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# COMPARISON ON ACOUSTIC PERFORMANCE BETWEEN DUST AND COIR FORM EMPTY FRUIT BUNCHES (EFB) AS SOUND ABSORPTION MATERIAL

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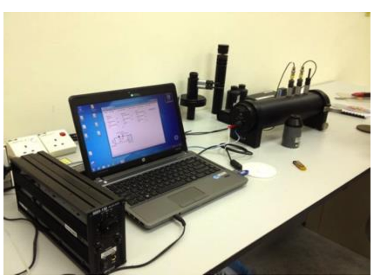
## Graphical abstract

## Abstract

Positive growth in palm oil Industry resulting in large quantities of solid waste generation and created a major disposal problem to the country. Among the major solid wastes generated from oil palm manufacturing processed are empty fruit bunches (EFB), mesocarp fruit fibres (MF) and palm kernel shells (PKS). This study investigated the utilization of EFB as sound absorption material for noise control in building. The effect of different form of EFB (coir and dust) was investigated in three different thicknesses (6mm, 12mm and 18mm) to determine the maximum sound absorption coefficient (SAC) and optimum frequencies. All samples were tested using impedance tube at low and high frequencies guided by BS EN ISO 10534. Results shows that dust EFB samples absorbed more sound energy compared to coir EFB samples at both low and high frequency region. Maximum SAC obtained by 18mm thick dust EFB samples at low frequency is 0.6 at 1500Hz while at high frequency; the maximum absorption was also obtained by 18mm thick dust EFB samples with SAC value of 0.990 at 3750Hz. This result indicated that thicker samples absorbed more sound energy compared to thinner samples. Moreover, small particles fibers consequently create less pores to the samples with higher density and higher sound absorption. In conclusion, palm oil fibre is highly potential to be used as raw material for sound absorption material replacing synthetic materials since these fiber are renewable, cheaper, nonabrasive, abundance and give less negative effect to human health.

*Keywords*: Empty fruit bunches (EFB), sound absorption coefficient, dust, coir

## Abstrak

Pertumbuhan positif industri minyak sawit negara telah menyebabkan banyak kuantiti sisa pepejal yang terjana dan seterusnya mengakibatkan masalah pelupusan sisa pepejal kepada negara. Tiga jenis sisa pepejal yang terhasil daripada proses pengilangan minyak sawit ialah tandan buah kosong (EFB), gentian mesokarp buah sawit (MF) dan tempurung biji sawit (PKS). Kajian ini bertujuan untuk menyiasat keberkesanan pengunaan EFB sebagai bahan penyerap bunyi untk kawalan bunyi bising dalam bangunan. Kesan rupabentuk EFB (debu dan sabut) pada ketebalan berbeza (6mm, 12mm dan 18mm) dikenalpasti bagi mendapatkan pekali penyerapan bunyi maksimum dan frekuensi optimum. Kesemua sampel diuji menggunakan tiub impedan pada frekuensi rendah dan tinggi berpandukan BS EN ISO 10534. Keputusan menunjukkan EFB dalam bentuk debu menyerap lebih banyak bunyi berbanding EFB dalam bentuk sabut pada frekuensi rendah dan tinggi. Nilai pekali penyerapan bunyi maksimum pada frekuensi rendah yang dicapai oleh sampel berasaskan debu berukuran 18mm tebal ialah 0.6 pada frekuensi 1500Hz, manakala pada frekuensi tinggi nilai penyerapan maksimum turut diperolehi sampel berasaskan debu EFB berketebalan 18mm dimana nilai SAC nya ialah 0.990 pada frekuensi 3750Hz. Keputusan i menunjukkan sample yang lebih tebal menyerap lebih banyak tenaga bunyi berbanding sample yang nipis. Selain itu, zarah fiber yang kecil mengakibatkan sedikit liang udara terhasil dan meningkatkan ketumpatan serta kadar penyerapan bunyi. Kesimpulannya, serat kelapa sawit adalah yang sangat berpotensi digunakan sebagai bahan mentah untuk penyerap bunyi menggantikan bahan sintetik kerana serat ini terhasil dari sumber yang boleh diperbaharui, tidak kasar, murah, bole diperolehi dengan banyak dan kurang memberikan kesan negatif kepada kesihatan manusia.

*Kata kunci*: Tandan buah kosong (EFB), pekali penyerapan bunyi, debu, sabut.



## 1.0 INTRODUCTION

Malaysia is the second largest oil palm producer in the world behind Indonesia. Oil palm planted in Malaysia is from *Elaeis guineensis* species and was first found in West Africa. Resulting from British Industrial Revolution, oil palm plantation was later expanded and commercially planted in South East Asia especially in Malaysia and Indonesia. Oil palm was first introduced to Malaysia in 1870 by British colony and the first commercial oil palm plantation in Malaysia was set up in year 1917 in Tennamaran Estate, Selangor [1]. Population growth and vast economic development by most countries importing oil for food has derived the demand for palm oil production in Malaysia and Indonesia. Oil palm is mainly become an important food and a major source of lipids, and with the increase of world population, the demand for oil palm was also increased [2].

In 1999, Malaysia and Indonesia have produced more than 80% of the world supply of palm oil [3]. Previously, Malaysia was the major oil palm producer in the world. However, after 2005, Indonesia has increased their oil palm production by 68% and has surpassed Malaysia to become the leading producer in the world [4]. In 2014 alone, Malaysia has produced 19.6 million tons of oil palm where 17.3 million tons were exported worldwide. India and China are the two major importers with more than 10 millions tons of Malaysian palm oil were exported to these countries in 2014 [5].

Today, oil palm had dominates the landscape throughout the country [[3] with more than 4.5 million hectares of land had been planted with palm oil. Result from the high demand and booming industry in the palm oil sector; thousands of tonne of palm oil waste (POW) are being produced annually by 200 palm oil mills in Malaysia [6]. The oil palm production produced plenty of biomass which includes wastes from oil palm trunks (OPT), oil palm frond (OPF), empty fruit bunches (EFB) and palm pressed fibres (PPF), palm shells and palm oil mill effluent (POME) [7] [1]. Their presence has created a major wastes disposal problem to the country. Moreover, due to huge amount of palm oil wastes (POW) accumulated resulting from the oil palm production, government need to allocate more money and assign more hectares of land to dispose those wastes. Moreover, the accumulating palm oil wastes in the landfill will cause other environmental issues if not been reused [6].

In general, three major solid wastes generated from oil palm processing, namely empty fruit bunches (EFB), mesocarp fruit fibres (MF) and palm kernel shells (PKS). Among those wastes, palm fibre (PF) or EFB is the larger lignocellulosic biomass generated from the oil palm processing [7]. Moreover, for every kg of palm oil, approximately a kg of wet EFB was produced. Normally, EFB is being burnt in simple incinerators and their ash was recycled as fertiliser at the plantation. However, since the fresh EFB containing more than 60% of moisture content, higher heating value is required to burnt EFB in the incinerator. This will result in higher emission and causing air pollution problem to the country, which is discouraged by the government [6] [1]. Alternatively, EFB are composed and returned to the plantation as mulch and was further been used as fertiliser and soil conditioning agent. However, due to inconvenience of handling and transporting, as well as unreasonable cost of handling, some owners prefer EFB to be disposed rather to being reused [1]. EFB is a natural material that contains of thick and rough filaments [8], and is fibrous in characteristics. Moreover, EFB was also renewable, abundance, low cost [8], nonabrasive, and show less health hazard during handling and processing [9]. These factors makes EFB more effective than industrial materials which are non renewable, hazardous to human health and environment, and quite expensive for small needs [10].

Nowadays, sound comfort constitutes one of the major requirements for human comfort. Since decades, glass or minerals fiber had become the most dominant acoustic treatment material for building. However, growing concern in health and safety related issues due to potential health risks from the use of synthetic and mineral fibers had divert researchers interest on the utilization of natural fiber as sound absorption material for building [11]. The used of natural fibres as sound absorption materials has been done by many researchers across the worlds. For examples, palm sugar [10], wool [12], wood-based [13], rice straw [14], bamboo [15], kenaf [16], coconut coir [17], tea-Leaf [18], coir fibre [19], , dried-paddy [20], date palm [21] sugarcane [23], kenaf, wood, cane[24]. Factors that influence the acoustic performance of sound absorption materials of natural fibres are fiber size, air flow resistivity, porosity, tortuosity, thickness, density, compression, surface impedance, placement or position of sound absorptive material and performance of sound absorptive materials [25].

This study aims to investigate performance of EFB as sound absorption material in different fibre form (coir and dust). The effects of different material thicknesses (6mm, 12mm and 18mm) were investigated to optimize the fibre performance for sound absorption.

## 2.0 MATERIALS AND METHOD

### 2.1 Preparation of Raw Materials

Oil palm empty fruit bunches (EFB) was used in this research. Raw EFB fibre was obtained from Palm Oil Industries located at Batu 9 3/4, Jalan Labis, Yong Peng Johor. Hand pull-out method was used to extract the fibre since the quantity of the fibre needed is not too much. The extracted fibre was then washed under running water to clean it from dirt and unwanted particles. EFB was then soaked with sodium hydroxide solutions (NaOH) for 24 hours to ensure the extracted fibre was clean and free from any contaminants that might influences the results. The fibre was rinsed under clean water and being oven-dried for 24 hours at 80°C-90°C to removed its moisture to less than 10%.

After being dried, the clean fibre was weighed and divided into two portions for fabrication purposes. One portion was shaped into coir while the other portion was grinded to become dust. Urea formaldehyde (UF) resin was used as binding agent to form the fibre become panel. Both dust and coir EFB were weighed and mixed with UF before being placed into respective wooden moulds sized 20cm x 20cm at three different thickness (6mm, 12mm and 18mm) for hot press. The hot-press was pre-set with 180°C and the respective PF's were pressed for 5 minutes under 1000psi. The pressed panels were left under room temperature to cool down the temperature before removing the mould. The fibre panels were then cut into desired shapes and sizes (28mm and 100mm diameter) and trimmed to ensure it can fit into the impedance tubes for sound absorption measurement. Figure 1, summarized the sample preparation process that had been carried out for this study. Two types of panels manufactured in this study are dust and coir form samples. Both category were prepared at three different thicknesses (6mm, 12mm and 18mm) and cut into two different diameters (28mm and 100mm) for high and low frequencies tube. Target density for the new samples is 1g/m³, and amount of UF resin was calculated based on recommended manufacturing practice by the industry. Table 1 shows the ratio of fibre and resin content in samples at different thickness.

**Table 1** Ratio of fibre and resin content in samples (coir and dust form)

| | Thickness (mm) | | |
|---|---|---|---|
| | 6 | 12 | 18 |
| Target density (g/m³) | 1 | 1 | 1 |
| Weight of fibre required per mould (kg) | 0.24 | 0.48 | 0.72 |
| Amount of liquid resin (UF) content (kg) | 0.06 | 0.10 | 0.17 |

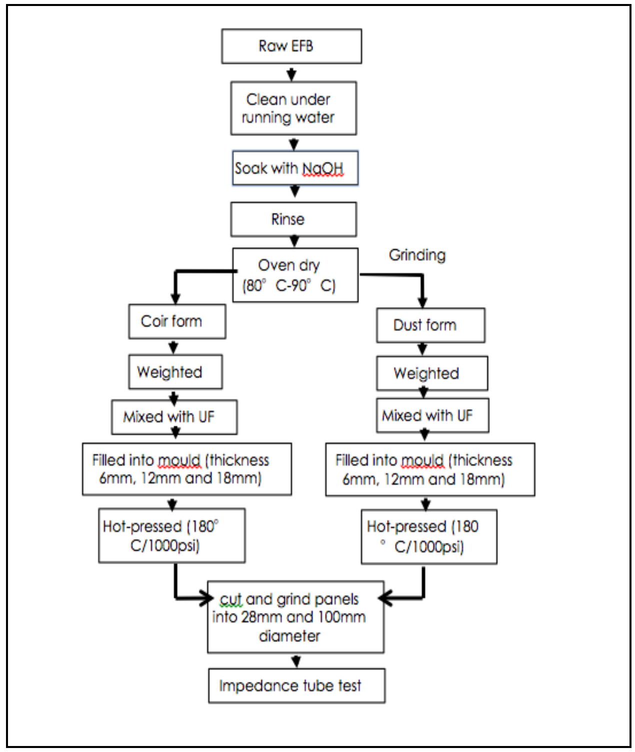



**Figure 1** Process Chart for Sample Preparation

Physical properties of dust and coir form samples are described in Table 2.

**Table 2** Physical property of coir and dust shape samples

| Fibre Form | Thickness (mm) | Average density (kg/m³) |
|---|---|---|
| Coir | 6 | 610 |
| | 12 | 780 |
| | 18 | 650 |
| Dust | 6 | 960 |
| | 12 | 780 |
| | 18 | 620 |

### 2.2 Impedance Tube Test

All samples were tested for sound absorption coefficient according to BS EN ISO 10534: Acoustic determination of sound absorption coefficient and impedance in impedance tube: Part 1: Method using standing wave ratio [26]. Figure 2 shows the measurement tubes used in this study. The 4208 Series two microphone tubes type (Impedance Tube) was used to measure the sound absorption coefficient of soft and porous samples. All measurements were done at Acoustic Laboratory, Faculty of Civil and Environment, University Tun Hussein Onn Malaysia. The apparatus consisted of two arrays of tubes sizes 100 mm and size 28 mm diameter. The wideband acoustic plane wave sources measurement chamber holding a couple of microphone receptacles, and an adjustable sample holder according to Bruel & Kjaer 227:1697. Results were analyzed by AFD-1001 Acoustic Tube transfer function method software in the ratio of the reflect wave to the incident wave.

Two tubes were used in the measurement. The small tube having 28 diameter is for acoustic measurement in the high frequency range (2000Hz to 6000 Hz), while the large tube with diameter 100 mm is for measurements in the low frequency range (150Hz to 1500 Hz). The results reported are the peak value of sound absorption coefficient at both (high and low) frequencies region.

**Figure 2** Impedance tubes

## 3.0 RESULTS AND DISCUSSION

### 3.1 Sound Absorption Coefficient

Figure 3 and 4 below show sound absorption coefficient (SAC) value for different thickness of dust and coir form samples at low frequency region. Sound absorption performance of 18mm thick dust and coir form POF samples were found increases as the tested frequency increased. Meanwhile, 12mm thick dust form sample shows somehow constant value of SAC throughout the tested frequency. However, all samples were started to show increments in SAC after reaching 850Hz and achieved their maximum SAC values at the higher frequency area.

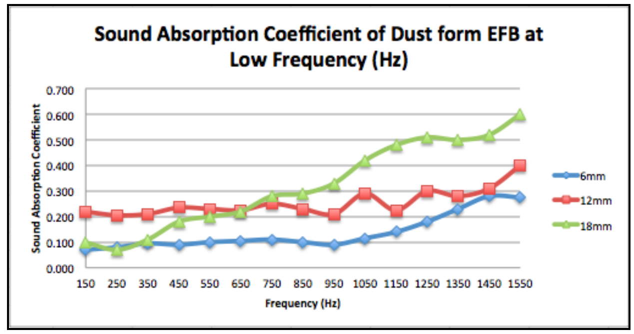



**Figure 3** Sound absorption coefficient of dust form EFB at low frequency region

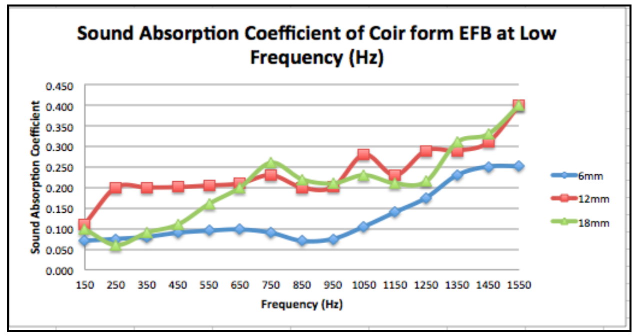



**Figure 4** Sound absorption coefficient of coir form EFB at low frequency region

As been shown in Figure 5 and 6, high absorption value showed by dust form POF samples at higher frequency region. The SAC values of dust form samples are better compared to coir form fibre at the same thickness. At high frequency region, 18mm thick dust form POF achieved 0.99 in SAC at 3250Hz compared to coir form fibre, which exhibits the maximum value of 0.62 in SAC at frequency in between 3500Hz to 5000Hz. All samples were found started to decrease in absorption after reaching 5000Hz. However, higher frequency range does not affect normal human hearing very much since humans are more sensitive to low frequency region sound and at frequency in between 3000Hz to 5000Hz at high frequency region.

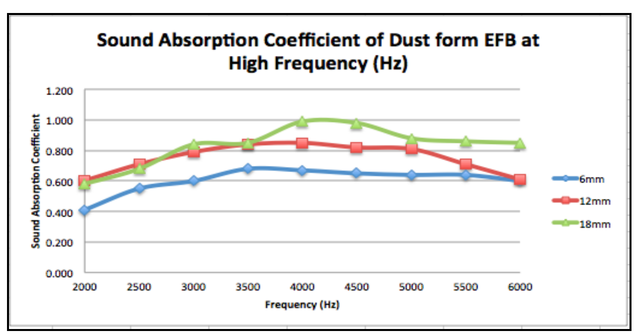



**Figure 5** Sound absorption coefficient of dust form EFB at high frequency region

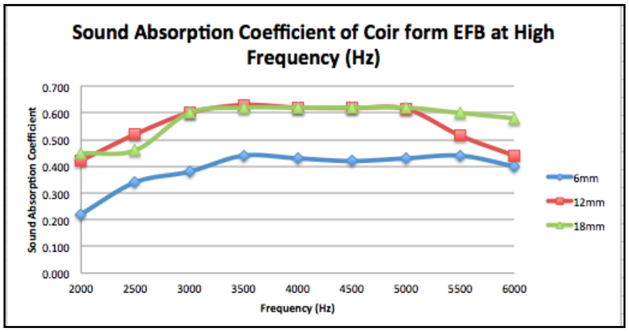



**Figure 6** Sound absorption coefficient of coir form EFB at high frequency region

Both dust and coir form POF samples having 18mm thickness had the highest SAC value throughout the tested frequencies. Maximum SAC obtained by 18mm dust form sample (SAC=0.6) at 1500Hz. Uniformity and increasingly high in absorption performance was shown by dust form samples at all thicknesses compared to coir form fibre samples which have been observed to be very poor in sound absorption in low frequency region. Coir form POF only exhibits maximum sound absorption coefficient of 0.4 at 1550Hz, which is at the same value achieved by 12mm thick dust and coir form fibre at the same frequency. Comparison between dust and coil form palm oil fibre performance at maximum thickness are shown in Figure 7 and 8 below.

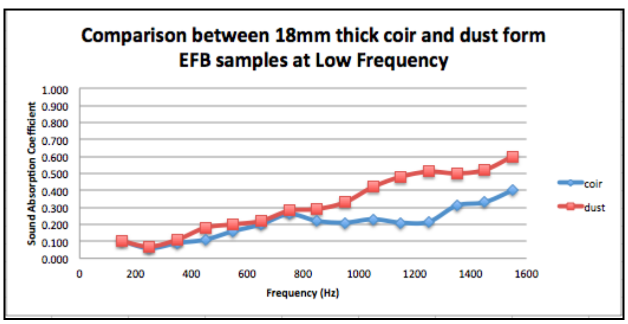



**Figure 7** Sound absorption coefficients of 18mm thick coir and dust form EFB at low frequency region

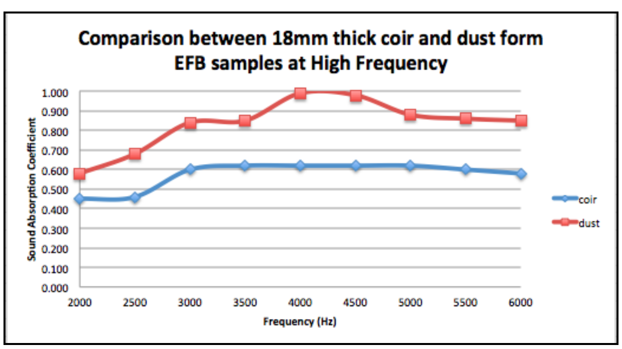



**Figure 8** Sound absorption coefficients of 18mm thick coir and dust form EFB at high frequency region

## 4.0 CONCLUSION

Accumulated EFB if not been recycled or manage properly could lead to environmental problem issues to this country. This study has proven that dust form EFB is a good sound absorbent at high and low frequencies region. Small particles in the thicker samples have created high-density sound absorption material compared to less thin and coir form samples. These shows that physical factors such as fibre sizes and shape significantly effect the pores content and material density and contributes to the sound absorption performance. However, further research is required to investigate the effect of others physical properties such as density and porosity on sound absorption performance of EFB. In conclusion, based on positive performance shown by EFB in this study, it is worth to introduce EFB as sound absorption material for noise control application in building. EFB is a fibrous material that contain large amount of lignocellulose, which makes this fibre is good in absorbing heat. Since heat dissipation in fibre elements lead to reduction of noise, this factor makes EFB as potential raw material for sound absorption replacing readily available synthetic materials in the market.

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