Comparison of compressive strength and flexural shear strength for hybrid fibre reinforced concrete with the controlled concrete

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Abstract— **Plain concrete is a brittle material. In this modern age, civil engineering constructions have their own structural and durability requirements. Every structure has its own intended purpose and hence to meet this purpose, modification in traditional cement concrete has become mandatory.**

Concrete has relatively high compressive strength, but significantly lower tensile strength (about 10% of the compressive strength). As a result, without compensating, concrete would almost always fail from tensile stresses, even when loaded in compression. The practical implication of this is that concrete elements subjected to tensile stresses must be reinforced with materials that are strong in tension. Reinforced is the most common form of concrete. The reinforcement is often steel; rebar (bars mesh, spirals, and other forms). Structural fibres of various materials are also used.

The cracks generally develop with time and stress to penetrate the concrete, thereby impairing the waterproofing properties and exposing the interior of the concrete to the destructive substances containing moisture, bromine, acid sulphate, etc. The exposure acts to deteriorate the concrete, with the reinforcing steel corrosion. To counteract the cracks, a fighting strategy has come into use, which mixes the concrete with the addition of discrete fibres. One important limitation of conventional concrete, even of good quality is the presence of micro cracks, capillaries and micro capillaries into which water is able to penetrate; sucked in surface tension forces or driven by an external hydrostatic pressure. The presence of micro cracks at the mortar aggregate interface is responsible for the inherent weakness of plain concrete.

The present experimental work is mainly concerned with the study of behavior of cement concrete by adding Hybrid Fibers. Addition of fibers to cement concrete enhances the overall strength properties of concrete as fibers have a relatively high strength and modulus of elasticity.

Index Terms—**Hybrid Fiber, Controlled Concrete, HFRC. Flexural Strength**

I. INTRODUCTION

The principal reason for incorporating fibers into a cement matrix is to increase the toughness and tensile strength and improve the cracking deformation characteristics of the resultant composite. In order for Fibre Reinforced Concrete (FRC) to be a viable construction material, it must be able to compete economically with existing reinforcing systems.

As said earlier, concrete is inherently a brittle material, with low tensile strength and limited ductility. Contribution of the conventional steel reinforcement in RCC construction in taking care of the tensile stresses is limited in its own plane. Widespread cracking due to secondary effects like temperature and shrinkage in fresh concrete is quite common, which affects its performance. Incorporation of continuous uniformly dispersed unidirectional fibers in the matrix of concrete or mortar improves tensile and flexural strength, ductility, toughness, and impact and fatigue resistance of Hybrid Fiber Reinforced Concrete (HFRC) as compared to the plain concrete.

The objective of this study is to investigate the behavior of HFRC composite with various volume fractions and to investigate the following properties:

1. The strength properties of HFRC composite with various volume fractions such as compressive strength split tensile strength, flexural strength.
2. To investigate the properties of fresh concrete such as workability and density.
3. To compare the properties of this special concrete with that of normal concrete.

The present experimental work is mainly concerned with the study of behavior of cement concrete by adding hybrid fibers.

Addition of fibers to cement concrete enhances the overall strength properties of concrete as fibers have a relatively high strength and modulus of elasticity.

II. EXPERIMENTAL WORK

In the present research work production of control mix (normal concrete of grade (M-30) in the laboratory is carried out by IS method designed proportions. Hybrid fiber reinforced concrete(HFRC) is produced by adding crimped steel fibers and alkali resistant glass fibers to the cement concrete. Fibers were varied from 0.25% to 2% at a constant interval of 0.25 by weight of cement.

The ingredients of concrete i.e. cement, fine aggregate & coarse aggregate are tested before producing the concrete. All cement, sand and coarse aggregate are measured with Digital balance. The water is measured with measuring cylinder of capacity 1 liter and measuring jars of capacity 2000 ml. Plasticizer, steel fibers and glass fibers are measured with Digital balance of accuracy 1mg.

The ingredients were thoroughly mixed over a G.I.sheet. The sand, cement and aggregate were measured accurately

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and were mixed in dry state for normal concrete. Similarly, for hybrid fiber reinforced concrete, the required quantities of steel fibers and glass fibers (i.e. from 0.25 % to 2%) were measured by weight of cement. The required weighted quantity of fibers was then uniformly sprinkled by hands on dry concrete mix containing CA, FA and cement. 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. Selected percentage of super plasticizer was added to designed quantity of water and stirred vigorously so that it is mixed uniformly in the entire water. The solution is then spread over the concrete mix and remixed thoroughly again for few minutes. The relevant Indian standard codes were followed for conducting various tests on the concrete. All properties of cement are tested by referring relevant IS Code.

Compressive strength of cubes is determined at 7 days and 28 days using compression testing machine (CTM) of capacity 2000 kN. Split tensile test, flexure test is carried out on universal testing machine of 400 kN capacity. During flexure test deflection for each beam were measured.

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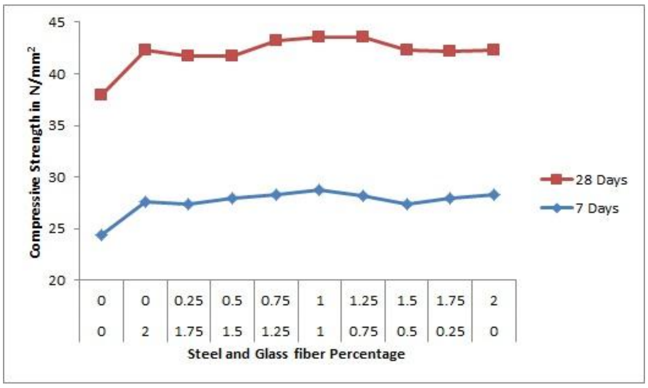
III. RESULT AND DISCUSSIONS

Compressive tests and flexural test on hardened concrete prepared by using Hybrid fiber and Normal concrete are carried out according to relevant standards wherever applicable. Results of various strengths are computed according to the strength of material theory. Results of hardened HFRC are discussed in comparison with those of normal concrete

The results of compressive strength are presented in Table 1.

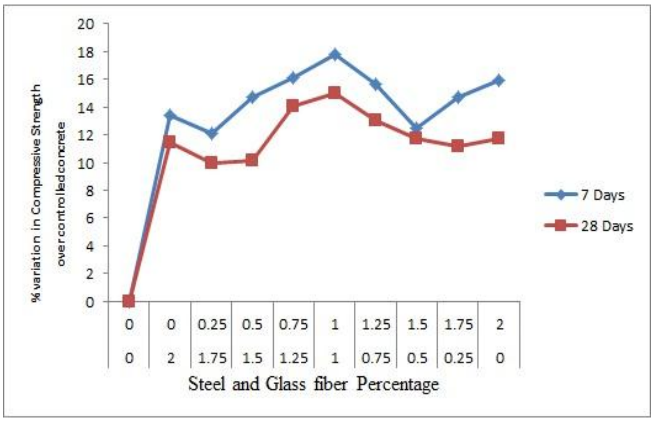
Sr No	Fiber fraction (V_f %)		Compressive Strength (N/mm^2)		% Variation in Compressive Strength Over Control Concrete	
	Steel	Glass	7 Days	28 Days	7 Days	28 Days
1	**0**	**0**	24.39	37.89	0	0
2	2	0	27.66	42.23	13.40	11.45
3	1.75	0.25	27.34	41.68	12.09	10.00
4	1.5	0.5	27.97	41.75	14.67	10.18
5	1.25	0.75	28.32	43.23	16.11	14.09
6	1	1	28.74	43.56	17.83	14.96
7	0.75	1.25	28.21	43.54	15.66	14.91
8	0.5	1.5	27.43	42.32	12.46	11.69
9	0.25	1.75	27.97	42.12	14.67	11.16
10	0	2	28.27	42.32	15.90	11.69

Table 1: Compressive strength of Normal and HFRC



Graph 1: Compressive strength –Fiber fractions for steel and glass at 7 and 28 days

Results of compressive strength are shown in Table 1 From graph 1 indicates that for hybrid fibers percentage (1% steel and1% glass) which gives maximum strength 28.74 N/mm^2 and 43.56 N/mm^2 for 7days and 28 days respectively and minimum compressive strength is 24.39 N/mm^2 and 37.89 N/mm^2 for normal concrete. As percentage of steel fibers increases in comparison with glass fibers compressive strength up to 50 % of both fibers.



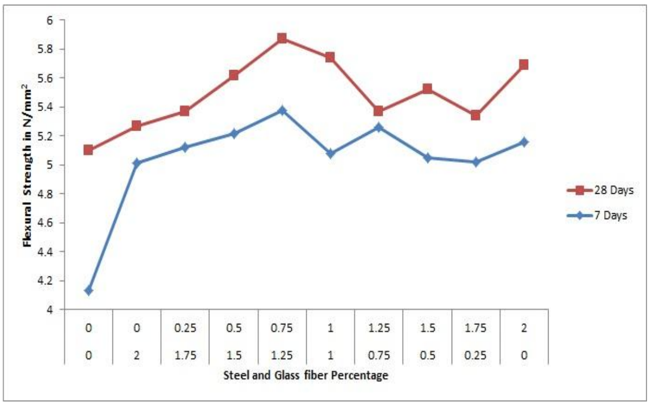
Graph 2: Percentage variations in compressive strength over control concrete-Fibre fractions for steel and glass at 7 days and 28 days

From graph 2 it is observed that for fiber percentage (1% steel and1% glass) , compressive strength 17.83 N/mm^2 and 14.96 N/mm^2 percentage increased over control (normal) concrete at 7 days and 28 days respectively. As steel fiber percentage increases and glass fiber percentage decreases, compressive strength increases up to 1% steel and 1% glass fibers and after that steel fiber percentage decreases and glass fiber percentage increases then compressive strength decreases.

Flexural strength is obtained for various fiber volume fraction and results are presented in Table 2.

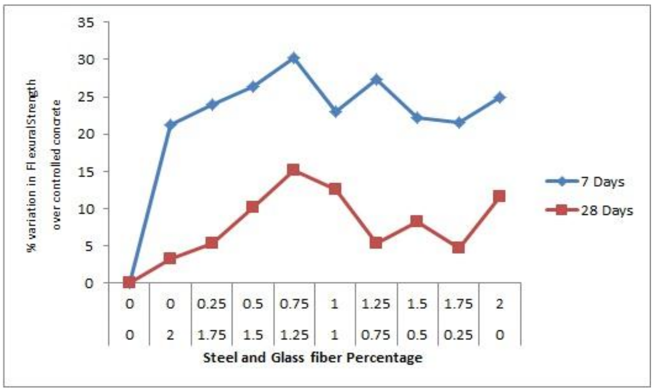
Sr N o.	Fiber fraction (V_f %)		Flexural Strength (N/mm^2)		% Variation in Flexural Strength Over Control Concrete	
	Steel	Glass	7 Days	28 Days	7 Days	28 Days
1	**0**	**0**	4.13	5.10	0	0
2	2	0	5.01	5.27	21.30	3.33
3	1.75	0.25	5.12	5.37	23.97	5.29
4	1.5	0.5	5.22	5.62	26.39	10.19
5	1.25	0.75	5.38	5.87	**30.26**	**15.09**
6	1	1	5.08	5.74	23.00	12.54
7	0.75	1.25	5.26	5.37	27.36	5.29
8	0.5	1.5	5.05	5.52	22.27	8.23
9	0.25	1.75	5.02	5.34	21.54	4.70
10	0	2	5.16	5.69	24.93	11.56

Table 2: Flexural strength of Normal & HFRC



Graph 3: Flexural strength –Fiber fractions for steel and glass at7 days and 28 days

Results of flexural strength are shown in Table 2, Graph 3 indicates the optimum volume fraction of fibers 1.25% steel and 0.75% glass which gives maximum flexural strength 5.38 N/mm^2 and 5.87 N/mm^2 at 7 days and 28 days respectively .Cracks occur in microstructure of concrete and fibers reduce the crack formation and propagation. After optimum level, there is reduction in flexural strength



Graph 4: Percentage variations in flexural strength over control concrete-Fibre fractions for steel and glass at 7 days and 28 days

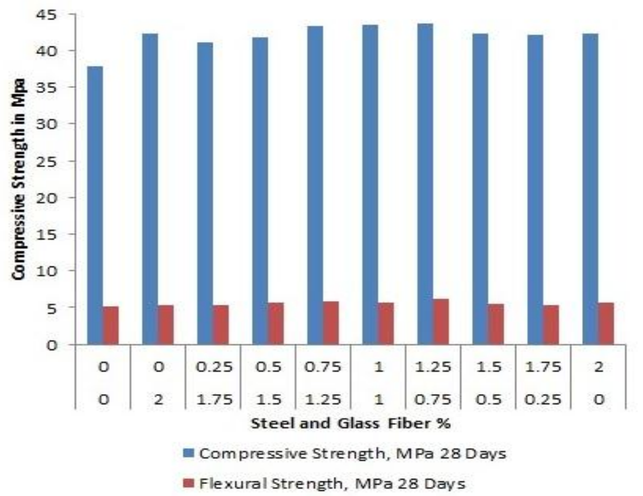
From Graphs 4 it is observed that at 7 and 28 days flexural load has increased, deflection has non linearly increased which shows increase in ductility over normal concrete. This indicates toughness improvement in HFRC over normal concrete and also, addition of fiber increases the energy absorption as compared to that of normal concrete for fiber percentage (1.25% steel and 0.75% glass)

Compressive strength and Flexural shear strength are compared in Table 3.

Sr No	Fiber fraction (V_f %)		Compressive Strength, MPa	**Flexural Strength, MPa**
	Steel	Glass	28 Days	**28 Days**
1	**0**	**0**	37.89	5.10
2	2	0	42.23	5.27
3	1.75	0.25	41.10	5.37
4	1.5	0.5	41.75	5.62
5	1.25	0.75	43.23	5.87
6	1	1	43.56	5.74
7	0.75	1.25	43.57	6.27
8	0.5	1.5	42.32	5.52
9	0.25	1.75	42.12	5.34
10	0	2	42.32	5.69

Table 3: Comparison of compressive strength and flexural strength

Fig. 1: Flexural strength of HFRC Beam Specimen



Graph 5: Comparison of Compressive and flexural strength for fiber fractions of steel and glass at 28 days

From graph 5, it is observed that flexural strength varies as the steel fiber and glass fiber percentage varies from (0-0)%, (0-2) %, (0.25-1.75) %,(0.5-1.5) %,(0.75-1.25)% (1.25-0.75) %, (1.5-0.5) % ,(1.75-0.25) % and (2-0)%. Maximum compressive strength for hybrid fiber percentage (1% steel and 1% glass) is obtained 43.56 N/mm2 at 27 days and minimum compressive strength obtained normal concrete is 37.89 N/mm2 at 28 days. Compressive strength decreases as the steel fiber and glass fiber percentage varies from (1.25-0.75) %, (1.5-0.5) % and (1.75-0.25) %

Maximum flexural strength 5.87 N/mm^2 for hybrid fiber percentage (1.25% steel and 0.75% glass) is obtained at 28 days 2.83 N/mm^2 and minimum flexural strength obtained for normal concrete is 5.10 N/mm^2 at 28 days.

IV. Conclusion

The summary of present study, the major conclusions of the investigation with the applications of HFRC.
Following conclusion are drawn based on the result discussed

in the experimental work:

1. In general, the significant improvement in various strengths is observed with the inclusion of Hybrid fibres in the plain concrete. However, maximum gain in strength of concrete is found to depend upon the amount of fibre content. The optimum fibre content to impart maximum gain in various strengths varies with type of the strengths.
2. The optimum percentage fibre volume fraction for compressive strength is 1% steel and 1 % glass for HFRC, flexural strength 1.25%steel and 0.25 % glass for HFRC.
3. Maximum percentage increase in compressive strength is 14.96% for HFRC (1% steel and 1% glass), flexural strength 15.09 % for HFRC (1.25 % steel and 0.75 % glass) over controlled or normal concrete.

4. With increasing fibre content, mode of failure was changed from brittle to ductile failure when subjected to compression and bending.
5. From above, conclusion can be drawn that hybrid fibre reinforced concrete increases the different mechanical properties of concrete.

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