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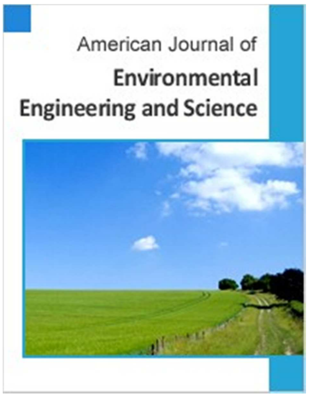

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Effects of Density and Thickness on Acoustic Properties of Oil Palm Trunk (OPT) Natural Fiber

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Abstract
Natural fibers are being widely studied as an alternative option of acoustic absorption material. It is well known that natural fiber has less health concern on human and no harm to the environment. Oil Palm Trunk (OPT) is an abundantly available resource that can be used as a substitution to synthetic material. The objective of this study was to examine the potential of OPT natural fiber as sound absorption material. The OPT natural fibers were fabricated in three different densities; 100 kg/m^3, 200 kg/m^3 and 300 kg/m^3 and three different thickness; 8 mm, 12 mm and 16 mm. Fiberboards were fabricated using Low-Density Fiberboard (LDF) method with Urea Formaldehyde (UF) as binder. Sound Absorption Coefficient (SAC, α) of the samples were measured using Impedance Tube Method (ITM) at frequency range of 0 Hz to 6400 Hz. The results show that all OPT fiberboard has a very good sound absorption level with a minimum SAC, α of 0.6 at frequency below 1000 Hz. The samples also show a constant increment at a high-frequency range from 3000 Hz to 6000 Hz. OPT fiberboard with density of 100 kg/m^3 and thickness of 12 mm possessed the highest performance of SAC, α = 0.99 which almost reach unity at frequencies of 3000 Hz, 6000 Hz and 6400 Hz. OPT is a biodegradable material that is very much suitable to be used as an acoustical material.

1. Introduction

Technology on improving sound absorption characteristic has been studied over the years. The development of materials using natural fiber is progressively being researched and produced. Currently, the available synthetic material in the market such as fiberglass and asbestos are very well known to have a health effect on human and harmful to the environment. Therefore, these are the main drives for researchers to find substitution material that acts both acoustically and eco-friendly.

From the investigation conducted by Oldham, both fibrous and non-fibrous natural material such as raw cotton, straws and reeds are proven to be sustainable acoustic absorbers that can be further developed commercially [1]. Waste fiber from paddy has been found to be an effective material in sound absorption as the coefficient could reach up to 0.8 at frequency level above 2500 Hz. The acquired information from this research are as good as synthetic glass wool [2].

Another research with coir fiber from coconut shows that it can be utilized as alternative option of sound absorber. Few further studies including fiber diameter, different layer of thickness and density variation has improved the absorption level. Diverse acoustical qualities of coir fiber were investigated by Fouladi and average absorption coefficient of 0.8 is accomplished but samples with additives shows lower absorption rate at high frequency [3].

Acoustic properties of Arenga Pinnata fibers has been accounted and found to have similar results with coconut coir fiber. Between 2 to 5 kHz frequency ranges, the absorption coefficient reaches up to 0.75 – 0.85 [4]. Ordinary incidence test on sugarcane bagasse shows good absorption rate at frequency above 0.5 to 1 kHz. Starting from 2 to 4.5 kHz, the average absorption coefficient is 0.8 concluding the performance of these fibers as sound absorber [5].

Oil Palm Empty Fruit Bunch (EFB) has also been studied as acoustic absorber by changing the density and establishment of air gap between the samples. The increase in density and thickness yields high absorption coefficient at high frequency region [6].

Oil Palm Trunk (OPT) are available on large scale during replanting as the life span of a tree are up to 25 to 30 years. Moreover, the plantation is being cleared out due to increase in development of urban areas. OPT are known to be a good source of fiber and the extraction process is done using simple method [7]. With regard to the previous research, medium density fiberboard (MDF) from OPT was stronger and had better fiber-to-fiber strength recorded than the frond and empty fruit bunch MDF [8]. For that purpose, a systematic study on the effects of different density and thickness on acoustic properties of Oil Palm Trunk (OPT) natural fiber.

2. Methodology

The OPT fiberboards were prepared using the method of fabrication of Low-Density Fiberboard (LDP). The fabrication involves chipping process, refining process, glue blending process, mat forming process, pre-pressing process and hot pressing process. For further clarification can refer to my previous publication [9].

3. Results and Discussion

The SAC (α), is simply the ratio of the sound power transmitted through the material sample into another medium to the sound power incident on one side of a material sample. For example, when a material has a SAC (α) of 0.8 at a frequency of 1000 Hz. This means that 80% of the incident sound was absorbed by the material where else 20% of the sound is reflected back to space or surrounding. As a matter of fact, the value of 0.0 and 1.0 merely exist as all materials have some ability to both absorb and reflect at least small amount of sound.

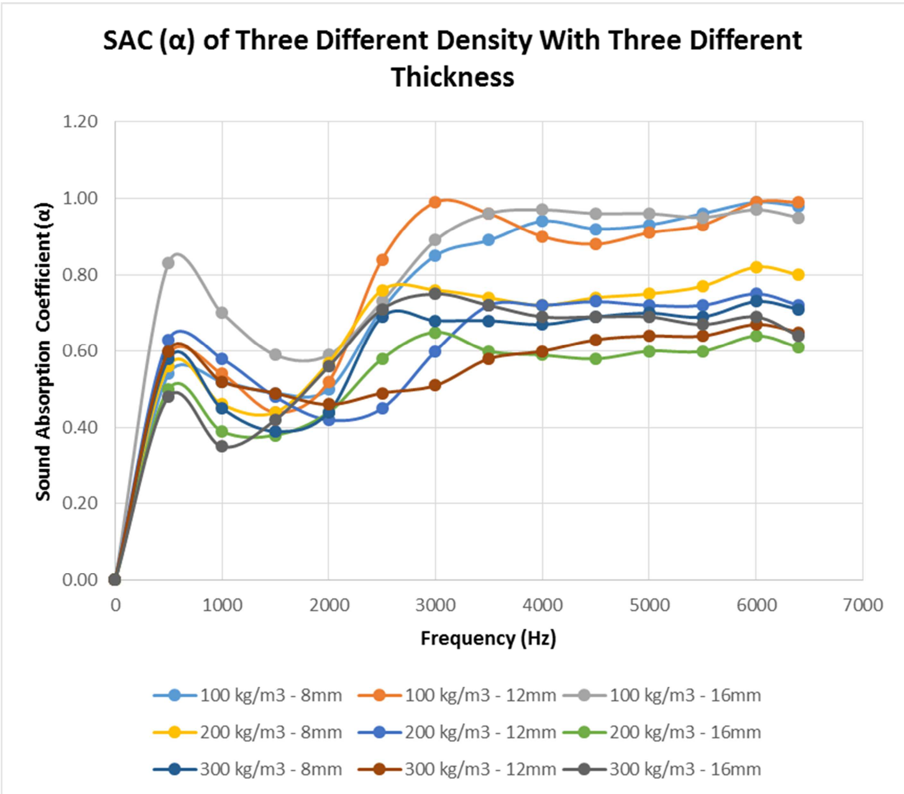
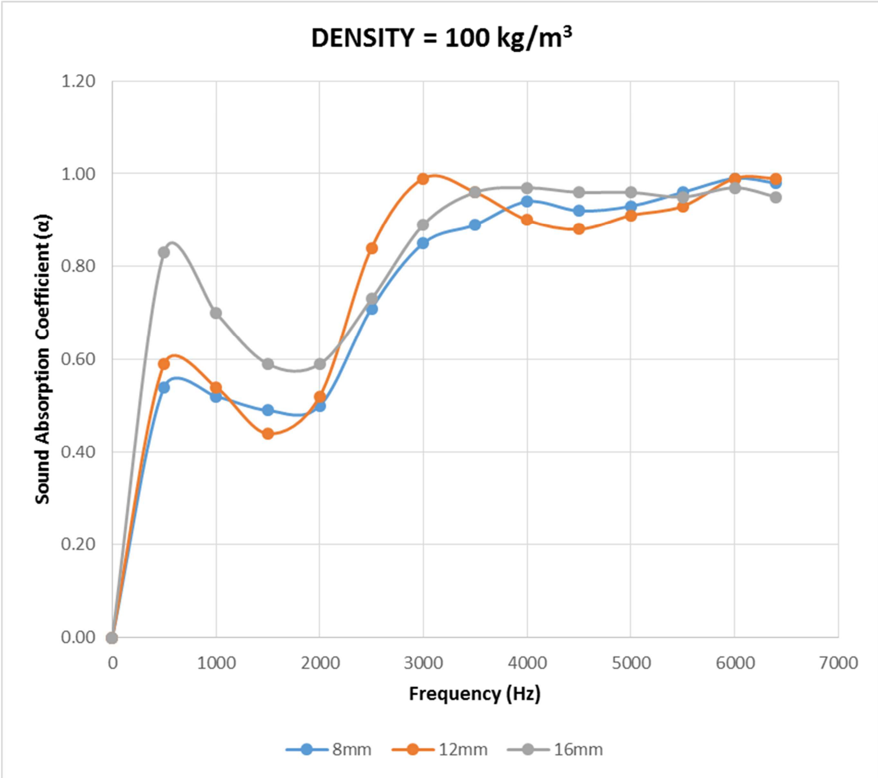
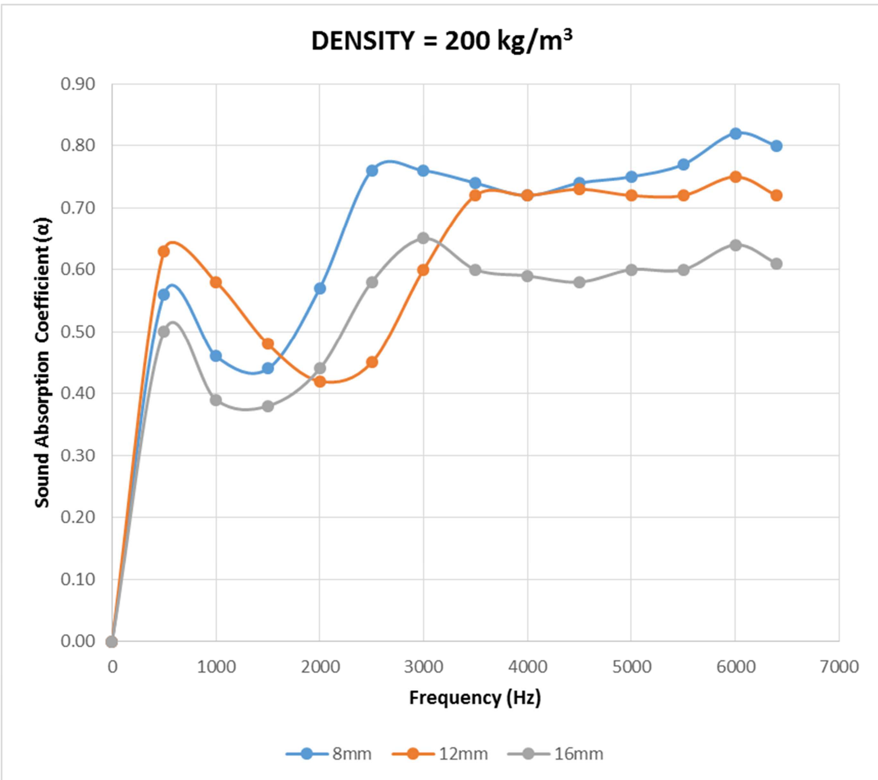


Figure 1. *SAC (α) vs Frequency (Hz) for three different targeted density and three Different targeted thickness.*

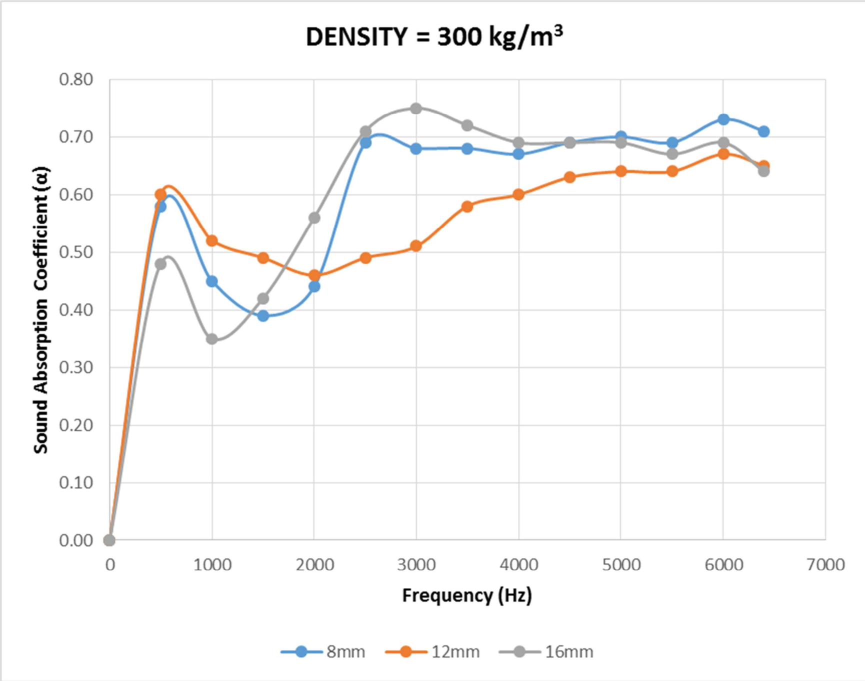
Based on Figure 1, all OPT natural fibers have resonance peaks at 500 Hz. From 2000 Hz to 6400 Hz, all samples show consistent pattern with significant absorption behavior. At low frequencies (0 to 500 Hz), the acoustic absorption coefficient for all samples increased with the increase in thickness and density. Whereas, at high frequencies the trends are marginally unique with few highs and lows [10]. Notwithstanding, sample with density of 100 kg/m^3 and thickness of 12 mm demonstrated the highest SAC (α) and almost reach unity (~0.99) at frequency of 6000 Hz.



(a)



(b)



(c)

Figure 2. *SAC (α) vs Frequency (Hz) for (a) ρ = 100 kg/m³ in thickness of 8 mm, 12 mm and 16 mm. (b) ρ = 200 kg/m³ in thickness of 8 mm, 12 mm and 16 mm. (c) ρ = 100 kg/m³ in thickness of 8 mm, 12 mm and 16 mm.*

Figure 2(a) shows the sample with density of 100 kg/m^3 gives higher SAC (α) compared to samples with density of 200 kg/m^3 and 300 kg/m^3. It may be due to sample with low density consists of larger porosity. The most elevated SAC (α) = 0.99 for the thickness of 12 mm is accomplished at frequency of 3000 Hz, 6000 Hz and 6400 Hz. This can be clarified as the sample is able to absorb the incident sound of 99% with 1% being reflected back. Be that as it may, they diminished fairly at frequency of 2000 Hz and then increased again. This point of inflexion was due to the specific characteristic of OPT fiber reflecting sound at 2000 Hz, yet engrossing sound in the low, center and high frequency ranges [11].

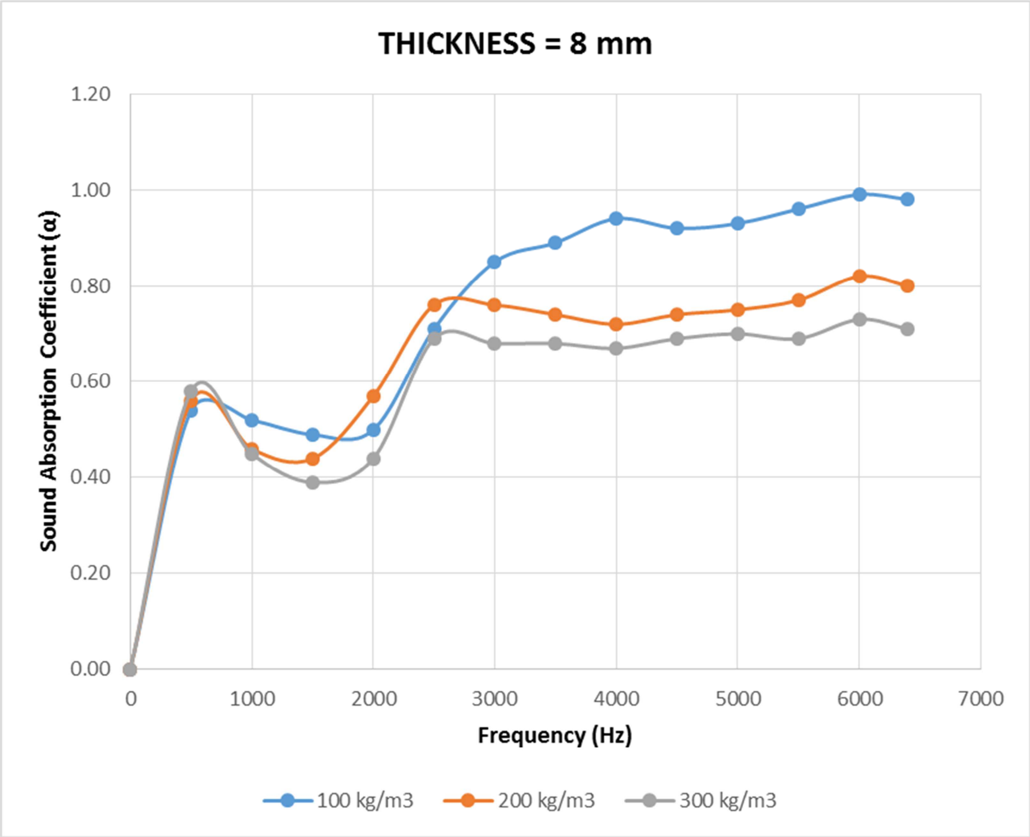
The testing for OPT fiberboards with density of 200 kg/m^3 and 300 kg/m^3 does not accomplish the standard limit for sound absorption referring to Figure 2(b) and Figure 2(c). When the density is increased from 100 kg/m^3 to 300 kg/m^3, the amount of OPT fiber used in the sample also increased. Excessive usage of fiber contributed to a more compact test specimen which reduces the capacity of sound wave absorption. Therefore when the density of sample is increased, the sound absorption rate decreases accordingly. Therefore, it may conclude that the rate of sound absorption level is directly proportional to the density of OPT fiber.

This is because higher usage of the material will reduce the air movement in the sample. The finely crushed fiber material help to dissipate the sound energy. In this case, the OPT fiber molecules were unable to do so due to highly compacted and closely arranged fiber molecules. Basically, the porosities of fibers are increased corresponding to the increase of density where high perforation exist within the sample causes the SAC (α) to decrease. It also moves the resonance peak to higher frequencies. Excessive usage of OPT fiber with inappropriate thickness contributed to the failure of this sample to achieve the standard SAC (α).

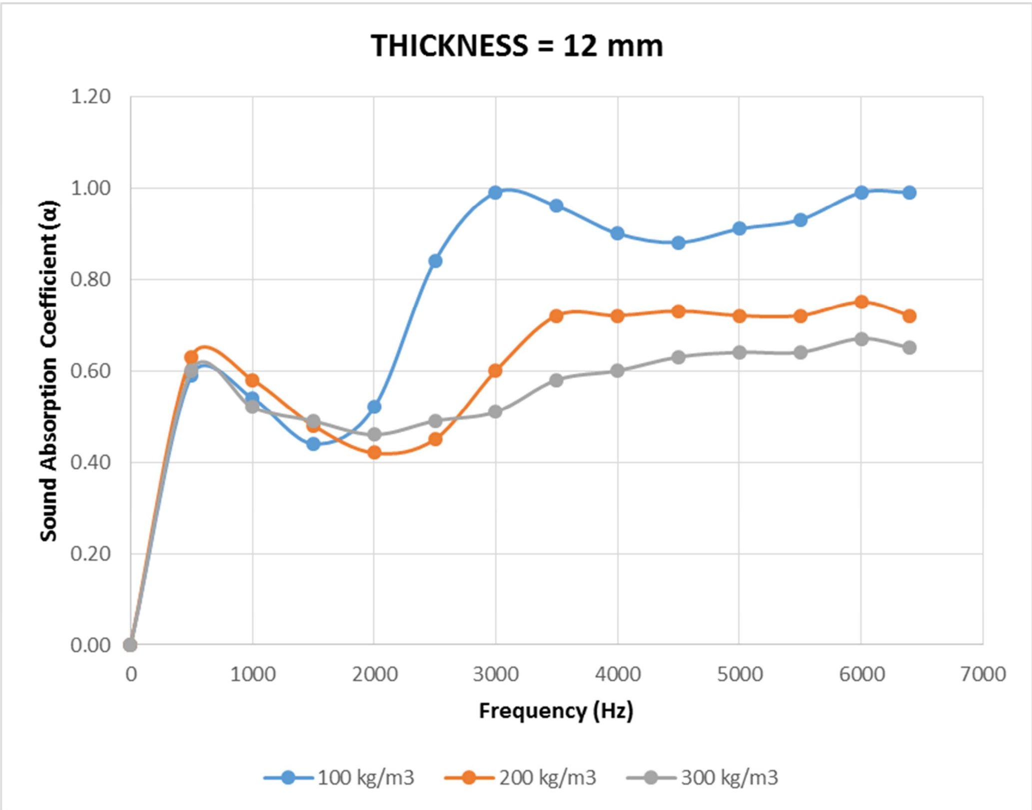
The density of a material is often a significant factor governing its sound absorption qualities. The investigation of materials density is very important, as the current study is dealing with the combined density of two materials such as fibrous and granular material. Materials with higher density show increased absorption performance, since the density has a great influence on the porosity and flow resistivity of the composite [12].

However, Koizumi [13] stated that the increase in sample density causes an increase in sound absorption at medium and high frequency regions. They explained that, with increases in the number of fibers per unit area, the sample density increases. As a result, energy loss of sound waves increases due to the increase of surface friction, which leads to an increase in sound absorption performance.

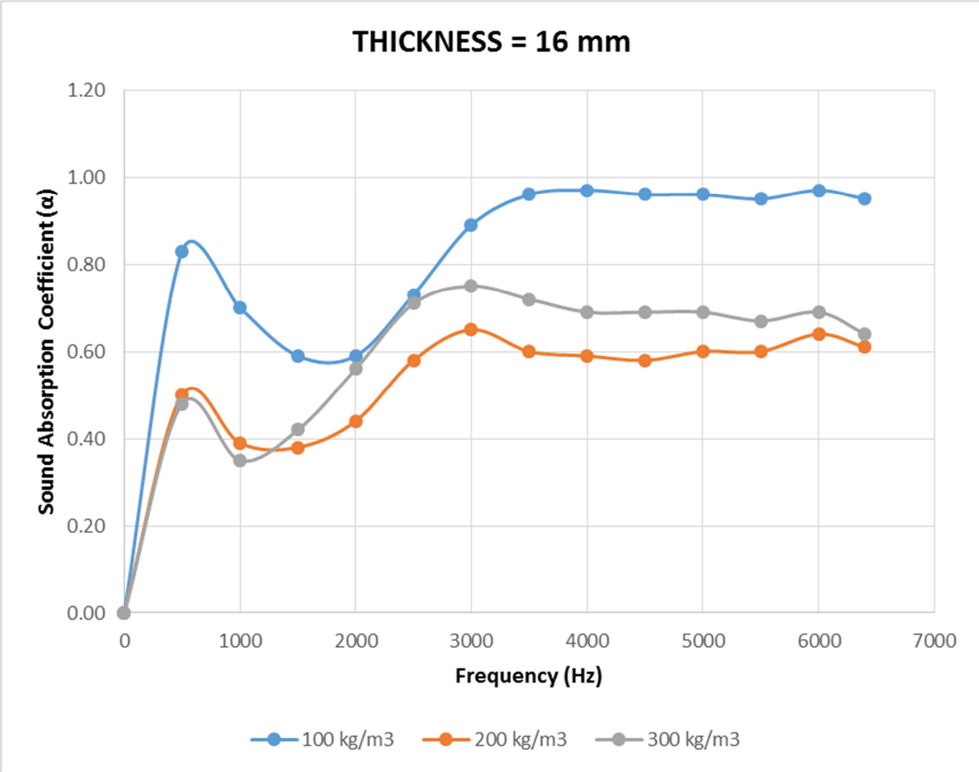
The air permeability of the materials can be characterized in terms of airflow resistance, which is measured by the ratio of static differential pressure between both sides of the specimen to the airflow velocity when air flows through the materials. Flow resistivity is the flow resistance per unit thickness of the tested material. Actually, as the density and airflow resistivity increased, the average sound absorption coefficient was firstly increased and then decreased. In a certain range of the thickness of the materials, the larger density means the denser structure [14].


THICKNESS = 8 mm
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Sound Absorption Coefficient (α)
0
1000
2000
3000
4000
5000
6000
7000
Frequency (Hz)
100 kg/m3
200 kg/m3
300 kg/m3

(a)


THICKNESS = 12 mm
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Sound Absorption Coefficient (α)
0
1000
2000
3000
4000
5000
6000
7000
Frequency (Hz)
100 kg/m3
200 kg/m3
300 kg/m3

(b)



(c)

Figure 3. *SAC (α) vs Frequency (Hz) for (a) thickness of 8 mm in density of 100 kg/m³, 200 kg/m³ and 300 kg/m³. (b) thickness of 12 mm in density of 100 kg/m³, 200 kg/m³ and 300 kg/m³. (c) thickness of 16 mm in density of 100 kg/m³, 200 kg/m³ and 300 kg/m³.*

Figure 3(a) shows the SAC (α) of samples with thickness of 12 mm in three different density. All the samples have a steady increase in sound absorption rate as the frequency increases from 0 Hz to 500 Hz until SAC (α) = 0.6 and it drops to as low as SAC (α) = 0.4. Sample with density of 100 kg/m^3 shows a significant absorption coefficient as it increases drastically with frequency from 1500 Hz and reaches almost unity at the high frequency of 6000 Hz. Samples with the density of 200 kg/m^3 and 300 kg/m^3 exhibit similar behavior with the density of 100 kg/m^3 but with lower SAC (α).

In Figure 3(b), at high-frequency range more than 2000 Hz, the sample with density of 100 kg/m^3 exhibits a very decent SAC (α) as it could nearly achieve unity at the frequency of 3000 Hz, 6000 Hz and 6400 Hz. This shows that the low-density sample possessed high SAC (α) value compared to the density of 200 kg/m^3 and density of 300 kg/m^3. Based on this figure, clearly at low-frequency range, the value for the coefficient of sound absorption was indistinguishable for all three different densities samples with 12 mm thickness. The SAC (α) of the sample with density of 200 kg/m^3 at mid frequency range only changes from a range of 0.45 till 0.7 and acts continually at high frequency. Similarly, for sample with density of 300 kg/m^3 acts but with lower SAC (α) ranges from 0.5 to 0.65.

As seen in Figure 3(c), all the samples with thickness of 16 mm show good results at low frequencies, ranging from 0 Hz to 500 Hz. However, the sample with density of 100 kg/m^3 is the only sample that has reached the maximum absorption rate at both high and low frequencies.

According to general guidelines of absorption phenomena inside a porous material, a long dissipative process of viscosity and thermal conduction between the air and absorbing material within the composite improves the absorption. This improved sound absorption is due to the increased thickness of the sample material. Sample layer thickness also plays an important role in enhancing low frequency sound absorption. The reason is the increase in layer thickness, causing the incident sound waves to lose more energy as they take a longer path through the material. In thicker materials, the impinged sound waves have to undergo a long dissipative procedure of viscosity and thermal conduction in the air within the composite [12].

Increasing the sample layer thickness has a significant effect on enhancing the sound absorption at the low frequency region of the porous material, while there is an insignificant effect at the higher frequency range [15].

4. Conclusion

Natural fibers not only exhibited good absorption behavior but also play an important role in design for ergonomics. Natural fibers are biodegradable and their productions are associated with lower emission than that in the production of synthetic fiber [16]. They maintain a comfortable environment by reducing noise level and health risks at the same time. OPT fiber shows a very good acoustic properties when it was tested for a frequency range from 0 Hz till 6400

Hz. In such way, some OPT fiber sample was able to reach almost unity with SAC (α) = 0.99.

OPT natural fiber was never been tested for acoustic properties and therefore this research study was a new effort of determining natural fiber as a substitute of synthetic material.

In this research, OPT natural fiber with density of 100 kg/m^3 and thickness of 12 mm were able to exhibit a maximum SAC (α) of 0.99. The OPT fiber experimental test results show that it has good acoustic properties and can be used as an alternative replacement of synthetic based commercial product.

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