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Noise Control Using Coconut Coir Fiber Sound Absorber with Porous Layer Backing and Perforated Panel

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Abstract: Problem statement: Noise control was one of the major requirements to improve the living environment. One of the methods to do that is provided by sound absorber. Commonly, multi-layer sound absorbers are applied to absorb broadband noise that was composed of perforated plates, air space and porous material. However, multi-layers sound absorbers effectiveness depends on their construction. This study was conducted to investigate the potential of using coconut coir fiber as sound absorber. The effects of porous layer backing and perforated plate on sound absorption coefficient of sound absorber using coconut coir fiber were studied. **Approach:** Car boot liners made from woven cotton cloth were used as type of porous layer in the study. This material has been used widely in automotive industry. Perforated plate used was machined with perforation ratio of 0.20, thickness of 1 mm and holed diameter of 2 mm. The samples were tested at the acoustic lab of the Faculty of Engineering and Built Environment, University Kebangsaan Malaysia, according to ASTM E 1050-98 international standards for noise absorption coefficient. **Results:** The experiment data indicates that porous layer backing can improve noise absorption coefficient at low and high frequencies with significant increasing. 20 mm thick layer coconut coir fiber with porous layer backing exhibit peak value at frequencies between 2750-2825 Hz with maximum value of 0.97. The experimental results also found that the coconut coir fiber with perforated plate gives higher value for lower frequencies range from 600-2400 Hz. The optimum value for coconut coir fiber with perforated panel is around 0.94-0.95 for the frequency range 2600-2700 Hz. **Conclusion:** Noise absorption coefficient of coconut coir fiber was increased at all frequency when they were backing with Woven Cotton Cloth (WCC). At low frequency, the NAC have significant increasing. This is because WCC have higher flow resistivity than coconut coir fibers, so that sound can be dissipated as it travels through material significantly. The results from the experimental tests show that it has good acoustic properties at low and high frequencies and can used to be an alternative replacement of synthetic based commercial product. By using the porous layer and perforated plate backing to coconut coir fiber, the sound absorber panel shows a good potential to be an environmentally friendly product. This innovative sound absorption panel has a bright future because they are cheaper, lighter and environmentally compare to glass fiber and mineral based synthetic materials.

Key words: Noise absorption coefficient, coconut coir fiber, porous layer, perforated plate

INTRODUCTION

Along with technology development, noise has become a seriously environmental problem. Noise can cause general types negative effects they are; hearing loss, no auditory health effect, individual behavior, effect on sleep, communication interference and effect on domestic animals and wildlife. There are several methods to decrease noise, one of which uses sound absorption materials. Currently, sound absorption materials commercially available for acoustic treatment consisted of glass or mineral-fiber material. However, when review the issue of safety and health, these fibers when exposed to human can interference human health mainly lungs and eyes. These issues explore an opportunity to look for alternative materials from organic fibers to be developed as noise absorption material.

Organic fibers as basis material for absorber materials have several benefit; renewable, nonabrasive, cheaper, abundance and less potential health risks and safety concern during handling and processing.

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Several researchers (Khedari *et al*., 2003; 2004; Zulkifli *et al*., 2008) have succeeded in developing particle composite boards using agricultural wastes. Yang *et al*. (2003) produced rice straw-wood particle composite boards which properties are to absorb noise, preserve the temperature of indoor living spaces and to be able to partially or completely substitute for wood particleboard and insulation board in wooden construction. They reported that the sound absorption coefficient of rice straw-wood particle composite boards are higher than other wood-based materials in the 500-8000 Hz frequency range, which is caused by the low specific gravity of composite boards, which are more porous than other wood-based materials. Wassilieff (1996) used sound absorber with wood as a base material, he demonstrates that three parameters (plus the sample thickness), airflow resistivity, porosity, turtuosity are sufficient to define the normal incidence sound absorption.

In automotive application, absorption is desired at lower frequencies, thickness and weight are limited, sound absorber with different specific airflow resistance can be used to achieve desirable results. One method of increasing flow resistivity is the addition of a flow resistant scrim or film layer. Scrim means a fibrous cover layer with finite flow resistance and film means a plastic cover layer with infinite flow resistance (Zent and John, 2007).

To improve the acoustic characteristic further, a perforated plate design can be used in construction of the panels. The porosity of the perforated panel and density of porous material would considerably change the acoustic impedance and absorption coefficient of the acoustic absorber (Davern, 1977). Baranek and Ver (1992) presented a compact expression for acoustic impedance of perforated plates. The expression indicated that the influence factor include the thickness, hole radius, hole pitch and porosity of the perforated plates and air contained in the holes.

For porous material, Delany and Bazley (1970) stated that the complex wave propagation constant and characteristic impedance could be expressed in terms of the flow resistivity, wave number, air density and sound frequency. Sound absorption characteristic of porous material is not so much a function of type material but airflow resistivity and how well material construction can be executed to achieve desirable properties for sound absorbers (Lee and Chen, 2001).

Ersoy and Kucuk (2009) have investigated with three different layers of tea-leaf fiber waste materials with and without backing provided by a single layer of woven textile cloth were tested for their sound absorption properties. The experiment show that 1 cm thick tea-leaf-fiber waste material with backing provides sound absorption which almost equivalent to that provided by six layers of woven textile cloth 2 cm thick layers of rigidly backed tea-leaf-fiber and non-woven fiber material exhibit almost equivalent sound absorption in the frequency range between 500 and 3200 Hz.

Wang and Torng (2001) have investigated some fibrous porous material, rock wool and glass that manufactured in Taiwan. They have indicated that sound absorption characteristic values of rock wool were measured and found to be similar to glass fiber. Increasing the thickness material of the panel will improve the sound absorption ability, especially in the low frequency range.

A composite structure with a combination of perforated panel, rubber particle, porous material, Polyurethane (PU) foam and glass wool, were found to demonstrate significant sound attenuation (Hong *et al*., 2007). This research was carried out to study the potential use of coir fiber in replacing synthetic and mineral based fibers for sound control applications. This study investigated effect of the porous layer backing and perforated panel on the sound absorption coefficient of coconut coir fiber as sound absorber.

MATERIALS AND METHODS

For this study, coconut coir fiber is the main raw material. Coconut Coir Fiber (CCF) panel treated with latex during forming in order to coat the coir fiber and to maintain the structure of the coir fiber sheets. The sample test has a 100 mm in diameter for low frequency and 28 mm for high frequency. To proper fitting of samples into the measurement tube, a steel rod was machined to a length of 100 mm for each diameter. It was utilized to push the material into a pre-adjusted depth. For each thickness of the material, three different sample measurements were made and the average of the measured data was presented here.

Perforated plate was provided using zinc, 1 mm thickness, perforation ratio 0.20 and hole diameter 2 mm. perforated plate design acting as a top layer of the material and being utilized as sound absorption panel. The others experimental equipment used are calibrator 94.0 dB, 1000 Hz (Cal 21 01 dB), microphones (GRAS 26 AK), speaker, amplifier and symphony (Dual-Channel Real Time Acquisition Unit).

Test: The most critical property here is normal incidence sound absorption coefficient which is a function of frequency valued between zero and one. Sound absorption is the percent of sound energy being absorbed by the material sample. This is the primary indicator to the way any absorber material will react in any given environment. The test was performed on a two-microphone transfer function method according to ASTM E 1050-98 international standards. Figure 1 shows the test samples with porous layer, perforated panel and coconut coir fiber. Figure 2 showed the impedance tube device set and set-ups for its measurement.

Fig. 1: Photographs of the test samples (a) porous layer; (b) perforated panel; (c) coconut coir fiber

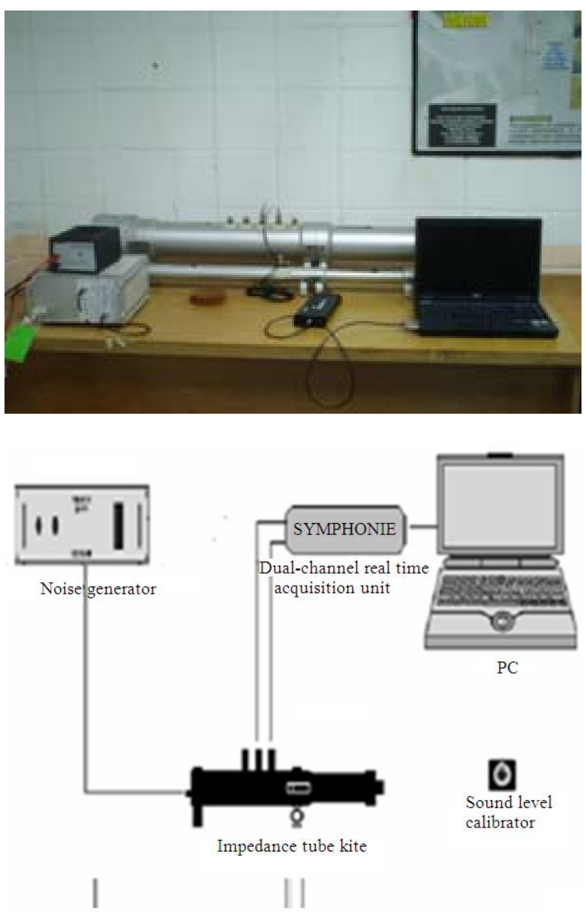

Fig. 2: Impedance tube device and set-ups for impedance tube measurement

The impedance tube device set includes the low and high frequency tubes with samples holders, loudspeakers case and audio amplifier, two microphones and supply sets. The small tube (high frequency) can be used as stand alone with its own loudspeaker case, or alternatively be mounted on the bigger one (low frequency). The microphones are connected to the PC, which also includes a random noise generator. A user-friendly software (SCS8100) interface guides the user through the measurement and the store and print operations of the results.

RESULTS

The results of the impedance tube measurements at low and high frequencies (50-5000 Hz) for coconut coir fiber with and without backing is shown in Fig. 3 and 4. Figure 5 shows the comparison of NAC of CCF, 10 mm thickness, with and without porous layer backing.

Figure 6 shows the results obtained for the NAC of coconut coir fiber, 20 mm in thickness, with backing and without porous layer backing. Figure 7 shows the result from experimental sound absorption coefficient when coconut coir fiber is layered with 1 mm thickness, perforation ratio 0.20 and hole diameter 2 mm of zinc.

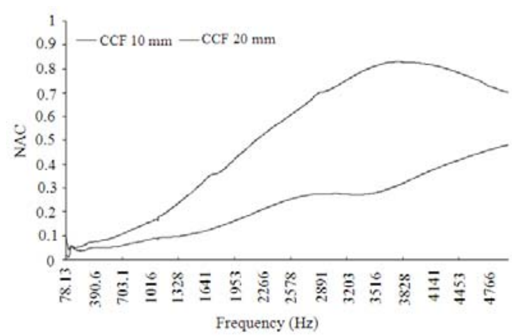

Fig. 3: The NAC coconut coir fiber without porous layer

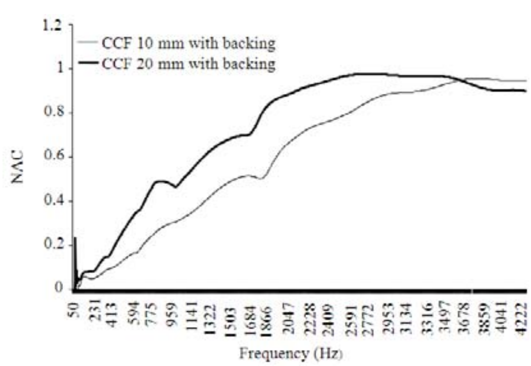

Fig. 4: The NAC of coconut coir fiber with porous layer backing

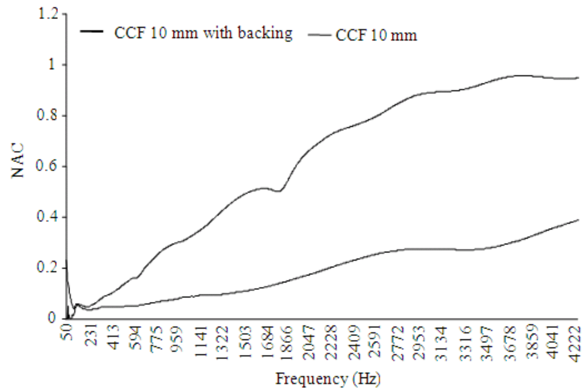

Fig. 5: Comparison of NAC of CCF, 10 mm thickness, with and without porous layer backing

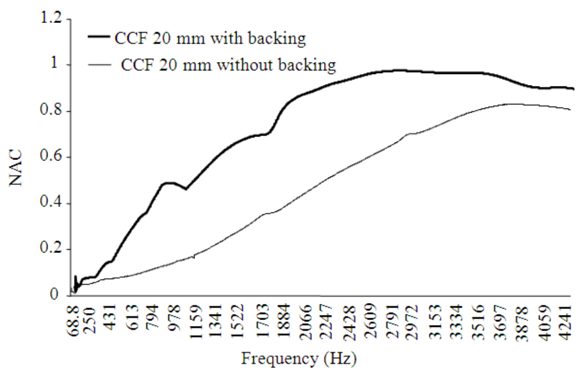

Fig. 6: Comparison of NAC versus CCF, 20 mm thickness, with and without porous layer backing

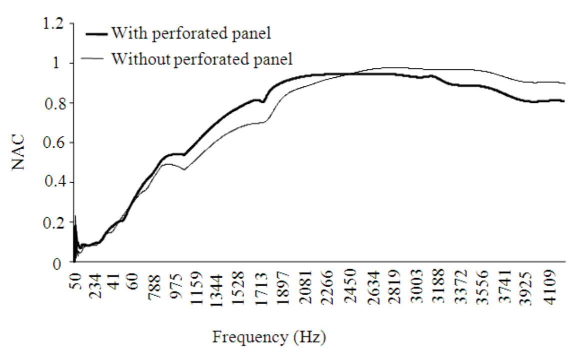

Fig. 7: Comparison of NAC of CCF, 20 mm thickness, with and without perforated panel backing

DISCUSSION

Effect of porous layer backing: Figure 3 shows the noise absorption coefficient values when coconut coir fiber without porous layer backing is mounted in front of rigid wall. Each thickness samples were 10 and 20 mm, respectively. From experiment data, the noise absorption coefficient of samples with 20 mm thickness has maximum value at 3680-3860 Hz frequency range. The peak noise absorption value is about 0.83 at frequency 3784 Hz. For samples with 10 mm thickness, the Noise Absorption Coefficient (NAC) maximum value was 0.39 at frequency 5000 Hz.

Noise absorption coefficient of coconut coir fiber was increased at all frequency when they were backing with Woven Cotton Cloth (WCC) as shown in Fig. 4. For samples with 10 mm thickness, after backing with WCC, the NAC have increased with the maximum values at 3753-3834 Hz frequency range and the peak value is about 0.96 in frequency 3800 Hz. At low frequency, 10 mm samples thickness, the NAC have significant increases as shown in Fig. 5. This is because WCC have higher flow resistivity than coconut coir fiber, so that sound can be dissipated as it travels through material significantly (Zent and John, 2007).

From Fig. 6, at low frequency, the NAC have significantly increases at all frequencies when compared with coconut coir fiber without porous layer backing. The maximum noise absorption values at frequency range 2750-2825 Hz, the peak value is about 0.97. However, the NAC values have decreases at 3900-5000 Hz.

Effect of perforated plate: the effect of perforated plate on the acoustic absorption can be shown in Fig. 7. Compared to the coconut coir fiber without perforated panel. The perforated panel will shift the absorption coefficient peak to lower frequency range and noise absorption coefficient will decrease in high frequency. The experimental results found that the coconut coir fiber with perforated gives higher value for lower frequencies range from 600-2400 Hz. The optimum value for coconut coir fiber with perforated panel is around 0.94-0.95 for the frequency range 2600-2700 Hz. Lee and Chen found that porous material would distinctly promote the acoustic absorption and shift the acoustic resonance frequencies to lower frequency bands.

The experiment using perforated panel gave a better result than the experiment without the plate. This shows that the perforated plate has the capacity to reduce sound.

CONCLUSION

Coconut coir fiber has been introduced as one of the sound absorber in this study. The results from the experimental tests show that it has good acoustic properties at low and high frequencies and can used to be an alternative replacement of synthetic based commercial product. By using the porous layer and perforated plate backing to coconut coir fiber, the sound absorber panel shows a good potential to be an environmentally friendly product. This innovative sound absorption panel has a bright future because they are cheaper, lighter and environmentally compare to glass fiber and mineral based synthetic materials.

In this experiment, sound absorber using coconut coir fiber backing with porous material (WCC) and perforated panel with 0.20 perforation ratio have been tested to measure its sound absorption coefficient. Coconut coir fiber backing with porous layer shows that its sound absorption coefficient significantly increases at low and high frequencies. According to the experimental data, the coconut coir fiber backing with woven cotton cloth is better than tea-leaf fiber backing with woven cotton cloth.

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