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Absorption Coefficient of Acoustic Coir Fibre Panel and Effects of Varying Percentage of Perforated Plates

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Abstract: The effects of perforated plates with different percentage of perforation affecting the sound absorption coefficient of coir fibre acoustic panels were investigated. Two types of perforated plates of 6.93 and 19.24% perforation were combined with the similar coir fibre layer. Acoustic tests for measuring the sound absorption were conducted in the reverberation room according to the ISO 354:2003 standard. The based coir fibre panel showed to possess good sound absorption characteristics from intermediate to high frequency range (800-2000 Hz). Perforated plates (6.93 and 19.24%) with coir fibre panel were found to achieve maximum sound absorption coefficients of 0.77 and 0.63 at 2000 Hz, respectively. As frequency increased to 4000 Hz, the sound absorption coefficient for the higher percentage perforation produced a higher sound absorption coefficient value.

Key words: Sound absorption, acoustic absorption, natural fiber, perforated panel

INTRODUCTION

Awareness of the importance of good acoustic architectural design in concert halls, recording studios and auditoriums are well known. However, people spend most of their time in homes, lecture halls, classrooms, offices, or factories where only basic attention has been given to their acoustical environment. Thus, most buildings are designed and built without special emphasis on the acoustic architecture and as a result, the development and practical use of sound absorption acoustic panels are gaining greater attention these days.

Sabine (1922) worked on architectural acoustics, much has been learnt about what is important to get a good acoustic. To alter the acoustics of an existing room, treatment in the form of sound absorption acoustic panels are usually located at the boundaries. Currently, most commercially available sound absorption materials for acoustic treatment consist of synthetic-fibre or fibreglass materials. Due to the dominance of these materials in the international market, the study of sound propagation in alternative materials has been limited. However, there are growing concerns related to health hazards and safety issues of these materials possess. The shredding of synthetic-fibre or glass-fibre materials can be detrimental to the health if exposed to the eyes or lungs or if their fibres are inhaled, since they can lay down in the lung alveoli and as well as causing skin irritations. According to the United States of America's Occupational Safety and Health Administration (OSHA), an 8 h exposure to 0.043 glass fibres per cubic centimetre of air is sufficient to cause lung cancer in one-in-every-thousand exposed workers during a 45 year working lifetime. These harmful health issues can be seen as an opportunity for natural-based material, namely coir fibre, to be used as a safer alternative in developing sound absorption acoustic panels.

In Sabah, Malaysia, agricultural wastes such as coir fibre from coconut palms (*Cocos nucifera*) are in abundance and are usually either burned or used as agricultural by products, such as ropes, upholsteries and mattresses. Coir fibres are increasingly being studied for their usage in various applications as in structural and non-structural applications, such as a substitute for synthetic fibres in composite materials, the lining of automotive components and as erosion control blankets and geotextiles for slope protection and also as acoustic treatment and noise control material (Zulkifli *et al*., 2010; Nor *et al*., 2004, 2005). Therefore, coir fibre is potentially a suitable material to replace synthetic fibre in the development of sound absorption acoustic panels. The advantages of using coir fibre include its availability, lower costs, non-abrasiveness, biodegradable, lower impact to the environmental, as well as no potential health and safety risks issues during its processing and handling (Joshi *et al*., 2004).

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Perforated panel gaped from the wall form a resonant sound absorption improvement. Each hole acts as the neck and the cavity behind belonging to that hole is comparable to the cavity of Helmholtz resonator. In fact, it is a host of coupled resonator. Everest and Pohlmann (2009) approximately define the resonance frequency of perforated panel absorbers with circular holes backed by a subdivided airspace as:

$$f_0 = 200\sqrt{\frac{p}{d_a \times t}} \quad (1)$$

where, f_0 is the frequency of resonance (Hz), p is the perforation percentage (hole area divided by panel area), t is the effective hole length (in) with correction factor applied (panel thickness + hole diameter (0.8) (in)) and d_a is the depth of air layer (in).

Davern (1977) had also conducted a detailed investigation on the acoustic absorption effect of perforated panels backed with porous material as well as layer of air. He studied various boundaries including the effects of perforated percentage on plate. To increase the frequency range of sound absorption performance of perforated panel, the air cavity behind the wall was filled with a porous fibre and preserving an air-gap between them. Further, he found, increasing the thickness of the perforated panel and the depth of the air gap would lower its resonance frequency. Therefore, allowing sound absorption performance of the perforated panel to influence over a broader frequency range by varying the thickness of the perforated panel and the depth of the air space (Lawrence, 1970). The perforation percentage more than 20% with small aperture was also not affecting the sound absorption performance of porous fibre. However, Maekawa and Lord (1994) found smaller percentage of perforation would reduce the sound absorption of the porous fibre at higher frequency. As such, a perforated panel placed over a porous absorber lowers the frequency absorption compared to the porous material alone. However, the panel may also reduce the high frequency absorption of the porous material (Everest and Pohlmann, 2009).

MATERIALS AND METHODS

Coconut coir fibre was utilized as the main raw material. Each coconut coir fibre mats sample was 20 mm thick. The treated coir fibre mats weighed 2.25 kg each and had resulting bulk density of 112.5 kg m^{-3}. The coir fibre diameter was about 100-450 μm. Perforated plates were made of 1 mm thick zinc sheets. The plates divided into two groups, Group I consisted of plates with holes of 3 mm in diameter (6.93% perforation) and Group II consisted of plates with holes of 5 mm in diameter (19.24% perforation). The distance between each hole, the centre to centre distance, was 10 mm (Table 1).

Reverberation room test: In this experiment, sound absorbing properties of the perforated acoustic panels were evaluated in the reverberation room (Acoustic Laboratory, Fakulti Kejuruteraan, Universiti Malaysia Sabah). The experiment carried out was based on the ISO354:2003 standard. The experiment input parameters were the reverberation time for empty room (RT_0) and reverberation time for room with sample (Rt_m) (Fig. 1). The reverberation time measurements for the one-third octave bands of frequencies 125, 250, 500, 1000,

Table 1: Specification of zinc perforated plates

Group	Hole diameter (mm)	c-c distance (mm)	Total No. of holes	Total perforation area (mm^2)	Perforation percentage
I	3	10	9801	69279.19	6.93
II	5	10	9801	192442.19	19.24

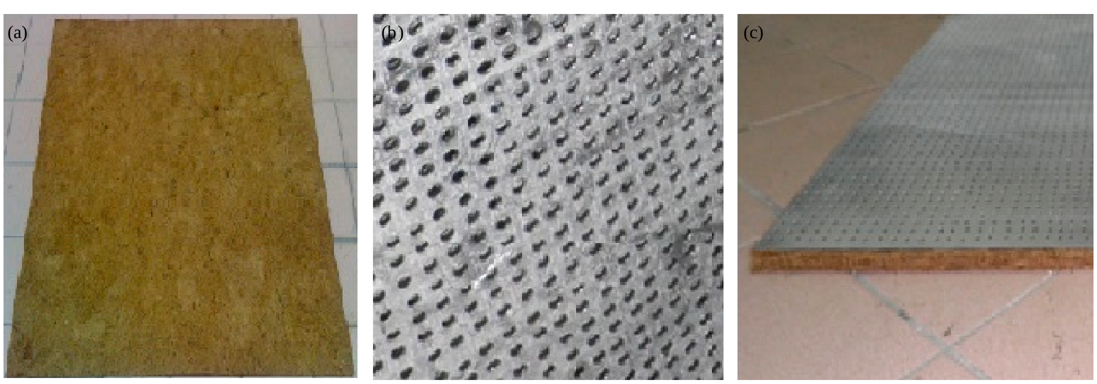

Fig. 1(a-c): Test samples, (a) Coir fibre, (b) Perforated plate and (c) Perforated plate with coir fibre

2000 and 4000 Hz were measured by the dBBATI32 software. The Sabine equation is expressed as:

$$RT = \frac{0.161v}{A} \quad (2)$$

where, RT is reverberation time (s), V is room volume (m^3), A is total absorption of room (metric Sabin) (Everest and Pohlmann, 2009).

RESULTS AND DISCUSSIONS

The sound absorption coefficient of coir fibre absorption panel and improvement of sound absorption with different percentage of perforated panels were determined through experiment, shown in Fig. 2. The coir fibre sound absorption panel represented as coir fibre and the Group I and Group II perforated plate with coir fibre were indicated by the 6.93 and 19.24%, respectively.

The sound absorption coefficient for Group I (6.93% perforation) and Group II (19.24% perforation) achieved peak values of 0.77 and 0.63 at 2000 Hz, respectively. Whereas, coir fibre sample peak sound absorption coefficient value was 0.75 at 4000 For the original coir fibre panel, sound absorption coefficient showed a more steadily increased. The variation could be attributed to varying sound energy dissipating as heat in the capillaries of the coir fibres. However, the absorption of coir fibres at low frequencies was poor. According to Maekawa and Lord (1994), the porous absorbers show highest absorption above 500 Hz and relatively low absorption in the lower frequency region. A thicker porous absorber panel had resulted in higher sound absorption at lower frequencies.

The perforated plates with different percentage of perforation at frequency range between 125-500 Hz,

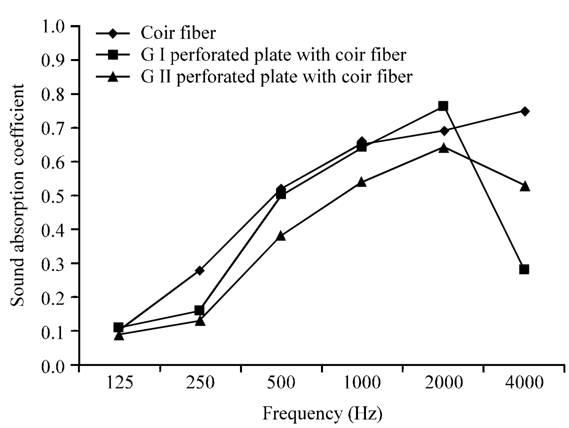

Fig. 2: Sound absorption coefficient versus frequency

showed no significant difference in the values of the sound absorption coefficient. At the higher frequency region between 500-2000 Hz, Group I showed higher sound absorption coefficients compared to the Group II. Peaking at 2000 Hz, both group showed decreasing of sound absorption coefficients thereafter. At 4000 Hz the sound absorption coefficient of Group II perforated plate with coir fibre sample was higher as compared to the Group I. Thus, increase of perforation percentage had shown to affects the sample sound absorption coefficient value.

Davern (1977) found that an increase in the percentage of perforation of acoustic panel increased the frequency of its resonance rather than affected by the holes dimension. The porosity of the perforated plate and the density of the porous material would significantly affect the acoustic impedance by increasing the sound absorption coefficient of the overall acoustic panel, in which case, the frequency band near the resonance frequency achieved high frequency absorption. Therefore, the increase in total percentage of perforation of Group II consequently increased the resonance and subsequently increases the sound absorption coefficient at higher frequencies. The result varified Maekawa and Lord (1994) statement, whereby percentage of perforation of more than 20% with small aperture would not affect the sound absorption performance of porous fibre and vice versa, a smaller percentage of perforation would reduce the sound absorption of the porous fibre at higher frequency.

CONCLUSION

The effects of zine sheets with different percentage perforation together with coir fibre acoustic panels on sound absorption coefficient were experimentally conducted. Results showed coir fibre exhibits good acoustic properties had potential as alternative based material for acoustic development. Introduction of perforated plate combined with coir fibre, showed evident sound absorption coefficient peak shifted to lower frequency range and decreasing coefficient at much higher frequencies. The effect of perforation percentage showed that both perforation percentages had higher value of sound absorption coefficient achieved at frequency range around 2000 Hz and decreases significantly at higher frequency range. Although, the high perforation percentage plate had lower value of the sound absorption coefficient compared to Group I. In conclusion, higher perforation percentage of plate with coir fibre backing would increase the sound absorption coefficient at high frequency range.

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