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Robustness Study of Hybrid Fiber Reinforced Concrete with Steel and Synthetic Fiber

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Abstract: Hybrid Fiber Reinforced Concrete (HFRC) is an optimized combination of two or more types of fibres in the same concrete mixture that can produce a composite with better engineering properties than that of individual fibres. This paper evaluates the strength of hybrid fibre reinforced concrete with a combination of steel and Polyester fibre. Mix design for M40 concrete was adopted and hybrid fibres were added at a volume fraction of 0.5%. Control specimen and three hybrid fiber composites were cast using various fiber proportions of steel and polyester. Mechanical properties such as Compressive strength, split tensile strength and flexural strength test at 7days, 14 days and 28 days were experimented and results were investigated to associate with above fiber combinations. Based on experimental studies, the paper identifies fiber combinations that exhibit maximum compressive, split tensile and flexural strength of concrete.

Keywords: *Hybrid fibres, Mechanical properties, Polyester fibre, Steel fibre, Volume fraction*

1. Introduction

Concrete is a relatively brittle material. Addition of fibers to concrete makes it more homogeneous and isotropic and transforms it from a brittle to a more ductile material. In Fibre Reinforced Concrete (FRC), fibres can be effective in arresting cracks at both macro and micro levels. For an optimal response, different type of fibres may be suitably combined to produce Hybrid Fiber Reinforced Concrete (HFRC).

The basic purpose of using hybrid fibres is to control cracks at different size levels, in different zones of concrete (cement paste or interface zone between paste and aggregate), at different curing ages and at different loading stages. This hybridization is combining fibres with different shapes, dimensions, tensile strength and young's modulus to concrete matrices. The large and strong fibres control large cracks. The small and soft fibres control crack initiation and propagation of small cracks.

This research work focuses on the steel polyester hybrid fibre reinforced system. In this system, steel fibre, which is stronger and stiffer, improves the first crack strength and ultimate strength, while the polyester fibre, which is more flexible and ductile, leads to improved toughness and strain capacity in the post cracking zone. Hence this study explores the feasibility of hybrid fiber reinforcement with a given grade of concrete at a volume fraction of 0.5%

2. Materials Used

In this experimental study cement, fine aggregate, coarse aggregate, steel fibres, polyester fibres were used.

2.1 Cement

Portland Pozzolona Cement of 53 grade was used in this experimentation conforming to IS:12269 : 1987.

Table 1: *Properties of cement*

Property	Values
Fineness Of Cement	7.5%
Grade Of Cement	53
Specific Gravity	3.15
Initial Setting time	28 min
Final Setting Time	600 min

Coarse aggregates: Locally available, aggregate passing through 20 mm sieve and retained on 12.5 mm sieve and as given in IS: 383 – 1970 is used for all the specimens.

Table 2: *Properties of coarse aggregate*

Property	Values
Specific Gravity	2.60
Size of Aggregates	20 mm

Sand: Clean and dry river sand available locally was used. Sand passing through IS 4.75 mm sieve and as per IS: 383:1970 was used for all the specimens.

Table 3: *Properties of sand*

Property	Values
Specific Gravity	2.64
Fineness Modulus	2. 79

Water: Potable water was used for the experimentation available in the college premises. Chemical Admixture Type: Super Plasticizer (ConPlast SP430) Steel Fibers: Continuously crimped Steel fibers with an aspect ratio of 80 were used.

***Table 4**: Properties of steel fiber*

Specification	Values
Length(mm)	40
Diameter(mm)	0.5
Aspect ratio	80
Specific gravity	7.48

Polyester Fibers: Recron 3S fibers were used.

***Table 5:** Properties of polyester fiber*

Specification	Values
Length(mm)	12.5
Diameter(mm)	0.05
Aspect Ratio	240
Specific Gravity	1.36

Mix Proportion

Mix design has been adopted from IS 10262:2009 to design for M40 grade of concrete. [Insert Table 6]

***Table 6:** Quantities of materials used*

Materials	By weight	By proportion
Cement	395 kg/m^3	1
Fine aggregate	715.28 kg/m^3	1.81
Coarse aggregate	1150 kg/m^3	2.91
Water	158 kg/m^3	0.4
Super plasticizer	7.9 kg/m^3	0.02

No fibers were added in control mix specimen whereas Steel and Polyester fibers were added to other concrete specimen at a volume fraction of 0.5%. Steel fibers were added by the volume of concrete and polyester fibers were added by the weight of cement.

***Table 7:** Different proportions of fibers used*

Mix	Steel fibers by volume of concrete (%)	Polyester fibers by weight of cement (%)
CM	-	-
S0.25PE0.75	25	75
S0.5PE0.5	50	50
S0.75PE0.25	75	25

Experimental Methodology

Compression strength test

For compressive strength test, cube specimens of dimensions 150 mm x 150 mm x 150 mm were casted for M_{40} grade of concrete. The moulds were filled with hybrid fibre concrete.

After 24 hours the specimens were demoulded and were transferred to curing tank wherein they were allowed to cure for 28 days. These specimens were tested in compression testing machine. The load was applied as per IS 516-1964. Compression testing machine having 2000kN is used for loading.

In each category, three cubes were tested and their average value is reported by using following formulae.

Compressive strength = Load / Area (MPa)

Split tensile strength test

For tensile strength test, cylinder specimens of dimension 150 mm diameter and 300 mm length were cast. The specimens were demoulded after 24 hours of casting and were transferred to curing tank wherein they were allowed to cure for 28 days. These specimens were tested under compression testing machine. In each category, three cylinders were tested and their average value is reported. Tensile strength was calculated as follows as split tensile strength.

Tensile strength (MPa) = $2P / \pi DL$
Where P = failure load,
D = diameter of cylinder,
L = length of cylinder.

Flexural strength test

The flexural strength of concrete prism was determined based on IS: 516 –1959.Beam specimens of size 100 mm x 100 mm x 500 mm were casted. The samples were demoulded after 24 h from casting and kept in a water tank for 28 days curing. The specimens were placed in UTM and tested for flexural strength.

Experimental results

Results of Compressive strength, split tensile strength and flexural strength for M_{40} grade of concrete on specimen with 0% HFRC, HFRC SO.25PE0.75, HFRC SO.5PE0.5 and HFRC SO.75PE0.25 at 7days, 14 days and 28 days are shown in table and graph.

***Table 8** Compressive strength test result*

MIX	Average Compressive Strength (MPa)		
	7 Days	14 Days	28 Days
CM	32.35	36.23	43.41
S0.25PE0.75	38.53	45.79	54.98
S0.5PE0.5	39.86	47.53	57.72
S0.75PE0.25	41.85	50.23	60.35

***Table 9** Split tensile strength test result*

MIX	AVERAGE FLEXURAL STRENGTH(MPa)		
	7 Days	14 Days	28 Days
CM	6.47	7.24	8.68
S0.25PE0.75	9.63	11.44	13.74
S0.5PE0.5	9.96	11.88	14.43
S0.75PE0.25	10.46	12.55	15.1

***Table 10** Flexural strength test result*

MIX	Average Split Tensile Strength(MPa)		
	7 Days	14 Days	28 Days
CM	4.85	5.43	6.51
S0.25PE0.75	6.16	7.32	8.24
S0.5PE0.5	6.37	8.1	10.37
S0.75PE0.25	7.5	9.04	12.43

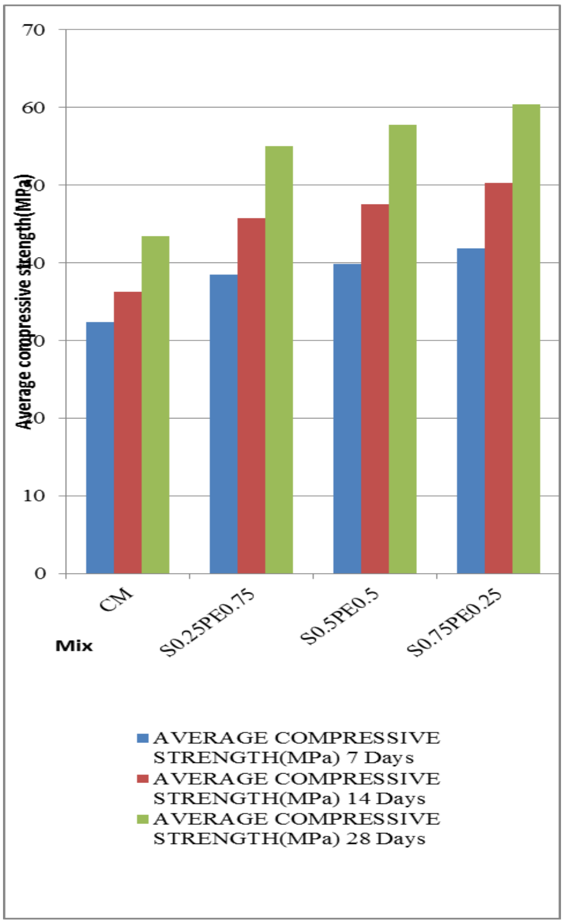

***Figure 1** Compressive strength test result*

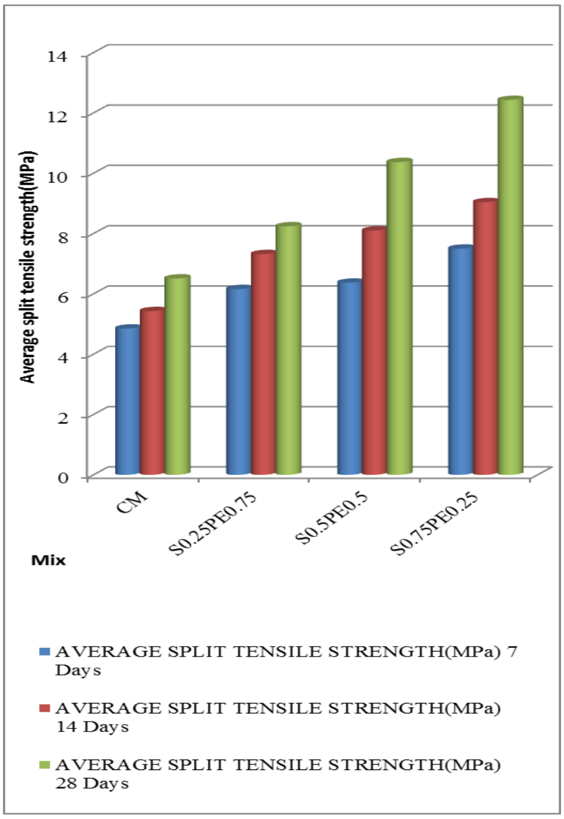

***Figure 2** Split tensile strength test result*

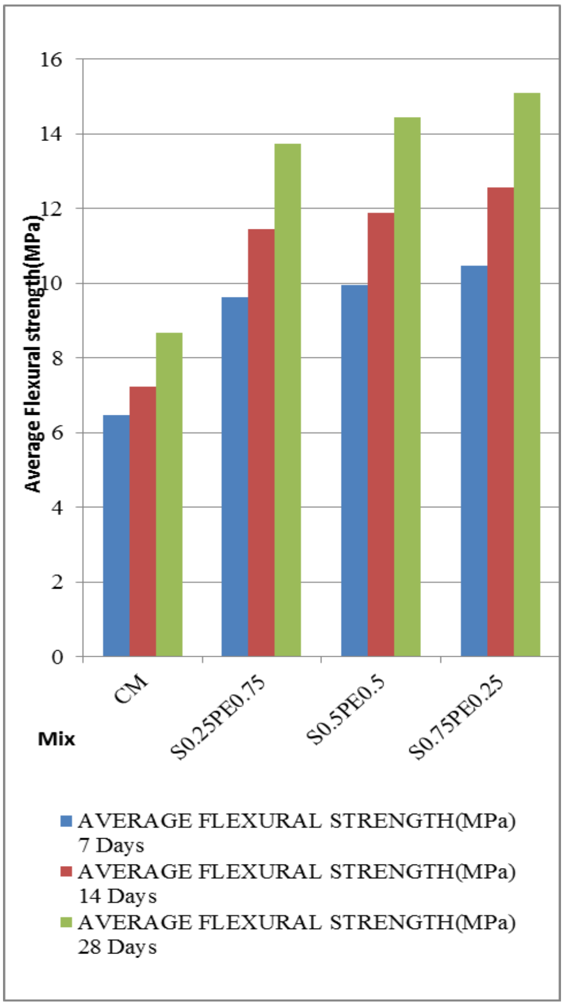

***Figure 3** Flexural strength test result*

- The maximum compressive strength reaches in the HFRC S0.75PE0.25, i.e., 75% steel fibers and 25% polyester fibers because of the high elastic modulus of steel fiber and the low elastic modulus of polyester fiber work in perfect combination.
- The spilt tensile strength of fiber percentage with S0.75PE0.25 shows slight increase in strength. The higher number of fibres bridging the diametral ‘splitting’ crack, the higher would be the spilt tensile strength.
- The flexural strength of HFRC containing the volume fraction of 75% steel fibers and 25% polyester fibers is higher than the other HFRC.
- It can be observed that, under axial loads, cracks occur in microstructure of concrete and fibres limit the formation and growth of cracks.

Conclusion

- The utmost compressive strength was attained in the HFRC S0.75PE0.25, i.e., 75% steel fibers and 25% polyester fibers.
- Fiber combination with S0.75PE0.25 showed better split tensile strength results than other combinations.

Concrete specimens with combination of steel 75% and polyester 25% exhibited maximum flexural strength compared to specimens with combination of S0.25PE0.75 and S0.5PE0.5

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