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Evaluation Of Mechanical Properties For Polypropylene And Steel Fibre Reinforced Concrete

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ABSTRACT

The objective of this research is to investigate and compare the compressive and flexural strength of concrete for various mixture proportion of concrete. Fiber reinforced concrete is a most widely used solution for improving tensile and flexural strength of concrete. Various types of fibers such as steel, polypropylene, glass and polyester are generally used in concrete. In this research, the effect of inclusion of polypropylene and steel fibers on the compressive and flexure properties of fiber reinforced concrete was studied. Polypropylene and Steel fibers with different levels of reinforcement index were investigated with pre-designed concrete mixtures consisting of various polypropylene fibers dosages of 0% to 0.45 % and steel fibers of 0% to 2% by volume of concrete. The experimental test results demonstrated that addition of polypropylene and steel fibers at 0.15% and 1% Vf respectively showed considerable gain of strength of 47.10 MPa and 58.20 MPa at 7 and 28 days respectively. The behavior of concrete under flexural loads was found to be consistently improved compared with reference mix design (M1).

Keywords:- Polypropylene fiber, Steel fiber, Compressive strength, Flexural strength, Concrete, Fiber reinforced concrete.

1. INTRODUCTION

The inclusion of various types of fibers to improve or modify the mechanical properties of Portland cement concrete (PCC) results in hence called fiber reinforced concrete (FRC). The reinforcing fibers are randomly distributed in the PCC matrix. Improvement in the mechanical properties of concrete like flexural, compressive strength, ductility, toughness can be attributed to the presence of fiber in concrete matrix. The types of commonly used fibers are steel, glass, polymeric, carbon, asbestos, and natural fibers. The polymeric fiber viz. polypropylene, polyethylene, polyester, acrylic, and aramid fibers are becoming popular these days. With nominal lengths of 6, 12 or 18 mm, polypropylene fiber is the ideal solution for concrete mixtures susceptible to plastic shrinkage, cracking and crazing. The fibers do not replace the steel reinforcement bars or the normal procedures for correct setting of the concrete. It is very often possible to replace meshes by the fibers.

Steel fibers are been used in concrete since the early 1900s. Initially the fibers were round and smooth like a wire cut or chopped to the required length. Straight, smooth fibers are rarely used now and modern modified fibers have rough surfaces and hooked ends. Commercially available steel fibers are manufactured from drawn steel wire, from sheet steel or by the melt-extraction process which produces fibers that have a curve-shaped cross section.

[1] concluded that Polypropylene fibers dose not evenly disperse in the mixing water. Inclusion of fibers to dry mix was found to be more patent. The failure mode of conventional concrete is mainly due to spalling, while the failure mode of fiber reinforced concrete is bulging in transverse direction.[2-3] studied the flexural behavior of LFC exposed to high temperatures with different PF percentages in range of 0.1 to 0.5% of mix volume and showed improved results.[4] investigated in their work that inclusion of polypropylene fiber greatly improves fracture toughness, decrease crack length and maximum mid-span deflection of the three-point bending beam specimens of concrete composite containing 15% fly ash and 6% silica fume.[5] demonstrated that addition of the polypropylene resulted in reduced workability and mix slump. Effect of polypropylene was more pronounced in tension than compression due to the adhesive and friction forces between concrete and Polypropylene fibers. [6] Concluded that the overall total shrinkage strain of concrete increases slowly but consistently with increase in volume of PP added. The increment in shrinkage is notable in concretes without any water curing (exposed at 1-day). In concretes with 7-days moist curing, the shrinkage differences are not significant.[7-8] concluded in their research studies that the compressive strength and flexural strength at first crack of fiber reinforced fly ash concrete cubes and deep beams respectively increase marginally as the fiber content is varied from 0% to 0.5% and 1%.[9] reported concrete to be workable with use of hooked fibers up to 1.5 percent Balling effect is

encountered when the percentages of added fibers are high .[10] concluded that the superiority of RC beams containing polypropylene fibers over those without polypropylene fibers in terms of increased ultimate residual strengths

2.0 Experimental Investigations

2.1 Cement

Ordinary Portland cement of 53 grade of 28 days compressive strength of 48.7 MPa, satisfying the requirements of IS: 12269–1987. The specific gravity of cement was found to be 3.16.

Table 1.

S.No.	Test	Value
1	Consistency	31%
2	Initial setting time	159 minutes
3	Final setting time	480 minutes
4	Specific Gravity	3.16
5	Fineness	2%
6	Soundness	2 mm
7	Compressive Strength 7 day 28 day	 26.53 N/mm^2 48.70 N/mm^2

2.2 Fine aggregates

The sand generally collected from the River bed,sand is the main component of the concrete that material passing through 4.75mm IS sieve, that is grading zone-II of IS: 383-1978 was used with fineness modulus of 2.57,specific gravity of 2.65 and water absorption of 0.70 % at 24 hours.

2.3 Coarse aggregates

Mechanically crushed granite stone with 12.5 mm maximum size, satisfying to IS: 383-1978 was used. The specific gravity was found to be 2.82, fineness modulus of 7.32 and water absorption is 0.59 % at 24 hours.

2.4 Chemical admixture

Polycarboxylate ether based super-plasticizer condensate as HRWR admixture was used and specific gravity of 1.18.

2.5 Polypropylene fibers

Crimped polypropylene fibres imported from Korea was used in the present study and the various properties of the material are given in **Table 2** and the snap shot of the fibre is given in **Figure 1.**

Table 2.

Material	Polypropylene
Appearance	Crimped white fiber
Relative Density	0.91
Length	45 mm

l/d ratio	90
Thickness	0. mm
Width	1.1 mm
Tensile strength	450 MPa
Failure strain	15%

Figure 1.

2.6 Steel fibers

The undulated/hooked in nature – 0.6 mm in diameter and 36 mm length with an aspect ratio of 60 were used in this research work. **Table 3** shows the properties of crimped steel fibers and the snap shot of the fiber is given in **Figure 2**.

Table 3.

Fiber Type	Steel
Length	36 mm
Equivalent Diameter	0.6 mm
Tensile Strength	1100 Mpa
Dosage	20-40 kg/m3

Figure 2.

2.6 Conceptual Concrete Mixture Proportions and Casting of specimens

The concrete mixture proportions used in the study are provided in **Table 4**. A total of 12 different concrete mixtures were proportioned based on the water to cement ratio (w/c) 0.35 and fine to coarse aggregate ratio (F/C) 0.6. The concrete mixtures were mixed using a 30 liters capacity of container with tilting drum type mixer and specimens were casted using steel mould, the standard cube 100 X 100 X 100 mm moulds and size of beam mould 100 X 100 X 500**.** The fresh concrete mixtures in moulds were compacted using table vibrator and the sspecimens were demoulded after 24 hours after casting and water cured at 27 ± 3^{o}C until the age of testing at 7 and 28 days.

Table 4. (MIX PROPORTIONS)

Mix Id	Cement	Fine Aggregate	Coarse Aggregate	Water	F/C	w/b	Polypropylene Fiber (%)	Steel Fiber (%)
	Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3				
M1	455	621	1035	160	0.6	0.35	0	0
M2	455	621	1035	160	0.6	0.35	0.15	0
M3	455	621	1035	160	0.6	0.35	0.3	0
M4	455	621	1035	160	0.6	0.35	0.45	0
M5	455	621	1035	160	0.6	0.35	0	1
M6	455	621	1035	160	0.6	0.35	0.15	1
M7	455	621	1035	160	0.6	0.35	0.3	1
M8	455	621	1035	160	0.6	0.35	0.45	1
M9	455	621	1035	160	0.6	0.35	0	2
M10	455	621	1035	160	0.6	0.35	0.15	2
M11	455	621	1035	160	0.6	0.35	0.3	2
M12	455	621	1035	160	0.6	0.35	0.45	2

3.0 EXPERIMENTAL TEST RESULTS AND DISCUSSIONS

3.1 Effect of Polypropylene and Steel fibers

The test results for various mixes (M1 to M12) on cube specimens at the ages of 3,7 and 28 days in the compression testing machine is given in **Table 5** and shown graphically in **Figure 3,4 and 5**. The average compressive strength achieved at 3,7 days and 28 days for reference mix is 31.5MPa,43.1MPa and 46.7 MPa and an addition of polypropylene and steel fibers showed an improvement up to 37MPa at 3 Days,47.1 MPa at 7 days and 58.2 MPa. However, with the higher dosage of PP fibers i.e. for mixes M4, M8 and M12 showed a slight reduction in the compressive strength compared to reference concrete. The test results for various mixes (M1 to M12) on beam specimens at the ages of 7 and 28 days in the flexural testing machine is given in **Table 6** and shown graphically in **Figure 6 and 7**. It was observed that flexure strength of 3.21 MPa at 7 days and 5.25 MPa at 28 days was seen for reference concrete; whereas with the fiber addition at 0.45% V_f of pp and 1% steel showed the strength was around 5.63 MPa at 7 days and 9.22 MPa at 28 days. The test results on the flexural strength showed a similar trend that upto 0.3% of fiber volume the enhancement of flexural properties was noticed. PP Fiber addition beyond the optimum fiber volume of 0.3% V_f resulted in decreasing trend. Also, the failure strain of PP fibers (15%) had shown a good improvement in the post cracking of concrete and results in high toughness. In this investigation, optimum percentage of fiber addition contributed for the strength enhancement of concrete which leads to the improvement on the hardened properties of concrete.

Table 5. (Compressive Strength (MPa))

Mix ID	3 DAY	7 DAY	28 DAY
M1	31.5	43.1	46.7
M2	33.1	45.5	49.9
M3	30	39.4	44.5
M4	29.4	37	43.1
M5	33	45.2	51
M6	37	47.1	58.2
M7	36.7	46.4	51.6
M8	33.3	40.9	48.9
M9	32.1	45	54.5
M10	37.6	43.6	57.8
M11	34.9	44.3	51.4
M12	30.5	42.9	48.2

Figure 3.

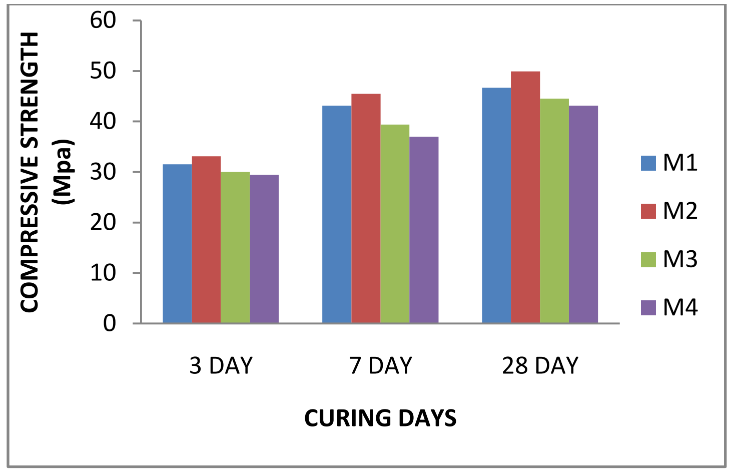

Figure 4.

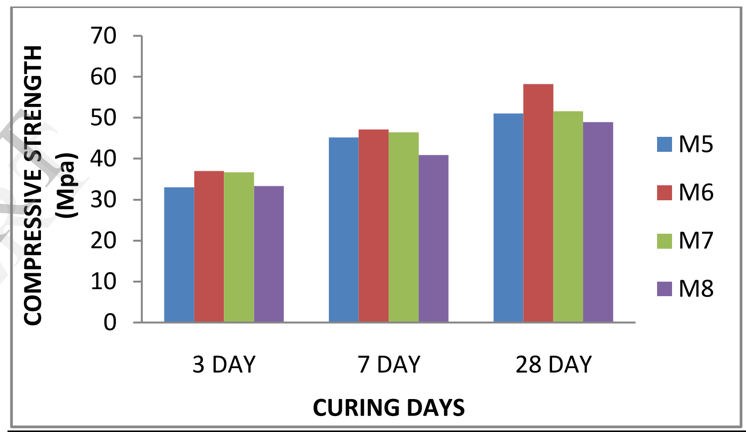

Figure 5.

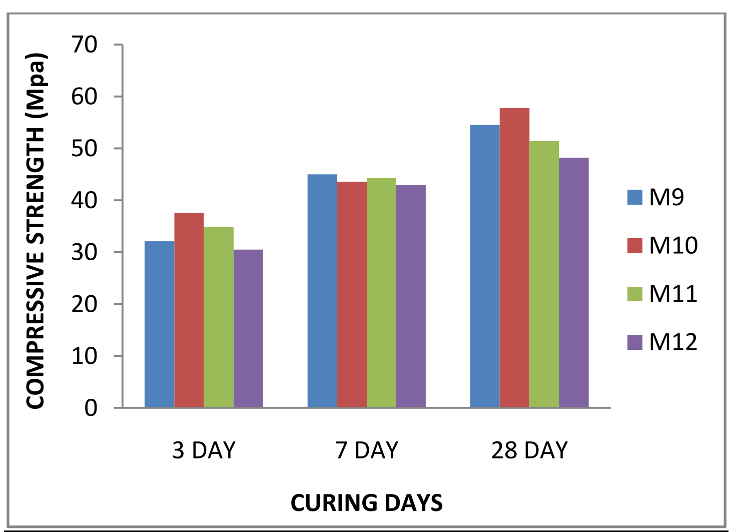

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Table 6.(Flexural Strength (MPa))

Mix ID	7 DAY	28 DAY
M1	3.21	5.25
M2	3.90	5.94
M3	4.32	6.91
M4	3.36	5.66
M5	4.17	7.12
M6	4.50	8.35
M7	5.05	8.93
M8	5.63	9.22
M9	3.76	6.74
M10	4.37	7.59
M11	5.11	6.97
M12	4.96	7.65

Figure 6.

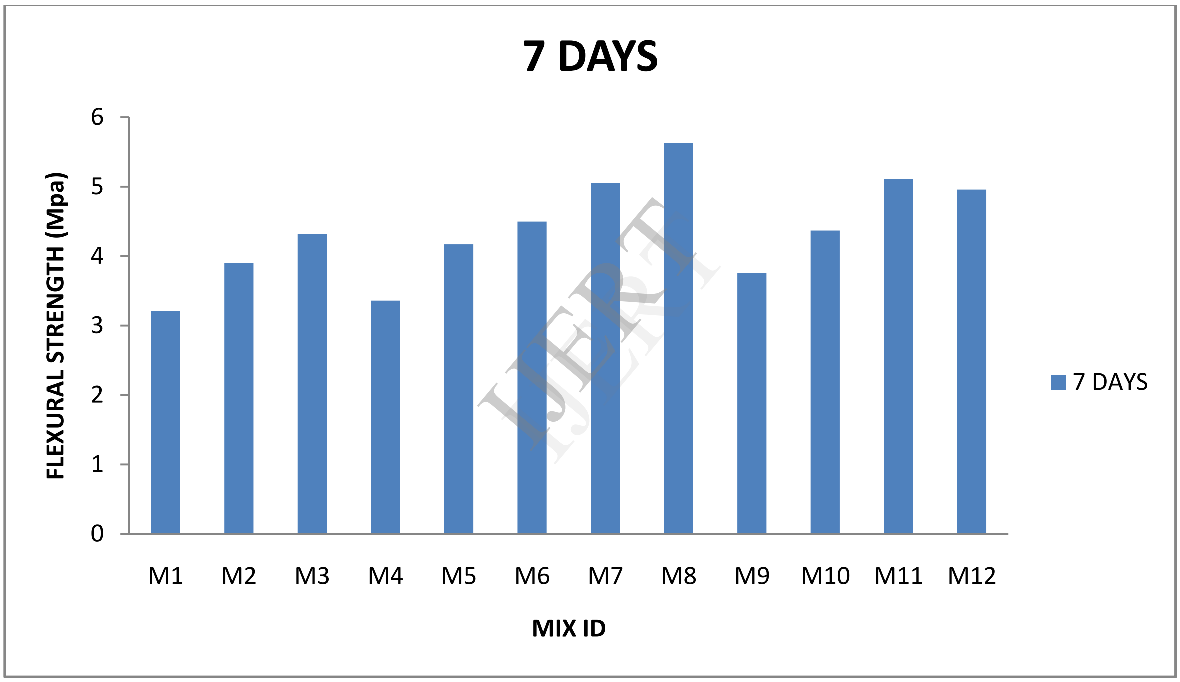

Figure 7.

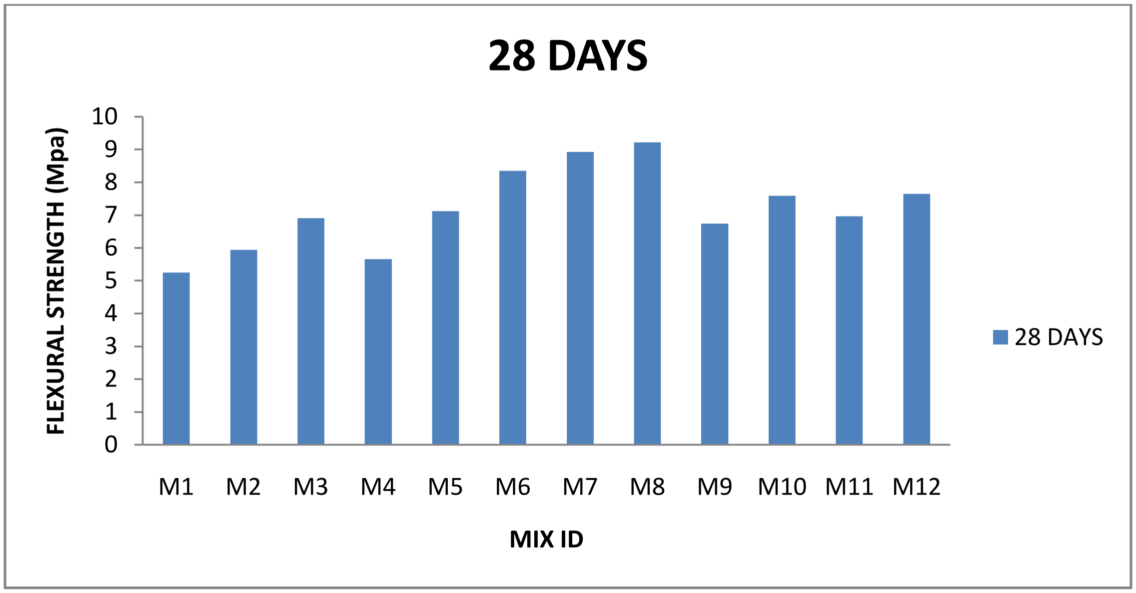

Figure 8.

Experimental Setup for Compression Testing

Figure 9.

4.0 Conclusions

Based on the research studies the following conclusions can be made:

- The performance characteristics of polypropylene and steel fibers were dependent on the optimum fiber dosage up to 0.45% and 2% since fiber addition resulted in loss of workability.
- Compressive strength of material increases with increasing fiber content. Strength enhancement ranges from 8% to 16% for PFRC.
- During the test it was observed that the FRC specimen has grater crack control due to reduction in crack widths and spacing. The flexural strength increases with increase in fiber content.
- The increase in compressive strength was found to be around 24% with the use of polypropylene and steel fibers compared to the reference concrete. Compressive strength was found out to be maximum for a mix of 0.3% PP and 1% SF.
- The maximum increase in flexural strength was found to be around 43 % and the role of polypropylene and steel fibers in preventing the crack formation were realized.

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