Effect of physical properties of natural fibre on the sound absorption coefficient

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The aim of the study was to analyse the effect of physical properties of natural fibre to the sound absorption coefficient. It was also aimed to study the relation of the physical properties of natural fibre to wider the frequency range and increase the sound absorption coefficient. There were two types of natural fibre will be studied such as kenaf fibre and rice straw fibre. The performance of sound absorption coefficient was measured using fabricated impedance tube according to ISO 10534-2. The physical properties of the natural fibre may affect the sound absorption coefficient either shifted to low frequency or shifted to high frequency range. All the physical properties that influence the sound absorption coefficient of natural fibre will be explained. The physical properties of natural fibre that will be studied were fibre thickness, fibre diameter and compressed fibre. Results have shown that the fibre thickness and diameter have a big effect to sound absorption coefficient. From the results, the utilization of the sound absorption coefficient can be achieved by choosing the suitable natural fibre according to its physical properties for a suitable application.

1. Introduction.

Agriculture sector now days have growth rapidly due the development of technologies that help the agriculture process. It has contributed a lot of number to the growth of Malaysia’s economy. As the number of agriculture products increase, the agriculture by-products will also increase. Thus, the agriculture by-products need to be managed properly to avoid opened burning. Opened burning may worsen the effect of global warning due to the release of carbon dioxide and heat to the environment [1-2]. Therefore, to help reduce the effect of global warming was by transforming the agriculture by-products into sound absorbent material.

Apparently, there were lot of sound absorbent materials made from synthetic fibre [3]. Prolong exposure to synthetic fibre may harm human health [4-5]. Introducing the natural fibre as sound absorbent material may reduce the sound intensity level and not harm human hearing. Thus, absorbent material from agriculture by-products will also benefit human health. Agriculture by-products were also known as natural fibre. The natural fibre is obtained from the stem, leaf, fruit and pulp of the plant. Besides that, natural fibre has been applied in many industries such as automotive, building,
factories and others. Natural fibre can be found in abundance in Malaysia. It was also cheap, renewable and bio-degradable [6-7]. Nevertheless, it also has its disadvantages such as weak in strength of mechanical properties, flammable, lead to fungi growth due to humidity [4].

Natural fibre was considered as promising sound absorbent materials [2,8]. Many researchers conducted the researches on the natural fibre for sound absorption purpose. Rice straw fibre was considered as a good sound absorbent material in frequency range of 2000Hz and above [1]. There was also study on composite of rice straw fibre for sound absorption purpose [9]. The result was also considered good. Moreover, tea waste fibre from tea industry was also tested for its sound absorption [5]. The result was great for the frequency range 1500-6300Hz of sound absorption coefficient with 0.5. Besides that, fibre from oil palm fruit has shown an average result of sound absorption coefficient of 0.75 for frequency 2500Hz and above [10].

In this study, two types of natural fibre will be studied for their physical properties that influence their sound absorption coefficient. The frequency range to be considered is 60-1800Hz. The sound absorption performance will be measured and analysed. There was abundance of natural fibre waste from agriculture waste every year. This small effort was an alternative to make use of the agriculture waste in order to reduce the global warming effect. Moreover, natural fibre might be promoted for the sound absorbent materials in future time.

2. Methodology

In this study, two types of natural fibre will be used; which were kenaf fibre and rice straw fibre. The sound absorption coefficient measurement was conducted using impedance tube. The fabrication of impedance tube was according to ISO standard 10534-2 Transfer Function Method. The impedance tube was considered as one direction flow of sound wave for the frequency range of 60-1800Hz. Below and beyond the frequency range was not valid. The value of sound absorption coefficient was range from 0 to 1. The value 0 was assumed no sound energy wave was absorbed and vice versa. Figure 1 is the setup of sound absorption coefficient measurement.

![Figure 1. Setup for the sound absorption measurement setup.](image1)

![Figure 2. The flow sound absorption coefficient measurement.](image2)

Basically the measurement setup consists of laptop, sound source, microphones, microphone calibrator and DAQ system. The equipments were connected to each other before starting the measurement. Firstly, the microphones sensitivity were calibrated. Secondly, the microphones were tested its phase equalisation using switching method. It was important to equalize the phase of both microphones. Lastly, the setup was ready for measurement after 10 minute sound source was on. Figure 2 is the flow of sound absorption coefficient measurement setup.
The kenaf fibre and rice straw fibre were common fibre in Malaysia, in which both natural fibre can be found in abundance. Figure 3 and Figure 4 show the natural fibre in loose form and compressed form. The natural fibre was shaped of circular in order to be inserted into the impedance tube for sound absorption coefficient measurement. The fibre in loose form were inserted into the mould and compressed with an average force of 45kg/cm² using Universal Testing Machine (UTM) which shown in Figure 5 [11]. The experiment was conducted using impedance tube. The impedance tube was used for small scale of sample size, up to the maximum diameter of 10cm sample size.

![Figure 3. Rice straw fibre; (a) rice straw fibre in loose form (b) rice straw fibre in compressed form](image)

![Figure 4. Kenaf fibre; (a) kenaf fibre in loose form (b) kenaf fibre in compressed form.](image)

![Figure 5. (a) Shimazu Universal Testing Machine, (b) mould used for the sample preparation.](image)

3. Results And Discussions
There were three physical properties will be discussed in this study. There were fibre thickness, fibre diameter and compressed fibre. All the factors have a great influence on the sound absorption coefficient performance. Both kenaf fibre and rice straw fibre were able to absorb sound energy but with different capability.

3.1 Fibre Thickness
Figure 6 and Figure 7 show the results of sound absorption coefficient for 40mm and 60mm thickness of natural fibre respectively. For 40mm thickness, both natural fibres have different sound absorption performance according to their physical. The maximum sound absorption coefficient for kenaf fibre and rice straw fibre were 0.59 and 0.38 respectively. As referred in Figure 6, the average sound absorption coefficient of kenaf fibre was 0.56 for the frequency more than 1122Hz and rice straw has a maximum sound absorption coefficient of 0.5 at frequency 1778Hz.

Based on Figure 6 and Figure 7, it indicated that, as the thickness of fibre increases, the sound absorption coefficient also affected [11-12]. The sound absorption shows an increment and shifted to the left hand side of the low frequency range [13]. This observation shows that, there was an enhancement of sound absorption coefficient at low frequency. Even though, it was only shows a small increment but it has a positive motivation for future study. In additional, as the thickness of fibre increases, the fibre will have more porous structure and more sound energy wave produced by the sound source in the impedance tube will be absorbed by the sample. It can be seen in Figure 6, the difference of size and number of pore between kenaf fibre and rice straw fibre. It was the reason for the increasing of the sound absorption coefficient for both fibres although both have the same thickness. Compared to kenaf fibre and rice straw fibre, it was shown that kenaf fibre has a better sound absorption coefficient performance. Both fibres have a different diameter of fibre size. This physical factor has a significant effect on sound absorption coefficient performance.

![Graph of Sound Absorption Coefficient](image)

**Figure 6.** Sound absorption coefficient of 40mm thickness of kenaf fibre and rice straw fibre respectively.

### 3.2 Fibre Diameter

The effect of fibre diameter will be discussed in this section. Previous researcher has found that, diameter of fibre has a significant effect to the sound absorption coefficient performance. Both kenaf fibre and rice straw fibre has a significant different of diameter size. According to Figure 6 and Figure 7, it can be observed that, fibre with small diameter has an increase on sound absorption coefficient. As shown in Figure 8, it can be seen that kenaf fibre diameter is smaller than rice straw fibre diameter. In this study, kenaf fibre has an increase of sound absorption coefficient at low frequency compared to rice straw. Both have an increment towards low frequency as the thickness of fibre increase.

As the diameter of fibre was decreased, the number of porous structure will also increase when the thickness of fibre increase. Thus, compared to kenaf fibre and rice straw fibre, kenaf fibre will have more porous structure. When the porous structure increase the frictional between the sound source and natural fibre will increase. This will decrease the sound wave energy and been absorbed by the natural fibre. Moreover, reduction of fibre diameter will required more fibre for the equality of the fibre thickness between kenaf fibre and rice straw fibre. Both have the same thickness, but in term of volume fibre, kenaf has more volume of fibre. Thus, it created more porous structure for kenaf fibre sample.
Figure 7. Sound absorption coefficient of 60mm thickness of kenaf fibre and rice straw fibre respectively.

Figure 8. Pores that resulted from the increases of fibre thickness of (a) kenaf and (b) rice straw fibre from normal vision.

3.3 Compressed Fibre
The impedance tube was in circular shape. Thus, natural fibre samples were needed to be shaped into circular form in order to be fitted into the impedance tube for measurement. In order to shape the natural fibre, it was compressed using the mould and UTM machine in Figure 5. As it been shape according to the size of the impedance tube, it will be fitted nicely into the impedance tube. The compression of the natural has a significant effect to sound absorption coefficient [7,14]. As the thickness fibre increase will provide more porous structure to the natural fibre sample. But at the same, as the force exerted onto the natural fibre during the shape process of the natural, the porous structure will become smaller and packed. This has contributed to the increase of frictional force and increase the sound absorption coefficient.

4. Conclusion
In this study, there were two types of natural fibre; kenaf fibre and rice straw fibre were investigated. The sound absorption coefficient of two types natural fibres were determined and measured successfully using impedance tube for the frequency range of 60-1800Hz. As a conclusion, both natural fibres were able to absorb sound wave energy effectively. It can be concluded that the fibre mass and diameter have a big effect to sound absorption coefficient. Based on the results, the utilization of the sound absorption coefficient can be achieved by choosing the suitable natural fibre according to its physical properties and other features for a suitable application. In future work, the natural fibres will be hybrid with Micro-perforated panel (MPP) to enhance its sound absorption
performance for the low frequency range. In commercial practice, the natural fibres need to be added some additives to improve its characteristics and shape.

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6. References
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