

## Acoustic properties of natural fiber of oil palm trunk

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### ABSTRACT

Natural fibers are being used as substitutes of synthetic material for sound absorbing material as it is more environmentally friendly and renewable. This paper presents the investigation of Sound Absorption Coefficient ( $\alpha$ ) of Oil Palm Trunk (OPT) natural fiber as an acoustic material. The experiment was carried out using Impedance Tube Method (ITM) where all samples of OPT are tested for Sound Absorption Coefficient. The natural fiber of OPT was fabricated to form panel in three different thickness of 8 mm, 12 mm and 16 mm with an average density of 100 kg/m<sup>3</sup>. From the result, it is found that OPT has a very good acoustic performance where all samples almost reached unity ( $\alpha \approx 0.9$ ) at a high frequency above 3000 Hz. The result also shows that at low frequency, below 500 Hz, the Sound Absorption Coefficient ranges from 0.5 to 0.85. The natural fiber panel with a thickness of 12 mm is found to have the highest sound absorption coefficient,  $\alpha \approx 0.99$  at frequencies of 3000 Hz, 6000 Hz, and 6400 Hz, hence Oil Palm Trunk is a very promising natural fiber to be used as a sound absorbing material.

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### 1. Introduction

Currently, the demand for the environmentally friendly material is increasing globally due to increase in awareness about synthetic materials effect on human and environment. Synthetic materials are a substance that is produced by chemical process rather than formed naturally. Moreover, many industries are moving towards green concept where sustainable products of the sound absorber are in huge demand. These synthetic materials consist of glass and/or mineral materials. The fiber shedding from this material is hazardous to human health especially infection in lung and irritation to skin, eyes, and throat which also lead to breathing difficulties.

According to the research conducted by US Government in 'Fiberglass effects on human DNA', it is proven that usage of fiberglass is one of the very first steps in approaching to cancer. International Agency for Research on Cancer has classified some fibers used in fiberglass as possible human carcinogens (IARC, 2002). Research shows that fiberglass has a seriously damaging effect on human

DNA. Animal studies were proven that some specific type of fiberglass causes the growth of tumor in the lungs as well as cell studies show that the fiber shedding can affect the DNA structure (Davis, 1986).

On the other hand, acoustic foam and other types of sound absorber such as fabrics are available in the market with different type of sizes. Usually, acoustic foam is used to control the noise with medium and high frequencies as well as vibration level. The utilization of these type of sound absorbent is less viable compared to synthetic materials. This is because of their natural properties which can be damaged or easily torn and deterioration due to high temperature and relative humidity along with time.

Therefore researcher has begun to look for natural fiber as an alternative choice which may also include composite materials. Once the acoustic performance on natural fibers was determined, further developments were investigated. Natural fibers exhibit many advantageous properties, they are a low-density material yielding relatively lightweight composites with high specific properties (Begum and Islam, 2013). The low cost, abundance, light weight and biodegradable make the natural fibers an attractive material considered for sound absorbers (Mamatha et al., 2014).

Moreover, many studies focused in developing natural fibers as raw material have been done and reported, such as palm, kenaf, coconut coir, and many others that have potential to be used as raw material of acoustical panel (Ismail et al., 2010).

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Paddy straw was reported suitable to be used as acoustic panel because of its high elasticity and hollow space (Mediastika, 2007).

Similarly, coconut and jute fiber have high potential to be used as a sound absorber material (Sabri, 2007). Coconut coir fiber has good sound absorption at higher frequencies but less for the lower frequencies (Zulkifli et al., 2009). Then, the industrial tea-leaf-fiber waste material also has sound absorption properties at high frequencies (Ersoy and Küçük, 2009). Besides, kenaf can be properly seen as an alternative, especially for thermo-acoustic applications and sound barriers (Xu et al. 2004). These show that natural fibers have high potential to be applied as raw materials of sound absorbing materials.

Oil Palm Trunk (OPT) is abundantly available, and it is less expensive to be used as raw material to produce the potential value-added product such as particleboard, laminated board, plywood, fiberboard and plywood (Sulaiman et al., 2012). However, OPT fiber has never been tested for acoustic properties and lack of information in acoustic properties from available literature. Therefore this research will be interesting to study the acoustic properties of OPT.

## 2. Methodology

### 2.1. Sample preparation

1. Chipping Process – 100 % OPT is chosen for this research. This raw material was manually cut and chipped into small pieces using Laboratory Maier Chipper. The OPT chips are later oven dried at 100 °C until the Moisture Content (MC) have reached 10 %.

2. Refining Process – The OPT chips were processed and converted to cottonized fiber by using the Sprout-Bauer (ANDRITZ) refiner. For this research, constant refining steam pressure of 6 bars and cooking time of 300 seconds were maintained for all the samples produced so that it does not affect the final result. The refined fiber was also oven dried until the MC reached 4 % – 5 %. The MC were measured using Moisture Content Meter (Mettler Toledo HB 43 Halogen).

3. Glue Blending Process – The refined fiber was blended in the Mechanical Blender and then Urea Formaldehyde (UF) glue were included in regular basis. In this stage, the mass of the refined fiber and UF glue were measured accordingly to achieve an average density of 100 kg/m<sup>3</sup>. The sample was formed in three different thickness of 8 mm, 12 mm and 16 mm. The glue was mixed thoroughly using air pressure to ensure a perfect mix.

4. Mat Forming Process – A wooden former with the dimension of 300 mm × 300 mm was used in this research. The mixture was manually formed by hand to remove the pores contained.

5. Pre-Pressing Process – The mat formed were compressed using Pre-Press Machine. Once it was done, the mat was removed from the wooden former.

6. Hot Pressing Process – Hot press machine was heated up to a temperature of 200 °C. Once the desired temperature is reached, the mat was consolidated at 160 kg/cm<sup>2</sup> for 300 seconds.

### 2.2. Sample characterization

SAC ( $\alpha$ ) was measured using Impedance Tube Method (ITM) (Bruel & Kjaer (B&K) Impedance Tube Type 4206 (Small Tube Setup)) as shown in Fig. 1.

The ITM has a quick and easy, yet perfectly reproducible, measurements of absorption coefficients. The impedance tube also allows for accurate measurement of the normally incident acoustic impedance and requires only a small piece of the samples of the absorbing material. A loudspeaker produces an acoustic wave which travels down the pipe and reflects from the test sample. The phase interference between the waves in the pipe which are incident upon and reflected from the test sample will result in the formation of a standing wave pattern in the pipe.

Each OPT fiber sample was cut into a small piece; 30 mm in diameter to be fitted into the impedance tube. All samples were tested from frequency range from 0 – 6400 Hz. Each sample took almost 30 minutes to complete the sound absorption testing with the frequency range setup.

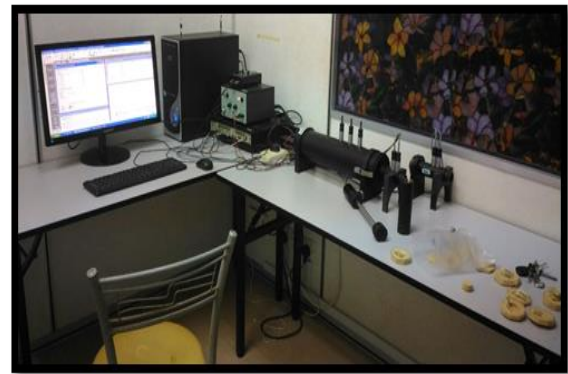


Fig. 1: OPT sample testing using B&K tube

## 3. Results and discussion

The SAC ( $\alpha$ ) of a material is a dimensionless number valued between zero (0.0) and one (1.0), over a range of frequencies, that represents a percentage of sound energy absorbed based on a unit area exposed to the sound. The value of 0.0 means all of the incidence sound energy is reflected or transmitted, whereas, the value of 1.0 means all of the incidence sound energy is absorbed (Ismail, 2012). The SAC ( $\alpha$ ) is the sum of the percentages of sound that were not reflected.

From Fig. 2, it can be seen clearly that all samples are nearly achieved unity ( $\alpha \geq 0.9$ ) at the frequency range of 3000 Hz to 6400 Hz. This shows and proves that less dense samples provide higher SAC ( $\alpha$ ) than denser samples. It is also because of the present of large porosity within them. The highest SAC ( $\alpha$ ) = 0.99 for the thickness of 12 mm is achieved at

frequency applied of 3000 Hz, 6000 Hz and 6400 Hz. This can be explained as the sample is able to absorb

the incident sound of 99% with 1% being reflected back.

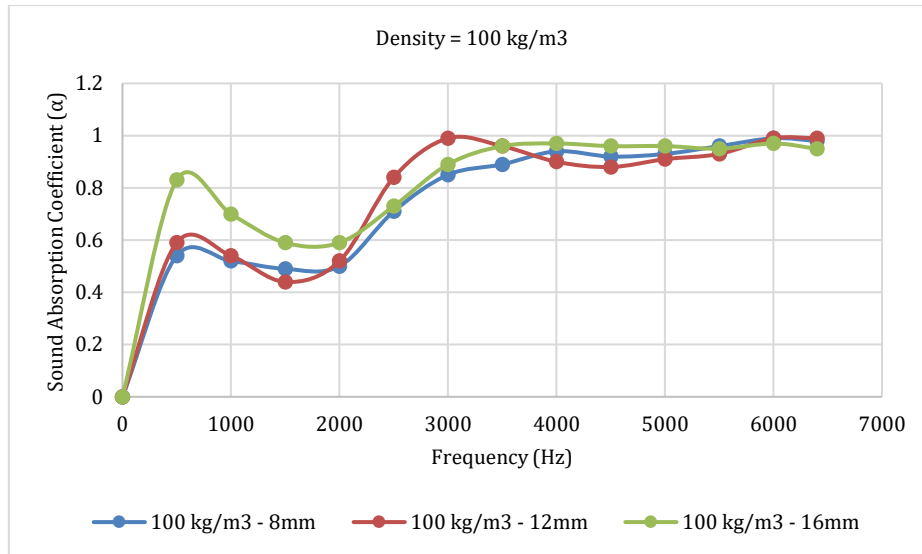


Fig. 2: SAC (α) vs frequency applied (Hz) on density of 100 kg/m<sup>3</sup> with three different thickness

For sample thickness of 8 mm, the highest SAC (α) = 0.98 is achieved at the highest frequency and for the sample thickness of 16 mm, the highest SAC (α) = 0.97 is achieved at the frequency of 4000 Hz and 6000 Hz. Specifically, the thickness of 8 mm which shows SAC (α) = 0.99 where it is almost reached unity at the high frequency above 6000 Hz.

Fig. 3 shows the SAC value of mesocarp fiber at frequencies of 0 to 5000 Hz with four different thickness (10 mm, 20 mm, 30 mm and 40 mm). All these four samples have its own unique way in sound absorption which cannot be related to each other. When compared to OPT fiber with the thickness of 12 mm, it can be seen clearly that OPT have higher absorption rate compared to all samples of mesocarp fiber at high-frequency range, specifically at the frequency of 5000 Hz. However, when comparing OPT fiber with mesocarp fiber at

low frequency, mesocarp fiber have a better absorption rate with proportional rate until frequency level of 1000 Hz for all samples.

Fig. 4 shows the comparison of SAC (α) between coir, corn, grass and sugar cane. Based on this four natural fibers, sugar cane exhibits the highest SAC (α) = 0.83 at a maximum frequency of 4000 Hz. Sugar cane shows a directly proportional relationship of SAC (α) with frequency applied. Grass and corn also show a directly proportional relationship of SAC (α) with frequency applied but with lower absorption rate. However, if compared with the OPT fiber at the frequency of 4000 Hz, it has reached SAC (α) = 0.90. This shows that OPT fiber is a better sound absorber material if compared to sugar cane and the rest of natural fibers.

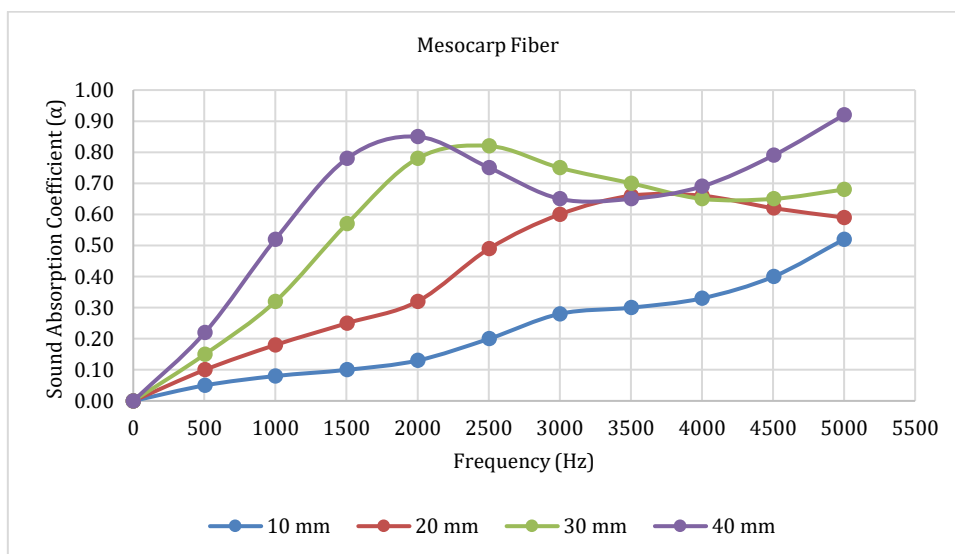


Fig. 3: SAC (α) vs frequency (Hz) of mesocarp fiber at different thickness (Abdul et al., 2015)

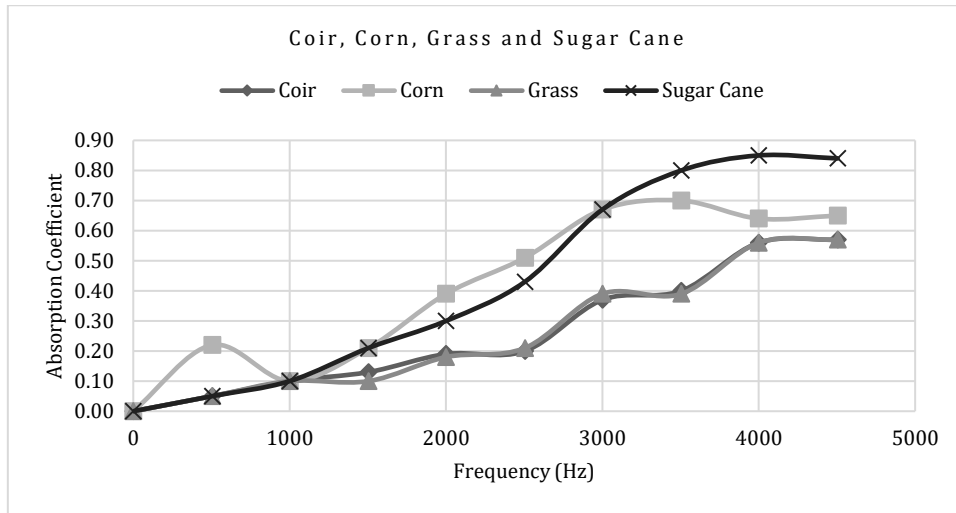


Fig. 4: SAC ( $\alpha$ ) vs frequency (Hz) of coir, corn, grass and sugar cane (Fouladi et al., 2013)

Lastly, OPT fiber with optimum thickness and density is compared with banana and sugar cane natural fiber as well as the combination of both banana and sugar cane (Fig. 5). This comparison shows a very obvious result that OPT has a very good SAC ( $\alpha$ ) rate. This is because both at low frequency and high frequency, banana, sugar cane

and the combination of both shows lesser absorption rate compared to OPT fiber. Therefore OPT fiber is a good option despite its good acoustical absorption characteristics as well as the nature of the material to be environmentally friendly with less health concern.

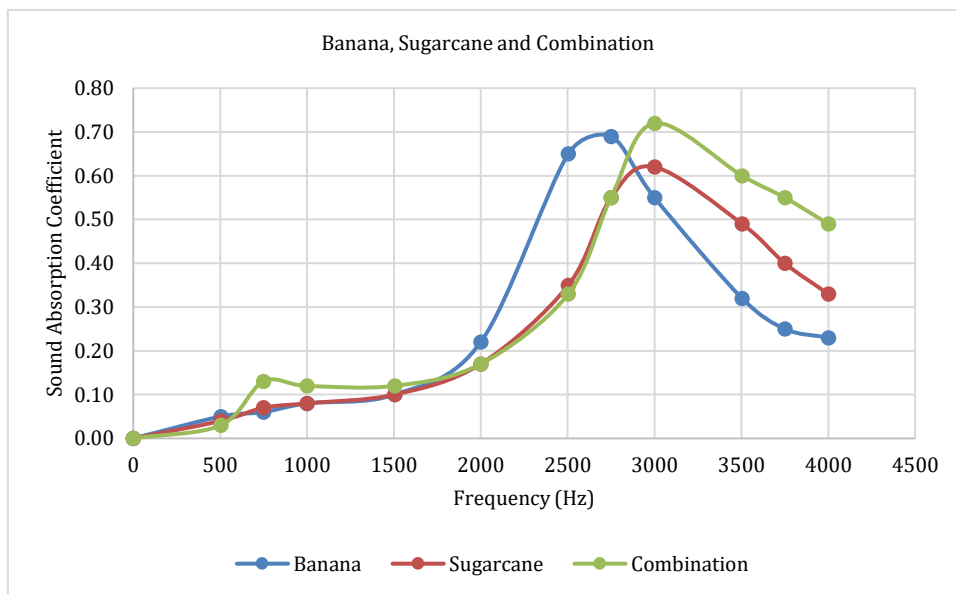


Fig. 5: SAC ( $\alpha$ ) vs frequency (Hz) of banana, sugarcane and combination of both (Abdullah et al., 2015)

#### 4. Conclusion

Fiberglass is not a good option despite its good acoustical absorption characteristics. Unfortunately, there have been serious health issues related to fiberglass that may occur immediately or within a few days of exposure such as skin irritation and redness, eye, nose and throat irritation. Not only may that, breathing in fiberglass dust result in coughing, bronchitis, shortness of breath, and even permanent lung disease if exposure is too excessive. This study was aimed at solely investigating the acoustic properties of OPT natural fibers and its ability to be used as a substitute of fiberglass.

Natural fibers not only exhibited good absorption behavior but also play an important role in design

for ergonomics. 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 ( $\alpha$ ) = 0.99. This means that 99 % of incident sound was able to be absorbed by OPT fiber and only 1% of incident sound was being reflected.

From the sample characterization, as the effect of thickness on OPT fiber were identified. The results show an obvious result that increase in thickness causes the absorption rate to decreases. This is because when the thickness increase, the amount of fiber in the sample increases causes the porosity in the sample to decreases. When porosity decreases, it

reduces the sound absorption rate and therefore the OPT fiber does not able to perform with high SAC ( $\alpha$ ) when the frequency increases. Thus the optimum thickness for OPT fiber was determined as 12 mm.

The primary objective of this research study was to determine the optimum density and thickness of OPT fiber. Hence, a density of 100 kg/m<sup>3</sup> and thickness of 12 mm were determined as the optimum OPT fiber. In this condition, the sample was able to exhibit a maximum SAC ( $\alpha$ ) = 0.99. The OPT 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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