Mechanical properties of Polypropylene Fibre reinforced concrete for M 25 & M 30 mixes: A Comparative study

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Abstract

This paper represents comparative experimental study on mechanical performance of polypropylene fibre reinforced concrete (PFRC) under compression and split tensile loading. The cube compressive strength and cylinder split tensile strength of conventional concrete and polypropylene fibre reinforced concrete were determined in the laboratory. The M25 and M30 grades of concrete mixes and polypropylene mono-filament macro-fibres of length 35 mm at volume fractions of 0.0%, 0.5%. 1.0%, 1.5%, 2.0%, 2.5% and 3.0% were used in the research. All specimens were tested at curing age of 28 days. In this paper the relationship between cube compressive strength and cylinder split tensile strength for conventional and polypropylene fibre reinforced concrete were established and compared with standards.The study suggested the significant improvement in compressive and tensile strength for concrete mixes reinforced with polypropylene fibres. The samples with added polypropylene fibres of 1% and 1.5% showed better results in comparison with the others.

Keywords: Polypropylene Fibre-Reinforced, Concrete, Compressive Strength, Split Tensile Strength, Cube and Cylinder

1. Introduction

To overcome some shortcomings of conventional concrete such as low tensile and flexural strength, poor toughness, high brittleness fibre reinforced concrete (FRC) has been developed in recent years.The ductility of fiber reinforced concrete depends on the ability of the fibers to bridge cracks at high levels of strain. Addition of polypropylene fibers decreases the unit weight of concrete and increases its strength [10]. Good concrete must have high strength and low permeability. Inclusion of polypropylene fibers reduces the water permeability, increases the flexural strength due to its high modulus of elasticity [19]. Polypropylene fibers have hydrophobic levels, which protect them against wetting with cement paste. The hydrophobic nature of polypropylene has no effect on the amount of water needed for concrete [1][4][5][6]. Polypropylene fibers are available in three different forms; Monofilaments, Multifilament and Fibrillated [2]. The Compressive strength and splitting tensile strength increases proportionately with the increase in volume ratios of Polypropylene Fibres[18]. Researchers have studied cement concrete and polypropylene fiber reinforced concrete and have investigated the effect of fibers on the mechanical properties of concrete. Howeverconsidering the mono-filament macro polypropylene fibres by volume fractions of 0.0%, 0.5%, 1.0%, 1.5%, 2.0%, 2.5%and 3.0% in M25 and M30 grades of concrete isan innovative approach. The objective of study is to analyse and determine the effects of polypropylene fibres (PPF) on various grades of concrete and to make a comparative study of compressive and split tensile strength of various grades of concreteusing PP fibres.

2. Experimental program

2.1 Materials

A. Cement

Ordinary PortlandCement of 53 grade having specific gravity 3.15 is used. The cement has been tested for various properties as per IS: 4031[22] part 5 and there by confirming to various specifications of IS: 12269[24].

Table 1 Physical Properties of Cement

S no.	Name of test	Results Obtained	IS:12269-1987Specifications
1	Initial setting time	160 min	30 min
2	Final setting time	470 min	600 max
3	Soundness	3mm	10mm (max)
4	Specific gravity	3.15	-
5	Consistency	33%	-
6	Compressive strength		
	7 days	43.42 Mpa	37 Mpa(min)
	28 days	60 Mpa	53 Mpa (min)
7	Fineness of cement	256 m^2/kg	225 m^2/kg (min)

B. Coarse Aggregate

Crushed angular aggregate of size 20mm having specific gravity 2.7 and fineness modulus of 4.05 confirming to IS: 383[25] is used.

C. Fine Aggregate

River sand with specific gravity 2.6 and fineness modulus 2.62 confirming to IS: 383[25] is used.

D. Polypropylene Fibres

A synthetic polymer, mono-filament macro fibre of length 35mm is used.

Table 2 Typical Properties of macro-polymer fibre

Elastic Modulus	3000-30000 MPa
Tensile Strength	300-700 M/mm2

Specific gravity	0.91
Design	Even
Length	35mm
Cross-section	Circular
Diameter	0.44mm
Surface	Smooth
I/D ratio	80

E. Fly Ash

The flyash used in the experimentation satisfies the requirements of IS: 3812[30] and the cement is replaced by 5% by the use of fly ash for all mix proportions and volume fractions.

Table 3 chemical properties of fly ash

Chemical Composition	**Results**	**Permissible results as per IS 3812-1981**
Silica dioxide	60.10%	35% min
Alluminium Oxide	14.66%	-
Ferrous Oxide	2.80%	5% max
Magnesium Oxide	0.60%	-
Calcium Oxide	1.23%	2.75% max
Sulphur Trioxide	0.58%	1.5% max
Sodium Oxide	1.45%	-

Soluble salt	0.54%	-
Loss of ignition	11.35%	12% max

* Data taken from the production centre

2.2 Mix Proportions and casting of specimens

In this work M25 and M30 mixes were used and the mix ratios 1:1:2 and 1:1.54:2.58 respectively asper standards of IS: 456 and IS: 10262[23] [28]. For every mix fibre is added by volume of cement from o% to 3% at increasing rate of 0.5%.The different cube and cylinder specimens as per requirements of tests were casted as per code of practices. These specimens were tested after 28 days of curing. Six specimens for 0.0 % and three specimens for other volume fractions were cast and tested, the average values of compressive strengths are reported in histogram.

The details of castings, fibre addition and mix ratios are given in table 4.

Table 4

Mix	C:S:A	w/c	% fiber added	Cement (kg/m^3)	Sand (kg/m^3)	Aggregate (kg/m^3)
M25	1:1.42:2.56	0.42	(0-3)	350	497	896
M30	1:1.3:2.5	0.43	(0-3)	350	455	875

From each concrete mix, 150 mm cube specimens for evaluation of compression strength and 150 mm diameter and 300 mm height cylindrical specimens for split tensile strength were casted from concrete mixes containing fiber and without fiber. The specimens were demoulded after 24 hours of casting. Thereafter, the demoulded specimens were marked for identification and kept submerged in a curing tank at a temperature (270 ± 2 0C) till the age of testing.

2.3 Testing methods

a. Compressive Strength

Compressive strength of each concrete mix was determined usingand compared with standard concrete mix at 0% fibre and also inter compared with all mixes. Three specimens of each mix were tested to determine the average compressive strength of concrete mixes at 28 days.

The specimens were tested under compression testing machine of 2000 KN capacity as per IS 516-1959[26].

b. Split Tensile strength

Split tensile Strength of each concrete mix was determinedand compared with standard concrete mix at 0% fibre and comparison with all mixes. Three specimens for each mix were tested to determine the average split tensile strength of concrete mixes at 28 days.

The specimens were tested as per IS: 5816-1999[29].

3. Results and discussion

a. Compressive strength of Cube vs Polypropylene Fibre

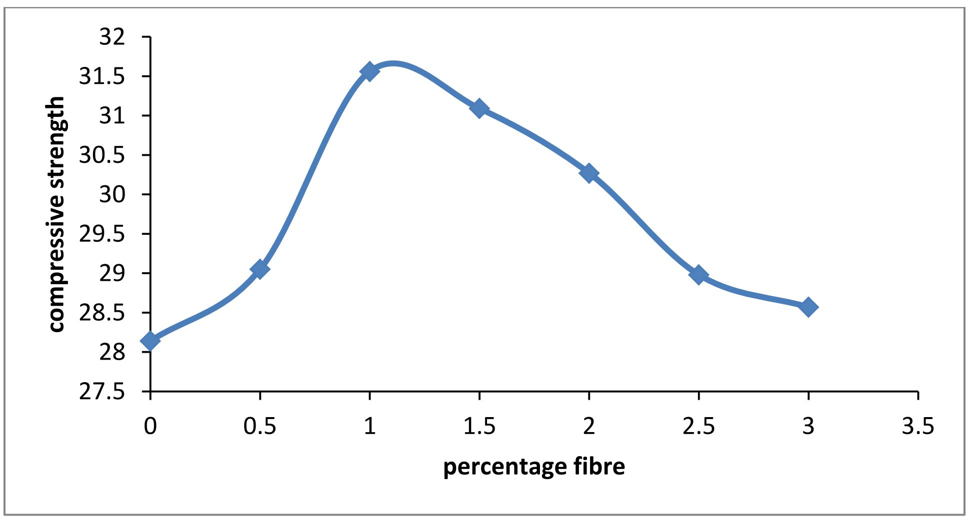

Fig 1. Compressive strength vs % of fibre for M25 design mix

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 cylinder increased by 3.23 % at 0.5 % fibre content, 12.15 % at 1 % fibre content, 10.48% at 1.5 % fibre content, 7.57 % at 2 % fibre content, 2.98 % at 2.5 % fibre content,1.53 % at 3% fibre content. The optimum dosage for maximum fibre content was 1 % giving compressive strength of 31.56 with 12.15% increase from control specimen. The minimum compressive strength was 28.57 with 1.52 % increase from control specimen.

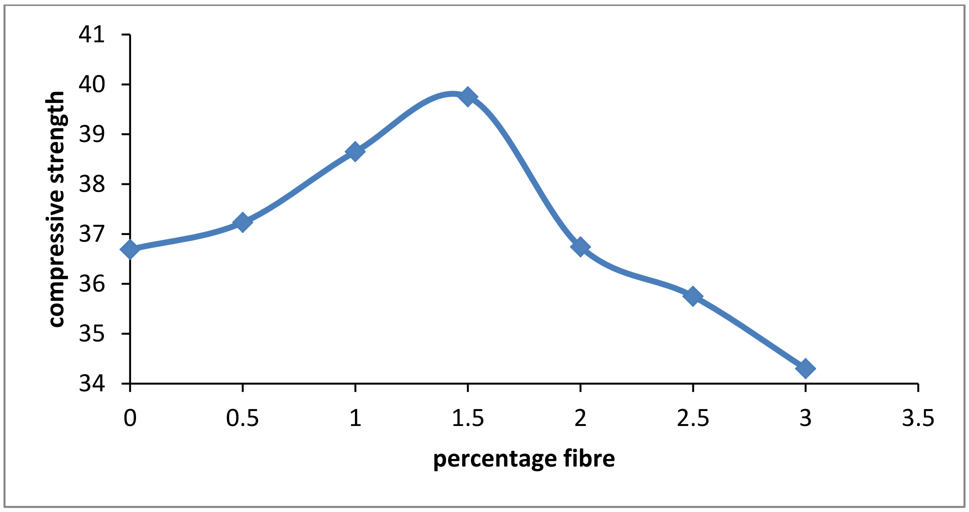

Fig 2. Compressive strength vs % of fibre for ***M30*** ***design mix***

The graph represents the compressive *strength of concrete cube* with 0-3% of Fibre to weight of cement. With the addition of fibre the compressive strength of concrete cylinder increased by 1.47 % at 0.5 % fibre content, 5.34 % at 1 % fibre content, 8.34% at 1.5 % fibre content, 0.32 % at 2 % fibre content and decrease by2.56 % at 2.5 % fibre content, 6.51 % at 3% fibre content. The optimum dosage for maximum fibre content was 1 % giving compressive strength of 35.75 with 8.34 % increase from control specimen. The minimum compressive strength was 34.3 with 6.51% decrease from control specimen at 3 %.

b. Comparison of cube compressive strength for standard concrete and percentage of fibre with different mixes (fig 3)

International Journal of Scientific Engineering and Applied Science (IJSEAS) - Volume-1, Issue-6, September 2015
ISSN: 2395-3470
www.ijseas.com

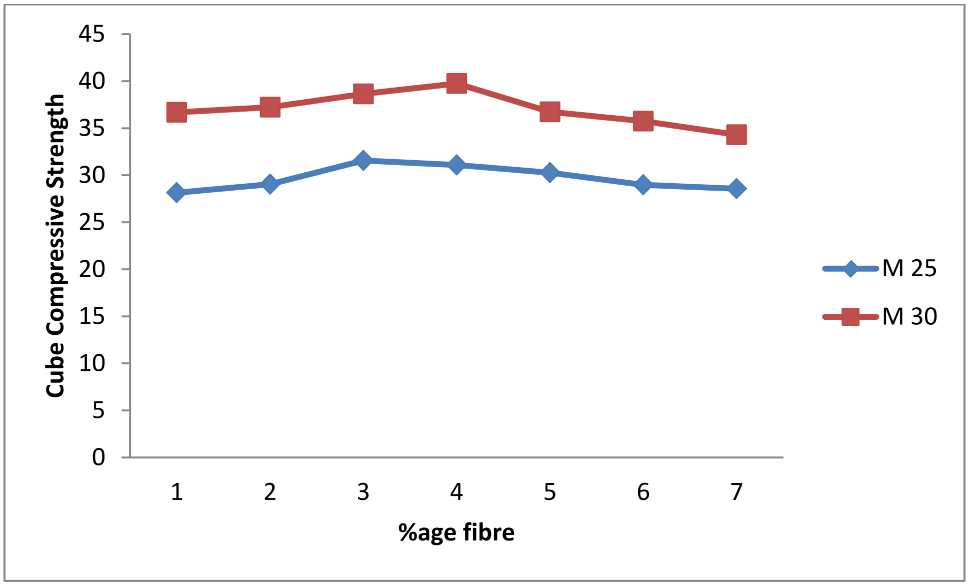

Fig 3. Comparative graph of cube compressive strength for M25 and M 30 mixes

The graph represents the comparative compressive strength M 25 & M 30 mix. The optimum dosage for M 25 and M 30 mixes was 1 %. The M 25 (25.31-33.89 MPa) and M 30 (31.7-42.97 MPa) mix concrete depicted a higher variation of strength variation with change of fibre content.

c. Tensile Strength of Cylinder vs percentage of Polypropylene Fibres

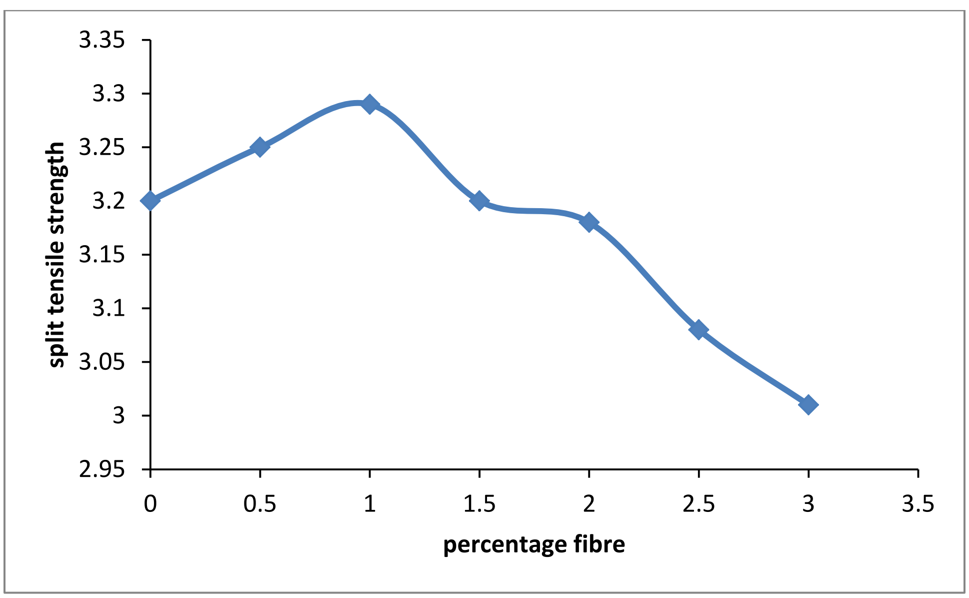

Fig 4. Split Tensile Strengthvs % Fibre for M 25 Design mix

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 1.56 % at 0.5 % fibre content, 2.81 % at 1 % fibre content, 0% at 1.5 % fibre content and decreased by 0.63 % at 2 % fibre content, 3.75 % at 2.5 % fibre content, 5.94 % 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.

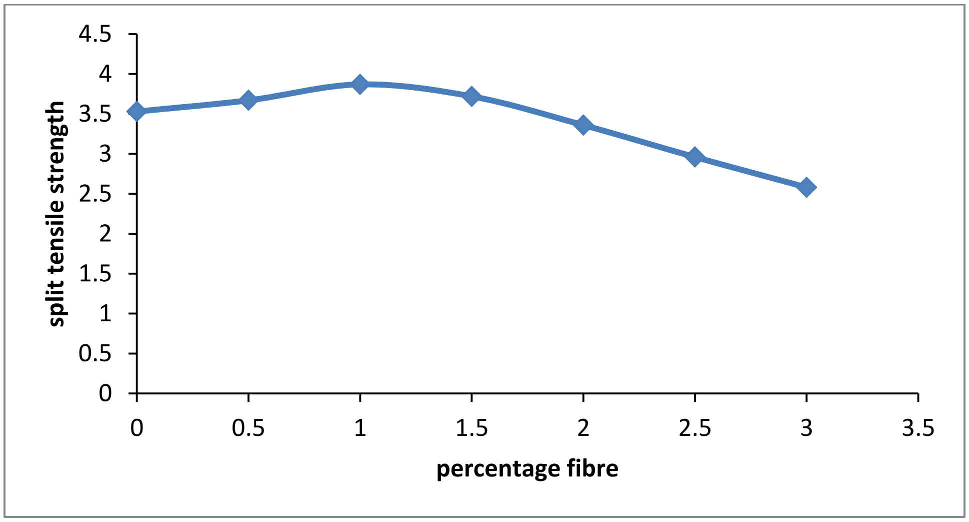

Fig 5. Split Tensile Strength vs % Fibre for M 30 Design mix

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 3.96 % at 0.5 % fibre content, 9.63 % at 1 % fibre content, 5.38% at 1.5 % fibre content and decreased by 4.81 % at 2 % fibre content, 16.14 % at 2.5 % fibre content, 26.91 % at 3% fibre content. The optimum dosage for maximum fibre content was 1 % giving tensile strength of 3.87 with 9.63 % increase from control specimen. The minimum tensile strength was 32.58 with 26.91 % decrease from control specimen.

d. Comparison of split tensile strength for standard concrete and percentage of fibre with different mixes

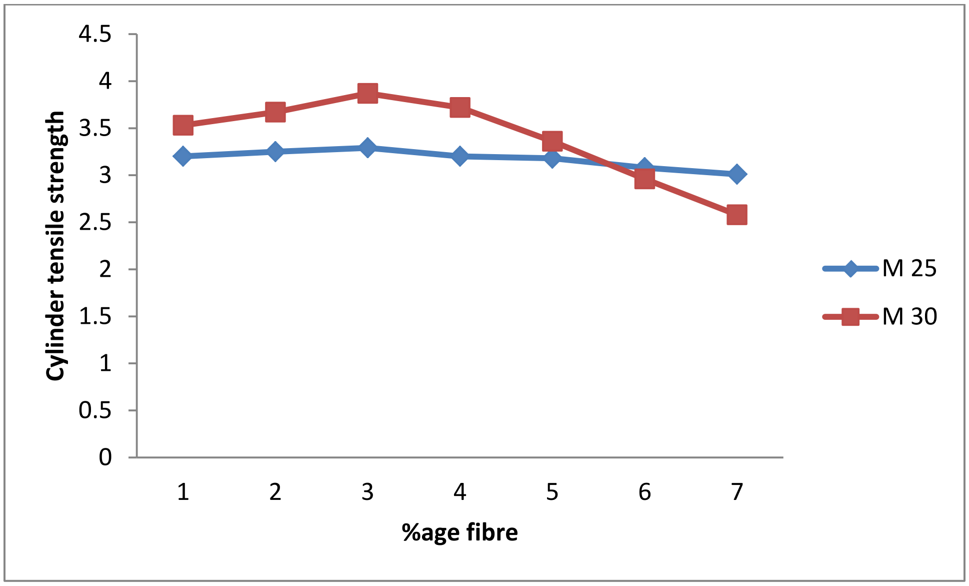

Fig 6. Comparative graph for tensile strength of M25 and M 30 mixes

The graph represents the split tensile strength vs percentage fibre for the concrete mixes viz. M 25 and M 30. The optimum dosage of fibre for M 25 and M 30 Mix is 1 %. The maximum strength loss due to fibre was 26 % depicted by M 30 mix at 3 % dosage.

4. Conclusion

- Inter comparison of compressive strength and tensile strength with fibre the maximum strength is achieved in M20 mix.
- So on an average to gain maximum compressive and tensile strength with mono-filament macro fibre the optimum dosage be limited 1%to 1.5%, after further increase these strength properties decreases.
- The comparison of compressive strength concludes that with increase in cement content the strength gain due to percentage of fibre decreases.
- The increase in cement content with increased percentage of fibre caused loss of strength even greater.
- 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.

- Secondly we can say that the fibres are acting as bridges between the concrete matrix to distribute the stresses uniformly thus making the whole matrix resist the deformation.
- The decreased amount of aggregates content in the concrete mix resulted in lesser bridging action moreover the increased cement content ratio could not bond with fibres as polypropylene fibres are hydrophobic and resulted in even loss of strength from cement bond resulting in strength loss of concrete matrix.
- Polypropylene fibre having non-polar nature and thus inhibits adhesion to concrete that can further improved by its surface treatment.
- Concrete reinforced with polypropylene mono-filament fiber may be used as secondary reinforcement but cannot replace the primary as the maximum strength gain is only 13 %.

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