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EXPERIMENTAL STUDY ON THE MECHANICAL PROPERTIES OF VARIOUS STEEL AND GLASS FIBER REINFORCED CONCRETE

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ABSTRACT: Cement concrete is the most extensively used construction material in the world. It has been found that different type of fibers added in specific percentage to concrete improves the mechanical properties, durability and serviceability of the structure. It is now established that one of the important properties of hooked steel, crimped steel& glass fiber reinforced concrete is its superior resistance to cracking and crack propagation. Fiber reinforced concrete (FRC) is a concrete in which small and discontinuous fibers are dispersed uniformly. The fibers used in FRC may be of different materials like steel, G.I., carbon, glass, asbestos, polypropylene, jute etc. The addition of these fibers into concrete mass can dramatically increase the compressive strength, tensile strength, flexural strength and impact strength of concrete. FRC has found many applications in civil engineering field. Based on the laboratory experiment on fiber reinforced concrete (FRC), cube and cylinders specimens have been designed with steel fiber reinforced concrete (SFRC) and Glass fiber reinforced concrete (GFRC) containing fibers of 0% and 0.5% volume fraction of hook end Steel fibers of 53.85, 50 aspect ratio and alkali resistant glass fibers containing 0% and 0.25% by weight of cement of 12mm cut length were used without admixture.

In this paper effect of fibers on the different mechanical properties of grade M-80 have been studied. It optimizes 1.5% for steel Fiber content and 1% for glass fiber content by the volume of cement is used in concrete. The percentage increase in compressive strength at 28 days for hooked end steel fiber when compared to conventional concrete is 7.3%, crimped steel fiber with 6.08%, glass fiber with 4.30%. The percentage increase in split tensile strength at 28 days hooked end steel fiber when compared to conventional concrete is 4.54%, crimped steel fiber with 3.40%, glass fiber with 2.27% and also The percentage increase of flexural strength at 28 days for hooked end steel fiber when compared to conventional concrete is 3.57%, crimped steel fiber with 2.380%, glass fiber with 2.140%.

Keywords: Steel fiber reinforced concrete (SFRC) and Glass fiber reinforced concrete (GFRC), High strength concrete, M-80 Grade, IS:1386, IS:383.

I. INTRODUCTION

1.1 GENERAL

Concrete is a composite material containing hydraulic cement, water, coarse aggregate and fine aggregate. The resulting material is a stone like structure which is formed by the chemical reaction of the cement and water. This stone like material is a brittle material which is strong in compression but very weak in tension. This weakness in the concrete makes it to crack under small loads, at the tensile end. These cracks gradually propagate to the compression end of the member and finally, the member breaks. The formation of cracks in the concrete may also occur due to the drying shrinkage. These cracks are basically micro cracks. These cracks increase in size and magnitude as the time elapses and the finally makes the concrete to fail.

1.2 NEED FOR RESEARCH

Steel fibers are the strongest commonly-available fiber, and come in different lengths and shapes. Steel fibers can only be used on surfaces that can tolerate or avoid corrosion and rust stains. In some cases, a steel-fiber surface is faced with other materials. Glass fiber is inexpensive and corrosion-proof, but not as strong as steel. The design of glass fiber reinforced concrete panels proceeds from knowledge of its basic properties under tensile, compressive, bending and shears forces, coupled with estimates of behavior under secondary loading effects such as creep, thermal response and moisture movement.

1.3 SCOPE The usage of fibers in high strength concrete as an impact on its mechanical properties like compressive strength, shear strength, flexural strength, impact resistance etc. It also stops the propagation of cracks and reduces the brittleness of the high strength concrete.

1.4 OBJECTIVE The aim of our project is to use the Steel Fibers with hooked ends as Fiber reinforcement to concrete. Our objective is to add the Steel fibers (hooked end) to the concrete and to study the strength properties of concrete with the variation in fiber content. i.e., to study the strength properties of concrete (M25 Grade) for fiber content of 1.0, 2.0 and 3.0% at 28 days. The strength properties being studied in our thesis are as follows:

1. Compressive strength
2. Split tensile Strength
3. Flexural strength
4. Impact Resistance

These properties are then compared to the plain cement concrete.

- To find out the mechanical properties of high strength concrete reinforced with different fibers.
- To compare the results with the properties of normal high strength concrete.

1.5 RESAERCH SIGNIFICANCE

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. Addition of steel fibers into the concrete improves the crack resistance (or ductility) capacity of the concrete. Traditional rears are generally used to improve the tensile strength of the concrete in a particular direction, whereas steel fibers are useful for multi directional reinforcement. A Glass fiber has similar density to the concrete products. Cladding panels manufactured from 100 mm thick precast concrete weigh 240kgs/sq m compared to the similar GFRC panel 40-50 kgs /sq m.

II. EXPERIMENTAL STUDY

Experimental Program

In order to study the interaction of Steel fibres (hooked end) with concrete under compression, flexure, split tension and impact, 8 cubes, 8 beams and 16 cylinders were casted respectively. The experimental program was divided into four groups.

Each group consists of 2 cubes, 4 cylinders and 2 beams, of 15x15x15cm, 15(dia) x30cm and 15x15x70cm respectively.

- The first group is the control (Plain) concrete with 0% fiber (PCC)
- The second group consisted of 1% of Steel fibers (hooked end), with aspect ratio 80, by volume.
- The third group consisted of 2% of Steel fibers (hooked end), with aspect ratio 80, by volume.
- The fourth group consisted of 3% of Steel fibers (hooked end), with aspect ratio 80, by volume.

Table 2.1 Physical properties of OPC 53 grade ultra tech brand cement

S.No	Property	Test Value	Requirements as per IS: 12269 - 1987
1	Fineness of cement	4.52	10% (should not be more than)
2	Specific gravity	2.99	3.15
3	Normal consistency	33%	-
4	Setting time Initial setting time Final setting time	40 minutes 6 hours	30 minutes (should not be less than) 600 minutes (should not be greater than)
5	Compressive strength at 3 days 7 days 28 days	34 N/mm^2 44.8 N/mm^2 59 N/mm^2	27 N/mm^2 (min) 37 N/mm^2 (min) 53 N/mm^2 (min)

Table 2.2 Physical properties of fine aggregate

S. No.	Property	Value
1	Specific Gravity	2.68
2	Fineness Modulus	2.78
3	Bulk density Loose Compacted	14.67 kN/m3 16.04 kN/m^3
4	Grading	Zone –II

Table 2.3 Sieve analysis of fine aggregate

S. No.	I.S Sieve designation	Weight Retained	% of Weight retained	Cumulative % of weight Retained	% of Passing
1	4.75mm	15	1.50	1.50	98.50
2	2.36mm	16	1.60	3.10	96.90
3	1.18mm	59	5.90	9.00	91.00
4	600µ	78	7.8	16.8	83.2
5	300 µ	375	37.50	54.30	45.70
6	150 µ	392	39.2	93.50	6.50
7	75 µ	60	6.0	99.50	0.50

Fineness modulus=2.78
Total =277.70

Table 2.4 Physical properties of coarse aggregate

S.No.	Property	Coarse aggregate
1	Specific gravity	2.70
2	Bulk density Loose Compacted	13.29 kN/m^3 15.00 kN/m^3
3	Water absorption	0.7%
4	Flakiness index	14.22%
5	Elongation index	21.33%
6	Crushing value	21.43%
7	Impact value	15.5%

Table 2.5 Sieve analysis of coarse aggregate

S.No.	I.S Sieve designation	Weight Retained (gm)	% of weight retained	Cumulative % of weight Retained	% of Passing
1	20mm	935	18.70	18.7	81.30
2	10mm	3930	78.6	97.30	2.7
3	4.75mm	120	2.40	99.70	0.30
4	2.36mm	0	0	99.70	0.30
5	1.18mm	0	0	99.70	0.30
6	600µ	0	0	99.70	0.30
7	300 µ	0	0	99.70	0.30
8	150 µ	0	0	99.70	0.30

Fineness Modulus=7.14
Total=714.20

Table 2.6 Particle size analysis of silica fume given by distributer

Micron	%passing
100	100
50	99.6
20	97.9
10	94.5
5	84.6
2	55.6
1	35.0
0.4	12.2

Table 2.7 Basic properties of silica fume given by distributer

S.NO	Property	Test results
1.	Specific gravity	2.32
2.	Fineness	15000cm^2/gm

CERAPLAST 300 M

Cera-Chem Pvt Ltd, Chennai has developed Ceraplast 300 M which is compatible with blended cements, especially with slag cements. Ceraplast 300 M is a new generation, high grade, and high-performance retarding superplasticiser specially designed for concrete with replacement of cement upto 70-80 percent by slag. It was used in the construction of a breakwater (Asia's largest) . as a part of Ennore Coal Port Project in Tamil Nadu . It was a Rs 400-crore project consisting of 700-m jetty with South breakwater of 1 km length and north breakwater of 3.5 km length, involving about 85,000 m3 concreting. Concrete mix design using a combination of 30 percent of OPC 53 grade and 70 percent slag conforming to BS 6699 was used .The concrete requirements were 16 MPa and 35 MPa at 7 and 28 days respectively with workability of 0.86 compaction factor and good surface finish. Initial slump requirement was 120 mm and after 45 minutes, 80-mm slump was needed. Cera-Chem. Developing innovative admixtures Cera-Chem, was able to develop successfully Ceraplast 300 M an indigenous product to meet the concrete requirements at this project. Ceraplast 300M was put to test by conducting series of trials with different cements and slag sources. The evaluation process was a three-stage approach.

I Stage : Workability and setting time checks at low dosage.

II Stage : Strength development.

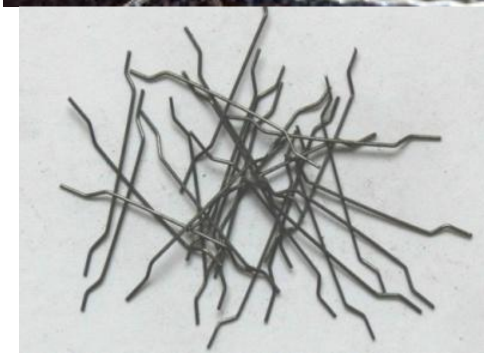
III Stage : Chemical analysis and long term durability studies.

Ceraplast 300 M is a new generation, high grade and superior performance retarding super plasticizer which has several advantages such as reduction in water-cement ratio of the order of 20-25 percent high early strength enabling early removal of form work increased ultimate strength high quality concrete of improved durability, reduction in heat of hydration even with very high strength cements easy pumpability compatibility with mineral admixtures improved water tightness and durability Ceraplast 300 M is available in 50, 100 and 210 liters packing.

STEEL FIBERS

Steel fiber-reinforced concrete (SFRC) is concrete (spray concrete) with steel fibers added. It has higher tensile strength than unreinforced concrete and is quicker to apply than weld mesh reinforcement. It has often been used for tunnels.

- Addition of steel fibers into the concrete improves the crack resistance (or ductility) capacity of the concrete. Traditional rebar's are generally used to improve the tensile strength of the concrete in a particular direction, whereas steel fibers are useful for multidirectional reinforcement. This is one of the reasons why steel fiber reinforced (shotcrete form) concrete successfully replaced weld mesh in lining tunnels.
- Less labour is required.
- Less construction time is required.

Crimped and Hooked Steel Fibers

GLASS FIBERS

Glass fiber reinforced concrete, also known as GFRC or GRC, is a type of fiber reinforced concrete. Glass fiber concretes are mainly used in exterior building façade panels and as architectural precast concrete. Somewhat similar materials are fiber cement siding and cement boards.

Glass Fiber

Table 2.8 Initial tests

Material test	Result
Specific gravity of cement	3.12
Specific gravity of fly ash	2.24
Specific gravity of silica fume	2.21
Specific gravity of coarse aggregate	2.74
Specific gravity of fine aggregate	2.7
Slump cone test	2 inches
Dry rod unit weight of fine aggregate	107.7 lb/ft^3
Dry rod unit weight of coarse aggregate	101 lb/ft^3
Initial and final setting time	96 min &207 min

Table 2.9 Mix Proportion

Cement	Fly Ash	Silica Fume	Fine Aggregate	Coarse Aggregate	Water	Super Plasticizer
1	0.28	0.28	1.38	2.38	0.23	0.01

III. RESULTS AND DISCUSSION

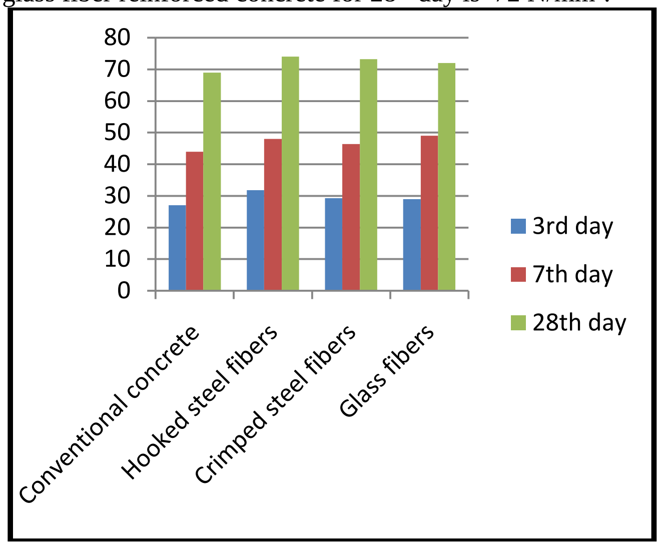
3.1 COMPRESSIVE STRENGTH

Table 3.1 Compressive strength results

Sl. no	cubes casted day	Conventional concrete (N/mm²)	Hooked end steel fiber (N/mm²)	Crimped steel fiber(N/mm²)	Glass fiber(N/mm²)
1	3rd day	27	31.75	29.3	29
2	7th day	44	48	46.4	49
3	28th day	69	74	73.2	72

In the above table 3.1 the compressive strength of conventional concrete for 3rd day is 27 N/mm^2 and compressive strength of conventional concrete for 7th day is 44 N/mm^2 and compressive strength of conventional concrete for 28th day is 69 N/mm^2 for M 70 grade concrete after adding hooked end steel fibers the compressive strength of hooked end steel fiber reinforced concrete for 3rd day is 31.75 N/mm^2 and the compressive strength of hooked end steel fiber reinforced concrete for7th day is 48 N/mm^2 and the compressive strength of hooked end steel fiber reinforced concrete for 28th day is 74 N/mm^2 likewise by adding crimped steel fibers the compressive strength of crimped steel fiber reinforced concrete for 3rd day is 29.3N/mm^2 and the compressive strength of crimped steel fiber reinforced concrete for7th day is 46.4 N/mm^2 and the compressive strength of crimped steel fiber reinforced concrete for 28th day is 73.2 N/mm^2 and by adding glass fibers the compressive strength of glass fiber reinforced concrete for 3rd day is 29N/mm^2.

The compressive strength of glass fiber reinforced concrete for 7th day is 49 N/mm^2 and the compressive strength of glass fiber reinforced concrete for 28th day is 72 N/mm^2.



Graph 3.1 Comparison of Compressive strength

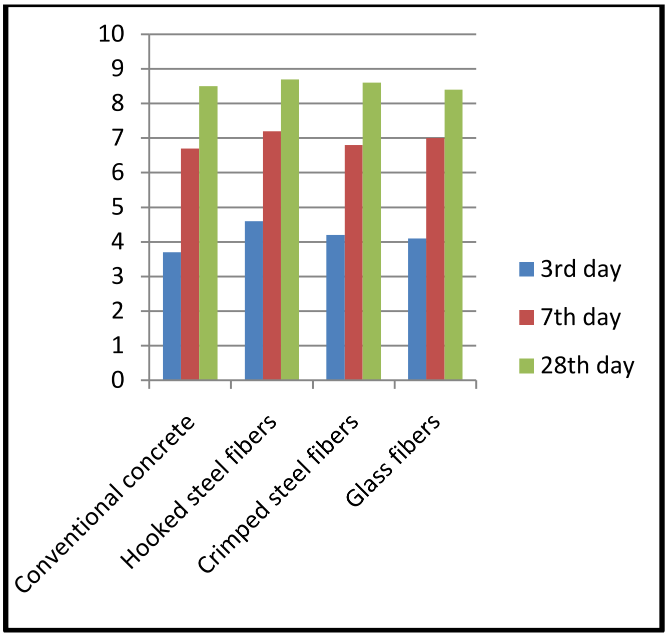
From the above graph 3.1 showing the results of comparison of compressive strength between conventional concrete cubes and hooked end steel fiber reinforced concrete cubes and conventional concrete cubes and crimped steel fiber reinforced concrete cubes and conventional concrete cubes and glass fiber reinforced concrete cubes. The increasing percentage of compressive strength of hooked end steel fiber reinforced concrete cubes when compared to the conventional concrete cubes at 3 days is 17.5%. The increasing percentage of compressive strength of hooked end steel fiber reinforced concrete cubes when compared to the conventional concrete cubes at 7 days is 9%. The increasing percentage of compressive strength of hooked end steel fiber reinforced concrete cubes when compared to the conventional concrete cubes at 28 days is 7.3%.And the increasing percentage of compressive strength of crimped steel fiber reinforced concrete cubes when compared to the conventional concrete cubes at 3 days is 8.5%. The increasing percentage of compressive strength of crimped steel fiber reinforced concrete cubes when compared to the conventional concrete cubes at 7 days is 5.45%. The increasing percentage of compressive strength of crimped steel fiber reinforced concrete cubes when compared to the conventional concrete cubes at 28 days is 6.08% and The increasing percentage of compressive strength of glass fiber reinforced concrete cubes when compared to the conventional concrete cubes at 3 days is 7.4%. The increasing percentage of compressive strength of glass fiber reinforced concrete cubes when compared to the conventional concrete cubes at 7 days is 11.36%. The increasing percentage of compressive strength of glass fiber reinforced concrete cubes when compared to the conventional concrete cubes at 28 days is 4.34%.

3.2 FLEXURE STRENGTH

Table 3.2 Flexure test results

Sl. no	Beams casted day	Conventional concrete	Hooked end steel fiber	Crimped steel fiber	Glass fiber
1	3rd day	3.7	4.6	4.2	4.1
2	7th day	6.7	7.2	6.8	7.0
3	28th day	8.4	8.7	8.6	8.5

In the above table 3.2 the flexural strength of conventional concrete for 3rd day is 3.7 N/mm^2 and flexural strength of conventional concrete for7th day is 6.7 N/mm^2 and flexural strength of conventional concrete for 28th day is 8.7 N/mm^2 for M 70 grade concrete after adding hooked end steel fibers the flexural strength of hooked end steel fiber reinforced concrete for 3rd day is 4.6 N/mm^2 and the flexural strength of hooked end steel fiber reinforced concrete for7th day is 7.2N/mm^2 and the flexural strength of hooked end steel fiber reinforced concrete for 28th day is 8.7 N/mm^2 likewise by adding crimped steel fibers the flexural strength of crimped steel fiber reinforced concrete for 3rd day is 4.2 N/mm^2 and the flexural strength of crimped steel fiber reinforced concrete for7th day is 6.8N/mm^2 and the flexural strength of crimped steel fiber reinforced concrete for 28th day is 8.6 N/mm^2 and by adding glass fibers the flexural strength of glass fiber reinforced concrete for 3rd day is 4.1N/mm^2 and the flexural strength of glass fiber reinforced concrete for7th day is 7.0 N/mm^2 and the flexural strength of glass fiber reinforced concrete for 28th day is 8.4 N/mm^2.



Graph 3.2 Comparison of Flexure Strength

From the above graph 3.2 showing the results of comparison of flexural strength between conventional concrete beams and hooked end steel fiber reinforced concrete beams and conventional concrete beams and crimped steel fiber reinforced concrete beams and conventional concrete beams and glass fiber reinforced concrete beams. The increasing percentage of flexural strength of hooked end steel fiber reinforced concrete beams when compared to the conventional concrete beams at 3 days is 24.3%. The increasing percentage of flexural strength of hooked end steel fiber reinforced concrete beams when compared to the conventional concrete beams at 7 days is 7.46%.

The increasing percentage of flexural strength of hooked end steel fiber reinforced concrete beams when compared to the conventional concrete beams at 28 days is 3.5%.And the increasing percentage of flexural strength of crimped steel fiber reinforced concrete beams when compared to the conventional concrete beams at 3 days is 13.5%. The increasing percentage of flexural strength of crimped steel fiber reinforced concrete beams when compared to the conventional concrete beams at 7 days is 1.49%.

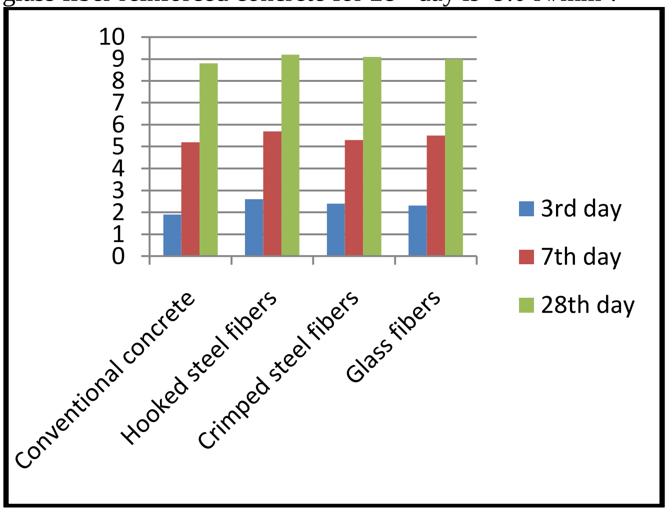
The increasing percentage of compressive strength of crimped steel fiber reinforced concrete beams when compared to the conventional concrete beams at 28 days is 2.38% and The increasing percentage of flexural strength of glass fiber reinforced concrete beams when compared to the conventional concrete beams at 3 days is 10.8%. The increasing percentage of flexural strength of glass fiber reinforced concrete beams when compared to the conventional concrete beams at 7 days is 4.4%. The increasing percentage of flexural strength of glass fiber reinforced concrete beams when compared to the conventional concrete beams at 28 days is 1.1%.

3.3 SPLIT TENSILE STRENGTH

Table 3.3 Split Tensile Strength results

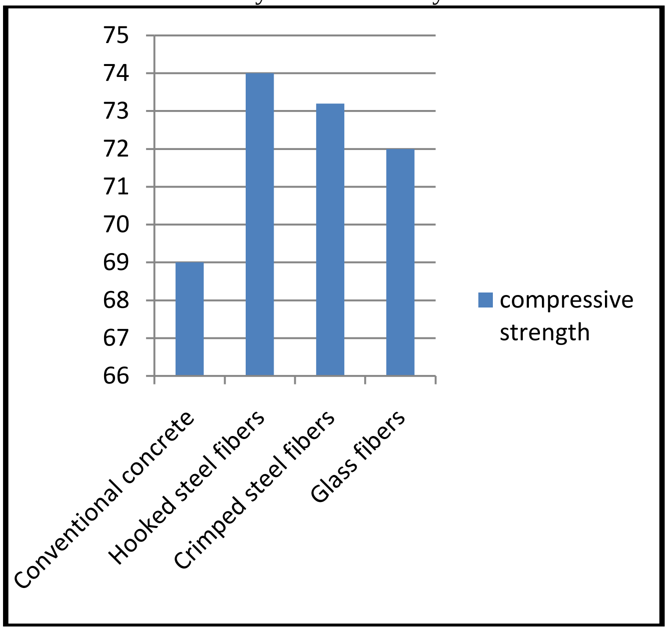
Sl. no	Cylinders casted day	Conventional concrete (N/mm^2)	Hooked end steel fiber (N/mm^2)	Crimped steel fiber (N/mm^2)	Glass fiber (N/mm^2)
1	3rd day	1.9	2.6	2.4	2.3
2	7th day	5.2	5.7	5.3	5.5
3	28th day	8.8	9.2	9.1	9.0

In the above table 3.3 the split tensile strength of conventional concrete for 3rd day is 1.9 N/mm^2 and split tensile strength of conventional concrete for7th day is 5.2N/mm^2 and split tensile strength of conventional concrete for 28th day is 8.8 N/mm^2 for M 70 grade concrete after adding hooked end steel fibers the split tensile strength of hooked end steel fiber reinforced concrete for 3rd day is 2.6 N/mm^2 and the split tensile strength of hooked end steel fiber reinforced concrete for7th day is 5.7N/mm^2 and the split tensile strength of hooked end steel fiber reinforced concrete for 28th day is 9.2 N/mm^2 like wise by adding crimped steel fibers the split tensile strength of crimped steel fiber reinforced concrete for 3rd day is 2.4 N/mm^2 and the split tensile strength of crimped steel fiber reinforced concrete for7th day is 5.3N/mm^2 and the split tensile strength of crimped steel fiber reinforced concrete for 28th day is 9.1 N/mm^2 and by adding glass fibers the split tensile strength of glass fiber reinforced concrete for 3rd day is 2.3N/mm^2 and the split tensile strength of glass fiber reinforced concrete for7th day is 5.5 N/mm^2 and the split tensile strength of glass fiber reinforced concrete for 28th day is 9.0 N/mm^2.



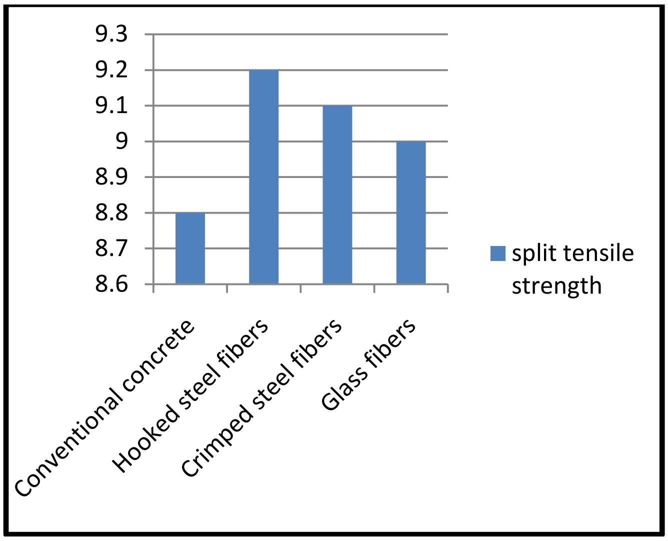
Graph 3.3 Comparison of split tensile strength results

From the above graph 3.3 showing the results of comparison of split tensile strength between conventional concrete cylinders and hooked end steel fiber reinforced concrete cylinders and conventional concrete cylinders and crimped steel fiber reinforced concrete cylinders and conventional concrete cylinders and glass fiber reinforced concrete cylinders. The increasing percentage of split tensile strength of hooked end steel fiber reinforced concrete cylinders when compared to the conventional concrete cylinders at 3 days is 36.8%. The increasing percentage of split tensile strength of hooked end steel fiber reinforced concrete cylinders when compared to the conventional concrete cylinders at 7 days is 9.61%. The increasing percentage of split tensile strength of hooked end steel fiber reinforced concrete cylinders when compared to the conventional concrete cylinders at 28 days is 4.54%.And the increasing percentage of split tensile strength of crimped steel fiber reinforced concrete cylinders when compared to the conventional concrete cylinders at 3 days is 26.3%. The increasing percentage of split tensile strength of crimped steel fiber reinforced concrete cylinders when compared to the conventional concrete cylinders at 7 days is 1.92%. The increasing percentage of split tensile strength of crimped steel fiber reinforced concrete cylinders when compared to the conventional concrete cylinders at 28 days is 3.40% and The increasing percentage of split tensile strength of glass fiber reinforced concrete cylinders when compared to the conventional concrete cylinders at 3 days is 21.05%. The increasing percentage of split tensile strength of glass fiber reinforced concrete cylinders when compared to the conventional concrete cylinders at 7 days is 5.76%. The increasing percentage of split tensile strength of glass fiber reinforced concrete cylinders when compared to the conventional concrete cylinders at 28 days is 2.27%.



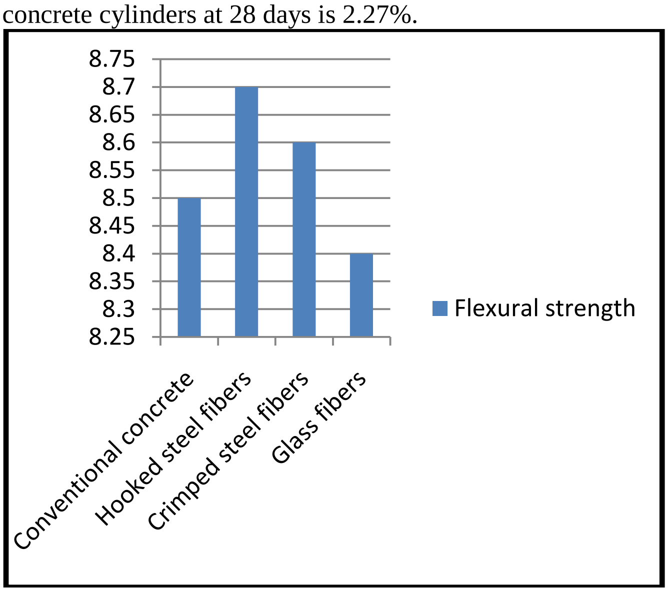
Graph 3.4 Comparison of compressive strength of different fiber reinforced concrete at 28 days

From the above graph 3.4 showing the results of comparison of compressive strength at 28 days between conventional concrete cubes and hooked end steel fiber reinforced concrete cubes and conventional concrete cubes and crimped steel fiber reinforced concrete cubes and conventional concrete cubes and glass fiber reinforced concrete cubes . The increasing percentage of compressive strength of hooked end steel fiber reinforced concrete cubes when compared to the conventional concrete cubes at 28 days is 7.3%.And the increasing percentage of compressive strength of crimped steel fiber reinforced concrete cubes when compared to the conventional concrete cubes at 28 days is 6.08%.And The increasing percentage of compressive strength of glass fiber reinforced concrete cubes when compared to the conventional concrete cubes at 28 days is 4.34%.



Graph 3.5 Comparison of split tensile strength of different fiber reinforced concrete at 28 days

From the above graph 4.5 showing the results of comparison of split tensile strength at 28 days between conventional concrete cylinders and hooked end steel fiber reinforced concrete cylinders and conventional concrete cylinders and crimped steel fiber reinforced concrete cylinders and conventional concrete cylinders and glass fiber reinforced concrete cylinders. The increasing percentage of split tensile strength of hooked end steel fiber reinforced concrete cylinders when compared to the conventional concrete cylinders at 28 days is 4.54%.And the increasing percentage of split tensile strength of crimped steel fiber reinforced concrete cylinders when compared to the conventional concrete cylinders at 28 days is 3.40%.And The increasing percentage of compressive strength of glass fiber reinforced concrete cylinders when compared to the conventional concrete cylinders at 28 days is 2.27%.



Graph 3.6 Comparison of Flexural strength of different fiber reinforced concrete at 28 days

From the above graph 3.6 showing the results of comparison of flexural strength at 28 days between conventional concrete beams and hooked end steel fiber reinforced concrete beams and conventional concrete beams and crimped steel fiber reinforced concrete beams and conventional concrete beams and glass fiber reinforced concrete beams. The increasing percentage of flexural strength of hooked end steel fiber reinforced concrete beams when compared to the conventional concrete beams at 28 days is 3.57%.And the increasing percentage of flexural strength of crimped steel fiber reinforced concrete beams when compared to the conventional concrete beams at 28 days is 2.380%.And The increasing percentage of flexural strength of glass fiber reinforced concrete beams when compared to the conventional concrete beams at 28 days is 2.140%.

IV. CONCLUSIONS

The present study is about using different fibers i.e., crimped steel fibers hooked steel fibers and glass fibers after optimizing them; comparison is made between the three fibers for different mechanical properties.

- The increasing percentage of compressive strength of hooked end steel fiber reinforced concrete cubes when compared to the conventional concrete cubes at 28 days is 7.3%.And the increasing percentage of compressive strength of crimped steel fiber reinforced concrete cubes when compared to the conventional concrete cubes at 28 days is 6.08%.And The increasing percentage of compressive strength of hooked end steel fiber reinforced concrete cubes when compared to the conventional concrete cubes at 28 days is 4.34%.
- The increasing percentage of split tensile strength of hooked end steel fiber reinforced concrete cylinders when compared to the conventional concrete cylinders at 28 days is 4.54%.And the increasing percentage of split tensile strength of crimped steel fiber reinforced concrete cylinders when compared to the conventional concrete cylinders at 28 days is 3.40%.And The increasing percentage of compressive strength of hooked end steel fiber reinforced concrete cylinders when compared to the conventional concrete cylinders at 28 days is 2.27%.
- The increasing percentage of flexural strength of hooked end steel fiber reinforced concrete beams when compared to the conventional concrete beams at 28 days is 3.57%.And the increasing percentage of flexural strength of crimped steel fiber reinforced concrete beams when compared to the conventional
- beams at 28 days is 2.380%.And The increasing percentage of flexural strength of glass fiber reinforced concrete beams when compared to the conventional concrete beams at 28 days is 2.140%.

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