

Full Length Research Paper

Thermal insulation and physical properties of particleboards from pineapple leaves

S. Tangjuank

Department of Science, Faculty of Science and Technology, Uttaradit Rajabhat University, Uttaradit, 53000, Thailand.
E-mail: singhadejt@yahoo.com. Tel: +6655 411096. Fax: +6655 411096.

Accepted 26 July, 2011

The aims of this research were to study the production processes and properties of thermal insulation produced from pineapple leaves using natural rubber latex as a binder. Thermal insulation boards were made by spraying the pretreated natural rubber latex onto pineapple fiber to form a squared thermal insulation with the size of 20 and 1.5 cm thickness. Test results on thermal and physical properties showed that the thermal insulation produced from pineapple leaves fiber exhibited a considerably good thermal insulation. The thermal conductivity of the thermal insulation was 0.035 W/m.K with density of 210 kg/m³, which was closed to the commercial insulator. The result showed that pineapple fibrous insulator was extremely potential to replace the synthesis fibrous insulator.

Key words: Agricultural residue, spray process, insulating boards, low thermal conductivity.

INTRODUCTION

The growth of population and global warming problem have lead to increase in energy consumption in many countries worldwide, due to increase in both building and comfort inside buildings for living (Omar and Mohammed, 2004; Yamtraipat et al., 2006; Radhi, 2008; Lombard et al., 2008). The rapid growth of energy use, and the fossil fuel used on daily bases have severe environmental impacts, that is, ozone layer depletion, global warming, climate change, etc. (Saidur, 2009). From an economic, energy and environment conservation point of view, building energy regulations such as, heating or air conditioning have a dire need (Iwaro and Mwashu, 2010; Aktacir et al., 2010). The energy consumption is very high in air-conditioning. The use of thermal insulation is regarded as one of the most energy efficient improvements in buildings and means of energy conservation in buildings. As the largest building component, the thermal insulation materials play an important role in achieving buildings' energy efficiency. This will result in decrease in the cost of cooling as well as decrease in pollution of the environment due to using energy hard. Commercial thermal insulators used generally for both

residential and commercial building are made of plastic foams, glass foams, mineral wools, rock wools, etc. The plastic foam is sometimes used as the core of a structural insulated panel by being sandwiched between oriented strand boards, and mineral wools that form a mat are often inserted into the airspace in walls. But the use of insulating materials is not popular, despite their long-term financial benefit, due to the fact that installation of such materials is expensive and requires skilled labour, and some concern is that they may be harmful to human health and body, and also cause environmental pollution, such as emissions of toxic gas and particle, and stick to skin (Liang and Ho, 2007). Because of the requirement of the environment safety and energy saving of the building, good thermal insulation materials are required. Considering the substitution of commercial synthetic materials, there is an interest in other renewable materials. The use of agro-fibres as thermal insulation to building sectors has increased interest in many countries. In previous works, the use of agricultural materials for particle board production from many different regions of the world, such as, coffee husk and hulls (Bekalo and Reinhardt, 2010), wood (Kawasaki and kawai, 2006), waste tea leaves (Shi et al., 2006; Yalinkilic et al., 1998), coconut husk (Viswanathan et al., 2000; Viswanathan et al., 2004), bagasse (Widyorini et al., 2005), cotton (Alma

Abbreviations: TS, Thickness swelling WA, water absorption.

et al., 2005) and oil palm (Abdul Khalil et al., 2007), not only provide a renewable material source and low thermal conductivity, but also generate a non food source of economical development for farming and rural areas. Therefore, this study concentrates on finding an alternative resource from locally available agricultural residues pineapple leaves to produce thermal insulation construction materials in board form. Traditionally in Thailand, after agriculturist's harvest of produce, the residues (stalk, pineapple leaves, etc.) are destroyed by burning. Burning the pineapple leaves also causes environmental problems such as pollution, soil erosion, and decreased soil biological activity. Therefore, industrial utilization (particleboards) of agricultural residues (pineapple leaves) does not only prevents air pollution due to burning of residues, which has adverse affect on air quality, human and environmental health, but is also economically profitable for agriculturists. The production of particleboards made from pineapple leaves is the idea to develop as a construction panel material with low thermal conductivity so as to reduce heat transfer into building in order to decrease the energy consumption of building facilities (air-condition). This will not only reduce the operation cost but also help to preserve the environment.

The study covers methods for efficient production of particleboards and physical properties of products made from pineapple leaves. In addition, the binder adhesive as natural rubber latex (free formaldehyde) which is of great interest from an environmental perspective, is chosen to produce particle boards, and the products are free from formaldehyde emission (The most widely used binders for particleboards are urea-formaldehyde, and emissions of toxic formaldehyde is harmful to human health and cause environmental pollution), which is especially suitable for interior construction use.

MATERIALS AND METHODS

Raw materials used in this study were pineapple leaves, which were collected from Uttaradit province located in the Northern part of Thailand. The pineapple leaves were cut to a length of approximately 20 cm by hand, and soaked into 10 wt% NaOH solution for 30 min to obtain soften fibers, and then dried in oven at 80°C for 12 h. The dried samples were cut into particle pieces of 2-5 mm length by commercial grinders. All particles were again oven-dried at 80°C for 12 h and are used for particle board's preparation.

Three types of boards were prepared with particle: binder ratios of 1:2, 1:3 and 1:4. The boards were made by spraying a binder (as the pretreated natural rubber latex) on the pineapple leave particles to form a squared thermal insulation with the size of 20 and 1.5 cm thickness in a forming box (Figure 1). After forming, the board was cut into various test samples. Each measurement was the average of three samples cut from each three different boards. The tests applied on the samples were density, water absorption, thickness swelling, fire-resistance and thermal conductivity. The tests were based on the JISA 5905, ASTM D 635-98 and ASTM C177-97 for measurement of density, water

absorption, thickness swelling, fire- resistance and thermal conductivity, respectively. Microstructures analysis was also performed on surface of boards by scanning electron microscopy.

RESULTS AND DISCUSSION

Physical properties

SEM micrographs of pineapple leave particleboards with different proportions of particle/binder are shown in Figure 2. The SEM micrograph reveals fibrous network structure with many pores on the surface of all boards. On observation of the board surface prepared with 1:4 ratio (Figure 2c), it showed a great deal of binder on the surface and dispersed into spaces between fibers in mat, but the distribution was non-uniform. However, a great amount of binder on the surface which the voids are closed, leading to the increase of the board density. As the case of the 1:2 (Figure 2a) and 1:3 ratios (Figure 2b) there was more distribution of binder into the mat, where the 1:3 ratio has the best distribution, and a good fiber orientation. However, it is seen that the fibrils were not bonded strongly with each other and could be easily separated, which resulted in poor density of boards. This is the effect of the preparation process, which is performed by hand and without pressing by machine. Correspondingly, in a study by Zhou et al. (2010) for cotton stalk fibers, the high pressing temperature and time during hot-pressing will increase the lignin fluidity of fibers to help form better inter-fiber bonds.

The test results of the physical properties such as moisture contents, density, thickness swelling (TS) and water absorption (WA) are given in Table 1. From Table 1, it is shown that the moisture content was inversely proportional to the density of boards. The average moisture contents of boards were 4.99, 4.52 and 3.77 for 1:2, 1:3 and 1:4 ratios, respectively. This is because the lower density board has higher voids and space in the mat. As a result, the lower density board can absorb more moisture. The density of board is found to be increased with increasing content of binder. Average densities of boards were 178, 210 and 232 kg/m³ for boards bonded with particle: binder ratio of 1:2, 1:3 and 1:4, respectively. This observed from SEM, where board of higher binder had lower void in board. This is because the binder is cured more effectively in the void spaces. Since, the high porosity is related to the low density board, and the board made from higher binder has higher density. The results of the TS and WA tests shown in Table 1 were measured after 2 and 24 h immersion in distilled water at 20°C, following the JIS A 5905 standard (1994). Three boards were tested for each soaking time and for each board type (in total, 3×2×3 = 18 boards). The WA values in this study were relatively high owing to the porous character of the low-density board. This is due to porosity of the low-density board, which absorbs more

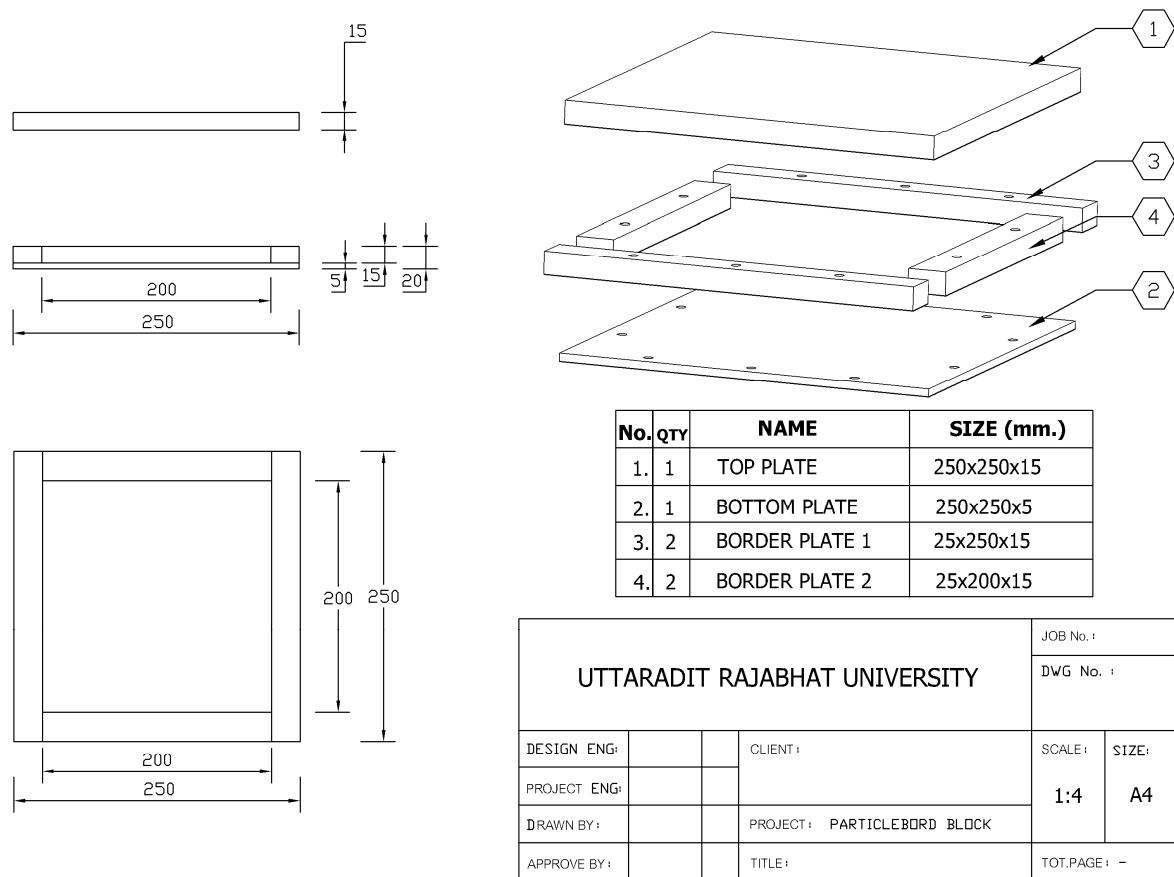


Figure 1. Diagram of forming box for particleboards preparation.

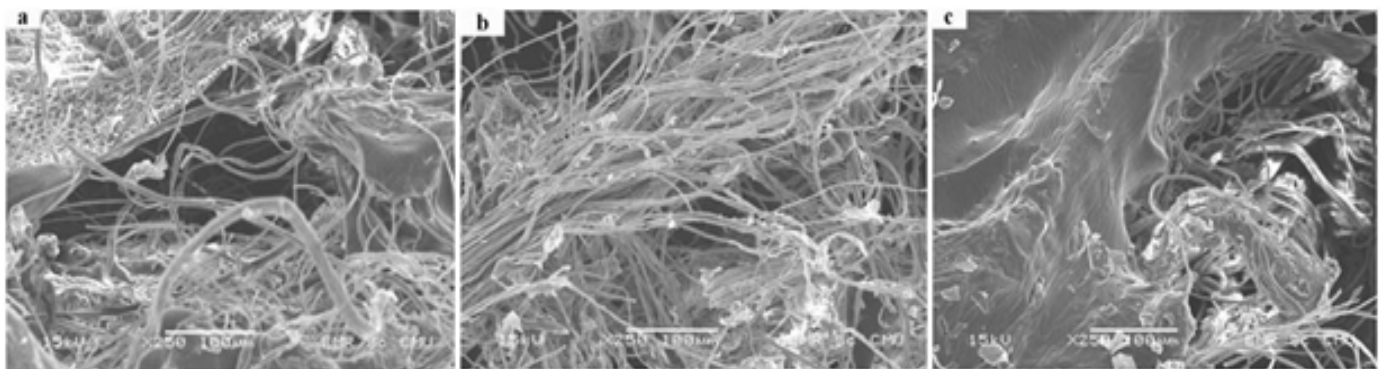


Figure 2. SEM micrographs of boards made with particle: binder ratio of : (a) 1:2, (b) 1:3 and (c) 1:4.

Table 1. The physical properties of particleboards.

Particle:Binder	Moisture contents (%)	Density (kg/m ³)	Water absorption (%)		Thickness swelling (%)	
			2 h	24 h	2 h	24 h
1:2	4.99	178	376	413	19	25
1:3	4.52	210	272	310	21	34
1:4	3.77	232	190	250	20	27

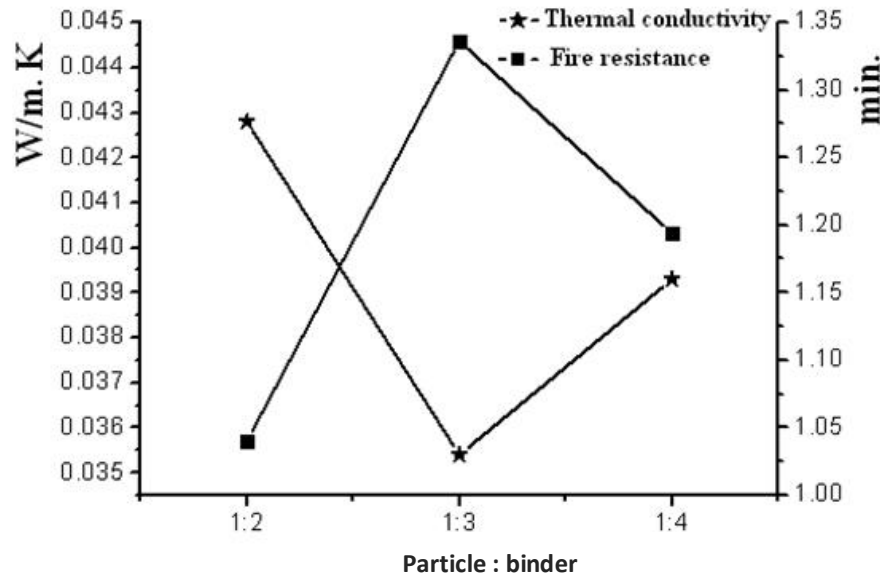


Figure 3. The results of the fire - resistance and the thermal conductivity versus particle: binder ratio.

water than the high-density board. The WA values decreased with increasing board density. The average of WA after 2 h immersion was 376, 272 and 190%, and after 24 h immersion was 413, 310 and 250% for the board density of 178, 210 and 232 kg/m³, respectively. TS average values of the boards are shown in Table 1. The percentage TS was greater in higher density board than the lower density board. This is because the more fibrous material in the higher density board can assist the more water absorption, and consequently increase the thickness and linear expansion after the absorption of the moisture. However, for the board used high binder between the particles in the mat, the binder is cured more effectively in the void spaces of the board and there is less water absorption. Thus, even the fibers absorb much water resulting in higher TS of high-density board, whereas WA decreases because of limited void spaces. The minimum TS of 19% along thickness was for the board density of 178 kg/m³ for 2 h soaking and the maximum of 34% for the board density of 210 kg/m³ for 24 h soaking. The WA and TS values of this study were rather similar to those of low density boards made of other lignocellulosic materials such as, kenaf core (Xu et al., 2004) and durian peel (Khedari et al., 2003). The WA and TS were reported as 355 and 6.6% for kenaf core with board density of 200 kg/m³, and 152 and 22% for durian peel with board density of 366 kg/m³. However, the TS and WA values of boards obtained from this work were higher than those of insulation materials which were required in the Japanese Industrial Standard (JIS A 5905). This is the effect of the low density of the board, which was manufactured without using a compression

molding machine. Therefore, an increase of particleboard density could improve the physical properties to meet the standard value, as found in the boards produced from waste tea leaves (Yalinkilic et al., 1998), rubberwood (Loh et al., 2010) and wheat straw (Tabarsa et al., 2011).

Thermal properties

There are many parameters for selecting thermal insulation such as, durability, cost, thermal conductivity, ease of application and fire resistance (Al-Homoud, 2005). However, the fire resistance of the board is the most important property which presents the capability of flame spread retardation and can be considered for interior applications such as ceiling and wall. The results of the fire resistance are shown in Figure 3. The fire resistance was measured according to the ASTM D 635-98 standard. The board prepared with 1:3 ratios of particle: binder showed the best fire resistance (1.34 min).

The relationship between thermal conductivity values with board density for the different bonded boards is showed in Figure 3. It is seen that the thermal conductivity values are directly related to the density of the board, the highest density boards having the least insulating effect. This is due to the fact that the low-density board contains a large number of voids filled with air, which is one of the poorest conductors (Zhou et al., 2010). Thus the lower density boards conduct less heat than the higher density boards. As shown in Figure 3, at a density of 178, 210 and 232 kg/m³, the k values of the

board were 0.043, 0.035 and 0.039 W/mK, respectively. However, on confusion of the board of 1:2 ratio, this is due to the water content in the mat increases which leads to a good heat transfer and thus the thermal conductivity increases (Agoudjil et al., 2011). For comparison of thermal properties of various materials, It can be seen that the k of the pineapple leaf particleboard is close to that of fiber glass wool (0.039 W/mK) and polystyrene foams (0.041 W/mK) (Dai et al., 2005) and slightly higher than that of polyurethane (Al-Ajlan, 2006). However, this value is about 3 times lower than that of coffee husk and hulls boards (0.110 W/mK) (Bekalo and Reinhardt, 2010), 2.5 times lower than of plywood-faced sandwich (0.089 W/mK) (Dai et al., 2005), and 4 times lower than that of lightweight concrete (0.155 W/mK) (Al-Ajlan, 2006). Note that, materials with the thermal conductivity less than 0.25 W/mK are generally seen as thermal insulations (Zhou et al., 2010). Therefore, it can be concluded that the pineapple leaf particleboards are excellent materials for thermal insulators and this is also consistent with the previous work for Low-density straw panels (Sampathrajan et al., 1992).

Conclusions

The study clearly suggests that the application of pineapple leaves in building construction is practicable. The important conclusions can be focused as follow:

1. The particleboard can be manufactured by spraying the pretreated natural rubber latex onto pineapple fiber with board densities ranging from 178-232 kg/m³.
2. The thermal conductivity of the boards was fairly low varying between 0.043 and 0.035 W/mK.
3. For overall consideration of the thermal conductivity and physical properties of the pineapple leaves particleboard, the boards with particle: binder ratios of 1:3 with density of 210 kg/m³ are promising building materials for thermal insulation applications for energy saving.

ACKNOWLEDGMENT

The authors thank the Lower North Research Network for financial support.

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