Experimental Investigation on Mechanical Properties of Hybrid Fibres in M25 Grade Concrete

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Abstract - Hybrid Fibre Reinforced Concrete (HFRC) is a concrete in which two or more than two different types of fibers are rationally combined to produce a cementitious composite that improves the overall properties of concrete. Concrete is considered a brittle material, mainly because of its low tensile strain capacity and poor fracture toughness. Concrete can be modified to perform in a more ductile form by the addition of randomly distributed discrete fibres in the concrete matrix .In this investigation mechanical properties of Hybrid Fiber Reinforced Concrete (HFRC) is determined by using steel (ST) fibres and recycled polyethylene terephthalate (RPET) fibres . The M25 grade of concrete was designed as per the codal provisions of IS 10262:2009 . The effect of addition of mono fibres and hybrid fibres on the mechanical properties of concrete mixture is studied . Steel fibres and Recycled PET fibres were added individually as mono fibres and then they were added together as hybrid fibres into the concrete mix . Mechanical properties such as compressive strength, Split tensile strength , Flexural Strength and impact strength of the specimens were found out for various mix proportions of Hybrid Fibre Reinforced Concrete RPET.75-ST0.25, RPET0.5-ST0.5 and RPET0.5-ST0.75 for a fibre volume fraction of 1% and the results are compared with the control mix .

keywords - Hybrid fibre reinforced concrete , Recycled polyethylene terephthalate(RPET) fibre , Steel fibre, Compressive strength, Split tensile strength , Flexural Strength and impact strength .

I. INTRODUCTION

Concrete is the most popular material used in the construction industry. Plain cement concrete has some drawbacks such as limited ductility, low tensile strength, high brittleness, poor toughness and little resistance to cracking. The addition of fibres into the concrete mix is used to address this issue. The main reasons for adding fibres to concrete matrix is to improve the postcracking response of the concrete, i.e., to improve its energy absorption capacity and apparent ductility, and also to provide crack resistance and crack control. Also, it helps to maintain structural integrity and cohesiveness in the material .In the recent days a lot of non-biodegradable plastic wastes are being dumped into the environment which causes various pollution problems . Most PET bottles used as beverage containers becomes waste after their usage, causing environmental problems. To address this issue, a method to recycle wasted PET bottles is presented, in which short fibres made from recycled PET are used within structural concrete. The fibres used are Recycled Polyethylene Terephthalate and crimped steel fibres. The base polyethylene Terephthalate is highly resistant to the majority of aggressive agents and will never oxidize when exposed to the conditions which cause steel to rust. This paper is used to investigate the addition of hybrid fibres into the concrete mix with 1% fibre volume fraction and compare the results with mono fibres and control mix on the mechanical properties .

II .EXPERIMENTAL PROGRAM

A. MATERIALS

The material used for this experimental work are cement, fine aggregate, coarse aggregate , steel fibres , Recycled PET fibres, water and superplasticizer. The properties of materials used in concrete mixes are as given below,

1.CEMENT

Ordinary Portland Cement is a higher strength cement to meet the needs of the consumer for higher strength concrete. Ordinary Portland Cement of grade 53 confirming to IS : 12269-1987 is used in this experimental work .

Table 1: Properties Of Cement

S.No.	Description	Result
1	Specific gravity	3.15
2	Fineness	8.9
3	Surface area(m^2/kg)	250
4	Consistency (%)	31
5	Initial setting time	33 min
6	Final setting time	220 min

2.FINE AGGREGATE

Clean and dry locally available river sand passing through IS 4.75 mm sieve and confirming to zone II as per IS: 383:1970 is used for all the specimens.

3.COARSE AGGREGATE

Broken granite stone passing through 20 mm sieve and retained on 10 mm sieve satisfying gradation in table 2 of IS 383-1970 was used as coarse aggregate .The properties of aggregates are listed below in table :2 .

Table :2 Properties Of Aggregate

Description	Fine Aggregate	Coarse Aggregate
Specific gravity	2.67	2.72
Water Absorption	0.5 %	0.31 %
Fineness modulus	2.36	7.1
Moisture content	Nil	Nil

4.WATER

Ordinary potable water of good quality is used in this experimental study .

5.SUPER PLASTICIZER

To impart additional workability a superplasticizer named Glenium (B233) at a dosage of 1 % by weight of cement is used. It is based on modified polycarboxylic ether as per I.S: 9103-1999. GLENIUM B233 is free of chloride & low alkali and is compatible with all types of cements

6. STEEL FIBRES

There are different kinds of steel fibres as straight, hooked end, crimped , paddled, deformed type etc .. In this study Crimped steel fibres with aspect ratio 60 is used.

7. RECYCLED PET FIBRE

Recycled polyethylene terephthalate fibre with aspect ratio 1900 is used in this study .The properties of fibres used is shown table below ,

Table 3: Properties Of Fibres

S. NO	Description	Steel Fibre	RPET Fibre
1	Length (mm)	30	38
2	Diameter (mm)	0.5	0.02
3	Aspect ratio	60	1900
4	Tensile strength (MPa)	1200	670
5	Density (Kg/m^3)	7850	1300

Figure 1: Steel fibre and Recycled PET fibre

B.MIX DESIGN

The concrete mix design for M25 grade is obtained as per IS : 10262-2009 by using the properties of materials listed above .The proportions and the quantities of various materials for the concrete mix is shown in Table 4.

Table 4: Quantities of materials

Material	Quantity(Kg/m^3)	Mix Ratio
Cement	402.75	1
Fine aggregate	677.44	1.68
Coarse aggregate	1130.5	2.81
Water	181.24	0.45
Super plasticizer	4.0275	0.01

Table 5: Different Proportions Of Fibres Used

Mix	Fibre by % Of Volume	% Contribution Of Steel And RPET
CONTROL MIX	0	0-0
RPET -100	1	0-100
STEEL-100	1	100-0

ST75-RPET25	1	75-25
ST50-RPET50	1	50-50
ST25-RPET75	1	25-75

C. TESTS CONDUCTED

1. WORKABILITY

The workability of the fresh concrete mix is determined by carring out slump cone test .The test is conducted as per IS:1199-1999.

2.COMPRESSIVE STRENGTH

Compressive strength of concrete is one of the most important properties of concrete. 18 cube moulds of size 150 mm x 150 mm x 150 mm were cast and allowed for 28 days of curing .The cubes were tested on compression testing machine as per IS: 516-1959 .

3.SPLIT TENSILE STRENGTH

It is the well known indirect test conducted to determine the tensile strength of concrete. 18 Cylinder specimens of length 300 mm and diameter 150 mm were cast , cured for 28 days and tested . The tests were conducted as per IS :5816-1999.

4.FLEXURAL STRENGTH

Concrete prisms of 18 numbers with dimension 500 mm x 150 mm x 150 mm were cast and demoulded after 24 hours of casting .It is cured for 28 days and tested for flexural strength under two point loading as per IS:516-1959.

5.IMPACT STRENGTH

Impact strength of concrete is used to evaluate the impact resistance and percentage of energy absorption of concrete under impact kind of loadings. The test is conducted by drop hammer test as per ACI 544 method .

III . RESULTS AND DISCUSSIONS

In this present study the results of workability, compressive strength, split tensile strength, flexural strength and impact strength of M25 grade of concrete under different combinations of fibres is done and the results are compared with the control mix which is presented in the table and graph below.

1. SLUMP CONE TEST

Slump is a measure indicating the consistency or workability of fresh mix of concrete . A concrete is said to be workable if it is easily mixed , placed , compacted and finished .The results of slump cone test is shown in table 6 and the variation of slump is shown in figure 2 .

Table 6: Slump Test

Specimen	Slump (mm)
CONTROL MIX	97
RPET FIBRE 1%	83
STEEL FIBRE 1%	72

RPET 0.75 + ST 0.25	80
RPET 0.5 + ST 0.5	84
RPET 0.25 + ST 0.75	90

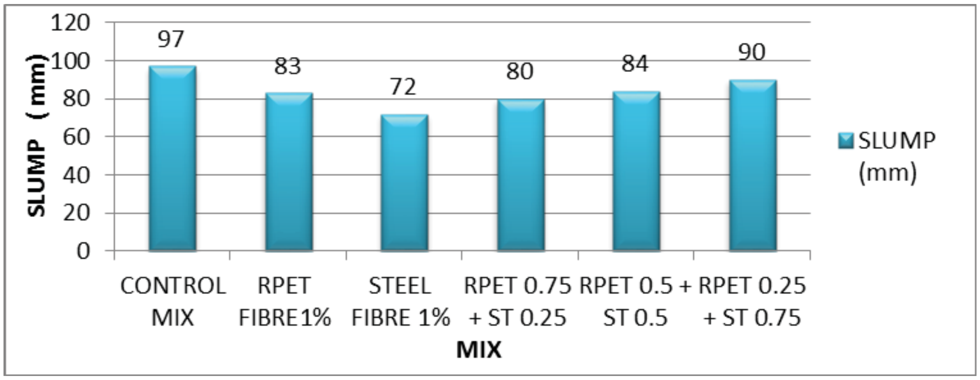

Figure 2: Slump value

From the graph it is clear that slump decreases by addition of fibres to the concrete mix . Maximum workability is observed for control mix that has 97 mm slump and it is also nearer to the mix RPET 0.25 + ST 0.75 which has 90 mm slump and minimum workability is observed for the mix STEEL FIBRE 1% . Super plasticizer is added to improve the workability of concrete .

The test results of compressive strength, split tensile strength, flexural strength and impact strength under different fibre combinations are presented in Table 7.

Table 7: Comparison On Mechanical Properties Of Concrete Specimens

Mix	Compressive Strength (N/mm^2)	Split tensile strength (N/mm^2)	Flexural Strength (N/mm^2)	Impact strength	
				Impact resistance (%)	Energy absorption (Joules)
CONTROL MIX	32.8	2.85	32.8	2.85	1942.38
RPET FIBRE1%	34.5	3.08	34.5	3.08	2494.19
STEEL FIBRE 1%	36.4	3.38	36.4	3.38	3023.9
RPET 0.75 +ST0.25	36.9	3.98	36.9	3.98	3112.22
RPET 0.5 + ST 0.5	40.2	4.20	40.2	4.20	3597.82
RPET 0.25+ ST0.75	44.3	4.85	44.3	4.85	4922.17

2. COMPRESSIVE STRENGTH

The results of compressive strength at 28 days of curing is given in table 7.The maximum compressive strength is obtained for mix RPET 0.25 + ST 0.75 which is much greater than the control mix and the mix of mono fibres .

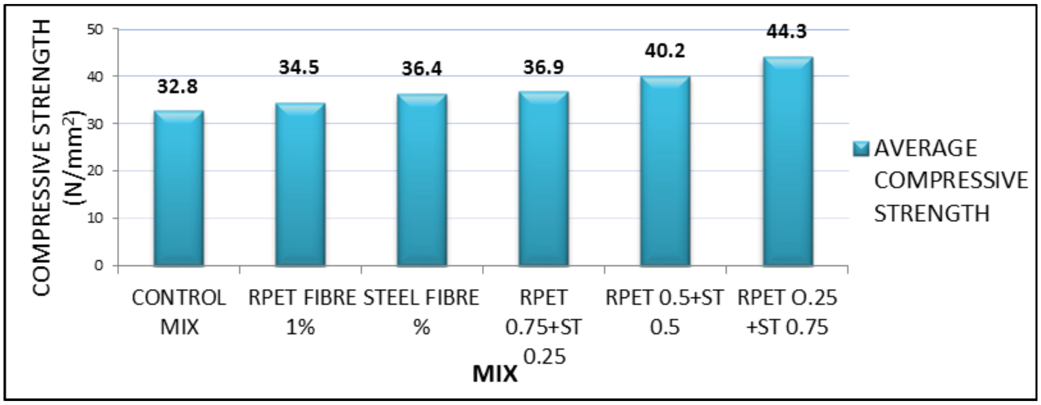

Figure 3: Compressive strength at 28 days .

From the figure, it is clear that the compressive strength made by the mono fibres is 5.2% (RPET- 1%) and 11 % (steel -1%) greater than the control mix . It is observed that the compressive strength of all hybrid fibre reinforced concrete mixes is greater that the control mix and the mono fibre mixes and the hybrid mix RPET 0.25 + ST 0.75 attains a strength which is 35 % higher than the control mix. It is observed that compressive strength of all hybrid fibre reinforced concrete mixes is much more than compressive strength of control mix (without fibre). Compressive strength is directly influenced by steel fibre and increases by increasing quantity of steel fibres. Because of high strength, stiffness and modulus of elasticity of steel fibre , metallic fibers (steel) are more capable of arresting the macro cracks hence provide ductility to the concrete.

3. SPLIT TENSILE STRENGH

The results of split tensile strength at 28 days of curing is given in table-7 and the results are plotted in the figure-4.

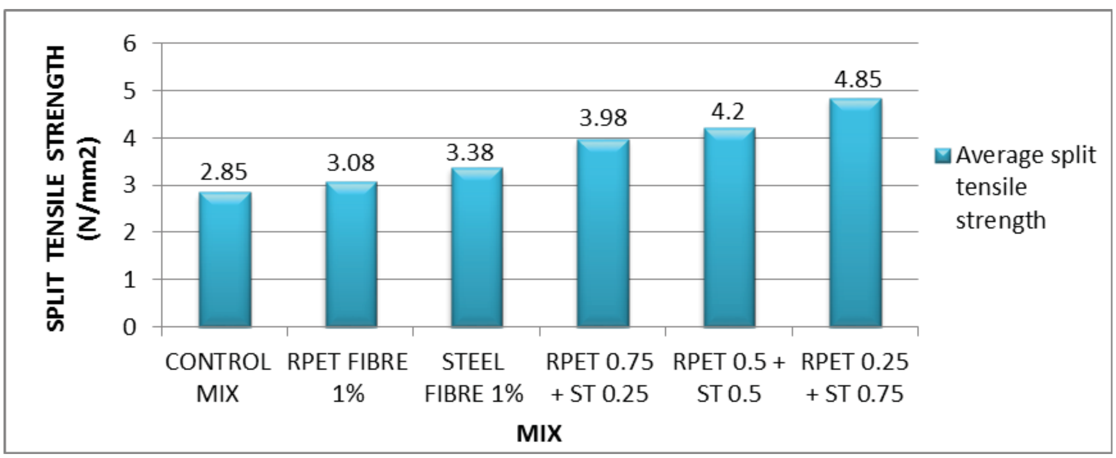

Figure 4 - Split tensile strength at 28 days .

From the figure it is clear that the maximum split tensile strength is obtained for the mix RPET 0.25 + ST 0.75 which is 70.2% greater than the control mix . This is mainly because of steel fibres that has higher modulus of elasticity making the concrete more ductile . When first crack occurred, the RPET Fibre restricts the growth of crack. When stress continuously damages the specimen, bridging effect of RPET fibres would gradually transfer to the steel fibres making the concrete more resistant to the stress, further increasing the split tensile strength. Hybrid fibres thus improves the split tensile strength noticeably as compared to mono fibres .

4. FLEXURAL STRENGTH

The results of flexural strength at 28 days is given in table-7 . The maximum Flexural strength is obtained for mix RPET 0.25 + ST 0.75 . Figure-5 gives the variation of Flexural strength with different fibre proportions .

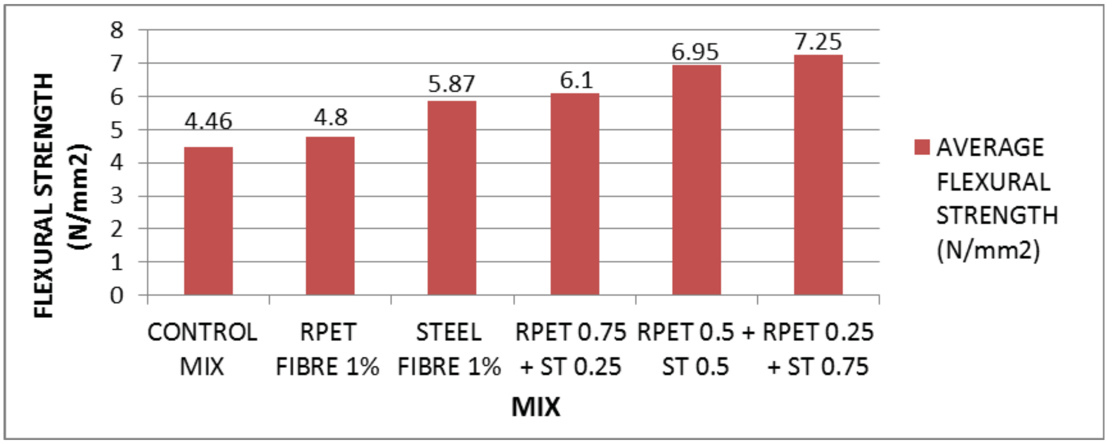

Figure 5: Flexural strength at 28 days

The flexural strength of mono fibres i.e, the mix STEEL fibre 1% and RPET fibre 1% has flexural strength 31.6% and 7.6% higher than the conventional mix. For HFRC the flexural strength is much greater than the control mix and mono fibres .Hybridization keeps improving the flexural strength as compared to the mono fibres . The modulus of rupture of steel fibers is more as compare to RPET fibers. Therefore steel fibers are effective to arrest the macro cracks and undergo ductile failure while RPET fibers are only effective to arrest the micro cracks and undergoes brittle failure. Therefore Steel-RPET combination also shows better performance during flexural strength test.

5. IMPACT STRENGTH

Impact strength of fibre reinforced concrete is an important parameter to be studied because the addition of fibre to the concrete finds major application in the pavements.The results of impact strength is shown in the table 7.

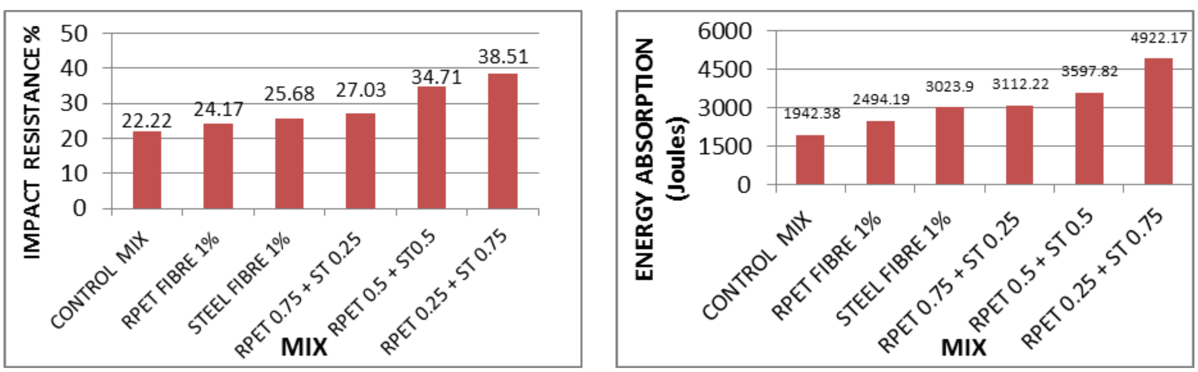

Figure 6: Percentage impact resistance and Energy absorption

Figure shows the Percentage impact resistance and Energy absorption of the impact specimen . From the test results it is evident that the Percentage impact resistance and Energy absorption is much higher for the Hybrid mix i.e., RPET 0.25 + ST 0.75 when compared to the control mix and mono fibres .

IV. CONCLUSION

From the experimental study the following conclusions are drawn ,

1. It is evident from the present investigation that the hybridization of fibres proved to be better when compared to mono fibres .
2. The maximum compressive strength reaches in the HFRC RPET 0.25 + ST 0.75 ,i.e., (25 % Recycled PET fibre and 75 % steel fibres) which is 35.06 % higher than the control mix and 28.4% and 3.34 % greater

than the mono fibre reinforced concrete i.e., (RPET FRC and STEEL FRC) . This is because of the high elastic modulus of steel fibre and the low elastic modulus of Recycled PET fibre work in perfect combination .

3. For split tensile strength the maximum strength is obtained for the mix RPET 0.25 + ST 0.75 which has strength 70.17 % greater than the control mix and 57.46% and 43.5 % greater than the mono fibre reinforced concrete .
4. Flexural strength of hybrid fibre combination RPET 0.25 + ST 0.75 is found to be maximum which is 62.55 % greater than the control mix and 51.04% and 23.51% greater than the mono fibre reinforced concrete .
5. The impact strength of the hybridized concrete mix is much superior than the control mix and the percentage impact resistance was found to be maximum for the mix RPET 0.25 + ST 0.75 that is 73.31% greater than the control mix and 59.33 % and 50 % greater than the mono fibre reinforced concrete .

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