



## RESEARCH FINDING IN NATURAL FIBERS SOUND ABSORBING MATERIAL

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### ABSTRACT

In simple terms, noise is unwanted sound. Sound is a form of energy which is emitted by a vibrating body and on reaching the ear causes the sensation of hearing through nerves. Sounds produced by all vibrating bodies are not audible. The frequency limits of audibility are from 20 HZ to 20,000 HZ. Excessive levels of sound can cause permanent hearing loss while continuous exposure could be physiologically and psychologically deleterious to one's well-being. Nowadays much importance is given to the acoustical environment. Noise control and its principles play an important role in creating an acoustically pleasing environment. This can be achieved when the intensity of sound is brought down to a level that is not harmful to human ears. Achieving a pleasing environment can be obtained by using various techniques that employ different materials. One such technique is by absorbing the sound. This paper review and describes how the physical prosperities of materials like fiber size, material thickness, density, porosity and tortuosity can change the absorption behavior. The sound absorption of different natural fibers was experimentally tested. The results show the relationship between natural fibers like kenaf, bamboo, paddy and the sound absorption, material density, thickness and air gap. Higher airflow resistance always gives better sound absorption values but for airflow resistance higher than 1000 the sound absorption have less values because difficulty movements of sound wave through the materials. More fibers can create more tortuous path (increase tortuosity) and can also increase the flow resistivity. However, by further increasing the density (adding more fibers), close pores could be formed and thus greatly increase the flow resistivity and eventually reduce the absorption capability.

**Keywords:** natural fibers, sound absorption coefficient, fiber size, material thickness, density and porosity.

### INTRODUCTION

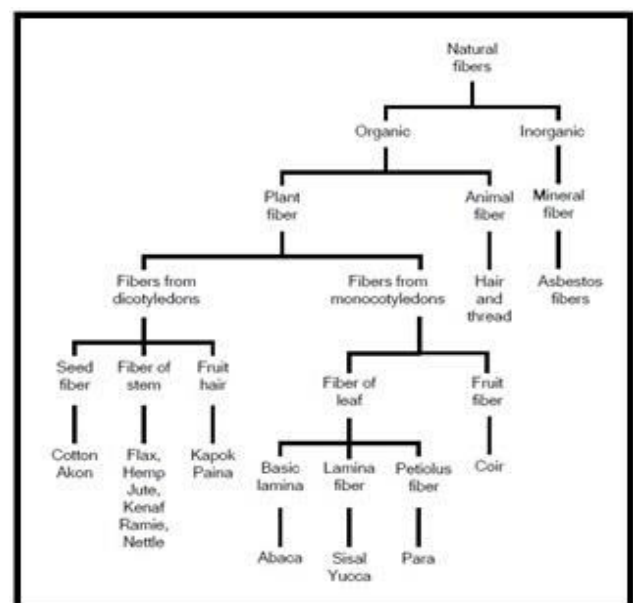
#### Introduction of natural fibers

The interest in natural fibers is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, non-abrasive, cheaper and safety concern during handling and processing [1]. Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibers used for the sound absorbing. The products such as foam, rock wool, and glass wool made from minerals are known for their toxicity and polluting effects which are harmful to human health as well as to the environment. It has been presented that their production can release more carbon dioxide into the atmosphere compared to those made from natural materials [2]. The natural fibers are more environmentally friendly, and are used in transportation such as automobiles, railway coaches and aerospace. It is also used in military applications, building and construction industries such as ceiling panelling, partition and boards.

#### Classification of natural fibers

Natural fibers in general can be classified based on their origin, and the plant-based fibers can be further categorized based on part of the plant they are recovered from. Fibers are a class of hair-like material that are continuous filaments or are in discrete elongated pieces, similar to pieces of thread. They can be spun into

filaments, thread, or rope. They can be used as a component of composites materials. They can also be matted into sheets to make products such as paper or felt. A general classification for natural fibers is provided in Figure-1 [3].



**Figure-1.** Classification for natural fibers.



### Advantages of natural fibers

- Resulting in a higher specific strength and stiffness than glass fibers, light weight.
- CO<sub>2</sub> is used while oxygen is given back to the environment, renewable source, little energy are requires to make a production.
- Producibile with low cost, which makes the material an interesting product for low wage countries.
- Thermal recycling is possible while glass causes problem in combustion furnaces.
- Good thermal and acoustic insulating properties.
- Reduced wear of tooling, healthier working condition, and no skin irritation.

## LITERATURE SURVEY

### Introduction

Acoustical material plays a number of roles that are important in acoustic engineering such as the control of room acoustics, industrial noise control, studio acoustics and automotive acoustics. Sound absorptive materials are generally used to counteract the undesirable effects of sound reflection by hard, rigid and interior surfaces and thus help to reduce the reverberant noise levels [4]. They are used as interior lining for apartments, automotive, aircrafts, ducts, enclosures for noise equipment and insulations for appliances [5].

Researches to find alternative materials to be utilized in the making of acoustical panel especially in the reduction of noise level have been extensively conducted. The common acoustical panels are made from synthetic fibers such as glass fiber and known to be hazardous to our health as well as to the environment. Fabrication of products from the material is also quite expensive and costly. Due to that, more attention has been given to natural fibers as alternative materials in order to produce products with a combination of high acoustic and thermal properties but with less impact to the environment and human health. Natural fibers are chosen to be alternative materials because they have very low toxicity which is good to protect the environment [6].

### Factors that affect the absorption of sound fibers size

Koizumi *et al* [7] reported an increase in sound absorption coefficient with a decrease in fiber diameter. This is because, thin fibers can move more easily than thick fibers on sound waves. Moreover, with fine denier fibers more fibers are required to reach equal more fibers for same volume density which results in a more tortuous path and higher airflow resistance [8]. A study by Youn Eung Lee *et al* [9] concluded that the fine fiber content increases sound absorption coefficient values due to an increase in airflow resistance by means of friction of viscosity through the vibration of the air.

### Thickness

Numerous studies that dealt with sound absorption in porous materials have concluded that low frequency sound absorption has direct relationship with thickness. The rule of thumb rule that has been followed is the effective sound absorption of a porous absorber is achieved when the material thickness is about one tenth of the wavelength of the incident sound [10]. Peak absorption occurs at a resonant frequency of one-quarter wavelength of the incident sound (ignoring compliance effect) [11]. A study by Ibrahim *et al* [12]. showed the increase of sound absorption only at low frequencies, as the material gets thicker. However, at higher frequencies thickness has insignificant effect on sound absorption.

### Density

Density of a material is often considered to be the important factor that governs the sound absorption behavior of the material. At the same time, cost of an acoustical material is directly related to its density. A study by Koizumi *et al* [7] showed the increase of sound absorption value in the middle and higher frequency as the density of the sample increased. The number of fibers increases per unit area when the apparent density is large. Energy loss increases as the surface friction increases, thus the sound absorption coefficient increases. Moreover, they showed the following effect of density on sound absorption behavior of nonwoven fibrous materials.

- Less dense and more open structure absorbs sound of low frequencies (500Hz).
- Denser structure performs better for frequencies above than 2000 Hz.

### Porosity

Number, size and type of pores are the important factors that one should consider while studying sound absorption mechanism in porous materials. To allow sound dissipation by friction, the sound wave has to enter the porous material. This means, there should be enough pores on the surface of the material for the sound to pass through and get dampened. The porosity of a porous material is defined as the ratio of the volume of the voids in the material to its total volume [13]. Refer to the equations in the text as Eqn. (1) for porosity (H).

$$\text{Porosity (H)} = \frac{V_a}{V_m} \quad (1)$$

where:

$V_a$  = Volume of the air in the voids

$V_m$  = Total volume of the sample of the acoustical material being tested

Shoshani *et al* [14], stated that, in designing a nonwoven web to have a high sound absorption coefficient, porosity should increase along the propagation of the sound wave.

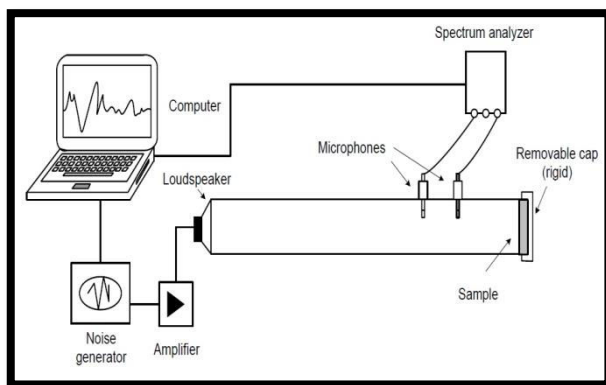


### Tortuosity

Tortuosity is a measure of the elongation of the passage way through the pores, compared to the thickness of the sample. According to Knapen *et al* [5], tortuosity describes the influence of the internal structure of a material on its acoustical properties. Con Wassilieff *et al* [15] describes tortuosity as a measure of how far the pores deviate from the normal, or meander about the material. Horoshenkov *et al* [16], stated that, tortuosity mainly affects the location of the quarter-wavelength peaks, whereas porosity and flow resistivity affect the height and width of the peaks. It has also been said by the value of tortuosity determines the high frequency behavior of sound absorbing porous materials.

### MEASUREMENT OF SOUND ABSORPTION

To determine the acoustical property, the measurement of sound absorption coefficient was conducted using the impedance tube method according to ISO 10534-2:2001 [17]. The sound absorption coefficient is measured using the two-microphone method where a sample of the material to be tested is placed in a sample holder and mounted to one end of a straight tube. A rigid plunger with an adjustable depth is placed behind the sample to provide a reflecting surface. A sound source, typically a high-output acoustic driver, is connected at the opposite end of the tube. A pair of microphones is mounted flush with the inner wall of the tube near the sample end of the tube. The sound absorption coefficient is measured according to ASTM E1050. Figure-2 shows the measurement setup for the test.



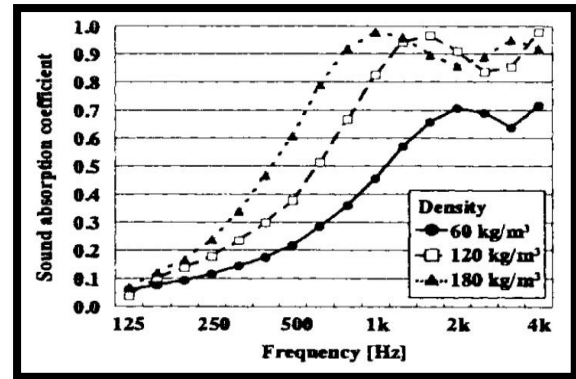
**Figure-2.** Measurement setup for the sound absorption test.

### TESTING, RESULT & DISCUSSION ON BAMBOO, KENAF AND PADDY WASTED FIBERS

#### Fibers effects on density

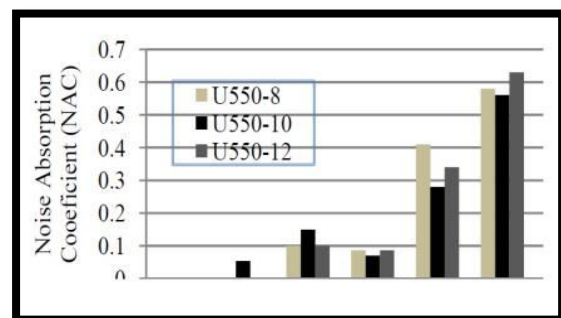
Figure-3 plots the sound absorption coefficient for the bamboo fibers material with apparent densities of 60 kg/m<sup>3</sup>, 120 kg/m<sup>3</sup>, and 180 kg/m<sup>3</sup>. It was confirmed that the sound absorption coefficient increases in the middle and high frequency range as the density of the sample

becomes higher. The number of the bamboo fibers increases per the unit area when the apparent density is large. When the energy loss increases as the surface friction increases, the sound absorption coefficient becomes high.

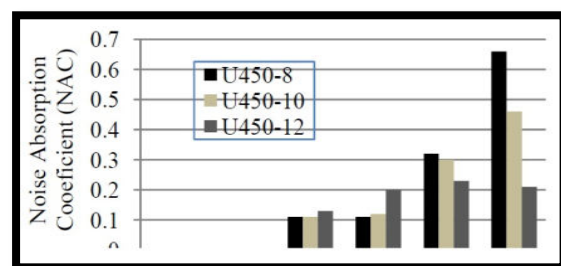


**Figure-3.** Sound absorption coefficient for 60 kg/m<sup>3</sup>, 120 kg/m<sup>3</sup>, and 180 kg/m<sup>3</sup> density bamboo fiber backed by a rigid wall.

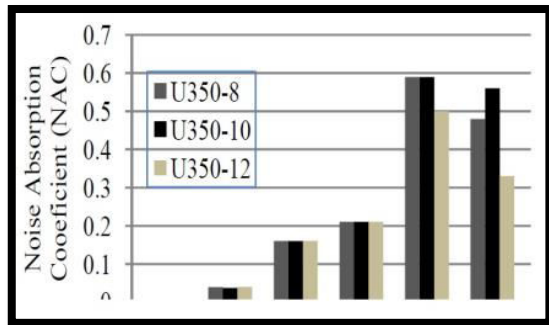
Figure-4, 5, 6 plots the sound absorption coefficient for the kenaf fibers material with different densities of 550 kg/m<sup>3</sup>, 450 kg/m<sup>3</sup> and 350 kg/m<sup>3</sup>. It was found in the low, medium or even in the high noise frequencies, board at the 350 kg/m<sup>3</sup> density absorbed more noise might be due to its better porosity behaviour which able to reduce noise interference.



**Figure-4.** The Sound absorption coefficient versus frequency of kenaf core particleboard at density of 550 kg/m<sup>3</sup>.

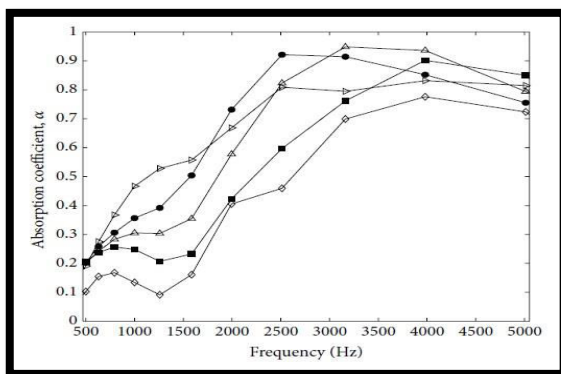


**Figure-5.** The Sound absorption coefficient versus frequency of kenaf core particleboard at density of 450 kg/m<sup>3</sup>.



**Figure-6.** The Sound absorption coefficient versus frequency of kenaf core particleboard at density of 350 kg/m<sup>3</sup> UF loading.

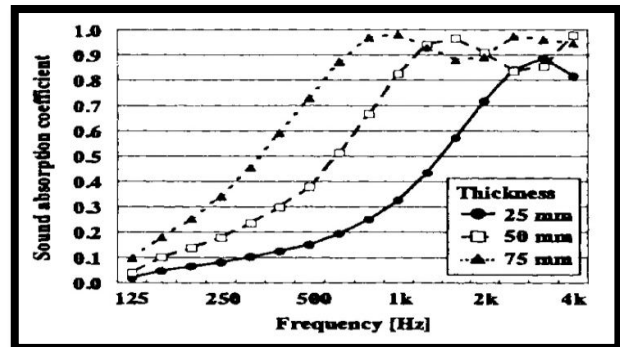
The effect of density on paddy wasted fibers is plotted in Figure-7. This is done by increasing the fiber weight for a 20mm thick sample up to 6 grams. As seen in Figure-7, the sample with 6-gram fiber weight has lower absorption coefficient than that from the sample with 3-gram fibers. This is consistent with the finding fibers were also used to develop a fiber board of a resonant-type absorber and are found to have better acoustic performance compared to plywood. The fabrication process can also have effect on the pores formation inside the sample.



**Figure-7.** Measured absorption coefficient of 20mm thick samples with different fiber weights: —□— 2 grams, —△— 3 grams, —○— 4 grams, —●— 5 grams and —■— 6 grams.

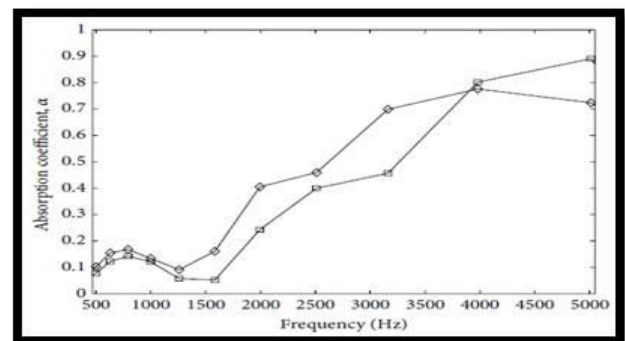
#### Fibers effects on thickness

The sound absorption coefficient for 25 mm, 50 mm, and 75 mm thick bamboo fibers material is shown in Figure-8. The sound absorption coefficient increases in all frequency ranges as the thickness of the sample increases. When there is air space depth inside and behind the material, the maximum value of the sound absorption coefficient moves from the high to the low frequency range. Therefore, sound absorption coefficient design is achieved by varying the air space depth and adjusting the maximum value with the sound absorption coefficient to the frequency.



**Figure-8.** Sound absorption coefficient for 25mm, 50mm, and 75 mm thickness bamboo fiber backed by a rigid wall.

Figure-9 plots the acoustic absorption of 2 gram paddy fibers with different thicknesses of 10mm and 20 mm. The result for 10mm thick sample shows that good acoustic performance ( $\alpha > 0.5$ ) is achieved at frequency above 3 kHz. This is a typical performance of a fibrous absorber, especially a hard-type fiber as also found for the coir fiber, where good sound absorption starts at high frequencies [18]. Doubling the thickness can be seen to increase the absorption coefficient below 3.5 kHz, which is also due to reduction of the fiber density [19]. However, reduction of the density also reduces the flow resistivity. Due to the same amount of fibers introduced for the increase volume of the sample, the sample might now have more open pores which allow the sound to propagate easily, especially for high frequency, without having significant viscous losses to convert the sound energy into heat [20]. For the 20mm thick sample, the absorption coefficient can be seen to be reduced above 3.5 kHz.



**Figure-9.** Measured absorption coefficient of samples with the same fiber weight of two grams: —□—  $t = 10\text{mm}$  and —○—  $t = 20\text{mm}$ .

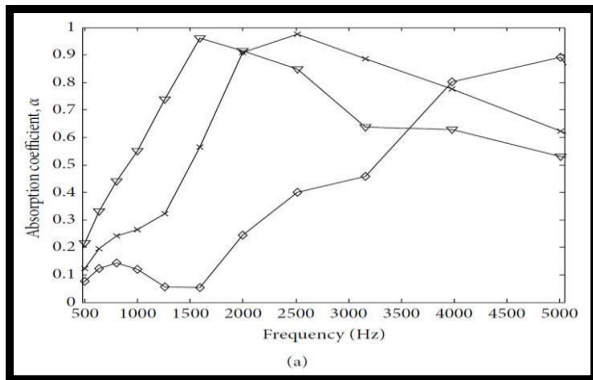
#### Fibers effects on air gap

The results in Figure-10 show something interesting about paddy waste fibers, where introducing the air layer to the sample with greater density, that is, 10mm thick sample (Figure-10(a)), yields greater sound absorption effect. For the sample with greater density of fibers, the sound passing through the sample might be

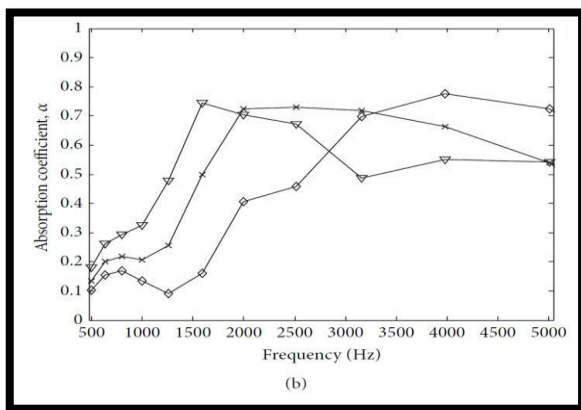




trapped longer in the air gap causing more energy loss compared to that with smaller density.



(a)



(b)

**Figure-10.** Measured absorption coefficient of 2 gram samples with thickness of (a) 10mm and (b) 20mm with different backed air layer thicknesses:—□—without air layer, —×— $D = 10$ mm, and—▽— $D = 20$ mm.

## CONCLUSIONS

The effects of various factors of a fibrous material on natural fibers is presented in this paper. Some of the important conclusions of this research are:

- [1] One of the most important qualities that influence the sound absorbing characteristics of a fibrous material is the specific flow resistance per unit thickness of the material. In general, It can be inferred that, higher airflow resistance always gives better sound absorption values but for airflow resistance higher than 1000 the sound absorption have less values because difficulty of movements sound wave through the materials
- [2] The creation air gap increases sound absorption coefficient values in mid and higher frequencies. At the same time, creation of air gap will have minima at various frequencies for various air gap distances.
- [3] Tortuosity mainly affects the location of the quarter-wavelength peaks, whereas porosity and flow resistivity affect the height and width of the peaks. It has also been

said by the value of tortuosity determines the high frequency behavior of sound absorbing porous materials.

[4] More fibers can create more tortuous path (increase tortuosity) and can also increase the flow resistivity. However, by further increasing the density (adding more fibers), close pores could be formed and thus greatly increase the flow resistivity and eventually reduce the absorption capability.

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