Fire Resistance Performance of Coir Fibre-Reinforced Foamed Concrete Wall Panel

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The main objective of this paper is to study the effects of coir fibre (cocos nucifera) on the fire resistance properties of foamed concrete wall panel. Coir fibre-reinforced foamed concrete wall panel (CFRFCWP) was designed and casted based on the results obtained from the investigations done on mechanical and thermal properties. When designing a building, a very significant consideration on the behaviour of fire and ensures the elements of the structure will not collapse but hold back the fire for prescribed time. Two sub-panels were casted separately at density of 1400kg/m³ initially and joined together by using nuts and screws to become one single wall panel with empty portions in the middle for infill purpose with low density mix (700kg/m³) to reduce the total density of the panel. Fire resistance test has been conducted in accordance of standard fire test rating for 65 minutes. The test indicated that CFRFCWP showed better response in term of fire insulation than control foamed concrete wall panel. Coir fibre added as reinforcement in LFC wall panel is capable to reduce the heat transfer due to high uniform pore formation of LFC and large percentage of lignin content which is highly capable in fire resistance.

INTRODUCTION

In the past two decades, a significant number of researches have been carried out into the performance of composite steel-concrete and normal strength concrete structures in fire [1]. Though, the same level of development has not taken place for other forms of construction material like lightweight foamed concrete. It should be pointed out that designing buildings structures against fire is constantly attracting more attention and importance in construction industry due to unforeseen circumstances such as huge injuries and fatalities and economic loss [2].

Construction industry has shown their interest towards use of foamed concrete instead of using traditional concept building material due to its remarkable characteristics such as excellent thermal and acoustical performances, lighter weight, durable and cost effective. A foamed concrete consists of only a cement paste (mortar) with homogeneous voids created by introducing air in the form of bubbles [3,4,5]. Foamed concrete has very low thermal conductivity and potential to be an insulating or fire resisting material due to its porous structure.

Walls should have sufficient load bearing capacity, insulation (controlling the temperature rise of unexposed surface of wall) and no significant cracks [6]. Even though, there have been many researches on mechanical and thermal properties of foamed concrete at ambient and elevated temperature, there are still lack of knowledge in its fire resistance performance [7]. Coir fibre is classified as natural biodegradable fibre. Natural fibres have been used as reinforcing agent in inorganic materials for many years. The main reasons of using natural fibres are abundantly available and relatively cheap. Coir fibre has potential to be used as replacement for coarse aggregate in concrete to produce structural concrete [8].

It is investigated that coir fibre when replaced the coarse aggregate, it were suitable as low-strength-giving lightweight aggregate. Therefore, this section explores the ability of coir fibre as an insulating material in the
foamed concrete wall panel when exposed to fire. This innovative material can be used as a partition wall in a low rise building to prevent fire from spreading.

**METHODS AND MATERIALS**

A few steps were performed to investigate the fire resistance test on two samples of wall panels (control foamed concrete and CFRFCWP) at Forest Research Institute Malaysia (FRIM). The experimental procedure was divided into three stages (Design, casting and testing). The whole processes of this experiment were explained in details in those three stages. Table 1 shows the specifications and mix design of the foamed concrete wall panels.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Control Foamed Concrete Wall Panel</th>
<th>CFRFCWP</th>
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<tbody>
<tr>
<td>Density</td>
<td>1400kg/m³</td>
<td>700kg/m³</td>
</tr>
<tr>
<td>Density of Infill</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mix ratio</td>
<td>1:1.5:0.45 (cement: sand: water)</td>
<td></td>
</tr>
<tr>
<td>Additives</td>
<td>Non-additive</td>
<td>Coir-Fibre (0.4%)</td>
</tr>
<tr>
<td>Size of panel</td>
<td>0.675m x 1.5m (thickness of 150mm)</td>
<td></td>
</tr>
<tr>
<td>Foaming agent</td>
<td>Norait PA-1</td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 1:** Sub-panel and one single joined wall panel with components and specifications

The fire test will be conducted either on small scale or big scale of non-load bearing wall panels in accordance of BS 476 Part 20: 1987: wall (furnace indicative). Connectors and components such as starter bar, reinforcement bar (BRC R6), nut and screws were used in the design. Two portions between sub-panels were left empty for infill material with low density to reduce the total density of the whole panel. The screws have provided good interaction to the panels.

**Experimental Setup:**

The single LFC wall panel was fixed and fitted in between of a frame sized (1.5m x 1.5m) at FRIM before the panel exposed to fire. Figure 2 shows the typical setup of wall panel for fire test and figure 3 shows the fire formation inside the furnace. Each wall panel was placed vertically on the side of the furnace as the source of heat, so that one surface of the wall panel was subjected to be exposed towards fire and the other side faced to the room temperature. Fire resistance test has been conducted in accordance of standard fire test rating for 65 minutes. Five thermocouples (1-5) were installed on the unexposed side to investigate the development of temperature through each wall panel.
RESULTS AND DISCUSSION

This section reported indicative study to determine fire resistance performance of foamed concrete panels when exposed to fire on one side. Fire insulation properties of building materials and structural assemblies are evaluated by fire test methods. The requirement for fire resistance, where the average temperature obtained at unexposed side should not exceed 140°C from ambient temperature [9,10]. From Table 2, it can be observed that the both wall panels have the ability of structural elements to withstand and give protection from fire. Heat transferred analysis were carried for 65 minutes. Thermocouples used to record the data of temperature rise during the test on the unexposed side as shown in the table above. The changes and formation of the concrete structure after the test were observed and recorded for further analysis.

Table 2: Temperature recorded on the surface of unexposed wall panel

<table>
<thead>
<tr>
<th>Sample</th>
<th>Time (Min)</th>
<th>Mean Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Normal FC Wall</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>CFRFCWP</td>
<td>29</td>
<td>29</td>
</tr>
</tbody>
</table>

During post-experiment, there were observed on the internal structure of the exposed side, that the coir fiber completely burnt about 20mm (thickness) and the bonding between matrix and fiber were destroyed due to high temperature [11]. The behavior of concrete on fire and ensure the elements of structure will not destruct but hold back the fire for prescribed time is very significant when designing a building. Previously, the insulation performance was concerned on the density of foamed concrete [12]. The low density mix will give better thermal properties but eventually failed to develop the strength. In this case, coir fibre plays a significant role in enhancing the strength of low density mix while improves the fire resistant properties of foamed concrete as well [13]. From the indicative study results on these panels, there was potential of using CFRFCWP as fire resistant partition wall in low rise construction Since this system can be utilized in our country, it has to abide by the requirements stipulated in Part VII UBBL [14].

Conclusion:
This research of fire resistance performance of that CFRFCWP under standard fire exposure from one side has summarized that it has better insulation performance for fire resistance. Previously, coir fibre has recorded leading results in mechanical and thermal properties, so that it will be a suitable material in term of strength and fire insulation in low rise building construction. Due to uniform size of voids and high content of lignin and better compatibility between particles, the coir fibre would reduce its thermal conductivity.

REFERENCES


