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Sound Insolation of Local Economic Materials Prepared by Natural Rubber Latex and Pineapple Leaf Fiber

Sonthaya Pongthanee, Nuorn Choothong*

Faculty of Engineering, Rajamangala University of Technology Rattanakosin,
96 Moo 3 Phutthamonthon, Nakhon Pathom 73170, Thailand
***Corresponding author e-mail: nuorn.cho@rmutr.ac.th**

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Abstract

The sound insulation properties of local economic materials made from natural rubber latex and pineapple leaf fiber were investigated, in order to develop and increase the economy of the community. The surface of pineapple leaf fiber was treated with alkaline treatment individually. The random fiber range was mixed with natural rubber latex in five different fractions, varying from 10% to 50% with an increment of 10%. The thickness of each sample is kept constant at 50 mm. Method used to measure sound absorption coefficient (α) is Impedance Tube Method ASTM E1050-09, which has been used for measuring the sound absorption and sound transmission loss. It was found that the sound absorption coefficient (SAC) increases with the fiber fraction. The sound insulation test results show that the obtained product of natural rubber with pineapple leaf fiber has a promising possibility that can be used as a potential material for the development of sustainable sound absorber material.

Keywords: Natural rubber latex, Pineapple leaf fiber, Sound insolation property

1. Introduction

Noise pollution is one of the world's points concerns as it affects human health and environment quality (Peng, 2017; Zhu, Kim, Wang, & Wu, 2014). In order to control the noise, sound barrier as an acoustic material is a trend to be investigated for use in building for sound isolation purposes. However, most of the acoustic materials currently are found to be unsustainable in terms of energy consumption, greenhouse gas emission and their impact on human health. For instance, mineral wool causes health impact (Abdul Latif et al., 2015; Asdrubali, 2007) and the synthetic materials such as synthetic fibers which are being widely used as acoustic material because of their high stiffness and strength properties (Rout, Misra, Tripathy, Nayak, & Mohanty, 2001). These synthetic materials also offer good acoustical performance. However, the synthetic fibers have serious disadvantages in terms of initial processing cost, recyclability, energy consumption and machine abrasion (Faruk, Bledzki, Fink, & Sain, 2012). Therefore, sustainable acoustic material, especially natural fiber which gained much attention in recent years under the sustainable development building agenda.

Among the natural fibers used in acoustic material, Pineapple leaf fiber is an alternative replacement for synthetic fiber in acoustical application because of its fiber properties. They have been reported to have high young's modulus and tensile strength (Asim et al., 2015), including its conductivity (Asdrubali, D'Alessandro, & Schiavoni, 2015) among other natural fibers. The fibers are well known to have high content of cellulose and thus can be used as the source of cellulose nanofibrils for biotechnology applications (Cherian et al., 2010).

Recently, the pineapple leaf was reported to be an alternative natural acoustic material (Putra et al., 2018). The different densities and thicknesses of the pineapple leaf fiber have been reported. From the sound absorption measurement, it revealed that the pineapple leaf fiber could achieve a sound absorption coefficient of 0.9 on average above 1 kHz by controlling the densities of the fibers. It is also demonstrated that the sound absorption performance is similar to that of the commercial rock wool fibers and synthetic polyurethane foam. However, there are some disadvantages of using pure natural fiber such as fire point mechanical properties and moisture. Therefore, the fiber-reinforced composites were developed to improve its properties in order to use for interior sound absorber material.

The aim of this work was to prepare pineapple leaf fiber bond with natural rubber in various amounts of natural rubber latex which act as a binder; that was, 40% 30% and 20% of natural rubber latex. The sound absorption of the samples was performed by using the impedance tube method. The effect of density and porosity of the samples with various binder contents were investigated in order to improve the absorption at low frequencies.

2. Materials and Methods

2.1 Materials

Natural rubber latex with high ammonia was purchased from Sri Trang Agro-Industry Public Company Limited, Songkhla, Thailand. Pineapple leaf fiber was received from Tambon Nongplub, Amphoe Hua-Hin, Prachuapkhirikhan province [Figure 1]. In order to remove unwanted shells and dirt, the fibers were first dewaxed by extracting in 1:2 (V/V) mixture of ethanol and benzene for 72 h [Figure 2]. Then, the fibers were soaked in alkaline treatment at 5 wt% of NaoH for 72 hours to remove cellulose layer and unwanted properties of the law fibers. After that the soaked fibers washed with distilled water until pH 7. The fibers were dried in the oven at 50°C for 24 hours. Sodium hydroxide, NaOH, sodium dodecyl sulfate, SDS was purchased from Carlo Erba reagent.

2.2 Method

2.2.1 The preparation of pineapple leaf fiber bound with natural rubber latex (PF/NRL)

The pineapple leaf fibers were bound together with natural rubber latex in various percentages of 40%, 30% and 20%. All the samples were fabricated at constant thickness of 50 mm by casting, following the standard thickness of synthetic acoustic panels that are available in the commercial market. Since the thickness has influence on the sound absorption coefficient of the material (Ismail, Ghazali, Mahzan, & Zaidi, 2010).

2.2.2 Bulk density

The specific density of the PL/NRL is determined from the principle of Archimedes. The weight of the dry fiber sample was measured and recorded by placing it on the weight tray, then, PL/NRL was placed into the water and the weight of the immerse fiber sample was recorded using equation (1).

Figure 1. Pineapple plant at a pineapple farm in Prachuapkhirikhan province, Thailand.

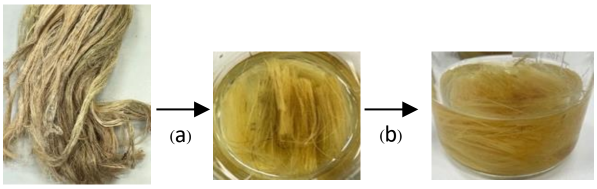

Figure 2. The extraction steps of pineapple leaf fiber following by dewaxation of the fiber (a) and alkaline treatment (b).

$$\rho = \frac{W_d}{W_d - W_s} - \rho_w \tag{1}$$

Where, W_d is the weight of a dry sample in grams. W_s belongs to the weight of the sample saturated in water and ρ_w is density of water.

2.2.3 Porosity

In sound absorption mechanism terms, porosity is an important factor that influences the sound absorption. Since there are many researchers who have declared the importance of porosity on calculating the acoustical absorptive properties of porous material (Biot, 1962). The measurement of the open porosity was performed using the same Archimedes principle as porosity indicator by using equation (2).

$$\emptyset = \frac{W_d}{W_s} \tag{2}$$

Sound absorption coefficient (SAC)

The acoustic analysis of pineapple leaf fiber bound with natural rubber latex (PL/NRL) was performed by Impedance tube following ASTM E1050. Sound absorption coefficient (SAC) is the fraction of sound energy absorbed by the materials, which represents a value ranging from 0 to 1. It is

Suan Sunandha Science and Technology Journal

the ratio of absorbed energy to incident energy, represented by α in equation (3)

$$\alpha = 1 - \frac{E_r}{E_i} \quad (3)$$

Where Er is the reflected acoustic power and Ei is the incident acoustic power**.**

The sound absorption was tested using ASTM E1050-09, with the two-way microphone**.** This test method covers the use of an impedance tube, also known as standing apparatus, for the measurement of impedance ratios and the normal incidence sound absorption coefficients of acoustical materials**.**

3. Results and Discussion

Since the bulk density is a significant parameter that affects the sound absorption properties (Sreekala, Kumaran, Joseph, Jacob, & Thomas, 2000). The bulk densities of PF without and with NRL are tested and listed in Table 1. The results indicated that the density of pineapple leaf fiber was increased from 204.5 kg/m^3 to 773.5 kg/m^3 of pineapple leaf fiber bind with natural rubber latex at 40%. The increased pineapple leaf fiber content in natural rubber latex, the higher bulk density.

Table 1. The physical characteristics of pineapple leaf fiber bind with natural rubber latex.

Ratio PF/NRL (%)	Density (kg/m^3)	Porosity	Average Diameter (µm)
40	773.5	0.56	18.8
30	636.1	0.69	17.3
20	513.9	0.78	15.2
0	204.5	0.88	11.9

The porosity of PF/NRL was increased while the pineapple leaf fiber content was decreased (Table 1). The PF/NRL at 40% of binder showed the lowest porosity compared to PF/NRL at 30% and 20%. It is because the gab of fiber is less existing due to the higher percentage of binder cover up and dissolves in the pore and micro gaps inside the sample.

The surface morphology of treatment pineapple leaf fiber was analyzed by scanning electron microscope (SEM). Figure 3 shows SEM micrograph of treated pineapple leaf fiber with 5 wt% of NaOH. The treated fiber had a rough surface. Furthermore, the treatment also has an effect on the fiber, the amount of cellulose exposed on the fiber surface increased, and the surface roughness increased. This condition promotes better interlocking between binder and fiber. Moreover, the porous structure was observed in NaOH treatment. These porous structures bonded to the natural rubber latex that melted and interlock together.

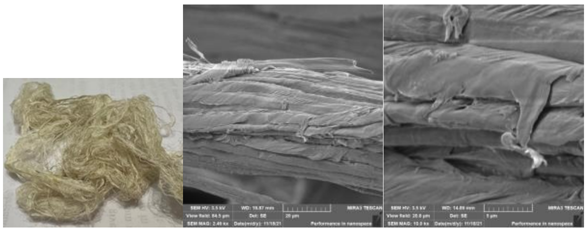

Figure 3. Picture image of the pineapple leaf fiber surface which treated with 5 wt% NaOH **(**a**)**, Scanning electron micrographs at 2 kx **(**b**)** and 10 kx **(**c**).**

The sound adsorption coefficient of PF/NRL was measured from impedance tube test on 40% 30% and 20% of binder**.** The results showed in Figure 2. Since the sound absorption coefficient is dependent on the sound frequency. Therefore, the absorption coefficient frequency Hz curves were plotted by the mean values of samples for each binder percentage group**.** From the results, the NF/NRL0% shows the different results compared to others; that is, cover up mid-low **(**1500 Hz**)** and high (4500 Hz) frequency**.** It is indicated that at 1500 Hz and above 4500 Hz frequency, the sound absorption coefficient of the NF/NRL0% nearly reaches 0.8. Even the PF without binder showed a good coefficient value but the frequency was still below 1000Hz when compared with binding with binder**.** The coefficient values of PF/NRL20%, PF/NRL30% and PF/NRL40% were slightly increased, nearly 1.0 at lower 1000Hz. amount the binder content, the PF/NRL20% showed the highest absorption coefficient value at 0.98 due to the high porosity of PF/NRL20%. This result suggested the pineapple leaf fiber bound with natural rubber would be suitable for using in low sound frequency application.

Suan Sunandha Science and Technology Journal

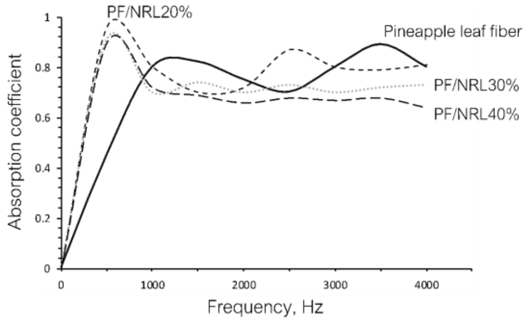

Figure 4. Absorption coefficient as a function of frequency of PF with and without NRL binder.

4. Conclusion

In this work, the pineapple leaf fiber bonded with natural rubber latex was successfully prepared by vary amount of natural rubber latex which acted as a binder**.** The sound absorption coefficient of the samples was investigated**.** The results indicated that the density and porosity of PF/NRL were playing an important role to improve the sound absorption**.** The PF/NRL20% showed the highest absorption coefficient value due the effect of density and porosity, while the absorption peak was slightly moved toward lower frequencies. It was the preliminary founding of sound isolation of pineapple leaf fiber bonded with natural rubber. More research should be done for preparing sound absorption material at low frequency in next work.

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