

Performance of High Strength Fiber Reinforced Concrete

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Abstract - High Strength Fiber Reinforced Concrete (HSFRC) is an innovative material that has gained widespread attention in recent years due to its superior mechanical properties and durability compared to traditional concrete. This high-performance material has been extensively researched and tested, and the results have shown that it can significantly enhance the strength, toughness, and durability of concrete structures, making them more resilient to various types of loading and environmental factors. The use of HSFRC in construction has opened up new possibilities for the design of more efficient and sustainable structures that can withstand extreme conditions and provide long-lasting performance. The incorporation of fibers in the concrete matrix enhances its tensile strength, ductility, and energy absorption capacity, while reducing the risk of cracking and spalling under load. The review of HSFRC highlights the key benefits and challenges associated with the material, as well as the current state of research in this field. It presents an overview of the properties of HSFRC, including its strength, stiffness, durability, and workability, and discusses the various types of fibers that can be used in its production.

Keywords: high-strength fiber reinforced concrete, mechanical properties, durability, structural elements, construction.

1. Introduction

Modern civil engineering structures require concrete with special properties to meet specific performance requirements. Ordinary cement concrete has limited tensile strength, ductility, and resistance to cracking, making it unsuitable for many applications. To address this, high-strength fiber-reinforced concrete (HSFRC) has been developed to enhance characteristics such as mechanical properties, toughness, durability, and serviceability in severe environments. The addition of small, closely spaced, and uniformly dispersed fibers acts as a crack arrester and substantially improves the static and dynamic properties of the concrete.

2. Experimental Work

The experimental research conducted in this study involves a systematic investigation of various methodological aspects. The properties of the material, admixture, fiber, mix design, mixing, and casting parameters are thoroughly examined in this chapter. The results of this study are expected to provide valuable insights into the behavior and characteristics of the concrete material under consideration.

3. Material and Grade of Control Mix

Selection of type and grade of mix, mix design by an appropriate method, trial mixes, final mix proportions.

Estimating total quantity of concrete required for the whole experimental work.

Estimating quantity of cement, fine and coarse aggregates required for work.

Testing of properties of cement, fine aggregate, coarse aggregate.

Estimating quantity & obtaining properties of fibers.

4. Production of Concrete Mixes

1. Production of control mix (normal concrete of grade M-40) in the laboratory is carried out by Indian Standard 10262 method designed proportions.

2. Fiber Reinforced Concrete is produced by adding polypropylene fibers to the cement concrete. Fibers were varied from 0.5 % to 2% at constant interval of 0.5 by weight of cement.

3. Mineral admixture varied from 0 to 30% at interval of 5%.

5. Experimental Program

The aim of the experimental program was to investigate the impact of incorporating mineral admixtures and polypropylene fiber on the properties of concrete and its practicality in construction. The study focused on examining the flexural strength, bond strength, compressive strength, and

split tensile strength of high strength concrete that has been modified with the materials after conducting some preliminary trials.

6. Test performed on Material used

Various tests were conducted on the materials used in the present experimental work as per relevant Indian Standard Codes. The materials included cement, fine aggregate, coarse

aggregate (10 and 20mm), fly ash, silica fume, polypropylene fiber, super plasticizer, and water. The tests performed on these materials included tests for compressive strength of cement, specific gravity and water absorption of aggregate, fineness modulus of fine aggregate, and tests for chemical and physical properties of fly ash and silica fume. These tests were conducted to ensure that the materials used were of appropriate quality and met the required specifications for use in the experimental program.

Table 1: Material Properties of ingredients

Material	Tests Performed	Result
Cement (OPC 43 Grade)	Standard Consistency	0.48
	Fineness (Residue on 90µ IS sieve)	0.02
	Specific Gravity	3.15
	Setting Time	
	A] Initial setting time	78 minutes
	B] final setting time	260 minutes
Fine Aggregate	Particle size	below 4.75 mm
	Particle shape	Round
	Fineness modulus	2.87
	Specific gravity	2.6
	Bulk density	1785 kg/m ³
	Silt content	1.4%
	Bulking of sand	4.18%
Coarse Aggregate	Particle size	20 mm & 10 mm down
	Particle shape	Angular
	Fineness modulus of 20 mm down aggregate	6.97
	Fineness modulus of 10 mm down aggregate	6.02
	Specific gravity	2.73
	Bulk density of 20 mm down aggregate	1589 kg/m ³
	Bulk density of 10 mm down aggregate	1612
	Water absorption	1.3%

7. Mix Design of Concrete

IS method of mix design is used for mix design of M-40 grade of concrete. The quantity of ingredient materials and mix proportions as per design is as under. For experimental work, specimens were prepared. Test is conducted on concrete to determine various strength characteristics at age of 28 days. In this study, compressive test on cubes, split tensile test on cylinder and flexural test on beam were carried out on specimens. Schedule of specimen preparation has been shown in table.

8. Mixing of concrete

The ingredients were thoroughly mixed over a G.I. Sheet. The sand, cement, aggregate, fly ash, silica fume, polypropylene fiber was measured accurately and was mixed in dry state for normal concrete. The dry concrete mix was then thoroughly and uniformly mixed till uniform and homogeneous mixing of fibers in dry mix was observed. Care was taken to avoid balling i.e. agglomeration of fibers.

Table 2: Mix Proportion of Concrete C = Cement, FA = Fine Aggregate, CA = Coarse Aggregate, W/C = Water Cement Ratio

Mix ID	C	FA	CA	W/C	Silica Fume %	Fly Ash %	Polypropylene Fiber %
Mix 1	1	2.288	2.914	0.4	-	-	-
Mix 2	1	3.219	4.067	0.4	-	30	-
Mix 3	1	3.219	4.067	0.4	5	25	-
Mix 4	1	3.219	4.067	0.4	10	20	-
Mix 5	1	3.207	4.052	0.4	15	15	-
Mix 6	1	3.248	4.104	0.4	10	20	0.5
Mix 7	1	3.271	4.133	0.4	10	20	1
Mix 8	1	3.295	4.163	0.4	10	20	1.5
Mix 9	1	3.319	4.194	0.4	10	20	2
Mix 10	1	3.248	4.104	0.4	15	15	0.5
Mix 11	1	3.271	4.133	0.4	15	15	1
Mix 12	1	3.295	4.163	0.4	15	15	1.5
Mix 13	1	3.319	4.194	0.4	15	15	2
Mix 14	1	3.219	4.067	0.4	20	10	-
Mix 15	1	3.219	4.067	0.4	25	5	-
Mix 16	1	3.219	4.067	0.4	30	-	-

Tests Conducted on Hardened Concrete

The specimens used were cubes, beam specimens and cylinders. Beam specimens were used to determine flexural strength, Cubes of 150 mm size were used to find the compressive strength & Cylinders were used to determine the split tensile strength.

Dimensions of each test specimen are as under: Cube: 150 mm × 150 mm × 150 mm

Beam: 150 mm × 150 mm × 700 mm

Cylinders: 150 mm in diameter & 300 mm in length



Figure 1: Failure of beam in Single Point Loading Test Figure 2: Failure of Cylinder in Split Tensile Test

It is observed from the results shown in table 2, that, the compressive strength of the specimens containing admixtures have increased for 15% silica fume, 15% fly ash & 0.5% polypropylene fiber content as compared to normal mix then it is reduced with increase in polypropylene fiber content.

Table 3: Details of Test Results for Different Test Conducted

Sr. No	Mix ID	Silica Fume in	Fly Ash in volume	Polypropylene Fiber in volume %	Compressive Strength (N/mm ²)	Flexural Strength (N/mm ²)	Split Tensile Strength (N/mm ²)
1	Mix 1	-	-	-	48.24	4.87	4.69
2	Mix 2	-	30	-	57.07	5.82	5.56
3	Mix 3	5	25	-	56.42	5.75	5.5
4	Mix 4	10	20	-	50.85	5.15	4.95
5	Mix 5	15	15	-	60.39	6.18	5.89
6	Mix 6	10	20	0.5	53.55	5.44	5.21
7	Mix 7	10	20	1	56.89	5.8	5.55
8	Mix 8	10	20	1.5	52.34	5.31	5.09
9	Mix 9	10	20	2	49.27	4.98	4.79
10	Mix	15	15	0.5	51.51	5.22	5.02
11	Mix	15	15	1	51.41	5.21	5.01
12	Mix	15	15	1.5	49.92	5.05	4.86
13	Mix	15	15	2	50.11	5.07	4.88
14	Mix	20	10	-	58.73	6	5.73
15	Mix15	25	5	-	56.79	5.79	5.54
16	Mix	30	-	-	51.78	5.25	5.04

9. Conclusions

The observations made from material testing to manufacturing of concrete specimens in the laboratory, few conclusions were drawn. The experiments are carried out separately for fly ash, silica fume and polypropylene fibre reinforced concrete. The conclusions drawn from this experimental investigation are as follows.

- 1) The significant increase in compressive, split tensile and flexural strength is observed with addition of 15% fly ash, 15% silica fume, and 0% polypropylene fibre in plain concrete.
- 2) Beam could sustain cracking load under much larger deflection as compared to normal concrete.
- 3) The optimum fiber content for increase in compressive strength is found to be 1%.
- 4) Increase in compressive, split tensile and flexural strength is observed with addition of 10% fly ash, 20% silica fume in plain concrete.

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Citation of this Article:

Girish S. Deshmukh, "Performance of High Strength Fiber Reinforced Concrete" in proceeding of International Conference of Recent Trends in Engineering & Technology ICRTET - 2023, Organized by SCOE, Sudumbare, Pune, India, Published in IRJIET, Volume 7, Special issue of ICRTET-2023, pp 206-211, June 2023.
