EVALUATION OF COMPOSITE POLYPROPYLENE FIBRE REINFORCED CONCRETE

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ABSTRACT- **Improvements in fly ash based concrete strength in compression and flexural direction are the main objectives of this study. The compressive and flexure strength of concrete for various mixture proportions of concrete containing the inclusions of different percentage of polypropylene fibers from 0% to 0.3% and fly ash replacement levels at 25% , 50% of fly ash were investigated. The experimental test results showed that PP fibers possess increased extensibility and tensile strength, both at first crack and at ultimate, particular under flexural loading; and the fibers were able to hold the matrix together even after extensive cracking. The net result of all these is to impart to the fiber composite pronounced post – cracking ductility which is absence of ordinary concrete. To provide a basis for comparison, reference concrete specimens were cast without polypropylene fiber. The experimental test result showed that the addition of polypropylene fibers at 0.1% volume fraction (V_f) showed a consistent improvement in the concrete strength of 44.50 MPa and 55.50 MPa at 7 and 28 days respectively.**

Keywords:- Polypropylene fiber, Strength of concrete, Fiber reinforced concrete, Fly ash, Super plasticizer.

I. INTRODUCTION

Concrete made with Portland cement has certain characteristics: it is relatively strong in compression but weak in tension and tends to be brittle. The weakness in tension can be overcome by the use of conventional rod reinforcement and to some extent by the inclusion of a sufficient volume of certain fibers. The use of fibers also alters the performance of the fiber-matrix composite after it has cracked, thereby improving its toughness. The addition of various types of fibers to mechanically improve or modify the performance of Portland cement concrete (PCC) results in what is called fiber reinforced concrete (FRC). Polypropylene fibers cannot provide the primary reinforcement in a concrete because of relatively low modulus and strength values when compared with steel fibers. Polypropylene fibers are used to provide what is termed secondary reinforcement, or the encouragement of a desired material behavior such as decreased plastic and shrinkage cracking and improved toughness. Polypropylene fibers have been widely used in structural applications since the late 1950's and more recently in fiber reinforced concrete [1] in their research studies showed that an addition of fibers to dry mix was found to be more practical and the presence of fibers in concrete alerts the failure mode of material. It is found that the failure mode of plain concrete is mainly due to spalling, while the failure mode of fiber concrete is bulging in transverse directions. [2-3] in their research studies showed that the bending behavior of high temperature exposed LFC incorporating different PF percentages in the range of 0.1 to 0.5% of mix volume was investigated. The Flexural strength test was conducted on LFC with a density range from 600 to 1400. Then, the effects of temperature, density, PF content and pore structure on the properties of LFC containing PF were investigated. [4] Investigated that the addition of polypropylene fiber has greatly improved the fracture parameters of the concrete composite containing 15% fly ash and 6% silica fume, such as fracture toughness, fracture energy, effective crack length, maximum mid-span deflection, the critical crack opening displacement and the maximum crack opening displacement of the three-point bending beam specimens. [5] Demonstrated that the addition of the polypropylene leads to a reduction in the workability and mix slump. It is more effective in the tension than compressive strength due to the adhesive and friction forces between concrete paste and Polypropylene fibers [6] in their research they showed that the Increasing dosages of PP fibers in concrete caused small but consistent increases of the overall total shrinkage strain of concrete. The increases in shrinkage are notable in concretes without any 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 there has been marginal increase in the compressive strength and flexural strength at first crack of fiber reinforced fly ash concrete cubes and deep beams respectively as the fiber content increased from 0% to 0.5% and 1% in all grades of concrete considered for investigations. [9] Concluded that no workability problem was encountered for the use of hooked fibers up to 1.5 percent in the concrete mix. The straight fibers produce balling at high fiber content and require special handling procedure. [10] Showed that it is concluded that the ultimate residual strengths of RC beams containing polypropylene fibers are higher than those without polypropylene fibers. [11] The review of research work shows that the replacement of natural sand with artificial sand is fissile and behavior and strength of reinforced concrete will improved. Also the use of polypropylene fiber will enhance strength and behavior of reinforced concrete also improves resistance against impact loading and fire. [12-15] it was observed from the test results that the ultimate shear strength of the beam is mainly dependent on the diagonal cracking load and subsequent reserve of strength beyond the load due to the present of the longitudinal reinforcement. [16-18] Observed that Fiber reinforcement with fly ash replaced concrete showed a marginal increase on the compressive strength with increase in fibers volume fraction and Flexural strength of the concrete increased with the increase in fibers volume fraction. [19] In their research studies showed that the different stage of fresh cement paste with various percentage of flyash and accelerator were incorporated and monitoring the ultrasonic pulse velocity techniques.

II. Experimental Methodology

The details of materials used in the present experimental investigation are as follows:-

A. Materials Used

OPC-Ordinary Portland cement of 53 grade having 28 days compressive strength of 47.02 MPa, satisfying the requirements of IS: 12269–1987. The physical properties of cement value are presented in Table I.A Class F fly ash obtained from the thermal power plant was used in the study and the fly ash contained less than 10% of lime content (CaO) as shown in Table II. River sand obtained from locally available in the river bed, fine aggregate passing through IS sieve, conforming to grading zone-II as per IS: 383-1970. The fineness modulus value is 2.97, specific gravity of 2.71 and water absorption of 0.64 % at 24 hours. Machine crushed well graded angular blue granite stone of size 12.5 mm were used, for different size of sieve used as per standard, which is maintained with different proportion of coarse aggregate and conforming to IS: 383-1970. The specific gravity was found to be 2.75, fineness modulus is 7.2 and water absorption is 0.67 % at 24 hours. A Polycarboxylate ether based super-plasticizer condensate as high range water reducing admixture (HRWR) to maintain a satisfactory of workability for different mixes with constant w/b ratio throughout the experimental work. It had a specific gravity value of 1.18; pH value of 5.7 and solids content of 40%. A crimped polypropylene fiber was used in the study, the schematic picture as shown in Figure 1 and the properties of fibers are given in Table III**.**

Table I: Physical properties of cement

S No.	Name of the test	Value
1	Consistency	32%
2	Initial Setting Time	165 minutes
3	Final Setting Time	450 minutes
4	Specific Gravity	3.25
5	Fineness of cement	4%
6	Soundness	3 mm
7	Compressive Strength	
	7 days	25.37 MPa
	28 days	47.02 MPa

Table II: Chemical composition of fly ash

Properties (%)	Fly ash Class F
SiO_2	58.9
Al_2O_3	33.4
Fe_2O_3	5.86
CaO	1.02
MgO	0.38
SO_3	0.12
Na_2O	1.28
K_2O	0.01
Cl^-	0.49
Loss on ignition	2.2
Insoluble residue	-
Specific gravity	2.48
Moisture content	0.73

Table III: Physical Properties of polypropylene fibers

Property	Polypropylene
Appearance	Crimped white fiber
Relative Density	0.91
Length	48 mm
l/d ratio	80
Thickness	0.6 mm
Width	1.1 mm
Tensile strength	450 MPa
Failure strain	15%

Fig 1. Snap shot of polypropylene fibres

B. Concrete Mixture Proportions and Casting of specimens

The concrete mixture proportions used in the study were provided in Table IV. A total of 12 different concrete mixtures were proportioned based on the water to binder ratio (w/b) 0.4 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 cylinders (100 mm diameter X 200 mm height) and size of beam mould 100 X 100 X 500. The experimental test set up for flexural strength is shown in Figure 2. 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 as shown in Figure 3.

Table IV: Various Concrete Mix Proportions in the Study

Mix Id	Cement	Fly ash	Fine Aggregate	Coarse Aggregate	Water	F/C	w/b	Polypropylene fiber (%)
	kG/m^3							
M1	400	100	713	1188	120	0.6	0.3	0
M1P1	400	100	713	1188	120	0.6	0.3	0.1
M1P2	400	100	713	1188	120	0.6	0.3	0.3
M2	400	100	713	1188	160	0.6	0.4	0
M2P1	400	100	713	1188	160	0.6	0.4	0.1
M2P2	400	100	713	1188	160	0.6	0.4	0.3
M3	400	200	675	1125	120	0.6	0.3	0
M3P1	400	200	675	1125	120	0.6	0.3	0.1
M3P2	400	200	675	1125	120	0.6	0.3	0.3
M4	400	200	675	1125	160	0.6	0.4	0
M4P1	400	200	675	1125	160	0.6	0.4	0.1
M4P2	400	200	675	1125	160	0.6	0.4	0.3

Fig 2. Compressive strength Machine with Digital Recording

Fig 3. Experimental setup for flexural test

III. Experimental Test Results and Discussion

The obtained experimental results reveal the influence of the fly ash and polypropylene fibers on the behavior of hardened concrete.

Table V: Experimental test results for various mixture proportions of concrete

Mix Id		M1	M1P1	M1P2	M2	M2P1	M2P2	M3	M3P1	M3P2	M4	M4P1	M4P2
w/c	Ratio	0.3	0.3	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.4	0.4	0.4
F/C	Ratio	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Fly ash	%	25	25	25	25	25	25	50	50	50	50	50	50
Polypropylene Fibers (Vf)	%	0	0.1	0.3	0	0.1	0.3	0	0.1	0.3	0	0.1	0.3
Compressive strength (MPa)	3 days	37.75	35	36.4	43	46.4	37.9	32.2	40.6	33	30.6	35	31.5
	7 days	41	44.25	47	44.5	48	41.5	45	48	38.1	40.9	43.1	37.9
	28 days	45	55.5	51	49	51.2	48.5	47.5	50.5	44.5	43.9	47.5	42.45
Split tensile strength(MPa)	28 days	4.1	4.35	4.2	3.9	3.94	3.81	3.55	3.72	3.64	3.61	3.84	3.45
Flexural strength (MPa)	7 days	4.1	4.4	5,4	4.3	5.8	6.1	5.2	5.8	6	4.3	5.4	5.6
	28 days	5	6.6	7.8	5.24	8	8.6	7.4	7	8.2	6.2	7	7.6
IS 13311 PART 1 — UPV (m/sec)	3 days	3290	3910	3750	3950	3820	3450	3650	3590	3445	3300	3155	3010
Rating		Medium	Good	Good	Good	Good	Medium	Good	Good	Medium	Medium	Medium	Medium
UPV (m/sec)	7 days	3780	4010	4090	4120	4090	4140	4010	3820	3710	3670	3530	3690
Rating		Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good
UPV (m/sec)	28 days	4520	4630	4230	4170	4025	4300	4415	4350	4190	4240	4300	4190
Rating		Excellent	Excellent	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good

A. Compressive Strength

The increase in the percentage of polypropylene fiber addition showed a marginal improvement in the compressive strength compared to reference concrete as given in Table V. The strength of various concrete mixes containing different dosage level of fibers for different curing days was plotted in Figures 4 to7. It can be concluded that addition of 0.1% V_f of PP fibers showed an increase in compressive strength upto 7.92 % and 23.33% at 7 days and 28 days and the compressive strength was found to be 44.25 MPa and 55.5 MPa respectively. With the further increase in PP fiber dosage the strength was found to be decreased compared to reference concrete due to defects arising internally as a result of loss in workability. This can be concluded that optimum fiber addition upto 0.1% V_f can result in good fiber dispersion as well as improving the fiber reinforcement index.

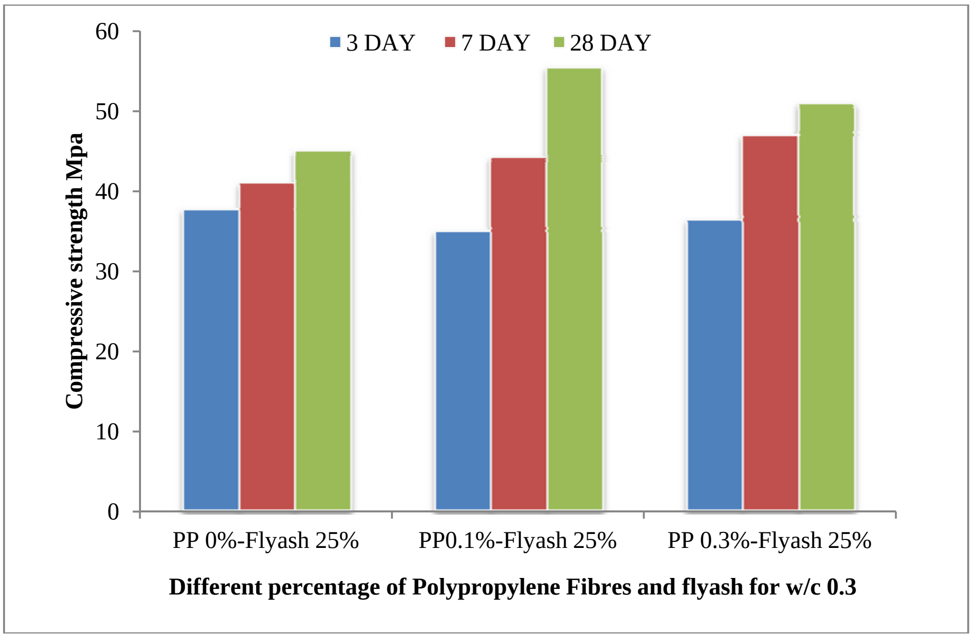

Fig 4. Compressive strength of concrete for different mixture proportions at w/c 0.3

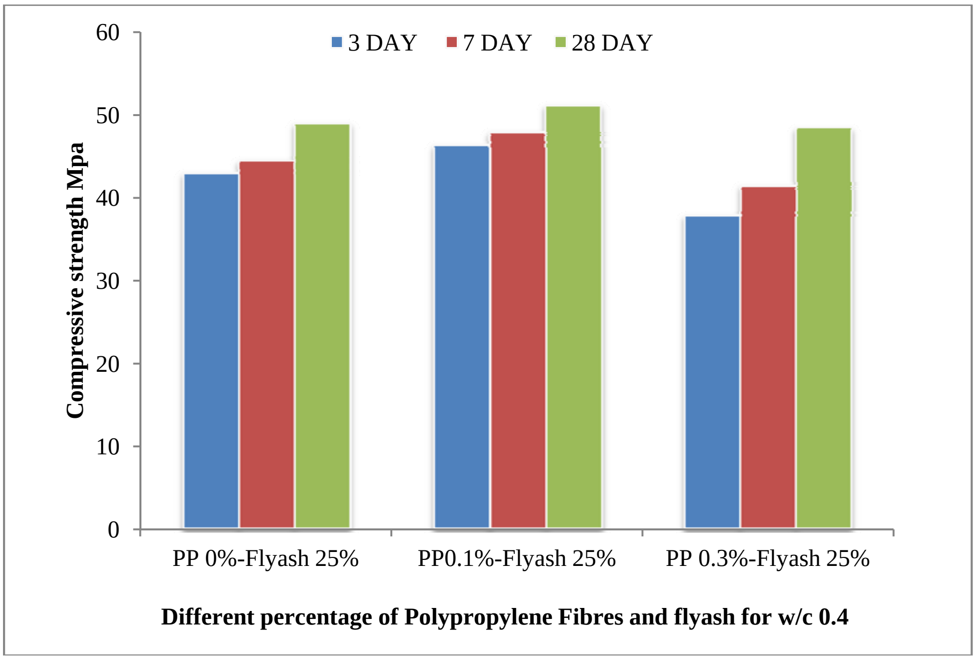

Fig 5. Compressive strength of concrete for different mixture proportions at w/c 0.4

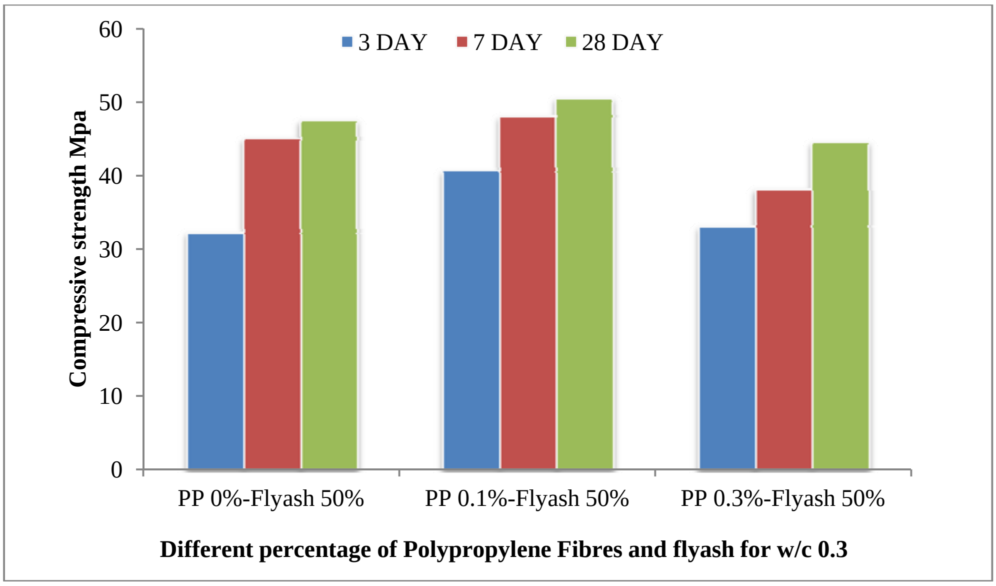

Fig 6. Compressive strength of concrete for different mixture proportions at w/c 0.3

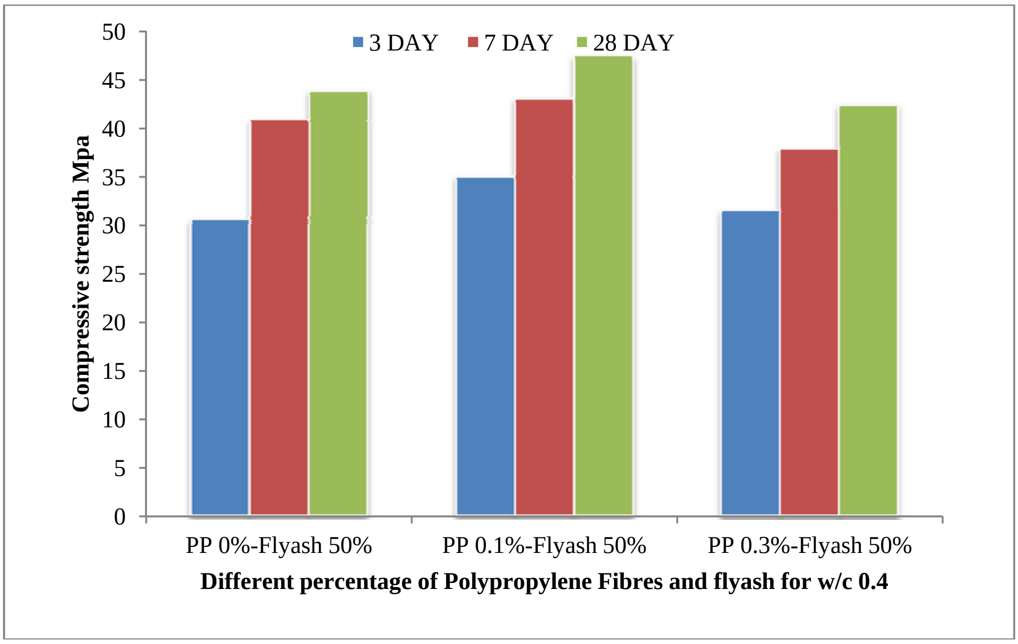

Fig 7. Compressive strength of concrete for different mixture proportions at w/c 0.4

B.Flexural Strength

The flexural strength results are provided in the Table V and shown graphically in Figures 8 to 11. It was observed that a maximum strength of 4.30 MPa at 7 days and 5.24 MPa at 28 days for reference concrete; whereas with the fiber addition at 0.3% V_f the strength was around 6.1 MPa at 7 days and 8.6 MPa at 28 days. This can be substantiated that addition of fibers beyond the required reinforcement index may reduce the contribution of interfacial bond strength provided by matrix and can result in poor stress redistribution. A matrix reinforced with optimum fibers can envisage efficient stress transfer mechanism upon reaching maximum fiber stress and this result in composite energy absorbing capacity. Also, the failure strain of PP fibers (15%) had shown a good improvement in the post peak straining 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.

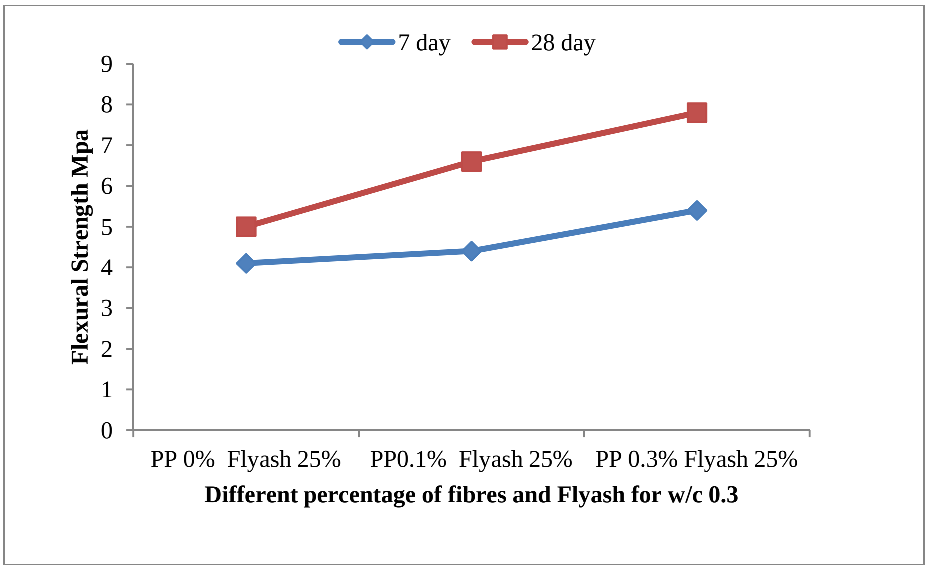

Fig 8. Flexural strength of concrete for different mixture proportions at w/c 0.3

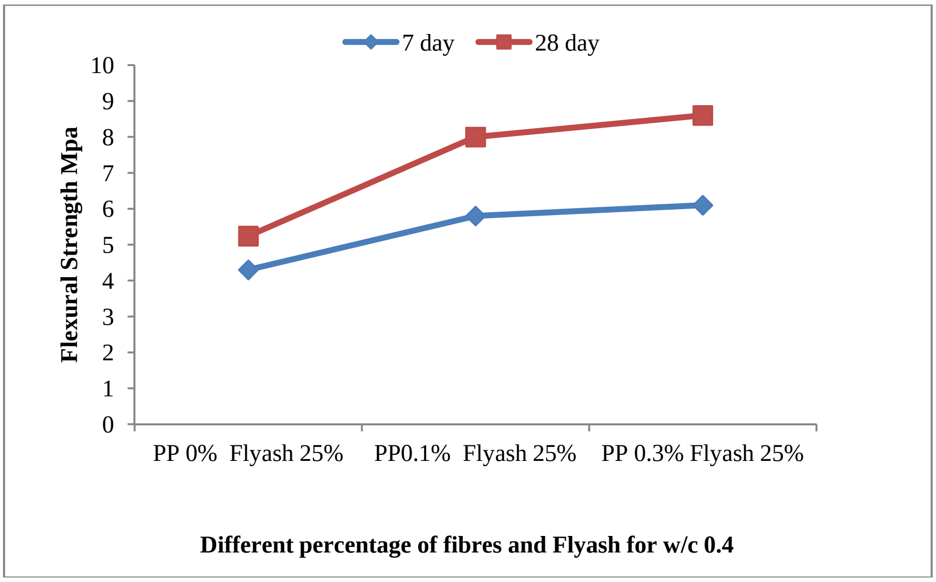

Fig 9. Flexural strength of concrete for different mixture proportions at w/c ratio 0.4

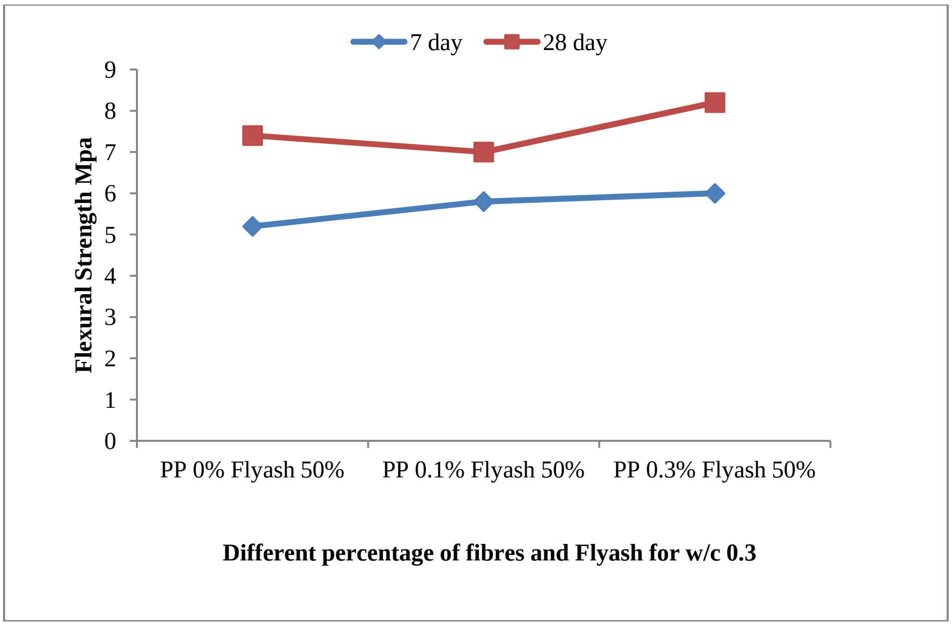

Fig10. Flexural strength of concrete for different mixture proportions at w/c ratio 0.3

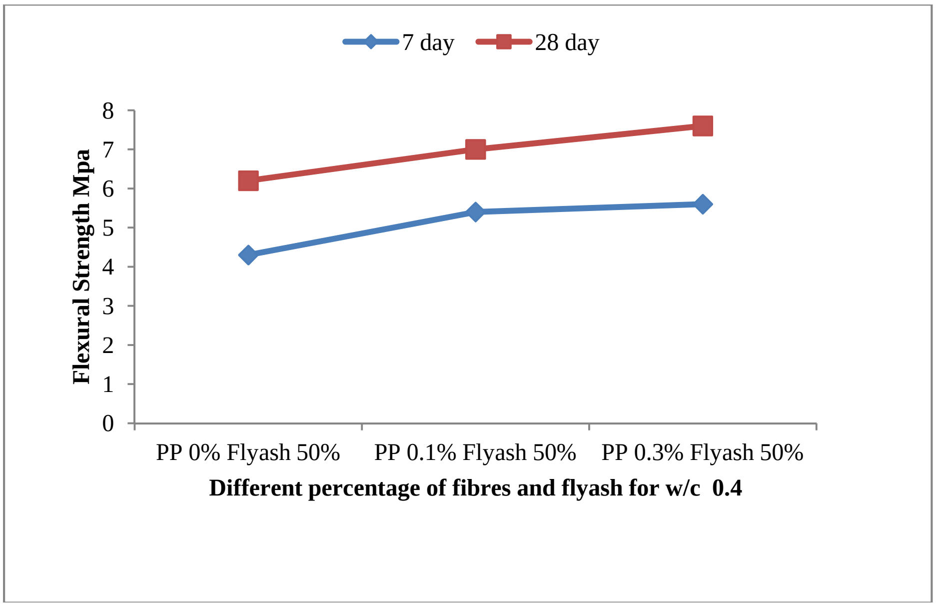

Fig11. Flexural strength of concrete for different mixture proportions at w/c ratio 0.4

C. Split Tensile Strength

The tensile resistance of concrete was determined indirectly by split tensile strength test. The test results for various concrete mixes on cylindrical specimens at the ages of 7 and 28 days in the compression testing machine is given in Table V and shown graphically in Figure 12. The average split tensile strength achieved at 28 days for reference mix is 4.1 MPa and an addition of 0.1% of polypropylene fibers showed an improvement upto 6.09% (4.35 MPa) at 28 days. However, with the higher dosage of PP fibers showed a slight reduction in the split tensile strength compared to reference concrete.

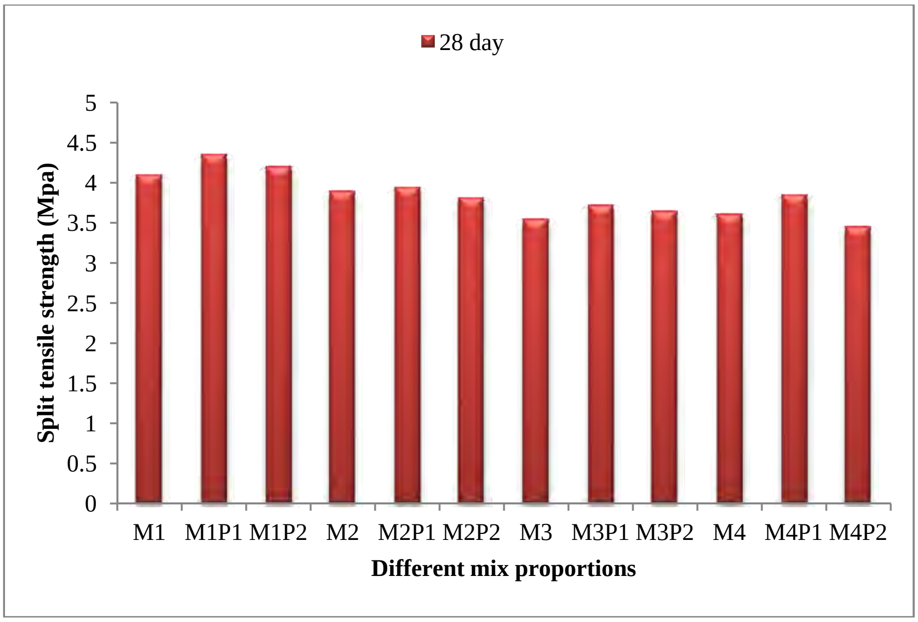

Fig12. Split tensile strength of concrete at different mixture proportions

D. Ultrasonic Pulse Velocity

Test results on ultrasonic pulse velocity showed that there was a good increase in pulse velocity and satisfies the Indian standard [IS 13311]. The UPV values for different mix proportions for different curing days are presented in Table V and the values are plotted as shown in Figures 13 to 16. The UPV values of different specimens were found to be in the range of 3010 m/sec to 4630 m/sec for different curing days of various concrete mixture proportions. These values indicated a good relationship between compressive strength and ultrasonic pulse velocity. A good prediction of the strength based on the UPV values can be drawn from the relationship and can be ideal estimate for estimating the quality of concrete. The test results also provided a useful estimate for assessing the quality of concrete with the polypropylene fiber addition and for checking the integrity.

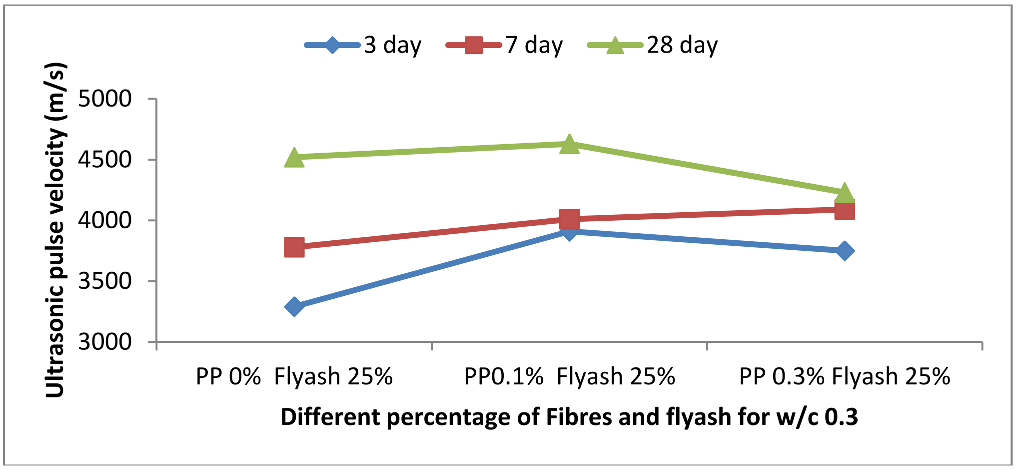

Fig13. Ultrasonic Pulse velocity for various mixture proportions at w/c ratio 0.3

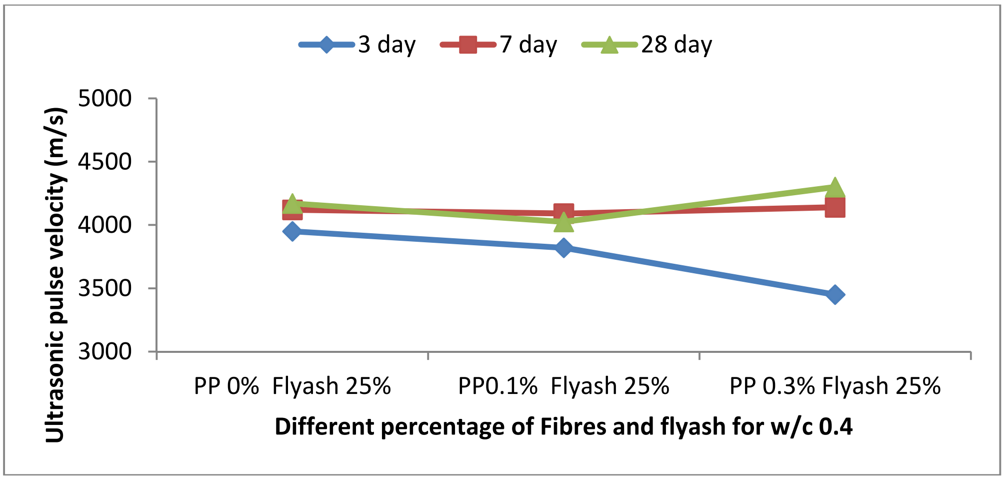

Fig14. Ultrasonic Pulse velocity for various mixture proportions at w/c ratio 0.4

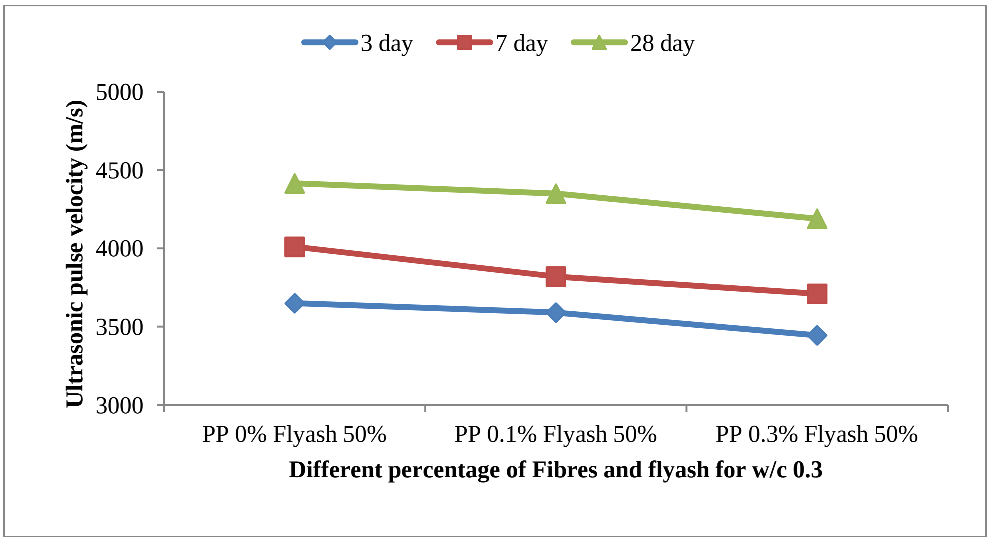

Fig15.Ultrasonic Pulse velocity for various mixture proportions at w/c ratio 0.3

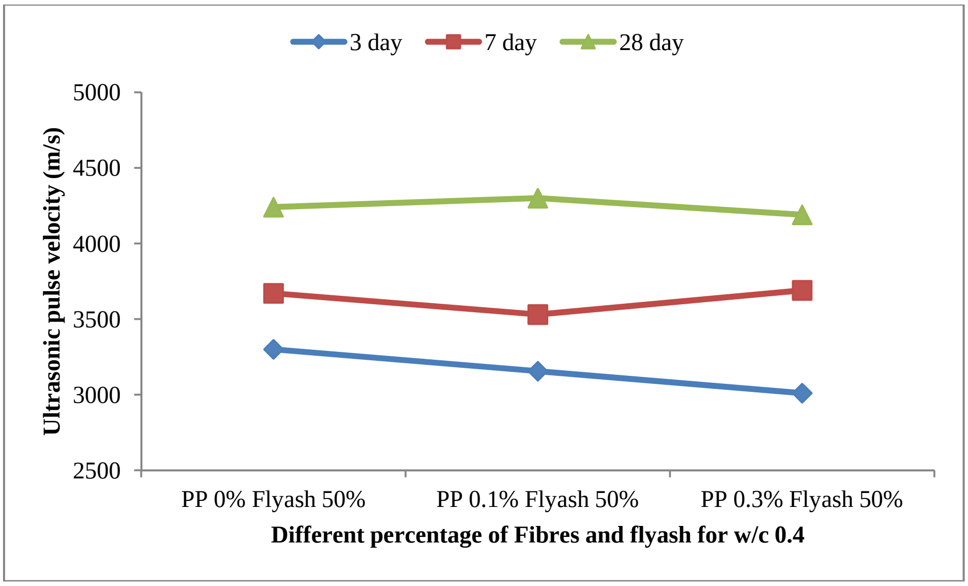

Fig16. Ultrasonic Pulse velocity for various mixture proportions at w/c ratio 0.4

IV. CONCLUSIONS

Based on the experimental investigation the following conclusions are drawn within the limitations of the test results.

- The performance characteristics of polypropylene fibers were dependent on the optimum fiber dosage upto 0.1% for different proportion of concrete and further inclusion of fibers resulted in loss in workability.
- Unconditional failure of plain concrete specimens was restricted with volumetric bulging due to presence of PP fibers and gradual release of fracture energy was anticipated.
- The maximum increase in compressive strength was observed to be around 23.33% with the use of polypropylene fibers compared to the reference concrete.
- The maximum increase in split tensile strength was around 6.09% at 28 days with the use of polypropylene fibers compared to the reference concrete.
- The maximum increase in flexural strength was found to be around 64.12 % at 28 days (M2P2) and the role of polypropylene fibers in delaying the crack formation were realized.
- The ultrasonic pulse velocity test results also confirmed that the quality and integrity of concrete was not affected with PP fiber addition.

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