Vol. 11, No. 1, pp. 19-21, June 2012

INTERNATIONAL
JOURNAL OF SAFETY
www.kosos.or.kr

An Experimental Study on the Fracture Strength of Steel Fiber Reinforced Concrete

Won-Kyu Chai*

Department of Civil Engineering, Shingu University, Sungnam-si 462-743, Korea

(Received March 6, 2012; Accepted June 5, 2012)

Abstract : In this thesis, fracture test was performed in order to investigate the fracture strength of SFRC(steel fiber reinforced concrete) structures. The relationship between the compressive force and strain value of SFRC specimens were observed under the compressive strength test. From the fracture test results, the relationship between percentage of fiber by volume, compressive strength, elastic modulus, and tensile strength of SFRC beams were studied, and the measured elastic modulus of SFRC were compared with the calculated elastic modulus by ACI committee 544.

Key words : steel fiber reinforced concrete, fracture test, percentage of fiber by volume, compressive strength, tensile strength, elastic modulus

1. Introduction

The mechanisms of fiber reinforced concrete was first studied by Romualdi and Batson [1,2]. They proposed that the increases in flexural strength and ductility of concrete with steel fibers can be attributed to the ability of the fiber to restrain cracks. Romualdi and Mandel [3] showed that the first crack strength is dependent upon the spacing of fibers. Hsu *et al*. [4] showed that all concrete contains flaws which could increase in size under loads which were less than 50% of the ultimate loads. Chang and Chai [5,6] studied that the fatigue strength with 2,000,000 repeated loading cycles in SFRC with the steel fiber content varying 0.5, 1.0, 1.5% shows about 71.3, 74.4, 77.8% on the first crack static flexural strength, respectively.

From the previous studies above, it can be concluded that the strength of SFRC is a function of the fiber content and the fiber aspect ratio. However, the effect of these parameters on the fracture strength of SFRC has not been clearly examined, and few studies on the fracture strength for SFRC beams with notches have been performed.

On this basis, this study was performed to investigate the fracture strength of SFRC beams with different fiber contents and fiber aspect ratios.

2. Test Program

Steel fibers with diameters of 0.6 mm, and lengths of 36, 48 and 60 mm were used to reinforce the concrete specimens. The material properties of steel fiber are shown in Table 1. Portland cement was used and the maximum size of coarse aggregate was 19 mm. The mix proportion is used is shown in Table 2 [7] .

Where W is water content, C is cement content, S is fine aggregate content, and G is coarse aggregate content, respectively.

In this thesis, the compressive strength test by the universal testing machine was done. The loading rate

Table 1. Material properties of steel fiber

Diameter(D) (mm)	Length(L) (mm)	Aspect ratio(L/D)	Density (g/cm^3)
0.6	36	60	7.85
0.6	48	80	7.85
0.6	60	100	7.85

Table 2. Mix proportion of concrete

W (kg/m^3)	C (kg/m^3)	S (kg/m^3)	G (kg/m^3)
185	482	752	936

*Corresponding author: cwk@shingu.ac.kr

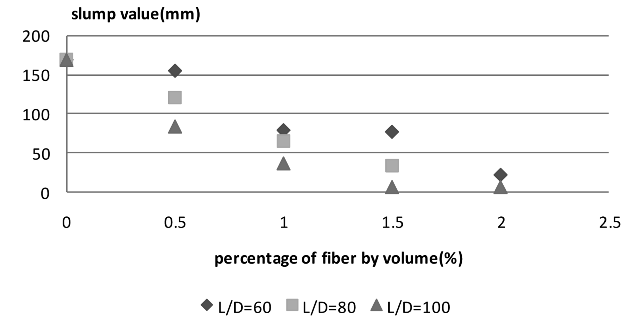

Fig. 1. The relationship between the percentage of fiber by volume and the slump value.

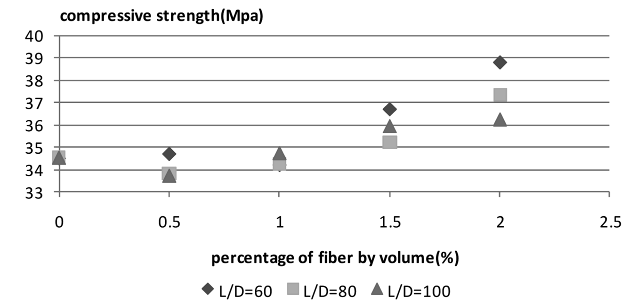

Fig. 2. The relationship between the percentage of fiber by volume and the compressive strength.

was kept continuously at 0.1 mm/min until the specimens were fractured. Loading value and the compressive strain were measured periodically using concrete strain gauges located at the specimen side.

3. Results of Fracture Test

3.1 Slump value

The slump test was performed according to KS F 2402 (Korean Industrial Standards F 2402) [7] in order to study the effects of the fiber content and the fiber aspect ratio on the consistency of SFRC. The relationship between the percentage of fiber by volume and the slump value are shown in Fig. 1.

According to the slump test results as shown in Fig. 1, by increasing the percentage of fiber by volume, the slump value decreases rapidly and the workability of SFRC is worse. Therefore, water content has to be increased adequately or a water reducing agent be used when the percentage of fiber by volume is more than about 1.0%.

3.2 Relationship between the fiber content and the compressive strength

Cylindrical specimens of $\phi 100 \times 200$ mm were made in order to investigate the compressive strength of SFRC. The relationship between the percentage of fiber by volume and the compressive strength of SFRC are shown in Fig. 2.

According to the compressive strength test results as shown in Fig. 2, by increasing the percentage of fiber by volume, the compressive strength increases. And when the fiber aspect ratio is 60, the compressive strength was maximum value.

3.3 Relationship between the fiber content and the tensile strength

The tensile strength of SFRC, σ_t, by Kobayashi [8] is as follow:

$$\sigma_t = K_t \times \left(\frac{1}{\sqrt{S_t}} - \frac{1}{\sqrt{S_c}}\right) + \sigma_{tm} \tag{1}$$

where, K_t is the constant is determined by bond strength, S_t is the average space of steel fiber in tensile area, S_c is the maximum value of S_t, and σ_{tm} is the tensile strength of the plain concrete. And S_t is as follow:

$$S_t = 5 \times \sqrt{\frac{\pi}{\beta_t}} \times \frac{D}{\sqrt{V_t}} \tag{2}$$

where, $\beta_t = 0.002 \times (L/D)$, L is fiber length, D is fiber diameter, and V_f is the fiber content.

The estimated tensile strength of the above equations was about 0.1times of the average compressive strength when the fiber content is 0.0~0.5%. And when the fiber content is 2.0%, tensile strength was about 0.15times.

From these results, it was known that the tensile strength of SFRC can be increased by increasing of fiber content. These results are shown in Table 3.

3.4 Elastic modulus of SFRC

In this thesis, according to the performed compressive strength test, the secant elastic modulus was measured. And measured elastic modulus are compared with suggested elastic modulus by ACI committee 544 [9], the comparison results is shown in Table 4.

Table 3. Tensile strength of SFRC

Fiber content (%)	Tensile strength(MPa)		
	L/D=60	L/D=80	L/D=100
0.0	-	3.4	-
0.5	3.4	3.4	3.5
1.0	4.1	4.2	4.3
1.5	4.7	4.8	4.9
2.0	5.1	5.2	5.4

Table 4. Comparison results of calculated elastic modulus and measured elastic modulus

Fiber content (%)	Calculated elastic modulus (GPa)	Measured elastic modulus (GPa)
0.0	22.3	22.3
0.5	23.2	24.1
1.0	23.7	23.1
1.5	24.1	24.3
2.0	25.0	27.0

The calculated elastic modulus of SFRC, E_{fc}, by ACI committee 544 is as follow:

$$E_{fc} = \left(1.0 - \frac{V_f}{100}\right) \times E_m + \frac{V_f}{100} \times E_{fi} \quad (3)$$

where, E_m is the elastic modulus of matrix(concrete) and E_{fi} is the elastic modulus of fiber.

In these results, it was found that the measured elastic modulus of SFRC was consistent with the calculated elastic modulus by ACI committee 544, approximately.

4. Conclusions

1. The slump values decrease rapidly when the percentage of fiber by volume of SFRC is more than about 1.0%. In such a case, the slump values must be increased by increasing a unit water volume or by adding the water reducing agent in order to achieve adequate effects of the fiber reinforcement.

2. According to the compressive strength test results, by increasing the percentage of fiber by volume, the compressive strength increases. And when the fiber aspect ratio is 60, the compressive strength was maximum value.

3. The estimated tensile strength was about 0.1times of the average compressive strength when the fiber content is 0.0~0.5%. And when the fiber content is 2.0%, tensile strength was about 0.15times

4. The measured elastic modulus of SFRC was consistent with the calculated elastic modulus by ACI committee 544, approximately.

References

[1] Romualdi J.P. and Batson G.B., Behavior of reinforced concrete beams with closely spaced reinforcement, Journal of ACI, Proceeding Vol.60, pp 775-790, 1963.

[2] Romualdi J.P. and Batson G.B., Mechanics of crack arrest in concrete, Journal of ASCE, EM3, pp 147-168, 1963.

[3] Romualdi J.P. and Mandel J.A., Tensile strength of concrete affected by uniformly distributed and closely spaced short lengths of wire reinforcement, Journal of ACI, Proceeding Vol.61, pp 657-671, 1964.

[4] Hsu T.T.C., Slate F.O., Sturman G.M. and Winter G., Microcracking of plain concrete and the shape of the stress-strain curve, Journal of ACI, Proceeding Vol.60, pp 209-224, 1963.

[5] Chang D.I., Chai W.K., An experimental study on the fracture behavior of steel fiber reinforced concrete prisms with notches, An International Journal of Structural Engineering Review, Pergamon Press, UK, Vol.4, No.2, pp 159-162, 1992.

[6] Chang D.I., Chai W.K., Min I.K., An experimental study on the fatigue behavior of steel fiber reinforced concrete structures, The Fourth East Asia-Pacific Conference on Structural Engineering & Construction, pp 1213-1218, 1993.

[7] The minister of construction in korea, Concrete standard specification, Seoul, Korea, 1988.

[8] Kobayashi, K, and Cho, R., Strength and deformation of steel fiber reinforced concrete in uniaxial tension, Proceedings of JSCE, No. 257, pp 85-94, 1977.

[9] ACI Committee 544, State-of-the-art report on fiber reinforced concrete, Journal od ACI, proceedings Vol. 70, No.11, pp 729-744, 1973.