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EFFECTIVENESS OF CHEMICAL TREATMENT OF OIL PALM EMPTY FRUIT BUNCH FIBER AS REINFORCEMENT IN FOAMED MORTAR

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Abstract:
These days, construction material manufacturers in Malaysia have put an effort to utilize industrial waste in the production of building materials especially concrete based products. It should be pointed out that natural fibers have become attention-grabbing and interesting to be employed as an industrial and structural material for restoring of structures. Nonetheless, these natural fibers which are available in large quantities in Malaysia have certain issues in attaining the anticipated engineering and durability properties particularly concerning the interface connections with the cement matrix. Hence, chemical treatment is essential to improve the matrix to filler adhesion, consequently refining its overall properties. In this study, oil palm empty fruit bunch (EFB) fiber was studied for use as reinforcement materials for cementitious composites in foamed mortar. The effect of fiber chemical treatment (2%-10% wt. sodium hydroxide chemical treatment) on durability and engineering properties of EFB fiber reinforced foamed concrete was investigated expansively. The test results show that treatment of the EFB fibers modifies the fibers interface sufficiently triggering a variation in the durability and engineering properties. Above all, 6% sodium hydroxide chemical treatment of EFB fiber offered excellent compressive and bending strength hence it's considered a better treatment concentration value in the range of 2% to 10% wt. in turn to enhance the durability and engineering properties of EFB reinforced foamed mortar.

Keywords: Foamed concrete; Empty fruit fiber; Oil palm fiber; Engineering properties; Compressive strength

1.0 INTRODUCTION

Cement industry is one of the major contributors to the emission of the greenhouse gasses like carbon dioxide which is about 1.35 billion tons annually. The production of Portland cement increases with the increasing demand from the construction industry which has been over one thousand million tons per year. The construction industry in recent years has shown a significant interest in lightweight foamed concrete as a building material. Lightweight concrete is the combination of cement, fine aggregates, water and foam. There is no coarse aggregates involve in this type of concrete. The lightweight foamed concrete are consists with the entrapped bubbles that act as the aggregate in order to make it better in the terms of workability, flowability, thermal properties and lighter in weight (Mydin et. al, 2015). Even though it increases the workability, flowability, thermal properties of the concrete and lighter in weight but lightweight foamed concrete are considerable brittleness, results in low flexural strength, poor fracture toughness, poor resistance to crack propagation and low impact strength (Jones & McCarthy, 2005).

2.0 LITERATURE REVIEW

Natural fibers are widely used in the cementitious matrices to modify the tensile and the flexural strengths and increase the toughness, impact resistance and the fracture strength of the lightweight foamed concrete. Malaysia is currently heading towards the biotechnology hub area thus there will be billion tons of palm oil by-products will be produced and this oil palm by-product are treated as waste disposal (Chen et. al, 2014). In this era, the growing need for sustainable development is increase in demand. This motivated scientist to perform researchers on the use of industrial by-products for other application (Li et. al, 2012). From the researches that have been conduct, oil palm empty fruit bunches fibers have the potential to be developed as the alternative fibers in the fiber reinforcing concrete (Mugahed Amran et. al, 2015). There are three types of fiber that comes from oil palm tree. The oil palm frond fibres come from the oil palm frond or the leaf like part of the palm. The empty fruit bunch fiber comes from the fruit bunch of the oil palm. And last the oil palm trunk fibers come from the oil palm trunk (Nambiar & Ramamurthy, 2000). Empty fruit bunches fibers are used for the fuel combustion for the generation of the steam boiler. However not all the fibers will be used, some of the amounts will be discarded and thrown away. This empty fruit bunches is about 3cm in length and 0.01mm in diameter after being crushed and dark brown in colour (Narayanan & Ramamurthy, 2000). Empty fruit bunches can be easily found in Malaysia as Malaysia is the largest oil palm producer in Asian. Empty fruit bunches known as it has excellent tensile strength, good elongation at break and has large fracture toughness (Wang et. al, 2015).

3.0 METHODOLOGY

Type 1 Ordinary Portland cement (OPC) produced by YTL Cement Bhd was used which comply to BS 12:1996 standard. Locally available fine aggregate was used which was supplied by a local distributor. Protein based foaming agent namely, Noraite PA-1 was chosen to be used in this study due to its stable and smaller bubbles and its stronger bonding structure of the bubbles in comparison to the synthetic based surfactant. Water to cement ratio that been used for this research is 0.45 as it had achieved reasonable workability of foamed mortar (Mydin & Wang, 2012). For sodium hydroxide chemical treatment of oil palm empty fruit bunches fibers, solution percentages of 2%, 4%, 6%, 8% and 10% wt. were opted. For the 2% wt., 2 grams of sodium hydroxide chemical was liquefied in 100ml tap water which is correspondent to 100 grams. Figure 1 shows the surface of oil palm empty fruit bunches fiber surface using the scanning electron micrograph. The alkali treatment process induced morphological changes that increased void volume and surface roughness. Table 1 demonstrates the foamed mortar mix design for both densities (1100 kg/m^3 and 1400 kg/m^3)

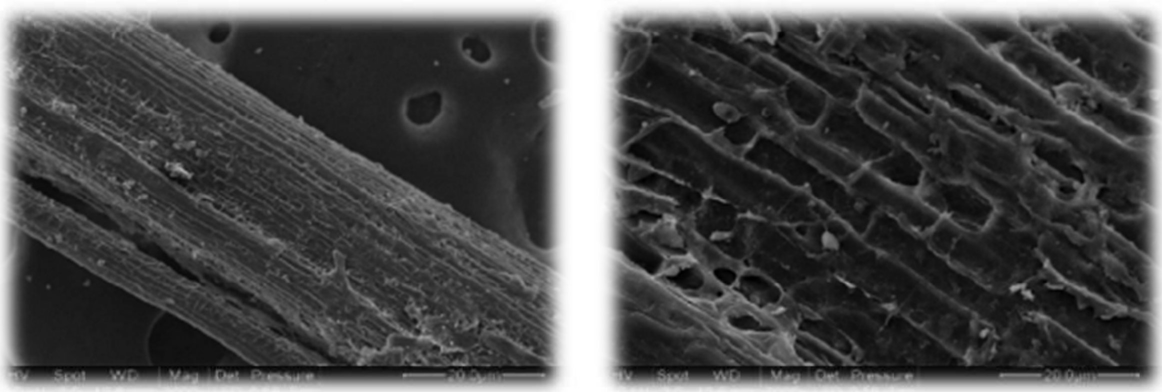

Figure 1: SEM micrographs of oil palm empty fruit bunches fiber surface

Table 1: Foamed mortar mix design

Mix	Mix Density (kg/m^3)	Foam Mass (kg)	Cement (kg)	Fine Sand (kg)	Water (kg)
Control Mix	1100	0.826	12.32	18.49	5.55
No Chemical Treatment	1100	0.826	12.32	18.49	5.55
Chemical Treatment 2%	1100	0.826	12.32	18.49	5.55
Chemical Treatment 4%	1100	0.826	12.32	18.49	5.55
Chemical Treatment 6%	1100	0.826	12.32	18.49	5.55
Chemical Treatment 8%	1100	0.826	12.32	18.49	5.55

Chemical Treatment 10%	1100	0.826	12.32	18.49	5.55
Control Mix	1400	0.545	15.57	23.36	7.01
No Chemical Treatment	1400	0.545	15.57	23.36	7.01
Chemical Treatment 2%	1400	0.545	15.57	23.36	7.01
Chemical Treatment 4%	1400	0.545	15.57	23.36	7.01
Chemical Treatment 6%	1400	0.545	15.57	23.36	7.01
Chemical Treatment 8%	1400	0.545	15.57	23.36	7.01
Chemical Treatment 10%	1400	0.545	15.57	23.36	7.01

For durability testing, 4 tests were performed which were water absorption test (Figure 2), porosity test (Figure 3), drying shrinkage test (Figure 4) and ultrasonic pulse velocity test (Figure 5). The water absorption test was carried out in accordance to BS 1881-122:2011. The porosity of foamed mortar was determined via vacuum saturation method. The drying shrinkage test was executed using 40 x 40x 160 mm size prism in accordance to BS 6073-1:1981. The ultrasonic pulse velocity test was performed in line with ASTM C597:1997. For engineering properties test, 2 tests were carried out which were axial compression test (Figure 6) and flexural test (Figure 7). The compressive strength was carried in compliance with BS EN 12390-3:2009. Flexural test was carried out in accordance with BS EN 1521:1997 (Ramamurthy et. al, 2009)



Figure 2: Water absorption test Figure 3: Porosity test Figure 4: Drying shrinkage
test



Figure 5: Ultrasonic pulse velocity test Figure 6: Compression test Figure 7: Flexural test

4.0 EXPERIMENTAL RESULTS

Figure 8 and Figure 9 show the water absorption and porosity results for both densities respectively. From both figures, with increment of chemical solution percentages of EFB fibers, it reduced the water absorption capacity and porosity of foamed mortar intensely for both densities.

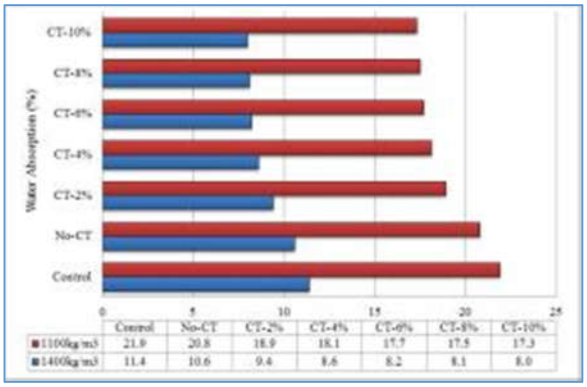

Figure 8: Water absorption results

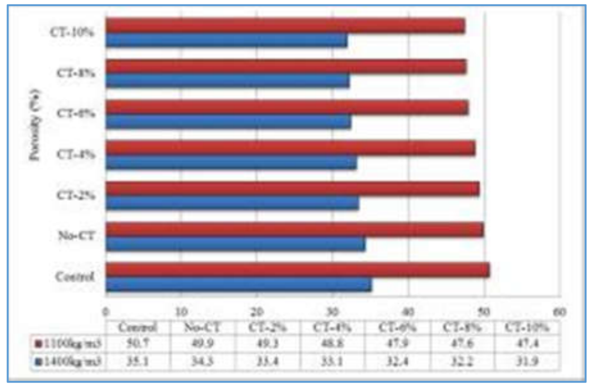

Figure 9: Porosity results

Figure 10 and Figure 11 show the drying shrinkage results for both densities correspondingly. For both densities, 6% wt. sodium hydroxide chemical treatment of EFB fibers offered outstanding drying shrinkage results compared to other chemical solution percentages.

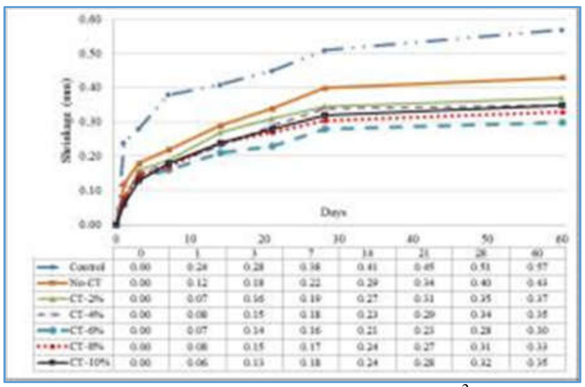

Figure 10: Drying shrinkage of 1100 kg/m^3 density

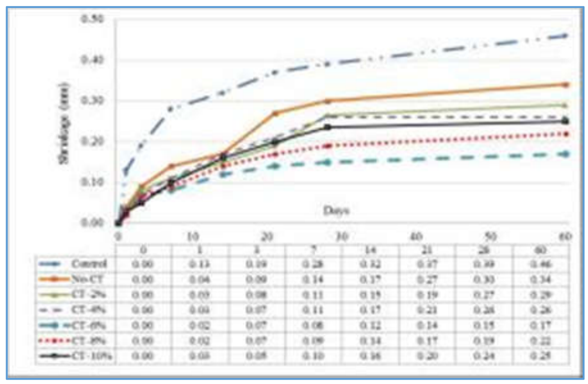

Figure 11: Drying shrinkage of 1100 kg/m^3 density

Figure 12 displays the ultrasonic pulse velocity (UPV) results for both densities. It can be seen from Figure 12 that chemical treatment has improved the ultrasonic pulse velocity (UPV) compared to control and non-treated samples. For both densities, 6% wt. sodium hydroxide chemical treatment of EFB fibers gave an excellent ultrasonic pulse velocity (UPV) reading of 2411m/s for 1100 kg/m^3 density and 3258m/s for 1400 kg/m^3.

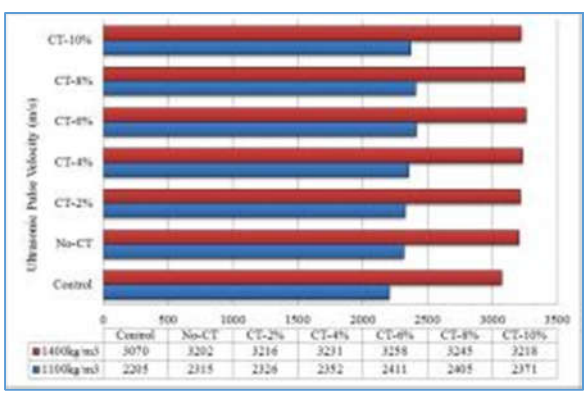

Figure 12: Ultrasonic pulse velocity (UPV) results

Figure 13 and Figure 14 show the axial compressive strength results for 1100 kg/m^3 and 1400 kg/m^3 densities respectively. From both figures, it can be clearly seen that 6% wt. sodium hydroxide chemical treatment of EFB fibers contributed to exceptional axial compressive strength results compared to other chemical solution percentages which were 4.4 N/mm^2 for 1100 kg/m^3 density and 8.1 N/mm^2 for 1400 kg/m^3 at 60-day.

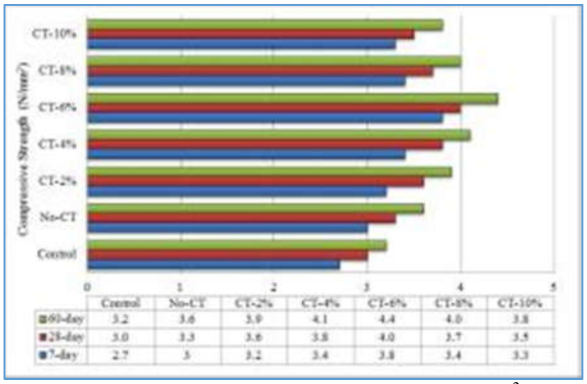

Figure 13: Compressive strength of 1100 kg/m^3 density

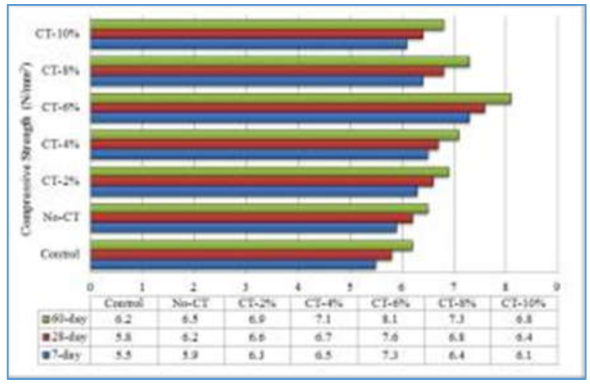

Figure 14: Compressive strength of 1100 kg/m^3 density

On the other hand, Figure 15 and Figure 16 show the flexural strength results for 1100 kg/m^3 and 1400 kg/m^3 densities correspondingly. Same results were obtained as per axial compressive strength. From both figures, it can be noticeably seen that 6% wt. sodium hydroxide chemical treatment of EFB fibers gave remarkable flexural strength results compared to other chemical solution percentages which were 1.25 N/mm^2 for 1100 kg/m^3 density and 2.31 N/mm^2 for 1400 kg/m^3 at 60-day. The improvement in axial compressive strength and flexural strength is attributed to the improvement in EFB fibers and interfacial adhesion after treatment (Soleimanzadeh & Mydin, 2013).

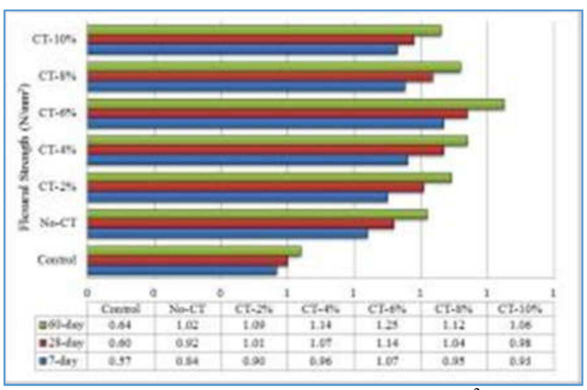

Figure 15: Flexural strength of 1100 kg/m^3 density

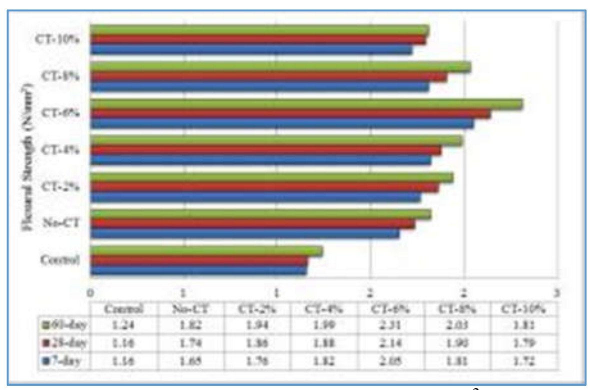

Figure 16: Flexural strength of 1100 kg/m^3 density

The failure modes of the foamed mortar specimen under axial compression and flexural were fiber retreat, fiber rupture and fiber debonding from the cement matrix, which are presented in Figures 16. As can be seen from Figure 17, there are lots of voids be present at the cement surface signifying the fiber retreat failure in the matrix.

Figure 17: Retreat of empty fruit bunch fiber from the cement matrix

5.0 CONCLUSION

This paper has discussed the effectiveness of chemical treatment of oil palm empty fruit bunch fiber as reinforcement in foamed mortar on its durability performance and engineering properties. With increment of chemical solution percentages of EFB fibers, it reduced the water absorption capacity and porosity of foamed mortar intensely. In general, 6% wt. sodium hydroxide chemical treatment of EFB fibers offered outstanding drying shrinkage, ultrasonic pulse velocity, compressive strength and flexural results compared to other chemical solution percentages. The improvement in durability and engineering properties is attributed to the improvement in EFB fibers and interfacial adhesion after treatment. The failure modes of the foamed mortar specimen under axial compression and flexural were fiber retreat, fiber rupture and fiber debonding from the cement matrix. Although encouraging results have been reported in this study, more future researches are needed to thoroughly understand the EFB fibers performance as reinforcement in concrete based material.

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