Comparative Study Of Compressive And Tensile Behaviour Of Polypropylene Fibre Reinforced Concrete (PPFRC) With And Without Fly Ash

Saman Khan[1],
Postgraduate Student, Integral university, Lucknow-226026

1. **Md Tabsheer Ahmed[2]**
Assistant Professor, Integral University, Lucknow-226026

***Abstract*—This experimental research investigates the effect of low volume fly ash on strength properties of polypropylene fibre reinforced concrete (PPFRC) and compared with PPFRC without fly ash. The compressive and split tensile strength of concrete specimen was studied. The specimen was reinforced with monofilament polypropylene fibre with length of 12 mm at varying amount of fibres 0-3% by weight of cement, with an increasing rate of 0.5%. A constant weight of 10% of Fly ash was used. The testing period for concrete specimen was 28 days. Compressive strength and tensile strength of concrete increases with increase in fibre content but the optimum dosage was found to be 1% to 1.5% as further increase of fibre content leads to decrease in the concrete strength. Comparatively the maximum strength gain of PPFRC was obtained by using low volume fly ash. The study concluded that use of fly ash in PFRC makes concrete to set earlier and also involves in improvement of the compressive and tensile properties but marginally at low volume. Further more research is required to strengthen the bond between cement paste and the fibre, which can enhance the strength of the concrete.**

1. INTRODUCTION:

Fibres have been used to reinforce materials that are weaker in tension than in compression since ancient times. Today, FRC is very widely used; the principal applications are slabs on grade, shotcrete, and precast members, as well as a number of specialty applications. Until now, most of the production of FRC has been for “non-structural” applications, with the fibres added primarily for control of cracking due to plastic or drying shrinkage.

Polypropylene fibre reinforced concrete is embryonic construction material and a new generation chemical fibre and can be used as secondary reinforcement but cannot replace primary one [1]. The term fibre reinforced concrete (FRC) is defined by ACI Committee 544 as a concrete made of hydraulic cements containing fine and coarse aggregates and discontinuous discrete fibres [8]. The workability of concrete decreases with the increase of fibre volume fractions [2] but it can be overcome by high range of water reducing admixtures [3]. The mechanical properties of concrete improved upon using polypropylene fibres [5]. Normal-strength-fibre-reinforced fly ash concrete affects by fibre volume fractions up to 1% after further increase in polypropylene fibre results in retarding. However compressive strength decreases with increase of fly ash content while improves the workability of PFRC [7]. It is found that the split tensile strength increased with increasing fibre content. Fibres tend to bridge the micro cracks and hamper the propagation of cracks. When tensile stress is transferred to fibres, the micro cracks are arrested and thus improve the split tensile strength of concrete [6]. Polypropylene when used as composite with steel fibres also improves the mechanical properties of concrete [4].

2. MATERIALS

Cement

The cement used was Ordinary Portland cement 53 grade [12], with a specific gravity of 3.13. Initial and final setting times of the cement were 110 min and 270 min respectively and chemical composition is given in Table 1.

Fly ash

Low lime fly ash is used confirming to IS 3812 [18] in fixed rate of 10% by mass of cement with specific gravity of 2.2.

Table-1 Specification of Cement

S no.	**Name of test**	**Results Obtained**	**IS:1226 9-1987 Specific ations**
1	Initial setting time	110 min	30 min
2	Final setting time	270 min	600 max
3	Soundness	3mm	-
4	specific gravity	3.13	-
5	Consistency	33%	-
6	Compressive strength		
	7 days	43.42 MPa	43 min
	28 days	54 MPa	53 min
7	Fineness of cement	3%	-

Aggregate

Dry and clean natural, river aggregate was used in concrete mixture [13]. The gravel was 20 mm maximum nominal size with 1% absorption value and its relative density at saturated surface dry (SSD) condition was 2.71. The absorption value of the sand used was 1.2% and its relative density at saturated surface dry (SSD) condition was 2.51. The specific gravity of sand and aggregate is 2.72 and the silt content of sand is 2%. The grading of the mixed aggregate was presented in Table 2.1 and table 2.2.

Table 2.1 Grading limits of fine aggregate

IS Sieve Designation	**Percentage passing by weight**				
	Grading Zone 1	**Grading Zone 2**	**Grading Zone 3**	**Grading Zone 4**	**In our case**
10 mm	100	100	100	100	100
4.75mm	90-100	90-100	90-100	95-100	100
2.36 mm	60-95	75-100	85-100	95-100	100
1.18 mm	30-70	55-90	75-100	90-100	100
600 µ	15-34	35-49	60-79	80-100	99.5
300 µ	5-20	8-30	12-40	15-50	46.3
150 µ	0-10	0-10	0-10	0-15	3.9

Table 2.2 Grading limit for coarse aggregate IS: 383-1970[53]

IS Sieve Designation	**Percentage passing for single sized aggregate by weight**					
	63 mm	**40 mm**	**20 mm**	**16 mm**	**12.5 mm**	**10 mm**
80	100					
63	85-100	100				
40	0-30	85-100	**100**			
20	0-5	0-20	**85-100**	100		
16	-			85-100	100	
12.5	-				85-100	**100**
10	-	0-5	**0-20**	0-30	0-45	**85-100**
4.75	-		**0-5**	0-5	0-10	**0-20**
2.36	-					**0-5**

Fibres

Polypropylene fibre, which was named Recron 3s, monofilament polypropylene fibres of length 12mm with a density 0.91, and a tensile strength ranging between 500 and 600 MPa. Specifications are given in table 2.3.

Table 2.3 Specification of Recron

Cut length	12mm
Tensile strength	About 500-600MPa
Melting point	>250 C
Dispersion	Excellent
Acid Resistance	Excellent
Alkali Resistance	Good

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3. Methodologies

3.1 Mixture composition and preparation

Mixture design is made with according to Mix Design method of Indian standard [11]. At the beginning of the mixture design, cement content 516 kg/m3 and water–cement ratio 0.40 were chosen as constant. Fresh concretes containing 10% constant fly ash as cement replacement in mass basis were prepared by modifying the control Portland cement concrete. Fresh fibre-reinforced concretes containing 0.5%, 1%, and 1.5%, 2%, 2.5% and 3% polypropylene fibre in volume basis were prepared while 0% represents standard concrete.

The mixing procedure of fibre reinforced concrete involved the following steps. First, the sand and gravel were place in tilting drum mixer and mixed dry for 1 min. Second, the binder and fibre were spread and mixed dry for 1min. Third, the mixing water was slowly added and mixed for 3 min. Last, the freshly mixed polypropylene-fibre-reinforced-concrete (PFRC) was fed into specimen moulds and vibrated on vibrating table simultaneously. After casting, each specimen was demoulded after 24 hours. Demoulded specimens are then cured in water tank at 27° ± 2°C until age of testing [14] [15].

3.2 Testing Methods

Compressive strength of each specimen was determined using IS: 516-1959 [16] and split tensile strength was determined using IS 5816-1999 [17]. The compressive strength and split tensile strength were measured at 28 days. Specimen dimensions were 150x150x150 mm for compressive strength and 150x300 mm for split tensile strength.

4. RESULT AND DISCUSSION:

The experimental study was performed for analyzing the compressive and split tensile strength of PPFRC with and without incorporation of fly ash. The study analyzed the effect in terms of percentage increase or decrease in the strength parameters of the concrete.

a) Compressive strength of cube vs. polypropylene fibres

The compressive strength of PPFRC with low volume fly ash is given in table 4.1.

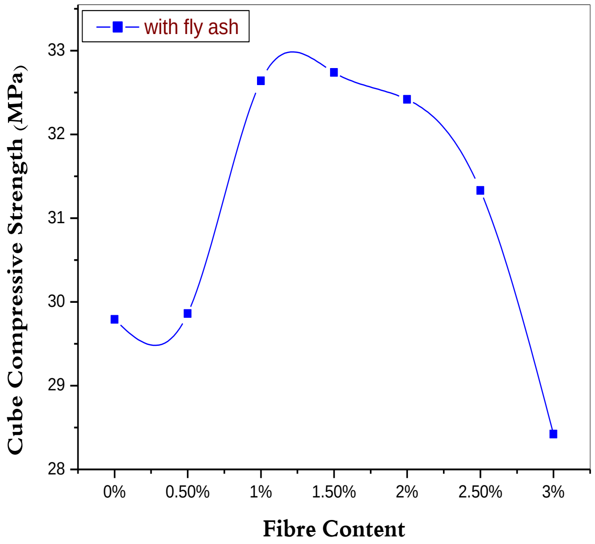

Fig. 1.*Compressive strength vs percentage of fibre for M 25 Design mix*

The graph represents the compressive strength of concrete cube with 0-3% of Fibre to weight of cement with 0% as standard concrete. With the addition of fibre the compressive strength of concrete cube increased by 0.23 % at 0.5 % fibre content, 9.56% at 1 % fibre content, 9.90% at 1.5 % fibre content, 8.82% at 2 % fibre content, 5.16% at 2.5 % fibre content and decreased by 4.56 % at 3% fibre content. The optimum dosage for maximum fibre content was 1.5 % giving compressive strength of 32.74 with 9.90% increase from control specimen. The minimum compressive strength was 28.42 with 4.56% decrease from control specimen.

Table 4.1. Compressive strength of PPFRC with low volume fly ash vs percentage fibre

S. No.	Mixes Identification	%age fibre	cube compressive strength with fly ash (MPa)
1	Mix I	0	29.79
2	Mix II	0.50	29.86
3	Mix III	1	32.64
4	Mix IV	1.50	32.74
5	Mix V	2	32.42
6	Mix VI	2.50	31.33
7	Mix VII	3	28.42

b) **Tensile Strength of Cylinder vs percentage of Polypropylene Fibres**

The Spilt tensile strength of PPFRC with low volume fly ash is given in table 4.2.

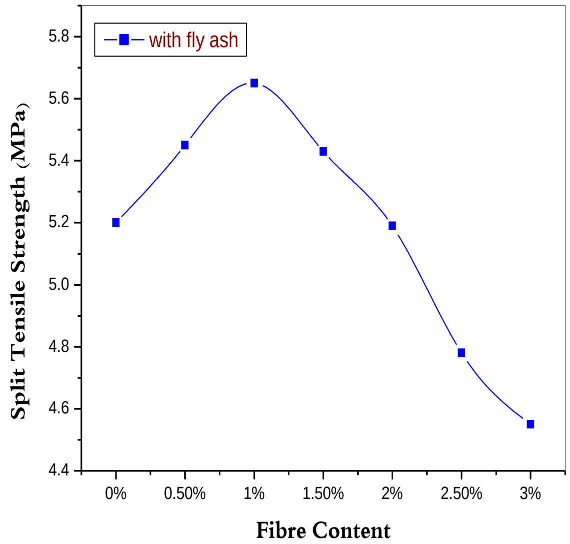

Fig. 2.*Split Tensile Strength vs. % Fibre for M 25 Design mix*

The graph represents the split tensile strength of concrete cylinder with 0-3% of Fibre to weight of cement with 0% as standard concrete. With the addition of fibre the compressive strength of concrete cube increased by 4.81 % at 0.5 % fibre content, 8.61% at 1 % fibre content, 4.42% at 1.5 % fibre content, decreased by 0.19% at 2 % fibre content, 8.07% at 2.5 % fibre content and decreased by 12.50% at 3% fibre content. The optimum dosage for maximum fibre content was 1 % giving tensile strength of 5.65 with 8.65% increase. The minimum tensile strength was 4.55 with 12.50% decrease from control specimen.

Table 4.2. Compressive strength of PPFRC with low volume fly ash vs percentage fibre

S. No.	Mixes Identification	%age Fibre	split tensile strength with fly ash (MPa)
1	Mix I	0	5.2
2	Mix II	0.50	5.45
3	Mix III	1	5.65
4	Mix IV	1.50	5.43
5	Mix V	2	5.19
6	Mix VI	2.50	4.78
7	Mix VII	3	4.55

c) Compressive strength of cube vs polypropylene fibres

The compressive strength of PPFRC without fly ash is given in table 4.3.

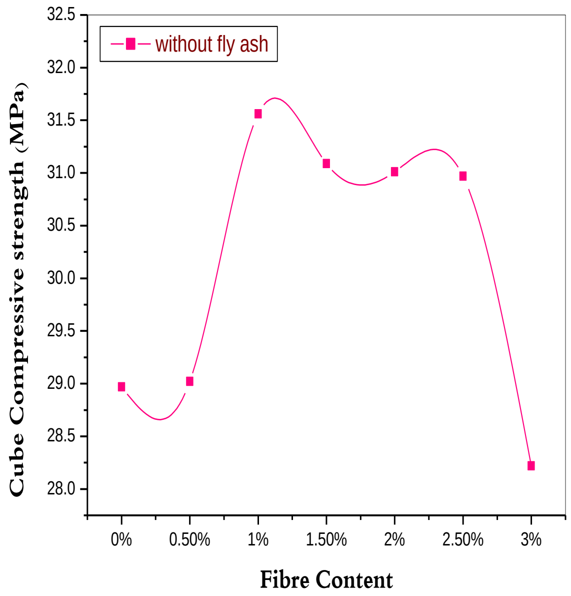

Fig. 3. *Compressive strength vs. % of fibre for M25 design mix*

The graph represents the compressive strength of concrete cube with 0-3% of Fibre to weight of cement with 0% as standard concrete. With the addition of fibre the compressive strength of concrete cube increased by 0.17 % at 0.5 % fibre content, 8.94 % at 1 % fibre content, 7.32 % at 1.5% fibre content, 7.04 % at 2 % fibre content, 6.90 % at 2.5 % fibre content and decrease 2.50 % at 3% fibre content. The optimum dosage for maximum fibre content was 1 % giving compressive strength of 31.56 with 8.94% increase from control specimen. The minimum compressive strength was 28.22 with 2.50 % decrease from control specimen at 3%.

Table 4.3. Compressive strength of PPFRC without fly ash vs. percentage fibre

S. No.	Mixes Identification	%age Fibre	cube compressive strength without fly ash (MPa)
1	Mix I	0%	28.97
2	Mix II	0.50%	29.02
3	Mix III	1%	31.56
4	Mix IV	1.50%	31.09
5	Mix V	2%	31.01
6	Mix VI	2.50%	30.97
7	Mix VII	3%	28.22

d) Tensile Strength of Cylinder vs percentage of Polypropylene Fibres

The split tensile strength of PPFRC without fly ash is given in table 4.4.

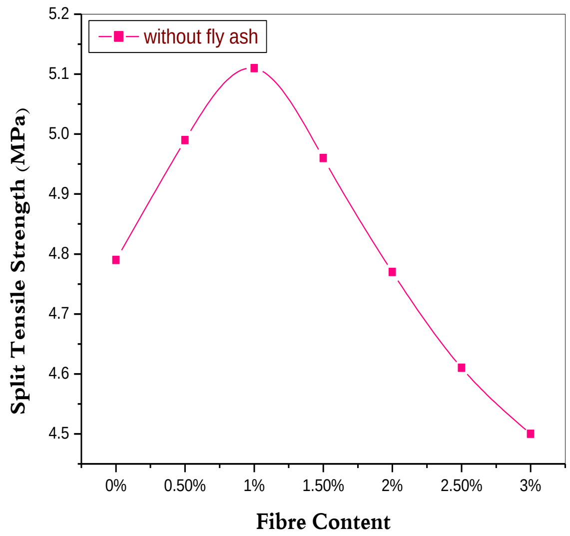

Fig. 4.Split Tensile Strength vs. % Fibre for M 25 Design mix.

The graph represents the Tensile strength of concrete cylinder with 0-3% of Fibre to weight of cement. With the addition of fibre the tensile strength of concrete cylinder increased by 4.17 % at 0.5 % fibre content, 6.68 % at 1 % fibre content, 3.55% at 1.5 % fibre content and decreased by 0.42 % at 2 % fibre content, 3.76 % at 2.5 % fibre content, 6.05 % at 3% fibre content. The optimum dosage for maximum fibre content was 1 % giving tensile strength of 3.29 with 2.81 % increase from control specimen. The minimum tensile strength was 3.01 with 5.94 % decrease from control specimen.

Table 4.4. Split tensile strength of PPFRC with low volume fly ash vs. percentage fibre

S. No.	**Mixes Identification**	**%age Fibre**	**split tensile strength without fly ash (MPa)**
1	Mix I	0%	4.79
2	Mix II	0.50%	4.99
3	Mix III	1%	5.11
4	Mix IV	1.50%	4.96
5	Mix V	2%	4.77
6	Mix VI	2.50%	4.61
7	Mix VII	3%	4.5

e) **Comparison of cube compressive strength with and without fly ash vs. percentage fibre**

This graph represents the comparative compressive strength of PPFRC in presence and absence of fly ash. Comparatively fly ash marginally strengthens the compressive strength.

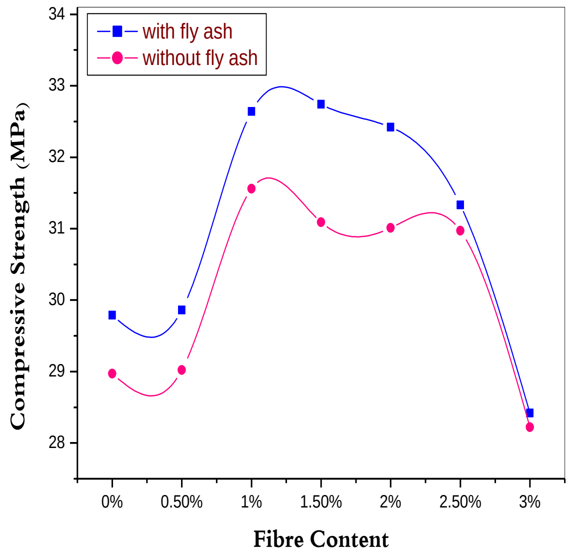

Fig. 5.*Compressive Strength vs. % Fibre with and without fly ash for M 25 Design mix*

The graph represents the comparative compressive strength of concrete cube with 0-3% of Fibre to weight of cement with fly ash (i. e. 10% constant) and without fly ash. With the addition of fly ash in PFRC the compressive strength of concrete cube increased by 2.83 % at 0 % fibre content, 2.89 % at 0.5 % fibre content, 3.42% at 1% fibre content, 5.30% at 1.5% fibre content, 4.55% at 2% fibre content, 1.16% at 2.5% fibre content and 0.71% at 3% fibre content.

f) Comparison of split tensile strength with and without fly ash vs. percentage fibre

This graph represents the comparative split tensile strength of PPFRC in presence and absence of fly ash. Comparatively fly ash marginally strengthens the tensile strength.

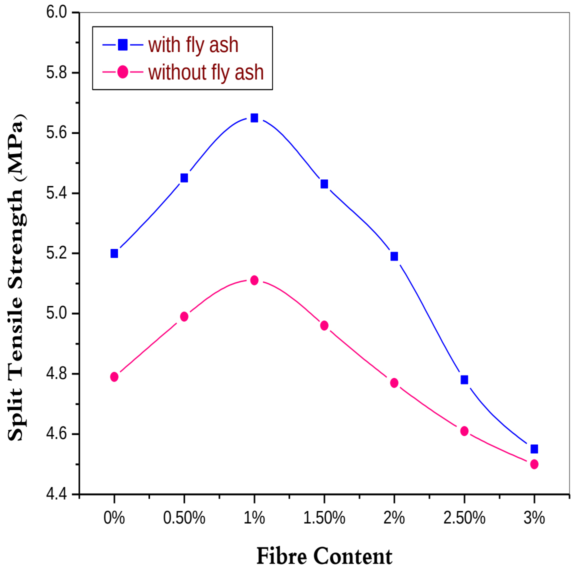

Fig. 6.*Tensile Strength vs. % Fibre with and without fly ash for M 25 Design mix*

The graph represents the comparative split tensile strength of concrete cube with 0-3% of Fibre to weight of cement with fly ash (i.e. 10% constant) and without fly ash. With the addition of fly ash in PFRC the split tensile strength of concrete cube increased by 9.01 % at 0 % fibre content, 9.22 % at 0.5 % fibre content, 10.57% at 1% fibre content, 9.47% at 1.5% fibre content, 8.80% at 2% fibre content, 3.68% at 2.5% fibre content and 1.11% at 3% fibre content.

CONCLUSION

From the experimental work and results the study has concluded the following:

As PP fibres are hydrophobic and also during study it was observed that they did not disperse with ease in mixing water. Addition of fibres to dry mix was found to be more practical.

Compressive strength and tensile strength of concrete increases with increase in fibre content but the optimum dosage was found to be 1% to 1.5% as further increase of fibre content leads to decrease in the concrete strength.

Maximum compressive strength of 32.74 MPa with increment of 9.90% at 1.5% fibre dosage was found in PPFRC with fly ash and 31.56 MPa with increment of 8.94% at 1% fibre dosage in PPFRC without fly ash.

Maximum split tensile strength of 5.65 MPa with increment of 8.65% at 1% fibre dosage was found in PPFRC with fly ash and 5.11 MPa with increment of 6.68% at 1% fibre dosage in PPFRC without fly ash.

Comparatively the maximum strength gain of PPFRC was obtained by using low volume fly ash. Further more research is required to strengthen the bond between cement paste and the fibre, which can enhance the strength of the concrete.

So use of fly ash in PFRC makes concrete to set earlier and also involves in improvement of the compressive and tensile properties but marginally at low volume.

So we can say that the increased compressive strength due to fibre percentage is due to fibre and aggregate bonding and not due to cement paste bonding. The fibres are acting as anchors between the cement paste and the fine and coarse aggregates which results in increased durability of concrete before failure.

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