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Experimental Determination Of Compressive, Split Tensile And Flexural Strength Of HFRC Using Steel And Polypropylene Fibres In Different Proportions

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ABSTRACT:
The use of concrete, i.e. composite mix of hydraulic cement and aggregates in building applications is extensive and hence hybrid fibre reinforced concrete was developed and tested for practical use in day to day life. The strength properties of hybrid fibre reinforced concrete was determined by using steel and polypropylene fibres with total volume of fibre fraction of 0.75% and the results were analyzed to determine the optimum combination of fibre which gives better performance in terms of strength. The investigation and comparison of the compressive, flexural and tensile strength of concrete for various mixture proportion of concrete was done In the paper, the effect of inclusion of polypropylene and steel fibers on the compressive, flexural and tensile properties of fiber reinforced concrete using M40 grade concrete is studied. Control and five hybrid fiber composites were cast using different fiber proportions of steel and polypropylene at a total volume fraction of 0.75%. The experimental work was divided into six group. Each group consists of 6 cubes, 6 cylinder and 6 beam. Compressive strength, split tensile strength and flexural strength test were performed and results were extensively analyzed to identify performance synergy.
Keywords: Aggregate, strength, steel

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I. INTRODUCTION AND LITERATURE REVIEW:

Concrete is a composite material containing hydraulic cement, water, coarse aggregate and fine aggregate. The formation of cracks is the main reason for the failure of the concrete. To increase the tensile strength of concrete many attempts have been made. One of the successful and most commonly used method is providing steel reinforcement. The term fiber reinforced concrete (FRC) is a concrete made of hydraulic cements containing fine or fine and coarse aggregates and discontinuous discrete fibers. The use of fibres to increase the structural properties of construction material is not a new process. From ancient times fibres were being used in construction. In BC, horse hair was used to reinforce mortar. Asbestos was used in the concrete in the early 19th century, to protect it from formation of cracks. A. Kumar et al [1] investigated and compared the compressive and flexural strength of concrete for various mixture proportion of concrete by adding steel and polypropylene fibre. M. T. Selvi and T.S. Thandavamoorthy [2] studied the properties of Steel and Polypropylene Fibre Reinforced Concrete without any Admixture using M30 grade concrete. The steel, polypropylene and hybrid polypropylene and steel (crimped) fibres of various proportion i.e., 4% of steel fibre, 4% of polypropylene fibre and 4% of hybrid polypropylene and steel fibre. Parveen and Sharma [3] investigated the effect of variation of polypropylene fibres ranging from 0.1% to 0.4% along with 0.8% steel fibres on the behavior of fibrous concrete. The mechanical properties of the concrete such as compressive strength, split tensile strength and flexural strength have been investigated. Rajarajeshwari et al [4] studied the effect of addition of mono fibers and hybrid fibers on the mechanical properties of concrete mixture. L. A. Qureshi et al [5] investigated the effect of mixing hybrid fibre on cracking strength of concrete. The research work has been carried out by preparing and testing 30 specimens of plain and reinforced concrete incorporating different ratios of fibres. Nusret et al [6] studied the effect of single and hybrid fibres on fibre reinforced concrete. Both single and hybrid fibre reinforced concrete mixes were produced using 3 macro and 1 micro steel fibres in different lengths and aspect ratios. Vikrant S. et al [7] investigated the hybrid fiber reinforced concrete of M25grade. Pu Wang et al [8] studied experimentally the synergic mechanical properties of hybrid fiber reinforced concrete with different kinds and percent of steel fibers and polypropylene fiber. N.A. Libre et al [9] investigated the mechanical properties of hybrid fiber reinforced lightweight aggregate Concrete incorporating steel and polypropylene fibres. R. Hameed et al [10] studied the flexural properties of metallic-hybrid-fibre-reinforced concrete. Y. Ding et al [11] investigated mechanical properties of hybrid fibre reinforced concrete. the suitable fibre types (steel fibres, PP-fibres and fibre cocktail) and fibre dosages for fibre reinforced concrete were selected. S. Eswari et al [12] studied the influence of fibre content on the ductility performance of hybrid fibre reinforced concrete specimens having different fibre volume fractions. A total of 27 specimens, 100 mm x 100 mm x 500 mm, were tested. A. Sivakumar et al [13] investigated the properties of high strength concrete reinforced with hybrid fibres (combination of hooked steel and a non-metallic fibre) up to a volume fraction of 0.5%. H.Oucief et al [14] studied the influence of hybrid fibre on fibre reinforced concrete. Control, single, two fibers hybrid composites were cast using different fiber type steel and polypropylene with different sizes. Flexural toughness tests and compressive strength tests were performed and results were extensively analyzed to identify synergy, if any, associated with various fiber combinations. P.S.Song et al [15] investigated the first-crack strength, failure strength, and strength reliability of steel–polypropylene hybrid fiber-reinforced concrete in comparison with the steel fiber-reinforced concrete. Ordinary Portland cement was used in the investigation, fine aggregate used was natural river sand with a fineness modulus of 2.50. The coarse aggregate consisted of gravel with a maximum size of 25 mm. S.M. Soleimani et al [16] investigated the flexural response of hybrid fibre reinforced concrete using various combinations of fibre. Three different types of fibre were combined in each mix. Hybridization of fibre were amongst steel/polypropylene macro fibres and carbon/polypropylene/steel micro fibres. C.X. Qian et al [17] investigated the optimization of fibre size, fibre content in hybrid polypropylene-steel fibre concrete with low fibre content based on general mechanical properties. The fibre contents used are in the low range steel fibre volume content up to 1.2% and Polypropylene fibre up to 0.3%. Most of the researchers have investigated the properties of hybrid fibre reinforced concrete, by adding quantity of fibres in fixed percentage, they have not compared the result by changing the proportion of quantity of different fibre within the same volume fraction. The main objective of this research included developing Hybrid fiber reinforced concrete mixes which is suitable for structural applications, testing the mixes of Hybrid fiber reinforced concrete for compressive strength, split tensile strength and flexural strength and comparing the results and finding the optimum percentage of hybrid fibres.

II. EXPERIMENTATION:

In order to determine the strength characteristics of HFRC using steel and polypropylene fibres in different proportions, compressive strength tests, split tensile strength tests, and flexural strength tests were carried out for M40 grade concrete using total volume of fibre fraction of 0.75%. In total 108 no. of tests specimen were cast (36 cubes for compressive strength test, 36 beams for flexural strength test and 36 cylinder for tensile strength test). The experimental work was divided into six group. Each group consists of 6 cubes (150 mm x 150 mm x 150 mm), 6 cylinder (300 mm x 150 mm dia.) and 6 beam (500 mm x 100 mm x 100 mm). First group consists of control (plain) concrete using 0% volume of fibres. Second group consists of 0% steel fibre and 100% polypropylene fibre out of total volume of fibre. Third group consists of 25% steel fibre and 75% polypropylene fibre out of total volume of fibre. Forth group consists of 50% fibre each of steel and polypropylene fibre out of total volume of fibre. Tests results were find out for 28 and 56 days curing.

2.1. Material testing:

The following materials were used in the experimental work are cement, fine aggregates, coarse aggregates, super plasticizer and fibre.

2.1.1. Cement:

In the present investigation ordinary Portland cement 43 grade with brand name 'Jaypee Cement' conforming to IS:8112-1989 was used. The cement was tested in accordance with the test methods specified in IS:4031-1988 and results obtained are in table 1.

Table 1 Cement test results

S. No.	Characters	Experimental value	As per IS:8112 1989
1	Cement consistency	31	-
2	Specific gravity	3.15	3.15
3	Initial setting time	55 min	> 30 min
4	Final setting time	275 min	< 600 min
5	Cement fineness	10%	10%
6	Compressive strength 3 days 7 days	 23.5 N/ mm^2 35.8 N/ mm^2	 23 N/ mm^2 33 N/ mm^2

2.1.2. Fine aggregates:
Specific Gravity = 2.65. The sand used conforms to zone III. Sieve analysis for the sand was performed and results obtained are in table 2.

Table 2 Sieve analysis of fine aggregates (weight 1 kg)

IS sieve designation	Wt retained on sieve (gm)	Cumulative wt retained (gm)	Cumulative % wt retained	% passing	IS: 383-1970
10 mm	0	0	0	100	100
4.75 mm	16	16	1.6	98.4	90-100
2.36 mm	82	98	9.8	90.2	85-100
1.18 mm	150	248	24.8	75.2	75-100
600 µm	133	381	38.1	61.9	60-79
300 µm	298	679	67.9	32.1	12-40
150 µm	257	938	93.8	6.2	0-10
< 150 µm	71	1000	100	-	-

The % passing vs sieve size curves for both aggregate and coarse aggregates are shown in figure 1. It is clearly shown that % passing increase with sieve size but it becomes constant for coarse aggregates at 100 % passing value.

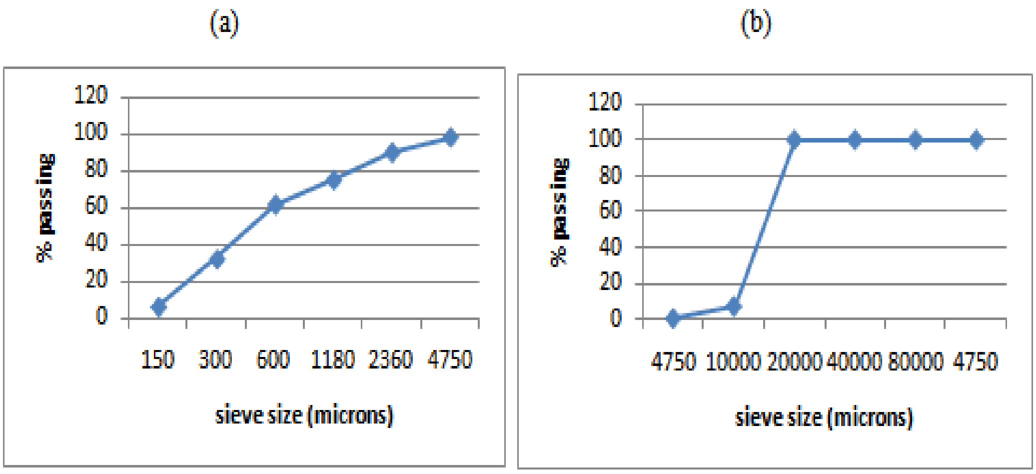

Fig.1. (a) Grading curve for aggregates, (b) Grading curve for coarse aggregates

2.1.3. Coarse aggregates:
Maximum size of aggregates = 20 mm, Specific gravity = 2.67

In table 3, sieve analysis of coarse aggregates has been done.

Table 3 Sieve analysis of coarse aggregates (weight 5 kg)

IS sieve designation	Wt retained on sieve (gm)	Cumulative wt retained (gm)	Cumulative % wt retained	% passing	IS: 383-1970
80 mm	-	-	-	100	100
40 mm	-	-	-	100	100
20 mm	-	-	-	100	95-100
10 mm	4.6	4.6	92	8	0-20
4.75 mm	0.34	4.94	98.8	1.2	0-5
< 4.75 mm	0.06	5	100	-	-

2.1.4. Super plasticizer:
Super plastisizer of the make 'Sika Viscocrete-10 (H1)' was used for the concrete. It is aqueous solution of modified polycarboxylate, brown appearance, density 1.10, pH 5.

2.1.5. Fibres:

Continuously crimped Steel fibres with an aspect ratio of 80 were used, having length 40, diam. 0.5, aspect ratio 80, specific gravity 7.48. Fibrillated fibers were used, having length 38 mm, dia 0.1, aspect ratio 380, specific gravity 0.9.

2.2. Mix proportion:

Mix design has been adopted from IS 10262:2009 to design for M40 grade of concrete. The mix ratio used for study is 1:1.81:2.91. No fibres were added in control mix specimen whereas Steel and Polypropylene fibres were added to other concrete specimen at a volume fraction of 0.75%. Steel fibres were added by volume of concrete and polypropylene fibres were added by the weight of cement.

2.3. Mixing, casting and curing of specimen:

The mixing of concrete was done to have a homogeneous mixture of all ingredients in concrete. The hand mixing was done for the ingredients. Batching of concrete was done by weight and the mixing process was as given below. Firstly, coarse aggregate was weighed and put in mixing pan. Fine aggregate was added to the coarse aggregate. Cement of measured quantity was added on to the above ingredients. Steel fibres and

polypropylene fibres were added as per the proportions. The mixture was dried mixed until uniform colour of the mixture was obtained and no concentration of any material was visible. The required quantity of water was added into the mix and the whole mixture was mixed. The required quantity of superplasticizer is added to maintain the required workability and the mixture was mixed thoroughly until uniform colour was achieved.

(a) (b) (c)

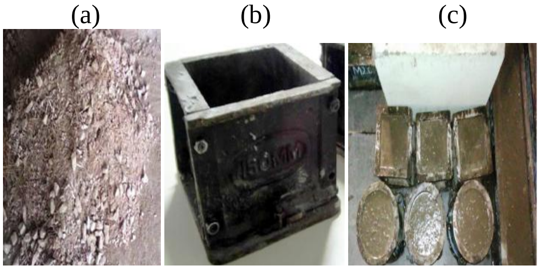

Fig.2. (a) Initial mixing of constituents of HFRC, (b) mould oiled before casting of concrete, (c) mould filed with fresh concrete

The moulds of cubes, cylinders and beams were cleaned thoroughly. A thin layer of oil was applied to inner surface of the moulds to avoid the adhesion of concrete with the inner side of moulds. For each mix, six cubes of 150 mm x 150 mm x 150 mm were cast for compressive strength test, six cylinders of sizes 300 mm x 150 mm were cast for split tensile strength test and six beams of sizes 100 mm x 100 mm x 500 mm were cast for flexural strength test. The compaction of all the specimen were done with the help of plate vibrator. The specimens were kept in clean water tank just after removal from the mould and kept continuously moist till the time of testing. Initial mixing, oiling and mould filled with concrete is shown in fig.2 (a), (b) and (c) respectively.

2.4. Testing procedure:

Slump test is the most commonly used method for measuring consistency of concrete which can be employed either in laboratory or at site of work. It is not a suitable method for very wet or very dry concrete. It is used conveniently as a control test and gives an indication of the uniformity of concrete from batch to batch. Dampen the slump test mould and place it on a flat, moist, non absorbent, rigid surface, like a steel plate. Fill the mould to 1/3 full by volume and rod the bottom layer with 25 evenly spaced strokes. Fill the mould to 2/3 full and rod the second layer with 25 strokes penetrating the top of the bottom layer. Heap the concrete on top of the mould, and rod the top layer with 25 strokes penetrating the top of the second layer. Strike off the top surface of the concrete even to the top of the mould. Remove the mould carefully in the vertical direction (take about five seconds). Immediately invert and place the mould beside the slumped concrete and place the rod horizontally across the mould, and measure the slump, in cm.

2.4.1 Compressive strength Testing of hardened concrete:

Compressive strength test is initial step of testing concrete because the concrete is primarily meant to withstand compressive stresses. Compressive strength tests were carried out on 150 mm x 150 mm x 150 mm cubes with compression testing machine of 2000 KN capacity. The specimens after removal from the curing were cleaned and properly dried. The surface of the testing machine was cleaned as shown in fig.3 (a). The cube was then placed with the cast faces in the contact with the platens of the testing machine. Cubes were tested at 28 and 56 days of curing. In each category, three cubes were tested and their average value is reported.

Fig. 3(a) Failure of cube under compression, (b) split tension, (c) flexural test setup

2.4.2. Split tensile strength:

The split tensile test are well known indirect tests used for determining the tensile strength of concrete, sometimes referred to as the splitting tensile strength of concrete. The test consists of applying compressive line load along the opposite generators of a concrete cylinder placed with its axis horizontal between the platens (fig.3(b)). Cylinders were tested at 28 and 56 days of curing. In each category, three cylinders were tested and their average value is reported.

2.4.3. Flexural strength test:

Flexural strength test is essential to estimate the load at which the concrete members may crack. The specimens cast for this test were of shape of a square prism of side 100 mm and axis length of 500 mm. Specimens were tested at 28 and 56 days of casting for strength analysis as shown in fig.3 (c). Flexural Strength test was conducted as per the guidelines given in IS 516:1959.

III. RESULTS AND DISCUSSION:

The results of strength properties for Hybrid Fiber Reinforced Concrete containing different combinations of steel and polypropylene fibres are discussed below.

3.1. Compressive strength:

Compressive Strength Tests were conducted on total 36 specimen for six different mixes and the results were carried out by taking an average from three test specimen for each mix. The results for both 28 and 56 days compression test are shown in table 4.

Table 4. Compression test results

Mix	**Fibre mix proportion by vol %**		**28 days compression strength (MPa)**					**56 days compression strength (MPa)**				
			Cube compression									
	SF	PPF	B1	B2	B3	Avg.	% inc	B1	B2	B3	Avg.	% inc
M1	0	0	39	40	40	40	0	43	44	44	44	0
M2	0	100	36	35	36	35	-10	39	39	38	39	-12
M3	25	75	37	46	39	39	-2.8	41	43	43	42	-3.9
M4	50	50	45	49	44	45	14	49	50	49	49	14
M5	75	25	47	44	45	47	19.5	51	53	51	52	19.4
M6	10	0	41	44	41	42	7	45	49	46	47	8.3

The results of the compressive strength test conducted on HFRC containing different combinations of steel and polypropylene fibres are presented in table 4.1 and 4.2 for 28 days and 56 days strength respectively. Strength of plain concrete is also shown in the table for reference. It is observed that with the introduction of 100% polypropylene fibres to the plain concrete, the compressive strength drops to 35.7 MPa from 40.1 MPa resulting in approximately 10% reduction. Banthia and Soleimani also reported approximately 13% reduction in compressive strength of concrete containing 100% polypropylene fibres as compared to that of plain concrete with 1% of total fibre content. That is with the introduction of less quantity of steel fibre content there is considerable reduction in compressive strength properties. However, an increase in the compressive strength of fibrous concrete is observed with the addition of steel fibres to the mix and maximum compressive strength is obtained for concrete containing 75% steel fibres+25% polypropylene fibres. In general, there is an increase in compressive strength varying from 6% to 18% on addition of fibres to concrete and in this investigation also with the optimum fibre combination of 75% steel fibres + 25% polypropylene fibres for which the maximum

increase in compressive strength of 18% over plain concrete is observed. But with adding 0.75% of fibre instead of 1% there is little increase in compressive strength compared to 1% fibre content in case of 75% steel and 25% polypropylene fibre composition. Further, it can also be seen that the compressive strength of concrete mix containing 50% steel fibres + 50% polypropylene fibres is higher than that of concrete mix containing 100% steel fibres. The percentage increase/decrease in compressive strength of HFRC over plain concrete is presented in table 4.1 and 4.2.

3.2. Split tensile strength:

Split Tensile Strength test were conducted on total 36 specimen for six different mixes and the results were carried out by taking an average from three test specimen for each mix. The results are shown in table 5.

Table 5. Split tension strength results for both 28 and 56 days test

Mix	**Fibre mix proportion by vol %**		**28 days split tension strength (MPa)**					**56 days split tension strength (MPa)**				
	SF	PPF	B1	B2	B3	Avg.	% inc	B1	B2	B3	Avg.	% inc
M1	0	0	4.2	4.7	4.1	4.3	0	4.6	4.8	4.4	4.5	0
M2	0	100	4.8	5.4	5	5	18	5.7	5.9	5.6	5.7	24
M3	25	75	6.2	6.9	6.4	6.3	49	7	7	7	7	54
M4	50	50	8	8.9	8.7	8.2	93	9.5	9.5	8.8	9	98
M5	75	25	11	9.9	9.6	9.9	130	10	11	11	11	130
M6	10	0	12	11	11	11	160	12	12	11	12	159

The results of the spilt tensile strength test conducted on HFRC containing different combinations of steel and polypropylene fibres are presented in table 4.3 and 4.4 for 28 days and 56 days curing strength. The 28 and 56 days spilt tensile strength of plain concrete is also shown in the table for reference. It is observed that with the introduction of 100% polypropylene fibres to the plain concrete, the spilt tensile strength increases from 4.3 MPa to 5.1 MPa resulting in approximately increase of 18%. Compared to the research conducted by V.S.Vairagade, there is reduction in strength by almost 18%, which is due to less quantity of steel fibre used in the investigation. There is no considerable effect of polypropylene fibre on tensile strength. The percentage increase/decrease in spilt tensile strength of HFRC over plain concrete is presented in table 4.3 and 4.4.

3.3. Flexural strength:

Flexural Strength test were conducted on total 36 specimen for six different mixes and the results were carried out by taking an average from three test specimen for each mix, results shown in table 6.

Table 6: Flexural strength test results

Mix	**Fibre mix proportion by vol %**		**28 days flexural strength (MPa)**					**56 days flexural strength (MPa)**				
	SF	PPF	B1	B2	B3	Avg.	% inc	B1	B2	B3	Avg.	% inc
M1	0	0	4.2	4.2	5	4.3	0	5	4.9	5.3	5	0
M2	0	100	3.3	3.4	4.4	3.7	-16	4	4.5	5	4.5	-12
M3	25	75	6.2	6	5.9	5.9	34	7	7.2	6.6	7	35
M4	50	50	6	6.2	6.5	6.3	45	7.1	7.5	7.4	7.3	43
M5	75	25	8	7.2	7.7	7.5	68	8.2	8.6	8.7	8.5	67
M6	10	0	6	5.3	6.6	5.8	32	6.3	6.8	7	6.8	31

The flexural strength results for HFRC containing different combinations of steel and polypropylene fibres are presented in Table 4.5 and 4.6. The flexural strength of plain concrete is also listed for reference and comparison in the table. It can be seen that in general, like compressive strength, the flexural strength of concrete containing 100% polypropylene fibres is less than that of the plain concrete. There is a drop of approximately 16% in the flexural strength of concrete containing 100% polypropylene fibres as compared to that of plain concrete. Banthia and Soleimani reported approximately 11% reduction in flexural strength of concrete containing 100% polypropylene fibres as compared to that of plain concrete with 1% total fibre content. With gradual replacement of polypropylene fibres with steel fibres, an increase in the flexural strength is observed up to a fibre combination of 75% steel fibres + 25% polypropylene fibres. With further replacement of polypropylene fibres with steel fibres i.e. for concrete containing 100% steel fibres, a decrease in flexural strength is observed. The increase in flexural strength taken as average of three batches of fibrous concrete containing different combinations of steel and polypropylene fibres varied from 30% to 70%, showing an increase of 34% for HFRC with 25% steel fibres + 75% polypropylene fibres; 45% for 50% steel fibres + 50% polypropylene fibres; 68% for concrete containing 75% steel fibres + 25% polypropylene fibres and 31% for concrete containing 100% steel fibres. Thus the optimum fibre combination for maximum flexural strength is 75% steel fibres + 25% polypropylene fibres as obtained in this investigation. Various strengths of concrete such as compressive, split tensile and flexural are affected by many factors. These are compaction, curing conditions, aggregate size and mineralogy, admixture types, specimen geometry and moisture conditions, type of stress and rate of loading. Thus, the strengths are found to vary at various ages. In the present study, locally available materials were used. The variation in properties of the materials could be the reason for its variation from the results reported in literature.

IV. CONCLUSION:

The maximum compressive strength reaches in the HFRC at 75% steel fibres and 25% polypropylene fibres because of the high elastic modulus of steel fibre and the low elastic modulus of polypropylene fibre work in perfect combination.□The spilt tensile strength of fibre percentage with 100% steel fibre shows maximum increase in strength. Improved tensile strength can be achieved by increasing the percentage of steel fibres. The higher number of fibres bridging the diametrical splitting crack, the higher would be the spilt tensile strength.□The flexural strength of HFRC containing the volume fraction of 75% steel fibres and 25% polypropylene fibres is higher than the other fiber composition. It was observed that, under axial loads, cracks occur in microstructure of concrete and fibres limit the formation and growth of cracks.□The brittleness of concrete can also be improved by addition of steel fibers than polypropylene fibre. Since concrete is very weak in tension, the steel fibers are beneficial in axial-tension to increase tensile strength.□During the test it was observed that the HFRC specimen has greater crack control due to reduction in crack widths.□Steel fibre yielded higher strength values in comparison to polypropylene fibre. The specimen in which the percentage of steel fibre is more shows better result.□It is evident from the present investigation that the hybridization of fibres proves to be better as compared to mono fibers in improving the strength properties of concrete.

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