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A BRIEF REVIEW ON HFRC USING STEEL AND POLYPROPYLENE FIBRE

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ABSTRACT:

Concrete is a composite material containing hydraulic cement, water, coarse aggregate and fine aggregate. Concrete is a brittle material which is strong in compression but very weak in tension. To increase the tensile strength of concrete normally steel is provided .However steel bars reinforce concrete against local tension only.

Cracks in reinforced concrete members extend freely. Thus need for multidirectional and closely spaced steel reinforcement arises that can not be practically possible. Fibre reinforcement gives the solution for this problem which provide multidirectional and closely spaced steel reinforcement. So to increase the tensile strength of concrete a technique of introduction of fibres in concrete is being used.

These fibres act as crack arrestors and prevent the propagation of the cracks. These fibres are uniformly distributed and randomly arranged named as fibre reinforced concrete. The addition of more than one type of fibre is called hybrid fibre reinforced concrete.

Keywords: Hybrid fibre reinforced concrete (HFRC), polypropylene**,** Fine aggregate, coarse aggregate, Fibre concentration, Fibre orientation, Fibre geometry.

I INTRODUCTION:

The use of fibres to increase the structural properties of construction material is not a new process. From ancient times fibres were being used in construction. In BC, horse hair was used to reinforce mortar. Egyptians used straw in mud bricks to provide additional strength. Asbestos

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was used in the concrete in the early 19th century, to protect it from formation of cracks. But in the late 19^{th} century, due to increased structural importance, introduction of steel reinforcement in concrete was made, by which the concept of fibre reinforced concrete was over looked for 5-6 decades. From 1960, there was a tremendous development in the FRC, mainly by the introduction of steel fibres. 1980's certified process was developed for the use of FRC.

Objectives of the research:

1. The objective of this research is to investigate and compare the compressive, flexural and tensile strength of concrete for various mixture proportion of concrete with the inclusion of polypropylene and steel fibres using M40 grade concrete.

2. Five hybrid fiber composites were cast using different fiber proportions of steel and polypropylene at a total volume fraction of 0.75%.

3. The experimental work was divided into six group. Each group consists of 6 cubes, 6 cylinder and 6 beam. Compressive strength, split tensile strength and flexural strength test were performed and results were extensively analyzed to identify performance synergy.

4. Developing Hybrid fiber reinforced concrete mixes which is suitable for structural applications.

5. Comparing the results and finding the optimum percentage of hybrid fibers.

6. The combination of different types of fibers to optimize the performance in the hardened state, with respect to strength has been studied in the present investigation.

Role of fibres in concrete-

1) Fibres are available in different sizes and shapes.
2) They can be classified into two basic categories, namely those having a higher elastic modulus than concrete matrix (called hard intrusion) and those with lower elastic modulus (called soft intrusion).
3) High modulus fibres improve both flexural and impact resistance ,where as low modulus fibres improve the impact resistance of concrete.
4) In contrast to reinforcing bars in concrete which are continuous and carefully placed in the structure to optimize their performance, the fibres are discontinuous and randomly distributed throughout the concrete matrix.

Gap area of study-

1. Most of the researchers have investigated the properties of hybrid fibre reinforced concrete, by adding quantity of fibres in fixed percentage, they have not compared the result by changing the proportion of

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quantity of different fibre within the same volume fraction. And no research work was done on hybrid fibre reinforced concrete using steel and polypropylene fibre with total fibre volume fraction of 0.75%.

2. In this investigation, the strength properties of hybrid fibre reinforced concrete is determined by using steel and polypropylene fibres with total volume of fibre fraction of 0.75%. And the results were analyzed to determine the optimum combination of fibre which gives better performance in terms of strength.

Materials Used:

Ingredents of Fibre Reinforced Concrete-

- Cement
- Aggregates
- Fibres
- Water

Fibres:

- Fibre is discrete material having some characteristic properties. The fibre material can be anything. But not all will be effective and economical. Some fibres that are most commonly used are:-

1. Steel
2. Glass
3. Carbon
4. Natural
5. Synthetic

Steel:- Steel fibre is one of the most commonly used fibre. Generally round fibres are used. The diameter may vary from 0.25 to 0.75mm. Use of steel fibres makes significant improvements in flexure, impact and fatigue strength of concrete.

Glass:- Glass fibre is a recently introduced fibre in making fibre concrete. It has very high tensile strength of 1020 to 4080Mpa. Glass fibre concretes are mainly used in exterior building façade panels and as architectural precast concrete.

Natural:- Natural fibres are low cost and abundant. They are nonhazardous and renewable. Some of the natural fibres are bamboo, jute, coconut husk, elephant grass.

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Polypropylene:- Polypropylene fibres (synthetic fibre) are produced as continuous mono-filaments, with circular cross section that can be chopped to required lengths, or fibrillated films or tapes of rectangular cross section.

Properties of Fibre Reinforced Concrete-

Properties of concrete is affected by many factors like properties of cement, fine aggregate, coarse aggregate. Other than this, the fibre reinforced concrete is affected by following factors:

1) Type of Fibre:- A good fibre is which has Good adhesion within the matrix, Compatibility with the binder, which should not be attacked or destroyed in the long term.
2) Aspect Ratio:- Aspect ratio is defined as the ratio of length to width of the fibre.The value of aspect ratio varies from 30 to 150. Generally the increase in aspect ratio increases the strength and toughness till the aspect ratio of 100. Above that the strength of concrete decreases, in view of decreased workability and reduced compaction. Keeping that in view we have considered fibres with aspect ratio of 80.
3) Fibre Quality:- Generally quantity of fibres is measured as percentage of cement content. As the volume of fibres increase, there should be increase in strength and toughness of concrete.
4) Orientation of Fibre:- The orientations of fibres play a key role in determining the capacity of concrete. In RCC the reinforcements are placed in desired direction. But in FRC, the fibres will be oriented in random direction. The FRC will have maximum resistance when fibres are oriented parallel to the load applied.

Experimental Investigation:

In order to determine the strength characteristics of HFRC using steel and polypropylene fibres in different proportions, compressive strength tests, split tensile strength tests, and flexural strength tests were carried out for M40 grade concrete using total volume of fibre fraction of 0.75%. In total 108 no. of tests specimen were cast (36 cubes for compressive strength test, 36 beams for flexural strength test and 36 cylinder for tensile strength test).

The experimental work was divided into six group. Each group consists of 6 cubes (150 mm x 150 mm x 150 mm), 6 cylinder (300 mm x 150 mm dia.) and 6 beam (500 mm x 100 mm x 100 mm).

a) First group consists of control (plain) concrete using 0% volume of fibres.
b) Second group consists of 0% steel fibre and 100% polypropylene fibre out of total volume of fibre.
c) Third group consists of 25% steel fibre and 75% polypropylene fibre out of total volume of fibre.
d) Forth group consists of 50% fibre each of steel and polypropylene fibre out of total volume of fibre.
e) Fifth group consists of 75% steel fibre and 25% polypropylene fibre out of total volume of fibre.
f) Sixth group consists of 100% steel fibre and 0% polypropylene fibre out of total volume of fibre.

Tests results were find out for 28 and 56 days curing.

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The following materials were used in the experimental work are :

- Cement
- Fine aggregates
- Coarse aggregates
- Super plastisizer
- Fibres

Steel fibres :- Continously crimped Steel fibres with an aspect ratio of 80 were used.

Polypropylene Fibres: Fibrillated fibers were used.

Mix propotion :- Mix design has been adopted from IS 10262:2009 to design for M40 grade of concrete. The mix ratio used for study is 1:1.81:2.91. Steel and Polypropylene fibres were added to concrete specimen at a volume fraction of 0.75%.

Various test performed:-

1) Compressive Strength Test –

Compressive strength test is initial step of testing concrete because the concrete is primarily meant to withstand compressive stresses. Compressive strength tests were carried out on 150 mm x 150 mm x 150 mm cubes with compression testing machine of 2000 KN capacity. The specimens after removal from the curing were cleaned and properly dried. The surface of the testing machine was cleaned. The cube was then placed with the cast faces in the contact with the platens of the testing machine. Cubes were tested at 28 and 56 days of curing. In each category, three cubes were tested and their average value is reported.

2) Split Tensile Strength Test-

The split tensile test are well known indirect tests used for determining the tensile strength of concrete, sometimes referred to as the splitting tensile strength of concrete. The test consists of applying compressive line load along the opposite generators of a concrete cylinder placed with its axis horizontal between the platens. Cylinders were tested at 28 and 56 days of curing. In each category, three cylinders were tested and their average value is reported.

3) Flexural Strength Test-

Flexural strength test is essential to estimate the load at which the concrete members may crack. The specimens cast for this test were of shape of a square prism of side 100 mm and axis length of 500 mm. Specimens were tested at 28 and 56 days of casting for strength analysis. Flexural Strength test was conducted as per the guidelines given in IS 516:1959.

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Results and Discussions:

1. **Table-1 Compressive Strength (28 days)**

MIX	Fibre mix proportion by volume (%)		Fibre vol. fraction (%)	28 DAYS COMPRESSIVE STRENGTH (MPa) CUBE COMPRESSSION				
	SF	PPF		B1	B2	B3	Average	%age Increase
M1	0	0	0	39.8	40.5	40.2	40.1	0
M2	0	100	0.75	36.0	35.5	35.7	35.7	-10
M3	25	75	0.75	37.8	39.5	39.9	39.0	-2.7
M4	50	50	0.75	45.6	46.3	44.7	45.5	13
M5	75	25	0.75	47.7	49.6	45.2	47.5	18.4
M6	100	0	0.75	41.3	44.8	41.6	42.5	6

1.1 Table 2 Compressive Strength (56 days)-

MIX	Fibre mix proportion by volume (%)		Fibre vol. fraction (%)	56 DAYS COMPRESSIVE STRENGTH (MPa) CUBE COMPRESSSION				
	SF	PPF		B1	B2	B3	Average	%age Increase
M1	0	0	0	43.8	44.5	44.2	44.1	0
M2	0	100	0.75	39.2	39.7	38.1	39.0	-11.5
M3	25	75	0.75	41.7	43.5	43.3	42.8	-2.9
M4	50	50	0.75	49.8	50.3	49.7	49.9	13.1
M5	75	25	0.75	51.7	53.6	51.3	52.2	18.3
M6	100	0	0.75	45.3	49.9	46.7	47.3	7.2

2. **Table 3 Split tensile Strength (28 days**

MIX	Fibre mix Proportion by volume (%)		Fibre vol. fraction (%)	28 DAYS SPLIT TENSILE STRENGTH (MPa)				
	SF	PPF		B1	B2	B3	Average	%age Increase
M1	0	0	0	4.2	4.6	4.2	4.3	0
M2	0	100	0.75	4.9	5.3	5.1	5.1	18.6
M3	25	75	0.75	6.1	6.8	6.5	6.4	48.8
M4	50	50	0.75	7.9	8.8	8.4	8.3	93.0
M5	75	25	0.75	10.3	9.8	9.7	9.9	130
M6	100	0	0.75	11.3	10.9	11.5	11.2	160

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2.1 Table 4 Split tensile Strength (56 days)

MIX	Fibre mix proportion by volume (%)		Fibre vol. fraction (%)	56 DAYS SPLIT TENSILE STRENGTH (MPa)				
	SF	PPF		B1	B2	B3	Average	%age Increase
M1	0	0	0	4.6	4.7	4.5	4.6	0
M2	0	100	0.75	5.6	5.8	5.7	5.7	23.9
M3	25	75	0.75	7.3	6.9	7.1	7.1	54.3
M4	50	50	0.75	9.0	9.4	8.9	9.1	97.8
M5	75	25	0.75	10.3	10.7	10.8	10.6	130
M6	100	0	0.75	11.9	11.8	12.2	11.9	158

3. Table 5 Flexural Strength (28 days)

MIX	Fibre mix proportion by volume (%)		Fibre vol. fraction (%)	28 DAYS FLEXURAL STRENGTH (MPa)				
	SF	PPF		B1	B2	B3	Average	%age increase
M1	0	0	0	4.3	4.2	4.9	4.4	0
M2	0	100	0.75	3.4	3.5	4.3	3.7	-15.9
M3	25	75	0.75	6.1	6.0	5.8	5.9	34
M4	50	50	0.75	6.6	6.3	6.4	6.4	45.4
M5	75	25	0.75	7.5	7.3	7.6	7.4	68.1
M6	100	0	0.75	5.5	5.4	6.5	5.8	31.8

3.1 Table 6 Flexural Strength (56 days)

MIX	Fibre mix Proportion by volume (%)		Fibre vol. fraction (%)	56 DAYS FLEXURAL STRENGTH (MPa)				
	SF	PPF		B1	B2	B3	Average	%age increase
M1	0	0	0	5.1	4.8	5.4	5.1	0
M2	0	100	0.75	4.1	4.4	5.1	4.5	-11.7
M3	25	75	0.75	6.9	7.1	6.7	6.9	35.2
M4	50	50	0.75	7.2	7.4	7.5	7.3	43.1
M5	75	25	0.75	8.3	8.5	8.8	8.5	66.6
M6	100	0	0.75	6.4	6.7	7.1	6.7	31.3

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Discussions:

Steel Fibre is used because:-

1. It improves structural strength.
2. It Reduces steel reinforcement requirements
3. It Improves ductility.
4. It reduces crack widths and control the crack widths tightly , thus improve durability.
5. It improves impact and abrasion resistance .
6. It improve freeze- thaw resistance.

Polypropylene Fibre is used because:-

1. It improve mix cohension , improving pumpability over long distances.
2. It improves freeze –thaw resistance.
3. It improves resistance to explosive spalling in case of severe fire.
4. It improves impact resistance.
5. It increases resistance to plastic shrinkage during curing.

II.CONCLUSIONS:

1. The maximum compressive strength reaches in the HFRC at 75% steel fibres and 25% polypropylene fibres because of the high elastic modulus of steel fibre and the low elastic modulus of polypropylene fibre work in perfect combination.
2. The spilt tensile strength of fibre percentage with 100% steel fibre shows maximum increase in strength. Improved tensile strength can be achieved by increasing the percentage of steel fibres.
3. The flexural strength of HFRC containing the volume fraction of 75% steel fibres and 25% polypropylene fibres is higher than the other fiber composition. It was observed that, under axial loads, cracks occur in microstructure of concrete and fibres limit the formation and growth of cracks.

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