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PERFORMANCE OF HYBRID FIBRE REINFORCEDCONCRETE

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Abstract— ***In the present study, the optimum dosage of fibres in Hybrid Fibre Reinforced Concrete (HFRC) and the compressive strength, split tensile strength, stress strain characteristics and flexural behaviour of Hybrid Fibre Reinforced Concrete (HFRC) with addition of glass fibre, polypropylene fibre and steel fibre was investigated. Cubes, Cylinders and beams were cast by adding fibres to cement by volume fraction at various percentages like steel fibre (0% ,0.4% ,0.8% ,1.2% ,1.6%) , glass fibres (0% ,0.2%, 0.4% ,0.6% ,0.8%) and polypropylene fibres (0% ,0.2%, 0.4% ,0.6% ,0.8%).Compression and Split tensile tests were done on cubes and cylinders respectively to obtain the optimum dosage of fibres, stress strain characteristics were found by testing the cylinders and flexural tests were conducted on beams to determine the flexural behaviour of Hybrid Fibre Reinforced Concrete.***
Keywords— Hybrid Fibre Reinforced Concrete (HFRC), steel fibre, glass fibres, polypropylene fibres, optimum dosage, compressive strength, split tensile strength, stress-stain behaviour, and flexural behaviour.

I. INTRODUCTION

Fibre-reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibres that are uniformly distributed and randomly oriented. Fibres include steel fibres, glass fibres, synthetic fibers and natural fibres – each of which lend varying properties to the concrete. In addition, the character of fibre-reinforced concrete changes with varying concretes, fibre materials, geometries, distribution, orientation, and densities

During last few years, several investigations has done on the behaviour of fibre reinforced concrete (FRC) structural elements subjected to various types of loading. Different types of fibres and their efficient techniques of mixing and placing of FRC have been reported. In addition to steel, glass and polypropylene fibres, natural fibres like sisal, coir and bamboo are also employed. FRC has been used in the production of different sizes of manhole covers, industrial floors and apron slab in airports.

Even though there are many advantages of FRC, it has also some limitations. It cannot be used where high impact, high vibration and high wear and tear is expected. Many problems have to be faced during construction of FRC, especially when quantity of fibre used is more. The fibres if put in bulk along with other ingredients do not disperse but next together. This phenomenon is called balling effect. The balling effect may be reduced to some effect by mixing the fibers and other ingredients in dry form and then adding water. The fibres placed in concrete, may block the discharge port. Since the flow of FRC is low, the FRC has to be placed near to the place where it is to be used finally.

A composite can be termed as hybrid, if two or more types of fibres are rationally combined in a common matrix to produce a composite that drives benefits from each of the individual's fibres and exhibits a synergetic response.

Addition of short discontinuous fibres plays an important role in the improvement of mechanical properties of Concrete. It increases elastic modulus; decreases brittleness controls cracks initiation and its subsequent growth and propagation. Deboning and pull out of the fibre require more energy absorption, resulting in a substantial increase in the toughness and fracture resistance of the materials to the cyclic and dynamic loads.

I. OBJECTIVE

The main objectives of this experimental work is to study the behavior of Hybrid Fibre Reinforced Concrete under flexural and impact loading conditions in which the reinforcement is between the Glass fiber, Hooked end Steel fiber, Polypropylene fiber. The different parameters considered under this experimental work are:

- To determine optimum dosage of fibres in Hybrid Fibre Reinforced Concrete (HFRC).
- To determine the compressive strength and split tensile strength of Hybrid Fibre Reinforced Concrete (HFRC).
- To study the Stress-Strain behaviour and flexural behaviour of Hybrid Fibre Reinforced Concrete (HFRC).

II. MATERIALS

A. Cement: Ordinary Portland cement of 53 grade confirming to IS:8112-1989 which was free from lumps and foreign matter is used. The properties of cement are shown in Table I

TABLE I
PROPERTIES OF CEMENT

Property	value
fineness	5 (%)
Specific gravity	3.15
consistency	31 (%)
initial setting	45 minutes

*B. Fine Aggregate:*The sand used was locally procured and confirmed to IS: 383-1970. The fine aggregates belonged to grading zone II. The properties of fine aggregate are shown in Table II

TABLE. II
PROPERTIES OF FINE AGGREGATE

Property	value
Bulking (%)	3
Porosity (%)	33.57
voids ratio	0.505
specific gravity	2.526
fineness modulus	3.05

C. Coarse Aggregate: Locally available coarse aggregate having the maximum size of 20 mm for core and 10 mm for cover was used. The properties of coarse aggregate are shown in Table III

TABLE.III
PROPERTIES OF COARSE AGGREGATES

Property	20mm aggregate	10mm aggregate
Bulk density	1.463	1.450
Porosity	50.44%	49.44%
Void Ratio	1.017	0.991
Specific Gravity	2.952	2.887

D. Water: Potable water which is free from impurities was used in the experimental work for both mixing and curing.

E. Glass Fibres: Alkali Resistant glass fibres were used throughout the experimental work. From the micro to the macro fibre range, these fibres control the cracking processes that can take place during the life span of concrete.

F. Steel Fibre: Steel fibres which are to be used are hooked end and possess length not more than 30mm.They are used for high ductility, improve impact resistant, fatigue endurance, hooks are provided to increase the bonding. They also provide uniform multi directional reinforcement. The properties of steel fibre are shown in Table V

Fig. 1 Alkali resistant Glass Fibre

Figure.2 Hooked End Steel Fibres

TABLE. IV
PROPERTIES OF GLASS FIBRES

Property	value
Diameter (μm)	13.5±2.0
Moisture content (%)	7.5±5.0
Strand length (mm)	6.0±2.0
Density (g/cm^3)	2.65
Tensile strength (Mpa)	1500-3700
Modulus of elasticity (Mpa)	72000
Ultimate strain (%)	2

TABLE. V
PROPERTIES OF STEEL FIBRE

Property	Value
Type	Hooked End
Diameter (D)	0.60mm
Length (L)	30mm
Aspect Ratio L/D	50
Young's Modulus	210
Tensile Strength	532

G. Macro Filament Polypropylene Fibre:

The polypropylene fibres (PPF) as shown in Figure 3 reduce early age shrinkage and moisture loss of the concrete mix even when low volume fractions of PPF are used. Macro Polypropylene fibre is used so that balling does not take place and they can be uniformly distributed.

Fig. 3Macro filament Polypropylene Fibre

TABLE VI
PROPERTIES OF MACRO POLYPROPYLENE FIBRE

Property	Value
Raw material	100% polypropylene
Type	Bamboo Shaped,Wave
Length (mm)	50
Diameter (mm)	1
Density	0.91 g/cm^3
Tensile strength	≥ 380 Mpa
Modulus of elasticity	5000 Mpa – 7600 Mpa
Melting point	170°c

III. EXPERIMENTAL INVESTIGATION

A. ***Mix Design***: Mix design was done for M30 grade of concrete. The water cement ratio of 0.45 is used. Mix Proportion of 1: 1.41 : 3.01 was obtained. The mix design was prepared based on the guidelines of IS: 10262(2009).

B. ***Casting and curing of specimens:*** Cubes and Cylinders were casted. The constituent materials are weigh batched. The specimens were cast in steel moulds.Standard cube of 150×150×150mm size, Standard cylinders of 300mm height and 150mm diameter size and Standard beams of size 600mm×100mm×150mm made of steel were used.The standards moulds were fitted such that there are no gaps between the plates of the moulds. If there are small gaps, they were filled with plaster of Paris. The moulds are then oiled and kept ready for casting.The wet mix is poured into the moulds in three layers with each layer being given 25 blows with a tamping rod. At the end of casting the top surface was made plane using trowel to ensure a top uniform surface.

C. ***Testing:*** The Compressive Strength and Split-Tensile strength tests were done on 100T Universal Testing Machine confirming to IS: 516-1959.

TEST RESULTS:

A. *Compressive Strength of cubes:*

TABLE VII AVERAGE COMPRESSIVE STRENGTH OF CUBES FOR 14 AND 28 DAYS

Fibres used (%)			Average compressive strength of cubes for 14 days (MPa)	Average compressive strength of cubes for 28 days (MPa)
Polypropylene	**Steel**			
0.2	0.4		38.54	42.40
0.4	0.8		39.58	43.55
0.6	1.2		45.45	50.00
0.8	1.6		44.43	48.88
Fibres used (%)			**Average compressive strength of cubes for 14 days (MPa)**	**Average compressive strength of cubes for 28 days (MPa)**
Glass	**Steel**			
0.2	0.4		42.61	46.88
0.4	0.8		45.04	49.55
0.6	1.2		39.99	44.00
0.8	1.6		45.45	50.00
Fibres used (%)			**Average compressive strength of cubes for 14 days (MPa)**	**Average compressive strength of cubes for 28 days (MPa)**
Glass	**Polypropylene**			
0.2	0.2		35.55	39.11
0.4	0.4		40.92	45.02
0.6	0.6		39.38	43.33
0.8	0.8		41.60	45.77
Fibres used (%)			**Average compressive strength of cubes for 14 days (MPa)**	**Average compressive strength of cubes for 28 days (MPa)**
Glass	**Steel**	**Polypropylene**		
0	0	0	39.18	43.11

B. *Split-Tensile Strength of Cylinders*

TABLE VIII AVERAGE SPLIT-TENSILE STRENGTH

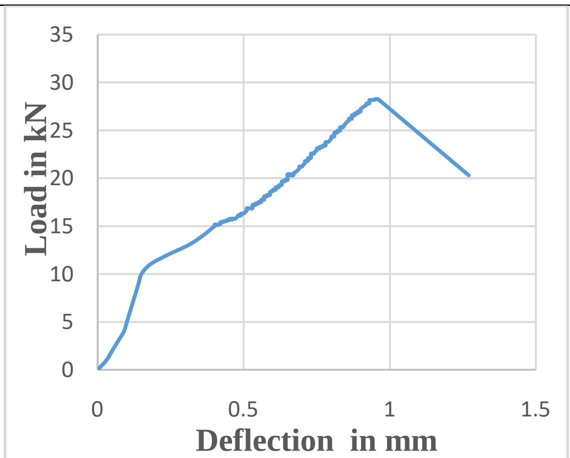
Fibres used (%)			Average Split-Tensile Strength of Cylinders for 28 days (MPa)
Glass	**Steel**	**Polypropylene**	
0	0	0	3.094

Fibres used (%)		Average Split-Tensile Strength of Cylinders for 28 days (MPa)
Polypropylene	**Steel**	
0.2	0.4	3.400
0.4	0.8	3.330
0.6	1.2	3.816
0.8	1.6	3.261
Fibres used (%)		**Average Split-Tensile Strength of Cylinders for 28 days (MPa)**
Glass	**Steel**	
0.2	0.4	3.192
0.4	0.8	3.400
0.6	1.2	3.747
0.8	1.6	3.677
Fibres used (%)		**Average Split-Tensile Strength of Cylinders for 28 days (MPa)**
Glass	**Polypropylene**	
0.2	0.2	3.538
0.4	0.4	4.024
0.6	0.6	3.885
0.8	0.8	3.400

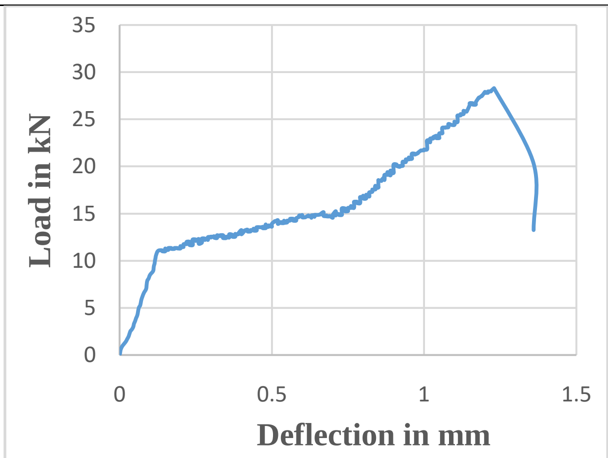
C. Flexural strength of beams

TABLE. IX FLEXURAL BEHAVIOR FOR 0.4% POLYPROPYLENE AND 0.8% STEEL COMPOSITIONS

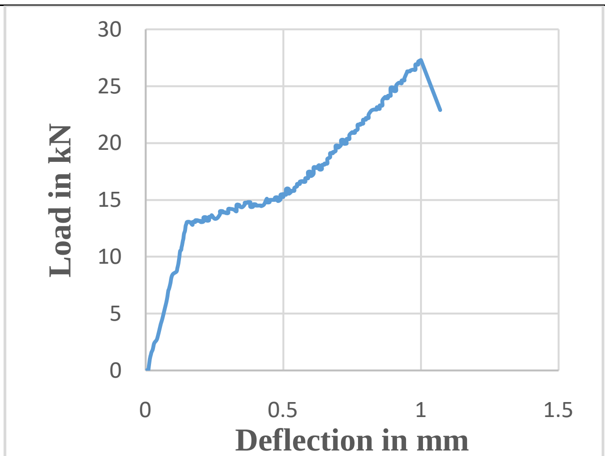
Fibres used (%)			**Flexural Strength (MPa)**	**Load at peak kN**	**Deflection at peak load mm**
Polypropylene	**Steel**		6.27	28.250	1.12
0.4	0.8				
0.6	1.2		6.288	28.30	1.35
0.8	1.6		6.06	27.300	1.82
Glass	**Steel**		5.94	26.750	0.91
0.6	1.2				
0.8	1.6		7.17	32.300	1.29
Polypropylene	**Glass**		6.67	30.050	1.21
0.6	0.6				
0.8	0.8		6.46	29.100	1.66
Polypropylene	**Glass**	**Steel**	5.85	26.350	0.72
0	0	0			



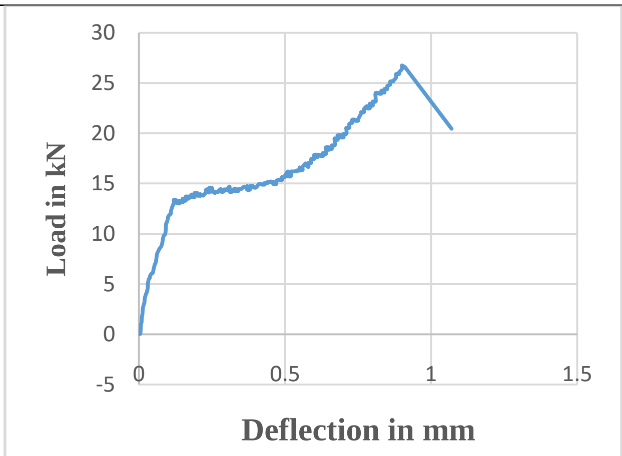
Graph.1. Load VS Deflection curve of HFRC cast with 0.4%Polypropylene and 0.8%Steel Fibre



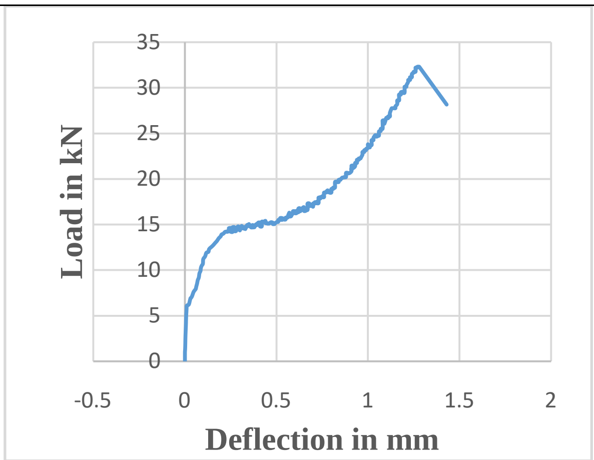
Graph.1. Load VS Deflection curve of HFRC cast with 0.6%Polypropylene fibre and 1.2 %Steel Fibre



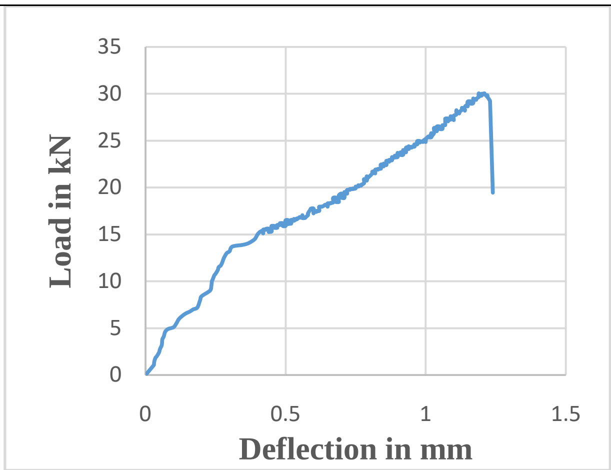
Graph.1. Load VS Deflection curve of HFRC cast with 0.8%Polypropylene and 1.6% Steel Fibre



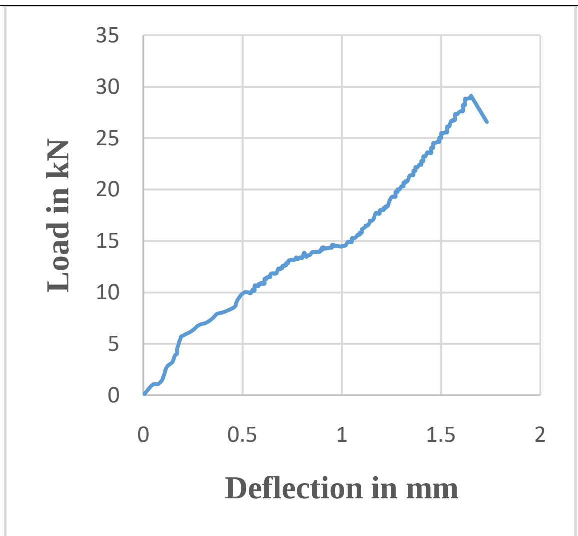
Graph.1. Load VS Deflection curve of HFRC cast with 0.6%Glass fibre and 1.2 % Steel Fibre



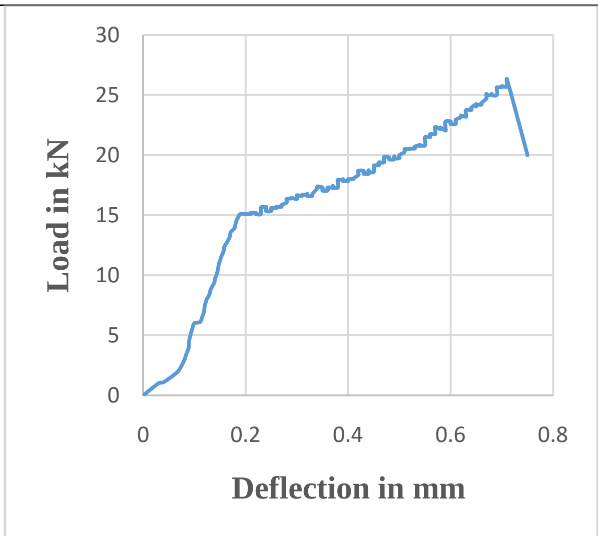
Graph.1. Load VS Deflection curve of HFRC cast with 0.8%Glass fibre and 1.6 % Steel Fibre



Graph.1. Load VS Deflection curve of HFRC cast with 0.6%Polypropylene fibre and 0.6 %Steel Fibre



Graph.1. Load VS Deflection curve of HFRC cast with 0.8%Polypropylene and 0.8%Glass Fibre



Graph.1. Load VS Deflection curve of HFRC cast with 0%Polypropylene, %Steel and 0%Glass Fibre

V. CONCLUSION

- By addition of 0.6% polypropylene fibre and 1.2% steel fibre the compressive strength was found to be 50 MPa which is 16% more than the compressive strength (43.11MPa) of conventional concrete.
- By addition of 0.8% glass fibre and 1.6% steel fibre the compressive strength was found to be 50 MPa which is 16% more than the compressive strength (43.11MPa) of conventional concrete.
- By addition of 0.8% polypropylene fibre and 0.8% glass fibre the compressive strength was found to be 45.77MPa whch is 7% more than the conventional concrete.
- The split tensile strength of conventional concrete for 28 days was found to be 3.09 MPa.
- By addition of 0.6% polypropylene fibre and 1.2% steel fibre the split tensile strength was found to be 3.816MPa which is 24% greater than the conventional concrete.
- By addition of 0.6% glass fibre and 1.2% steel fibre the split tensile strength was found to be 3.747 which is 21% greater than the conventional concrete.
- By addition of 0.4% polypropylene fibre and 0.4% glass fibre the split tensile strength was found to be 4.024 which is 30% greater than the conventional concrete.
- By addition of 0.6% polypropylene fibre and 1.2% steel fibre the flexural strength was found to be 6.288 MPa which is 8% greater than the flexural strength (5.85) conventional concrete.
- By addition of 0.8% glass fibre and 1.6% steel fibre the flexural strength was found to be 7.17 which is 23% greater than the flexural strength of conventional concrete.

- By addition of 0.6% polypropylene fibre and 0.6% glass fibre the flexural strength was found to be 6.67 which is 14% greater than the flexural strength of conventional concrete**.**
- Though there is a little increase in compressive strength by addition of fibers which is purely due to bonding and crack arresting nature of the fibers.
- Addition of polypropylene and glass fibers in HFRC can increase the tensile strength of concrete upto 30 % when compared to other combinations of Hybrid fibers.
- Addition of Glass fiber and steel fibers in HFRC showed a better flexural strength when compared with the other combinations of Hybrid Fibers.

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