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Research Article

Experimental Study on High Strength Concrete with partial replacement of fine aggregate using polypropylene steel fiber

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ABSTRACT

The present study is to investigates changes polypropylene used with various percentages such as 0%,0.5%,1%,1.5%,2%,2.5% in M25 grade of concrete. In this investigation, OPC 53 grade cement, fine and coarse aggregates were utilized. Further, the characteristics of each construction materials and polypropylene properties were determined under the laboratory tests. Afterwards, the specimens were constructed as per Indian standards then sent for seven days, fourteen days, and twenty-eight days curing, then the specimens were tested under the Tension, compression and flexural strength test. The attained maximum compression strength, tensile strength and flexural strength were 22.15N/mm2,3.81N/mm2,5.2 N/mm2, respectively. Finally, these highest strengths of polypropylene concrete, were achieved by 2.5% polypropylene used in concrete.

1. INTRODUCTION

Concrete composed of three basic components: cement, natural aggregates, and water. Portland cement is utilized in the majority of construction projects. Because of its brittle nature, concrete is weak in stress zones. with general, bleeding, plastic shrinkage, and fissures occur with pain concrete. Fibers are included to concrete compensate for these inadequacies [1]. Concrete is a prominent building material. The ductility of the concrete structural component is influenced by the spreading of fractures. Plain concrete had less split tensile strength, low flexibility, and no fracture resistance. Internal micro cracks are inherent in concrete, and their proliferation causes brittle disintegration in concrete. The typical reinforcing with high strength steel is the most commonly acknowledged solution to this flexural weakness of concrete. Techniques of restraint are also employed. Although these techniques give members tensile strength, they do not augment the intrinsic tensile strength of composite material [2]. Furthermore, ordinary concrete is not resistant to impact or tensile strains. As a result, traditional concrete, which can withstand compressive and shear loads, became a more common and extensively utilized construction material across the world. However, typical concrete does not perform as well when subjected to impact loads and has not addressed the durability limitations. By including a single kind of fibre into the concrete, the ductile and weak characteristics caused by tensile stress and impact loads may be avoided. As a result, the concrete consisting of fibre is known as Fibre Reinforced Concrete. Using fibre as secondary reinforcement provides less value to the concrete and does not totally achieve the aim. The inclusion of fibres incomposite concrete not only raises the required technical features, but also allows the concrete to be utilized as the best material for a wide range of applications. Since ancient times, fibres have been utilized to supply the TENSILE and flexural strength of composite material, and few academics also examined the influence that fibre has on various aspects of the concrete. Since then, numerous various types of fibres, including carbon, steel, glass, and polypropylene fibre, have been used in concrete. Concrete's brittleness and ductility are affected by the inclusion of fibre. These chemicals seeped into concrete structures through fractures, corroding them and causing deterioration, which has an impact on the structure's durability. Polypropylene Fiber is a thermoplastic polymer that, because of its thermoplastic nature, adds to adhesive force and can hold the concrete, reducing bleeding, shrinkage, and cracks. Fiber scattered in concrete forms a bridge across fissures, allowing for some ductility after cracking. Fiber reinforced concrete may endure significant stresses across a relatively high strain in the post-cracking condition if polypropylene fibers are used that are strong enough and form excellent connections with the material. Polypropylene fibers of various sorts can be used to strengthen concrete, reducing the formation of cracks. Polypropylene fibres increase various characteristics of the composite concrete, including tensile, flexural, toughness, and impact strength, as well as defining modes of failures. PP (Polypropylene)fibre is used for holds the concrete mix together, reducing the settlement of coarse aggregate and decreasing bleeding of the concrete, which indirectly reduces the pace of drying, resulting in reduced shrinkage. Polypropylene fibers resist fractures and offer strength as any

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other secondary reinforcement in hardened concrete. The fibers prevent cracks from propagating by holding the concrete together, preventing cracks from spreading wider or becoming longer. Polypropylene fibers, on the other hand, are effective near to where fractures begin at the aggregate paste interface because they are disseminated throughout the concrete [3].

Scopes and Objectives

- To minimize the impact load failure and provide an adequate resistance in concrete.
- To assess the fresh concrete workability.
- To decrease the formation of fractures caused by plastic shrinkage.
- Using polypropylene fibre to increase the various strengths of concrete.
- To mitigate the effects of liquefying, subfreezing, and burning in concrete.

2. BACKGROUND

Rani and Priyanka (2017) [4] conducted an experimental investigation employing polypropylene fiber to research the behavior of characteristics of the SCC (Self Compacting Concrete), including compressive and flexural strength. There was also a comparison of polypropylene fibers and traditional fibers. Depending on the test results,the highest quantity of the fiber in Self Compacting Concrete was0.75 percent to one percent of the entire cement content per mix.

Yeswanth et al., (2016) [5] the inclusion of fibers and fly ash, the influence of polypropylene fiber on composite concrete were examined. Different amounts of fiber (0%, 0.05 %, 0.1 %, 0.15 %, 0.2 %, 0.25 %, 0.30 %, 0.35 %, 0.40 %) were added to the volume of concrete, while different amounts of fly ash (0 percent, 10%, 20%, 30%, and 40%) were added to the volume of cement. The addition of PPF to concrete containing fly ash has been determined to have a small negative effect on the workability of the composite concrete; however, the inclusion of the polypropylene fiber (PPF) and fly ash improves the harden concrete strength. In comparison to conventional concrete there was also increase in cross-resistance.

Alsadey (2016) [6] The influence of PPF utilize on the properties of the, mortar was researched. An experiment was conducted on cement mortar reinforced with various amounts of polypropylene fiber, such as 0 %, 0.5 %, 1 %, and 1.5 %. On regular mortar and PPF reinforced mortar specimens, flow table tests and compressive strength at twenty-eight days were performed. Test findings demonstrate that the using of polypropylene concrete, hence the best PPF percentages have been considered.

Pansuriya1 and Shinkar (2016) [7] By adding polypropylene fibers to the mix at 0.5% to 2.5% with the interval 0.5% by weight of cement added to the composite concrete, the mechanical characteristics of the M30 grade composite concrete can be investigated. A comparison of regular concrete to fiber reinforced concrete in terms of compression, tensile and flexural tests has been done for the purposes of the analysis. In comparison to typical bituminous asphalts, cement is becoming a more appealing choice for base venture due to growing oil costs and a Tighter Monetary Climate. India's Ministry of Road Transport and Highways has recognized that a modern civilization cannot function effectively without concrete roadways. Cement has a number of flaws, including poor tensile strength, a short fatigue life, and brittle failure, which results in a near-complete loss of loading capacity once failure occurs.

Kumar (2016) [8] The characteristics of HFRC were investigated. HFRC (Hybrid fiber reinforced concrete) is a composite mixture made up of any two fibers in ordinary concrete that provides benefits from each added fiber and demonstrates substantial reaction. Steel fibers and polypropylene fibers are employed in this experiment. Concrete of M30 grade can be prepared in this thesis. Steel and polypropylene fibers are introduced in 50 percent increments, with hybridization ranging from 0% to 1.5 percent. The concrete specimens were casted and cured twenty-eight days before being tested in the lab for compression, Split Tensile, and Flexural tests. According to the findings, the strength parameters raise as the percentage of fiber, and a hybrid ratio of 1.5 percent provides efficient results when compared to the other ratio of hybrid fibers.

Mohod (2015) [9] influence of adding various quantities of polypropylene fibers to high strength concrete for M30 and M40 mixes on compression, split tensile and flexural strength under various curing conditions were revealed. This entails determining the optimum Polypropylene fiber content for high strength gain in concrete by altering the polypropylene fiber content from 0% to 0.5 %, 1 %, 1.5 %, and 2 %. The mechanical characteristics of concrete were investigated on concrete specimens at various ages. In this study, half of the concrete specimens were left to cure naturally in the environment, while the other half was cured in a curing tank.

Verma et al., (2015) [10] Effect of polypropylene fibers various from 0.1 to 0.4%, as well as steel fibers 0.8% on stress strain behavior of fiber concrete investigated. The results show that adding polypropylene fiber decrease the strain failure

as the volume percent of PPF raises. According to the research, polypropylene fibers with a larger percentage of polypropylene fiber have a better toughness.
[11] Khan et al., (2015) Investigate the behavior of PFRC under compressive and tensile loads in a comparative experimental investigation. Traditional concrete and PPF r/f concrete were tested for compressive strength and cylinder tensile strength. Concrete mixes with the M25 and M30 grades and polypropylene monofilament macro-fibers with a length of 35 mm at volume fraction of 2.5% and 3%. The following percentages were employed in the study:1%,1.5%,2.5%, and 3%. At a age of curing 28 days, all specimens were tested. This paper established and compared the bond between cube compression strength and cylinder tensile strength for the conventional and PFRC. A considerable increase in compressive and tensile strength was found in this study for concrete reinforced with polypropylene concrete. In compared to the others, the specimen samples with additional polypropylene fiber (PPF) of 1% and 1.5 percent produced better outcomes.
[12] Sathya Prabha and Rajasekar (2015) The bottom ash used as a good replacement for the fine aggregate in the composite concrete and Polypropylene fiber has also utilized to increase load resisting capacity of the concrete. The mix design of concrete is for M25 concrete grade. Concrete mix is designed for different percentages of sand replacement by bottom ash with 0.5 % PPF by total weight of the Cube: 0%, 10%, 20%, and 30%, respectively. When the mechanical properties of concrete were compared to a control mix, it was arrived that a 30 percent bottom ash and 1.0 percent polypropylene fiber combination produced the best results.
[13] Wenjie Ge Jiwen Zhang (2015) This research investigates the flexural behavior of hybrid concrete which is reinforced with the basalt fiber reinforced plastic bars and steel bars. split tensile test, and static flexural strength were carried out on five distinct hybrid reinforced concrete beams. When compared to steel bars, basalt fiber reinforced plastic bars have a higher split tensile strength and minimum modulus of elasticity. The strength relationship between the ribbed basalt fiber reinforced plastic bars and composite concrete comparable to steel bars of the equal diameter and bond performance appear to be satisfactory. The 8mm diameter steel bars have a small higher bond strength than steel bars with a diameter of ten millimeter. When AF/AS is properly managed, the ductility of hybrid reinforced concrete beams may fulfil the requirement.
[14] Milind V. Mohod (2015), researched PPF concrete. In this study conducted on M30 and M40 mixes with varying fibre percentages of 0%, 0.5%, 1%, and 2%. This study indicated that fibre concentrations of up to 0.5percent provide best strength like split tensile and flexural, compressive, and split directions.
[15] Dr. Hemant Sood (2017) in this research, varied proportions of granite powder (ten percent, twenty percent, thirty percent, and 0.25% polypropylene fiber by cement weight) were inclusion to M45b concrete. The study observed a 20% substitution of sand with granite powder yields the best compressive strength value.
[16] Chaitra Patil (2017) In this experiment, utilized 1percent polypropylene fiber with various quantities of manufactured sand (0%, 20%, 40%, 60%, 80%, and 100%) as a partial substitution for sand. The experiment was carried out on M30 concrete mix and determined that using one percent PPF and 20% manufacturer's percentage gives the best value for compressive tensile and flexural strength
[18] Hanish Dhiman (2018), In this research investigation utilized 1% PP fibre with various quantities of manufactured sand (0%, 20%, 40%, 60%, 80%, and 100%) as a partial replacement for fine aggregate. The experiment was carried out on M30 grade concrete determined that using 1% polypropylene gives the best results in compression, tensile and flexural strength tests
Tamanna (2018) Ceramic waste tile was employed as coarse aggregate in this study work, and OPC forty three grade cement was utilized. Ceramic waste tile was used to substitute coarse aggregate at 10%, 20%, 30%, and 40%. Sikka plast is used as an additive (a water reducer in concrete). The research was carried out for compression, tensile, and the results suggest that using up to twenty percentage ceramic tile waste as coarse aggregate delivers the best strength for M40 concrete mix.
Rinu Isha RJ (2017) In this experimental investigation, varying proportions of ceramic tile waste (0%, 10%, 20%, 30%, 40%, and 50%) wer substituted as coarse aggregate and twenty percentage acrylic polymer was included to M30 grade concrete. This study indicated that using 20% ceramic tile waste as coarse aggregate produces better results than standard concrete for compression, tensile and flexural strength test.
Skhaviy (2017) I researched discarded ceramic tile utilized in the concrete industry. Sand partially substituted in this study with waste ceramic tiles in varying proportions of 25%, 30%, and 35% for the concrete mix. This research concluded that with 30% substitution of ceramic waste as natural aggregate, the compression strength and tensile strength were higher than in ordinary concrete.

3. MATERIALS AND METHODS

3.1 Cement

The Fifty three grade OPC was utilized as per IS 269-1976.The general characteristics of the cement was shown in table 1.

TABLE I. CHATACTERISTICS OF CEMENT

Properties	Value
Compressive strength (Mpa)	53
Sp. gravity	3.15
Setting time (initial)	30minutes
Final setting time	600 minutes

3.2 Fine Aggregate

The river sand used as a fine aggregate in this experimental investigation. According to the sieve analysis and comparison with the grading chart IS 383-1970, chart 3.2, the sand utilised corresponds to zone-III. The parameters of the fine aggregate are shown in Table 2.

TABLE II. CHATACTERISTICS OF SAND

Properties	Value
Finess Modulus	2.39
Sp.gravity	2.60
Size	Passing through 4.75mm sieve
Water absorption ratio	1%
Sand zone	II

3.3 Coarse Aggregate

Table 3 shows the coarse aggregate qualities.

TABLE III. CHATACTERISTICS OF COARSE AGGREGATE

properties	Value
Specific gravity	2.64
Size	Passing through 16mm sieve and and retaining in 12.5mm sieve
Water absorption ratio	1%

3.4 Polypropylene Fiber

The 6.2mm length monofilament polypropylene fiber was used for this investigation. Table 4 provides a property of polypropylene fiber.

TABLE IV. CHATACTERISTICS OF POLYPROPYLENE FIBER

properties	Value
Diameter of the Fiber(mm)	0.045
Length of the Fiber(mm)	6.2
Aspect Ratio(I/D)	139.3
Tensile strength	308
Sp.gravity	1.3

3.5 Water

The potable water used for manufacturing the specimen

3.6 Mix Design

The below table shows on the mix proportion for the M25 grade of concrete.

TABLE V. MIX PROPORTION OF THE M25 GRADE CONCREATE

Water	Cement	Fine Aggregate	Coarse aggregate
200.85 kg/m^3	669.5 kg/m^3	285 kg/m^3	1160 kg/m^3
0.30	1	0.42	1.73

TABLE VI. REPLACEMENT OF CEMENT BY POLYPROPYLENE FIBER

Replacement (%)	**Quantity (kg/m^3)**
0.5	3.34
1	6.69
1.5	10.04
2.0	13.39
2.5	16.73

4. EXPERIMENTAL WORK

4.1 Compressive Strength Test

Both specimens of size 150mmX150mmX150mm were casted M25 grade of concrete for compression testing. Polypropylene fibres were used to fill the moulds. After twenty-four hours, both specimens were remolded and moved to the curing process, for seven days, fourteen days, and twenty-eight days. Then seven, fourteen-, and twenty-eight-days curing, these specimens were examined on compressive strength testing machine in accordance with I.S. 516-1959. The failure load was recorded. Three specimens evaluated in each category, and ttheir compressive strength were presented in table 7.

The compression strength of the specimen was computed as follows:

$$\textit{Compressive strength (MPa)} = \textit{Failure load / cross sectional (C.S) area}. \quad (1)$$

Fig.1. Compression Test

TABLE VII. COMPRESSIVE STRENGTH TEST RESULTS

Grade of concrete	**%Replacement**	**Type of concrete**	**Compressive strength (N/mm^2)**		
			7(days)	**14(days)**	**28 (days)**
M_{25}	2.5%	CC	13.5	16.9	18.89
		PFC	16.52	19.8	22.15

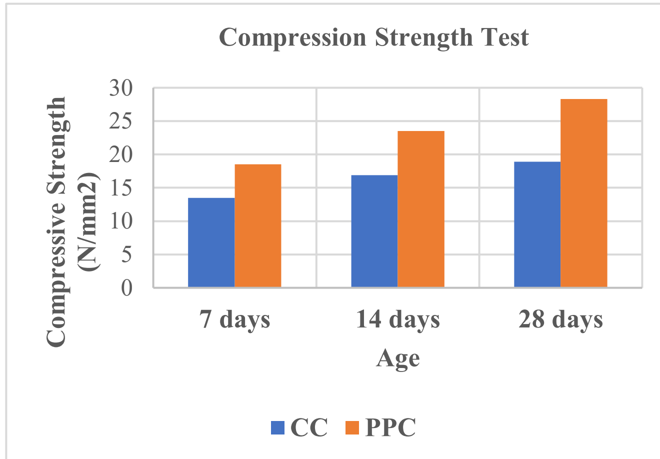

Fig.2. Compression Test Results

4.2 Split Tensile Test

A Universal Testing equipment is used to measure it on concrete cylinders of uniform size. The average value was determined after testing both conventional and fibre reinforced specimens at varied amounts of fibre. Split tensile test 3 shows that after fourteen and twenty eight days of curing, the tensile strength of the concrete mixture improves by PFC. The inclusion of fibres to the concrete mix significantly increases the split tensile strength. When compared to mono fibres, polypropylene fibres significantly enhance split tensile strength.

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Fig.3. Split tensile Test

TABLE VIII. TEST RESULTS OF THE SPLIT TENSILE STRENGTH

Grade of concrete	%Replacement	Type of concrete	Split tensile strength (N/mm^2)		
			7 days	14 days	28 days
M_{25}	2.5%	CC	1.05	1.23	2.17
		PFC	1.2	2.61	3.81

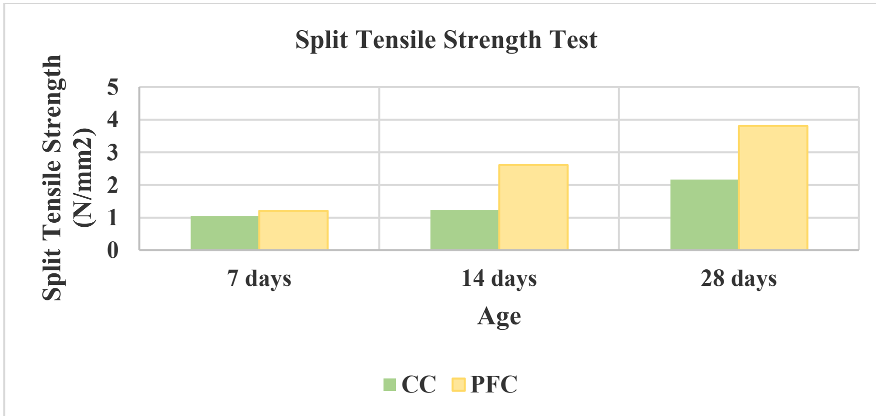

Fig.4. Split Tensile Test Results

4.3 Flexural Strength Test

Flexural strength test used to evaluate the bending property of the concrete. It comprises place a beam specimen between the two supports and applying a load using two-point loads. The maximum stress and strain were based on the increasing the loads. The results are given graphical representation, with tabular data containing the flexural strength and yield strength.

TABLE IX. FLEXURAL STRENGTH TEST RESULTS

Grade of concrete	%Replacement	Type of concrete	Flexural strength (N/mm2)		
			7 days	14 days	28 days
M_{25}	2.5%	CC	1.95	2.19	2.98
		PFC	3.8	4.4	5.2

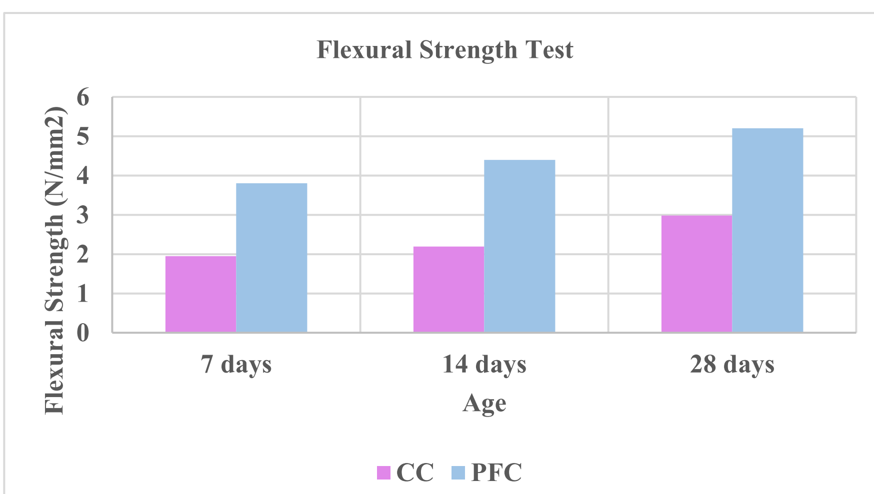

Fig.5. Flexural Strength Test Results

5 CONCLUSION

The different test on concrete was done for different conditions like control curing & irregular condition, from this it has been seen that for the irregular condition initially have more compressive strength than control curing condition but as the days advances it loses its strength or do not give satisfactory strength as compare to curing condition. Hence for a better strength we may conclude that the curing is an essential parameter.

Polypropylene fibers (PPF) can reduce early age shrinkage and moisture loss in concrete mix, even when used in low volume fractions. However, the use of fiber in concrete decreases its workability, as evidenced by the standard slump test results. High volume dosage rates above 1.5% result in stiff and difficult-to-compact concrete, but reduce bleeding and segregation. The loss in weight and compressive strength of cube specimens improves with age, with a compression strength increase up to 2.5%. Tensile strength only improves by 2.5% in splitting tensile strength tests. The improvement in flexure strength due to PPF is similar to tensile strength. As the construction industry faces new challenges, PPFC could be a suitable substitute to meet these needs. Currently, new types of concrete are being invented to address the problems observed in traditional concrete.

Conflicts of Interest

The authors declare that they have no conflict of interest regarding the publication of this paper.

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