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The Use of Oil Palm Fiber as Additive Material in Concrete

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Abstract. This study investigates the use of Oil Palm Fiber (OPF) as additive material in concrete. The effect of OPF in workability and compressive strength of concrete was evaluated through slump test and compression test respectively. Concrete mix design of grade C30/37 is employed in this study referred as control specimen. The total samples were divided into four different concrete mixtures i.e. control specimen (CO), 5 kg/m^3 of OPF (O5), 10 kg/m^3 of OPF (O10) and 15 kg/m^3 of OPF (O15). Three samples of each mix design were tested under slump test. Meanwhile for compression test, three samples of each mix design were tested on 3 days, 7 days and 28 days. Based on the test result, it can be observed that the workability of the OPF concrete was slightly lower than CO concrete and its decreasing rate was proportionally to the amount of OPF in the concrete. In terms of compressive strength, OPF concrete was greatly higher than the CS Concrete and its increasing rate was proportionally to the amount of OPF in the concrete as well.

1. Introduction

Oil palm fiber (OPF) is a 100% natural, non-hazardous and biodegradable material that can be used to improve the properties of concrete. OPF is produced from oil palm's vascular bundles in the empty fruit bunch (EFB) in which EFB is considered as waste products after fresh fruit bunch (FFB) have been processed. Therefore, large landfill disposal will be resulted if EFB is not properly managed. The plantation area for oil palm is more than three (3) million ha [1-2] and contributes about 57.6% of the total supply of palm oil in the world [3]. This indicate that Malaysia has a good source of natural fiber that possess high tensile strength (300-600 N/mm2), high density (1200 kg/mm3) and high content of lignin (23.03%) [3-4]. Therefore, there should be an effort to fully utilize the oil palm waste such as its leaves, trunks and bunches significantly to the building or other construction industry. While most of the research concentrated on the oil palm trunk fiber [3-5] and oil palm shell [6-8] to improve the performance of concrete, limited research has been conducted to study the effectiveness of OPF. Thus, this study aimed to examine the suitability of OPF as additive material in concrete. The effects of OPF content on compressive strength and workability were also justified.

The quality of natural-fiber reinforced concrete is judged mainly by their compressive strength [5], therefore compression test was considered as the basic test in most of the study on concrete mixtures contained OPF. Previous research revealed that the content of OPF play significance role in compressive strength and workability of concrete mixtures. Ahmad and Mohd [9] found that the addition of OPF at 0.25%, 0.5% and 0.75% in volume fraction gave adverse effect on compressive strength and workability of the concrete mixtures. Kroehong et al. [10] demonstrated that the increase of OPF content decreased the compressive strength of high calcium fly ash geopolymer paste. Ramli and Dawood [11] revealed that the use of 0.8% OPF in of volume fraction was an optimal content for light weight crushed brick concrete to achieve its desired compressive strength. Due to the inconsistencies of previous findings, this study focused on the effect of OPF in basic concrete mixture that consisting of cement, coarse aggregates, fine aggregates and water.

2. Experimental Program

2.1. Materials

The design mix proportion of concrete class 30/37 was employed in this study. Oil palm fiber (OPF) was added in the concrete matrix by the amount of 5 kg/m^3, 10 kg/m^3 and 15 kg/m^3 without replacement of any ingredients. Table 1 shows the mix proportion of the control (C0), OPF 5 kg/m^3 (O5), OPF 10 kg/m^3 (O10) and OPF 15 kg/m^3(O15). For all mixtures, water to cement ratio was fixed at 0.47. The four different mixtures were prepared for compression test at 3, 7 and 28 days. Besides, slump test of each fresh concrete mixture was carried out to study the workability of the mixtures. It is worthy to mention that the OPF (figure 1) employed in this study were supplied by Sime Darby Oil Palm Factory, which is located at Labu, Negeri Sembilan. The OPF with diameter of 0.2 mm to 1.0 mm and the length of 20 mm to 40 mm were employed in this study.

Table 1. Mix proportion (kg/m^3)

Mixture	Cement	Fine Aggregates	Aggregates 10mm	Aggregates 20mm	Water	OPF	Density
C0	340	515	460	925	160	0	2400
O5	340	515	460	925	160	5	2405
O10	340	515	460	925	160	10	2410
O15	340	515	460	925	160	15	2415

Figure 1. Oil Palm Fiber (OPF).

2.2. Preparation of specimens and testing

Prior the mixing of concrete, OPF were dried naturally in open area. For each mixture, three repetitive specimens of 100 mm x 100 mm x 100 mm cubes were prepared for compression test. Table 2 shows the number of specimens prepared for both compression test and slump test. Basically, for all mixtures, fine aggregates and cement were first mix thoroughly in the concrete mixture, coarse aggregates were then added followed by adding water to the mixture to achieve fluidity and uniformly of concrete. For OPF mixtures, OPF were inserted gently and slowly to avoid balling that could cause inaccuracy of the test results. Mixing process was terminated when all OPF fibers were evenly distributed. The fresh concrete was then cast into the prepared moulds and specimens were cured in the water for 3, 7 and 28 days for compression test. Compression test was carried out according to the European Standard (BS EN 12390-3: 2009) [12] while slump test was conforming to European Standard (BS EN 12350-2: 2009) [13].

Table 2. Number of specimens

Mixture	Compression 3 days	Compression 7 days	Compression 28 days	Slump test
C0	3	3	3	3
O5	3	3	3	3
O10	3	3	3	3
O15	3	3	3	3

3. Result and Discussion

3.1. Slump test

Table 3 shows the result of slump test. Generally, the slump value decreased when OPF was added to the concrete mixtures. The reduction of slump value was proportional to the OPF content added as shown in Table 3. Figure 2 depicts the relationship between slump value and OPF content. No optimum content of OPF can be observed through slump test. All mixtures demonstrated the same type of slump i.e. true slump and the slump value (ranged 31-40 mm) represented low workability of the fresh mixtures. When OPF added to the concrete matrix that having the same mix proportion of cement, fine aggregate, coarse aggregate and water, workability was reduced because the inclusion of fiber led to high volumes of entrapped air in concrete mixtures [14], stiffened the mixture resulting in an increased stability of the matrix [3].

Table 3. Result of slump test

Mixture	Slump value (mm)			Average slump (mm)	Type of slump	Reduction of slump (%)
	Sample 1	Sample 2	Sample 3			
C0	40	42	38	40	True slump	0
O5	37	35	38	37	True slump	7.5
O10	33	36	34	34	True slump	15.0
O15	31	30	33	31	True slump	22.5

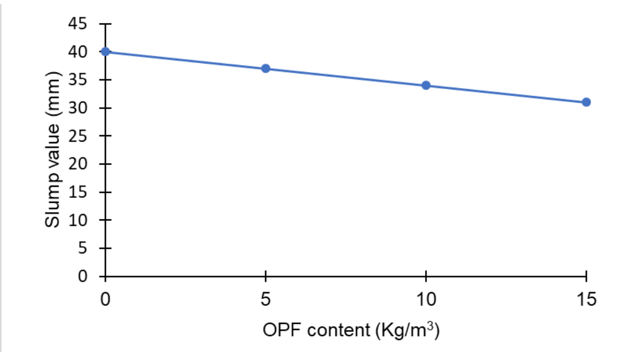

Figure 2. The effect of OPF content on slump

3.2. Compressive strength

Result of compressive strength is summarised in Table 4. figure 3 shows the average compressive strength at 3 days, 7 days and 28 days. It is worthy to mention that the average compressive strengths were obtained from three repetitive cubes. Control specimen (CO) obtained 47.3 MPa of compressive strength at 28 days while OPF specimens demonstrated enhanced compressive strength over control specimen at all ages. It is clearly that compressive strength increased constantly as the content of OPF increased from 5 to 15 kg/m^3, a compressive strength of 55.1 MPa was recorded for specimen O15 at 28 days. Figure 4 shows the trend of enhancement in compressive strength for OPF specimens at different ages. At 3 days, the enhancement was not significant for O5 but rapidly increased for O10 and O15. On the other hand, the enhancement was rapid for O5 and O10, but it had been slow down for O15 at 7 days. At 28 days, the enhancement was increased proportionally to the content of OPF. The inclusion of OPF in concrete helped in bounding the concrete matrix in lateral direction, thus increased the confinement effect and indirectly improved the strength of concrete when the OPF cubes were compressed.

Table 4. Result of compressive strength

Mixture	Average Compressive Strength (MPa)			Enhancement of Compressive Strength (%)		
	3 days	7 days	28 days	3 days	7 days	28 days
C0	17.9	28.7	47.3	0	0	0
O5	18.3	31.1	49.5	2.2	8.4	4.7
O10	20.1	33.8	52.8	12.3	17.8	11.6
O15	21.4	34.3	55.1	19.6	19.5	16.5

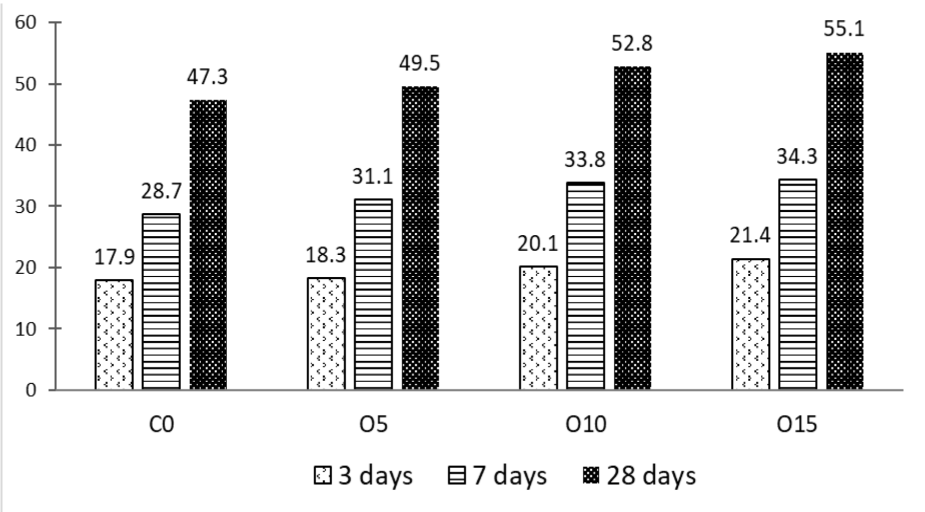

Figure 3. Compressive strength at different ages

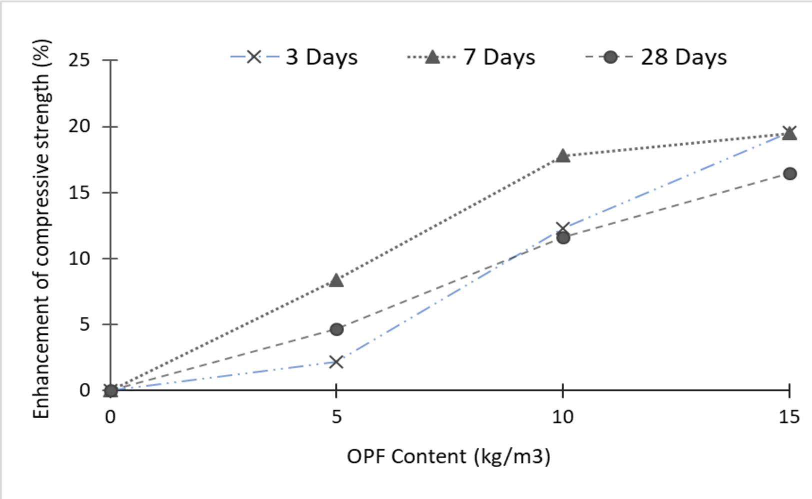

Figure 4. Enhancement of compressive strength

4. Conclusions

The workability and compressive strength of OPF concrete were compared with plain concrete (control specimen) through slump test and compression test. Plain and OPF concrete mixtures were designed with a fix proportion, the only variable parameter was the addition of OPF at 5, 10 and 15 kg/m^3. As a result, the fresh density of OPF mixtures was slightly increased (in the range of 0.2-0.6%). The following conclusions were derived.

- OPF reduced workability of fresh concrete, the rate of slump reduction was proportional to the amount of OPF added. OPF 15 kg/m^3 reduced the slump by 22.5%.
- OPF able to enhance compressive strength of hardened concrete at all ages, compressive strength increased when the amount of OPF increased. At mature age (28 days), the enhancement of compressive strength is linear when the amount of OPF increased to 5, 10 and 15 kg/m^3.
- No optimum content of OPF was obtained in this study for the enhancement of compressive strength. However, the result of slump value and the fresh density of OPF concrete could be employed to limit of amount OPF added to concrete matrix.

5. References

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