Production of Thermal Insulator from Water Hyacinth Fiber and Natural Rubber Latex

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ABSTRACT

Aquatic weeds as raw materials for thermal insulator are considered as great advantages of the utilization of the weeds to conserve energy and environment as well as economic benefits. In this work, an environmental-friendly thermal insulator made from water hyacinth fiber (aquatic weed) with natural rubber latex as binder was developed. The objective is to monitor and compare the physical properties of different compositions between water hyacinth fiber and natural rubber latex as well as to compare with commercial insulators as fiberglass and rockwool. The results showed that the insulator with a density of 465-646 kg/m^3 had the thermal conductivity values ranging from 0.0246-0.0305 W/m K, which was close to that of the commercial ones. Thus, this friendly insulation material is a good candidate for insulation in building. However, moisture content and water absorption capacity of the material must be taken into account due to its higher moisture content and water absorption than that of the testing standard, TISI 876-2532.

Keywords: Thermal Insulator, Natural Rubber Latex, Water Hyacinth, Physical Properties

INTRODUCTION

Recently, the economic growth of the developing countries has resulted in rapid increasing of energy consumption in Thailand, for instance, the total electricity consumption increased by 1.6% as compared with that in the previous year, reaching the amount of 164,341 GWh in 2013. Generally, the electricity consumption is classified by economic sectors as industry, transportation, and commercial building & residential, and agriculture. Commercial and residential sectors consumed up to

41% of the national electricity consumption published by Energy Policy and Planning Office (EPPO, 2014).Air conditioning systems are essential for both sectors in maintaining good thermal environment. They consume about 30 – 60% of the building's energy for cooling and dehumidification purposes (Kwong and Ali, 2011). Thermal insulation materials play an essential role in achieving building's energy efficiency. There are many types of thermal insulation materials for buildings classified into 3 categories (Mohammad, 2005): (1) inorganic materials such as fibrous (glass, rock, and slag wool) and cellular (calcium silicate, bonded perlite, vermiculite, and ceramic products); (2) organic materials such as fibrous (cellulose, cotton, wood, pulp, cane, or synthetic fibers) and cellular (cork, foamed rubber, polystyrene, polyethylene, polyurethane, polyisocyanurate, and other polymers); (3) metallic or metalized reflective membranes. Among them, as environment-friendly and renewable materials, natural materials have numerous advantages over other materials and thus the most promising for building.

Water hyacinth with scientific name of *Eichhornia crassipesis* a free-floating aquatic plant of worldwide distribution, which has become anacute, persistent and expensive environmental problem due to its extremely rapid proliferation and congested growth (Ibrahim et al., 2012). In addition, it rapidly depletes nutrients and oxygen from water bodies, interferes with navigation, fishing, shipping, recreation, irrigation and hydropower generation, favors breeding zones for disease-causing insects, quickens evapotranspiration and reduces biodiversity, which, in turn, lead to adverse effects on the environment, flora, fauna, human health and economic development (Malik, 2007).However, the water hyacinth has high lingo cellulosic fibers (Methacanon et al., 2010) as shown in Table 1 consisting of three main constituents which are cellulose, hemicelluloses, and lignin. Cellulose is the main structural component that provides strength and stability to the plant cell walls. The amount of cellulose in fiber influences the properties and determines the utility of the fiber for various applications. Hemicelluloses are plant cell wall polysaccharides closely associated with cellulose, which consist of comparatively low molecular weight polysaccharides built up from hexoses, pentoses, and uronic acid residues. They are also mainly responsible for moisture sorption and biodegradation. Lignin is a highly cross linked molecular complex with amorphous structure and acts as glue between individual cells. The lignin content of the fibers influences the structure, properties, morphology, flexibility and rate of hydrolysis.

Table 1 Chemical composition of the water hyacinth fiber

Composition	Wt% on dry basis
Cellulose	52.20
Hemicelluloses	16.78
Lignin	9.42
Ash	12.14
Moisture	9.46

This research is to develop an insulation material from water hyacinth as aquatic weed and study factors in manufacturing thermal insulator from water hyacinth fiber (WHF) and natural rubber latex (NRL) as a binder by varying the ratio between WHF and NRL. In addition, its physical properties are tested. The results from this research can be used to develop a commercial product having the same quality with that of the insulators in the market. With this product, it can assist in reducing the manufacturing investment and environmental pollution.

METHODOLOGY

Fiber preparation

Water hyacinth dried under natural condition was cut into small pieces approximately 2 – 3 cm and then ground into a crusher to produce small fibers. The fibers as shown in Figure 1a were then boiled with 10 wt% concentration of sodium hydroxide (NaOH) solution at 100 °C for 20 min in order to achieve the soft fiber (Suankaeo, 2011). The boiled fibers were rinsed with water until they were clean from NaOH and then dried in the oven at 80 °C for 6 hours as shown in Figure 1b.

Figure 1 a) WHF after ground into crusher b) WHF after boiled in 10wt% sodium hydroxide and dried.

Latex preparation

Natural rubber latex (NRL) is chosen as a binder due to its good adhesion and high flexibility. In this preparation, NRL was stirred on the stirrer at temperature between 60 and 70 °C with the stirring speed of 50 – 60 rpm to remove ammonia and then added sulfur and toric A16 with amount of 2.4 g and 1.2 g respectively for its stability. The prepared latex was continuously stirred for 4 hours.

Manufacturing of the insulator

The prepared WHF were shaped using 2 forming containers for different property testing with the dimensions: 1) 10 cm-wide×10 cm-long×1.5 cm-thick, 2)15 cm-wide×15 cm-long× 1.5 cm-thick. The volume ratio between WHF and NRL shown in Table 2were mixed as shown in Figure 2a.After forming, each sample was pressed at 100 °C for 2 min and then oven-dried at 100 °C for 2 hours as shown in Figure 2b.

Table 2 The volume ratio of the WHF and NRL samples

WHF (g)	NRL (g)
70	130
	150
	170

Figure 2 a) WHF after mixing with NRL b) Mixed WHF after oven-drying

Thermal conductivity

The thermal conductivity of all studied samples with dimension of 15 cm×15 cm was measured at room temperature and normal pressure. The one-dimensional conduction heat transfer at steady state is applied as:

$$q = kA\frac{\Delta T}{\Delta x} \qquad (1)$$

where q is the steady-state heat (W), k is thermal conductivity (W/m K), A is the cross-sectional area of the samples (m^2), ΔT is the temperature difference between two sides of the samples (°C) and Δx is thickness of the samples (m) (Theodore et al., 2011).

The following property testing is conducted according to TISI 876-2532 published by Thai Industrial Standards Institute (TISI, 1989).

Density and moisture content

The samples with dimension of 10 cm-long × 10 cm-wide were measured by micrometer for their thickness in order to determine the density as in the following equation:

$$\rho = \frac{m}{V} \times 10^6 \qquad (2)$$

where ρ is density of sample (kg/m^2), m is weight of the sample (g), V is volume of the sample (mm^3).

The same samples were weighed before and after oven-drying at temperature of 103 ± 2 °C and then placed inside the desiccator until they cool down. Moisture content was estimated as follows:

$$MC = \frac{w_m - w_d}{w_d} \times 100 \quad (3)$$

where MC is the moisture content (%), w_m is the weight (g) before oven-drying and w_d is the weight (g) after oven-drying.

Water absorption and swelling

The samples with dimension of 10 cm-long × 10 cm-wide were used for water absorption and swelling testing. In these tests, there were two time intervals of water immersion, which were 2 hours and 24 hours. When the samples were immersed for 2 hours in the water at temperature of 20±1 °C with pH 6±1 after weighting, they were pressed with 3 kg plate for 30 sec and then weighed and measured for their thickness. After 2 hours immersion, they were continuously immersed for another 22 hours and the same procedures were followed for their measurement. The water absorption capacity was calculated as follows:

$$WA = \frac{w_a - w_b}{w_b} \times 100 \qquad (4)$$

where WA is the water absorption content (%), w_a is the weight (g) after immersion and w_b is the weight (g) before immersion.

And the swelling capacity is expressed as follows:

$$SW = \frac{th_a - th_b}{th_b} \times 100 \qquad (5)$$

where SW is the swelling capacity (%), th_a is the thickness (mm) after immersion and th_b is the thickness (mm) before immersion.

RESULTS AND DISCUSSIONS

Thermal conductivity and density

The thermal conductivity of all samples in this study was plotted as a function of NRL quantity as shown in Figure 3. It was found that by adding more amount of NRL in the samples tended to increase their thermal conductivity because the NRL reduced the air gap between the WHFs resulting in the high heat transfer. These experimental results agreed with that of other workers (Suankaeo, 2011 and Khudsee, 2011).When comparing their thermal conductivity with that of other thermal insulation materials as shown in Table 3, it was found that the WHF with NRL had a lower range of thermal conductivity than that of particle board from mixture of durian peel and coconut coir within in the same density range. Moreover, it also has slightly the same thermal conductivity range with insulation board from pineapple leaf fiber with NRL and commercial insulation materials which are fiberglass and rockwool. Therefore, it can be concluded that WHF with NRL is an excellent insulating material for building.

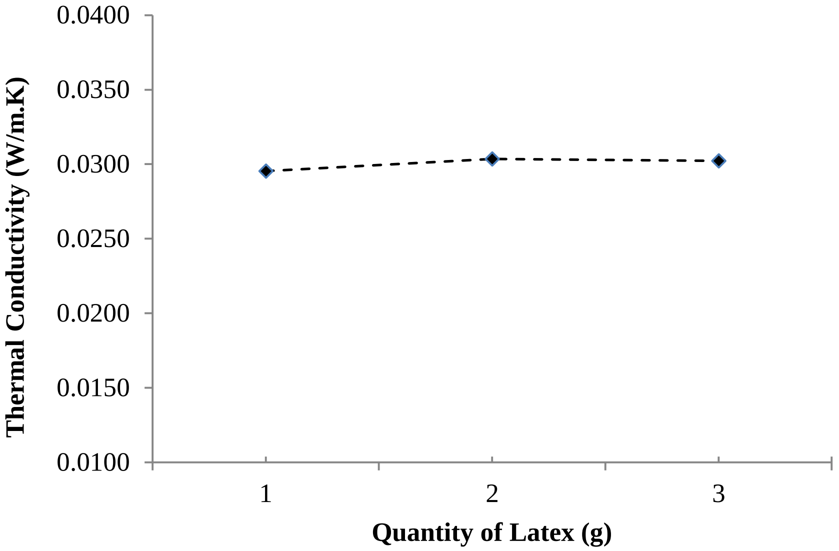

Figure 3 Thermal conductivity as a function of latex quantity

Table 3 Thermal conductivity and density of different thermal insulation materials

Materials	**Density (kg/m2)**	**Thermal conductivity (W/m K)**	**Source**
Insulation board from water hyacinth fiber with natural rubber latex	465-646	0.0246-0.0305	
Insulation board from pineapple leaf fiber with natural rubber latex	178-232	0.0223-0.0257	Suankaeo, 2011
Particle board from mixture of durian peel and coconut coir	311-611	0.0728-0.1117	Khedari et al., 2004
Fiberglass	24-120	0.0340-0.0470	Zou, 2008
Rockwool	80-200	0.0250-0.0350	Zou, 2008

Density and moisture content

The density and moisture content of the studied samples were measured according to the testing standard of TISI 876-2532. All of the experimental results are shown in Figure 4 and 5. It was found that when the quantity of NRL was increased, the density of the samples was also increased. Higher density tended to reduce the moisture content. However, only one sample having 70g of WHF and 170g of NRL met the testing-standard percentage of the moisture content in range of 9 – 15%.

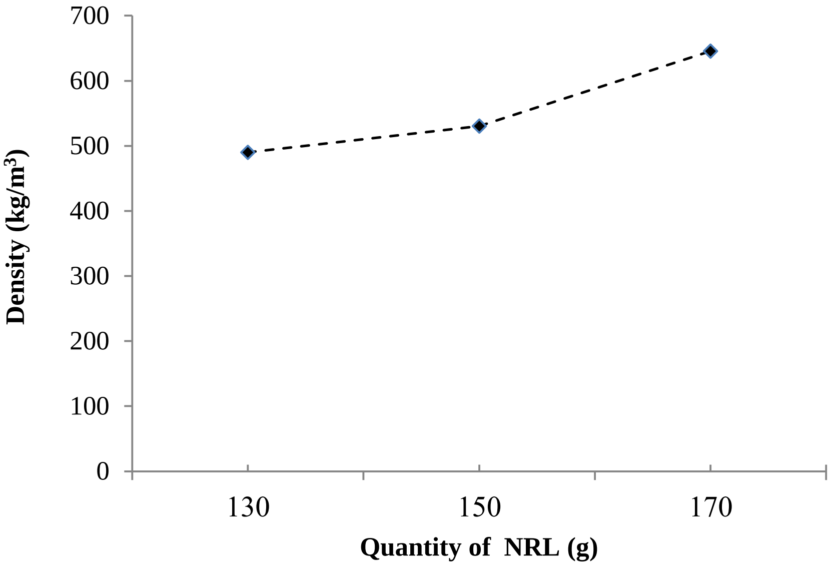

Figure 4 Density as a function of latex quantity

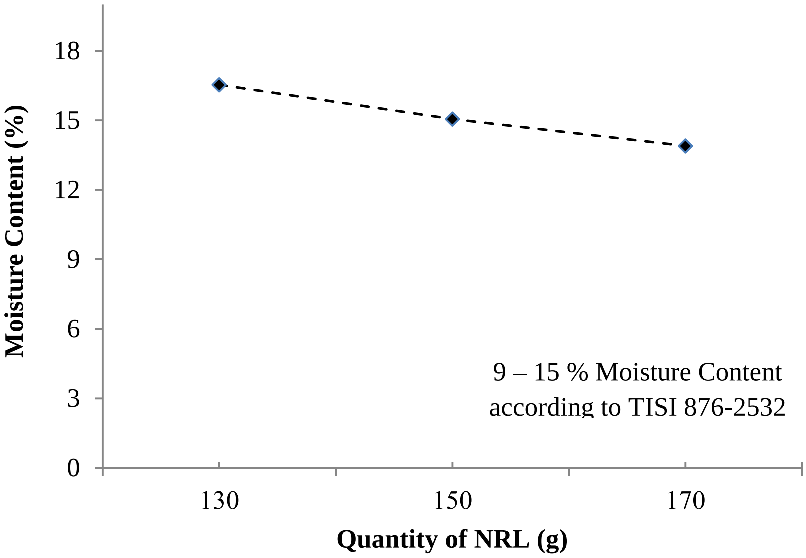

Figure 5 Moisture content as a function of latex quantity

3.3 Water absorption and swelling

All the samples were also tested for water absorption and swelling capacities according to the standard tests Their percentage of these capacities must be in range that is less than 40 % at 2 hours and less than 80 % at 24 hours for water absorption and less than 8 %at 2 hours and less than 12% at 24 hours for swelling. From the results, it was found that water absorption capacity decreased with increasing amount of NRL and also increased with longer immersion as shown in Figure 6. Only a few samples were capable to absorb the water within the required testing-standard ranges. The swelling capacity of the samples responds the same trend as that of the water absorption test All of the tested samples met the standard of the swelling test as shown in Figure 7.

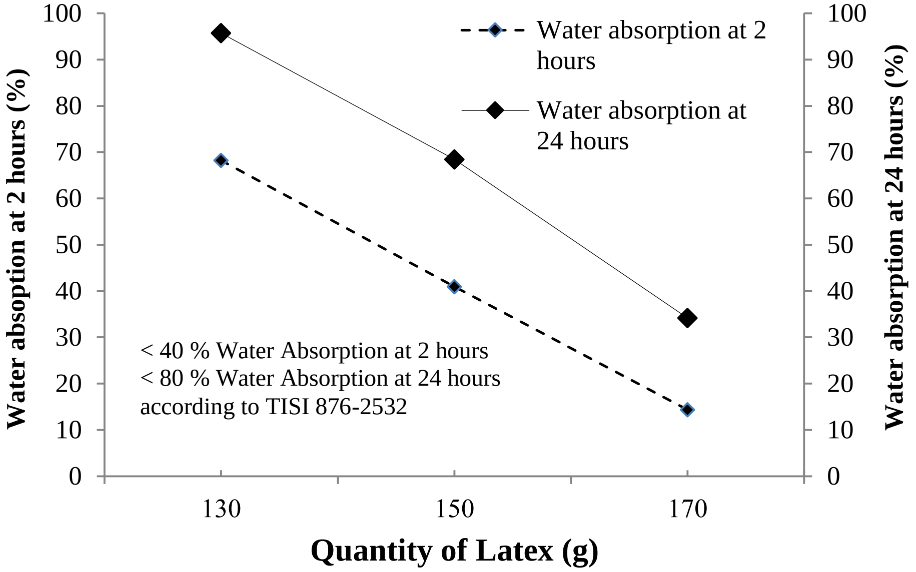

Figure 6 Water absorption capacity of the samples at 2 hours and 24 hours as a function of NRL quantity

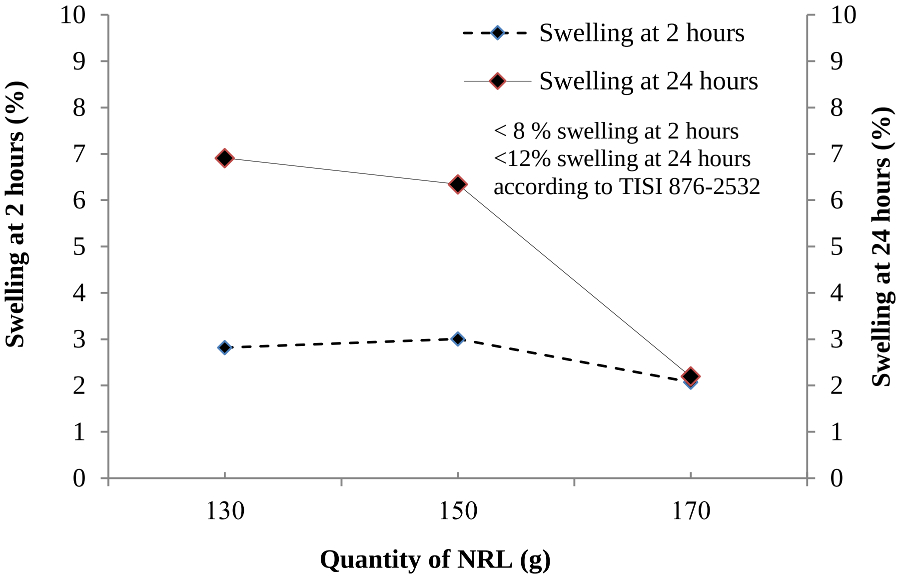

Figure 7 Swelling capacities of the samples at 2 hours and 24 hours as a function of NRL quantity

CONCLUSIONS

The insulation materials from water hyacinth as aquatic weed with natural rubber latex (NRL)were fabricated and tested for their physical properties such as thermal conductivity, density, moisture content, water absorption, and swelling capacity. The experimental results were shown that by adding amount of NRL resulted in increasing their thermal conductivity and density as well as decreasing moisture content, water absorption, swelling capacities. The studied samples are good candidate for thermal insulator as compared with that of fiberglass and rockwool. However, their moisture content and water absorption capacity would affect the usage of the insulation material.

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