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Research Article

Evaluation of Performance of Hybrid Fibre Reinforced Concrete (HFRC) for M25 Grade

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Abstract

The use of two or more types of fibers in a suitable combination may potentially improve the overall properties of concrete and also result in performance of concrete. The combining of fibers, often called hybridization, is investigated in this paper for a M25 grade concrete. Control and two-fiber hybrid composites were cast for 0.5% & 1% total fiber volume fraction by using different fiber proportions of steel and polypropylene. Compressive strength test, flexural strength test & split tensile strength were performed and results were extensively analyzed to associate with above fiber combinations. Based on experimental studies, the paper identifies fiber combinations that demonstrate maximum compressive strength, flexural and split tensile strength of concrete.

Keywords: *Steel Fiber, Polypropylene Fiber, Compressive strength, Compaction factor, Hybrid composites, Split tensile strength, Flexural strength, Workability.*

1. Introduction

Concrete is mostly wide construction material in the world due to its ability it can be mould and shape. It is characterized by quasi-brittle failure, the nearly complete loss of loading capacity, once failure is initiated. However concrete has some deficiencies such as Low tensile strength, Low post cracking capacity, Brittleness and low ductility, Limited fatigue life, not capable of accommodating large deformations, Low impact strength. This characteristic, which limits the application of the material, can be overcome by the inclusion of a small amount of short randomly distributed fibers (steel, glass, synthetic and natural) and can be practiced among others that remedy weaknesses of concrete, such as low growth resistance, high shrinkage cracking, low durability, etc. Fiber reinforced concrete (FRC) is a fiber reinforcing cementitious concrete composite, and by adding discrete short fibers randomly in concrete it exhibits many substantially improved engineering properties in compressive strength, tensile strength, flexural strength etc. The fibers are able to prevent surface cracking through bridging action leading to an increased impact resistance of the concrete. The combination of two or more different types of fibers (different fiber types and/or geometries) is becoming more common, with the aim of optimizing overall system behavior. The intent is that the performance of these hybrid systems would exceed that induced by each fiber type alone. That is, there would be a synergy. Banthia and Gupta [2004] classified these synergies into three groups, depending on the mechanisms involved:

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1. Hybrids based on the fiber constitutive response, in which one fiber is stronger and stiffer and provides strength, while the other is more ductile and provides toughness at high strains [Banthia and Gupta 2004].
2. Hybrids based on fiber dimensions, where one fiber is very small and provides micro crack control at early stages of loading; the other fiber is larger, to provide a bridging mechanism across macro cracks.
3. Hybrids based on fiber function, where one type of fiber provides strength or toughness in the hardened composite, while the second type provides fresh mix properties suitable for processing.

The introduction of the paper explains the nature of the problem, previous work, purpose, and the contribution of the paper. The contents of each section may be provided to understand easily about the paper.

2. Material Specification

2.1 Cement

The cement used in this experimental work is 53 grade Ordinary Portland Cement. All properties of cement are tested by referring IS 12269 - 1987 Specification for 53 Grade Ordinary Portland cement. The specific gravity of the cement is 3.15. The initial and final setting times were found as 150 minutes and 260 minutes respectively. Standard consistency of cement was 31.50%.

2.2 Water

Potable water used for the experimentation.

2.3 Fine aggregate

Locally available sand passed through 4.75mm IS sieve is used. The specific gravity of 2.81 and fineness modulus of 3.31 are used as fine aggregate. The loose and compacted bulk density values of sand are 1094 and 1162 kg/m^3 respectively. The water absorption is of 0.84%.

2.4 Coarse Aggregate

20MSA:-Crushed aggregate available from local sources has been used. The coarse aggregates with a maximum size of 20mm having the specific gravity value of 2.99 and fineness modulus of 7.07 are used as coarse aggregate. The water absorption is of 0.84%.

10MSA:-Crushed aggregate available from local sources has been used. The coarse aggregates with a maximum size of 10mm having the specific gravity value of 2.99 and fineness modulus of 7.07 are used as coarse aggregate. The water absorption is of 0.84%. The loose and compacted bulk density values of coarse aggregates are 1463 and 1696 kg/m^3 respectively.

2.5 Steel Fiber (S.F.)

The steel fiber is procured from precision Drawell Pvt. Ltd., Nagpur. The steel fiber used in the study is the hook ended type HK0750 having aspect ratios 71. The dosages of fibers 0.35 % to 0.8% are used by total volume of concrete. The length of dividing fiber is 50mm and the diameter of fiber is 0.7.

2.6 Polypropylene Fiber (P.F.)

The Polypropylene fiber is procured from Bajaj Past Fibre Tashi India Ltd., Nagpur. The Polypropylene fiber used in the study is Fibrillated 20 mm cut length fibers. The dosages of fibers 0.1 % to 0.5% are used by total volume of concrete.

3. Experimental Procedure

3.1Mix Design

The proportions for normal mix of M25 Normal Mix are 1:1.68:3.34 with water cement ratio of 0.48. In the present study, method for mix design is the Indian Standard Method. The mix design involves the calculation of the amount of cement, fine aggregate and coarse aggregate in addition to other related parameters dependent on the properties of constituent material. The modifications are made and quantities of constituent materials used to cast Hybrid Fiber Reinforced concrete.

3.2 Batching, Mixing and Casting

Batching, mixing and casting operations were carefully done. The Concrete mixture was prepared by hand mixing on a watertight platform. The coarse Aggregates and fine aggregates were weighed first with an accuracy of 0.5 grams. On the watertight platform, the coarse, fine aggregates, polypropylene fiber & Steel fiber were mixed thoroughly. In manual mixing method fiber is added by sprinkling. Then water was added carefully so that no water was lost during mixing. The moulds were filled with various mix category of different percentage of fiber in hybrid composite. Vibration was given to the cube moulds using table vibrator. The top surface of the specimen was leveled and finished. After 24 hours the specimens were demoulded and were transferred to curing tank where in they were allowed to cure for 7 & 28 days. The entire specimen was tested in the Structural Engineering laboratory of Walchand Institute of Technology, Solapur.

3.3 Workability Test

Workability is carried out by conducting the slump test and compaction factor test as per I.S. 1199-1959 on ordinary concrete and fiber reinforced concrete.

3.4 Compressive strength test

The compressive strength of concrete is one of the most important properties of concrete in most structural applications. For compressive strength test, cube specimens of dimensions 150 x 150 x 150 mm were cast for M25 grade of concrete. After curing, these cubes were tested on Compression Testing machine as per I.S. 516-1959. The failure load was noted. In each category two cubes were tested and their average value is reported. The compressive strength was calculated as follows, Compressive strength (MPa) = Failure load / cross sectional area.

3.6 Flexural strength test

For flexural strength test, beam specimens of dimension 150x150x700 mm were cast. The specimens were demoulded after 24 hours of casting and were transferred to curing tank where in they were allowed to cure for 28 days. These flexural strength specimens were tested under two point loading as per I.S. 516-1959, over an effective span of 600 mm divided into three equal parts and rest on Flexural testing machine. The load is normally increased & failure load is noted at cracking of beam specimen. In each category, two beams was tested and their average value is reported. The flexural strength was calculated as follows. Flexural strength (MPa) = (P x L) / (b x d2), Where, P = Failure load, L = Centre to centre distance between the support = 600 mm, b = width of Specimen=150 mm, d = depth of specimen= 150 mm.

3.7 Tensile strength test

For tensile strength test, cylinder specimens of dimension 150 mm diameter and 300 mm length were cast. The specimens were demoulded after 24 hours of casting and were transferred to curing tank where in they were allowed to cure for 28 days. These specimens were tested under compression testing machine. In each category, three cylinders were tested and their average value is reported. Tensile strength was calculated as follows as split tensile strength: Tensile strength (MPa) = 2P / π DL, Where, P = failure load, D = diameter of cylinder, L = length of cylinder.

4. Experimental Results

4.1 Fresh Concrete

The fresh concrete properties slump, compaction factor & density are shown in Table I Result of Slump, Compaction Factor & Density of Fresh Concrete. The samples are designated as sample F(SF%&PF%) where, F denotes mix category of M25 grade HFR concrete, SF denotes percentage of Steel Fiber in sample & PF denotes percentage of Polypropylene Fiber in sample for total 0.5% fiber volume fraction (TF0.5) & 1% fiber volume fraction(TF1).

Table I Properties of Fresh concrete

Series (S.F. % &F.A.%)	Slump Value (mm)	Compaction Factor	Density (kg/m^3)
F0 (0.0/0.0)	40	0.87	2583.70
Total 0.5% Fiber volume fraction (TF0.5)			
F1 (0.4/0.1)	20	0.80	2717.03
F2 (0.35/0.15)	30	0.81	2708.14
Total 1% Fiber volume fraction (TF1)			
F3 (0.8/0.2)	20	0.77	2708.14
F4 (0.7/0.3)	15	0.72	2681.48
F5 (0.5/0.5)	15	0.73	2660.74

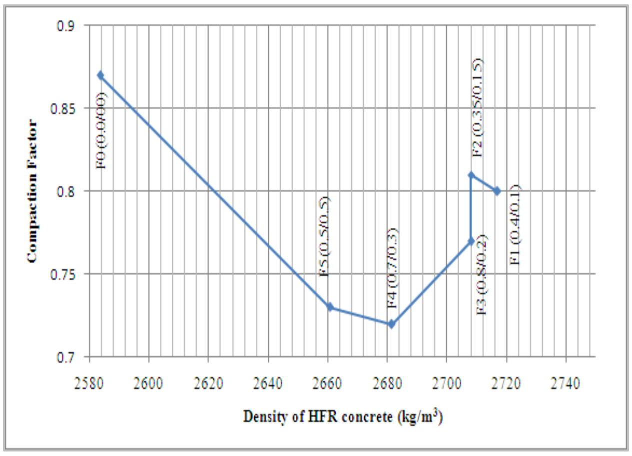


Fig 1 Relationship between Compaction Factor & Density of concrete

4.2 Hardened Concrete

The hardened concrete specimen properties are checked by compressive strength, Flexural strength & split tensile strength.

4.2.1 Compressive Strength: The compressive strength of cube specimen is checked after 7 & 28 days in compressive testing machine. The result of compressive strength is shown in Table II and Fig. No.2

Table II Result of Compressive Strength at 7th Day & 28th Day

Series (S.F. % & F.A. %)	Compressive Strength (N/mm^2)	
	7th Day	28th Day
F0 (0.0/0.0)	25.49	34.91
Total 0.5% Fiber volume fraction (TF0.5)		
F1 (0.4/0.1)	25.61	39.04
F2 (0.35/0.15)	29.53	34.28
Total 1% Fiber volume fraction (TF1)		
F3 (0.8/0.2)	29.86	34.91
F4 (0.7/0.3)	27.58	39.86
F5 (0.5/0.5)	24.55	30.46

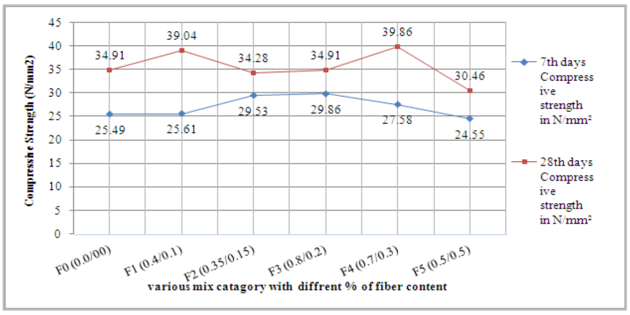


Fig.2 Compressive Strength on 7th Day & 28th Day as per various mix categories

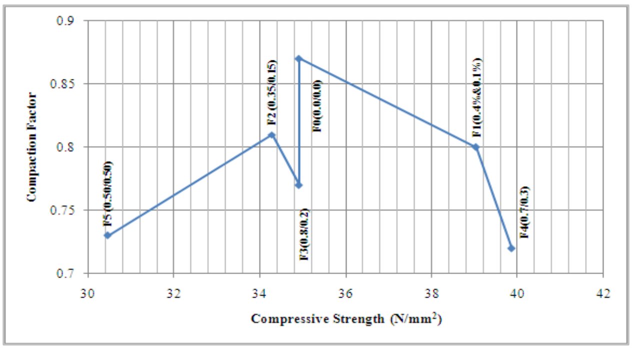


Fig.3 Relationship between Workability & compressive strength of concrete

Fig.4 Failure of a specimen of HFR & plain concrete under compressive strength test.

4.2.2. Flexural Strength: The Flexural test of beam specimen is checked after 28days. The result of flexural strength is shown in the Table III and Fig. No.5

Table III: - Result of Flexural Strength at 28th Day

Series (S.F. % & F.A. %)	Flexural Strength at 28th Day (N/mm^2)
F0 (0.0/0.0)	4.10
Total 0.5% Fiber volume fraction (TF0.5)	
F1 (0.4/0.1)	5.16
F2 (0.35/0.15)	5.05
Total 1% Fiber volume fraction (TF1)	
F3 (0.8/0.2)	5.56
F4 (0.7/0.3)	5.30
F5 (0.5/0.5)	4.64

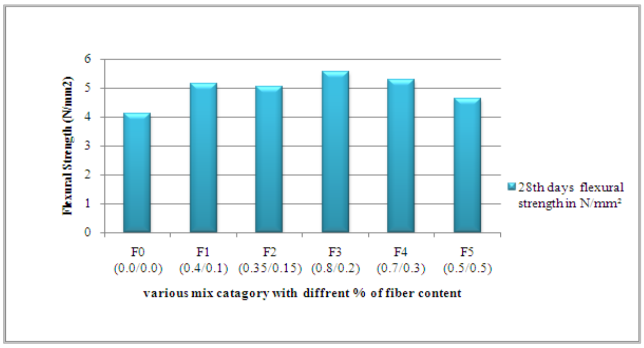


Fig.5 Flexural Strength at 28th Day as per various mix categories

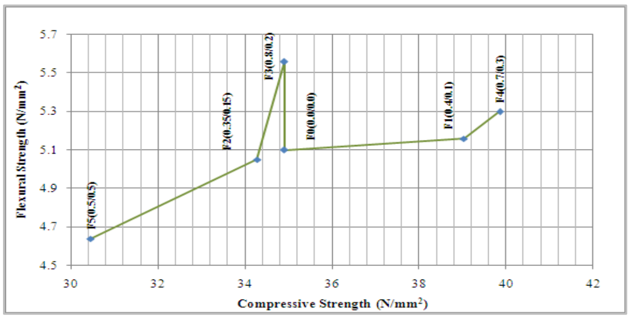
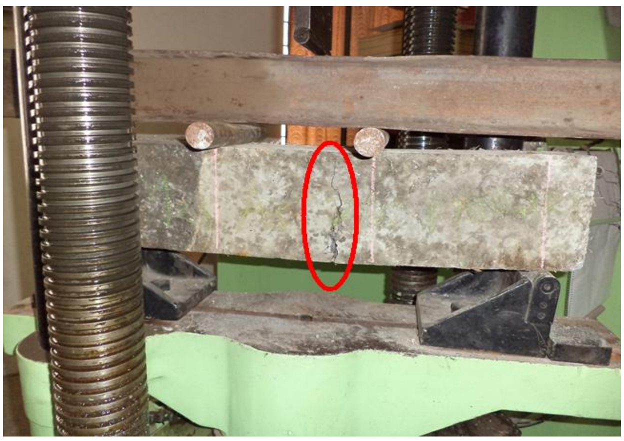


Fig.6 Relationship between flexural strength & compressive strength of concrete



(a) Plain Beam (b) HFRC Beam

Fig.7 Failure of a Beam specimen of plain & HFR concrete under compressive strength test.

4.2.3. Split Tensile Strength: The Split Tensile Strength test of Cylinder specimen is checked after 28days. The result of Split Tensile Strength is shown in Table IV and Fig. No.8

Table IV: Result of Split Tensile Strength at 28th Day

Series (S.F. % & F.A. %)	Split Tensile Strength at 28th Day (N/mm^2)
F0 (0.0/0.0)	3.54
Total 0.5% Fiber volume fraction (TF0.5)	
F1 (0.4/0.1)	4.44
F2 (0.35/0.15)	4.16
Total 1% Fiber volume fraction (TF1)	
F3 (0.8/0.2)	5.76
F4 (0.7/0.3)	4.54
F5 (0.5/0.5)	4.16

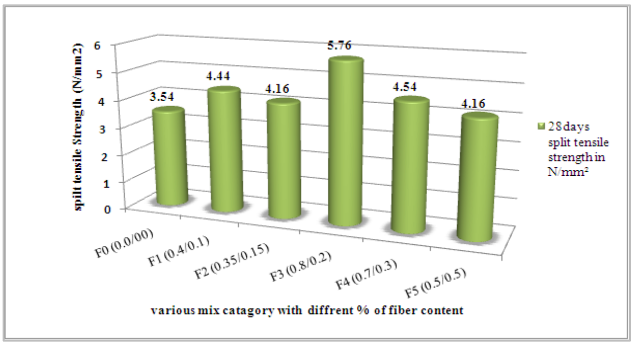


Fig.8 Split Tensile Strength at 28th Day as per various mix categories

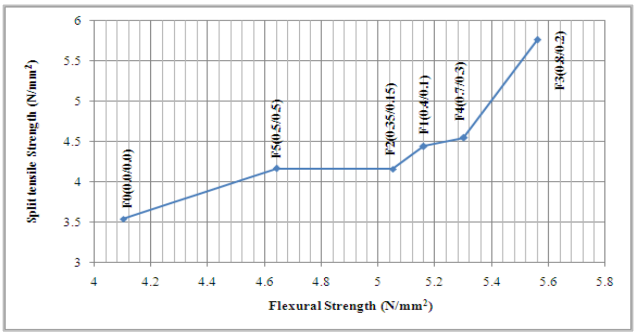


Fig.9 Relationship between flexural strength & split tensile strength of concrete

(a). Plain cylinder (b). HFRC cylinder

Fig.10 Failure of a cylinder specimen of plain & HFR concrete under split tensile strength test.

Conclusion

1) Slump, compaction factor and density of concrete is better for F2 (0.35/0.15) in TF0.5category and F3 (0.8/0.2) in TF1 category.
2) 20% and 30% replacement of steel fiber by polypropylene fiber is proved reasonable for TF0.5 and TF1 from workability point of view.
3) F1(0.4/0.1) and F3(0.8/0.2) are preferable from strength point of view which indicates 20% and 30% of replacement of steel fiber by polypropylene fiber which gives good compressive strength, higher flexural strength and split tensile strength.
4) In hybrid composite if polypropylene fiber percentage increases, the homogeneity of mix is affected, E.g. F5 (0.5/0.5) which gives very low workability, poor compressive strength, flexural strength and split tensile strength.

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