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FRAMEWORK STUDY OF ACOUSTICAL CHARACTERISTICS OF REINFORCED NATURAL FIBERS

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ABSTRACT

Sound pollutions have become a disturbing source that interfere with the human life. Most ofthe expensive sound absorption materials are employed to control noise disturbances.Therefore, this research is aimed to study the effect of sound absorption properties ofalternative absorption materialsfrom naturalfibres with different types of mixture composition.This includesnatural fibresofcoconut coir, rice straw, arenga pinnata, palm oil and kenaffibres.Researchers are more interested in natural and renewable materials where the fibres are well modified by adding some polymers or binder and also recycled materials such as recycled rubberfrom industries. The method used for identifying the performance of absorptionis by using the impedance tube where the loudspeaker feeds the signal in the tube as the incident wave and the reflected sound is recorded by the microphones which is then processed to quantify the absorption coefficient of the material. The other method are by using the reverberant room which is rarely because it required a large and expensive facilities but both method have same purpose. From the result, we can get the value of noise reduction coefficient for each of the samples. Predictably, different materials and compositions give different result of sound absorption coefficient same as other potential aspects that influence the absorption performance. As progress in technology, reinforced natural fiber has enhanced the control of sound quality in the room interior and it is important to balance the development of advanced materials which is cost effective and environmental friendly.

Keywords: natural fibres, sound absorbing material, reinforced material.

INTRODUCTION

Nowadays, sound pollution has become much more complex and serious. The demands for more diversified life styles yet a better environment are highly increased. Therefore, the thin, lightweight, and low-cost materials that will absorb sound waves in wider frequency regions are strongly desired. Recently, polymer has been extensively applied for absorption of sound and reduction of noise; with attractive characteristics including its excellent viscoelasticity, relatively simple processing, and commercial availability. Natural fibres are low-cost, lightweight and environmental friendly compared to glass fibre and mineral based synthetic materials. Moreover, natural fibres are sustainable, i.e. a resource produce for the needs of present without affecting the future needs. In addition, these natural materials are bio-degradable, nonabrasive, abundance and having less health and safety risk while handling and processing [1].

Yang (2001) identified the porous laminated composite material manufactured by lamination, preheating and moulding of premix, exhibits a very high sound absorption property in the frequency range of 500–2000 Hz [2]. Murugan (2006) investigated the two-stage compression moulding of recycled polyolefin-based packaging wastes along with plastic-coated aluminium foils, expanded polystyrene and coir pith, offers sound absorption properties comparable to glass wool [3]. As proved by Kosuge (2005), the combinations of non-woven fabric and Para-amid paper were studied and a sound absorption performance at frequencies higher than 2000 Hz was found to be better than that of glass wool [4]. Meanwhile Hong (2007) had used recycled rubber particles with perforated polymer-material resulted in comparable sound absorption properties. The sound absorption of the composite material is dominated by recycled rubber with different particle sizes, coming from the shredding of tyres from vehicles as other materials used in the samples were vermiculite and expanded polystyrene (EPS) as it can see in Figure-1. A composite structure with a combination of perforated panel, rubber particle, porous material, polyurethane (PU) foam and glass wool were found to demonstrate significant sound attenuation. Usually, wasted rubber particles demonstrate lower sound absorption at higher frequencies [5]. This is altered by matching the polypropylene and polystyrene particles with a selected composite material that has a higher sound absorption for a wider frequency range.

Figure-1. Microphoto of recycled rubber sample obtained Mitutoyo vision machine [5].

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LITERATURE SURVEY

Impedance tube method

Most of the sound absorption coefficients of the material were determined by using the impedance tube that employs the two-microphone method, following the ASTM E1050-98 and ISO10534-2 international standards as shown in Figure-2. The samples were prepared in two diameters which is 100mm for low frequency and 28mm for high frequency. The impedance tube creates sound by a generator mounted at one end, in the form of broadband stationary random waves. The generated sound travels to hit the sample which is attached at the other end. The sound pressure is measured at two fixed points using two ¼″ microphones. An analyzer calculates the complex transfer function in order to obtain the sound absorption coefficient of material [6].

The sensitivity of microphones was calibrated utilizing calibrator type GRAS-42AB at 114 dB levels and 1 kHz. The frequency span of experiment was 100-4500 Hz with 3 Hz resolution and it took approximately 10 seconds for the instrument to achieve the absorption spectrum. Based on Delany-Bazley model, the acoustic absorption coefficient, α can be defined as (1):

$$\alpha = \frac{4 R_r / \rho_o C_o}{(R_r / \rho_o C_o + 1)^2 + (X_r / \rho_o C_o)^2} \qquad (1)$$

Where,

C_o = speed of sound
ρ_o = density of air
R_r = real components of surface acoustic impedance
X_r = imaginary components of surface acoustic impedance

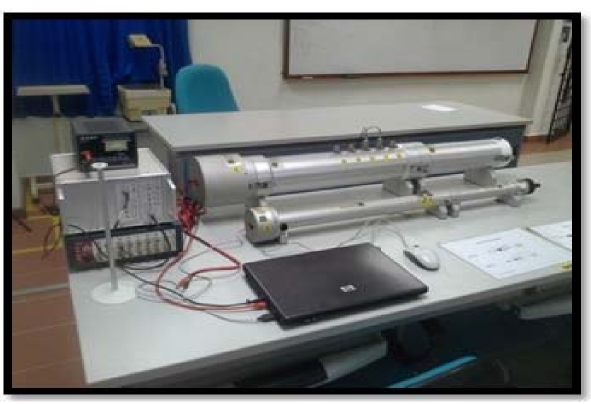

Figure-2. The impedance tube for acoustic analysis [6].

Reveberant room method

D'alessandro and Pispola (2005) have measured the sound absorbing panels made of Kenaf and blankets of recycled polyester (PET) fibers. Two different novel fibrous materials were tested in a reverberation room. The first materials were sound absorbing blankets of kenaf fibres assembled in semi-rigid panels without using adhesives. Small percentages of polyester (8-10 %) and a fireproof additive have been added and thermo-bonded. The second tested samples were sound absorbing blankets of recycled polyester (PET) fibres. These were made of 100% polyester fibres obtained from a recycling process of PET bottles. Blankets are assembled in a 3D fibre arrangement through a thermobonding process without any adhesive.

As the natural fibres and polyester blankets are less harmful to the environment, both samples were tested in a reverberation chamber and the acoustic properties of both samples were at good frequency range of1000 Hz to 5000Hz with the sound absorption coefficient average of 0.8 as Table-1 [7].

Table-1. Sound absorption coefficient of Kenaf and PET [7].

Frequency [Hz]	800	1000	1250	1600	2000	2500	3150	4000	5000
α_S kenaf	0.85	0.91	0.90	0.90	0.86	0.82	0.83	0.83	0.84
α_S PET	0.94	0.97	0.99	0.91	0.95	0.88	0.88	0.88	0.85

According to F.Z Ismail (2014), the measurement of sound absorption coefficient of the test sample in the reverberation chamber was carried out in accordance with ISO354:1985 standard. The required inputs are reverberation time for empty room, RTo and reverberation time for room with sample, RTm. Volume for an empty reverberation room and samples testing area were classified as parameter for the experiment setup. The samples were laid directly over the reverberation chamber floor. The schematic diagram of the experimental setup and the arrangement layout of the absorption test can be seen in Figure-3 and Figure-5 respectively. For the test simulation, dBBAT132 Building acoustics software is used. This experiment allows a quick configuration of the measurement analysis and measurement could be carried out in batch mode [8].

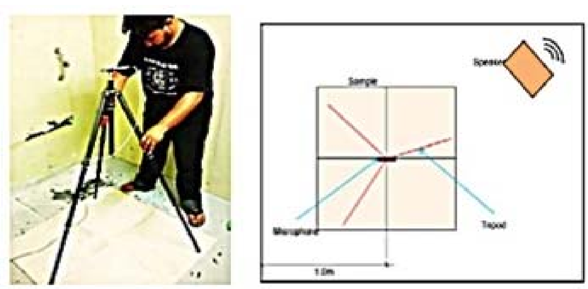

Figure-3. Arrangement of the samples and sound source in the reverberation room [8].

Acoustical measurement aspects effect of air gap

In the studies of multi-layer coir by Hosseini (2010), the coconut coir fiber is mounted with 50 mm airspace in front of a rigid wall. The airspace layer will enhance sound absorption coefficient in the low frequency range. This is because porous materials can provide more absorption when they are located in positions where the particle velocity of the sound wave are large where it is maximum at the distance of λ/4 and ¾ λ . The absorption coefficient is slightly decreased at a distance of λ/2 and λ. In this case, when λ/4 and ¾ λ are equal to 60 mm (distance from the center of the coconut coir fiber to the back wall surface), the maximum absorption coefficients should be around 1430 Hz and 4290 Hz which is similar to the simulation result and for λ/2,the absorption coefficient is around 2860 Hz [9].

Effect of composite mixture or binder

Sound absorption coefficients of natural fiber reinforced with two kinds of plastics have been tested. As mentioned by M.J.M Nor (2004), the results show the samples that made of Thermoplastics (Polypropylene) have high sound absorption coefficients compared with the samples made of Thermoset plastic (Urea-formaldehyde). Next, the coconut coir is added with recycled rubber to implement as sound absorption panel. The effect of adding recycled rubber particles and the influence of polyurethane are investigated as the potential replacement of synthetic and mineral fibers [10].

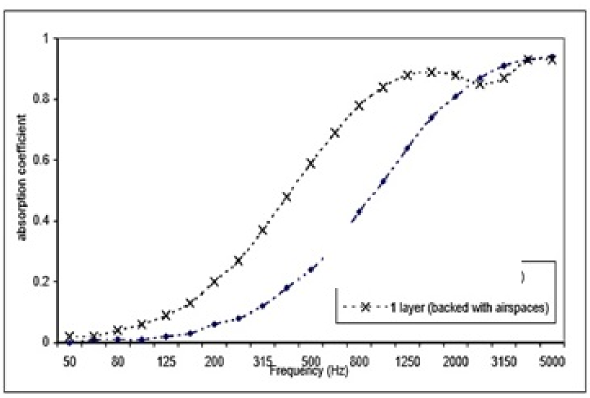

Figure-4. Comparison of the diffused incidence sound absorption coefficients of 20 mm thick coconut coir fiber sample of density 74 kg/m3 without airspaces and backed with airspaces [9].

Y. Abdullah (2010) has tested two samples with different composition. The amount of methylcellulose was varied while preparing these samples. Methylcellulose was acting as glue or binder for the fibers. The ratio of the methylcellulose between the samples is 1:1.6, respectively for sample 1 and sample 2. The methylcellulose binder is also found to affect the absorption coefficient. Figure-5 shows the absorption coefficient for sample 1 and 2. It can be seen that larger amount of methylcellulose improves the absorption of sound energy at low frequencies (sample 2), but reduces it at high frequencies [11].

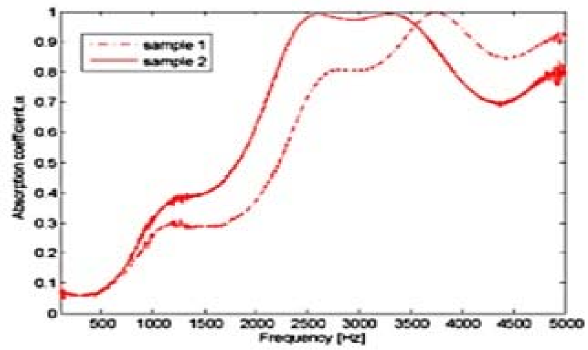

Figure-5. Comparison of the absorption coefficient of the paddy straw with different composition of methylcellulose [11].

The effect of the fiber, however, can be optimized with less methylcellulose and therefore increases the absorption at high frequencies (sample 1). It is found that the binder composition affects the acoustical performance of the sound absorber. Optimum acoustic performance was obtained when the composition of binder are 30% of the total weight of the fibers. Then, it will be controlled to compromise between the strength of the panel and its sound absorption performance [12].

Yang (2003) has utilized the rice straw to become insulation boards to overcome lacking of solid woods in wood-industry. The rice straw was mixed with commercial binder to have certain shape and strength. The absorption coefficient is found to be on the average 0.5 between 1000 Hz to 8000 Hz. Sound absorption characteristic values of rock wool were measured and found to be similar to glass fibre [13]. E. Jayamani (2013) has investigate the influence of two kind of polymers (Urea-formaldehyde and Polypropylene) mixed with natural fiber (Kenaf). The samples of A1 and A2 are made of Kenaf core fiber with adhesive of high emission Urea-formaldehyde resin (HN 100) with 51.6 % solid content. The other samples of B1 and B2 are made of thermoplastic polymer reinforced with kenaf natural fibre composites. The results show that the samples made of Thermoplastics (Polypropylene) have high sound absorption coefficients compared with the samples made of Thermoset plastic (Urea-formaldehyde) [14].

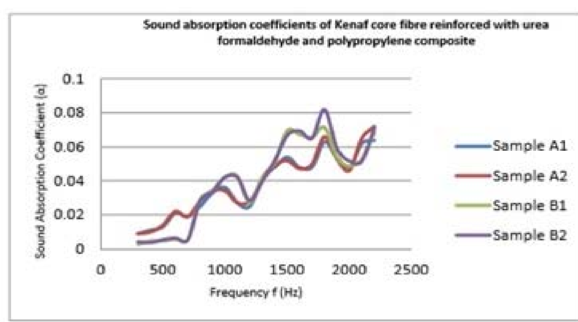

Figure-6. Comparison of experimental results for sound absorption coefficients of samples.

Effect of thickness

As in L.Ismail(2010) research, the acoustic properties of Arenga Pinnata fiber, 40 mm thick panel shows good absorption coefficient from 2000 Hz to 5000 Hz. Comparisons were also made with other natural fibers such as coir and palm oil. Arenga Pinnata shows good properties above 2000 Hz, better than that of coir fiber, but slightly lower than that of the palm oil fiber at the average of 0.7 [15].

Hosseini (2011) identified that the acoustic absorption of fiber was improved as the thickness of sample increased. He also stated that increasing the thickness to 2.0 cm reduced their porosity and improved the absorption coefficient [16]. Masrol (2013) has figured out that the composition of 15 wt% of natural POMFS fiber with sample thickness of 25 mm shows the optimum sound absorption coefficient and NRCj compare to overall sample. Besides, sample of 35 mm of thickness and 15 wt. % of POMFS fiber composition also show some potential as sound absorption panel [17].

Effect of porosity

Another experiments tested on the composites fiber board were porosity test. Porosity test is a measurement of void space volumes over total volume. It is indicated as percentages between zeros to hundred percents. Porosity can be relic of deposition (primary porosity, where space between grains that were not compacted together completely) or can be developed through alteration of the rock (secondary porosity, when feldspar grains or fossils are preferentially dissolved from sandstones).

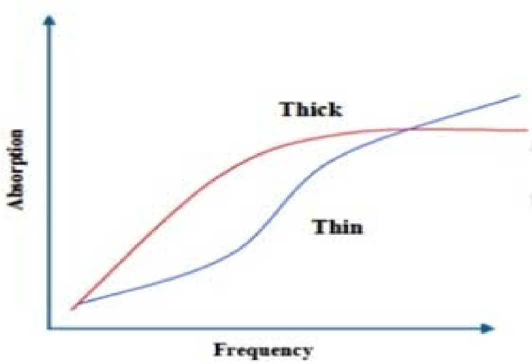

Figure-7. Schematics of the key features driving absorption performance for thickness [18].

Information about porosity, void spaces between fillers and resins, as well as surface texture of the composite could be identified. The ratio of the volume of openings to the total volume of the sample and affects the absorption efficiency of each sample. Mass, thickness and fiber diameter of each sample determines the porosity and can be calculated using Equation. (2):

$$\varphi = 1 - \frac{\rho bulk}{\rho fiber} \quad (2)$$

Where,

ρbulk = bulk density of sample
ρfiber = fiber density of sample

The quantity is the ratio of mass and volume of each sample as a disk, whereas depends on physical properties of the fiber itself. The porosity results in S.R Masrol (2013) also found out there are increment pattern when the NRC and sound absorption coefficient was increased.

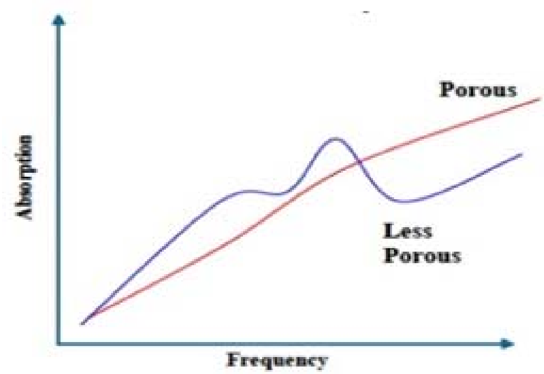

Figure-8. Schematics of the key features driving absorption performance for porosity [18].

Effect of density

Density is a physical property of matters as each element and compound has a unique density associated with it. Density is defined in a qualitative manner as the measure of the relative "heaviness" or high density of objects with a constant volume. Density is an important indicator of a composite's performance. It virtually affects all properties of the material as shown as below:

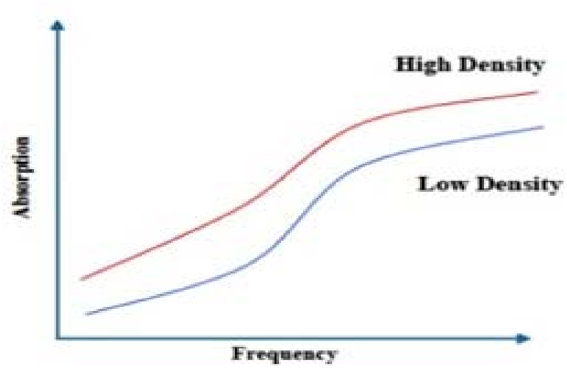

Figure-9. Schematics of the key features driving absorption performance for density [18].

CONCLUSIONS

The acoustical materials, either its natural or made of recycled materials, are quite often as one of the alternative compared to the traditional synthetic materials. Airborne sound insulation of natural materials such as flax or recycled cellulose fibres is similar to the one of rock or glass wool. Conventionally, most of the studies on natural fibre show good result in mixture composition or binder where the composite material is reinforced with the natural fibres. In other hands, cork or recycled rubbers are also become very effective for impact sound insulation. These materials show good thermal insulation properties and are often light. Basically, the results of the absorbing material are depends on its variable parameter or aspects which are potentially influence the result. However, in order to determine the effectiveness of each material, it needs to complete their characterization, both from an experimental and a theoretical point of view, and especially to propose a standard and unique procedure to evaluate their sustainability.

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