Australian Journal of Basic and Applied Sciences, 7(4): 184-188, 2013
ISSN 1991-8178

Flexural Behaviour Of High Performance Slurry Infiltrated Fiber Reinforced Concerete With Different Curing Method

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Abstarct: In the conventional steel fiber reinforced concrete, the structure is fabricated by combining steel fiber to the concrete mix. By using this method, the volume fraction of fiber is limited. So in order to improve the properties of fiber reinforced concrete, slurry infiltrated fiber concrete was introduced. In this study, concrete slurry grades 80 is 3%, 4%, 5% and also the control sample without fiber. Sizes of prism used in this study are 100 x 100 x 500 mm. In order to determine the effect of the curing method, each sample with different volume friction were prepared for two types of curing method. Water curing and steam curing at temperatures of 80° Celsius and cured for 24 hours were applied. The prisms were tested by two-point load test until failure. The behaviors of the prisms were observed and the load-deflection was recorded. Based on the result, it was concluded that the optimum steel fiber content in this report was 5 % by volume friction which provided the highest flexural strength and deflection. The prisms with steam curing obtained lower flexural strength compared to the water curing prisms except for the control specimen.

Key words: slurry infiltrated fiber reinforced concrete, steel fiber, water curing and steam curing

INTRODUCTION

In 18th century, concrete have been recognized as structure that very weak in tension (Neville, 1981). Thus, concrete need additional supporting material that can improve the tension capacity. The most common reinforcement used in the construction is the steel bar which is embedded in the concrete at specific position. As an alternative, fiber can be used to replace with the steel bar as reinforcement. (Naaman, 1985). In early 19th century, asbestos fiber is the first fiber used as concrete reinforcement. Steel, glass and synthetic fibers were used in concrete in 1960s because of the difficulty to handle the asbestos fiber (Abdonasrah, 2011).

Some experimental works have been done to trial the steel reinforcement such as metal clips, nails and wire segments (ACI Committee, 1996). The major experimental works about steel fibers as reinforcement have been done at United States in early 1960. Steel fiber has different shapes and cross sections. Shapes such as straight, hooked, crimped, double duoform, ordinary duoform, paddled, enlarged ends, irregular and indented, cross section such as round wire, rectangular sheet and irregular (Behbahani H.P., 2010)

According to Mon (2010), fiber reinforced concretes are classified into three groups based on the fiber volume friction and fiber effectiveness. The groups are very low volume (< 1% fiber volume), moderate volume (1-2 % fiber volume) and high volume (>3% fiber volume)fraction of fiber .

In 1979, Slurry infiltrated fiber concrete have been introduced by Lankard Materials Laboratory,Columbus, Ohio, USA, by incorporating huge amounts of steel fibers with cement to form the new structure (Lankard, 1984). For the normal fiber concrete, the limitation of the fiber volume (Vf) is between 1 % and 2 %, meanwhile for the Slurry infiltrated fiber concrete the range of the fiber volume is 5 % and 30 % (Lankard, 1985). Slurry infiltrated fiber concrete is one of high performance fiber reinforced concrete. Slurry infiltrated fiber concrete is made by distributing short discrete fibers in the mold to the full volume or designed volume fraction, and then infiltrated by a fine liquid cement-based slurry or mortar. The fibers can be sprinkled by hand or by using fiber-dispending units for large sections (Gilani, 2007).

The main objective in this study to investigate the effect of different curing method for high performance slurry infiltrated fiber reinforced concrete under flexural load. Therefore two different curing methods were prepared, for normal curing and steam curing at temperatures of 80° Celsius. To be more details, three different steel fiber volumes 3, 4 and 5% will be tested and compared with control specimen without steel fiber. Cement slurry grade 80 was used and combined with steel fiber to produced high performance slurry infiltrated fiber reinforced concrete. Furthermore, prism size of 100 x 100 x 500 mm was used in this study and the flexural strength test based on the British Standard BS 1881-118 (1983), method for determination of flexural strength.

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MATERIALS AND METHODS

The materials used in this study to form cement slurry include cement, silica fume, fine sand, superplasticizers, and water. The cement used in this project was Type I ordinary Portland cement manufactured to MS 522: Part 1: 1989 Specifications for Ordinary Portland Cement. Densified silica fume was used which contains more than 92% of silica dioxide (SiO_2) with particle size range of 0.1 to 1μm and surface fineness of 23700m^2/kg. Washed-sieved fine sand with particle size range between 100μm and 1000μm is also used. The superplasticizer used was polycarboxylic ether (PCE) based superplasticizer. Other material used is steel fiber, which is added in the cement slurry to produce high performance fiber reinforced concrete. Sizes of prism used in this study are 100 x 100 x 500 mm.

Table 1: Mix design of Grade 80 slurry.

	Mass(kg)	Specific Density (kg/m^3)	Volume (m^3)
G80 premix	2000	2727	0.733
Superplasticizer	47	1070	0.044
Total Water	224	1000	0.224
Total	2271		1.001

Table 2: Properties of hooked-end steel fiber.

Commercial Name	Length (mm)	Diameter (mm)	Aspect Ratio
Cho80/60nb	60	0.75	80

Mixing Procedure:

The slurry was mixed in the drum mixer for about 30 to 35 minutes. The cementitious materials are weighing to the required volume and placed into mixer at beginning of mixing process. Initially, 70% of liquid material (superplastisizer and water) is added into the mixer for 15 about to 20 minutes. The rest 30% of water is added equally at last 10 minutes and 5 minutes. Table 3 summarized of the time and volume of mixing process.

Table 3: Volume of Superplastisizer and Water added during mixing process.

Time of mixing	Volume of the Liquid Material (Superplastisizer and Water)
First 15 to 20 minutes	70%
Last 10 minutes	15%
Last 5 minutes	15%

Curing Method:

Two curing methods were applied for this study. The first curing is the normal curing method which is water curing. This process needs the surface of the specimens continuously in contact with water at room temperature for 28 days after which the specimens were tested (Neville, 2002). The second curing method is steam curing, which is similar to water curing but at higher temperature. The water temperature and duration of steam curing is depending on the required experimental design. In this study, the temperature was set at 80 °C and the specimen was placed on the acceleration curing tank for about 24 hour. After that the specimens were removed to the normal curing tank until 28 days for experimental test.

Test Procedure:

Two-point loading test is conducted based on the British Standard BS 1881-118 (1983), method for determination of flexural strength. This method describes the determination of flexural strength of test specimens of hardened concrete by moment in the centre zone using two point loading (BSI, 1983).

The specimen was placed at the center of flexural machine with two supports and two loadings arrangement as illustrated in schematic diagram in Figure 1. The two supports considered as simply supported condition. The loading was applied at the center of the specimen and transmitted to two points loading until failure. The load was directly measured by the unit test machine and the vertical deflection and load reading was appeared on the screen of the machine. The vertical deflection was measured by linear variable differential transducers (LVDT) located at the center of the specimen using magnetic stand. The load and deflection data required for each test specimens was recorded from data logger UCAM-70A.

RESULTS AND DISCUSSIONS

The result for flexural strength was tabulated in Table 4 and 5. All the water curing specimen's results is higher than steam curing except for the prism without steel fiber content. The highest flexural strength obtained in this research is 26.48 MPa with 5% volume friction of steel fiber.

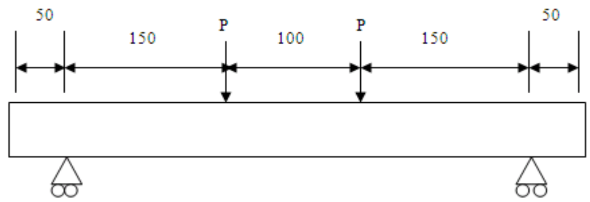

Fig. 1: Two-point loading test arrangement (all dimension in mm).

Table 4: Flexural strength of water curing specimens.

Percentage of fiber (%)	No. of samples	Flexural Load (kN)	Average Flexural Load (kN)	Average Flexural strength (MPa)
0	1 2	21.74 22.89	22.32	8.93
3	1 2 3	46.31 42.63 45.05	44.66	17.86
4	1 2 3	59.25 53.97 58.21	57.14	22.86
5	1 2 3	63.03 69.73 65.86	66.21	26.48

Table 5: Flexural strength of steam curing specimens.

Percentage of fiber (%)	No. of samples	Flexural Load (kN)	Average Flexural Load (kN)	Average Flexural strength (MPa)
0	1 2	30.12 28.85	29.49	11.80
3	1 2 3	40.80 42.37 38.14	40.44	16.18
4	1 2 3	51.39 47.22 53.17	50.59	20.24
5	1 2 3	54.95 59.19 57.71	57.28	22.91

The specimens with steel fiber show different result compared with the control samples. For the specimen with steel fiber, water curing specimens achieved highest flexural strength which is 26.4 MPa compared with steam curing with only 22.91 MPa. This is because presence of honeycomb and small crack in the specimens with steel fiber content. The steel fiber on the surface of specimens is not properly covered by the slurry during vibration process; therefore the honeycomb takes place at particular area. Small crack because of the shrinkage also occur during hardening process. This honeycomb and crack allowed and accelerated water to penetrate into the specimen during the steam curing process, as the result the specimen become weak.

Control samples of steam curing specimens in Table 4 and Table 5 obtained higher flexural strength than water curing specimens because of without steel fiber, it's eliminate possibility of honeycomb or porous to occurred at the prism surface, as a result water cannot penetrate into specimens. Therefore the effect of steam curing to speeds up the chemical reactions of hydration and thus affects the early strength of concrete can be applied with these specimens only.

Table 6: Deflection of water curing specimens.

Percentages of Fiber (%)	Average Flexural strength (MPa)	Average Deflection (mm)
0	8.93	0.70
3	17.86	2.92
4	22.86	3.20
5	26.48	4.10

Table 7: Deflection of steam curing specimens.

Percentages of Fiber (%)	Average Flexural strength (MPa)	Average Deflection (mm)
0	11.80	0.85
3	16.18	2.07
4	20.24	2.79
5	22.91	3.68

The highest deflection result from Table 6 and Table 7 are obtained by water curing specimens. The highest value of deflection for the prism size of 100 x 100 x 500 mm is 4.10 mm with 5% steel fiber contents. The relationships between flexural strength and deflection are illustrated in Figure 2. The highest deflection of water curing prisms is 4.10 mm at the maximum flexural strength of 26.48 MPa. The same result is shown by the steam curing prisms with maximum flexural strength of 22.91 kN obtained 3.68 mm deflection. Highest flexural strength gives the highest deflection value for both curing method. This is because the high flexural strength produces more toughness structure therefore it tends to achieved high deflection before the structure failure.

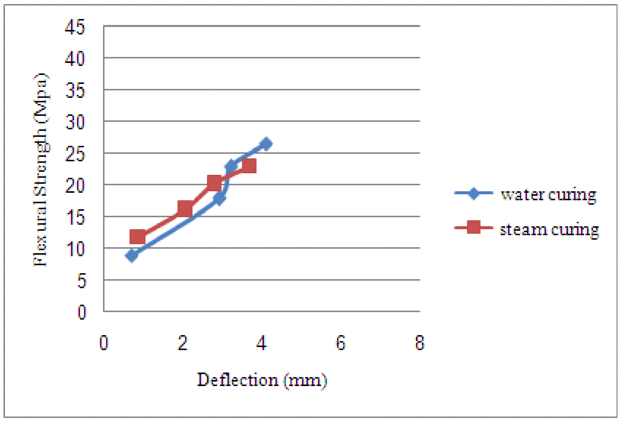

Fig. 2: Flexural Strength vs. Deflection for both curing method.

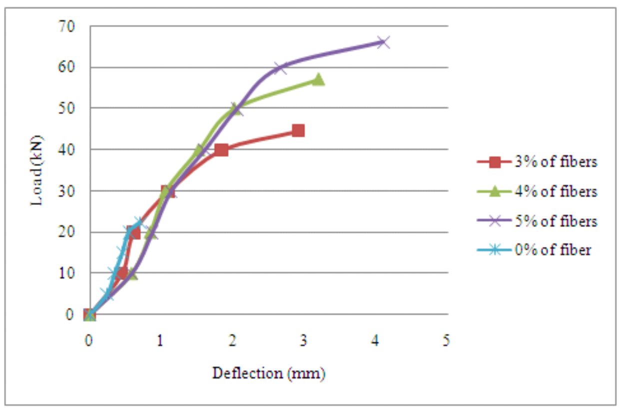

Fig. 3: Load-Deflection of water curing specimens.

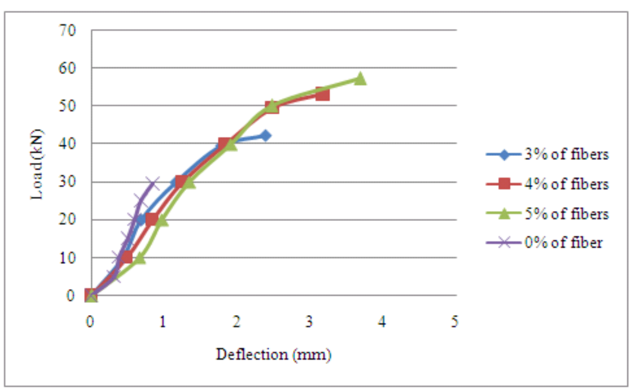

Fig. 4: Load-Deflection of steam curing specimens.

Figure 3 and 4 shows the Load-Deflection behavior of water and steam curing specimens. Generally, the similar behavior can be observed from the graph. The area under load-deflection curve shows the ductility of the specimen. Larger areas under the curve represent more ductile specimens. The control specimens have smallest area under the load-deflection curve because there is no steel fiber to increase the ductility of the specimens. Results of 3% steel fiber specimens are half than maximum graphs. There are only slightly different in the load-deflection behaviors of 4% and 5% steel fiber specimens. This result indicated that the steel fiber content should be in these range to achieve the good bonding between the steel fibers and the slurry.

All figures shown that 5% of the steel fiber specimens achieve the largest areas compared to the others fiber content. This is because denser specimen will increased the matrix density and provide good bonding between the slurry and the fibers. The maximum amount of 5% of the steel fiber specimens also increased the bridging effect between the steel fibers and subsequently increased the flexural strength as well the deflection as shown in all figures.

Conclusions:

This study is based on the experimental work to investigate the flexural strength and deflection behaviour of the different curing method for high performance slurry infiltrated fiber reinforced concrete. From the analysis of the results and observations of the experimental works, the conclusions that can be made are as follows:

a) The amount of steel fiber used effect strength of the beams. The flexural strength is increased constantly with increment of steel fiber content.
b) Flexural strengths and deflections of water curing beams are higher than steam curing beams except for beams without steel fibers (control sample).
c) Based on the flexural strength results, the maximum content of hooked-end steel fiber with aspect ratio 80 to obtained highest strength is 5% by volume friction.

ACKNOWLEDGMENT

The author wish to acknowledge the support from the structure and material technician of Faculty of Engineeering Universiti Putra Malaysia and several people contributed to this research, including but not limited to Dr Voo Yen Lai from Dura Technology Sdn. Bhd, Ipoh, Perak, Malaysia.

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