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PROPERTIES OF CEMENT TREATED TIRE CRUMB AND OIL PALM FRUIT FIBER MORTAR

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Various research studies have been conducted in an effort to improve the mechanical properties of concretes and mortars containing waste tire particles using chemicals and additives which lead to increase cost. This approach presents an economical and sustainable method, through adding oil palm fruit fiber (OPFF) at 0.5, 1%, and 1.5% by mass of cement content into the matrix and pre-treating the tire crumb aggregate (0-40%) by volume with cement, in order to improve the properties of the composite. Density, compressive strength and water absorption measurements were conducted on the mortar specimens. Results showed the addition of 0.5% OPFF in 10% treated tire crumb mortar was discovered to give the best improvement in the compressive strength of mortar modified with treated tire crumb.

Keywords: Lightweight aggregates, Waste tire, Tire pre treatement, Lightweight mortar.

1 INTRODUCTION

The accumulation of waste tires on dumping sites is continuously increasing on landfills due to their non-degradable nature. In Malaysia alone, the number of vehicle waste tires generated annually amounted to about 8.2 million and about 60% of this material is being disposed-off indiscriminately without definite route. It also posed a serious fire treat and pollution to the environment as it is highly inflammable and once ignited can continuously burn for as long as possible exposing environment to a number of harmful chemicals both in air and water (Naik and Singh 1991, Mavroulidou and Figueiredo 2010).

Malaysia and Indonesia are the world largest producers of oil palm crude, their production account for about 80% of the total palm oil of the world. Malaysia is the second largest producer of palm oil in the world producing about 18.5 million tons annually with about 3.87 million ha of land being used in the plantation of oil palm. The increase in the production of oil palm by the day has serious impact on the environment which entails increase in the production of waste oil palm kernel shell and fiber material to be disposed-off. Therefore, there should be an effort to fully utilize the oil palm waste such as its leaves, trunks and fruit bunches significantly to the other industry. Oil palm fruit fiber is a natural fiber produced during the extraction process of palm oil crude from oil palm fruit bunch after boiling and removal of the palm kernel seeds from the fruit bunch.

Over the last two decades, efforts have been made to substitute waste tire particles for aggregate or filler in concretes and mortars. However, the major challenges with this composite are the decreases in the mechanical properties of waste tire incorporated concretes, which have been reported by Siddique and Naik (2004), Cairns and Kenny (2004) and Khaloo *et al.* (2008). Thus many research studies have been carried out to improve the properties of waste tire by pre-treat it with sodium hydroxide (1M NaOH), silica fume and Ligno-sulphate admixture, alkaline activation and organic sulphur compounds with an intention of to improve the surface bonding strength of the tire crumb (Pelisser *et al.* (2011), Chou *et al.* (2010), Segre and Joekes (2000)). However use of chemical composition have its own limitations and restrictions, hence with the same intention, this study is carried out by pre-treating the tire crumbs with ordinary Portland cement and adding of OPFF to improve the surface bonding between mix compositions.

2 RESEARCH PROGRAM

2.1 Materials

The mix composition was made of fine aggregate from the stone dust retained in a 2.38 mm sieve which was supplied from a quarry in Selangor, Malaysia. The density, specific gravity, and water absorption were determined to be 1702 kg/m3, 2.63, and 3% for the fine aggregate respectively. Tire crumb of the same size as the fine mineral aggregate was used, which was supplied by Arajaya Enterprise Sdn. Bhd. Malaysia. The same particle size grading as used for the fine mineral aggregate was maintained in order to obtain suitable volumetric substitution. The pre-treatment of the tire crumb particles was conducted by soaking the tire crumb in water for two days. The soaked tire crumb was then removed from the water and dried in an open container to enable it to surface dry before being mixed thoroughly with cement powder using a concrete mixer. Finally, it was air dried and used as treated tire crumb aggregate. The tire crumb aggregates density and fineness modulus is668 kg/m^3 and 0.9, respectively. The tire crumb was used in the mortar mix to partially substitute for the sand in 10%, 20%, 30% and 40%.The oil palm fruit fiber (OPFF) was taken from Seri Ulu Langat Palm Oil Mill Sdn. Bhd, Dengkil, Malaysia. It was cleaned using water only without any additive. It was air dried and shredded into 30-50mm lengths. The OPFF was added into the mortar mix in 0.5%, 1.0% and 1.5% by weight of cement content.

2.2 Mortar Mix

Table 1 shows the mix composition of all the specimens produced in this exercise. The water-to-cement ratio was 0.485, and the ratio of cement to aggregates was 1:2.75; these were kept constant and in line with the provision of ASTM C109-05 (2005). The total water shown in Table 1 includes 3% water absorption by the aggregates. Treated tire crumb aggregate was partially substituted for fine aggregate at 0%, 10%, 20%, 30% and 40% by volume of aggregate. The OPFF was added to the matrix at 0.5%, 1.0% and 1.5% by weight of the cement content.

Table 1. Composition of mortar specimens for the experiment.

Designation	Cement (kg/m^3)	Fine aggregate (kg/m^3)	Treated tire crumb (kg/m^3)	Water (kg/m^3)	Fiber (kg/m^3)
F0	740	2035.0	0.0	420	-
F5MR10	740	1831.5	80.0	414	3.7
F10MR10	740	1831.5	80.0	414	7.4
F15MR10	740	1831.5	80.0	414	11.1
F0CR20	740	1628.0	140.8	408	-
F5MR20	740	1628.0	159.8	408	3.7
F10MR20	740	1628.0	159.8	408	7.4
F15MR20	740	1628.0	159.8	408	11.1
F0CR30	740	1424.5	211.3	402	-
F5MR30	740	1424.5	239.8	402	3.7
F10MR30	740	1424.5	239.8	402	7.4
F15MR30	740	1424.5	239.8	402	11.1
F0CR40	740	1221.0	281.7	396	-
F5MR40	740	1221.0	319.7	396	3.7
F10MR40	740	1221.0	319.7	396	7.4
F15MR40	740	1221.0	319.7	396	11.1

2.3 Experimental Program

Three typical samples were prepared for each test. The flow table test was performed in accordance with ASTM C1437 (2007). The density and water absorption tests were carried out in this study by immersion in line with the specification of ASTM C642 (2001) using cubes of 50 x 50 x 50 mm. A total of 60 samples were produced and tested after a 28-days curing period. An oven temperature of 1100±100 and normal tap water at room temperature were used for curing the samples. A Universal Testing Machine (UTM) with a maximum capacity of 5000 kN and a loading rate of 0.75 kN/s was used for the compression test after 28 days curing period. A total of 153 samples of 50 mm cubes were tested in accordance with the ASTM C109 (2005) specifications.

3 RESULTS AND DISCUSSIONS

3.1 Workability

The treated tire crumb was observed to be less workable than the control samples (Figure 1). The decrease in workability is due to the additional water absorption capacity of the treated tire crumb particles compared with the control specimen. The addition of OPFF into the matrix further lowered the workability, as natural fiber is also associated with a high water absorption capacity. The addition of 0.5-1.0% fibers into the 10% tire crumb mix showed an acceptable reduction as compared to normal mortar samples. For 20-40% tire crumb replacement, an effect of 0.5-1.0% OPFF was insignificant. The lower workability recorded is due to the multiple absorption effects of the aggregates, the treated tire crumb and the OPFF in the matrix.

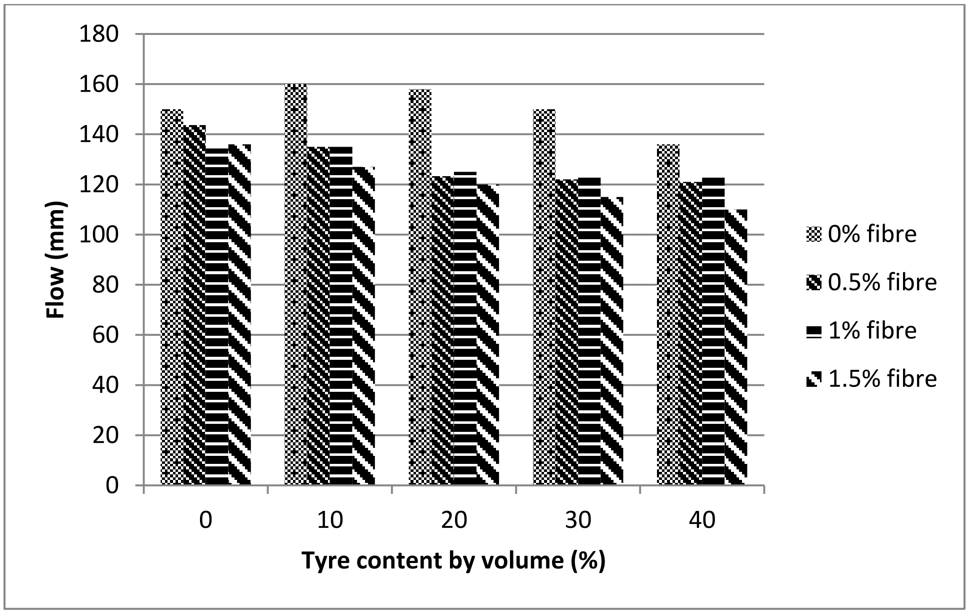

Figure 1. Workability of Treated TireCrumb Composite Mortars.

3.2 Density

The densities of mixes are measured by immersion method. It was observed that the density decreases with the increase in tire crumb content because of the low specific gravity of tire crumb particles, which is about 30% lower than the normal weight aggregate. The density of the tire crumb aggregate used is similar to the density achieved by Pierce & Blackwell (2003) and Benazzouk *et al.* (2007). It can be observed that the density decreased by 0-17% for a tire crumb substitution of 0-40% by volume of aggregate. Apart from 40% tire crumb substitution, the addition of the OPFF did not affect the density of the specimens significantly due to the negligible density of OPFF. The lowest density of 1673 kg/m3 was achieved at 40% tire crumb substitution with no added OPFF.

3.3 Water Absorption

It was discovered that the water absorption of the mortar specimen increases with the increase in the volume of the treated tire crumb content (Figure 2). An increase of tire crumb content of 10% results in an increase in absorption of up to 5% of the control sample. This may be due to the natural behaviour of OPFF, which has various sizes of vascular bundles creating voids which enable water to percolate (Khalil *et.al.* 2006). A maximum absorption of 22.2% was recorded for the highest treated tire crumb substitution of 40% by volume. Samples without OPFF show increased water absorption of up to 20% tire crumb content, after which it reduced back again. This may have been caused by an air gap trapped between the tire crumb particles and the cement matrix that enables the water to percolate. The decreased water absorption at higher tire crumb content is due to the nature of the tire crumb aggregate, which has zero water absorption and repels water.

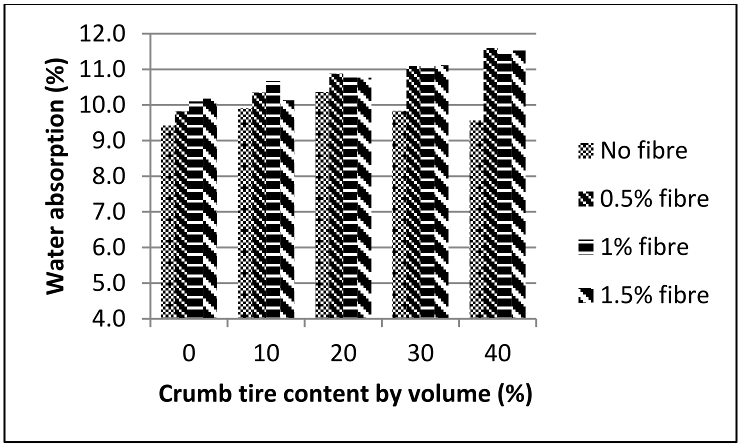

Figure 2. Water absorption of the treated tire crumb composite mortars.

3.4 Compressive Strength

The average compressive strength at 28 days of tire crumb substituted mortars is shown in Figure 3 showing the same pattern of strength reduction due to the compressible behavior coupled with the surface smoothness of the tire crumb particles.

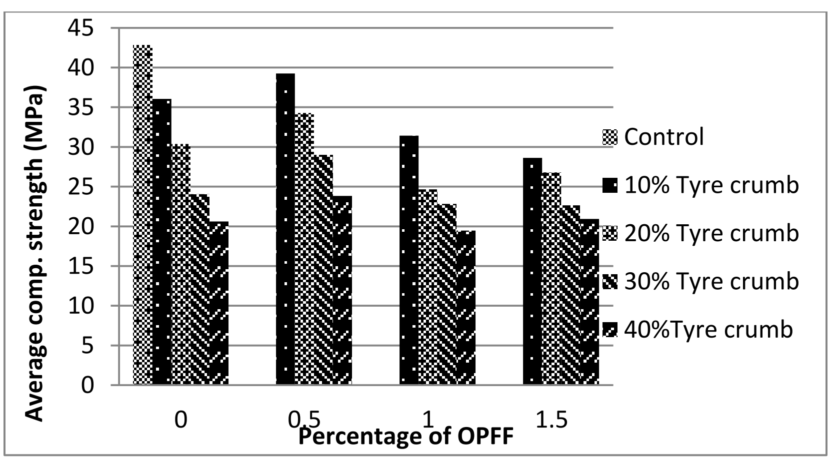

Figure 3. Average Compressive Strength of Mortar Cubes at 28 days.

This behavior causes early failure of the samples produced from such composites under compression force. However, with the addition of 0.5% OPFF, 10% tire crumb replacement shows a strength improvement on 28 days of 4.2%. The improvement may be due to the improved surface roughness of the treated tire crumb, which increased the total internal friction between the treated tire crumb, the mineral aggregate and the OPFF in the matrix. The presence of OPFF improved the interlocking and internal tensile strength in all directions, which results in an improved compressive strength. However, the addition of 1% and 1.5% OPFF resulted in a lower compressive strength than the other specimens. This reduction is due to the high volume of the fiber, which causes a lower resistance to the compression load due to the presence of more void volume leading to the failure of the specimen.

4 CONCLUSIONS

The workability of treated tire crumb mortars containing oil palm fruit fiber is reduced with an increase in the tire crumb content, and the reduction is up to 26.6% at 40% tire crumb content. However, the densities meet the criteria of moderate to structural lightweight mortar that range from 1400-1900 kg/m^3.Mortars containing treated tire crumb exhibit a continuous increase in absorption, and an increase in tire crumb content and addition of OPFF leads to further increases in absorption of up to 11.5%.Although the strength of these mix compositions is reduced with an increase in the tire crumb content, the addition of OPFF into the matrix was discovered to increase the compressive strength of the treated tire crumb mortars at 0.5% OPFF contents by mass of cement at all levels of tire crumb substitution in a range of 19.47-45 MPa. Based on this compressive strength, this mix composite can be used for bricks, pavements, sidewalks and precast walls, where no high strength is required.

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