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Direct Tensile Strength of Steel Fiber Reinforced Concrete by Using Clamping Grips

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Abstract

This report presents the tensile strength behavior of steel fiber reinforced concrete (SFRC).

In this experimental work, direct tensile test by using clamping grips is carried out for the prismatic mortar and concrete specimens reinforced with steel fibers. The volume content of steel fibers varies from 1.0 percent to 2.0 percent of the concrete volume.

Test results for different fiber content, fiber length, and specimen size are presented. The results are compared with the results of indirect tensile strength by splitting cylinder method.

Introduction

When we carry out direct tensile test by using clamping grips, it is very difficult to achieve a uniform tensile stress across a section of the concrete specimen without causing stress concentrations. Because clamping grips give rise to stress concentrations at the pressed points, the fracture is most likely to occur at this region. And its measured strength value becomes less than the real tensile strength.

A new type of clamping grips for direct tensile test on plain concrete is presented[1]. This grip is made of steel plates on which wedge-shaped rubber inserts are glued, and make it possible to use prismatic specimens without causing stress concentrations of too high magnitude.

In many cases, "necked" specimen is used for direct tensile test in order to cause the fracture at the middle part of the specimen. Compared with the prismatic specimen, the "necked" specimen produces fiber orientation at the "necked" region. And the fiber orientation in the cross section affects the tensile strength of SFRC. For this reason, prismatic specimen is employed for direct tensile test of SFRC in this experiment. The results are compared with the results of splitting cylinder tensile test for mortar.

Testing Equipment

Fig. 1 shows the clamping grip used for the direct tensile test. The grips are made of upper and lower steel plate and side steel plates on which several notches of 1 mm depth are provided perpendicular to the tensile direction. 3 mm thick rubbers are inserted between the steel plate and the concrete specimen. The rubber inserts reduce stress concentrations caused by clamping forces at the pressed points. The clamping forces at the ends of the specimen are greater than that of the grips closer to the middle of the specimen.

In this test, tensile load speed of 10 kgf/cm^2/min was employed. The load was measured by load cell and the concrete tensile strain was measured by wire strain gage of 30 mm in length at the middle part of the specimen. And they were recorded on x-y pen recorder for load-strain curves.

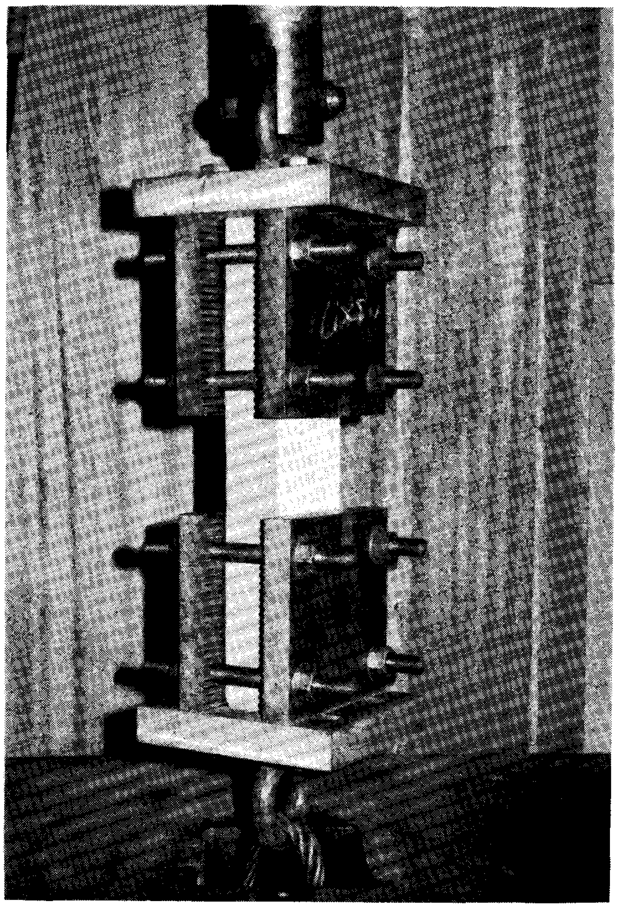

Fig. 1. Tensile test using clamping grips

Materials and Specimens

Table 1 shows the material properties for cement, aggregates and steel fiber. The mix proportions for one cubic meter of mortar and concrete are presented in Table 2. Four each specimens were prepared for every series. Fiber length and content are 20 mm, 30 mm, 40mm and 1.0, 1.5, 2.0 percent respectively.

The length of prismatic specimen used for direct tensile test is 400 mm. And three size specimens with different cross section, 25 mm × 100 mm (specimen I), 50 mm × 100 mm (specimen II), and 75 mm × 100 mm (specimen III) were made. Splitting tensile test was applied for cylinder specimen with 100 mm in diameter and 200 mm in length. In this splitting cylinder tensile test, load speed similar to that of direct tensile test was employed.

The specimens were cast manually. They were stripped after one day and cured in water (20°C ± 3°C) until the moment of the test. All the specimens were tested at the age of 28 days.

Table 1 Material properties

Material	Property
cement	normal portland cement, specific gravity = 3.17
fine aggregate	specific gravity = 2.55, absorption = 2.95% crushed sand
coarse aggregate	specific gravity = 2.61, absorption = 1.21% crushed stone
steel fiber	cross-sectional dimension 0.5 × 0.5mm fiber length Lf = 20, 30, 40mm tensile strength = 90kgf/mm^2

Table 2 Mix proportions (kg/m^3)

No	Vf (%)	Fine aggregate		Coarse aggregate		Cement	Water	Steel fiber
		0–2.5mm	2.5–5mm	5–10mm	10–15mm			
1	0	556	185	185	371	649	292	0
2	1	550	183	183	367	642	289	80
3	1.5	548	182	182	365	639	287	120
4	2	545	181	181	363	636	286	160
5	0	1250	0	0	0	625	313	0
6	1	1238	0	0	0	619	310	80
7	2	1225	0	0	0	613	307	160

Results and Discussion

Fig. 2 and Fig. 3 shows the relationships between direct tensile strength and fiber content, Vf, for mortar and concrete tested at 28 days respectively. It was observed that during loading, at a certain load, a crack appeared and the load dropped. Tensile strength of SFRC was calculated by using maximum tensile load.

Tensile strength of SFRC with 2.0 percent volume of fibers is about 60 percent greater than that of plain concrete. From Fig. 1, it can be said that with the increasing of fiber content, the effect of cross-sectional dimensions of the specimens on tensile strength is significant. It is considered that the difference in strength, for specimen I, II and III is the result of fiber orientation and size effect of the specimens.

Fig. 3 indicates that the length of fibers has little influence on tensile strength.

Fig. 4 shows the fracture surfaces of the concrete specimens reinforced with 2.0 percent volume of fibers. From the observation of failure location in the specimens, it was seen that 60 percent of the specimens fractured at the middle part and 40 percent of the specimens fractured at the region pressed by the grips close to the middle of the specimen. But, the difference of tensile strength between the specimen fractured at the middle part and at the region pressed by the grips can not be recognized.

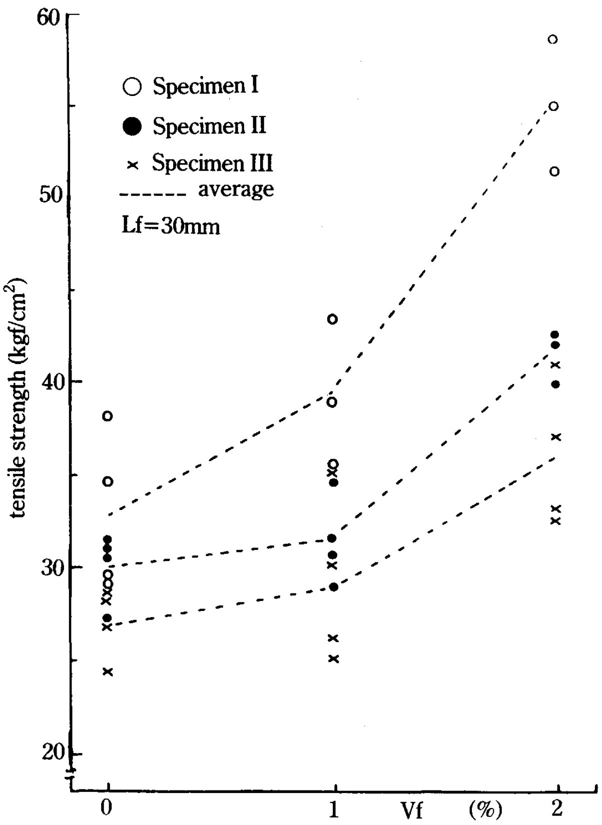

Fig. 2. Relation between tensile strength and fiber content (mortar, 28 days)

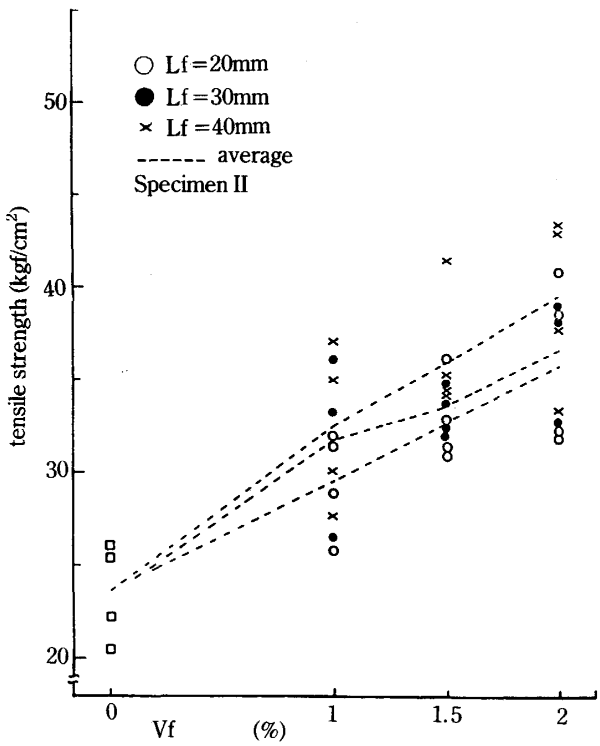

Fig. 3. Relation between tensile strength and fiber content (concrete, 28 days)

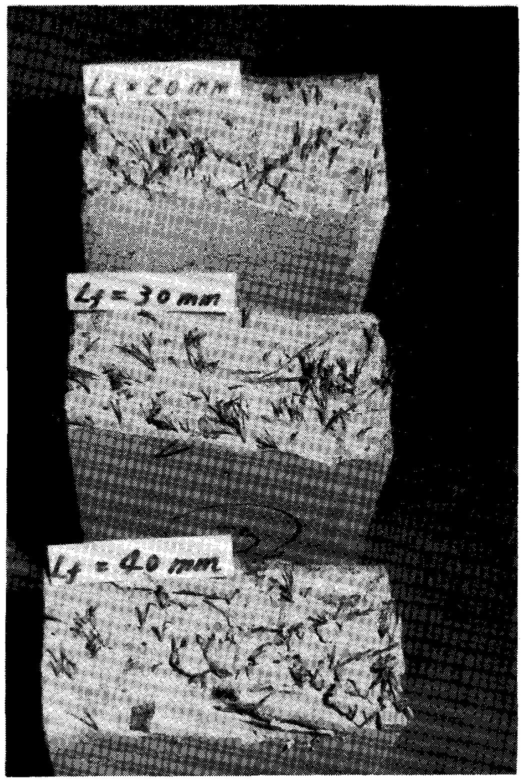

Fig. 4. Fracture surface of SFRC (Vf=2.0%)

Table 3 Direct tensile strength (specimen I, II and III) and splitting cylinder strength (mortar, 28 days)

	tensile strength (kgf/cm^2)		
	Vf (%)		
	0	1	2
splitting cylinder	30.5 (1.00)	33.2 (1.00)	54.0 (1.00)
specimen I	33.0 (1.08)	39.5 (1.19)	55.0 (1.02)
specimen II	30.0 (0.98)	31.8 (0.96)	42.0 (0.78)
specimen III	27.0 (0.89)	29.0 (0.87)	36.0 (0.67)

The results in Table 3 present the relationships between the direct tensile strength and the splitting cylinder tensile strength. In the splitting cylinder tensile test, as the load continues to increase even after the crack has occured, the tensile strength value is calculated by using the first crack load.

In this Table, the number in the parenthesis indicates the ratio of the direct tensile strength to the splitting cylinder tensile strength for mean value.

From the results, it can be seen that the splitting cylinder tensile strength is greater than the direct tensile strength for specimen II and III. And the difference increases, as the value of fiber content increases.

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