Investigation of the Properties of Roofing Tiles Manufactured from Agricultural Residues

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Abstract. The objectives of this research were to study the properties of roofing tiles. The roofing tiles are manufactured from agricultural residues. The agricultural residues in this work are corn cob fibre, palm fruit bunch fibre and water hyacinth fibre. Synthetic urea formaldehyde resin adhesive was selected as the binder. The binder was mixed with other contents 20 percentages. Main properties of roofing tiles investigated in this work were physical, mechanical and thermal properties. Consequently, these properties were compared to the properties of commercial roofing tiles. The experimental results revealed that roofing tiles produced manufactured from corn cob fibre, palm fruit bunch fibre and water hyacinth fibre properties were density (D) of 361.94 kg/m\textsuperscript{3}, 420.32 kg/m\textsuperscript{3} and 581.31 kg/m\textsuperscript{3}, respectively. The modulus of rupture (MOR) of corn cob fibre, palm fruit bunch fibre and water hyacinth fibre, were 1.83 MPa, 1.92 MPa and 1.97 MPa, The modulus of elasticity (MOE) of corn cob fibre, palm fruit bunch fibre and water hyacinth fibre, were 182 MPa, 197 MPa and 199 MPa respectively. Thermal conductivity (K) properties of roofing tiles produced manufactured from corn cob fibre, palm fruit bunch fibre and water hyacinth fibre were also 0.032 W/m.K, 0.095 W/m.K and 0.098 W/m.K, respectively. Finally, it was found that the properties of roofing tiles constructed in this work are similar to commercial roofing tiles.

Introduction

Agricultural residues used as raw materials in the roofing tiles product are sugar cane, bagasse pulp fibre, water hyacinth, sisal, palm fruit bunch and oil palm fibre. They were applied to used in the same way as wood but they have to be separated some impurities such as dust, sugar pits and wax. These are often barriers to bonding adhesive especially synthetic water based solution. Nowadays, the demand of energy and natural resources in Thailand tends to increase steadily dues to the growth of the development of this country. Hence, the development of roofing tiles from corn residues becomes as an alternative to energy and environment conservation as well as economy. Since Thailand is an agricultural country, it has plenty of crop residues such as straw, corn cobs, bagasse pulp fibre, water hyacinth, sisal, palm fruit bunch and oil palm fibre. Therefore, the researcher has researched how to recycle these agricultural residues materials, in hoping that it will help decrease the demand of using natural resources. At the beginning, many kinds of crop residues were recycled and reused; for example, sugar cane pulp 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 corn cob husks and bagasses fibres. 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. [1-2]. This showed that it has good thermal conductivity properties. The material composition of fibres 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 [3]. 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 [4]. The objective of this study is aimed to investigate of the property of roofing tiles manufactured from agricultural residues. The raw materials of roofing tiles were corn cob fibre, palm fruit bunch fibre and water hyacinth fibre. Synthetic urea formaldehyde resin adhesive was selected as the binder. They were mixed with other content 12 percentages. Main properties of roofing tiles investigated in this study were physical, mechanical and thermal properties. Consequently, these properties were compared to the properties of commercial roofing tiles.

Materials and Methods

Materials

The specimens that using in this study are made from agricultural residues. The agricultural residues are corn cob fibre, palm fruit bunch fibre and water hyacinth fibre. The fibres were cut in small size and cleaned of any impurity that impede the production of roofing tiles. The selection of fibre in accordance with selection criteria all the strand fibres were cut in lengths varying from 20-40 mm. The volume fraction fibre about is 2 percentages for one of series produced, looking for a synergetic effect between fibre of different lengths. The humidity 40 – 50 percentages by wet with solid catalyst coating and waterproofing. The form sheet preparation of roofing tiles before the hotpress foamed process were mixture compaction and hydraulic moulding of the composite. There is a considerable range of short length fibre residues [5], without use for textile or cordage industries, but still adequate as brittle matrices reinforcement. The strand fibres are affected by environment temperature and humidity, and also by the medium in which they are immersed, due to the hemicellulose and lignin decomposition [6]. These components are present in the intercellular layers and their decomposition reduces the reinforcement capacity of the individual fibres.

![Figure 1. Illustrate the moulding design of roofing tiles and experimental set up.](image)

Experimental Procedures

In the first part of the experimental study, several body formulation were prepared. Each mixture was wet-ground in a jet mill long enough until the 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 °C, then deagglomerated and humidified (5-6 wt.% moisture content) and finally sieved down to 1 mm before forming [7-8]. The roofing tiles forming process were uses the dry form (Dry process) by heating to cause bonding between the fibres material with adhesive. The illustrate the moulding design of roofing tiles and experimental setup are shown Figure 1.
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 °C for 15 minutes. The density of 600 kg/m$^3$ and weight of 533.7 g. The roofing tiles is extrusion process starts by sprinkling flax fibre materials; fibres from corncob fibre, plam fruit bunch fibre and water hyacinth fibre. Then, the composition was mixed and compacted in hydraulic pressing moulding machine. The ready composition-filled specimens were, then, tested by extrusion roofing tiles process. The experimental were performed using hydraulic hot pressing process. The specimens are made in triplicate in order to repeat the test. Therefore, there are totally 27 pieces of specimen for each composition. The experimental was stopped when the specimens extrusion roofing tiles until completed. The property of roofing tiles is tested based on some standard test listed in table 1.

Table 1. Standard test method of roofing tiles in this study.

<table>
<thead>
<tr>
<th>Property</th>
<th>Standard test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (D)</td>
<td>JIS A 5908-2003, TIS 876-2547</td>
</tr>
<tr>
<td>Modulus of rupture (MOR)</td>
<td>TIS 535-2540</td>
</tr>
<tr>
<td>Modulus of elasticity (MOE)</td>
<td>ASTM D 256 - 2006</td>
</tr>
<tr>
<td>Thermal conductivity (K)</td>
<td>ASTM C 117-2010</td>
</tr>
</tbody>
</table>

Results and Discussion

Example deformation histories of some specimens are shown in Figure 2. The deformation of specimens were corncob fibres, plam fruit bunch fibre and water hyacinth fibre. Three specimens were tested for each in order to receive more accurate results. Similar progressive pattern was also observed in other specimens.

Physical and Mechanical Properties

This roofing tiles is also observed in specimens tested in the present. Figure 3, the experimental results revealed that roofing tiles produced from corncob fibre, plam fruit bunch fibre and water hyacinth fibre properties were density (D) of 361.94 kg/m$^3$, 420.32 kg/m$^3$ and 581.31 kg/m$^3$ respectively. The specimens of roofing tiles were obtained from density test according to JIS A 5908-2003 and TIS 876-2547. Water hyacinth fibre was contained cellulose, a natural polymer, as the main reinforcement roofing tiles material. The chain of cellulose from microfibres, are held together by amorphous hemicellulose and from fibres. Comparing the density of roofing tiles extrusion of fibres. It was found that the major source of water hyacinth fibre are the most density, while corncob fibre is the least density. This is because the fibres of water hyacinth fibre have a lot of bunch fibre and the pretreatment prior to fibre extrusion is stick to adhesive better and good density characteristics.
Figure 3. Deformation histories of specimens corresponding to density (D).

Figure 4 (a) and (b), the experimental results revealed that roofing tiles produced from corncob fibre, plam fruit bunch fibre and water hyacinth fibre properties were modulus of rupture (MOR) of 1.83 MPa, 1.92 MPa and 1.97 MPa respectively, and modulus of elasticity (MOE) of 182 MPa, 197 MPa and 199 MPa respectively. The mechanical properties of the roofing tiles specimens, i.e. modulus of rupture and modulus of elasticity, were obtained from strength test according to TIS 535-2540 and ASTM D 256 - 2006a. 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 fibre from the matrix. The nature of the interface region is of extreme importance in determining the toughness of the composite.

**Thermal Properties**

Figure 5 shows Thermal conductivity (K) properties of roofing tiles produced from corncob fibre, plam fruit bunch fibre and water hyacinth fibre which were also 0.032 W/m.K, 0.095 W/m.K and 0.098 W/m.K, respectively. The experimental results showed that the thermal conductivity properties of water hyacinth fibre has the best thermal conductivity followed by plam fruit bunch fibre and corncob fibre, respectively. Since the amount of adhesive to be added to the strand fibres bunch, the gaps or holes in the roofing tiles was getting smaller increasing the thermal conductivity.

Figure 5. Deformation histories of specimens corresponding to thermal conductivity (K).
Comparison to Commercial Materials

Table 2. Comparison of roofing tiles.

<table>
<thead>
<tr>
<th>Type of roofing tiles</th>
<th>Density (kg/m$^3$)</th>
<th>Thermal conductivity (W/m·K)</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn cob fibre</td>
<td>600</td>
<td>0.032</td>
<td>Roofing tiles</td>
</tr>
<tr>
<td>Plam fruit bunch fibre</td>
<td>600</td>
<td>0.095</td>
<td></td>
</tr>
<tr>
<td>Water hyacinth fibre</td>
<td>600</td>
<td>0.098</td>
<td></td>
</tr>
<tr>
<td>Roofing tiles : A</td>
<td>775</td>
<td>0.229</td>
<td>Commercial roofing tiles</td>
</tr>
<tr>
<td>Roofing tiles : B</td>
<td>745</td>
<td>0.030</td>
<td></td>
</tr>
<tr>
<td>Roofing tiles : C</td>
<td>745</td>
<td>0.040</td>
<td></td>
</tr>
<tr>
<td>Roofing tiles : D</td>
<td>885</td>
<td>0.041</td>
<td></td>
</tr>
</tbody>
</table>

Table 2 shows the comparing the results of this study to the above standard testing. The roofing tiles manufactured from corn cob fibre, plam fruit bunch fibre and water hyacinth fibre was compared to the commercial roofing tiles. The results was found that the properties of roofing tiles from manufactured fibres were given a suitable performance and similar to commercial roofing tiles.

Conclusions

This paper has studied investigation of the properties of roofing tiles manufactured from agricultural residues. Found that the physical, mechanical and thermal properties performance of roofing tiles made with these fibres composites is in accordance with standard requirements. Roofing tiles specimens 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 constructed in this work are similar to commercial roofing tiles.

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References


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