Sound Properties Investigation of Date Palm Fiber

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Abstract. This research is carried out to determine the sound absorption coefficient (α) and noise reduction coefficient (NCR) of date palm fibre. The specimen made of date palm fibre has been compressed using certain weight to maintain desire thickness range from 10 mm to 50 mm. The specimen has been mixed with coconut fibre at a certain ratio. Experiment had been conducted using impedance tube to determine the sound absorption coefficient values follows ISO 10534-2:1998 standard procedure. Single value of coefficient had been calculated based on ASTM 423. Result showed that thicker specimen having higher value of α and NCR. Specimen with mixing ratio of 75% and 50 mm thickness have shown the highest NCR value of 0.6 compared other specimens. NCR comparison with domestic glass fiber used in the construction industries shows that this material has very good potential to be developed as one of the sound absorption component in related industry.

1. Introduction

Natural fiber composites are (mainly) price-driven commodity composites that provide useable structural properties at a relatively low cost. The use of natural fibers has many advantages such as, being derived from a renewable resource; they require low energy inputs in their manufacture. A major advantage is that they can be easily disposed of at the end of their life cycle by composting or by recovery of their calorific value in a furnace, which is not possible with glass fibers. It is also good in mechanical properties, non-abrasive, lightweight, and eco-friendly materials to be used in industries [1]. Currently, natural fibers as reinforcements in technical applications are mainly used in the automobile, and packaging industries in parts where a high load carrying capacity is not required. Natural fibers such as date palm are considered the most cultivated palms around the world. They have a fibrous structure which is one of the most important properties of natural materials to be used for sound absorption purposes [2].

Along with technology development, noise has become a seriously environmental problem. Noise can cause general types negative effects i.e; hearing loss, no auditory health effect, individual behavior, effect on sleep, communication interference and effect on domestic animals and wildlife. There are several methods to decrease noise, one of which uses sound absorption materials. Currently, sound absorption materials commercially available for acoustic treatment consisted of glass or mineral-fiber material. Long term exposure can cause harm to human health mainly lungs and eyes.
These issues explore an opportunity to look for alternative materials from organic fibers to be developed as noise absorption material.

Most practical sound absorbing products used in the building construction industry consist of glass or mineral-fiber materials. However, the growing concern about the potential health risks as being associated with glass or mineral-fiber materials provides an opportunity to develop sound absorption panels made of natural fibers. Very thin fibers (i.e., <0.1, um diameter) can cause mesothelioma, while thicker glass fibers can cause fibrosis and lung cancer. Besides that, a study on the natural fibers has proved that natural fibers were characterized with lower environment impact [4].

The advantages of date palm fiber are renewable, cheap, completely or partially recyclable and biodegradable. Many researches have been conducted in developing particle composite boards using agricultural wastes. Mixture the date palm fibers in making of parts and components in the automobile industry can be a good phenomenon as the date palm fibers have good endurance limit, hence improve the fatigue life of the components [5]. K.Almi et. al [6] concluded that date palm fiber is a good material for realization of natural fiber composite with several applications: building materials, automobiles and furniture industries. Some other research reported that the date palm fibers has good characteristics to be the main materials in building construction [7]. This research will provide opportunity to show diversity of using natural fiber in order to replace the present materials.

2. Methodology

2.1. Specimen preparation

Figure 1 shows the overall process flow for this research. The main material that has been used for this experiment is date palm fiber. This kind of natural fiber has been chosen because there is limited reference of finding α and NRC of this fibre. Although date palm not a common plant in this country, but in other country, such as Mediterranean, Middle Eastern and other tropical to subtropical areas, date palm has been commercialized. Apart of that, some of specimen has been mixed with coconut coir. Coconut coir has been used widely in sound absorption experiment as a material [8].

Figure 2 shows the step of specimen preparation that has been conducted in this research. The raw fiber was extracted from natural mat surrounding the stern. The specimens were preparing in two diameters, i.e., 20 mm and 100 mm in order to cater high and low frequency experiment. Apart of that, the fibre was mixed with the coconut coir in the ratio of 25 %, 50 % and 75 % of the overall weight. The thick and thin fibres need to be extracted before can be used as the specimens as shown in Figure 3. First, the fiber need to be weighted before it can be placed into the mold as shown in Figure 4 (a). The fiber was compacted with 30 kg of ballast for 6 hours in the specific mold made of Teflon as shown in Figure 4 (b) and (c) to make sure specimen retained the round shape. The finished specimens will be tight using yarn to maintain the thickness as shown in Figure 5 (a). The specimens of various thickness and mixing ratio was fabricated at Acoustic Lab, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia (Figure 5 (b)). It is worth to mention that the specimen and preparation is followed the ISO 10534-2:1998.

2.2. Experimental procedure

The experiment for measuring the sound absorption coefficient, α has been carried out at Acoustic Lab, Faculty of Engineering, Universiti Islam Antarabangsa (UIA). This experiment has been conducted using impedance tube to measure sound absorption coefficient losses as shown in Figure 3. The tube was then link to PC with dBRTA software, PC card, symphony tool and signal generator to perform sound absorption coefficient testing.
Fig. 1. Overall process flow for this study

- Raw date palm fiber
- Specimen preparation using compact weight
- Specimen at different thickness (10 mm, 30 mm, 50 mm)
- Specimen at different mixing ratio (25%, 50%, 75%)
- Testing using impedance tube at low and high frequency
- Result (value of α)
- Analysis (value of NRC)

Fig. 2. Specimen preparation

- Separating the good fiber
- Weighing process
- Compaction process using 30 kg loads
- Tighten process using yarn
- Specimen completed
2.3. Noise Reduction Coefficient (NRC)

The noise reduction coefficient is a scalar representation of the amount sound energy absorbed upon striking the surface. The American standard ASTM 423 (Standard Test Method for Sound Absorption and Sound Absorption Coefficient) provides similar test criteria to EN ISO 354 also provides method to calculate single parameter called Noise Reduction Coefficient (NRC). The arithmetic average of the absorption coefficients determined at the octave band of 250 Hz, 500 Hz, 1000 Hz and 2000 Hz. Equation 1 shows the formula to calculate NRC.

\[ NRC = \frac{\alpha_{250\text{Hz}} + \alpha_{500\text{Hz}} + \alpha_{1000\text{Hz}} + \alpha_{2000\text{Hz}}}{4} \]  

3. Result and discussion

Value of sound absorption coefficient, \( \alpha \) will be presented at different mixing ratio and thickness. The NRC will be then calculated at octave band and compared to other natural fiber.

3.1. Sound absorption coefficient value, \( \alpha \) at different thickness and mixing ratio.

There are four mixing ratios of the specimen i.e. 100%, 75%, 50% and 25%. The specimens are fabricated at three different thickness i.e. 10mm, 30mm and 50mm. Figure 4 (a) to (d) show the value of \( \alpha \) for the mixing ratio of 100% to 25%, respectively at different thickness. All graphs show that value of \( \alpha \) are increasing with increment of the thickness. This result coincides with Yang et. al [9] that state the same phenomenon, if particle velocity is maximum at quarter of frequency length from the subtract. Thick material will increase the viscosity rate of the air. Thus, sound cannot go through the specimen. For Figure 4 (b), (c) and (d), there are pattern changes of the lines at 1600 Hz of frequency. It is because the mixing material between the date palm fiber and coconut coir. The mixing of fiber caused the porosity change of the specimen. Porosity change will affect the coefficient value of the specimen as mentioned by a group of researchers in 2011 [10].

3.2. Noise Reduction Coefficient

The NRC is often used as a synthetic indicator to represent the sound energy absorbed by a material. The values of the NRC are useful to compare the different sound absorbing materials characteristics. Table 1 shows the value of \( \alpha \) for different thickness at different mixing ratio. These values were then calculated to determine the NCR value using Equation 1 and tabulated in Table 2. The highest NRC shows at 75% mixing ratio with 50 mm thickness.
Fig. 4. Value of $\alpha$ at different thickness for various mixing ratio (a) 100%, (b) 75%, (c) 50%, (d) 25%

Table 1 Value of $\alpha$ at different thickness for different mixing ratio

| Mixing ratio (%) | Frequency (Hz) | Sound Absorption Coefficient, $\alpha$ |
|------------------|----------------|---------------------------------------|
|                  |                | Thickness (mm)                        |
|                  |                | 10          | 30          | 50          |
| 100              | 250            | 0.043       | 0.0885      | 0.1395      |
|                  | 500            | 0.101       | 0.367       | 0.4595      |
|                  | 1000           | 0.119       | 0.676       | 0.756       |
|                  | 2000           | 0.393       | 0.8225      | 0.784       |
| 75               | 250            | 0.0425      | 0.0905      | 0.196       |
|                  | 500            | 0.0935      | 0.2615      | 0.5505      |
|                  | 1000           | 0.182       | 0.635       | 0.8645      |
|                  | 2000           | 0.7645      | 0.792       | 0.8395      |
| 50               | 250            | 0.046       | 0.0955      | 0.1875      |
|                  | 500            | 0.09        | 0.2745      | 0.4505      |
|                  | 1000           | 0.1985      | 0.558       | 0.7715      |
|                  | 2000           | 0.752       | 0.677       | 0.7465      |
| 25               | 250            | 0.0415      | 0.0785      | 0.1545      |
|                  | 500            | 0.091       | 0.2645      | 0.415       |
|                  | 1000           | 0.208       | 0.658       | 0.699       |
|                  | 2000           | 0.7845      | 0.794       | 0.6845      |
Table 2: Value of NRC at different thickness for different mixing ratio

| Thickness | Mixing ratio (%) |
|-----------|------------------|
|           | 100              | 75   | 50   | 25   |
| 10 mm     | 0.2              | 0.3  | 0.30 | 0.30 |
| 30 mm     | 0.5              | 0.40 | 0.40 | 0.45 |
| 50 mm     | 0.55             | 0.60 | 0.50 | 0.50 |

The value of $\alpha$ and NCR determined by the date palm fiber was compared to the domestic fiber glass that has been using in the construction industries. Usually the absorption properties are taken at frequency of 4000 Hz and 30 mm thickness. From Table 3, it can be concluded that the natural date palm fiber has a very good sound parameter to be used as an absorption material in building.

Table 3: Value of $\alpha$ and NCR of date palm fiber and fiber glass

| Type of fiber | Value of $\alpha$ | NRC  |
|---------------|------------------|------|
| Date palm fiber | 0.95             | 0.89 |
| Fiber glass   | 0.92             | 0.70 |

4. Conclusion

Result shows that thickness had given effect to value of sound absorption coefficient, $\alpha$. Trend shows values of $\alpha$ increase when specimen thickness increased. Sample with thickness 10 mm shows lower values of $\alpha$ compared to specimen with thickness 30 mm and 50 mm. The result proved that thickness increased value of sound absorption coefficient. However, the effect of mixing ratio was given no major difference between the results. Specimen with thickness 50 mm and mixing ratio of 75 % date palm fiber and 25 % coconut fiber shows 0.6 of NCR value which is highest among other specimens. Also comparison of the sound parameter to the domestic fiber glass used in the industries showed that the date palm fiber is very potential to be explored as the sound absorption materials.

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