Investigation on Natural Waste Fibers from Dried Paddy Straw as a Sustainable Acoustic Absorber

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Abstract: The use of synthetic materials as acoustic absorbers is still applied extensively in building industry. These non-biodegradable materials do not only cause pollution to the environment, but also contribute significantly in increasing the CO_2 causing the effect of global warming. Therefore researchers have now driven their attentions to find sustainable and eco-friendly materials to be an alternative sound absorber. This paper discusses the use of natural fibers from dried paddy straw as a fibrous acoustic material. Since this is one of common natural waste materials found across South East Asia, the usage will also minimize the production cost. A panel sound absorber from paddy straw is fabricated and its acoustic properties are investigated through experiment. Good acoustic performance is found particularly above 2000 Hz and is comparable against that from the classical synthetic absorber.

Keywords: Synthetic materials, sustainable, acoustic performance, non-biodegradable

INTRODUCTION

Acoustics control in building improves significantly with technology. As progress in technology has enhanced the control of sound quality in the room interior, it is important to balance the development of advanced materials with responsible environmental practices. Hence, researchers are becoming interested in natural or renewable materials instead of producing and using synthetic non-renewable materials. According to F. Asdrubali [1], these synthetic materials such as foamglass contribute much higher Global Warning Potential (GWP) kg CO2 equivalent compared to coconut fiber. Natural fibers are low-cost, lightweight and environmental friendly if compared to glass fiber and mineral based synthetic materials. Moreover, natural fibers are sustainable, i.e. a resource to keep produce for the needs of present without affecting the future needs [2]. In addition, these natural materials are bio-degradable, non-abrasive, abundance and having less health and safety risk while handling and processing [3].

Several works have been published to investigate the performance of natural fibers as the acoustic absorber. D'alessandro and Pispola [4] measure sound absorbing panels made of *Kenaf* and blankets of recycled polyester (PET) fibers. Both samples were tested in reverberation chamber, acoustic properties of both samples are good at frequency range between 1000 Hz to 5000Hz with the average of 0.8.

Lindawati et. al [5] examining acoustic properties of *Arenga Pinnata* fiber. 40 mm thickness of fiber show good properties from 2000 Hz to 5000 Hz. Comparisons also have been made with other natural fibers such as coir and palm oil. Arenga Pinnata shows good properties after 2000 Hz, even better than coir fiber but slightly lower than palm oil fiber at the average of 0.7.

Ersoy and Kucuk [6] have investigated sound absorption of natural fibers from tea-leaf fiber and compared it with woven textile cloth. It shows that sound absorption of six layers woven textile cloth are slightly equivalent to 1cm thick tea-leaf fiber at frequency range between 500 Hz to 3000 Hz.

Zulkifli et. al [7] worked on the coconut coir fibers compressed into a panel. From this point of view, alternative way is to substitute these synthetic materials with waste natural fibers as acoustic sound absorber. Coir fiber found to be good acoustic absorber when the fibers were compressed into sheet. Single layer of coir sheet shows good absorption coefficient at mid and high frequencies. Low frequency performance improves when the panel consist of multiple layers [8]. M.H Fouladi et. al [9] then utilize the coir panel with perforated panel which makes each peaks move forward towards lower frequencies.

Unmodified straw and reed also have been investigated for its acoustic properties, the natural non-fibrous material is found to have a good absorption coefficient from 500 Hz to 5000 Hz. [10].

H.S. Yang et al. [11] utilized 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.

Paddy straw is one of the natural fibers that abundantly available in South East Asia. Since the last decade, it was commonly use for many application such as roof, rope, animal foods and mat. However the sound absorption of dried paddy

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straw fiber as sound absorber panel has still not been investigated yet. Hence, this paper was carried out to investigate the potential of using dried paddy straw fiber as raw material for sound absorbing material.

RESEARCH METHODOLOGY

A. Raw Material Preparation

Construction into an absorber sample is divided into two stages, namely the pre-treatment stage and preparation stage. The flow chart of the process is shown in Figure 1.

In the pre-treatment stage, raw material was cut into 1 to 3 mm length as shown in Figure 2. It was then sundried for 1 week and again heated in the oven at 115°C for 10 minutes.

In preparation stage, the raw material was mixed with different composition of binders, blowing agent and additives such as methylcellulose, gypsum, water, aluminium oxide and lime. The amount of ingredient was applied using trial and error process to gain optimum strength of bonding. Each ingredient was then scaled and noted for future references. Then the mixture was compressed using hydraulic presser at 10 bars in specially fabricated mould to obtain a round shape. The shaped mixture was hardened by heating it in oven at 115°C for 30 minutes. The sample constructed has 33 mm diameter as seen in Figure 4.

In this experiment, two samples with different composition were tested. The amount of methylcellulose was varied while preparing these samples. Methylcellulose was acting as glue or binder. The ratio of the methylcellulose between the samples is 1:1.6, respectively for sample 1 and sample 2.

B. Sound Absorption Testing

The test was performed using home-made impedance tube by applying two-microphone transfer function method according to ISO 10534-2:2001 international standards [12]. The acoustic microphones used are the ½" Prepolarized free-field microphones (GRAS 40AE) with ½" CCP pre-amplifier (GRAS 26CA). Data acquisition system used was RT Pro Photon 6.34 analyzer with Dactron software. The signal processing of raw data was calculated using Matlab software.

Figure 3 shows the equipment used in the test and the setup. The sample was placed at the end of the impedance tube and backed by a rigid surface.

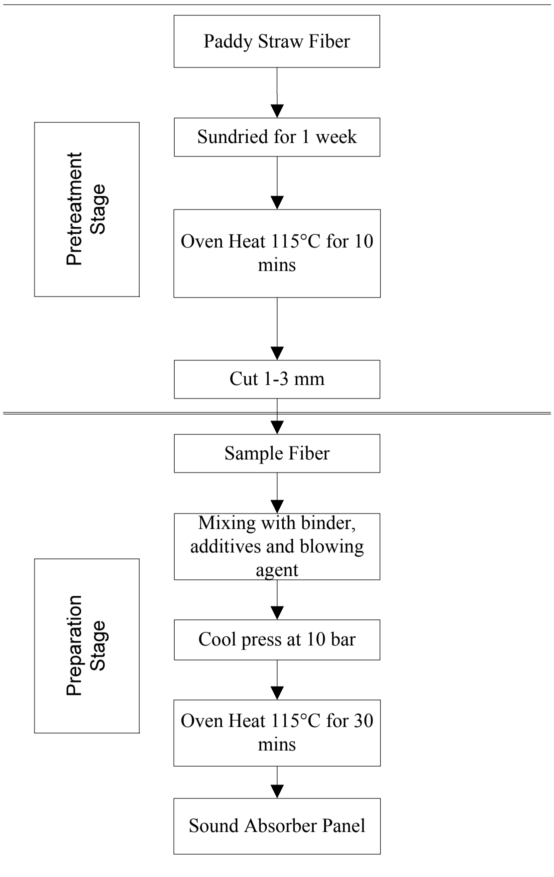

Figure 1: Flow chart of fiber pre-treatment and sample preparation process

Figure 2: Paddy Straw Fibers.

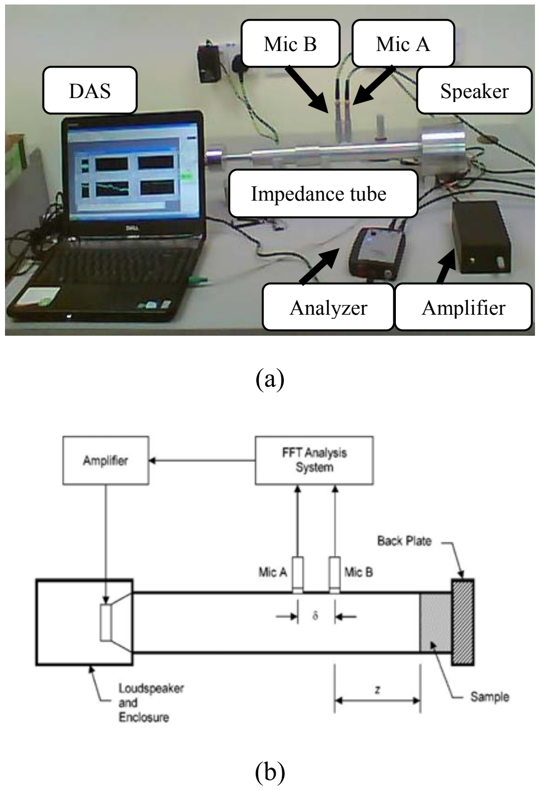

Figure 3: (a) Equipment used in the experiment and (b) diagram of the measurement set-ups (adapted from Handbook of Noise and Vibration Control 2007).

Figure 4: The constructed sound absorber sample from the paddy straw.

RESULTS AND DISCUSSION

Figure 5 show absorption coefficient for sample 1 and 2, respectively. It can be seen that below 2000 Hz the coefficient is less than 0.5 which shows poor performance of sound absorption. However, this improves above 2000 Hz with average coefficient of 0.8 particularly for sample 2.

The effect of the methylcellulose can also be seen to increase the absorption coefficient between 2250 – 3000 Hz. Larger amount of methylcellulose (sample 2) creates more pores inside the sample which then improves the absorption of sound energy. However, this should be controlled as excessive amount will prevent the optimum formation of pores.

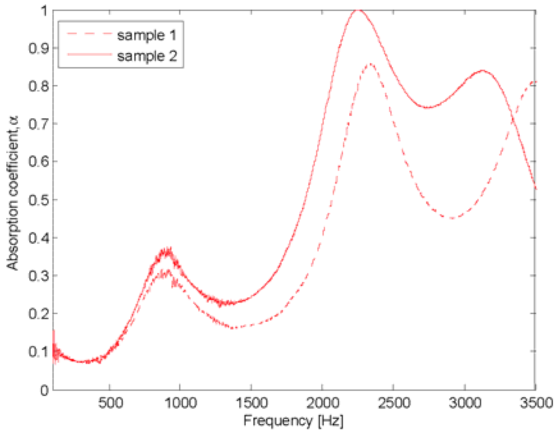

Figure 5: Comparison of the absorption coefficient of the paddy straw for sample 1 and sample 2.

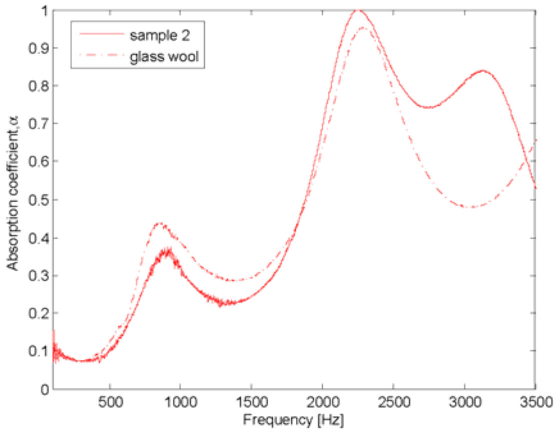

Figure 6: Comparison of absorption coefficient, α from paddy straw sample with commercial glass wool.

Figure 6 shows the comparison between the sample and the synthetic glass wool. It can be seen that the paddy absorber has comparable performance compared to the commercial glass wool absorber. The performance is even better above 2000 Hz.

CONCLUSION

Samples of sound absorber have been constructed from dried paddy straw. The experiment shows that this natural fiber can be a good alternative sound absorber among many other natural fibers. However from the samples, good performance is shown above 2000 Hz. Performance at lower frequency can be improved by increasing the sample thickness or by coupling it with perforated panel facing. These will be investigated in the future work.

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