir fiber with perforated panel shows higher coefficient index compared to the plain coir fiber for the range of 500 Hz until 2500 Hz. For the frequency range of more than 2500 Hz, the coir fiber without panel gives higher coefficient index. The highest coefficient index for coir fiber with perforated panel is in the range of 0.7 to 0.85 for the frequency range of 500 Hz until 2500 Hz while for the coir fibre without panel, it is around 0.8 for the range 2500 Hz until 5000 Hz.

The experimental results are found to be similar to the simulation results. Figure 6 shows the experimental result of the noise absorption coefficient. The coir fiber with the perforated panel gives higher value for the lower frequencies range from 800 Hz until 1800 Hz. Higher than that, the coir fiber give much higher value. The optimum value for coir fiber with perforated panel is around 0.70-0.80 for the frequency range of 1000 to 1800 Hz and the plain coir fiber is 0.78 for 2000 Hz frequency. Ballagh (1996) found that the noise coefficient increases with the smaller fiber diameter. With the impermeable size much smaller compare to sound wavelength, the change from the sound energy to heat energy will increase due to the vibration of friction air particle. Other parameters such as porosity and tortuosity are included to define the acoustic properties for impermeable material.

By using the composite perforated panel, the noise absorption coefficient peak is transferred to the lower frequency but the coefficient decreases at much higher frequency. Theoretically, when a perforated plate has an air gap, an air cell system can be assumed for every imaginary air cell behind each hole under the plate. The phenomenon is known as the Hemholtz resonator. Based on the study on the effect of using impermeable material behind the perforated plate, Lee and Chen (2001) found that the impermeable material increasing the noise absorption coefficient and decrease the resonance frequency to the lower frequency range. The absorption coefficient of porous material increases with thickness of the material, since particle velocity is maximum at a quarter

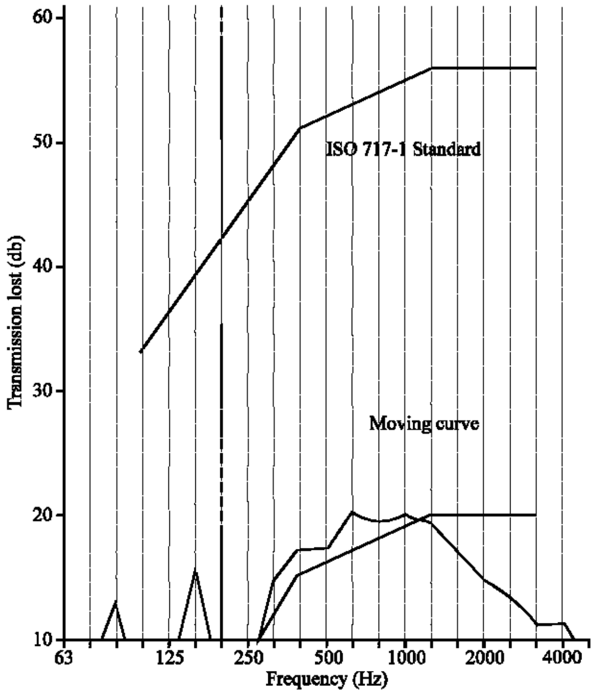

Fig. 7: Transmission lost index versus frequency for coir fibre in composite perforated panel

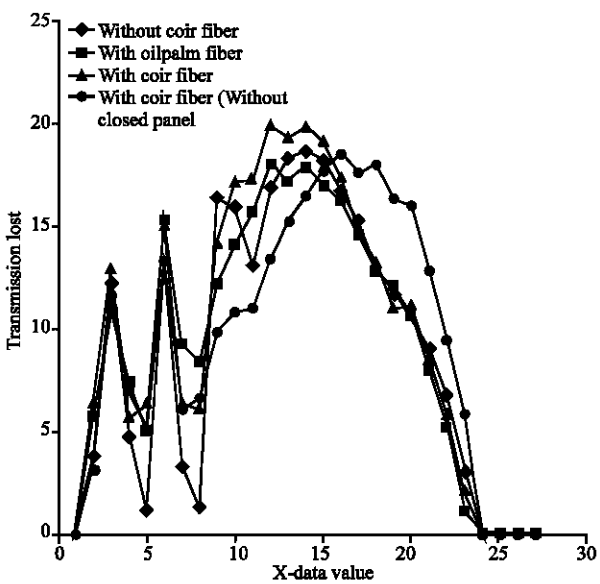

Fig. 8: Comparison of transmission lost index for different configuration of coir fibre and oil palm fibre

wavelength from the substrate. The increase of coconut coir fiber layers also means that the fibers have more chance to contact with the sound wave. This causes more resistance by means of friction of viscosity through the vibration of the air. Therefore, the inserted coconut coir fiber layers in the assembly of sound absorber contributed to increase the sound absorption coefficient through quite a wide range of frequency, because the reflected sound wave inside the sound absorber can be absorbed again and again through the multi-layer structure.

Transmission loss: The experimental results of the transmission loss index for the composite perforated panel have an average value of 20 dB. Several other tests have also been carried out to compare the results. Figure 7 shows the result of transmission lost index versus frequency for the coir fibre in the composite perforated panel. Figure 8 shows the comparison for several other composite perforated panel using different type of natural fibre materials. For the first 12 data point, the composite perforated panel with coir fiber gives the comparable transmission lost index compared to other samples. Beginning from No.12 to 16, for the range of 630 Hz until 1600 Hz, the composite gives higher value of transmission lost index compared to the curve for composite with coir fiber without perforated panel and from No. 17 until 27, it is giving the highest transmission lost index compared to the other samples.

Composite with oil palm fiber sample shows the optimum value from the 6th data (160 Hz) until 8th data (315 Hz). For the fourth sample (coir fibre without composite perforated panel), the optimum value for transmission lost index appears from the range 16th data (1600 Hz) until 24th data (10 kHz). In the case of perforated facing, the structure promotes the sound absorption coefficients in the low-frequency region, but it has the reverse effect in the high frequency region. Therefore, many considerations are required for the purpose of sound control; on the other hand, the multi-layer coconut coir fiber contributed to increase the sound absorption coefficients. This provides a reliable guidance for the design of multi-layer sound absorbers.

CONCLUSION

In this study coir fiber has been introduced as one of the sound absorption material. The results form the simulation and experimental tests show that it has a good acoustic properties and has a high potential to be an alternative replacement of synthetic based commercial product. By introducing the composite perforated panel made from fibre-reinforced polymeric materials, the innovative sound absorption panel shows a good potential to be an environmentally friendly product. As one of the green technology product, this innovative absorption panel has a bright future because they are cheaper, lighter and environmentally superior compare to glass fiber and mineral based synthetic materials. The results of the acoustic properties obtained shows that the coir fibre gave a good sound absorption coefficient and transmission loss index value. The fibres arrangement in the coir fibre can be modified in order to control the sound absorption properties. This will allow the coir fibre to be used in applications to reduce sound propagation in interior spaces or to improve the control of outdoor noise propagation. Further works can be carried out to optimize and increases the performance of the coir fibres.

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