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STUDY OF MECHANICAL PROPERTIES OF CONCRETE USING SYNTHETIC AND STEEL FIBER

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ABSTRACT

Fiber reinforce concrete is a family of composite materials that combine the high compressive strength properties of cement mortars with significantly increased impact, flexural and tensile strengths imparted by the fiber reinforcement The aim of this study is to investigate the effect of variation of synthetic fibers i.e polypropylene fibres ranging from 0.1% to 0.5% along with 0.9% steel fibres on the behaviour of concrete. The experimental investigation is carried out with 60 Nos. of fibre based reinforced concrete cubes, 60 nos. of fibre based reinforced concrete cylinder & 60 Nos. of fibre based reinforced concrete beams, having overall dimensions (L x B x D) as 150 x 150 x 150 mm for cubes, for cylinder (L x D) as (300 x 150 mm) & for beams (L x B x D) as 500 x 100 x 100 mm. The experimental results shows that there is little variation in the compressive strength of concrete, but there is increase in tensile strength and flexural strength with the increase in fiber percentage. Steel-Synthetic fibre reinforced concrete showed increase in flexural strength when compared with steel fibre reinforced concrete.

KEYWORDS: Polypropylene fiber (PPF), Fiber Reinforced concrete (FRC), Polypropylene Fiber Reinforced Concrete (PFRC), Steel Fiber Reinforced Concrete (SFRC)

INTRODUCTION

Concrete is acknowledged to be a relatively brittle material when subjected to normal stresses and impact loads, whose tensile strength is only approximately one tenth of its compressive strength. As a result for these characteristics, concrete member could not support such loads and stresses that usually take place in majority of concrete structures. Historically, concrete members reinforced with continuous reinforcing bars can withstand tensile stresses and compensate for the lack of ductility and strength. The addition of steel reinforcement significantly increases the strength of concrete members. Moreover, it is desired to produce a concrete with homogeneous tensile properties which is equipped with better micro-crack arresting mechanism. The introduction of fibers was brought in as a solution to develop concrete with enhanced flexural and tensile strength. Fibers are most generally discontinuous, randomly distributed throughout the cements matrices. Fibers used as reinforcement, can be effective in arresting cracks at both micro-level as well as in macro-levels. At the micro-level, fibers inhibit the initiation and growth of cracks and after the micro-cracks coalesce into macro-cracks, fibers provide mechanisms that abate their unstable propagation, provide effective bridging, and impart sources of strength gain, toughness and ductility. A multifilament polypropylene fiber and steel fiber has been used in this study. The fibers are added into the concrete with different volume fraction of polypropylene fiber and a constant amount of steel fiber. Objective of the study mainly lies on effective use of the fibers into concrete to enhance its flexural properties along with tensile strength, toughness and cracking behavior, so as to use in construction of various structural

members. The use of a polypropylene fiber and steel fiber at relatively low volume fractions provides concrete with improved performance characteristics at reasonable cost. Steel and Polypropylene fiber reinforcement is considered to be an effective method for improving the structural strength, reduce steel reinforcement required, shrinkage cracking characteristics, toughness and impact resistance of concrete materials. The steel fibers have high elastic modulus and stiffness so they can improve compressive and tensile strength as well as toughness of the concrete. On the other hand, the polypropylene fibers have good ductility, fineness, and dispersion so they can restrain the plastic cracks. Therefore, proper mixture of these two complementary fibers can make better mechanical properties of concrete. The shape, geometry and mechanical properties and dispersion of fibers in the cementations' matrix greatly influence the FRC. Furthermore, fibers that have large values of failure strain will tend to have better ductility. However, different types of fibers can be used in the concrete composites depending to the needs.

Steel Fiber

Polypropylene Fiber

EXPERIMENTAL SET UP

Materials

A) Cement: The cement used was Ordinary Portland cement of 43 Grade available in local market. The cement used has been tested for various properties as per IS: 4031 and found to be confirming to various specifications of I.S 8112- 1989. The specific gravity of cement was 3.14, initial and final settings of OPC 43 grade cement was 65 min and 285 min and Compressive strength of 7 & 28 days is 34.2N/mm^2 and 49N/mm^2 respectivly.

B) Aggregate: Aggregates give body to the concrete, reduce shrinkage effect and make concrete economical. The aggregates occupy around 75% of the volume of concrete, which dominate various characteristics of concrete. Therefore, one of the major contributing factors to the quality of concrete is the quality of the aggregates. In this study only the vital parameters of aggregates have been studied as per the procedures laid down in IS: 2386 (Part 1-8) for testing of aggregates for concrete**.** Table 1 Table 2 specifies the experimental values of fine aggregate, coarse aggregate (20mm & 10mm).

Table 1: Physical Properties of Fine Aggregate

S.No	Characteristics	Requirement as per IS 383 : 1970	Tested Values
1.	Specific Gravity	2.6-2.7	2.65
2.	Fineness Modulus	2-3.5	3.033
3.	Water Absorption (%)	-	1.76
4.	Moisture Content (%)	-	0.50
5.	Grading	-	Zone II(IS 383-1970)

Table 2: Physical Properties of Coarse Aggregate

S.No	Characteristics	Requirement as per IS 383 : 1970	Tested Values
1.	Specific Gravity	2.6-2.7	2.68
2.	Fineness Modulus	5.5-8	6.55
3.	Water Absorption (%)	-	0.50
4.	Moisture Content (%)	-	Nil
5.	Texture	-	Rough

C) Polypropylene Fiber: Polypropylene fibers were used in present study which was provided by the FORTA Corporation. It offers good bonding power; enhance mechanical properties, long term durability, and true secondary temperature control. These are non corrosive, chemically inert, and 100% alkali proof. The physical properties of polypropylene fibers are given in Table 3

Table 3: Properties of Polypropylene Fiber

Properties	Forta Ferro Multifilament Fiber
Form	Twisted bundle multifilament Fiber
Specific gravity	0.90
Tensile strength (MPa)	680
Modulus of elasticity (GPa)	5.8
Length (mm)	54.0
Aspect ratio	158.8

D). Steel Fiber: Steel fibers were used in present study which was provided by the DURAFLEX steel fibers. It improves structural strength, reduce steel reinforcement requirement, reduce crack width, and improve crack and abrasion resistance. The physical properties of steel fibers are given in Table 4

Table 4: Properties of Steel Fiber

Properties	Duraflex Steel Fiber
Form	Crimped shape steel fiber
Tensile strength (MPa)	1015
Diameter (mm)	0.51
Length (mm)	31
Aspect ratio	60.78

MIX PROPOTION

Concrete mix proportioning is in fact a process of selecting suitably ingredient of concrete and determining their relative quantities with object of producing, as economically as possible, concrete of certain minimum desired properties, strength and durability etc. Proportions for the mix adopted for this study has been given in the Table 5.

Table 5: Mix Proportion for One Cubic Meter of Concrete for M30 Concrete Mix with Steel and Synthetic Fiber

S.No.	Constituent	Quantities
1	Cement (kg)	426.79
2	Fine aggregate (kg)	568.4
3	Coarse aggregate (kg)	1205
4	Water (Lit.)	197.16
5	w/c ratio	0.46
6	Proportion **C : FA : CA**	**1 : 1.33 : 2.82**
7	Polypropylene fiber percentage by weight of cement	0.1%,0.2%,0.3%,0.4%,0.5%
8	Steel Fiber Percentage by volume of concrete	0.9%

EXPEREMENT METHOLOGY

60 Nos of Cubes of standard size 150 mm x 150 mm x 150 mm length conforming to IS-10086 (1982) were cast for testing the compressive strength. 60 Nos Cylinders of standard size 150mm diameter and 300mm height were casted for testing split tensile test. Prismatic test samples with rectangular cross section of 100 mm x 100 mm x 500 mm were cast for evaluating the flexural tensile strength.

EXPERIMENTAL RESULTS AND DISCUSSION

Compressive Strength Test

The Compressive strength of casted cubes of size 150mm x 150mm is tested in Compression testing machine at 7 day and 28th day from the date of casting. Table 6 shows the results of cube compression strength.

Table 6: Compressive Strength Test Result at 07 Day and 28 Day

S. No	Percentage of polypropylene Fiber along with 0.9% Steel Fiber	Compressive Strength(N/mm^2) at 07 days	Compressive Strength(N/mm^2) at 28 Days
1	0%+0.9%	27.8	39.77
2	0.1%+0.9%	28.33	40.24
3	0.2%+0.9%	29.68	41.77
4	0.3%+0.9%	28.76	41.35
5	0.4%+0.9%	28.22	40.66
6	0.5%+0.9%	26.75	38.66

From the above results it observed that the addition of the polypropylene fiber in the control mix has a little effect on the compressive strength. It is observed that the use of fibers increases the compressive strength of concrete when the polypropylene fibers were upto 0.2% and then reduction in compressive strength is observed. An increase in 7.5% in compressive strength occurs when the percentage of polypropylene fiber increases upto 0.2%. The decrease in compressive strength is observed when percentage of fibers increases beyond 0.2%. The increase in the compressive strength is due to the increase in bonding effect of fiber with matrix. With the increase in percentage volume of fiber beyond its optimum value (which is 0.2% in present case) compressive strength decreases, this is due to the increase in interference of fiber with each other. This will produce internal voids in concrete mix which leads to decrease the total density of mix and thereby decrease the compressive strength of the mix.Figure1.shows the variation of compressive strength results at 7 and 28 day with percentage of polypropylene fiber.

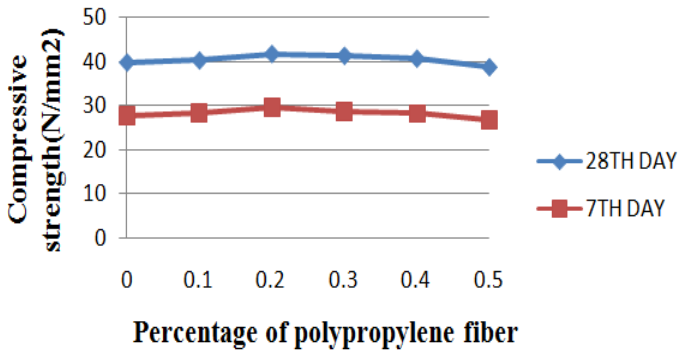

Figure 1: Compressive Strength at 7 and 28 Days v/s Percentage of Polypropylene Fiber

FLEXURAL STRENGTH TEST

Flexural strength of a concrete is a measure of its ability to resist bending. Flexural strength can be expressed in terms of 'modulus of rupture. The Prismatic specimen of dimension 100x100x500mm specimen was made and tested in flexural testing machine on 7 day and 28 day. Table 7. shows the test results of flexural strength at 7 day and 28 day.

Table 7: Flexural Strength Test Result at 07 Day and 28 Day

S. No.	Percentage of polypropylene Fiber Along with 0.9% Steel Fiber	Flexural Strength(N/mm^2) at 7 Day	Flexural Strength(N/mm^2) at 28 day
1	0%+0.9%	3.4	5.04
2	0.1%+0.9%	3.75	5.56
3	0.2%+0.9%	4.08	6.00
4	0.3%+0.9%	4.6	6.76
5	0.4%+0.9%	5.12	7.36
6	0.5%+0.9%	4.12	6.16

It is observed that with the increase in polypropylene fiber, the flexural strength increases. However, it is noticed that the rate of increase of flexural strength is more as compared to compressive strength. The results show that optimum dosage for flexure is 0.4% of polypropylene fiber along with 0.9% of steel fiber. The above results show that flexural strength increases with increase in fiber volume fraction; this is due to the additional load taken by the fibers present in the matrix. However, after increasing the volume percentage of polypropylene fiber beyond the optimum value (0.4%) improper mixing of fibers with the matrix takes place due to balling effect of fiber, this increases the amount of vibrations required to remove air voids from the mix which in turn causes the problem of bleeding and decreases flexural strength of the mix. The failure pattern of plain and hybrid fibrous concrete in flexural strength test shows that fibrous concrete are more ductile as compared to plain concrete. This is because when the matrix cracked, the load was transferred from the composite to the fibers at the crack surfaces, which prevents the brittle failure of the composite. Figure2.shows the variation of Flexural strength results at 7 and 28 day with percentage of polypropylene fiber.

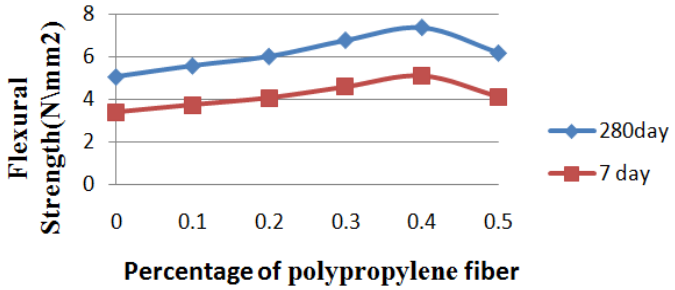

Figure 2: Flexural Tensile Strength at7 and 28 Days v/s Percentage of Polypropylene Fiber

TENSILE STRENGTH TEST

In Split tensile test, a specimen was loaded in a compression on its side along a diameter plane. Failure occurs by the splitting of the cylinder along the load plane. The Cylendrical specimen of dimension 150mm diameter and 300mm height specimen was made and tested in compression testing machine on 7 day and 28 day. Table 8. shows the test results of tensile strength at 7day and 28 day.

Table 8: Test Results for Split Tensile Strength at 07 Day and 28 Day

S. No	Percentage of Polypropylene Fiber Along with 0.9% Steel Fiber	Split Tensile Strength(N/mm^2) at 07 Day	Split Tensile Strength(N/mm^2) at 28 Day
1	0%+0.9%	2.34	3.44
2	0.1%+0.9%	2.49	3.91
3	0.2%+0.9%	2.83	4.54
4	0.3%+0.9%	2.97	4.81
5	0.4%+0.9%	3.61	5.20
6	0.5%+0.9%	2.76	4.04

It is noted that with the increase in the polypropylene fibers upto 0.4% the split tension strength increases. The above results shows that split tensile strength increases with increase in fiber volume fraction, because of the holding capacity of the fibers which helps in preventing the splitting of concrete. However, after increasing the volume percentage of polypropylene fiber beyond the optimum value (0.4%) improper mixing of fibers with the matrix takes place due to balling effect of fiber, this increases the amount of vibrations required to remove air voids from the mix which in turn causes the problem of bleeding and decreases split tensile strength of the mix. Figure3.shows the variation of Tensile strength results at 7 and 28 day with percentage of polypropylene fiber.

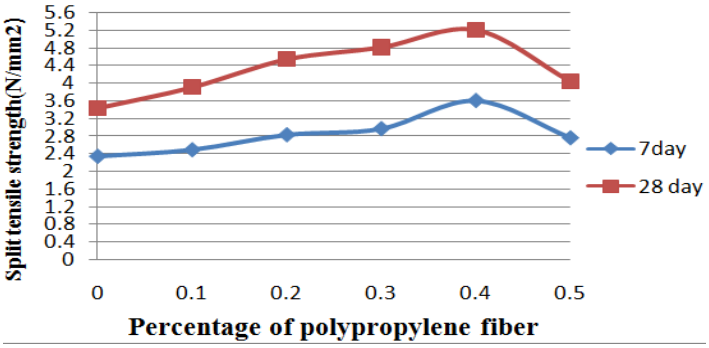

Figure 2: Split Tensile Strength at7 and 28 Days v/s Percentage of Polypropylene Fiber

CONCLUSIONS

Based on experimental investigation and analysis of results obtained, the following conclusions may be drawn broadly

- Steel-polypropylene mix shows a slight increase in the compressive strength as compared with the plain concrete. Hybrid (steel + polypropylene) fiber showed about 5.7% increase in compressive strength. It is observed that polypropylene fiber have not contributed significantly towards compressive strength.
- The maximum gain in compressive strength was achieved for 0.2% polypropylene fiber. Thereafter increase in fiber content has marginally reduced the compressive strength.
- Hybrid FRC (steel + polypropylene) shows an increase in split tensile strength as compared to the plain concrete. Fiber reinforced concrete mix showed a considerable increase of about 43% in split tensile strength.
- The maximum gain in split tensile strength was achieved for 0.4% polypropylene fiber. Thereafter increase in fiber content has marginally reduced the split tensile strength.

- Steel-polypropylene fiber reinforced concrete showed increase in flexural strength when compared with steel fiber reinforced concrete. The maximum gain in flexural strength was achieved for 0.4% polypropylene fiber. Thereafter increase in fiber content has marginally reduced the flexural strength.
- From the present study it is observed that the optimum dosage of polypropylene fiber fraction is 0.4%.

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