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Experimental Investigation on the Behaviour of Hybrid Fiber Reinforced Concrete

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***Abstract* - This paper focuses on the study of the toughness of Fibre Reinforced Concrete (FRC) based on different fibre proportions .The experimental investigation is carried out on fibre reinforced concrete containing different hybrid combinations of Crimpled steel and Hooked end fibers are reported. The mechanical properties, namely compressive strength and Split tensile strength were studied for concrete prepared using different fibre combinations –crimpled steel(Aspect ratio 50)- hooked steel(Aspect ratio 80), crimpled steel(Aspect ratio 50)- hooked steel(Aspect ratio 65),Crimpled steel fibers alone, Hooked end fibers alone and a plain concrete specimen. Among all fibre combinations, the M5-Crimped + H1 (Aspect ratio 50+80 & volume fraction 0.5%+0.5%) performed better in all respects compared to the double fibres in concrete. All the other combinations gave similar and better results.**

***Keywords* - Hooked end, crimpled steel fibers, Aspect ratio**

I. INTRODUCTION

Fibers are usually used in concrete to control cracking due to plastic shrinkage and to drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water.. Generally fibers do not increase the flexural strength of concrete, and so cannot replace moment–resisting or structural steel reinforcement. Indeed, some fibers actually reduce the strength of concrete. Degree of consolidation of the matrix, which is a function of water to cement ratio, consolidation technique, and type and content of the steel fiber. Uniformity of fiber distribution, which is mainly influenced by the workability and mixing procedure used. The objective of the present investigation is to evaluate the compressive strength and split tensile strength of hybrid fiber reinforced concrete and comparing with the conventional concrete.

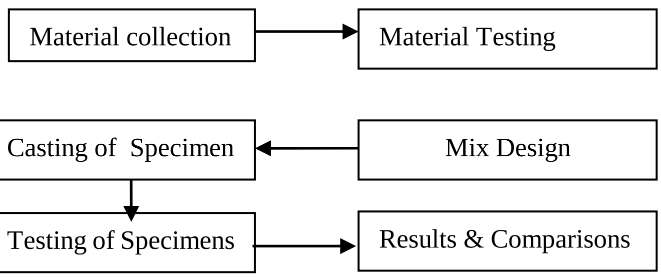
II. EXPERIMENTAL PROGRAMME

Cement used was Type I Portland cement conforming to OPC 53 grade. Coarse aggregate consists of river gravel, crushed stone or manufactured aggregate with particle size equal to or greater than 4.75mm. It shall comply with the requirements of IS383-1970 fineness modulus of 2.5 and a specific gravity of 2.57 was also utilized in SSD condition. For the coarse aggregates, the following test has been carried out conforming to IS2386 (part 1) 1963. In this study coarse aggregate of maximum size 20 mm was used. The fibers used in the study were crimpled steel, hooked steel; the properties of these fibers are listed in table 1.

Table 1 Properties of various fibers used

Properties	Crimpled steel	Hooked steel
Length (mm)	40	35
Diameter (mm)	0.75	0.55
Aspect ratio (l/d)	72	64
Density (kg/m^3)	7850	7850
Elastic Modulus (GPa)	200	200
Tensile strength (GPa)	2.6	2.6

III. METHODOLOGY



IV. EXPERIMENTAL STUDY

Compressive strength of concrete

Cube specimens were casted under conventional and fiber added concrete, after curing 28day testing was carried out. Compressive strength of the specimens are calculated using the following formula:

Compressive strength = Load/Area of cube

Spilt tensile strength of concrete

specimens were casted under conventional and fiber reinforced concrete, after curing seventh day testing was carried out.. Split tensile strength of the specimens are calculated using the following formula:

Split Tensile strength = $2P/\pi DL$

Table 2 Volume Fractions

S.NO	Specifications	Volume Fraction (%)	Aspect Ratio (L/D)
1	M1	----	----
2	M2	1%	50
3	M3	1%	80
4	M4	1%	65
5	M5	(0.5+0.5)%	50+80
6	M6	(0.5+0.5)%	50+65
7	M7	(1.5 %)	50
8	M8	(1.5 %)	80
9	M9	(1.5 %)	65
10	M10	(1 %+1 %)	50+80
11	M11	(1 %+1 %)	50+65
12	M12	2 %	50
13	M13	2 %	80
14	M14	2 %	65
15	M15	(1.25%+0.75%)	50+80
16	M16	(1.25%+0.75%)	50+65

- M1-Control mix
- M2-Crimped fiber alone (A/r 50 & VF 1%)
- M3-H1 alone (A/r 80 & VF 1%)
- M4-H2 alone (A/r 65 & VF 1%)
- M5-Crimped + H1 (A/r 50+80 & VF 0.5%+0.5%)
- M6-Crimped + H2 (A/r 50+65 & VF 0.5%)
- M7-Crimpled fiber alone (A/r 50 & VF 1.5%)
- M8-H1 alone (A/r 80 & VF 1.5%)
- M9-H2 alone (A/r 65 & VF 1.5%)
- M10-Crimpled+H1 (A/r 50+80 & VF 1%+1%)
- M11-Crimpled+H2(A/r 50+65 & VF 1%+1%)
- M12 Crimpled alone(A/r 50 & VF 2%)
- M13 H1 alone(A/r 80 & VF 2%)
- M14 H2 alone (A/r 65 & VF 2%)
- M15-Crimpled+H1 (A/r 50+80 & VF 1.25%+0.75%)
- M16-Crimpled+H2(A/r 50+65 & VF 1.25%+0.75%)
- H1-Hooked end fiber with aspect ratio 80
- H2-Hooked end fiber with aspect ratio 65
- **Note::**A/r-Aspect ratio VF-volume fraction

Preparation of Test specimens

The test specimens were cast in cast iron steel moulds. The mould specimens were applied with oil in all inner surfaces for easy removal of specimens after de-molding. The raw materials used for making concrete are weighed with correct proportions. For obtaining more binding, initially sand is mixed thoroughly in dry state. After that coarse aggregate, cement and binder are mixed thoroughly in dry condition. For addition of water, initially three-fourth of the mix water is added to the dry mix material to mix thoroughly. After that remaining water is mixed with super plasticizer are stirred well and added to mix. Mixing is done up to the level of uniform workable concrete are obtained.

The concrete is then placed in the mould in three layers of equal heights which is vibrated to get a uniform concrete without any segregations. After 24 hours, the specimens are demoulded and placed in water tank for curing till age of testing to be done.

Preparation Fiber Samples

1. Take the required quantities of materials from the table depending upon the mix under preparation.

S.NO	Specifications	Compressive Strength	Split tensile
1	M1	28	3.11
2	M2	32	4.18
3	M3	29	3.63
4	M4	31	3.89
5	M5	36	4.12
6	M6	33	3.89
7	M7	35	3.92
8	M8	32	3.72
9	M9	33	4.05
10	M10	35	3.96
11	M11	34	4.02
12	M12	33	3.99
13	M13	34	3.88
14	M14	32.5	3.68
15	M15	33	3.88
16	M16	30	3.78

2. Cement and sand are thoroughly mixed until the mixture is of uniform color.
3. The coarse aggregates & Steel fibers is then added and mixed it in dry state.
4. Add water and mix the whole mass for minimum two minutes so that the resulting concrete is uniform in color.
5. The moulds, both cubes (150 mm X 150 mm X 150 mm) and cylinders (150 mm diameter and 300 mm height) should be oiled to prevent the concrete from sticking.
6. The concrete should be, filled in the mould in three equal layers. Each layer should be compacted 35 times with a 16 mm diameter rod for each, 600 mm long and bullet pointed at lower end. When cylinder is used the strokes for each layer should not be less than 30.
7. Strike off the surface with a trowel.
8. Place the moulds containing the test specimen in moist air of at least 90% humidity and a temperature (27° + 2°)C for 24 hours.
9. Next day, the specimens are taken out from the moulds and cured under clean, fresh water at temperature (27° 62°) C.

Testing

Tests shall be conducted at the end of 7 days and 28 days. The tests should be carried out immediately upon the removal of specimens from water.Measure the dimensions of the given specimen. Keep the specimens in compression testing machine so that the load is applied to the transverse sides as cast and not to the top and bottom sides as cast. The rate of loading should be 140kg/cm^2/minute.

Note: The test strength of sample shall be the average of the strength of three specimens. The individual variation should not be more than 6.15 % of s average.

Fig. Failure of specimen

V. RESULTS AND DISCUSSIONS

Test results

The below graph shows the compressive strength of various mixes after 28 days for M20 grade of concerete

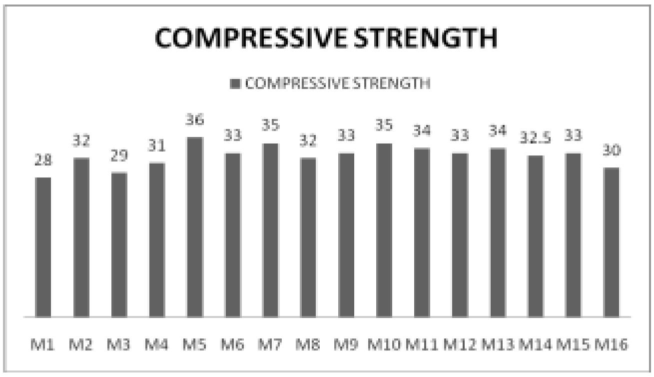


Fig. Compressive strength

Among all fibre combinations, the steel fibers (Crimped + H1 (Aspect ratio 50+80 & volume fraction 0.5%+0.5%) performed better in Compressive strength aespects compared to the double fibres in concrete. All the other combinations gave similar and better results. The below Fig. shows the split tensile strength of various mixes after 28 days for M20 grade of concrete

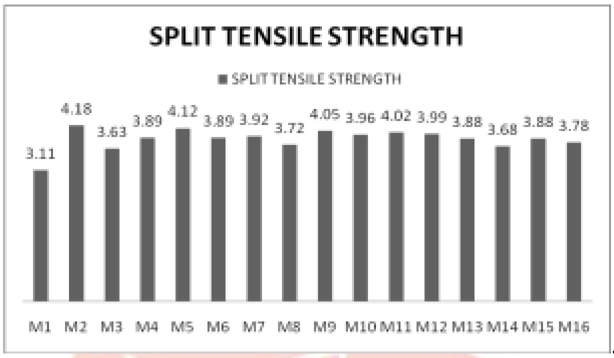


Fig. Split tensile strength

VI. CONCLUSION

The action of fibres at different volume fractions has enhanced the mechanical properties of fibre reinforced concrete for all the test results. Results from the study indicate the following:

- It is possible to produce concrete composites using Hooked end Steel Fibers and Crimpled steel fibres with an enhanced performance of 100% when compared to concrete without fibres.
- Fibre inclusion of all types increased compressive strength by only 5%, although this increase was not that significant and could have been obtained with simpler and more economical methods like reducing water-cement ratio. steel fibre proved to be efficient in strengthening the matrix.
- The addition of micro fibres in hybrid systems produces a favorable effect on both the strain softening and multiple cracking behavior of fibre reinforced concrete. As the amount of fibres increases, the tensile properties increases and the number of cracks were significantly improved.
- Among all fibre combinations, the steel fibers (Crimped + H1 (Aspect ratio 50+80 & volume fraction 0.5%+0.5%) performed better in Compressive strength aespects compared to the double fibres in concrete. All the other combinations gave similar and better results.
- Among all fibre combinations, the steel fibers(Crimped + H1 (Aspect ratio 50+80 & volume fraction 0.5%+0.5%) performed better in Split tensile strength aespects compared to the double fibres in concrete. All the other combinations gave similar and better results.

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