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Experimental Study on Behaviour And Strength of SIFCON With Two Fibers

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Abstract *— The present study focus on the behaviour and strength of SIFCON with combination of two fibers. The different fibers that were used in this experiment were steel fiber and polypropylene fiber. The different fiber volume considered was 4.5, 5, and 5.5% with different fiber combination ratios. In each fiber volume, 3 different fiber combination ratios were used. The fiber combination ratios are in the form steel fiber : polypropylene fiber. The ratios are 1:1, 1:2 and 2:1. Results indicate that amongst 4.5, 5 and 5.5 percentage with different fiber combination ratios of steel and polypropylene fibers, 5.5% with 2:1 ratio showed the optimum value in compression, tension and as well as in flexural strength. For 5.5% with 1:2 ratios, the results showed a decrease in strength compared to 5.5% with 2:1 ratio, but it showed a bridging effect to resist crack. Also, the crack width and density of specimen can be reduced by introducing polypropylene fibers in combination.*

Keywords*- SIFCON, Fibers, Combination of Fibers, Steel Fiber, Polypropylene Fiber*

I. INTRODUCTION

Slurry infiltrated fiber concrete (SIFCON) was first produced in 1979 in the USA, by incorporating large amounts of steel fiber in molds to form very dense network of fibers. Proportions of cement and sand generally used for making SIFCON are 1:1, 1:1.5 (or) 1:2 cement slurry alone have some applications. Water cement ratio varies between 0.3 to 0.4. Percentage of super plasticizers varies from 2 to 5% by weight of cement. The percentage of fibers by volume can be anywhere from 4 to 20% even though the current practical ranges from 4 to 12%. In conventional fiber reinforced concrete (FRC), where fibers are mixed together with other ingredients of concrete, this percentage is limited to only about 2% for practical workability reasons. Beyond 2% of fiber, the workability of mix reduces drastically, the consistency of mix is greatly affected and the fibers segregate from the concrete (balling phenomenon). The main differences between FRC and SIFCON, in addition to the clear difference in fiber volume fraction, lie in the absence of coarse aggregates in SIFCON which. If used will hinder the infiltration of slurry through the dense fiber network. Furthermore, SIFCON contains relatively high cement and water contents when compared to conventional concrete. Although it is still a relatively new construction product SIFCON has been used successfully in a number of areas since the early 1980's. SIFCON is not inexpensive and needs fine tuning, but it holds potential for applications exposed to severe conditions. Some of those applications are explosive-resistant containers, security blast-resistance vaults, and repair of structural components, bridge decks, airfield pavements and abrasive-resistance surfaces.

The study includes the effects of the following on durability of SIFCON, Matrix type (slurry or mortar), Fibres contents (4.5%, 5%, and 5.5% by volume), Fiber combination ratio (1:1, 1:2 &2:1) and Steel fiber (Hooked end) & Polypropylene fiber are used. In the combination of fiber the tests like flexure, compression and indirect tension are to be conducted. From a material and structural point of view, there is a delicate balance in optimizing the bond between the fiber and the matrix. If the fibers have a weak bond with the matrix, they can slip out at low loads and do not contribute very much to bridge the cracks. In this situation, the fibers do not increase the toughness of the system. If the bond with the matrix is too strong, many of the fibers may break before they dissipate energy by sliding out. In this case, the fibers behave as non-active inclusions leading to only marginal improvement in the mechanical properties.

II. EXPERIMENTAL INVESTIGATION

2.1 General

This experimental study deals with the strength and behaviour of SIFCON with combination of fibers. The fiber combination is in the form steel fiber with polypropylene fiber. The tests that are conducted flexural, compression and split tensile.

2.2 Experimental program

The experimental program consists of casting 162 SIFCON specimens. Testing was carried out after 7th and 28th days of curing. The different fiber volumes considered are 4.5, 5, and 5.5% with different fiber combination ratios. In each fiber volume, 3 different fiber combination ratios were used. The fiber combination ratios are 1:1, 1:2 and 2:1. Also the crack pattern of specimens using both fibers with different fiber volume and ratios was studied. The cement used in all mixtures of the study was a 53 grade ordinary Portland cement, which conforming to IS 12269. M sand passing through 4.75mm sieve was used as fine aggregate to prepare all specimens. The tap water was used as the mixing water. Only one type of superplasticizers (SP) was used in the study. Because a lack of workability was observed hence superplasticizer (conplas LN) were used. The mix proportion of cement and fine aggregate adopted for this experiment was 1:2. The water cement ratio of 0.45 was adopted. The steel fiber used in this study was hooked end having 1mm diameter and an aspect ratio of 50. Polypropylene fiber having length of 50.8mm was used.

III. TESTING OF SPECIMEN

The tests that are conducted flexural, compression and split tensile. To determine the strength and behaviour of specimens.

3.1 Compressive strength test

The compression test was carried out as per IS 516:1959. Compression test were carried out for cube specimen using steel and polypropylene fibers. A total of 54 cube specimens using steel fiber were prepared for the testing at the age of 7th and 28th days. A cube size of 15 x 15 x 15 cm was considered. The test were carried out at a uniform stress rate, after the specimen was centered in the testing machine. The load was applied continuously and uniformly without vibrations until the specimen fails due to compression. The ultimate load divided by cross sectional area of the specimen is equal to the ultimate compressive strength.

3.2 Splitting tensile strength test

The aim of this test is to determine the splitting tensile of concrete cylinder according to IS 5816-1999. A total number of 54 cylinder specimens were casted. As concrete is weak in tension and strong in compression. Therefore, all the tensile forces are resisted by steel reinforcement provided in the concrete members. However, the tensile stresses are likely to develop due to drying shrinkage, rusting of steel reinforcement and temperature gradient. Therefore, some methods are developed to find tensile strength of concrete is briquette test (Direct method – uniaxial tension) and split tensile strength (Indirect method – compressive force). Application of direct method of concrete specimen is not uniform and is difficult. So, compressive force is applied to specimen such that specimen fails due to induced tensile stresses in the specimen.

3.3 Flexural strength test

The aim of this test is to determine the flexural strength of beam according to IS 516-1959. Beam size of 10 x 10x 50 cm was considered. A total number of 54 beam specimens were prepared. The flexural strength test is performed to estimate the tensile load, at which the specimen may cracks, this is an indirect test for assessing the tensile strength at failure or modulus of rupture. The beam specimen was loaded with two-point loading. The specimen must be carefully aligned with axis of loading device. The load increased continuously until the specimen fails and maximum load applied to the specimen at failure was noted.

IV. RESULT AND DISCUSSION

The result of various tests carried out to determine the strength and behaviour of SIFCON using combination of two fibers, steel and polypropylene fiber are noted here. In different percentages the fibers are added with 3 different combination ratios are presented here.

4.1 Test result using steel and polypropylene fiber

4.1.1 Compressive strength

Table 1. Compressive strength of cube specimen (N/mm^2)

Volume fraction in %	Ratio	7th day	28th day
4.5	1:1	20.4	29.8
	1:2	18.4	26.6
	2:1	23.7	31.1
5	1:1	30.7	38.4
	1:2	28.1	35.1
	2:1	32.2	39.1
5.5	1:1	32.6	39.5
	1:2	30.7	37.1
	2:1	35.1	41.6

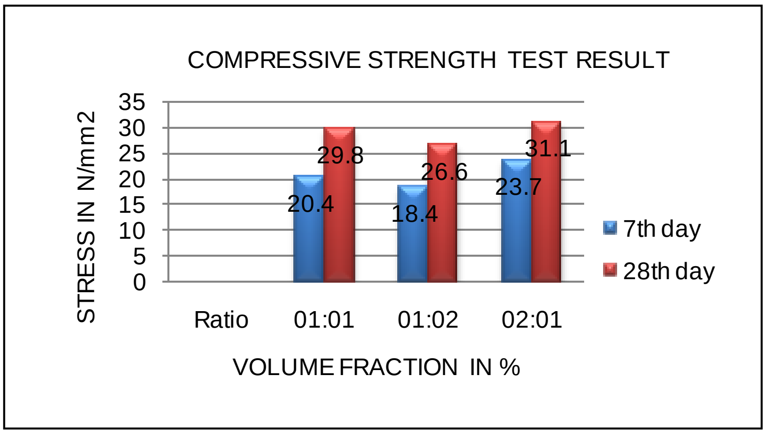

***Figure 1.** 7th and 28th day compression test result of cube specimen*

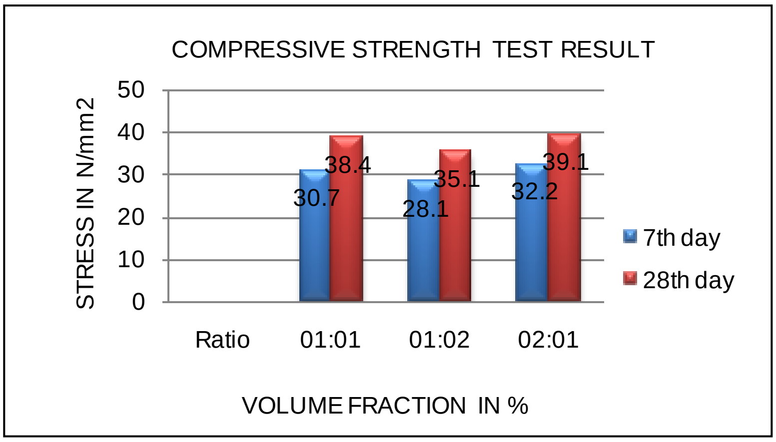

***Figure 2.** 7th and 28th day compression test result of cube specimen*

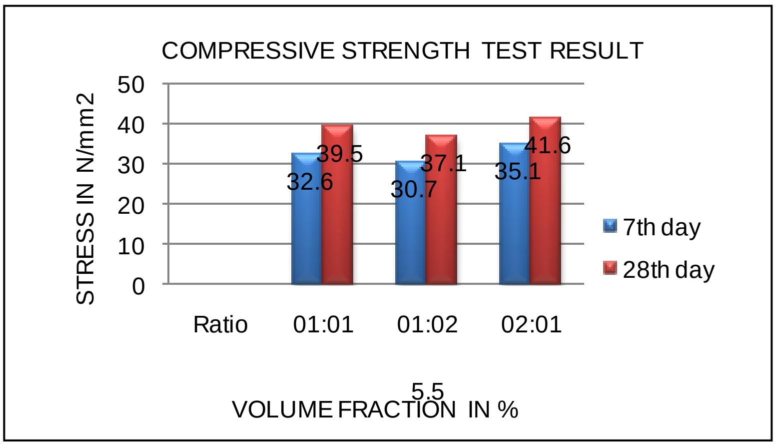

***Figure 3.** 7th and 28th day compression test result of cube specimen*

Figures 1, 2 and 3 shows the variation in the compressive strength at the age of 7 and 28 days cube specimen with steel and polypropylene fiber. The compressive strength values of 5.5% with ratio 2:1 shows the optimum comparing 1:1 and 1:2 ratios. The compressive strength of cube using steel and polypropylene fiber with 5.5% of 2:1 ratio shows the optimum value. For 5.5% of ratio 1:2 fiber, the results show a decrease in strength compared to 5.5% of ratio 2:1 because there is an increase in volume of steel fiber.

4.1.2 *Split tensile strength*

Table 2. Splitting tensile strength of cylindrical specimen (N/mm^2)

Volume fraction in %	Ratio	7^{th} day	28^{th} day
4.5	1:1	3.8	4.7
	1:2	2.6	3.9
	2:1	4.8	5.5
5	1:1	4.5	5.6
	1:2	3.2	4.3
	2:1	5.5	6
5.5	1:1	4.8	5.7
	1:2	3.5	4.7
	2:1	6.1	7.9

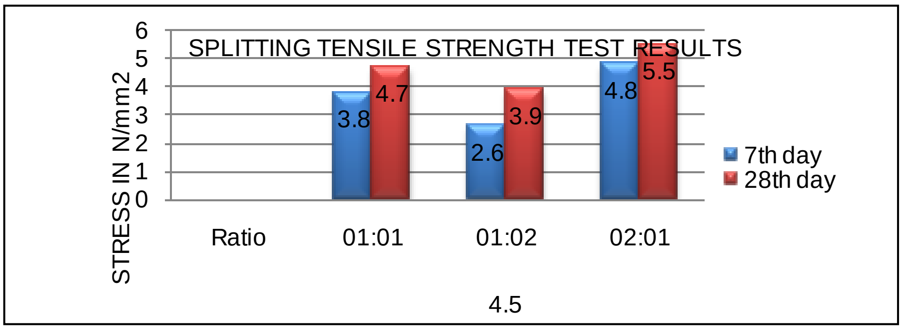

Figure 4. 7^{th} and 28^{th} day Split tensile test results of cylindrical specimen

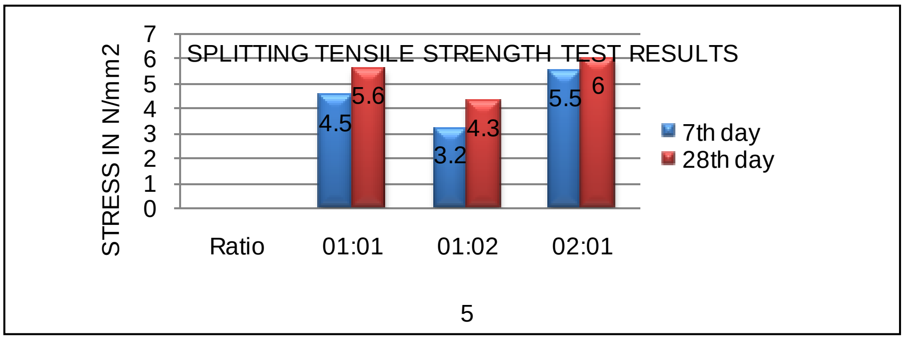

Figure 5. 7^{th} and 28^{th} day Split tensile test results of cylindrical specimen

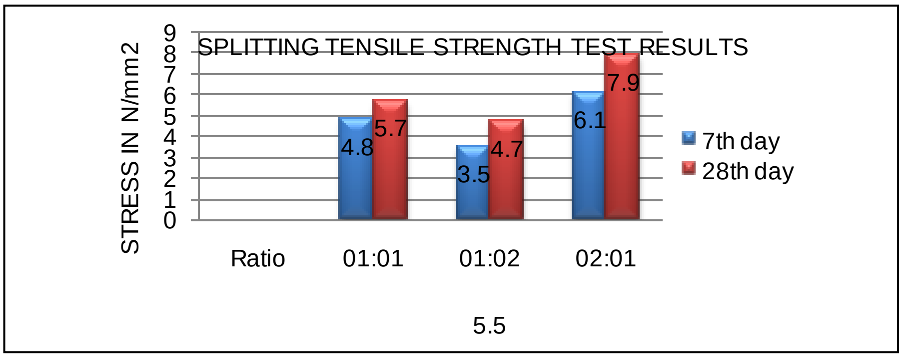

Figure 6. 7^{th} and 28^{th} day Split tensile test results of cylindrical specimen

Figures 4, 5 and 6 shows the variation observed in the split tensile strength for all volume percentage and combination ratio of fiber. The split tensile strength values using steel fibers at the age of 7 and 28 days are shown in the figures 4, 5 and 6 respectively. Using steel and polypropylene fiber, figure 6 shows the split tensile strength is optimum at 5.5% with ratio 2:1 for 7 days and 28 days. So the results indicate that the 5.5% of ratio 2:1 is the optimum percentage of steel fiber volume gives optimum strength.

4.1.3 Flexural strength

Table 3. Flexural strength of beam specimen (N/mm^2)

Volume fraction in %	Ratio	7th day	28th day
4.5	1:1	6.2	7.9
	1:2	4.4	5.6
	2:1	7.8	9.3
5	1:1	8	10.1
	1:2	5.9	8.2
	2:1	9.8	11.2
5.5	1:1	11.3	9.6
	1:2	7.5	10.2
	2:1	10.7	12.7

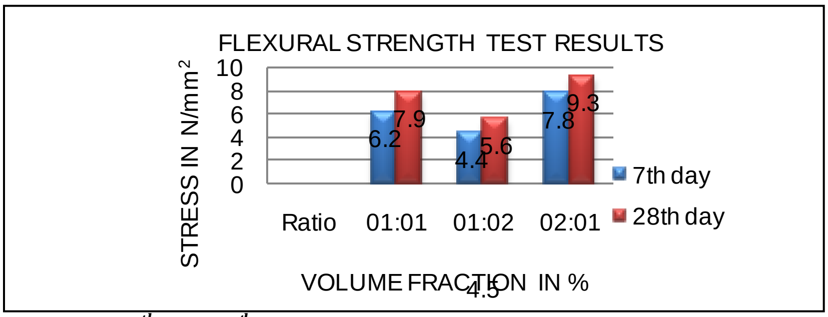

Figure 7. 7th and 28th day Flexural strength test results of beam specimen

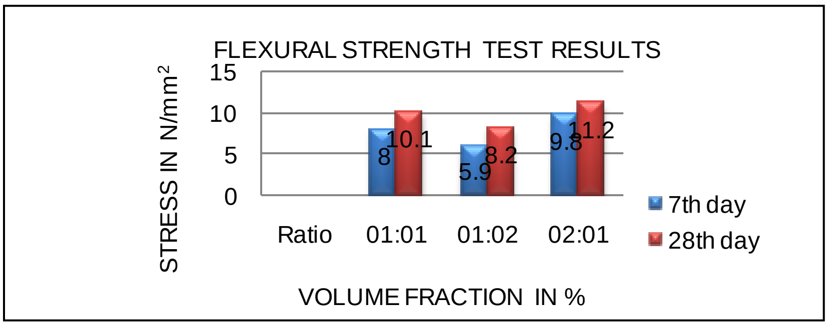

Figure 8. 7th and 28th day Flexural strength test results of beam specimen

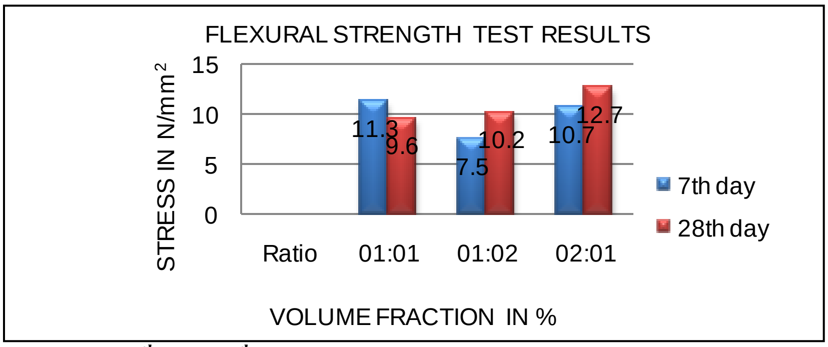

Figure 9. 7th and 28th day Flexural strength test results of beam specimen

Figures 7, 8 and 9 shows the values of flexural strength at the age of 7 and 28 days of curing. Using steel and polypropylene fiber 5.5% with 1:2 ratio, the strength achieved are 7.5 and 10.2 N/mm^2 for 7 and 28 days. Using 5.5% with 2:1 ratio of fiber, the values are 10.7and 12.7 N/mm^2 for 7 and 28 days. The results indicate that the 5.5% with 2:1 ratio of fiber is the optimum percentage of steel fiber volume gives optimum strength. For all the tests, the combination of fiber with 5.5% of 2:1 ratio specimen exhibits higher strength than 5.5% with 1:2 ratio of specimen. The crack width and density were reduced in the case 1:2 ratio where polypropylene fiber has more fiber volume.

4.2 Crack pattern of steel and polypropylene fiber

The pattern of crack and its propagation were similar in both steel and polypropylene fiber. But more widened crack was seen in specimen with more steel fiber than the polypropylene fiber, this is due to the bridging effect of polypropylene fiber. In the case of load carrying capacity, SIFCON specimens with more steel fibers exhibits better performance than polypropylene fiber specimens. The spacing of crack is observed to decrease with increase in percentage volume of fibers. This is expected because at higher percentage volumes more crack bridging takes place. The SIFCON specimens with combination of steel and polypropylene fiber were intact even after ultimate load is reached.

V. CONCLUSION

From the above test results, it can be said that addition of fiber combination with steel fibers and polypropylene fibers in SIFCON significantly increased the compressive, tensile and flexural strength. On comparing the strength of SIFCON, steel fibers performed better than polypropylene for all tests. Amongst 4.5, 5 and 5.5 percentage with ratios 1:1,1:2 and 2:1 of steel and polypropylene fibers, 5.5% with ratio 2:1 showed the optimum value in compression, tension and as well as in flexural strength. For 5.5% with ratio 1:2 fiber, the results of fiber showed a decrease in strength compared to 5.5%(2:1) volume. The cube specimen with optimum ratio of steel fibers performed better than the polypropylene fiber when their compressive strength was compared. The experimental study also indicates that it is possible to reduce the crack width by incorporating the polypropylene fiber. This is due to the bridging effect of polypropylene fiber. Also on comparing the density, polypropylene specimen with 5.5%(1:2) ratio of fiber has lower density than the specimen with steel fiber 5.5%(2:1) ratio of fiber. This helps to reduce dead load of the structure.

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