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Improvement of Date Palm Fibre Acoustic Properties Using Perforated Plate, Woven Cotton Cloth and Polyester

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Abstract: The aim of this study was to explore the effect of date palm fibre as backing on sound absorption using three types of perforation plates and porous layers. The predicted results were verified by measurements conducted in an impedance tube on normal incidence sound absorption of 30 and 50 mm-thick date palm fibre and backing that may have positive effect are elaborated in this study. It describes how the porous materials of date palm fibre absorber panel can change the absorption behavior. The results obtained show that perforation plate, porous layers have a significant effect on absorption, whereas thickness panel have considerable effect too. This further indicate that three types have been used and also supported can be powerfully exploited to improve the absorption of date palm fibre and at the same time a reasonable thickness chosen, would be very efficient for absorption sound. An example is presented to show the approaches of enhancing the absorption, by utilizing the advantage of modification in the absorption sound. It exhibits that properly chosen perforation ratio along with suitable sample thickness can increase the absorption as well as the selected porous layers. It was evident that these can be powerfully exploited to improve the absorption of date palm fibre. Three types of perforation plate, porous layers were used to improve acoustic properties of date palm fibre. This means the innovative fibre becomes more active and efficient, plus it is renewable, waste material and very light compared to industrial substances.

Keywords: Acoustic absorption coefficient, date palm fibre, perforated plate, polyester woven cotton cloth

INTRODUCTION

The increasing noise levels caused by technological advances have many negative implications for human health and exposure may lead to hearing loss (temporary or permanent), nervous weakness, internal tissue and heart problems and even high blood pressure in the long-term (Gupta and Ghatak, 2011). The most prominent physiological problem caused by unwanted noise is ear pain (HL). One method of overcoming this issue is the use of absorber materials. In the past, industrial substances were used to treat noise problems, but these substances are physically and chemically harmful to humans (Suter, 2002). For this reasons, the use of novel materials, such as agricultural waste, to replace industrial substances as absorbing materials would have many advantages, including ready availability and fewer harmful effects on human health. 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.

Whereas, Davern (1977) studied the effect of the density and porosity of a perforated plate on the acoustic properties of a material. He found that the porosity of the perforated plate and the density of porous material significantly affect the acoustic impedance and acoustic absorption coefficient of the panel, improving the acoustic absorption of the frequency band near the resonance frequency. Afterthat, Beranek and Ver (1992) presented a compact expression for the acoustic impedance of perforated plates. This expression indicates that the relevant factors include the thickness, hole radius, hole pitch and porosity of the perforated plates and the air contained in the holes. As a summary, Wassilieff (1996) presented wood as a sound-absorbing material in terms of three main parameters, flow air resistivity, porosity and tortuosity, in addition to the sample thickness. All of these parameters are naturally used to describe the effectiveness of a sound absorber. In power plants, absorber materials must be lighter and thinner to satisfy the demand for absorbing both low- and high-frequency sounds. Afterwards,Wang and Torng (2001) have investigated two fibrous porous materials manufactured in Taiwan, rock wool and glass, finding that the sound absorption characteristic values of rock wool were similar to those of glass fibre. At the same year, Lee and Chen (2001) reported that the acoustic absorption of multi-layer substances is better when using perforation plates backed with airspaces.

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A few years ago, several researchers investigated the use of farm waste to improve sound absorption. First of all (Yang *et al*., 2003) used rice straw-wood "with a high absorption coefficient" in the 500-8k Hz frequencies range, indicating that the porosity is higher for this material than for other substances. Then, Khedari *et al*. (2004) attempted to create improved particle boards using such materials as durian peel and coconut coir fibres by constructing boards with a lower thermal conductivity to decrease heat transfer in space. Meanwhile, Kosuge *et al*. (2005) examined sound absorption materials comprised of non-woven fabric and para-aramid fibre and polyester fibre instead of conventional materials, such as glass wool, flame-retardant foam and flame-retardant PET fibre. The flame-retardant properties were investigated using ISO 9237 and Federal Motor Vehicle Safety Standard FMVSS 302. The sound absorption properties by normal incidence can be found in ISO10534-1. So that, Kosuge *et al*. (2005) calculated the acoustic impedance for multi-layer absorbers, such as perforated plates and air space or perforated plates and porous materials, using an iterative method for three types of multi-layered absorbers to calculate the absorption coefficient. Their results were later validated experimentally. Also, Zent and Long (2007) presented one process to increase flow resistance by adding fibrous cover layers with finite flow resistivity or using plastic cover layers with infinite flow resistivity. A composite structure comprised of perforated panel, rubber particle, porous material, Polyurethane (PU) foam and glass wool demonstrated significant sound attenuation. Whereas, Zulkifh *et al*. (2008) studied transmission loss index and acoustic absorption coefficient to compare natural organic fibre perforated panels with or without filler. To further improve the acoustic properties, a perforated plate was used as backing for the panel samples. Inspite of, Ersoy and Küçük (2009) investigated three different layers of tea-leaf fibre waste materials with and without a single layer of woven textile cloth as backing. Their experiment revealed that a 1-cm-thick tea-leaf fibre waste material with backing provides sound absorption that is almost equivalent to that provided by six layers of woven textile cloth ,and that 2-cm-thick layers of rigidly backed tea-leaf-fibre and non-woven fibre material exhibit almost equivalent sound absorption in the frequency range between 500 and 3200 Hz. Meanwhile, Hosseini *et al*. (2010) studied the layer arrangements in terms of sound absorption enhancement. The results showed that when the perforated plate is backed by coir fibre and air gaps, the plate porosity has a strong influence on the low-frequency sound absorption capability.

Increasing the thickness of the panel material will improve sound absorption, especially in the low-frequency range. This research investigated the potential use of date palm fibres as replacements for synthetic and mineral-based fibres as sound absorbers. This study investigated the effect of the porous layer backing and perforated panel on the sound absorption coefficient of a date palm fibre sound absorber.

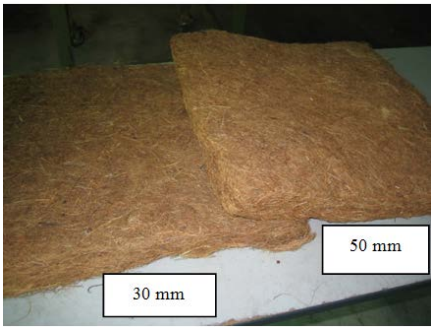

Fig. 1: Photographs of the sheet date palm fibre 50 and 30 mm

MATERIALS AND TEST METHODS

Date palm fibre, the primary raw material in this study, Date Palm Fibre (DPF) was prepared 30 and 50 mm-thick 400 mm square sheets and treated with latex to preserve the arrangement of the date palm fibre sheet. Figure 1 shows the sheet date palm fibre 50 and 30 mm. The samples used in the impedance tubes were 100 and 28 mm in diameter for low-and high-frequency studies, respectively and were cut into cylinders for this purpose. The five different measurements described below were performed on each panel. The date palm fibre backing with perforated plate, woven cotton cloth and polyester and were utilized as an acoustic absorption panels. To diffuse the vibration energy, a suitable combination of thickness, hole diameter and spacing between holes must be selected to increase the sound absorption capability. For a 1-mm-thick zinc perforated plate, three perforation ratios and hole diameters were studied: 10% with a 4 mm hole diameter, 10% with a 3 mm hole diameter and 22% with a 2 mm hole diameter. The calibration of the GRAS 26 AK microphones (speaker, amplifier and noise) was accomplished using a dual-channel real-time acquisition unit.

Test: The characteristic of interest is the incidence acoustic absorption coefficient, which is the range absorbance of the date palm fibre panels. This coefficient is dependent on how the substance absorbs sound. Testing was conducted using an impedance tube according to international standard ASTM E 1050-98. Figure 2 shows the perforated plate with three different perforation ratio and hole diameter combinations. Figure 3 shows woven cotton cloth and polyester. Figure 4 shows the date palm fibre panels. Figure 5 shows the impedance tube device.

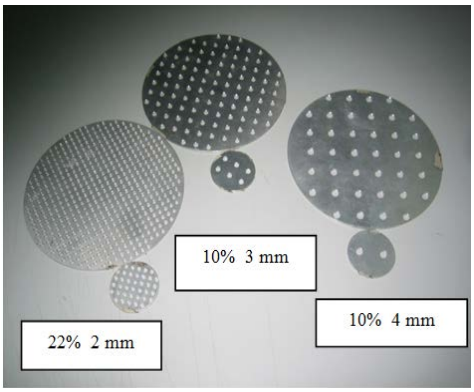

Fig. 2: Photographs of the perforated plate from the right perforation ratio and diameter

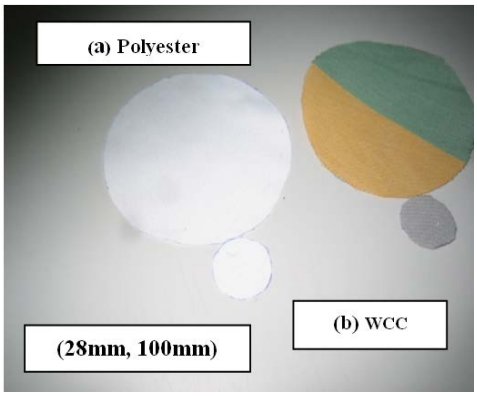

Fig. 3: Photographs of the test (a) woven cotton cloth (b) polyester

The impedance tube setup consists of two tubes, a 100 mm tube for low-frequency measurements and a 28 mm tube for high-frequency measurements, containing the samples. Data collection was accomplished using SCS 8100 software via the transfer of the signal sound to a function in a digital curve.

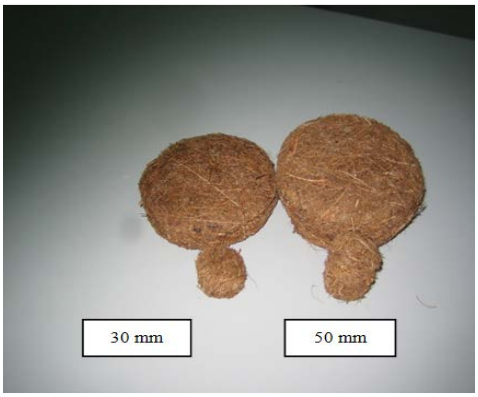

Fig. 4: Photograph of samples date palm fibre thickness 50 and 30 mm

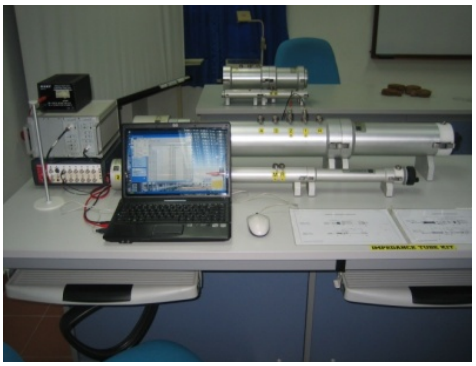

Fig. 5: Photograph of the impedance tube device

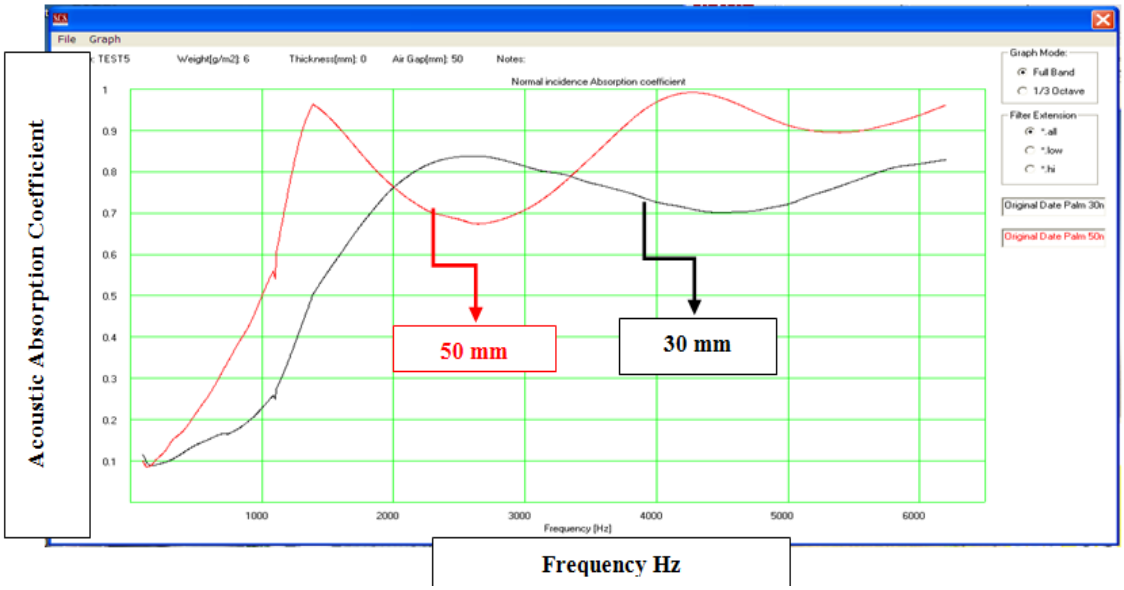

Fig. 6: Acoustic absorption coefficient for the 50 and 30 mm-thick date palm fibres without backing

RESULTS

The results of the impedance tube measurements at low and high frequencies (87.5-5000 Hz) for the 50 and 30 mm-thick date palm fibres without backing are shown in Fig. 6 to 9 compare the Acoustic Absorption Coefficients (AACs) of 50-mm-thick Date Palm Fibre (DPF) perforated plate backings with various ratio/hole diameter combinations. Figure 10 compares the Acoustic Absorption Coefficients (AACs) of Date Palm Fibre (DPF) at 50 mm. Figure 11 compares the acoustic absorption coefficients of 50-mm-thick date palm fibre with woven cotton cloth and polyester backings

Figure 12 shows the results obtained for the AAC of date palm fibre 30-mm with backing of perforated plate 10% and hole diameter 3 mm, 10% and hole diameter 4 mm and 22% and hole diameter 2 mm. Figure 13 shows the result from experimental acoustic

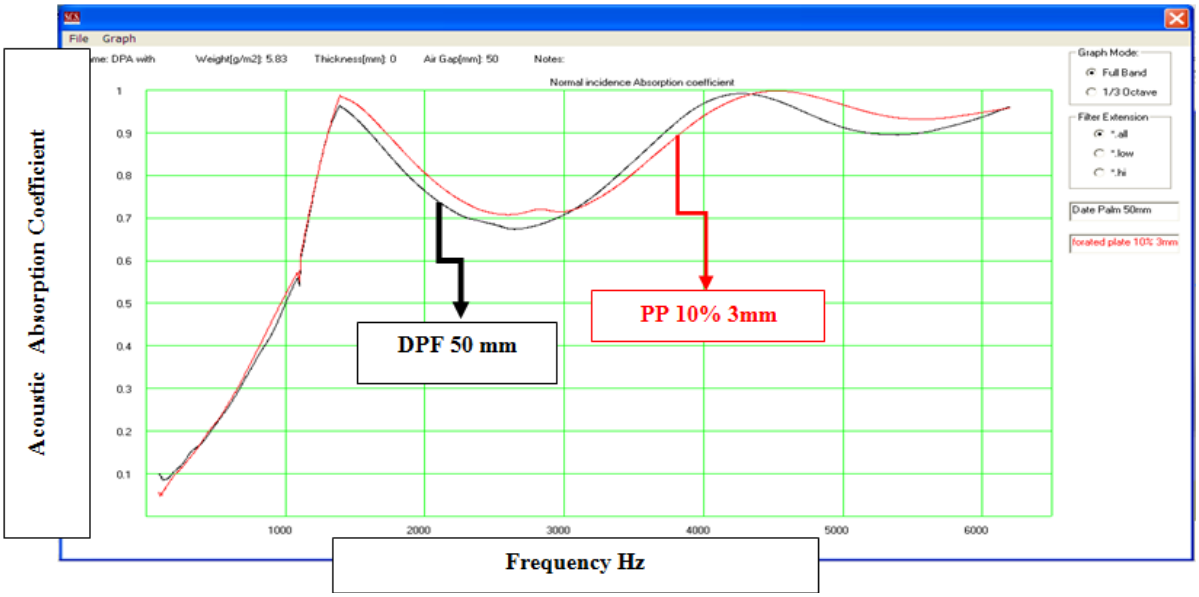

Fig. 7: Acoustic absorption coefficient of date palm fibre 50 mm with backing of perforated plate 10% and hole diameter 3 mm

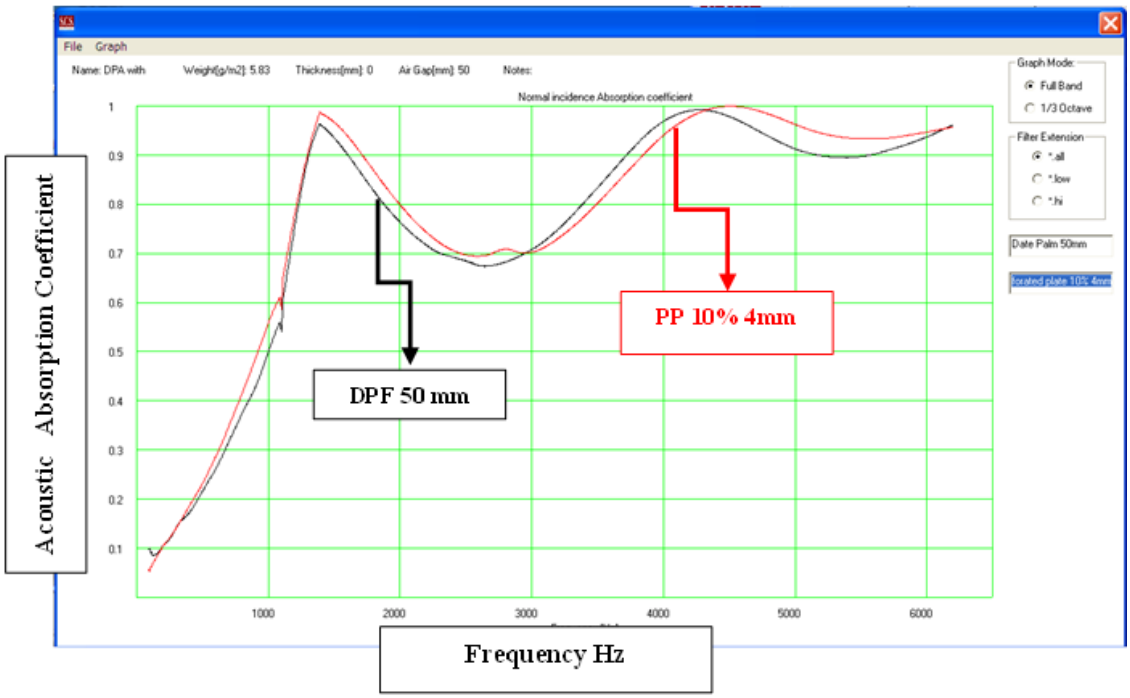

Fig. 8: Acoustic absorption coefficient of date palm fibre 50 mm with backing of perforated plate 10% and hole diameter 4 mm

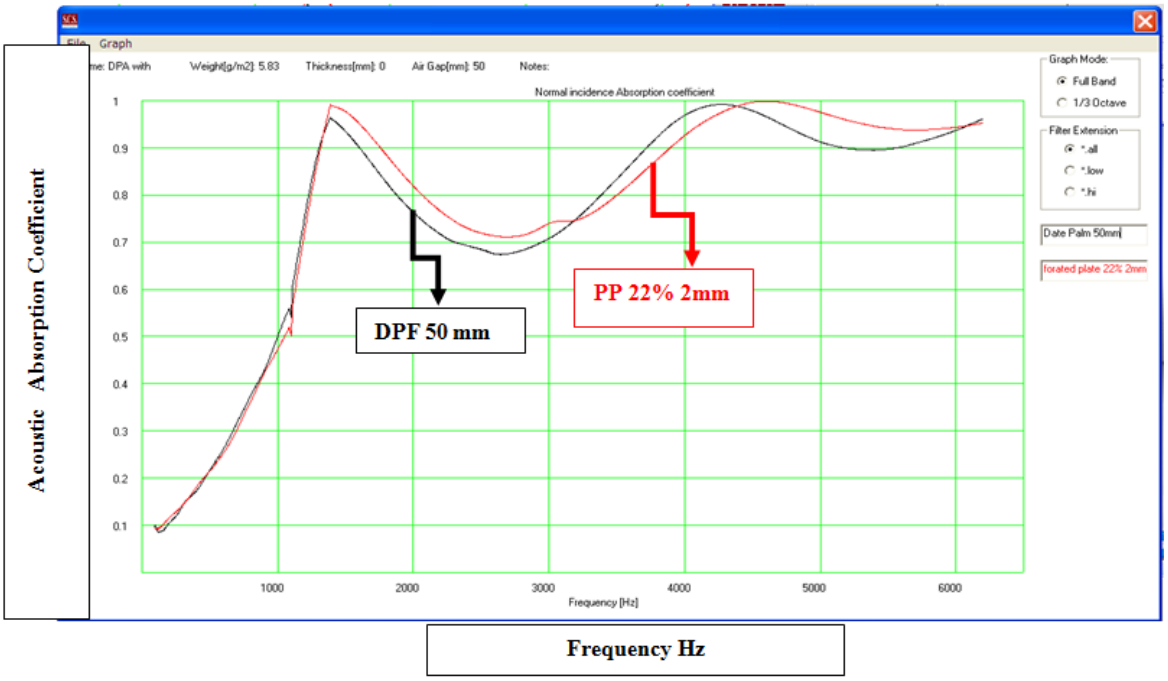

Fig. 9: Acoustic absorption coefficient of date palm fibre 50 mm with backing of perforated plate 22% and hole diameter 2 mm

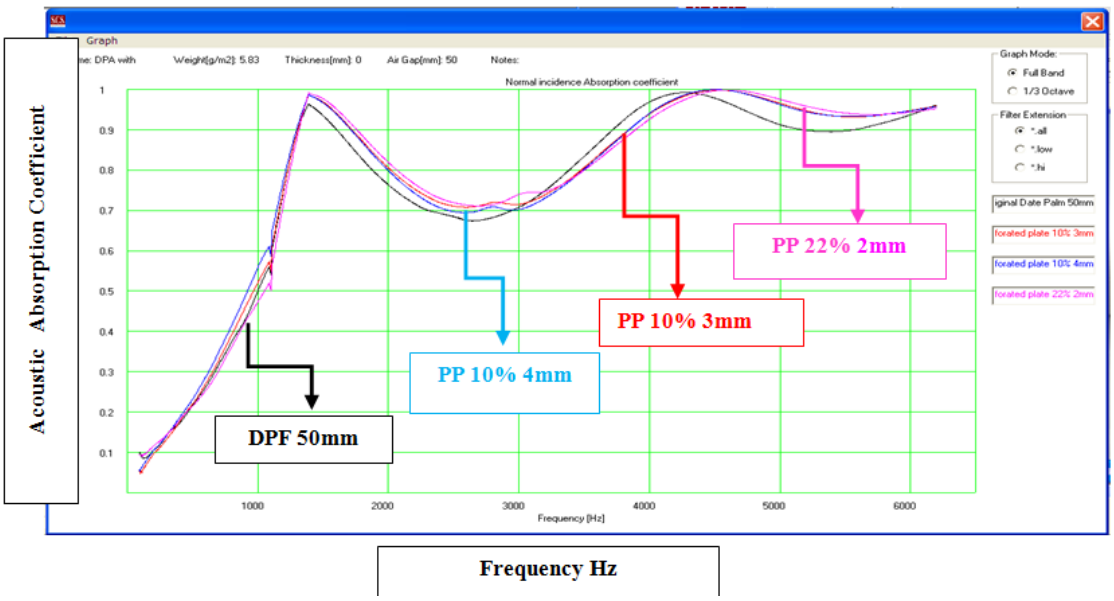

Fig. 10: The combined comparison of acoustic absorption coefficient of date palm fibre 50 mm with backing of perforated plate 10% and hole diameter 3 mm, 10% and hole diameter 4 mm and 22% and hole diameter 2 mm

absorption coefficient when date palm fibre 30 mm is layered with backing of woven cotton cloth and polyester.

DISCUSSION

Effect of perforated plate backing: Figure 6 shows the acoustic absorption coefficient for date palm fibre without a porous layer backing mounted on a rigid wall. The effect of the perforated plate on the acoustic absorption is shown in Fig. 7 to 10. The perforated panel will shift the absorption peak towards lower frequencies, increase the absorption throughout the frequency range, while decrease the acoustic absorption coefficient in the middle-frequency range. The empirical data indicated that the date palm fibre with perforation has a higher absorption in the lower-frequency range, 87.5-1478.13 Hz. The maximum

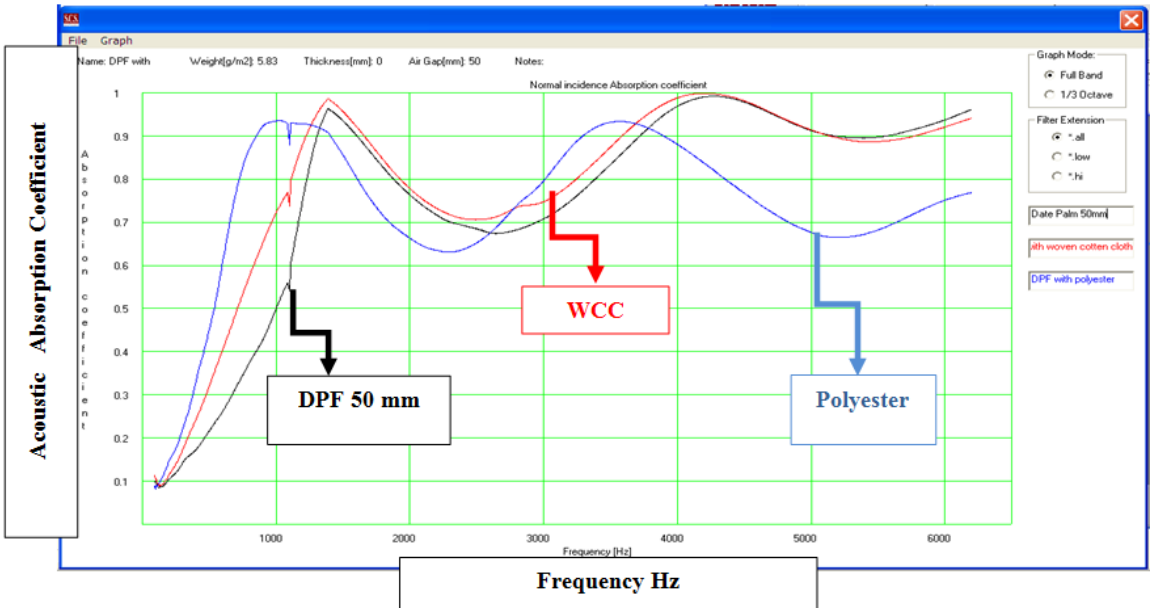

Fig.11: The comparison of acoustic absorption coefficient of date palm fibre 50 mm with backing of woven cotton cloth and polyester

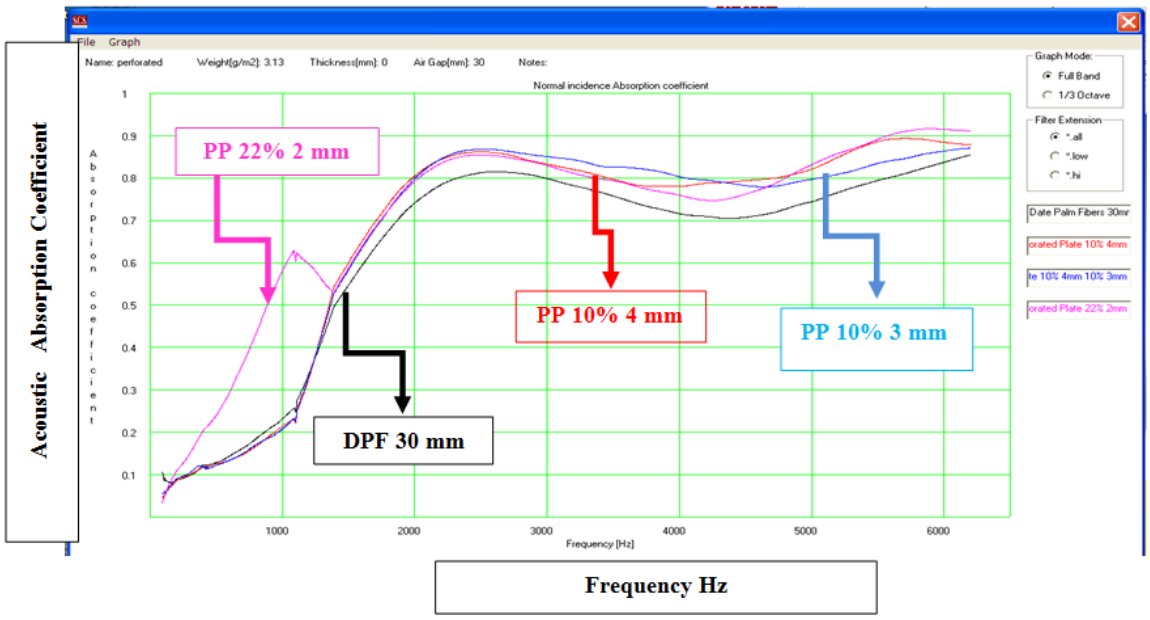

Fig. 12: The comparison of acoustic absorption coefficient of date palm fibre 30-mm with backing of perforated plate 10% and hole diameter 3 mm, 10% and hole diameter 4 mm and 22% and hole diameter 2 mm

value for date palm fibre with a 22% perforated panel and a 2 mm hole diameter is approximately 0.98 for the low-frequency range, 1381.25-1478.13 Hz and 0.99 for the high-frequency range, 4409.38-4821.88 Hz. The corresponding data for 30-mm-thick date palm fibre are shown in Fig. 12. The perforated panel shifts the AAC to 87.5-2768.75 Hz. The maximum value for date palm fibre with a 10% perforated panel and 3 mm hole diameter is approximately 0.86 for 2312.5-2768.75 Hz. Lee and Chen (2001) establish that porous substances clearly enhance acoustic absorption and shift the acoustic resonance to lower frequencies. The material including a perforated plate performed better than that without the panel (Nor *et al*., 2010), indicating that the perforated panel absorbs noise. Davern (1977) conducted experiments on a three-layer assembly consisting of a perforated plate, airspace and porous material. The results indicated that the porosity of the

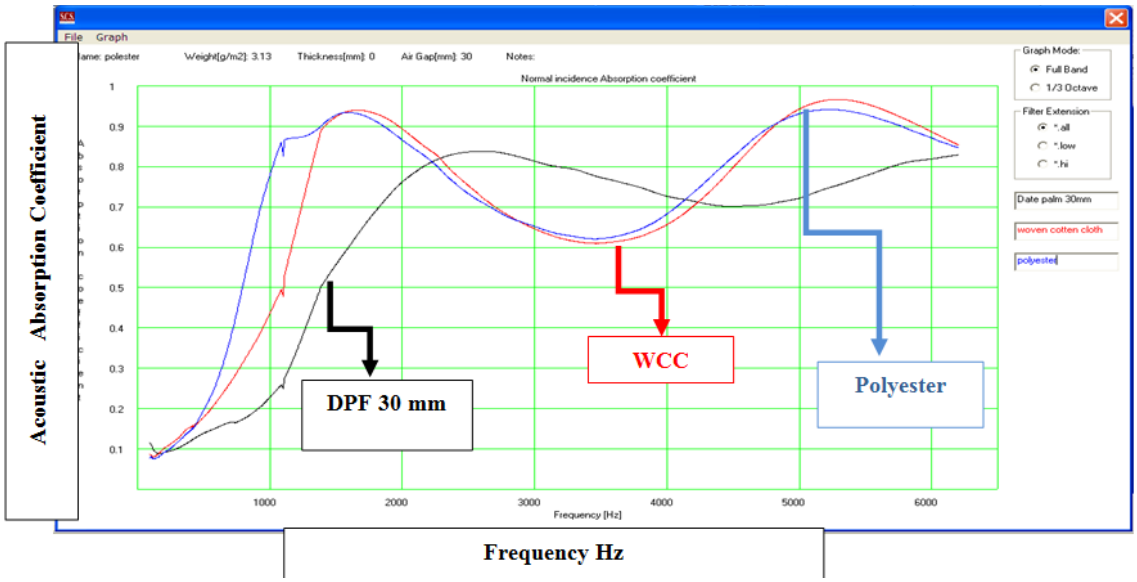

Fig. 13: The comparison of acoustic absorption coefficient of date palm fibre 30 mm with backing of woven cotton cloth and polyester

perforated plate and the density of the porous material have considerably influence on the acoustic impedance and absorption coefficient of the acoustic absorber.

Effect of woven cotton cloth backing: The material backed with woven cotton cloth WCC shifts the absorption to lower frequencies and significantly increases the AAC, as shown in Figures 11 and 13, respectively. For the 30-mm-thick samples, the use of WCC backing increased at the maximum AAC in the 1531.25-1806.25 Hz low-frequency range and the 4937.5-4987.5 Hz high-frequency range, with a peak value of approximately 0.93. For the 50-mm-thick samples, there are two AAC peak values are 0.98 in the 1371.88-1412.5 Hz low-frequency range and 0.99 in the 4025-4412.5 Hz high-frequency range. These results are caused by the higher flow resistivity of WCC relative to date palm fibre, which considerably dissipates the sound as it travels through the substance (Zent and Long, 2007). The experimental results indicated that the use of WCC improved the absorption relative to its omission.

Effect of polyester backing: The effects of Polyester (P) backing on the acoustic absorption coefficient are shown in Figures 11 and 13. At all frequencies, the ACC peak value for the 30-mm-thick samples is 0.93 for the respective 1515.63-1675 Hz and 4993.75-5000 Hz low-and high-frequency ranges. In contrast, the 50-mm-thick date palm fibre samples exhibited a maximum ACC of 0.93 in the 934.38-1078.13 Hz and 3481.25- 3665.63 Hz frequency ranges. These findings are attributed to the high flow resistivity of Polyester (P) relative to date palm fibre. The polyester will shift AAC to lower frequencies for both sample thicknesses and significantly increase the AAC at low frequencies (Kosuge *et al*., 2005).

CONCLUSION

Date palm fibre has been utilized as a sound absorber in this study. The empirical test results illustrate that this material has good acoustic absorption in the lower and higher frequencies and would be a viable substitute for industrial products. Using the perforated plate backing, woven cotton cloth and polyester with date palm fibre, the acoustic absorber plate exhibits high quality, ease of production and environmental friendliness. This innovative material has a promising future because it is much cheaper and lighter than industrial substances. In this empirical test, the researchers used innovative material of Iraqi date palm fibre as a backing with various 1-mm-thick zinc perforation ratios and whole diameters: 10% with 3 mm hole diameter, 10% with 4 mm whole diameter and 22% with 2 mm hole diameter. Relative to woven cotton cloth WCC or polyester P backings, the date palm fibre backing improves the acoustic absorption coefficient. Date palm fibre backing with a 10% perforated plate and 3 mm hole diameter exhibits a considerably higher acoustic absorption coefficient at low frequencies for 30-mm-thick backing and 22% with 2 mm hole diameter at all frequencies for 50-mm-thick backing. According to the empirical results, the date palm fibre backing with WCC performs best at low frequency and shifts to lower frequencies for both thicknesses. Finally, the date palm fibre backing with polyester is of higher quality than the porous layer at low frequencies for both thicknesses.

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