Solid State Phenomena
ISSN: 1662-9779, Vol. 304, pp 75-80
doi:10.4028/www.scientific.net/SSP.304.75

Submitted: 2019-12-06
Accepted: 2019-12-21
Online: 2020-05-19

Comparative of the Use of Carbon and Steel Fiber to the Mechanical Properties of Self Compacting Concrete

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Keywords: Carbon Fiber, Steel Fiber, Self Compacting Concrete, Tensile Strength, Flexural Strength

Abstract. This research is a comparative study, the use of carbon fiber and steel fiber for Self Compacting Concrete (SCC). In previous studies, it was proven that the addition of steel fibers can increase the compressive and tensile strength of SCC. While carbon fiber is one of the most widely used materials for structural reinforcement in recent years. Therefore it is necessary to do a comparative study of the use of carbon fiber if applied to SCC. The percentage increase in carbon fiber and steel is 0.5%, 1%, and 1.5%. Then do the testing of: slump test, compressive strength, tensile strength and flexural strength. The results showed the optimal percentage of steel fiber addition of 1.5%, can increase the compressive strength of SCC by 11%. However carbon fiber and steel do not increase the tensile strength of SCC, and tend to reduce flexural strength. Other results show that carbon fiber is not suitable for use in SCC.

Introduction

The progress of self-compacting concrete (SCC) technology is very helpful and beneficial for large volumes and very tight reinforcement distances. Some of its advantages include increased work productivity, reduced labor force, and elimination of vibrators [1-3]. However, there is continuous research on its developed, one of which is the addition of fiber to improve the mechanical properties of concrete [4]

However, this is likely to affect the workability of concrete because it has a higher specific surface compared to aggregates with the same volume. In addition, its use in a concrete mixture reduces workability depending on the type and content of the fiber utilized [5]. Addition of fiber in the concrete mixture increases compressive and tensile strength, thereby, making it more durable.

Previous research on the effect of adding 2% of steel fiber to the SCC mixture led to an increase in the tensile strength by 28.5%, with reduced workability [6]. Addition of steel fibers inhibits and increase the resistance of the concrete to cracking [7,8,9].

Carbon Reinforced Polymer (CFRP) has the advantage of having higher strength, a low weight, high stiffness, corrosion resistance, lower maintenance costs and faster installation time [10]

SCC Mix Design refers to previous studies [11]. However, modifications were made with the addition of a water volume of 4.9% and PCE type super plasticizer of 3.1%, which is capable of increasing concrete compressive strength by 26.77% [12].

This research therefore is a comparison of the use of steel and carbon fiber to the mechanical properties of SCC. It furthermore aims at producing the optimal percentage of fiber addition to improve the performance of SCC.

Methodology

Material OPC (Ordinary Portland Cement), coarse aggregate (10-20) mm and fine aggregate, type F fly ash from PT. Adhimix. In Table 1 shows the results of fine aggregate testing for Silica fume and Polycarboxylate Ether Superplasticizer (PCE).

Table 1 Fine aggregate test results

Test type	Result	Tolerance	Standard
Material Pass the Sieve No. 200 (%)	1,70	maximum of 3%	ASTM C. 117-95
Specific Gravity SSD	2,60	Minimal 2,55	ASTM C. 128-93
Absorption (%)	1,83	Maksimal 4%	ASTM C. 128-93
Fine Modulus	2,58	2,3 – 3,1	ASTM C. 33
Fill Weight	1,487	Minimal 1,2	ASTM C. 29-97
Organic Content	3	maximum 3	ASTM C. 40-92

The SCC mix design is shown in Table 2, with the proportion of specimens mix design in 1m^3
The C specimen is referenced by SCC concrete (without fiber), while the C1, C2, and C3 carbon fibers have an additional 0.5%, 1%, 1.5%.

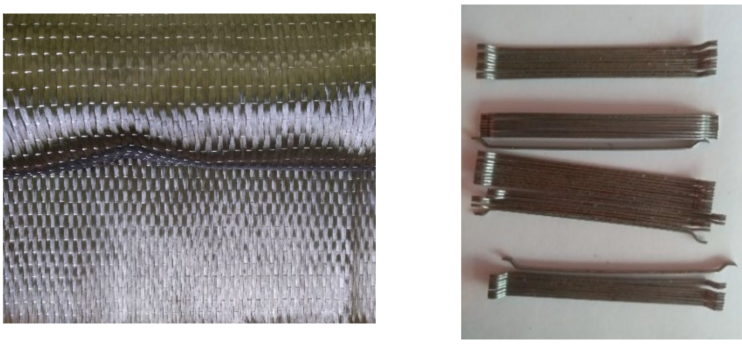
Table 2 The proportion of specimens mix design

Material	Unit	C	C1	C2	C3	S1	S2	S3
OPC	kg	400	400	400	400	400	400	400
Silica Fume	kg	50	50	50	50	50	50	50
Carbon fiber	kg	0	2,25	4,5	6,75	0	0	0
Steel fiber	kg	0	0	0	0	2,25	4,5	6,75
Coarse Aggregate	kg	657	657	657	657	657	657	657
Fine Aggregate	kg	904	904	904	904	904	904	904
Fly ash	kg	250	250	250	250	250	250	250
PCE	kg	26,5	26,5	26,5	26,5	26,5	26,5	26,5
Water	Liter	233,5	233,5	233,5	233,5	233,5	233,5	233,5

The carbon fiber used in this study is from PT. Fosroc Indonesia with brand of FRC 300, while the Steel fiber was from Dramix D. The technical data of both fibers is shown in Table 3 and Fifure 1. Show carbon and steel fiber.

Table 3 Technical data on carbon fiber and steel

Grade	Carbon Fiber (FRC 300)	Steel Fiber (Dramix 3 D)
Weight	300 (g/m2)	4.584 fibres/kg
Thickness	0.167 (mm)	Length :60 mm Diameter 0,75 mm
Tensile Strength (MPa)	3841	1225
Tensile Modulus(GPa)	230	210



Carbon fiber Steel fiber

Fig. 1 Carbon fiber and steel fiber

Tests were carried out to determine the slump value in concrete meets the test requirements of SCC, where the slump flow test requirements are 65-85 cm and t50 at 2-5 seconds [13].
The compressive strength of 3.7, was obtained in 28 days using ASTM C 39/C 39M-01, while, the tensile strength of the same values were also acquired using ASTM C 496-96. Flexural testing by ASTM C78 / C78-18 resulted in a beam specimen of 150 mm x 150 mm x 600 mm, tested at 28 days.

The tests performed are shown in Figure 2. Reference and fibrous SCC concrete were carried out by slump flow test and t_{50}

Fig. 2 Testing carried out on the sample

Result and Discussions

Slump test results as shown in Table 4. Based on the test results, it turns out that the reference SCC concrete (C), the percentage of carbon fiber 0.5% (C1), 1% (C2), percentage of steel fiber 0.5% (S1), 1 % (S2) and 1.5% (S3) steel, meet the requirements as SCC concrete. While Carbon fiber with a percentage of 1.5% produces slump below the standard, this is due to clumping of carbon fiber so that it does not meet existing requirements. So for the next sample addition of carbon fiber C3 no further testing of the mechanical properties (compressive strength, tensile and flexural)

The compressive strength test results are seen in Figure 3. At 3 to 7 days, fibrous concrete increased the compressive strength, without changing its value. However, on the 28 day, the control and fibrous concrete (carbon fiber and steel fiber) increased, with the value of compressive strength C, C1, C2. C3, S1, S2, and S3equals 40.11 MPa, 28.41 MPa, 14.83 MPa, 36.92 MPa, 39.79 MPa, and 44.56 MPa respectively.

Tabel 4 Slump value

Code	t_{50} (detik)	Standart$_{50}$ (detik)	*SlumpValue* (cm)	Standart SCC (cm)
C	5		67	
C1	5		74	
C2	5		71	
C3	-	2 - 5	-	65 - 85
S1	4		73	
S2	4		75	
S3	4		78	

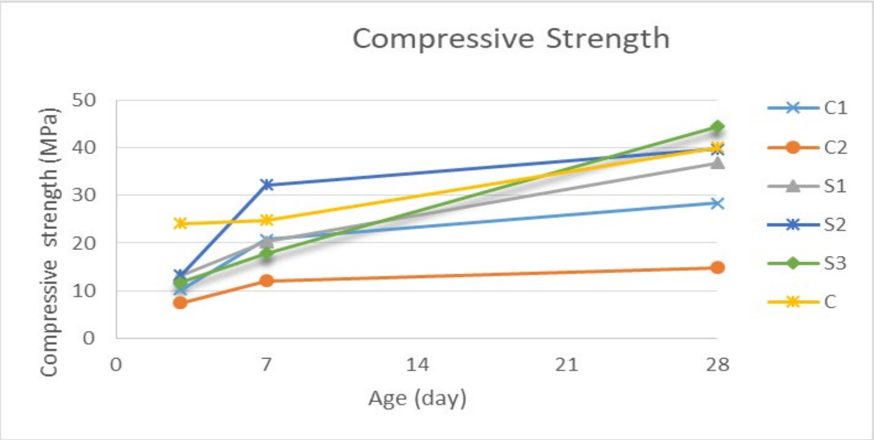


Fig. 3 Result of testing the Compressive Strength

The results of this test indicate that the use of carbon fiber with high tensile strength and modulus of elasticity which is incompatible when used as an additive in SCC. The percentage of carbon fiber addition resulted in a decrease in compressive strength compared to the reference concrete. This is due to carbon fiber clumping during mixing, thereby, disrupting its homogeneity. Whereas in steel fibers, its addition percentage tends to increase the compressive strength, with an optimum percentage of 1.5%, which is in line with previous studies [14].

The tensile test results are shown in Figure 4. At 28 days the strength of carbon and steel namely C, C1, C2, S1, S2, and S3 were 3.98 MPa, 3.92 MPa, 1.99 MPa, 3.4 MPa, 3 , 4 MPa, 3.45 MPa and 3.98 MPa respectively. The result of tensile strength with the percentage of steel fiber addition has a tensile strength close to the reference SCC, this is because of the adhesive between the concrete and steel fibers. While the percentage of carbon fiber addition shows a decrease in tensile strength.

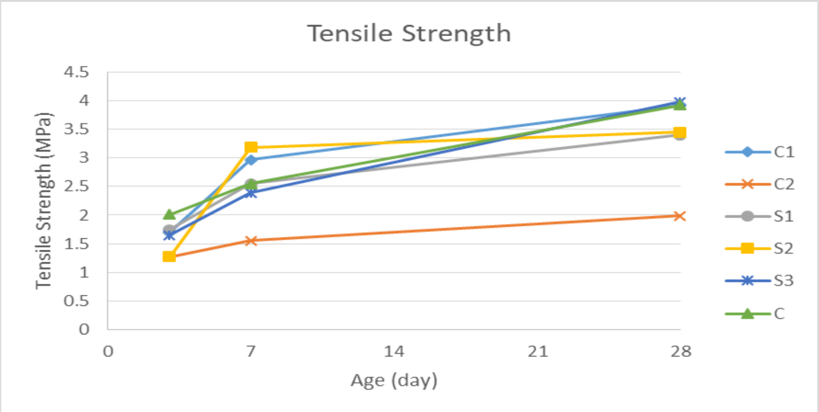


Fig. 4 Result of testing the Tensile Strength

The results of the flexural strength test shown in Figure 5, indicates the value between 7 and 28 days with values of 3.05 MPa and 4.94 MPa. In fibrous concrete (carbon and steel fibers), C1, C2, S1, S2, and S3 have flexural strength values of 3.30 MPa, 2.39 MPa, 3.72 MPa, 3.50 MPa, and 3.67 MPa respectively, where the flexural strength value increased but not significant. These results are in line with previous researches [15].

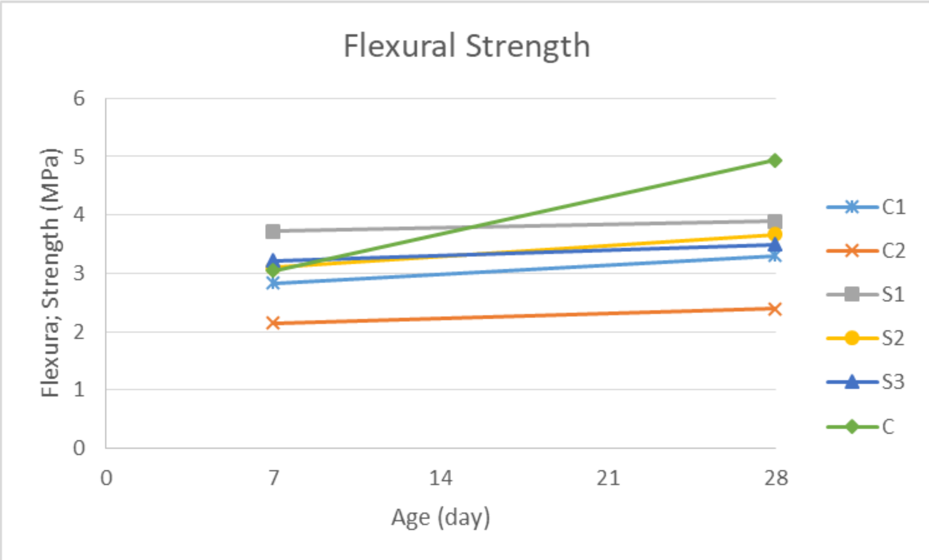


Fig. 5 Result of testing the Flexural Strength

Summary

Based on the results of this experimental study, the following summary were drawn:

1. Addition of 1.5% optimum steel fiber is capable of increasing the compressive strength by 11% of the reference concrete.
2. Carbon and steel fibers do not significantly increase the tensile strength of SCC and tend to reduce its flexural strength
3. Carbon fiber is not suitable for use in SCC.

Acknowledgement

The author thanks the financial support from Ministry of Research Technology and Higher Education of the Republic of Indonesia for this Research Grant with the Scheme of Competency Based Research for the year 2019.

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