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ORIGINAL ARTICLE

COMPRESSIVE STRENGTH OF THE 5CM X 5CM COCONUT EMPTY FRUIT BUNCH FIBER REINFORCED CEMENT CUBES

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ABSTRACT – As coconut cultivation expands, billions of tonnes of coconut waste, including empty fruit bunches (EFB) fibres are generated annually and mostly disposed in the landfills. The increase in environmental concern pertaining disposal of waste has leads to an interest to use empty fruit bunch (EFB) fibre from coconut waste as an alternative reinforcement in the construction materials, as presented in this research. The objectives of this research are to fabricate coconut EFB fibre reinforced cement cubes, investigate the effectiveness of the fibres in improving the compressive strength of the cement cubes, and also to analyse the fractured surface of the cubes after the compressive strength test. The cement cubes of 5cm x 5cm were prepared by mixing the cement, water, and coconut EFB fibres at several mixing designs. In comparison to the control-plain cement cubes, the compressive strength of the fibre reinforced cement cubes improved with the addition of the coconut EFB fibres by 1.6 times. The fractured surface analysis on the compressed cement cubes revealed that the control-plain cement cubes shatter into many pieces and completely parted. Meanwhile, in the EFB fibre reinforced cement cubes, the fractured pieces remain attached due to the bridging action by the coconut EFB fibre.

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INTRODUCTION

Natural fibre reinforced cement-based materials have been increasingly used in residential house components in recent years. The fibre-reinforced concrete is a composite material made up mostly of conventional concrete or mortar that has been reinforced by the dispersion of short, discontinuous, and discrete fine flames at random intervals [1]. In order to dispose the coconut wastes, the landfilling method is the common method, which is very expensive and causes solid waste management issues. Another method, the wastes are burned in furnaces, causing air pollution which contribute to the global climate change by producing carbon dioxide and methane. Therefore, an alternative method for converting these wastes into value-added products must be initiated.

LITERATURE REVIEW

Empty Fruit Bunch (EFB)

Malaysia is one of the world's most prominent producers of coconut. Coconut farms is sprouting up all across the country. This commodity is critical to Malaysia's economic development. A significant amount of coconut waste is generated as the business grows and expands. Trunks, fronds, kernel shells, and empty fruit bunches are the common coconut wastes. Among those, empty fruit bunch (EFB) fibre has several advantages, one of which is that it is light (1.4 g/cm^3) yet strong (1.2 GPa) [2]. The EFB waste has potential to be processed into value-added goods such as mattress, cushion, erosion control, medium density fibreboard [3], and lightweight cement blocks [4] which are suitable for green industry products. EFB is also known for its incredible strength, as well as being recyclable and biodegradable. Because of its abundant availability, the EFB is also reasonably priced.

Fibre Reinforced Cement Cubes

Basically, for this research the foundation of cement cubes reinforced with EFB fibre is from the fibre reinforced concrete (FRC). FRC is a type of concrete with additives that improve structural strength, ductility, and durability. Egyptians used straw to strengthen mud cubes and bricks circa 5000 years ago, which was the first concept of fibre reinforcement in construction materials. Coconut EFB fibres as a natural fibre is lighter compared to the other types of fibres, such as steel or glass. Due to its lightweight, cost effectiveness, and good for environmental sustainability, it can be an excellent substitute for cement materials. According to a paper by [5], adding a minimum of 3% by volume of fibre

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to cement composites able to improve the cement composite's characteristics. In another paper, an experiment conducted by [6] found that adding natural fibre to cement mortar slabs increased impact resistance by 3 to 18 times when compared to plain mortar slabs.

METHODOLOGY

Material The experimental work in this research were divided into four sections, namely preparation of EFB fibre, fabrication of cement cubes, compressive strength testing, and fractured surface analysis. The research flowchart of the experiment can be seen in Figure 1.

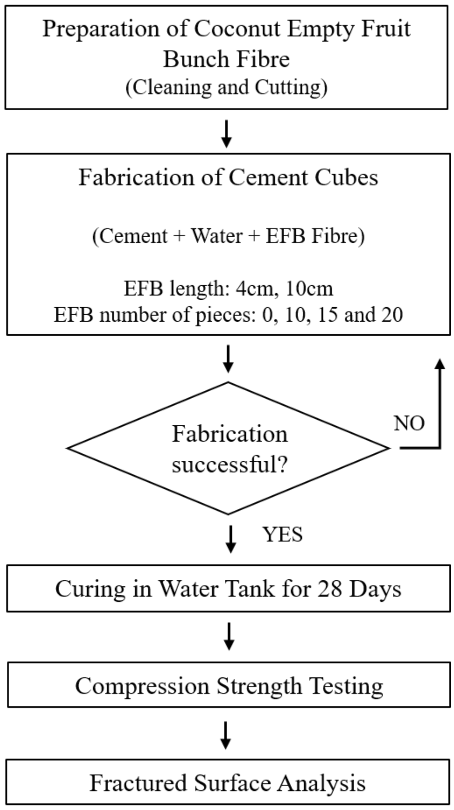

Figure 1. Research Flowchart

Preparation of Coconut Empty Fruit Bunch Fibre

The coconut EFB fibres which were collected from the village near Universiti Malaysia Pahang, were first soaked and cleaned to remove impurities, followed by drying process to prevent growth of mold and fungus. After that, the fibres were cut into a length of 4 cm and 10 cm. The short lengths of 4 cm and 10 cm were selected to prevent entanglement in the cement cube. Figure 2 shows the coconut EFB fibres used in this research.

Figure 2. Coconut EFB fibres

Fabrication of Cement Cubes

Total of 20 samples of cement cubes were casted using the 5cm x 5cm silicone cube mould (Figure 3). Prior to the fabrication of the cement cubes, all of the raw materials were weighed using a digital weighing scale in accordance to the mix design specifications (0, 5, 10, 15, 20 pieces of EFB). The mixture of cement and water were stirred using a concrete mixer tool for 1 minute. Then, the fibres were added into the mixture. In order to prevent the fibres from balling up, the mixture was mix for another 1 minute. The mixture of cement, water and fibre were then poured into the mould with the help of vibration to remove air bubbles and cavities. After the casting process, the cement cubes were set aside to dry for 1 day, followed by curing the cubes in a water tank for 28 days. The purpose of curing process is to maintain the cement cubes' moisture and temperature at a constant level so that the hydration reaction of the cement cubes can harden and join with the internal materials and reinforcement, reach its highest strength.

Figure 3. 5 cm x 5 cm Silicone Cube Mould

Compressive Strength Testing

The compressive test was carried out using Universal Testing Machine (UTM) to study the compressive strength of the cement cubes. 4 samples were tested for each 0, 5, 15, and 20 EFB fibre contents, equivalent to 20 samples. The samples were placed on the fixed lower head of the machine, while the movable upper head gradually lowered and compressed the sample at 5mm/min crosshead speed and 15 kN load until it breaks. The values of compressive strength were recorded accordingly.

Fractured surface analysis

Analysis on the fractured surface was done to determine a material's behaviour and response under crushing load. At this point, the presence of EFB fibres in the fractured surface of cement cubes was examined using naked eyes to study the bridging and strengthening effect in cement cubes.

RESULTS AND DISCUSSION

Unit Weight Measurement of Cement Cubes

The graph in Figure 4 depicts the unit weight of cement cubes with the addition of EFB fibres content at 0, 10, 15 and 20 with two distinct sets of EFB lengths of 4 cm and 10 cm, respectively. The horizontal axis indicates the quantity of EFB fibre pieces, while the vertical axis reflects the average unit weight of cement cubes. The unit weight of cement cubes is the greatest in plain cement cubes (2.25 g/cm^3) and the lightest with the addition of 20 pieces of EFB fibres with a length of 10cm (2.10 g/cm^3). As a result, when compared to plain cement cubes, the increase in EFB fibre results in a modest reduction in unit weight. This is due to the fact that EFB fibre is a low-density material which absorb a particular volume proportion of the cement cubes. This could be explained by the addition of less dense material to plain cement cubes, which results in a lighter weight cement cube. There was also possibility that the addition of EFB fibres increased the entrapped air percentage and void content, resulting in a decrease in cement cubes unit weight. Similar observation also observed by previous researchers in [7, 8, 9] using various types of natural fibre.

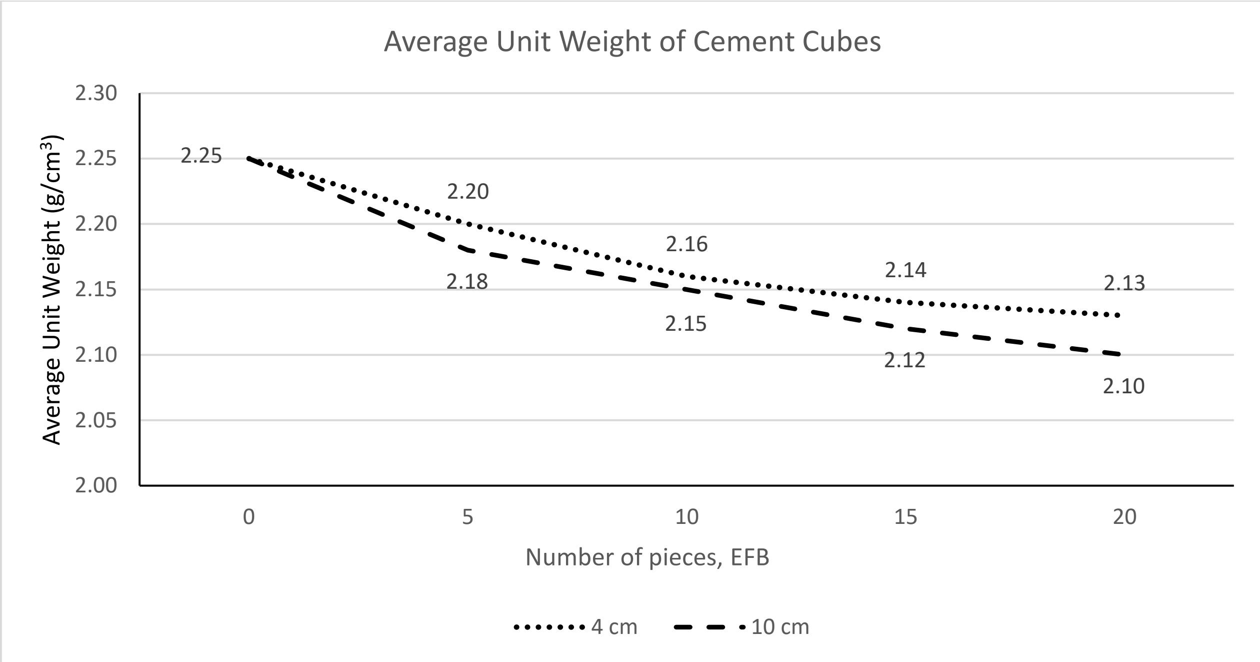

Figure 4. Average unit weight of cement cubes

Compressive Strength of Cement Cubes

Figure 5 shows the average compressive strength comparison between plain cement cube and EFB-reinforced cement cubes. It can be seen that all of cement cubes reinforced by EFB fiber have higher compressive strength compared to the control-plain cement cube. From the graph, it was observed that the highest compressive strength was in the sample with 15 pieces of 4 cm length EFB fibre content, which can withstand up to 15.93 MPa. However, the compressive strength of EFB-reinforced cement cube begins to decrease at the point where the EFB fibre value exceeds 15 pieces. As the quantity of EFB fibre present in the cement cubes rises, it is anticipated that the porosity and air voids would also increase accordingly. This leads to poor compaction and a drop in strength. To put it another way, the greater voids in the blocks make it more difficult to achieve proper compaction when using cement cubes with a higher percentage of EFB in the mixture.

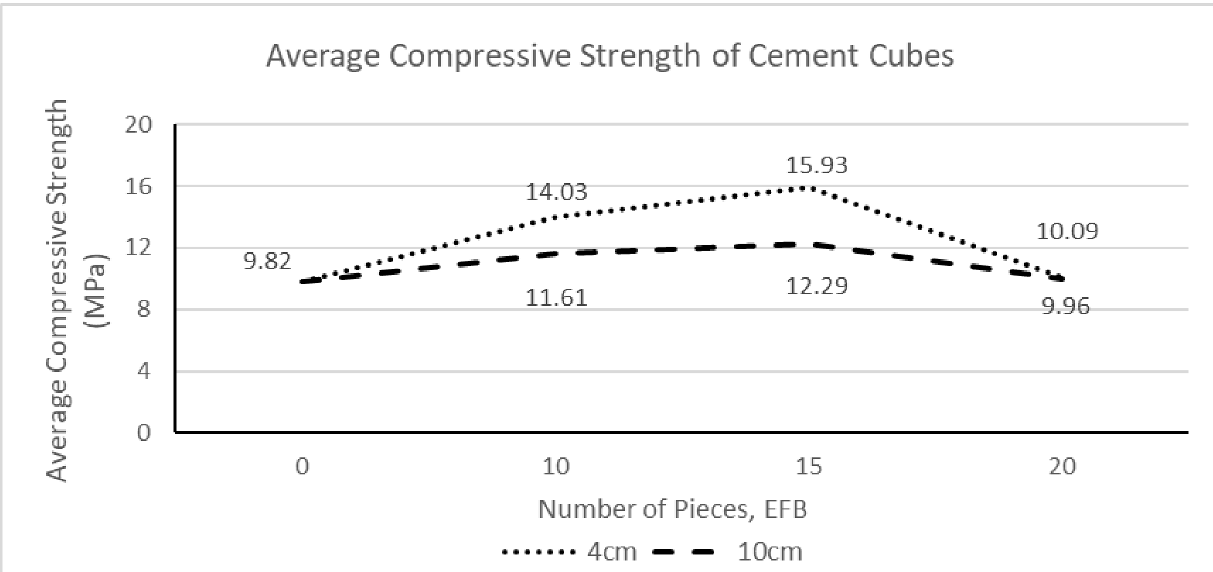

Figure 5. Average compressive strength of cement cubes

Fracture Surface Analysis

The analysis on the fractured behaviour discovered different pattern of fractured between plain cement cubes and EFB-reinforced cement cubes. As can be seen in Figure 6, plain cement cube completely fractured and separated into a sizeable chunk. On the other hand, the addition of fibres into cement cubes prevent the fractured cubes from separating. The close-up image in Figure 7 shows that the fibres hold the cement cubes together by crossing the gap between the cracks. At the same time, it was suggested that the presence of EFB fibre in cement cubes provides a physical impediment to crack propagation at the interface through mechanical interlocking process. According to [10], the mechanical interlocking process is among the most important aspects that have a role in strengthening the cement cubes. In another word, adding the fibre content improved the bridging of existing cracks by preventing them from further widening at certain extend. The durability of the cement cubes was improved, resulting in a reduction in fracture width. The reinforcement, fibres, and cement cubes matrix are all linked together to endure external loads before the cement cubes fractured.

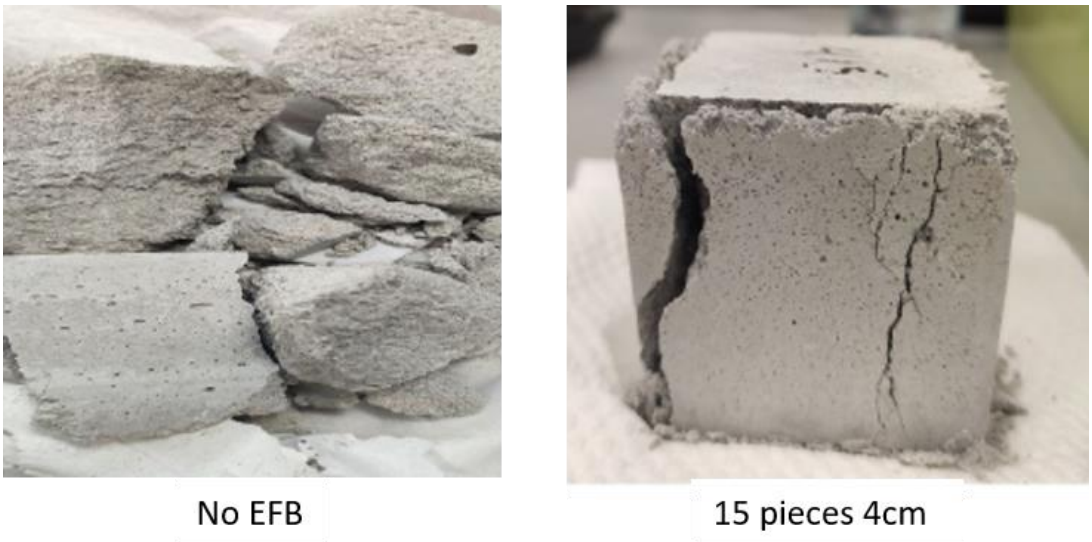

Figure 6. Fractured surface of plain cement cube

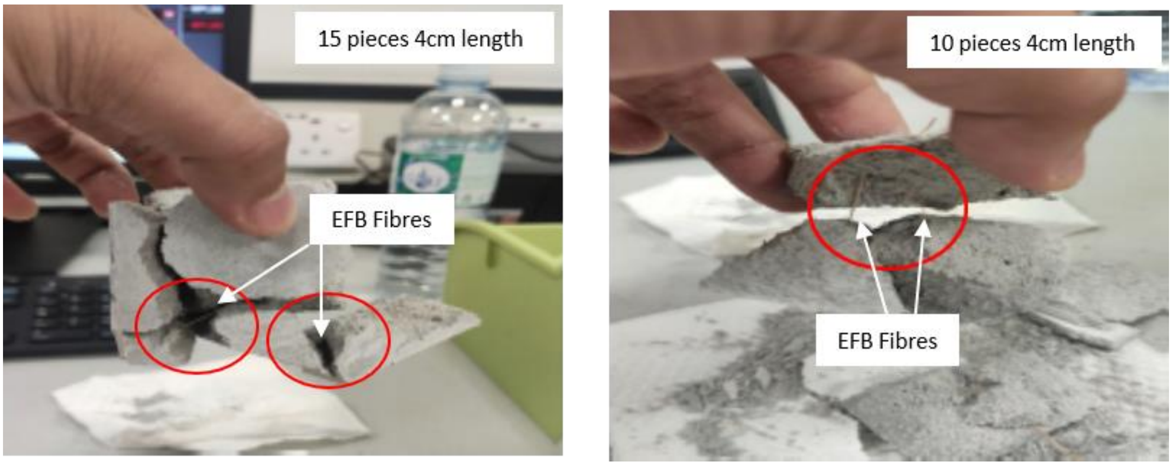

Figure 7. EFB fibres hold the fractured cement cubes

CONCLUSION

In conclusion, the addition of coconut EFB fibre in cement cubes shows weight reduction ranging from 2.22% to 6.67% compared to plain cement cubes, the compressive strength increased up to 62% and the analysis on the fractured surface displayed the coconut EFB bridging, holding the fractured cement chunk from completely parted. Therefore, in overall support the compressive load better than plain cement cubes.

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