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Compressive and Flexural Strength of Concrete Containing Palm Oil Biomass Clinker with Hooked-End Steel Fibers

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Abstract: This research was carried out to evaluate the influence of hooked-end steel fibers on compressive and flexural strength of concrete containing palm oil biomass clinker (POBC) as partial replacement of fine aggregates. The optimum percentage of POBC was taken as 10%, to replace natural sand. Due to the porous characteristic of POBC, hooked-end steel fibers were added to improve the flexural strength of concrete. This research involves 10% of POBC with varying percentages of the hooked-end steel fibers i.e. 0.2%, 0.4% and 0.6% by weight was produced. Total 48 specimens were casted, 24 concrete cubes for compressive strength and 24 prisms were casted for flexural strength at 7 days and 28 days. Hence, it was evaluated that the reduction of workability of concrete with the addition of steel fibers. Furthermore, maximum flexural strength was recorded as 2.54 MPa with 0.4% hooked-end steel fibers at 28 days and maximum compressive strength of was recorded as 27.51 MPa with 0.6% hooked-end steel fibers at 28 days. It was concluded that the hooked-end steel fibers have good potentiality to enhance the compressive as well as flexural strength of concrete.

Keywords: Hooked-end steel fibers, palm oil biomass clinker, workability, compressive strength, flexural strength.

1. Introduction

Concrete is the chief material in construction, due to its versatility, durability and sustainability. It is categorized by brittle failure as it nearly completed loss of load sustaining capacity [1]. In order to reduce the shrinkage cracks and impart economy of concrete, aggregates play an important role in the mix design [2]. Natural sand is one of the major constituents' materials used in preparation of concrete and development of infrastructure [3]. This situation directed to the extensive use of natural sand, which is also an environmental concern. Therefore, researchers are intended to introduce new alternatives for the sustainable concrete construction. One of such solution is the application of industrial wastes in concrete such as palm oil biomass clinker [4] [5], fly ash [6-8], coal bottom ash [9-12], rice husk ash [13-16] and silica fume [17] in the production of concrete.

The palm oil biomass clinker (POBC) is a mineral by-product, produced from the burning of the palm oil fiber and kernel shells in the boiler [4]. This study considered POBC as fine aggregates in concrete. The particle size distribution of POBC ranging from 100 mm to 400 mm, which indicates the suitability to be utilized as fine aggregates [18]. The literature review indicated that the replacement of sand with POBC resulted in decreasing the workability of concrete [4] [19] [20].In addition to that the compressive and flexural strength of concrete were observed as increasing with the incorporation of POBC in concrete [4]. Generally, excessive replacement level has produced porous concrete with lower strength concrete. Hence, to enhance the compressive and flexural strength of concrete, steel fibers were introduced into concrete [21].

It has been observed by Lee [22] that hooked-end steel fibers able to improve properties of concrete from brittle to ductile behavior of concrete structures. It was generally observed that hooked-end steel fibers are difficult to distribute uniformly in the concrete mixture and well distribution of fibers gives optimum benefits of hooked-end steel fibers [23]. Formerly 0.5 to 1.5% of steel fibers in concrete were used by the researchers [24]. Beside that the concrete has an advantage to prepared and fabricated easily in different shape in the structural

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systems. Therefore, concrete is popular and widely used material of construction in the world [25] Theoretically, in this research the hooked-end steel fibers were incorporated into the concrete containing 10% of POBC. The effects of hooked-end steel fibers on the fresh and hardened properties of concrete were investigated in this research.

2. Previous Related Research

Based on the previous studies, the concrete compressive strength was increased with the increasing of the palm oil biomass clinker [4] [19]. Typically, compressive strength of concrete was increased up-to 5 to 20% replacement level and reduction in compressive strength was observed when the replacement level more than 20% [4] [5]. This is due to glassy surface texture of palm oil biomass clinker (POBC) led to the negative effect on cohesion between the particles [26] and due to pozzolanic reaction offered by POBC in concrete, which is able to improve the interfacial bond between the paste and aggregates.

Fibers is a small discrete reinforcing material to arrest the crack in concrete in order to overcome the weakness of concrete in tension [27]. Nowadays, various types of fibers were available in market with different shape and size which included glass fibers, steel fibers, natural and synthetic fibers. Steel fibers were used in this research to investigate the influence of fibers on hardened properties concrete . It can be obtained through wire was cut or chopped to required lengths. Different types of crimps, notch and shape of steel fibers was introduced in order to improve the mechanical bond of concrete [28]. However, the addition of steel fibers into concrete mixtures could enhance the ductility, toughness, flexural, tensile and shear strength of concrete [29]. Steel fibers have many types such as hooked-end, end large, wave cut and deformed sheet steel fibers [28]. Hooked-end steel fibers were introduced in this study in order to reduce the brittle fracture of concrete when loads are applied [28]. Hooked-end steel fibers widely have high strengthening effect compared to other types of steel fibers. Furthermore, addition of fibers possibly reduces the severity of failure mode for concrete and the crack's width of concrete able to reduce when the presence of hooked-end steel fibers [28] [29]. This is because the development of micro-cracking and their propagation along the matrix was delay [21] as the pinching forces was applied at the tips of the crack.

The rise in compressive strength of concrete was recorded with additional of hooked-end steel fibers [26]. This is due to the internal passive confinement of the matrix by steel fibers that delays the spreading and propagation of crack. Meanwhile, some research [28] [29] have found that the compressive strength of concrete does not increased significantly with small amounts of hooked-end steel fibers added into concrete mixtures. Although the influence of hooked-end steel fibers on the flexural strength of concrete is greater than direct tension and compression [29]. Therefore, the flexural strength of concrete can be improved with hooked-end steel fibers added into concrete.

3. Material and Methodology

3.1 Materials

3.1.1 Cement

In this study, ordinary portland cement (grade 42.5) conforming to Malaysia Standard MS 197-7: 2007, was used.

3.1.2 Course Aggregates

The coarse aggregates collected from Muar, Johor, Malaysia. The coarse aggregate having size of 10 mm was selected for the research. After collection, the coarse aggregates were kept for dried drying purpose for several days to achieve saturated surface dry (SSD) condition. Thus, the coarse aggregates were sieved through 10mm sieve size.

3.1.3 Fine Aggregates

The fine aggregate (sand) was collected through river sand from Kahang, Johor, Malaysia and air dried for 2 days in order to achieve saturated surface dry (SSD) conditions. Before the laboratory work, the sand was sieved through 5 mm sieve.

3.1.4 POBC

In this study, palm oil biomass clinker (POBC) as shown in Fig.1 was used as fine aggregate at 10% from the total content of fine aggregate. in concrete. The selection of 10% replacement was based on the trial mix tests.

Fig. 1 Palm oil biomass clinker

3.1.5 Steel Fibers

Hooked-end steel fibers as shown in Fig.2, was supplied by Timuran Engineering Sdn Bhd. It is Group I (cold drawn wire) that conforms to BS EN 14889-1: 2006 and MS 2388: 2010 was used in concrete. Various percentages of the hooked-end steel fibers was added into concrete.

Fig. 2 Hooked-end steel fibers

3.2 Experimental Work

The concrete mix was prepared based on DOE method of concrete mix design at fixed water-to-cement ratio for all the samples as mentioned in Table 1. In this research total 48 specimen were prepared as mentioned in Table 2. 10% POBC proportion was calculated with reference to the amount of fine aggregate (sand) and steel fibers proportion were calculated with reference to the total volume of the batch by weight method. Concrete cubes of size 100 mm were casted for compressive strength and prisms 100 in cross-section and 500 mm in length were casted for flexural strength. Raw materials testing has been done for sand and POBC i.e. Sieve analysis and specific gravity in to evaluate the physical characteristics and particle fineness. Furthermore, the curing period was observed as 7 and 28 days and samples were kept immersed in water.

Table 1 Concrete mix design (Kgs/m^3) with 10% POBC containing hooked-end steel fibers

% of Hooked-end steel fibers	**Cement**	**Sand**	**C.A**	**POBC**	**Water**	**Fibers (kgs)**
0	18.24	37.84	28.62	3.78	9.12	0
0.2	18.24	34.06	28.62	3.78	9.12	0.19
0.4	18.24	34.06	28.62	3.78	9.12	0.37
0.6	18.24	34.06	28.62	3.78	9.12	0.56

Table 2 The Specimen casted for compressive and flexural strength

% of Hooked-end steel fibers	**7 days**		**28 days**	
	Comp. Test	**Flex. Test**	**Comp. Test**	**Flex. Test**
0	3	3	3	3
0.2	3	3	3	3
0.4	3	3	3	3
0.6	3	3	3	3
Sub Total	12	12	12	12
Total Samples		48		

4. Results and Discussion

Collected POBC were evaluated for the physical properties and results are provided in Table 3.

Table 3 Physical properties of POBC

Property of material	Value
Specific gravity	2.06
Sieve analysis	Zone of aggregates – Zone I

The particle size distribution results are provided in Fig. 3. It is demonstrated that the sand and POBC are in the range of the upper and lower limits. Furthermore, the pattern of size distribution graph for sand and POBC are in the same size. The total percentages of sand and POBC passed through 5 mm sieve were 95 to 99%. Moreover, there was 2% and 0.67% of sand and POBC particles passed through 0.063 mm sieve respectively. Thus, it can conclude that sand has finest particles than POBC and similar results have been noticed in the previous studies [4] [19].

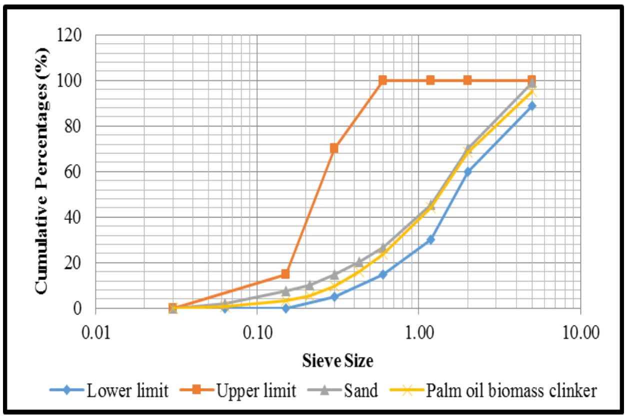

Fig. 3 Particle size distribution

The workability of concrete was measured, and the results are provided in Fig. 4. The results are indicated that the slump value was decreased with the increment of hooked-end steel fibers. The decrement of workability of concrete due reduction in mobility of material and fibers creates blocking to the relative movement of the aggregates [30]. Therefore, it restrained the concrete mixtures from segregation and flow and lower slump was observed with the increase proportion of steel fibers in the concrete. Comparable results have been noticed in the previous studies [23] [30].

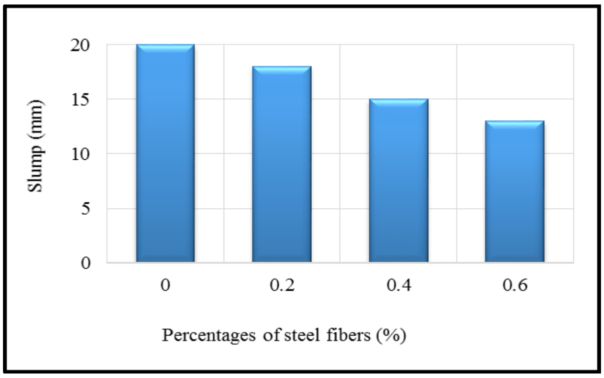

Fig. 4 The slump values of POBC-concrete with steel fibers

The compressive strength was investigated through concrete cubes containing 10% of POBC with varying percentage of hooked-end steel fibers. The average results for compressive strength are provided in Fig. 5. The result shows that the compressive strength tends to decrease with the addition of hooked-end steel fibers. The maximum compressive strength was recorded as 26.01 MPa and 27.51 MPa with 0.6% inclusion of hooked-end steel fibers at 7 days and 28 days respectively. The concrete compressive strength declines due to the unevenly distribution and improper orientation of hooked-end steel fibers [21]. Thus, it unable to resist the propagation of crack and reduced the concrete strength.

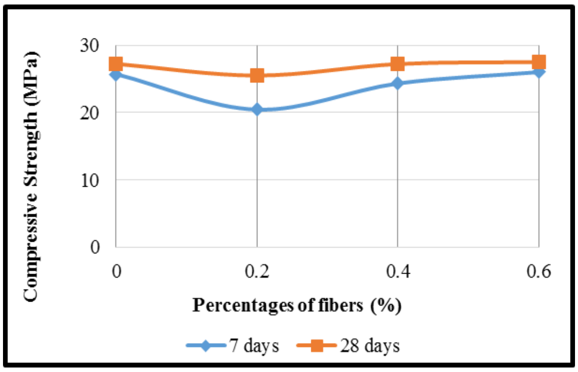

Fig. 5 Compressive strength of POBC-concrete with steel fibers

Apart from the compressive strength, the flexural strength of concrete containing 10% POBC with varying percentage of hooked-end steel fibers were also investigated in this research and results are demonstrated in Fig. 6. The maximum flexural strength in concrete was recorded as 2.23 MPa and 2.54 MPa at 7 days and 28 days respectively with 0.4% inclusion of hooked-end steel fibers. The growth of flexural strength due to the capability of hooked-end steel fibers in releasing the fracture energy around the crack tips [24]. But beyond the 0.4%, reduction of flexural strength was observed, however it is still higher than the control specimen. This situation happens due to low fibers content in the critical area was led to the unacceptable reduction of strength.

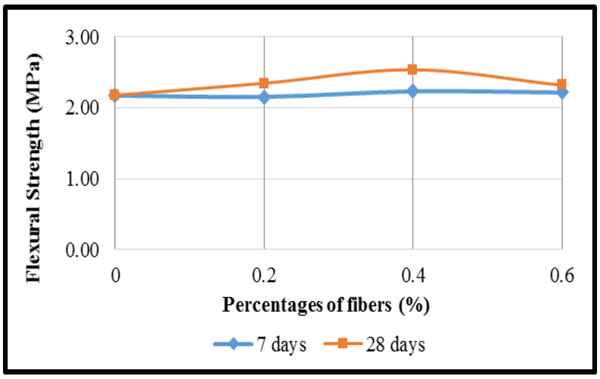

Fig. 6 Flexural strength of POBC-concrete with steel fibers

5. Conclusion

Based on the experimental results fallowing conclusions have been drawn:

i. The concrete with 10% POBC as sand replacement along with hooked-end steel fibers, decreases concrete workability.
ii. The maximum compressive strength was recorded as 26.01 MPa and 27.51 MPa with 0.6% inclusion of hooked-end steel fibers at 7 and 28 days respectively.
iii. Compressive strength tends to decrease with the addition of hooked-end steel fibers. The compressive strength of concrete declines may be due to the unevenly distribution and improper orientation of hooked-end steel fibers.
iv. The maximum flexural strength in concrete was recorded as 2.23 MPa and 2.54 MPa at 7 days and 28 days respectively with 0.4% inclusion of hooked-end steel fibers.

Therefore, it was concluded that the hooked-end steel fibers have good potentiality to enhance the compressive as well as flexural strength of concrete but appropriate mixing of concrete and proper distribution of hooked-end steel fibers should be ensured.

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