Coconut Coir Cement Board

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ABSTRACT

Natural organic fibers exist in reasonably large quantities in many countries of the world. Coconut coir fibers are widely available in Thailand. They are the seed-hair fiber obtained from the outer shell (endocarp) or husk of the coconut. In addition, coconut coir has low thermal conductivity. Using coconut coir cement board as a construction component with low thermal conductivity will reduce heat transferred into building which decrease energy consumption of building facilities (air condition). This will reduce the utility cost. Coconut coir cement boards are composites to alternative option to save energy consumption of building. The main parameter was investigated namely mixture ratio of coconut coir fiber, cement and water. Three mixing ratio by weight were varied 1:2:1, 1:1:1, and 2:1:2, respectively (cement : coconut coir : water). In this research, coconut coir fiber length of 0.5-1 cm. was used in coconut coir cement board production. In addition, boiled and washed pretreatment of coconut coir was obtained in fiber preparation. The specimens were cast in 350 mm. x 350 mm. x 10 mm. steel molds. After the cool pressing, the board was stacked and stored for 28 days in order to be completely cured, and then trimmed and cut into various test specimens. The investigation revealed that the optimum of mixture ratio is 2:1:2. The corresponding composite properties are as follows: thermal conductivity of 0.40 w/m K, MOR(Modulus of Rupture) of 19.94 MPa MOE(Modulus of Elasticity) of 5315 MPa internal bond of 0.73 MPa, thickness swelling of 3.64 MPa and 9.13 % moisture content. Examination of chemical composition analysis indicated that boiled and washed coconut coir fiber have high lignin and cellulose. High amount of lignin and cellulose would increase of the strength of composites.

Comparison of commercial board composite confirmed that the coconut coir-based lightweight composite have a low thermal conductivity. That is extremely interesting for energy saving with use as ceiling and wall material.

KEYWORDS

Coconut coir, Cement board, Fiber, Energy, Building

1 INTRODUCTION
Thailand located in the tropical zone. There are a huge amount of young coconut (Cocos nucifera). It is the most interesting product as it has the low thermal conductivity [Khedari 2000]. In additions, using coconut coir cement boards as a construction component with low thermal conductivity will reduce heat transferred into building which decrease energy consumption of building facilities (air condition). This will reduce the utility cost [Khedari 2002]. Energy has a significance influence in developing government, industrial and business sector of worldwide. Nowadays, energy price trends to be high. Thailand is the one of the country facing to this problem [Oranratnachai 1976]. Coconut coir cement boards are composites to alternate option to save energy consumption of building. In this work, investigation of difference mixture ratio between coconut coir and cement of low thermal conductivity cement composite board was the main objective.

2 EXPERIMENTAL SETUP

In this research, three board densities were considered for investigation: 0.8, 0.9, 1 g/cm$^3$ for coconut coir board. Three ratios used by weight were 1:2:1, 1:1:1, 2:1:2 (cement : coconut coir : water). The boards were made into three replicates for each combination. So there were 27 specimen boards (three board density x three ratios by weight x three replicates).

2.1 Raw materials

<table>
<thead>
<tr>
<th>Chemical composition</th>
<th>Coconut Coir fibre [%]</th>
<th>Boiled Coconut Coir fibre [%]</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash content</td>
<td>2.8</td>
<td>0.8</td>
<td>TAPPI-T211-om-93</td>
</tr>
<tr>
<td>Alcohol-benzene solubility</td>
<td>3.0</td>
<td>5.0</td>
<td>TAPPI-T204-cm-97</td>
</tr>
<tr>
<td>Lignin</td>
<td>32.1</td>
<td>32.7</td>
<td>TAPPI-T222-om-98</td>
</tr>
<tr>
<td>Holocellulose</td>
<td>68.9</td>
<td>73.9</td>
<td>Acid chlorite’s Browing</td>
</tr>
<tr>
<td>Alpha-cellulose</td>
<td>34.9</td>
<td>41.8</td>
<td>TAPPI-T203-cm-88</td>
</tr>
<tr>
<td>Hemi-cellulose</td>
<td>16.8</td>
<td>19.4</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 1 Chemical composition of not boiled coconut coir and boiled coconut coir fiber [4]

Coconut coir is the seed-hair fiber obtained from the outer shell (endocarp) or husk of the coconut. Chemical composition of coir is given in table 1. It can be seen that the coconut coir fiber contain a high lignin, holocellulose, alpha-cellulose, hemi-cellulose ratios. That makes fibers stiffer and tougher. The stiff and tough fibers are difficult to beat, do not conform and collapse against each other so well. It is necessary to know the basic and chemical properties of coconut coir before preparing sample. Information on the chemical compositions of coconut coir is important in order to understand cement board’ physical and mechanical properties. Actually, cement boards that have a high lignin content will be rather stronger with a high water-resistance.

2.2 Fiber preparation

Coconut coir fibers were cut into the length of 1-13 cm. They were boiled for 2 hours to extract the following water soluble chemicals: sugar, starch, fat, tannins, resin, quinines phenols and hemi cellulose. They are the coconut coir endo-substances. And then the fibers were washed with tap water. After they had been dried in solar radiation for 2 days, the fibers were cut into 0.5-1 cm. size.

2.3 Board preparation

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Fiber sample were mixed with cement and water in the ratios of cement : fiber sample : water, 1:2:1, 1:1:1, and 2:1:2 until homogenous. To obtained the coconut coir fiber cement boards, the mixture were compressed by cooling method with the pressure of 560 kg/cm² for 24 hrs. Cement, fiber and water ratio was varied to obtain boards of different density.

2.4 Specimen preparation and testing

After the cool pressing, the board were stacked in order to be completely cured for 28 days and then trimmed and cut into various test specimens. The specimens were conditioned in a conditioning room until they reached equilibrium for at least 2 weeks at room temperature. Afterwards, testing specimens were carried out according to JIS A 5908-1994 (Japanese Standard Association, 1994) for physical and mechanical properties (density, moisture content, water absorption, thickness swelling, modulus of rupture (MOR), modulus of elasticity (MOE) and internal bond). The thermal conductivity of the cement boards was measured by using JIS R 2618

2.5 Experimental apparatus according to JIS A 5908-1994

In this section, a brief description of testing equipments and method is presented. Universal testing machine (Instron type): was used for bending strength test (MOR): the testing method implies to apply a load of approximately 10 mm/min at a mean deformation speed from the surface of the test piece and to measure the maximum load (P). Next, calculate the bending strength of individual test piece from

\[
\text{Bending Strength} \left( \frac{N}{mm^2} \right) \left( \text{kgf/cm}^2 \right) = \frac{3P_m L}{2bt^2}
\]

Where \( P_m \) is the maximum load (N), (kgf), \( L \) the span (mm),(cm), \( b \) the width of test piece (mm),(cm), \( t \) the thickness of test piece (mm),(cm)

Breading load test (MOE): From the bending strength test, a graph which relates the maximum load (P) to the bending distance was plotted. The value of bending strength tests were calculated using the formula (2) when increasing load and bending distance using the liner line of the graph:

\[
\text{MOE} = \frac{L^2 \Delta W}{4bd^3 \Delta S}
\]

Where \( L \) is the span (mm), \( \Delta W \) the increasing load in the range of linear line of graph (N), \( \Delta S \) the increasing bending distance in the range of linear line of graph (mm), \( b \) the width of test specimen (mm), \( d \) the average thickness of specimen (mm).

Test of expansion ratio in thickness due to water absorption: First, measure the thickness in the center of a test piece (\( t_1 \)) to the nearest 0.05 mm with a dial gauge or a micrometer. Next immerse it in water at 20 ± 1° horizontally about 3 cm below the water surface for 24 h, take it out, wipe off the water and measure the thickness (\( t_2 \)) again in the same manner as above. Then, calculate the expansion ratio in thickness due to water absorption from the formula (3) below:

\[
\text{Expansion ratio in thickness} = \frac{t_2 - t_1}{t_1} \times 100
\]

Internal bond Measurement (Wolpert) for internal bond test: Adhere a test piece to steel or aluminum blocks. Apply a tension load vertically to the board face, measure the maximum load (\( P' \)) at the time of failing force (breading load of perpendicular tensile strength to the board), and calculate the
internal bond using the following equation (4). In this test, the tension loading speed shall be approximately 2 mm/min:

\[
\text{Internal bond} = \frac{P'}{(b \times L)}
\]  

(4)

Where, \(P'\) maximum load (N) \{kgf\} at the time failing force, \(b\) : width (mm) \{cm\} of test piece, \(L\) : length (mm) \{cm\} of test piece

3 Results and discussion

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Cement : Coconut coir : Water</td>
<td>Cement : Coconut coir : Water</td>
<td>[g]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 : 2 : 1</td>
<td>360 : 720 : 360</td>
<td>0.79</td>
<td>11.26</td>
<td>698.20</td>
<td>6.37</td>
<td>40.04</td>
<td>86.99</td>
<td>0.29</td>
<td>0.23</td>
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<tr>
<td>1 : 1 : 1</td>
<td>540 : 540 : 540</td>
<td>0.98</td>
<td>11.01</td>
<td>2266.03</td>
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<td>13.70</td>
<td>40.38</td>
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<td>720 : 360 : 720</td>
<td>1.16</td>
<td>10.12</td>
<td>4792.56</td>
<td>15.91</td>
<td>5.25</td>
<td>24.22</td>
<td>0.64</td>
<td>0.33</td>
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<tr>
<td>1 : 2 : 1</td>
<td>405 : 810 : 405</td>
<td>0.84</td>
<td>11.19</td>
<td>915.13</td>
<td>9.23</td>
<td>28.23</td>
<td>66.31</td>
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<td>0.24</td>
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<tr>
<td>1 : 1 : 1</td>
<td>607 : 607 : 607</td>
<td>1.03</td>
<td>10.98</td>
<td>2884.39</td>
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<td>10.66</td>
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<td>0.59</td>
<td>0.30</td>
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<tr>
<td>2 : 1 : 2</td>
<td>810 : 405 : 810</td>
<td>1.19</td>
<td>9.63</td>
<td>5031.14</td>
<td>17.60</td>
<td>4.04</td>
<td>21.25</td>
<td>0.69</td>
<td>0.40</td>
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<tr>
<td>1 : 2 : 1</td>
<td>450 : 900 : 450</td>
<td>0.87</td>
<td>11.02</td>
<td>1238.44</td>
<td>10.74</td>
<td>27.06</td>
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<td>1 : 1 : 1</td>
<td>680 : 680 : 680</td>
<td>1.03</td>
<td>10.65</td>
<td>2905.15</td>
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<td>35.20</td>
<td>0.68</td>
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<tr>
<td>2 : 1 : 2</td>
<td>900 : 450 : 900</td>
<td>1.22</td>
<td>9.13</td>
<td>5419.33</td>
<td>20.34</td>
<td>3.64</td>
<td>19.65</td>
<td>0.73</td>
<td>0.40</td>
</tr>
</tbody>
</table>

Table 2 Physical and mechanical properties of cement boards from coconut coir fibers.

Note: MC = Moisture Content, MOE = Modulus of Elasticity, MOR = Modulus of Rupture, TS = Thickness Swelling, WA = Water Absorption, IB = Internal Bond
Figure 1. Density of cement boards VS mixture ratio of cement and coconut coir and water

Figure 1. presents results of the mixture ratio of cement, coconut coir and water and total mass on board density. For the same total board mass, the density were changed with the increase of cement content in direct proportion. It was also increased with in increase total board mass. For the low total mass or light cement board (low density) have more space and void than high total mass or heavy cement boards (high density).

Figure 2. presents the effects of the total mass and cement mixture ratio on moisture content. The moisture content is inversely proportional to the total mass and cement content. It shows that high content of coconut coir provides high moisture content. With high content of cement, the internal bond between cement and cement can increase. The space and void of cement board decrease. A lower density yielded higher porosity, space and voids. Consequently, the moisture content increase when the porosity was increased.
MOE and MOR were varied when the content of cement in the mixture ratio and total mass was increased as shown in Fig 3 and Fig 4. This probably that the internal bond of cement in cement boards act as an adhesive and increase the strength of the cement bond. In addition, the high total mass or the high density board are stronger and stiffer than low total mass or low density cement boards.
The thickness swelling is inversely proportional to the increase of the cement content and total mass or density as shown in Fig 5. For the low total mass or low density have more space and void than high total mass or high density. Consequently, low total mass or low density of cement boards had a high thickness swelling while high total mass or high density of cement boards had a low thickness swelling value.

The water absorption is inversely proportional to the increase of the cement content, total mass of cement board or density of cement board as shown in Fig 6. Consequently, the higher proportion of cement, the lower of water absorption. This phenomena is caused by the low void space and higher internal bond between cement and cement than internal bond between cement and coconut coir fibers.

Figure 7. presents the effects of the mixture ratio and total mass on internal bond. It can be observed that the internal bond was changed when the cement mixture ratio and total mass of cement board or density were increased. Hence, an increase of total mass of cement board or density of cement boards accommodate a higher internal bond value. In addition, by considering the mixture ratio, if cement boards have a high content of cement, they will also have a high internal bond value. Consequently, the low total mass or low density of cement boards have more space and void than high total mass or density of cement board.
Figure 8. Thermal conductivity of cement boards VS mixture ratio of cement, and coconut coir and water

Figure 8 presents results of mixture ratio or the total mass on thermal conductivity. High total mass or high density cement boards have high thermal conductivity because space and void in cement board are decrease. For the same total mass, when the cement content is high, the thermal conductivity of the cement board is higher than that of the high coconut coir content. This is caused by the structure of board, whose porosity is closely dependent on the cement content. When measured thermal conductivity of the tested boards (0.4 W/mK) were compared to commercial board (Eterpan board 0.68 W/mK), it can be seen that the thermal conductivity of the boards tested was lower than that of commercial board, but it exceeded standard for Thailand (0.155 W/mK). Therefore, cement boards made from coconut coir have potential for development for using as an insulating component of building materials.

4 CONCLUSION

The development of randomly distributed short coir fiber reinforce cement composite with low thermal conductivity is the main purpose in this study. Main parameter was investigated namely mixture ratio of coconut coir fiber, cement and water. The optimum of mixture ratio is 2:1:2. The corresponding composite properties are as follows: thermal conductivity of 0.40, modulus of rupture (MOR) of 19.94 MPa, modulus of elasticity of 5,315 MPa, internal bond of 0.73 MPa, thickness swelling of 3.64 MPa and 9.13 % moisture content. These value showed the good properties of this cement board. Examination of chemical composition analysis indicated that boiled and washed coconut coir fiber have high lignin and cellulose. High amount of lignin and cellulose would increase of the strength of composites.

Comparison of commercial board composite confirmed that coconut coir-based lightweight composite have a low thermal conductivity. That is extremely interesting for energy saving with use as ceiling and wall material.

5 ACKNOWLEDGEMENTS

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6 REFERENCES

