Assessment of workability and spilt tensile strength of hybrid fiber reinforced concrete in comparison with controlled concrete

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Abstract—**Plain concrete is a brittle material. Under impact and dynamic loading plain concrete exhibits extensive cracking and undergoes brittle failure. The concrete is weak in tension and hence to overcome this problem cement concrete is reinforced using hybrid fibres and thus called as hybrid fibre reinforced concrete (HFRC) 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. Workability and split tensile strength crimped steel fibre and alkali resistant glass fibre as a hybrid fibre used interval of 0.25 % up to 2% used in M30 mix and results are compared with normal concrete.**

Index Terms— **HFRC, Workability, Split Tensile Strength.**

I. INTRODUCTION

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 fibers of various materials are also used. In this paper crimped steel fibre and alkali resistant.

II. LITRATURE REVIEW

Byung Hwan Oh, [1] "Flexural analysis of fiber reinforced concrete beams containing steel fibers"The flexural behavior of reinforced concrete beams containing steel fibers is investigated in this paper .An experimental program was set up and nine reinforced concrete beam tested, including two series of singly reinforced concrete beam and one series of doubly reinforced concrete beams. The fiber content of reinforced concrete beam for each series was 0%, 1% and 2% by volume. The load was applied in four point flexural loading condition. The various locations, the crack width and crack spacing at each loading step were observed during the loading process. It was found from this measurement that the crack widths increase almost linearly with the increase of steel stress and the crack widths at the same loading stages are greatly reduced as the content of steel fibers increases.

K.Murugappan, P.Paramasivam, and K.H.Tan[1]" Failure Envelope for steel –fiber concrete under biaxial compression"Steel Fiber Concrete (SFC) demonstrates better deformational and cracking characteristics as compared to plain concrete and is used in structures where significant tensile stresses are encountered .Improvement in the biaxial compressive strength of plain concrete can be achieved the addition of steel fibers. In this paper an attempt is made to obtain analytically the failure envelope for steel fiber concrete under biaxial compression.

Joaquim Barros,Eduardo Pereira,and Simao Santos[2] "Lightweight Panels of Fiber Reinforced self-compacting concrete" The SFRSCC mix design strategy and the experimental research conducted to characterize the bending and the compression behavior of SFRSCC at ages ranging from 12 h to 28 days presented. A particular effort is made to assess the SFRSCC post cracking behavior, carrying out three point notched beam bending tests.

Mustafa Sahmaran, Alperen Yurtseven and I. Ozgur Yaman[3] "Workability of hybrid fiber reinforced self-compacting concrete" In this paper two different types of steel fibers where used in combinations and effect of fiber inclusion on the workability of HFRC is studied .The effect of fibers are quantified on the based on the fiber volume, length and aspect ratios of the fibers

Liberato Ferrara [July 2012][4] "A comprehensive methodology to test the performance of steel fiber Reinforced Self-Compacting Concrete (SFR-SCC)"In this paper ,typical SFR-SCC mix composition (containing 50kg/m^{3}hooked steel fibers 35mm long with aspect ratio equal to 65) different method to evaluate the resistance to static and dynamic segregation of fibers have been discussed.

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III. EXPERMENTAL WORK

The present research work is experimental and requires preliminary investigations in a methodological manner.

2.1Production of Concrete Mixes

- Production of control mix (normal concrete of grade (M-30) in the laboratory is carried out by IS method designed proportions.

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- Hybrid fiber reinforced concrete is produced by adding steel fibers and 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.concrete, the required quantities of steel fibers and glass fibers (i.e. from 0.25 % to 2%) were measured by weight

2.2 Test Conducted on Material Used in Experimental Work

The ingredients of concrete i.e. cement, fine aggregate & coarse aggregate are tested before producing the concrete. The relevant Indian standard codes were followed for conducting various tests on the concrete.

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2.4 Measurement of ingredients

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.

2.5 Mixing of concrete

The ingredients were thoroughly mixed over a G.I.sheet. The sand, cement and aggregate were measured accurately and were mixed in dry state for normal concrete. Similarly, for hybrid fiber reinforced 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.

2.6 Placing of concrete

The fresh concrete was placed in the moulds by trowel. It was ensured that the representative volume was filled evenly in all the specimens to avoid segregation, accumulation of aggregates etc. While placing concretes, the compaction in vertical position was given to avoid gaps in moulds.

2.7 Compaction of concrete

Moulds are cleaned and oiled from inside for smooth demoulding. Concrete is mixed thoroughly and placed in the mould in three layers and compacted by electrically operated Table vibrator with suitable fixing frame. It is vibrated till concrete woes out of mould. The vibration is continued till cement slurry just ooze out on surface of moulds. Care is taken of cement slurry not to spill over, due to vibration and segregation.

2.8 Finishing of concrete

After removing from vibrating table, the moulds were kept on ground for finishing and covering up for any leftover position. The concrete is worked with trowel to give uniform surface. Care is taken not to add any extra cement, water or cement mortar for achieving good surface finish. The additional concrete is chopped off from top surface of the mould for avoiding over sizes etc. The density of fresh concrete is taken with the help of weigh balance. Identification marks are given on the specimens by embossing over the surface after initial drying.

2.9 Demoulding of specimens

The plain cement concrete specimens are demoulded after 24 hours of casting wet concrete and kept in water tank for curing. HFRC specimens are demoulded after 24 hours of casting wet concrete and kept for water curing at 7 days and 28 days.

2.10 Curing of test specimens

The specimens were demoulded after 24 hours of casting and immediately stored in the curing tank for continuous curing. M-30 grade plain cement concrete is cured in curing tank for 7 days and 28 days. Hybrid fiber reinforced concrete (HFRC) specimens of different fiber content are water cured for 7 days and 28 days for same grade of concrete.

2.11 Split Tensile Test on Cylinder

The split tensile test is well known indirect test used to determine the tensile strength of concrete. Due to difficulties involved in conducting the direct tension test, a number of indirect methods have been developed to determine the tensile strength of concrete. In these tests, in general a compressive force is applied to a concrete specimen in such a way that the specimen fails due to tensile stresses induced in the specimen.

The tensile strength at which failure occurs is the tensile strength of concrete. In this investigation, the test is carried out on cylinder by splitting along its middle plane parallel to the edges by applying the compressive load to opposite edges. The arrangement for the test is shown in photo with the pattern of failure. The split tensile strength of cylinder is calculated by the following formula below.

$$f_t = 2P_l / \pi LD$$

where,

f_t = Tensile strength, MPa
P_l = Load at failure, N
L = Length of cylinder, mm
D = Diameter of cylinder, mm

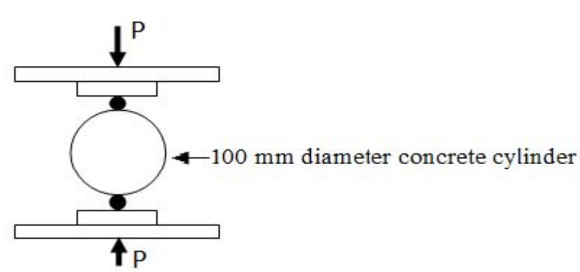


Fig 1:- Cylinder Split Tensile Test Setup

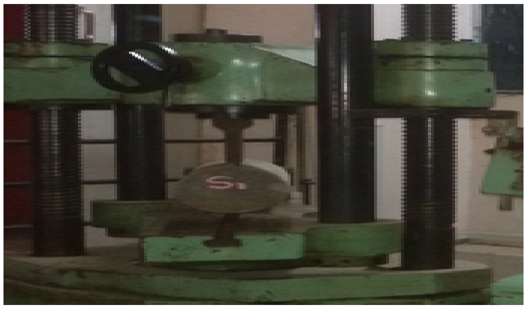


Photo 1:- Split tensile test on cylinder

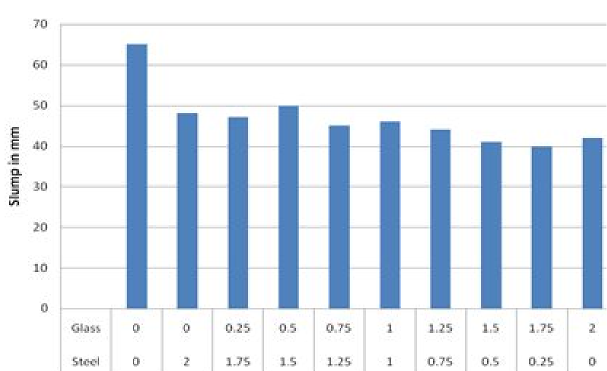
IV. RESULT AND DISCUSSION

4.1 Workability and density

Workability of concrete with and without fiber is determined with the help of slump cone test. The density is obtained by measuring the weight and volume of cube moulds respectively. Results of these properties are shown in Table 1

Table 1: Wet and dry density and workability of Normal and HFRC

Sr No	Fibre Content %	Fibre Content %	W/C Ratio	Wet Density Kg/m^3	Dry Density Kg/m^3 at 7 days	Dry Density Kg/m^3 at 28 days	Workability by slump mm
	steel	glass					
1	0	0	0.39	2700	2605	2675	65
2	2	0	0.39	728	2635	2693	48
3	1.75	0.25	0.39	2724	2628	2680	47
4	1.5	0.5	0.39	2718	2622	2672	50
5	1.25	0.75	0.39	2712	2624	2663	45
6	1	1	0.39	2709	2617	2664	46
7	0.75	1.25	0.39	2681	2615	2656	44
8	0.5	1.5	0.39	2692	2613	2649	41
9	0.25	1.75	0.39	2683	2614	2646	40
10	0	2	0.39	2680	2608	2655	42



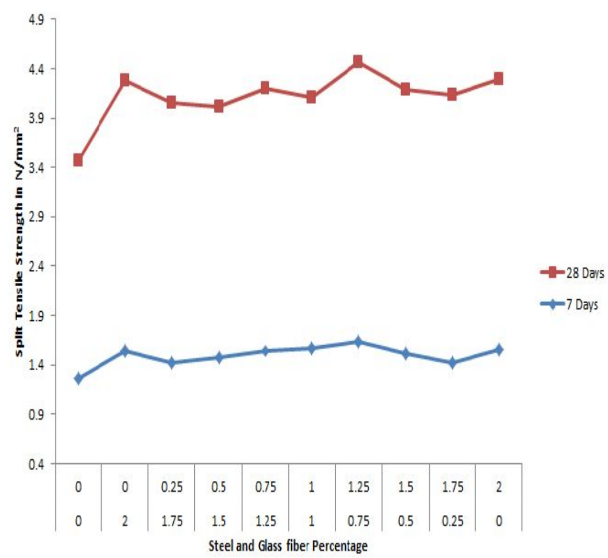
Graph 1: Comparisons of workability for Normal and HFRC

Workability is measured in terms of slump. From above graph 1 it is observed that for same mix proportion and same SP dose with same aspect ratio of fiber but increase in fiber content (%) workability is reduced. Workability is maximum for normal concrete and minimum for HFRC having Fiber percentage (0.25-1.75)

From Tables 1 it is observed that wet and dry density at 7 and 28 days has increased marginally for fiber reinforced concrete over normal concrete. The dry density has slightly decreased after fiber content of 1 % steel and 1% glass at 7 days due to poor bond formation between the fibers and cement matrix.

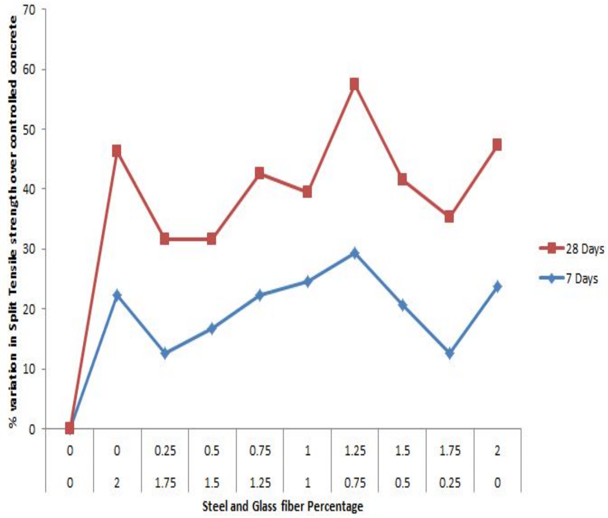
Table 2 Split Tensile Strength of Normal & HFRC Cylinde

Sr no	Fiber fraction (V_f %)		Split Tensile Strength (N/mm^2)		% Variation In Split Tensile Strength Over Control Concrete	
	Steel	Glass	7 Day	28 Days	7 Days	28 Days
1	0	0	1.26	2.21	0	0
2	2	0	1.54	2.73	22.22	23.52
3	1.75	0.25	1.42	2.63	12.69	19.00
4	1.5	0.5	1.47	2.54	16.66	14.93
5	1.25	0.75	1.54	2.66	22.22	20.36
6	1	1	1.57	2.54	24.60	14.93
7	0.75	1.25	1.63	2.83	29.36	28.05
8	0.5	1.5	1.52	2.67	20.63	20.81
9	0.25	1.75	1.42	2.71	12.69	22.62
10	0	2	1.56	2.74	23.80	23.98



Graph 2 Split tensile strength –Fiber fractions for steel and glass at 7 days and 28 days

From graph 2 it is observed that for fiber fractions of 0.75 % steel and 1.25 % glass gives maximum split tensile strength of 1.63 N/mm^2 and 2.83 N/mm^2 at 7 days and 28 days respectively. Minimum split tensile strength of 1.26 N/mm^2 and 2.21 N/mm^2 occurs for normal concrete at 7 days



Graph 3: Percentage variations in split tensile strength over control concrete-Fibre fractions for steel and glass at 7 days and 28 days

From graph 3 it is observed that split tensile strength for fibre fractions of 0.75 % steel and 0.25 % glass, 29.36 N/mm^2 and 28.05 N/mm^2 percentages increased over normal concrete for 7 days and 28 days respectively.

Conclusions

Following conclusion are drawn based on the result obtained

1. The wet and dry density at 7 and 28 days has increased marginally for fiber reinforced concrete over normal concrete. The density has slightly decreased after fiber content of 1% steel and 1% glass at 28 days due to poor bond formation between the fibers and cement matrix.
2. 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.
3. The optimum percentage fibre volume fraction for split tensile strength is 2% for GFRC
4. Maximum percentage increase in split tensile strength is 23.98 % for GFRC (2 % glass) over controlled or normal concrete.
5. With increasing fibre content, mode of failure was changed from brittle to ductile failure when subjected to compression and bending.
6. From above, conclusion can be drawn that hybrid fibre reinforced concrete increases the different mechanical properties of concrete.

Scope for Future Work

The present work has good scope for future research. Some of the research areas are as follows:

1. Investigation of ductility characteristics of HFRC for potential application in seismic design and construction
2. Behaviour under creep and shrinkage.
3. Behaviour of mechanical and physical properties of HFRC at various temperatures
4. Study the coatings for steel fiber to modify bond with the matrix and to provide corrosion protection.
5. Same parameters with recycled aggregates.
6. Fracture analysis.
7. Stress transfer mechanism.
8. Study of impact resistant, abrasion resistant and permeability of HFRC and resistant to chemical attack.

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