Sound Absorption Efficiency of Fibreboard Made from Oil Palm Frond

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Abstract

This study investigated the possibility of producing sound absorbing material as fibreboard made from oil palm frond. Various densities and thicknesses of the fibreboard were produced and their sound absorption capacity tested at the traditional octave band centre frequencies. Results from the experiment showed that the optimum density of the fibreboard was 0.276 g/cm^3. The sound absorption coefficients of ¾ inch fibreboard were higher than ½ inch fibreboard at low frequencies while the absorption capacity of 1 inch fibreboard was significantly lower than the others at most frequencies. Considering all samples, it was found that the higher the frequency, the greater the sound absorption coefficient.

Keywords: porous material, sound absorbing material, standing wave apparatus, oil palm frond, fibreboard

Introduction

In the past, asbestos was used as an acoustic material because of good sound absorption, fire retardant and low heat transfer characteristics. However, this material potentially causes adverse health effects to human, including lung cancer and mesothelioma (Nordmann, 1935; Wagner, 1960; Newhouse and Thompson, 1965; Ribak *et al.*, 1988) and has been banned in many countries. Although alternative materials such as rock wool, slag wool and glass wool have been widely used, there are still many health concerns as evidenced by many studies (Saracci *et al.*, 1984; Roller *et al.*, 1996; Miller *et al.*, 1999;

Drent *et al.*, 2000). Consequently, several natural organic materials such as natural bamboo fibre (Koizumi *et al.*, 2002), rice straw (Yang *et al.*, 2003), coconut coir fibre (Nor *et al.*, 2003), tea-leaves (Ersoy and Kucuk, 2008) and wool (Ballagh, 1996) have been developed for use as sound absorbing materials in place of those hazardous materials.

Due to the current oil crisis, approximately 1.6 ha of oil palm plantation area will be planted in Thailand by 2029 (Wichachu, 2008). If this plan succeeds, food and energy sources as well as a large amount of natural waste including fronds will be produced. Based on the database of Akesomtramet (Akesomtramet, 2002), approximately 10 million ton/year of oil palm frond are expected in the next 10 years. Therefore, the utilization of oil palm residues has been an intriguing challenge for acoustic absorption because of the large quantities being generated. In addition, this material is environmentally friendly. Moreover, it has basic sound absorptive characteristics because its fibre possesses interconnected pores and voids, which convert sound energy to other forms of energy. However, the optimum density of any acoustic material made from oil palm fronds is unknown. Consequently, this study was carried out to determine the density and sound absorption characteristics of oil palm residue. The benefits of this work are not only new, cheap and locally produced sound absorbing material but also waste management.

Materials and Methods

This study aimed to determine the optimum density of fibreboard to produce the best sound absorption coefficient at frequencies of 250, 500, 1000, 2000 and 4000 Hz, respectively. To carry out this research, the density of ½ inch fibreboard was varied from 0.204 to 0.347 g/cm^3. Optimum density boards with a thickness of ¾ and 1 inch were produced and their sound absorption characteristics tested. The method of fibreboard production is summarized below. Fronds from the 25-year-old oil palm trees in Krabi, Thailand, were cut and selected to get homogeneous pieces which were then chipped and screened with 6/18 inch openings. The raw materials were cooked starting at room temperature and increasing to 150 °C for 90 minutes in a 10% sodium hydroxide solution and maintained at this condition for 2 hours. The cooked materials were screened by a pulp screener to obtain fine pulp and were then dehydrated by a dewatering apparatus. The amount of fine pulp was calculated and weighed to form a target density board. Following separation into small bundles by a disintegrator for 10 minutes, the pulps were spread and suspended in water inside the cylinder former for 10 minutes. The forming of fibreboard occurred when the water flowed through the screen while the pulp was retained on it. The loose board was pressed at a pressure of 1 kgf/cm^2 for 10 minutes and exposed to sunlight for a couple of days. The rest of the water in the board was eliminated by baking in the oven at 60 °C until the moisture content was zero. Then, each board was set aside under room conditions for a week and the density and moisture content were measured. Sound absorption capacity was estimated by measuring the sound absorption coefficient using a standing wave apparatus assembled following ASTM 384 (Figure 1). A microphone was moved along the tube and the maximum (A) and minimum amplitude (B) were recorded in volts. The normal sound absorption coefficient was calculated as follows:

$$SWR = \frac{|A+B|}{|A-B|}$$

$$R = \left|\frac{B}{A}\right| = \frac{SWR-1}{SWR+1}$$

$$\alpha_0 = 1 - R^2 = 1 - \left(\frac{SWR-1}{SWR+1}\right)^2 = \frac{4}{SWR + (1/SWR) + 2}$$

where: SWR is the standing wave ratio and R is reflection coefficient.

To check the precision of the apparatus, a sample was tested three times. To check the quality control of the production method, three samples with the same density were replicated.

Results and Discussion

Standing Wave Apparatus

The normal sound absorption coefficients of the fibreboard were measured by the impedance tube method using a standing wave apparatus. Rather than measuring the random sound absorption coefficient with the reverberation room method (ASTM C423-02a), a standing wave apparatus was chosen as this method is quick, easy and highly reproducible. Moreover, this method requires a small sample (Russal, 2008). Although the reverberation room method is generally used for acoustic and noise control in a room, the method requires much larger samples and is complicated and expensive. Therefore, many researchers have preferred to investigate preliminary work using the impedance tube method. (Ballagh, 1996; Wassilieff, 1996; Ersoy and Kucuk, 2008) The current study aimed to determine the optimum density of the material without knowing how large the density range to test should be. Therefore, the impedance tube method was chosen because of the benefits mentioned above. As there was no calibration material for this method (ASTM C384–04), the apparatus was tested using three materials with dramatically different sound absorption capacities: a mirror, medium and low-density particleboard. The apparatus was shown to be effective because the measured values corresponded to the natural absorbent properties of the selected materials (a mirror has very low absorption capacity, while medium-density board has higher sound absorption capacity than low-density board). This result supported the process proposed that used the values measured by the equipment to carry out a relative comparison to determine the fibreboard with the optimum density. To enhance the precision of the test, the sound absorption coefficient of a sample was measured three times. The measurements were within one standard deviation, thus showing its high precision.

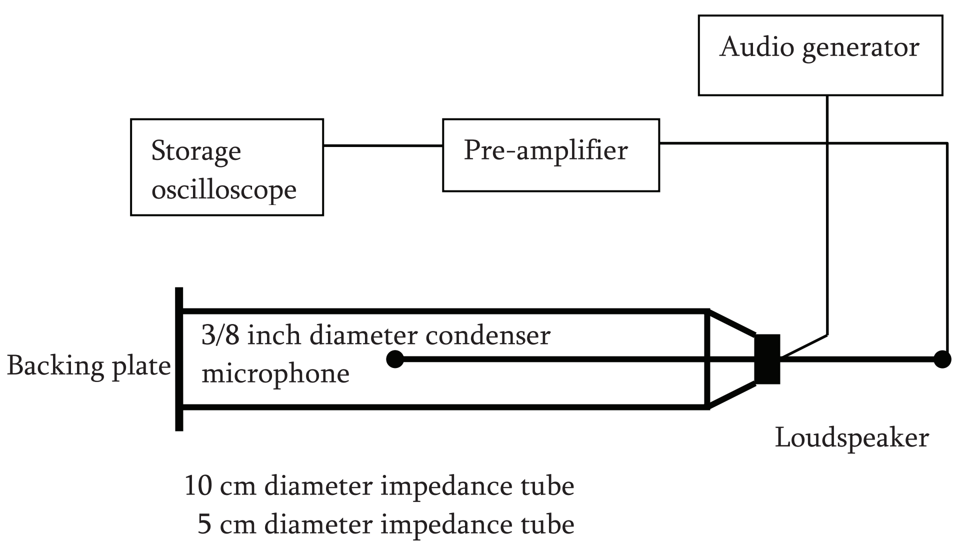

Figure 1 Schematic diagram of the standing wave apparatus.

Fibreboard Characteristics

A low-density board was formed from oil palm fronds using the wet forming process. No binder was required because of adhesion between fibres resulting from hydrogen bonding (Otto and George, 1987). The appearance of the board was very light and brown with a smooth surface as shown in Figure 2, thus making it convenient to install. Density, moisture control and the sound absorption coefficient of the fibreboards are reported in Tables 1 and 2. There was little difference in the density of the three replicated samples.

Figure 2 Fibreboard made from oil palm frond.

Sound Absorption Capacity of the Fibreboard

As shown in Table 1, the sound absorption coefficients measured at frequencies ranging 250-4000 Hz were 0.358-0.648, 0.413-0.686, 0.431-0.788, 0.380-0.799 and 0.352-0.793 for the fibreboard with densities of 0.204, 0.257, 0.276, 0.298 and 0.347 g/cm^3, respectively. In general, a higher frequency produced a larger sound absorption coefficient as shown in Figure 3. The sound absorption coefficients of the board with a density of 0.276 g/cm^3

were the highest at most frequencies. However, the 0.257 g/cm^3 board was an interesting product. This sample showed only slightly lower sound absorption coefficients than the 0.276 g/cm^3 board but needed relatively less pulp. When the thickness of the fibreboard with optimum density was varied, the sound absorption coefficient of the ¾ inch sample board was higher than for the ½ inch board at low frequency. Once the thickness of the fibreboard was increased up to 1 inch, the sound absorption coefficient significantly decreased at all frequencies except for 4000 Hz as shown in Figure 4. Theoretically, the thicker the material, the better the sound absorption should be at the lower frequencies. However, the one-inch board did not conform to this rule, perhaps due to the limitation of the forming machine. The forming of one-inch thick fibreboard required large amounts of pulp, with a portion of them sinking to the bottom of the forming cylinder. This resulted in the pulp being unevenly distributed throughout the thickness of the board, resulting in some unexpected outcomes.

Table 1 Density, moisture content and sound absorption coefficient of the ½ inch fibreboard.

Density* (g/cm^3)	Moisture content* (%)	Sound absorption coefficient**				
		250 Hz	500 Hz	1000 Hz	2000Hz	4000 Hz
0.204 ±0.001	8.47 ±0.33	0.358 ±0.007	0.382 ±0.006	0.477 ±0.008	0.532 ±0.006	0.648 ±0.011
0.257 ±0.004	8.30 ±0.23	0.413 ±0.010	0.454 ±0.008	0.521 ±0.010	0.560 ±0.011	0.682 ±0.012
0.276 ±0.003	8.81 ±0.12	0.431 ±0.004	0.459 ±0.007	0.537 ±0.012	0.581 ±0.007	0.788 ±0.008
0.298 ±0.001	8.40 ±0.16	0.380 ±0.009	0.405 ±0.011	0.514 ±0.008	0.577 ±0.011	0.799 ±0.010
0.347 ±0.003	8.59 ±0.11	0.352 ±0.008	0.368 ±0.007	0.442 ±0.005	0.572 ±0.010	0.793 ±0.008

Note: * n (replicated samples) = 3
** n (total repeated measurements) = 9

Table 2 Density, moisture content and sound absorption coefficient of the fibreboard with various thicknesses.

Fibreboard thickness (inch)	Density* (g/cm³)	Moisture content* (%)	Sound absorption coefficient**				
			250 Hz	500 Hz	1000 Hz	2000Hz	4000 Hz
½	0.276 ±0.003	8.81 ±0.12	0.431 ±0.004	0.459 ±0.007	0.537 ±0.012	0.581 ±0.007	0.788 ±0.008
¾	0.278 ±0.03	8.56 ±0.25	0.454 ±0.007	0.474 ±0.013	0.543 ±0.011	0.582 ±0.009	0.791 ±0.012
1	0.278 ±0.002	8.52 ±0.10	0.347 ±0.003	0.374 ±0.006	0.425 ±0.014	0.544 ±0.015	0.801 ±0.018

Note: * n (replicated samples) = 3

** n (total repeated measurements) = 9

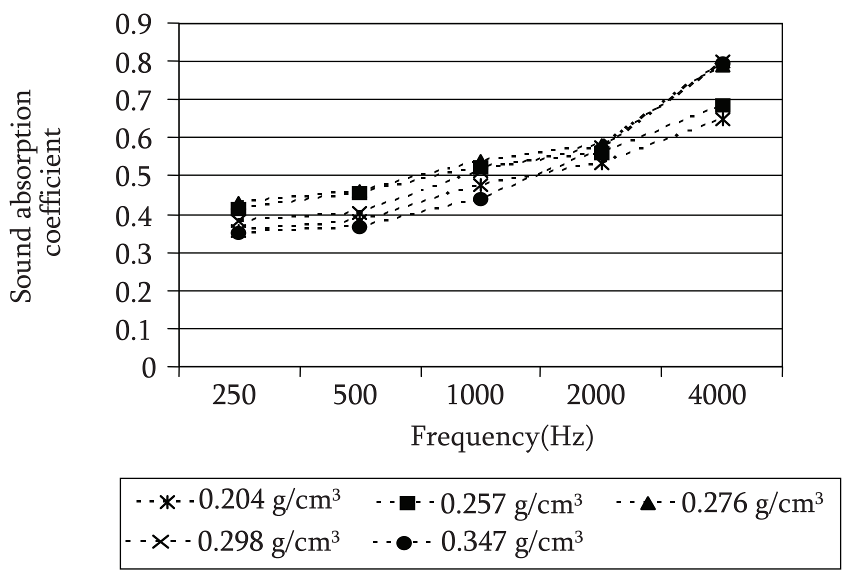

Figure 3 Sound absorption coefficient of oil palm frond fibreboard with various densities.

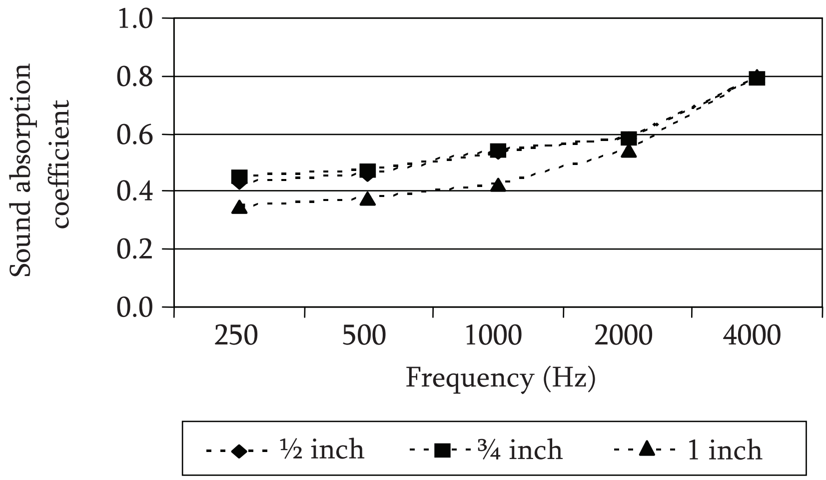

Figure 4 Sound absorption coefficient of 0.27 g/cm³ fibreboard with various densities.

Conclusion and Recommendation

This research found that oil palm frond fibre was an alternative material for producing sound-absorbing fibreboards. However, production procedure improvements are needed, since the yield was only 25%. Because noise generally strikes the surface randomly, the fibreboards should be further tested by the reverberation room method before commercially launching the product.

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References

Akesomtramet, T. 2002. Oil palm and value-added products. The Oil Palm Newsletter. March-May: 2-8. (in Thai).

ASTM C384-04 Standard Test Method for Impedance and Absorption of Acoustical Materials by Impedance Tube Method.

ASTM C423-02a Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method.

Ballagh, K.O. 1996. Acoustical properties of wool. Applied Acoustics 48(2): 101-120.

Drent, M., P.H.H. Bomans, R.J. Van Suylen, R.J.S. Lamers, A. Bast and E.F.M. Wouters. 2000. Association of man-made mineral fibre exposure and sarcoidlike granulomas. Respiratory Medicine 94(8): 815-820.

Ersoy, S. and H. Kucuk. 2009. Investigation of industrial tea-leaf-fibre waste material for its sound absorption properties. Applied Acoustics 70(1): 215-220.

Koizumi, T. N. Tsujiuchi and A. Adachi. 2002. The development of sound absorbing materials using natural fibre, pp. 157-166. *In* C.A. Brebbia and W.P. De Wide, eds. High Performance Structures and Composites. WIT Press, Southampton.

Miller, B.G., A. Searl, J.M.G. Davis, K. Donaldson, R.T. Cullen, R.E. Bolton, D. Buchanan and C.A. Soutar. 1999. Influence of fibre length, dissolution and biopersistence on the production of mesothelioma in the rat peritoneal cavity. The Annals of Occupational Hygiene 43(3): 155-166.

Newhouse, M.L. and H. Thompson. 1965. Mesothelioma of pleura and peritoneum following exposure to asbestos in London area. British Journal of Industrial Medicine 22: 261-268.

Nor, M.J.M., N. Jamaluddin and F.M. Tamiri. 2004. A preliminary study of sound absorption using multi-layer coconut coir fibres. Electronic Journal Technical Acoustics. Available Source: http://www.ejta.org /en/2004, 14 September 2008.

Nordmann, M. 1935. The occupational cancer of asbestos workers. Z Krebsforsh 47: 288-302.

Otto, S., and W.E. George. 1987. Fibreboard Manufacturing Practices in the United States. Forest Service Agriculture Handbook 640: 24-25. The US Department of Agriculture, USA.

Ribak, J., R. Lilis, Y. Suzuki, L. Penner and I.J. Selikoff. 1988. Malignant mesothelioma in a cohort of asbestos insulation workers: clinical presentation, diagnosis, and causes of death. British Journal of Industrial Medicine 45: 182-187.

Roller, M., F. Pott, K. Kamino, G.H. Althoff and B. Bellmann. 1996. Results of current intraperitoneal carcinogenicity studies with mineral and vitreous fibres. Experimental and Toxicologic Pathology 48: 3-12.

Russell, D.A. n.d. Absorption coefficient and impedance lab. Available Source:www.kettering.edu/~drussell/GMI-Acoustics/Absorption.html, 1 September 2008.

Saracci, R., L. Simonato, E.D. Acheson, A. Andersen, P.A. Bertazzi, J. Claude, N. Charnay, J. Esteve, R.R. Frentzel-Beyme and M.J. Gardner. 1984. Mortality and incidence of cancer of workers in the man made vitreous fibre producing industry: an international investigation at 13 European plants. British Journal Industrial Medicine 41: 425-436.

Wagner, J.C., C.A. Sleggs, P. Marchand. 1960. Diffuse pleural mesothelioma and asbestos exposure in the North Western Cape Province. British Journal Industrial Medicine 17: 260-271.

Wassilieff, C. 1996. Sound Absorption of Wood-Based Materials. Applied Acoustics 48(4): 339-356.

Wichachu, P. 2003. Oil palm: from vegetable oil to biodiesel. Available Source: www.kasetcity.com/Thaibioenergy/Plam/QAview.asp?id=4., 14 September 2008. (in Thai).

Yang, H.S., D.J. Kim and H.J. Kim. Rice straw-wood particle composite for sound absorbing wooden construction materials. Bioresource Technology 86: 117-121.