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The Effect of Different Fibre Length and Different Urea Formaldehyde (UF) content on Sound Absorption Performance of Empty Fruit Bunch (EFB)

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Abstract. Noise control is part of the major requirements to improve the living environment. One of the best methods to reduce noise is by employing sound absorber material into a space. Since traditional sound absorber in the market was believed could cause health problems to human, the need for alternative material is desired. This research intended to utilize waste materials from palm oil empty fruit bunch (EFB) in the production of natural sound absorber for noise control in building. Two parameters were investigated; the fibre length and binder content to determine their effect on sound absorption. Samples were tested using impedance tube using low and high frequencies according to ISO 10534-2:2001. Consequently, both parameters show that different fibre length and binder content affected the ability of the fibre to absorb sound. Results show that the optimum fibre size is in between 2mm to 5mm length while the optimum amount of binder is between 0% to 5% and 15% from fibre weight. This research has found that the highest Noise Reduction Coefficient (NRC) using 2mm to 5mm fibre size achieved 0.70 coefficients while the use of optimum amount of binder (particularly Urea Formaldehyde) could obtain 0.75 NRC. The newly develop panels are considered as a good sound absorbent and suitable to use as an alternative material replacing the synthetic absorber.

1 Introduction

Recently, noise has become one major source of human disturbance. Excessive noise also may deteriorate human physiologically and psychologically [1]. Many people has demanded the solution to this problem. Usually, using sound absorber materials are among the prominent way to solve this problem. However, traditional sound absorber that is extensively used in building compartment made up from synthetic materials including glass and rock wool. These materials are believed to emit carbon dioxide (CO_2), methane and nitrous oxide in their production [2]. Plus, this usage of materials also gives negative impact to human health and contributes to global warming issues [3].

Therefore, to counter this problem, many researchers have driven their interest by using alternative materials from natural fibre in purpose of replacing synthetic materials as sound absorber. Natural fibres are low in density, have good mechanical properties, easy to be processed, high in stability, health friendly, cheap and reduce the impact to environment during their productions [4]. Previous works have been done by employing natural fibre as sound absorber including sugarcane [5], coconut coir fibre [6], palm oil male flower spikes [7] and mesocarp fibre [8].

Mahzan et al. [9] produce rice-husk waste as reinforced composite and testing using two-microphone transfer function method. 5%, 10%, 15%, 20%, 25% and 30% of rice-husk added with polyurethane foam (PU). They found that most sample having high SAC value at 250Hz with highest SAC 0.899 for 25% rice-husk sample. Meanwhile, lowest SAC obtained by 15% rice-husk sample. By calculating the NRC value of the samples, 30% sample of the rice husk obtained the highest value. They conclude that the rice husk waste has a potential to become a sound absorber, especially at low frequency range.

Ismail et al. [10] utilized arenga pinnata as sound absorber at four distinct thickness, 10mm, 20mm, 30mm and 40mm. Based on the result, the thickness significantly influence the SAC value where thicker sample having high SAC at high frequency region with maximum SAC for 40mm sample thickness is 0.88. Arenga Pinnata fibre was then compared to coir fibre and palm oil fibre. The result indicate that SAC value of Arenga Pinnata was higher compared to coir fibre, around 0.7 to 0.9 but slightly lower than palm oil fibre.

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Another study by Putra et al. [5] aimed to utilize sugarcane waste as acoustic absorber with different percentages of fibre to binder. Up to 40% binder, absorption coefficient were not too affected. 3g of fibre with composition 70% of fibre with 30% of binder show good SAC among the other compositions. The SAC value gained over 0.5 at frequency 1000Hz to 4500Hz. This may be due to denser sample which has greater flow resistivity to create more paths for sound to be absorbed on the sample. By maintaining binder composition, with different amount of fibre 1g and 3g, shows an increasing amount of fibre to enhance the SAC value. Sample was then compared with three layer of woven cloth absorber. They found that, sugarcane sample were comparable with woven cloth absorber.

Research made by Samsudin et al. [11] differentiated the absorption performance between coir form and dust form of an empty fruit bunch (EFB) at three thickness 6mm, 12mm and 18mm. Thicker sample (18mm) for both dust and coir form fibre enhanced the SAC performances as the frequency increased. 18mm thick dust form sample had maximum SAC 0.9 at 3250Hz. While coir form 18mm sample gained maximum SAC lower than dust form, 0.62 at 3500Hz to 5000Hz. Dust form showed great performances of absorption compared to coir form caused by the small particle creating high-density sound absorption material and can easily turn sound energy to heat energy.

Therefore, this paper is discussing the potential of natural fibre waste in Malaysia to be an alternative as acoustic absorber which is the empty fruit bunch (EFB). Even this fibre have been discussed and studied by other researchers, but this research is focusing on the other parameters that are yet to be explored using this kind of natural fibre. The main parameters in this study are the fibre length and percentage of urea formaldehyde (UF) in the sample.

1.1 Empty Fruit Bunch (EFB)

Palm oil or known as *Elaeis guineensis Jacq*. was first planted int Selangor before it became a major plantations in Malaysia. Stated by Malaysian Palm Oil Board (MPOB), most of the states in Malaysia have palm oil plantation area as an agriculture by products with total planted area of 5,642,943 hectares. Subsequently, this oil production generates waste products including empty fruit bunches (EFB), palm kernal shells, mesocarp fruit fibers (MF) oil palm trunks (OPT), oil palm frond (OPF) and palm oil mill efflent (POME).

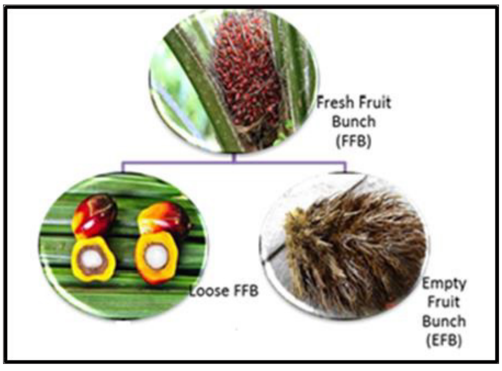

Fig. 1. Breakdown of EFB from FFB

EFB are the residue in solid form that are mostly produced from fresh fruit bunches [12]. Out of 100% of FFB, 22% of it is EFB which is the second largest product after sterilization and stripping process where 67% out of it is POME [13]. EFB that resulted from the extraction process of oil have the potential to be utilized as raw materials for new products in order to reduce the amount of disposal. Traditional way to dispose EFB are by turning it into fuel for production of steam in palm oil mills but faced environmental issues afterwards [14]. Figure 1 shows the breakdowns of EFB from the FFB.

2 Methodology

2.1 Pre-treatment Stage

EFB fibre supplied by Kulim Plantation, Ladang Tereh Mill located at Kluang Johor. First, fibre was shredded to get into loose form hair like materials. Fibre then soaked in water for 24 hours to remove unwanted dirt or particle retained on fibre. After 24 hours, fibre was soaked with 2% of Sodium Hydroxide (NaOH) solution for 30 minutes [15]. Finally, fibre was rinsed using clean water and sun dried 2 to 3 days depending on weather to reduce heating rate thus reduce carbon footprint. Controlled moisture content of 10% [16] was obtained by oven dry fibre for 30 minutes at 110°C.

2.2 Fabrication Stage

Dry fibres were weighted to require proportion. Urea Formaldehyde (UF) used as the binder obtained from S.A. Wood Chemicals Sdn Bhd was sprayed on the fibre using spray air gun to ensure fibres are evenly mixed. Then fibre is fitted into round shape mould, 100mm and 28mm diameter for Impedance Tube testing with 50mm thickness. Hot compression machine was used to compress the panel at 150°C for 20 minutes. Figure 2 shows the sample of sound absorber after taken out from the mould.

Fig. 2. 100mm and 28mm diameter sample

Two parameters were taken throughout these study, fibre length and UF content. For UF content parameter, 0%, 5%, 10%, 15% and 20% UF used with 0.4g/cm^3 target density. While for fibre length parameter, fibre was sieve to get the required length as presented in Table 1 with 65% solid content used in fabrication stage [17].

Table 1. Length of fibre

Number	Fibre Length
1	Retain sieve 15mm
2	Retain sieve 12mm
3	Retain sieve 5mm
4	Retain sieve 2mm
5	Below size 2mm

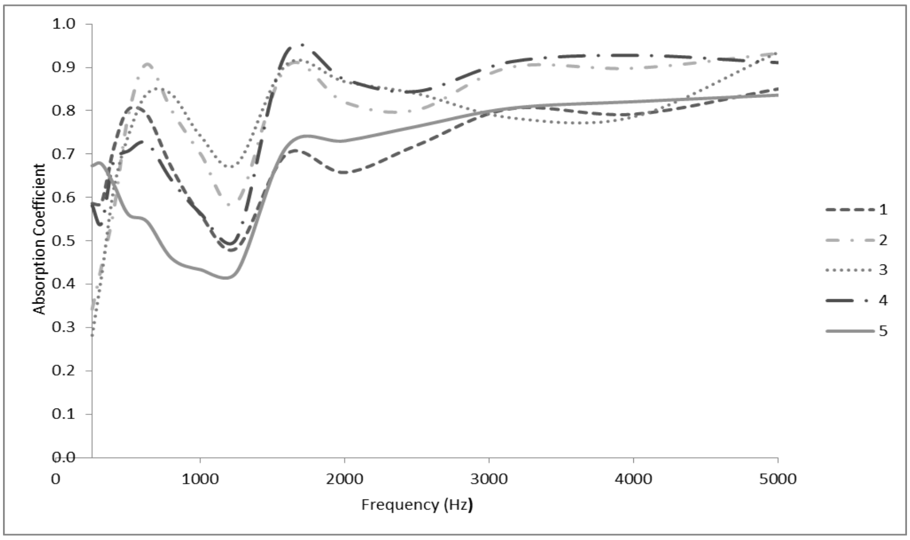

Fig. 4. The sound absorption coefficient with different fibre length

2.3 Sound Absorption Measurement

Sound absorption coefficient of the sample was measured using impedance tube according to ISO10534-2:2001, i.e. the transfer-function method [18]. Impedance tube able to measure absorption coefficient of materials using small sample size that was easy to assemble and disassemble [4]. Loudspeaker was placed at the one end of impedance tube and generates broadband, stationary random sound waves while sample placed at the other end. This study used Impedance Tube with AFD1001 software at Building Services Laboratory, Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia (UTHM). Figure 3 shows Impedance Tube set up.

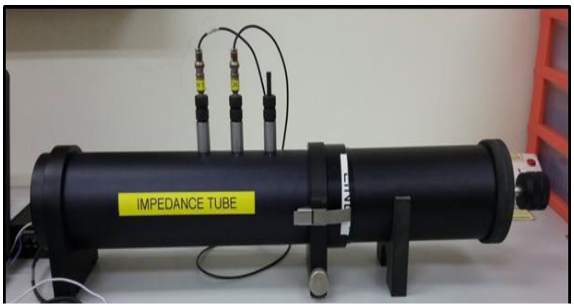

Fig. 3. Impedance Tube

3 Result and Discussion

The results of impedance tube measurement at high and low frequency from 250 Hz to 5000 Hz for empty fruit bunch (EFB) with two distinct parameter, fibre length and UF content are shown in Figure 4 and Figure 5.

Figure 4 shows the SAC result of five different lengths of fibre. Although there were inconsistencies in values all samples demonstrated a uniform pattern of absorption. It can be observed that the sound absorption coefficient increased between frequency 1600 Hz and 2000 Hz by shifting the peak from low frequency range to middle frequency range. Sample 2 showed superior performance of SAC at low range frequency while Sample 4 showed a good performance at high range frequency. Highest SAC recorded by Sample 4 with α = 0.937 at frequency 1600 Hz. Conversely, Sample 5 had least SAC compared to the other sample. Theoretically, these were due to the fibre content on the sample which contained dust form fibre and filled the empty space between the fibre and decreasing the porosity value of the sample that affected the SAC performances. It is found that the fibre length effects the acoustical performances of the material.

Table 2. Density and NRC value for fibre length parameter

Sample	Density (g/cm^3)	NRC
1	0.39	0.65
2	0.39	0.65
3	0.41	0.65
4	0.44	0.70
5	0.42	0.60

Table 2 tabulated different density and NRC performances for each sample for fibre length parameter. NRC is a term that describes the absorption properties of a materials, by averaging value of SAC of materials at frequencies of 250 Hz, 500 Hz, 1000 Hz and 2000 Hz and rounded off to the nearest multiple 0.05 [10]. Therefore, NRC value is a number between 0 to 1 which indicated no absorption for zero and full absorption for value one [19]. Generally, density affected the NRC value of sample. Denser structure gave better NRC value from mid to high frequency range but tends to decrease at the low frequency [8].

Urea Formaldehyde (UF) as the binder used in this study with different percentage, 0%, 5%, 10%, 15% and 20%. From Figure 5, the SAC value for all sample showed a uniform pattern. SAC performance is good above 500 Hz. Sample with highest UF content (15%) exhibited a higher SAC with α = 0.957. All samples had high absorption at the low frequency region, declined at the middle frequency region but then increased at the high frequency region. High content of UF (20%) showed the least absorption than other samples. Theoretically, high amount of binder will create less porosity on the sample and reduce the absorption performances of the materials. Jayamani et al. [20] claimed high porosity in sample will cause an increasing friction on the surface where resulted in the dissipation of the sound.

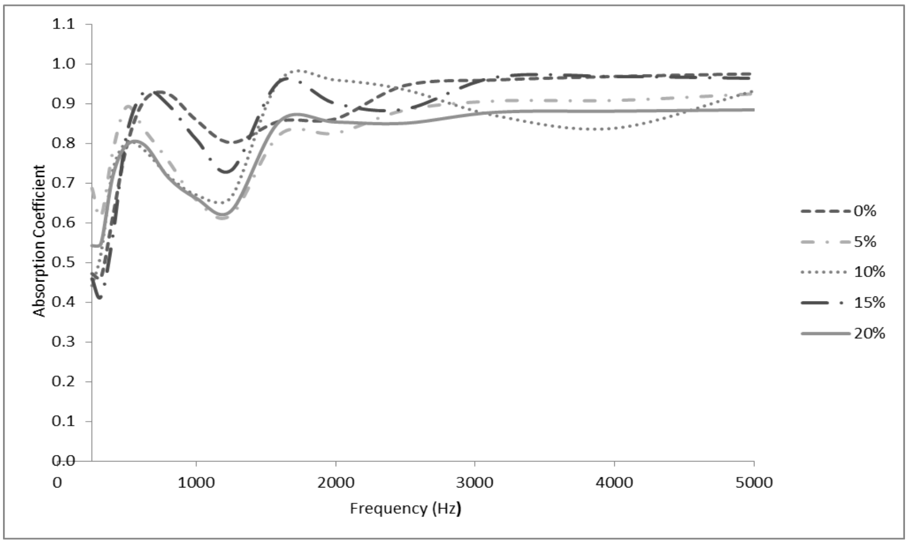

Fig. 5. The sound absorption coefficient with different percentage of UF

UF content parameter having a further analysis by calculating the noise reduction coefficient (NRC) and going through porosity testing.

Table 3. Density, Porosity and NRC value for different UF percentage

Sample	Density (g/cm^3)	Porosity (%)	NRC
0%	0.24	79.95	0.75
5%	0.29	79.69	0.75
10%	0.31	76.62	0.70
15%	0.32	71.30	0.75
20%	0.33	74.00	0.70

Table 3 summarizes the result of density, porosity and NRC value for all samples. All samples show about 70% of sound is absorbed. It is also indicated that as the percentage of UF increase, the density of samples also increase but significantly decrease the porosity value. According to Bratu et al. [21], high porosity value on sample results in good absorption of the sound wave.

4 Conclusion

Empty fruit bunch were studied as an acoustic absorber which have a potential to replace the common synthetic sound absorber materials such as glass wool, rock wool and asbestos. The results indicated that fibre length and binder content plays a role in the improvement of sound absorption performances. High amount of binder and too much small particles of fibre will create less porosity value, thus creating less SAC caused by the sound transmitted on it cannot be changed into heat energy. 15% of UF percentage as optimum binder with high absorption and resulting good sample without any depreciation on the sample. Therefore, for fibre length parameter, the optimum SAC of EFB is obtained when the fibre length is in between 2mm to 5mm.

Absorption properties of natural fibres can be increased by controlling the porosity value of newly developed panels. As a green technology product, these innovative absorption panels may have a bright future to replace available synthetic absorber in the markets. However, further research is required to investigate the properties of the natural sound absorber to ensure their safety and strengthness before becoming a commercial acoustic material.

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