A Study of the Roofing Tiles Product Properties Manufactured From Natural Fibers Residues

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Abstract

The objective of this work is aimed to study the roofing tiles product manufactured from natural fibers residues. The natural fibers residues in this work are kenaf fiber, corn cob fiber and palm fruit bunch fiber. Urea formaldehyde resin adhesive was selected as the binder. The properties of study were physical based on JIS A 5908-2003, mechanical based on TIS 535-2540 and ASTM D 256-2006a, thermal conductivity based on ASTM C 117-2010 and SEM technique was used to investigate the microstructural characteristics. Consequently, this work shows a compared to the properties of commercial roofing tiles in Thailand. The study results revealed that physical, mechanical, thermal conductivity and microstructural characteristics of the roofing tiles product are accordance with the standard test requirements. Finally, it was found that the roofing tiles product properties manufactured from natural fiber residues in this work are similar to commercial roofing tiles in Thailand.

Keywords : Roofing Tiles, Natural Fiber Residues, Roofing Tiles Properties, SEM Technique

I. Introduction

Nowadays, the demand of energy and natural resources in Thailand tends to increase steadily dues to the growth of the development of this country. The increasing number of publications during the recent years including reviews and reflectthe growing importance of these new biocomposites (Summerscales J et al., 2010 and Hassan A et al., 2010). Hence, the development of roofing tiles product from natural fiber residues becomes as an alternative to energy and environment conservation as well as economy. Since Thailand is an agricultural country, it has plenty of natural fiber residues such as straw, kenaf, corncobs, bagasse pulp fiber, water hyacinth, sisal, palm fruit bunch and oil palm fiber. Therefore, the researcher has researched how to recycle these natural fiber residues materials, in hoping that it will help decrease the demand of using natural resoures. At the beginning, many kinds of natural fiber residues were recycled and reused ; for example, sugarcane plup was blended in plywood. The results of testing showed that the strength and the ability to absorb moisture of this type of plywood were closed to other kinds of plywood in markets in two factors. First, it corresponded to the previous studied about the possibility of crop residues roofing tiles manufacturing by binding corncob husks and bagasses fibers. Second, the finding also showed that testing thermal roofing tiles with urea formaldehyde resin at the 10 percentages, the thermal conductivity average was 0.013 W/m.K. At the 13 percentages of binding adhesive; phenol formaldehyde resin, the thermal conductivity average was 0.015 W/m.K. and at the 7 percentages of binding adhesive; isometric cyanate resin, the thermal conductivity average was 0.012 W/m.K. (Arkom Pasilo and Umphisak Teeboonma, 2007, 2015 and 2016).

The material composition of fibers and adhesive are also contributed to higher heating bills. The increased density of the roofing tiles will result in parts that are mixed with adhesive. If the roofing tiles has low density, it will cause more rooms and make low thermal conductivity. On the other hand, if the extrusion roofing tiles has higher density, it will get high thermal conductivity, while the heat resistance is low. However, the thermal conductivity of each materials also depends on the structure of the materials, in particular, crystalline shape and the temperature during the extrusion (ASTM Standards, 2010). As a result, the thermal conductivity differs from one material to others. The surface of building materials which expose directly to the outside air temperature and the sun light will absorb heat radiation. It makes this area get higher temperature than other surface areas. As a result, it causes the temperature differences between the outside air and the exposed surface of the exterior building materials. Thermal energy from this area is also transferred to some surface adjacent to a lower temperature by the amount of heat transferred in each direction based on the thermal resistance and the mass of the building (Standard Test, ASTM C 177-2010).

The objective of this work is aimed to study the roofing tiles product are manufactured from natural fibers residues. The natural fibers residues in this work are kenaf fiber, corn cob fiber and palm fruit bunch fiber. Urea formaldehyde resin adhesive was selected as the binder. They were mixed with other content 12 percentages. The properties of study were physical based on JIS A 5908-2003, mechanical based on TIS 535-2540 and ASTM D 256-2006a, thermal conductivity based on ASTM C 117-2010 and The microstructure of the SEM technique was used to investigate the microstructural characteristics in a Hitachi S-4800 microscope using an acceleration voltage of 5 kV. The porosity of polished surfaces was evaluated using Esprit 2 image analysis software. For the working distance about 20 mm. Consequently, these properties were compared to the properties of commercial roofing tiles in Thailand.

EXPERIMENTAL DETILES

The specimens that using in this study are made form as a natural fibers residues. The natural fibers residues are kenaf fiber, corn cob fiber and palm fruit bunch fiber.
The natural fibers residues were cut in small size and cleaned of any impurity that impede the production of roofing tiles.

Table 1. Characteristics of natural fiber

Materials	Chemical composition		
	Cellulose (wt %)	Hemicellulose (wt %)	Lignin (wt %)
Kenaf	72	20.3	-
Corn cob	32-43	0.15-0.25	-
Palm fruit	65	-	-
Rice straw	41-57	19-25	8-38
Pineapple	81	-	-
Sisal	65	12	2

The natural fiber reinforced polymer composites performance depends on several factors, including fibers chemical composition, cell dimensions, microfibrillar angle, structure, defects, physical properties, and mechanical properties, and also the interaction of a fiber with the polymer. In order to expand the use of natural fibers for composites and improved their performance, it is essential to know the fiber characteristics. The chemical components are distributed throughout the cell wall which is composed of primary and secondary wall layers. "Table 1". shows the range of the average chemical constituents for a wide varity of plant types (Hattallia S et al., 2002 and Hoareau W et al., 2004).

The selection of fiber in accordance with selection criteria all the strand fibers were cut in lengths varying from 20-40 mm. The volume fraction fiber about is 2 percentages for one of series produced, looking for a synergetic effect between fiber of different lengths. The humidity of specimens is 40 – 50 percentages by wet with solid catalyst coating and waterproofing. The form sheet preparation product of roofing tiles before the hot press foamed process were mixture compaction and hydraulic moulding of the composite.

Fig. 1. The extrusion process of roofing tiles

In the experimental set up, several body formulation were prepared. Each mixture was wet-ground in a jet mill long enough until the natural fibers residue about 1-2 mm sieve was reduced to required values. The obtained slips were first allowed to dry in an oven at around 110 ^{o}C, then deagglomerated and humidified (5-6 wt. % moisture content) and finally sieved down to 1 mm before forming. The roofing tiles froming process were uses the dry form process by heating to cause bonding between the natural fibers material with binder. The extrusion process of roofing tiles product and experimental setup could be show in "Fig 1".

Table 2. Standard test method of roofing tiles in this study

Property	Standard test
Physical : Density (D)	JIS A 5908-2003
Mechanical: Modulus of rupture (MOR) Modulus of elasticity (MOE)	 TIS 535-2540 ASTM D 256-2006a
(K) Thermal conductivity	ASTM C 117-2010

The specimens size that using in this study are 108 mm x 219 mm x 12 mm. The experimental were performed using the hydraulic 1,000 kN universal testing machine and using hot pressing process under pressure 180 kg/m^2. The temperature at 150 ^{o}C for 15 minutes. The density of 600 kg/m^3 and weight of 533.7 grams. The roofing tiles is extrusion process starts by sprinkling flax natural fiber materials; natural fibers residues from kenaf fiber, corncob fiber and palm fruit bunch fiber. Then, the composition of roofing tiles was mixed and compacted in hydraulic universal testing machine. The ready composition-filled specimens were, then, tested by extrusion roofing tiles process. The specimens are made in triplicate in order to repeat the test. Therefore, there are totally 27 pieces of specimen for each roofing tiles residues product composition. The property of roofing tiles manufactured from natural fiber residues is tested based on some standard specification test requirement listed as shown in "table 2".

II. Results and Discussion

The results obtained in the experiments are summarized in the density, the modulus of rupture, the modulus of elasticity, thermal conductivity and microstructural characteristics of the roofing tiles product manufactured from natural fibers residues.are accordance with the standard test requirements.

(a) (b) (c)

Fig. 2. The deformation histories of specimens

"Fig. 2. (a, b and c.)". Shows the deformation histories of specimens natural fiber residues were kenaf fiber, corn cob fibers and palm fruit bunch fiber. The specimens natural fiber residues were tested for each in order to receiver more accurate results. Similar progressive pattern was also observed in other specimens.

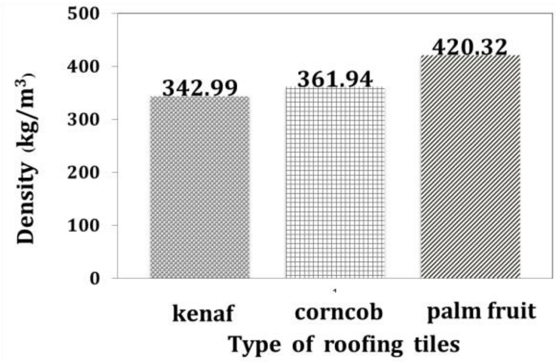

Fig. 3. The density (D) of roofing tiles

"Fig. 3". shows the experimental results revealed that roofing tiles product from kenaf fiber, corncob fiber and palm fruit bunch fiber properties were density (D) of 342.99 kg/m^3, 361.94 kg/m^3 and 420.32 kg/m^3, respectively. The specimens of roofing tiles were obtained from density test according to JIS A 5908-2003. The palm fruit bunch fiber was contained cellulose, a natural polymer, as the main reinforcement roofing tiles material. The chain of cellulose from microfibers, are held together by amorphous hemicellulose and from fibers. Comparing the density of roofing tiles extrusion of fibers. It was found that the major source of palm fruit bunch fiber are the most density, while kenaf fiber is the least density. This is because the fibers of palm fruit bunch fiber have a lot of bunch fiber and the pretreatment prior to fiber extrusion is stick to adhesive better and good density characteristics.

(Brahmakumar M et al., 2005, Chasemi I et al., 2009,Tajvidi M, et al., 2010, and Bettini SHP, 2010).

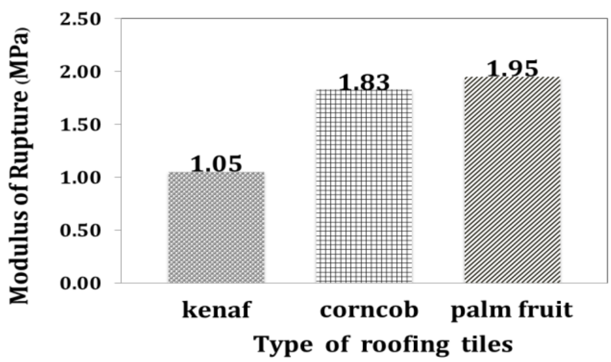

Fig. 4. The modulus of rupture (MOR) of roofing tiles

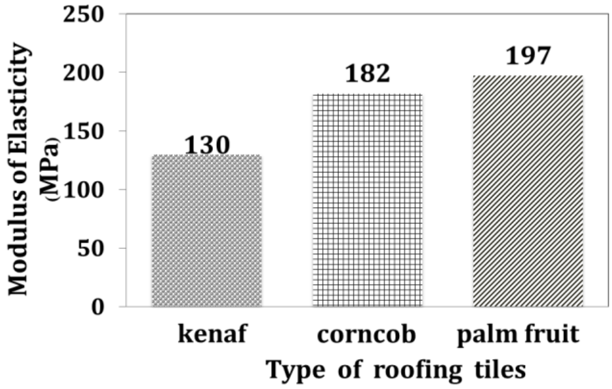

Fig. 5. The modulus of elasticity (MOE) of roofing tiles

The Mechanical properties of the roofing tiles specimens were obtained from strength test according to TIS 535-2540 and ASTM D 256-2006a. The experimental results revealed that roofing tiles specimens from kenaf fiber, corncob fiber and palm fruit bunch fiber properties were modulus of rupture (MOR) of 1.05 MPa, 1.83 MPa and 1.95 MPa. ,respectively. and modulus of elasticity (MOE) of 130 MPa, 182 MPa, 197 MPa and 199 MPa., respectively.

“Fig. 4 and 5”. shows the roofing tiles strength of a composite is influenced by many factors, including the toughness properties of the reinforcement, the nature of interfacial region and frictional work involved in pulling out the fiber from the matrix. The nature of the interface region is of extreme importance in determining the toughness of the composite.

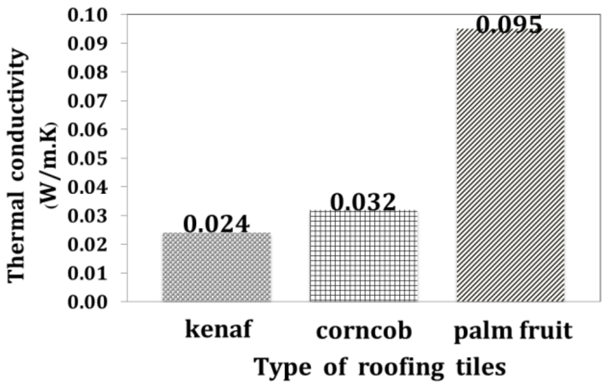

Fig. 6. Thermal conductivity (K) of roofing tiles

“Fig. 6”. shows the thermal conductivity (K) properties of roofing tiles specimens from kenaf fiber, corncob fiber and palm fruit bunch fiber which were also 0.024 W/m.K, 0.032 W/m.K and 0.095 W/m.K, respectively. The experimental results showed that the thermal conductivity properties of palm fruit bunch fiber has the best thermal conductivity followed by corncon fiber and kenaf fiber, respectively. Since the amount of adhesive to be added to the strand fibers bunch. the gaps or holes in the roofing tiles was getting smaller increasing the thermal conductivity.

(a)

(b)

(c)

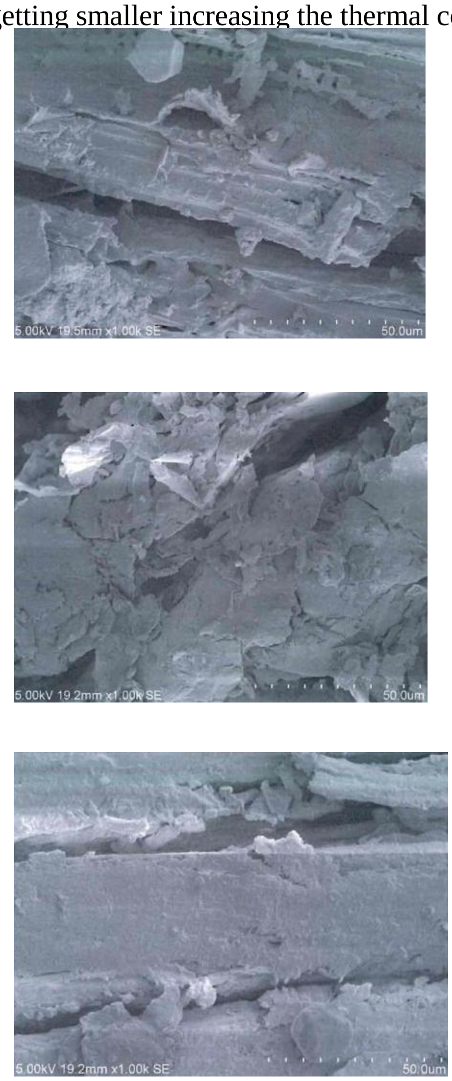

Fig. 7. The microstructure of roofing tiles : (a) kenaf fiber (b) corncob fiber and (c) palm fruit bunch fiber

“Fig. 7 a,b,c and d”. shows the scanning electron microscope (SEM) technique of the roofing tiles product manufactured from natural fibers residues specimens. The kenaf fiber by-product micrography have a strand of fibers and also with fibrillation striation through the length direction. The corncob fiber have a cylindrical shape with an external cellulosic cover, for strand protection against alkaline attack; superficial protuberances can also be seen, which help fiber anchorage in the reinforced matrix. The palm fruit bunch fiber presents particular morphology with fibrillated fibers quite altered by physical and mechanical procedures during the palm production. The palm fruit bunch fiber have a swollen cell wall containing more nano and micro hollows. The palm fruit bunch fiber in matrix affected slightly on enhancement mechanical properties of the composite specimens. In conclusion, these observations of the microstructure of the roofing tiles product of under the palm fruit bunch fiber were contained space for the most permeable adhesive penetrated into textile fibers as experimental, as the main reinforcement of the roofing tiles product strength followed by corncob fiber and kenaf fiber, respectively. The mechanical properties of roofing tiles and micro-mechanics of composites is shown in the SEM technique still contained the cellular residues such as lignin and hemicellulose, which roofing tiles fibers together. (Eichhorn SJ. and Young RJ., 2004, Antich P et al., 2006 and Omar F, et al., 2010).

Type of roofing tiles	Density (kg/m^3)	Thermal conductivity (W/m.K)	Remark
Kenaf fiber	600	0.024	Roofing tiles
Corncob fiber	600	0.032	
Palm fruit bunch fiber	600	0.095	
The roofing tiles : A	775	0.229	Commercial roofing tiles
The roofing tiles : B	745	0.030	
The roofing tiles : C	745	0.040	
The roofing tiles : D	885	0.041	

Table 3. Comparison of roofing tile

"Table 3". shows the comparison of the results of this study to the above standard test requirements. The roofing tiles product manufactured from kenaf fiber, corncob fiber and palm fruit bunch fiber was compared to the commercial roofing tiles in Thailand. The results was found that the roofing tiles product manufactured from the natural fibers residues were given a suitable performance and similar to commercial roofing tiles in Thailand.

III. Conclusions

This paper has studied the roofing tile products are manufactured from natural fibers residues. Found that the physical properties, mechanical properties, thermal properties performance and microstructural characteristics of the roofing tiles manufactured from natural fibers are accordance with the standard test requirements. The roofing tile products were then characterized and evaluated to determine the properties of the material and performance of the roofing tiles structures. Finally, It was found that the properties of roofing tiles product constructed in this work are similar to commercial roofing tiles in Thailand.

IV. Acknowledgment

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