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Research paper

Strength Assessment of Polypropylene Fibre Reinforced Concrete (PPFRC)

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Abstract

In this study, the strength performance of concrete with polypropylene (PP) fibre is studied. For this purpose, polypropylene (PP) fibre is added in varying volume fraction (V_f) of 0%, 0.5%, 1%, 1.5% and 2% of M25 grade concrete. The concrete was cast with Ordinary Portland Cement, M-Sand and blue metal, with and without fibres. There is a decrease in workability of concrete when the PP fibre V_f is increased from 0.5% to 2.0%. The compressive, flexural and split tensile strength of concrete have shown an improvement of 7.67%, 26.57% at V_f=1% and 33.61% and V_f=1.5% over conventional concrete. The optimum percentage of polypropylene is found to be 1% beyond which there is a reduction in strength.

Keywords: *Fibre Reinforced Concrete; Mechanical Properties; Strength; Polypropylene; Volume fraction*

1. Introduction

Inclusion of fibres in concrete has been widely researched in the recent years. Fibre Reinforced Concrete using synthetic fibres like polypropylene, polyethylene and polyvinyl-alcohol increases the flexural strength and ductility and reduces the crack width.

Polypropylene fibre is basically a new generation material manufactured through chemical process. When concrete is cast with fibre, it improves the mechanical strength and thus be used in roads and pavements drive ways, overlays and topping, ground supported slab, machine foundations and offshore structures and tanks. PP is light in weight, with density of 0.91 gm /cm^3. It has excellent chemical resistance to most acids and alkalis but the thermal conductivity of PP fibre is lower than that of other fibre material.

Vairagade et al. (2012) [1] have investigated the mechanical strength of M20 concrete with 3 types of polypropylene fibres of lengths of 15 mm, 20 mm and 24 mm at V_f=0.25%. The results show that the fibre with maximum length gives better compressive and split-tensile strength. But Alhozaimy et al. (1996) [2] have reported that the compressive and flexural strength of polypropylene fibre reinforced concrete at relatively low volume fractions (V_f) of 0.05%, 0.1%, 0.2% and 0.3%. Polypropylene fibres were found to have no statistically significant increase on the mechanical strength of concrete. Koksal et al. (2007) [3] have used steel fibre in concrete and found that on increase in steel fibre V_f from 0.5 to 1%, the compressive, split tensile and flexural strength have improved 1.19, 1.90 and 1.77 times (respectively) than that of control specimens. In another study, Yazici et al. (2007) [4] have used varying volume fraction (V_f) of steel fibre on the strength of concrete using hooked-end bundled steel-fibres of varying fibre volume fractions at 0.5%, 1.0% and 1.5%. The flexural strength at 28 days of steel fibre reinforced concrete significantly improved with increasing V_f. The workability of fibre reinforced concrete has decreased for V_f=1.0 and 1.5%.

The main objective of this experiment is to understand the effect of addition of Polypropylene fibre (using varying volume fractions, V_f=0.5, 1, 1.5 and 2%) on the compressive strength, split-tensile and prismatic flexural strength of concrete, when M-Sand is used as fine aggregate.

2. Materials and Methods

Ordinary Portland Cement (OPC-53 Grade) conforming to IS 12269 [9] has been used. M-Sand used as fine-aggregate is sieved passing through 4.36 mm sieve size. The properties of polypropylene fibre are given in Table 1. The length of the fiber is 12 mm, and density is 0.91 g/cc.

Table 1: Properties of Polypropylene Fibres

S.No.	Parameters	Polypropylene
1	Length	12 mm
2	Diameter	25-40 micron
3	Aspect Ratio	300-480
4	Density	0.91 g/cc

2.1. Casting of Specimens

The specimens are cast with cubes of size 150 mm × 150 mm × 150 mm, cylinders of 150 mm (diameter) × 300 mm (height) and prismatic beams of 100 mm × 100 mm × 500 mm (3 replicate specimens) to determine the compressive, splitting-tensile and flexural strength of hardened conventional concrete and fibre reinforced concrete for all volume fractions, V_f=0.5, 1.0, 1.5 and 2%. The moulds were cleaned, and oil was applied in the moulds. Cement, fine aggregate and coarse aggregate are weighed. The cement and M-sand were dry-mixed continuously until the mix became homogeneous and showed uniform colour. Then the coarse aggregate is added and thoroughly mixed. For control specimens, water is added to the ingredients and mixed. Next, for fibre reinforced concrete, the calculated amount of polypropylene fibre (in varying V_f) was added to dry mix to dry mix (cement, sand and blue metal) and mixed well. Subsequently, water is added and mixed well and all the ingredients are mixed together for 3 to 5 minutes till uniform colour is achieved with proper workability. The fresh concrete is now filled in the moulds in three layers and compacted manually. Then the top surface of the mould is levelled and finished with trowel. On de-moulding after 24 hours, the cubes, cylinders and prismatic beams are cured for 7 and 28 days.

Slump test is as per IS: 1199-1959 [5] and flow table as per IS 5512-1983 [6]; and the compressive, split-tensile and flexural tests are as per IS 516-1959 [7].

3. Results and Discussion

3.1. Workability Tests

The slump and flow table test results are presented in Table 2 and Figs. 4 and 5.

Table 2: Workability Test Results

Type of Specimen	Fibe V_f	Slump Value	Difference between CS and TS	Flow table tests	Difference between CS and TS
	%	mm	%	%	%
CS	0.0	62	--	76	--
TS	0.5	48	-22.58	62	-18.42
TS	1.0	34	-45.16	51	-32.89
TS	1.5	22	-64.51	38	-50.00
TS	2.0	14	-77.42	29	-61.84

Note: CS-Control Specimens; TS-Test Specimens

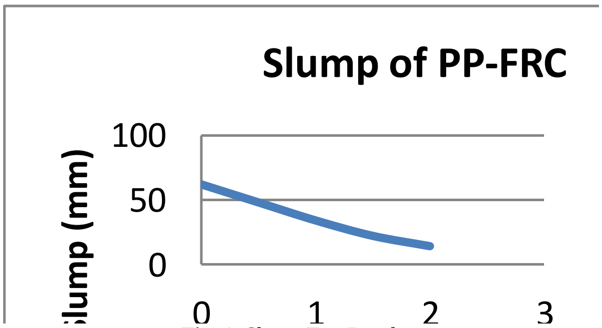

Fig. 4: Slump Test Results

From Table 2 and Fig.4, there is an increase in the amount of PP fibres, there is a decrease in workability of concrete. The present study results show that the slump value of control specimens is 62 mm, and when PP fibre was added in volume fractions 0.5 to 2% (with 0.5% interval), and there is a decrease in slump ranging between 45 and 77%. Similarly, the flow test results have shown that there is a reduction in flow of 18% to 62% when PP is added to concrete from V_f=0.5 to 2%. Whereas the studies of Alsadey and Salem (2016) [8] have shown that when PP fibre is increased from V_f=1 to 2%, there is a decrease in slump value due to the obstruction created by fibres to the free flow of concrete.

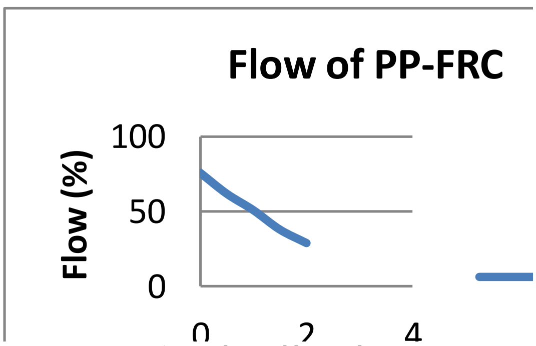

Fig. 5: Flow Table Results

Table 3: Cylinder Compressive Strength Results

Type of Spcimen	Fibre V_f (%)	Cylinder Compressive Strength (N/mm^2) of PO-FRC		
		7 days	28 days	% Strength Difference between CS and TS @28 Days
		N/mm^2	N/mm^2	%
CS	0.0	15.20	26.97	--
TS	0.5	20.08	28.19	+4.52
TS	1.0	20.37	29.04	+7.67
TS	1.5	11.60	26.03	-3.14
TS	2.0	8.77	20.74	-23.10

Note: CS-Control Specimens; TS-Test Specimens

From Table 3 and Fig.6, the PP-FRC has shown a maximum of 7.67% increase than the control specimen at V_f=1%. At higher volume fractions, i.e., at V_f=1.5 and 2%, there is a decrease in compressive strength of 3.14% and 23.10% respectively, when compared to control concrete. From the results, it is clear that the PP fibre does not have a great impact in increasing the compressive strength. In a similar study, Alsadey and Salem (2016) [8] have observed an increase of 12% in compressive strength when using desert sea sand as fine aggregate and PP fibre at V_f=2% in concrete, when compared to control specimens. Patil and Shivananda (2017) [9] have also found that the compressive strength of PP-FRC has increased upto 21.32% at V_f=1.5% , when compared to control specimen.

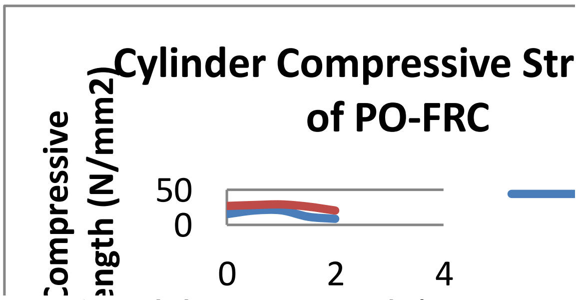

Fig. 6: Cylinder Compressive Strength of PP-FRC

Table 4: Split-Tensile Strength Results

Type of Specimen	Fibre V_f (%)	Compressive Strength (N/mm^2) of PO-FRC		
		7 days	28 days	% Strength Difference between CS and TS @28 Days
		N/mm^2	N/mm^2	%
CS	0.0	2.26	3.50	--
TS	0.5	2.40	4.20	+20.00
TS	1.0	2.68	4.43	+26.57
TS	1.5	2.68	3.48	-0.57
TS	2.0	1.69	2.47	-29.43

Note: CS-Control Specimens; TS-Test Specimens

From Table 4 and Fig.7, it has been found that the split-tensile strength of PP-FRC has improved upto V_f=1%, and decreased with further increase in V_f for both 7 and 28 days. PP-FRC has shown a maximum improvement in split-tensile strength at 28 days of 26.57% at V_f=1%, when compared to control specimens. In a similar study, Patil and Shivananda (2017) [6] have found an improvement in split-tensile strength of 19% at V_f=1.5% while using PP fibres in concrete, when compared to control concrete.

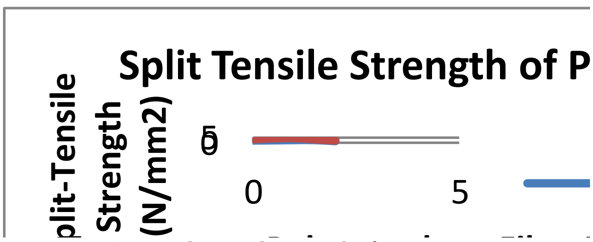

Fig. 7: Split-Tensile Strength of PP-FRC

From Table 5 and Fig.8 presented, the flexural strength of PP-FRC has improved in all volume fractions tested at both 7 and 28 days. The present study results show that there has been a maximum improvement in flexural strength at 28 days of 33.61% at V_f=1.5%, when compared to control specimens. The studies of Mohamed (2006) [10] when compared to the results of the present study show that the flexural strength of PP-FRC has increased by 30.04% at V_f=0.25%, when compared with control specimens, and decreased at all further volume fractions, Vf=0.5, 1 and 1.5%.

Table 5: Prismatic Flexural Strength Results

	Fibre V_f (%)	Prismatic Flexural Strength (N/mm^2) of PO-FRC		
		7 days	28 days	% Strength Difference between CS and TS @28 Days
		N/mm^2	N/mm^2	%
CS	0.0	3.45	3.66	--
TS	0.5	3.80	4.03	+10.11
TS	1.0	4.26	4.51	+23.22
TS	1.5	4.59	4.89	+33.61
TS	2.0	3.47	3.68	+0.55

Note: CS-Control Specimens; TS-Test Specimens

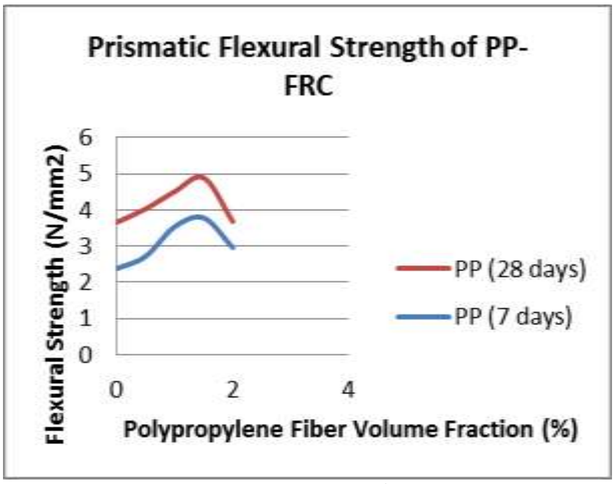

Fig. 8: Flexural Strength of PP-FRC

3. Conclusion

This study concludes that higher the volume fraction of polypropylene fibre in concrete, lower the slump and flow of concrete. Even though polypropylene fibres do not show a significant increase in compressive strength, there is a considerable improvement in split-tensile and flexural strength. This study recommends that polypropylene fibers can be used in concrete under low volume fractions.

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