STUDY ON STRENGTH PROPERTIES OF HYBRID FIBRE REINFORCED CONCRETE

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Abstract: **The main aim of the present study was to combine different fibres namely crimped stainless steel fibre, glass fibre and polypropylene fibre to produce HFRC and thus to evaluate its performance under compression, tension and flexure types of loading. Based on I.S. Code method of mix design, proportion of different ingredients was obtained to get M40 grade of concrete. Samples were prepared by varying the volume fraction of fibres from 0 to 1% for each fibres individually and then the optimum percentage of fibres were combined to obtain HFRC (Hybrid Fibre Reinforced Concrete). Total 11 different types of FRC matrices were considered for performance evaluation. The experimental test results demonstrated that, addition of stainless steel, glass and polypropylene fibres at 1% ,0.75% and 1% V_f respectively showed considerable gain of strength of 37.45%, 39.41% and 27.62% in compression, tension and flexure at 28 days respectively. The behaviour of concrete under loads was found to be consistently improved compared with reference mix design. Thus, the improvement in mechanical properties of a matrix having volume fraction hybridization of 1% stainless steel, 0.75% glass and 1% of polypropylene fibres was found to be the best mix with synergetic response.**

***Keywords*: Stainless steel fibre, Polypropylene fibre, Glass fibre.**

I. INTRODUCTION

It is known that concrete is relatively a brittle material with high compressive strength and low tensile strength. Reinforcing bars are used to improve the tensile strength. However concrete is prone to micro cracks. Reinforcement of concrete with randomly distributed short fibres may improve the toughness of cementitious matrices by preventing or controlling the initiation, propogation or coalescence of cracks. Fibre reinforced concrete has already found a wide range of practical applications and proved to be a reliable construction material having superior performance characteristics compared to conventional concrete. The commonly used fibres in concrete are steel fibres, glass fibres, carbon fibres and polymeric fibres. The polymeric fibres viz. polypropylene, polyethylene, polyester, acrylic and aramid fibres are becoming popular these days. Some types of fibres produce greater impact, abrasion and shatter resistance in concrete. Generally fibres do not increase the flexural strength of concrete, and so cannot replace structural steel reinforcement. Wu Yaoa et al., concluded that if the modulus of elasticity of the fibre is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. However, fibres which are too long tend to "ball" in the mix and create workability problems. Sakthivel.P.B et al inferred that the contribution of steel fibres can be observed mainly after matrix cracking in concrete, in that they help in bridging the propagating cracks. The addition of steel fibres at high dosages, however, has potential disadvantages in terms of poor workability and increased cost.[3] A compromise to obtain good fresh concrete properties (including workability and reduced early-age cracking) and good toughness of hardened concrete can be obtained by adding two different fibre types, which can function individually at different scales to yield optimum performance. The addition of non-metallic fibres such as glass, polyester, polypropylene etc. results in good fresh concrete properties and reduced early age cracking. The beneficial effects of non- metallic fibres could be attributed to their high aspect ratios and increased fibre availability (because of lower density as compared to steel) at a given volume fraction. Because of their lower stiffness, these fibres are particularly effective in controlling the propagation of micro cracks in the plastic stage of concrete. However, their contribution to post-cracking behaviour, unlike steel fibres, is not known to be significant. The combination of two or more fibres called the hybrid would incorporate synergy and improve the system potentially[4-7].

The objective of this study was to evaluate the mechanical properties of various fibre reinforced concrete systems, containing individual steel fibre, glass fibre, polypropylene fibre and hybrid combinations of steel and fibres such as glass and polypropylene for various volume fraction from 0-1%. Thus explores the feasibility of hybrid fibre reinforcement; on compressive strength, flexural strength, tensile strength study etc. with given grade of concrete.

II. EXPERIMENTAL PROGRAM

A. Materials Used

The materials used in this experimental investigation are: 1) *Cement*: 53 grade Fly Ash based Portland Pozzolana Cement (PPC) (IS 1489 PART I 1991) with a specific gravity of 3.15 2) *Fine aggregate*: Locally available river sand Zone III having a specific gravity of 2.62, fineness modulus of 3.45,

3) *Coarse aggregate*: crushed granite coarse aggregate of maximum size 20 mm, having a specific gravity of 2.67, fineness modulus of 7.81,
4) *Water*: Portable water from tap conforming to the requirements of water for concreting and curing as per IS: 456 2000.

5) *Super plasticizer*: Conplast SP- 430 high range super plasticizer with specific gravity of 1.2 was used to increase the workability of concrete. A dosage of 1.0% by weight of binder was used for all the mixes.

6) *Fibres*: The fibres used in the study were crimmped steel, polypropylene, and glass; the properties of these fibres are listed in Table 1.

TABLE 1
PHYSICAL AND MECHANICAL PROPERTIES OF VARIOUS FIBRES USED

Property	Crimmped Steel	Glass	Polypropylene
Length (mm)	35	12	24
Diameter (mm)	0.5	14 micron	40 micron
Aspect ratio	70	857.1	600
Specific gravity	7.8	2.68	0.91
Elastic modulus (GPa)	200	72	5
Failure strain(%)	3.5	3.6	18
Tensile Strength (MPa)	2500	600	450

B. Mix Proportioning

M40 grade of concrete mix was designed as per IS 10262-2009 with w/c of 0.4. The mix proportioning for M40 grade of concrete is given in table 2.

TABLE 2
MIX PROPORTIONING

Cement (Kg/m³)	Fine Aggregate (Kg/m³)	Coarse Aggregate (Kg/m³)	Water (litre/m³)
400	643.24	1168.78	160
1	1.60	2.92	0.40

TABLE 3
VARIOUS TRAIL MIXES

Mix	w/c	Cement	F.A	C.A	Water	% of fibres

ratio	ratio	(kg/m³)	(kg/m³)	(kg/m³)	(litre/m³)	SSF	GF	PPF
NM	0.40	400	643.24	1168.78	160	-	-	-
SS01	0.40	400	643.24	1168.78	160	0.50	-	-
SS02	0.40	400	643.24	1168.78	160	0.75	-	-
SS03	0.40	400	643.24	1168.78	160	1.00	-	-
GF01	0.40	400	643.24	1168.78	160	-	0.50	-
GF02	0.40	400	643.24	1168.78	160	-	0.75	-
GF03	0.40	400	643.24	1168.78	160	-	1.00	-
PP01	0.40	400	643.24	1168.78	160	-	-	0.50
PP02	0.40	400	643.24	1168.78	160	-	-	0.75
PP03	0.40	400	643.24	1168.78	160	-	-	1.00
HF01	0.40	400	643.24	1168.78	160	1.00	0.75	-
HF02	0.40	400	643.24	1168.78	160	1.00	0.75	1.00

C. Mixing and casting

The mixtures were batched by hand mixing. The cement, sand, and fibres were dry-mixed. This was followed by the addition of coarse aggregate, water, and super plasticizer, with a mixing time of 5 min. The fibres were uniformly dispersed into the mix by hand. After pouring the mix into oiled moulds, a vibrator was used to decrease the amount of air bubbles. The specimens were demoulded after a day and then placed in a curing tank with 90% relative humidity and 23°C for 27 days of curing. For 12 hrs prior to the tests, the specimens were allowed to air dry in the laboratory.

The following specimens were cast for all the mixes (3 nos each).

i. 150mm X 150mm X 150mm cubes for compressive strength test.
ii. 150mm X 300mm cylinders for split tensile strength test.
iii. 100mm X 100mm X 500mm beams for flexural strength test.

III.TEST RESULT

A. Compressive strength

A universal testing machine of capacity 100 tonnes was used for testing the compressive strengths of nine (150×150×150) mm cube specimens. Cube specimens at 7 and 28 days from casting were tested at a loading rate of 14 N/mm²/min according to ASTM C 39 [31]. The compressive strength was interpreted by stress generated from the result of compression load per area of specimen surface. Compressive strength results are shown in table 4 and figure1.

B. Split tensile strength

Split tensile strength at 28 days of curing of (150×300) mm cylinders is indirect measurement of tensile strength of concrete which were conducted according to the requirements of ASTM C496 [35]. In the split tensile strength test, cylindrical concrete specimen is placed on diametrical compressive force along its length.

The load is applied continuously at a constant rate until failure of cylinder along its vertical diameter. To allow the uniform distribution of applied compressive load, strips of plywood are placed between the specimen and loading platens of the testing machine. Split tensile results are shown in table 4 and figure 2.

C. Flexural strength

Flexural strength test after 28 days of curing was conducted according to the requirements of ASTM C 1609 [33] using three (100 × 100 × 500) mm beams under third-point loading on a simply supported span of 400 mm. Flexural strength results are interpreted in table 4 and figure 3.

TABLE 4
TEST RESULTS

Mix	Compressive strength (MPa)		Split tensile strength at 28days (MPa)	Flexural strength at 28days (MPa)
	at 7 days	at 28days		
NM	33.15	47.42	3.07	4.96
SS01	34.43	51.70	3.17	5.02
SS02	35.65	53.56	3.74	5.37
SS03	40.45	60.02	3.89	5.83
GF01	31.77	48.76	3.16	4.33
GF02	36.44	54.12	3.61	5.16
GF03	33.32	49.97	3.29	4.41
PP01	33.49	49.54	3.04	4.83
PP02	34.97	52.65	3.48	5.25
PP03	38.66	57.43	3.69	5.33
HF01	41.52	62.33	4.05	6.12
HF02	44.54	65.18	4.28	6.33

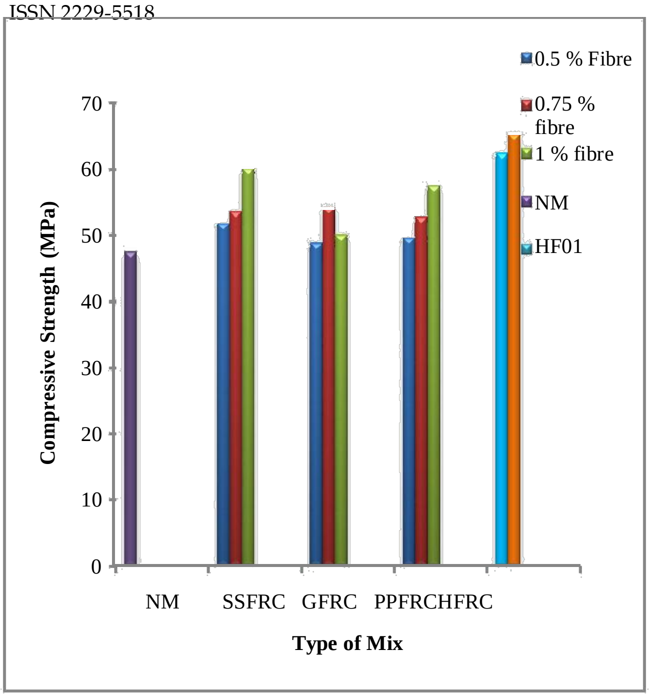

Fig1. Comparison of Compressive strength of v arious mixes

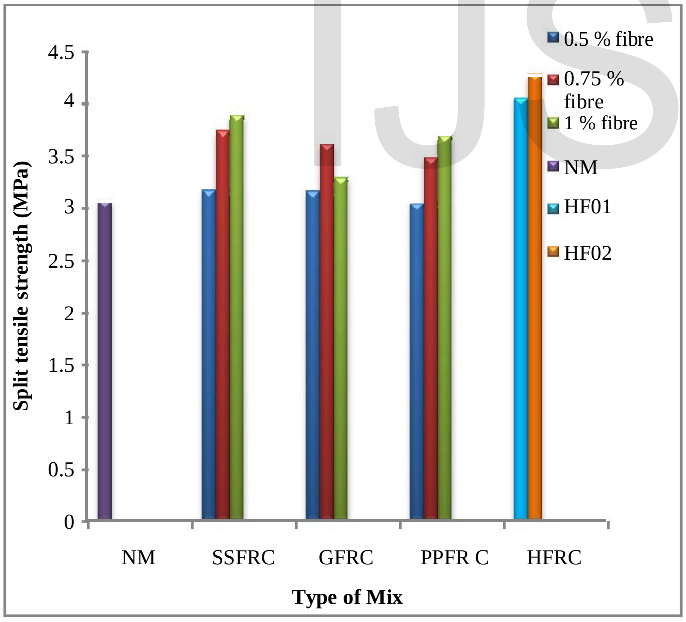

Fig 2. Comparison of split tensile strength of various mixes

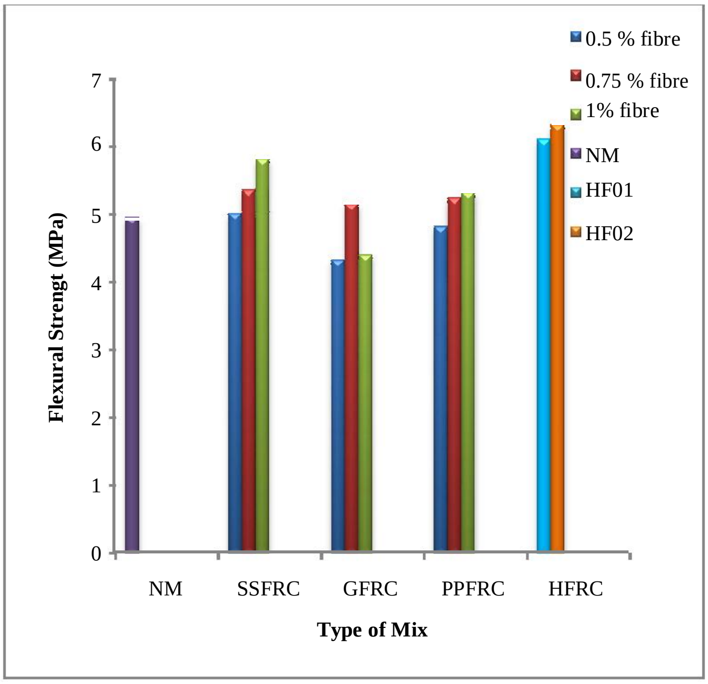

Fig 3. Comparison of Flex ural Strength of various mixes

IV CONCLUSION

Based on the experimental results by using three types of fibres stainless steel, glass and polypropylene the following conclusions are drawn.

1. In SSFRC, the mix (SSFRC03) with 1% of fibre to the volume of concrete was found to be op timum with increase in compression, t ension and flexure by 26.57%, 28.71% and 17.54% respectively.
2. The mix (GFR C02), by inclusion of 0.75% of fibre to the volume of cement was identified effective in compression, tension and fle xure with an increase in percentage of 14.12, 17.58 and 4.19 respectively.

3. In PFRC, the mix (PFRC03) with 1% of fibre to the volume of cement was found to be best with increase in compression, tension and flexure by 21.10%, 20.92% and 5.84% respectively.
4. The HFRC01 showed an increase in compression, tension and flexural strength by 31.42%, 31.92% and 23.48% respectively.
5. Increase in percentage of 37.42, 39.41 and 27.62 in compressive, split tensile and flexural strength respectively, was observed in HFRC02.
6. From the above it is known that, the mix HFRC02 has the highest compressive strength of 65.18 N/mm² with an increase in strength by 37.42% from the conventional mix.
7. Also in split tensile strength test HFRC02 exhibited the most optimum strength with an modest increase in strength by 39.41%
8. HFRC02 achieved a flexural strength of 6.33 N/mm² against the PCC with a strength of 4.96 N/mm².
9. Balling effect and Heterogeneity in the concrete is observed with higher volume fraction such as 0.75% & 1% volume fraction of fibre.

10. Thus overall observation of this study shows that it advantageous to use HFRC02 mix with (1% SSF + 0.75% GF + 1% PF) fibres which gives satisfactory results in all conducted tests for concrete of grade M40.

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