Test on the Behaviour of Hybrid Fiber Reinforced Concrete

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Abstract
. Now-a-days, many research works on fiber reinforced concrete are being carried out to enhance the properties of normal concrete.. Fibers are widely used as one of the construction material for many centuries. Fibers are made from steel, plastic, glass and natural materials that are available in variety of shapes, sizes and thickness. A study has been proposed to be conducted in laboratory to investigate the engineering properties of fiber reinforced concrete by using mixture of steel and polypropylene fibers in a hybrid mannerThe main aim of the present study is to investigate the effect of inclusion of hybrid fibers (i.e. various volume fractions of polypropylene fibers ranging from 0.2% to 0.4% at the increment of 1% along with a constant volume fraction of 1% of steel fibers) on the strength and behaviour of M30 grade concrete. In this study the strength of hybrid steel and polypropylene fibrous concrete cubes, cylinders and beams were investigated using M30 grade concrete. Cube size of 150mm x 150mm x 150mm and the cylinder size of 150mm x 300mm were cast and tested for compressive and split tensile strengths. Beam size of 100mm x 150mm x 1500mm were cast and tested for strength and flexural behavior under two point monotonic loading. The test result indicated that the inclusion of hybrid steel and polypropylene fibers in concrete improved the compressive and tensile strength of concrete markedly. Also the flexural behaviour of concrete beams reinforced with hybrid steel and polypropylene fibers are presented and discussed in this thesis.

I. INTRODUCTION

A. General

Concrete is one of the most popular materials used in construction. Fragility of concrete remains a handicap of its mechanical behaviour. As concrete begins to lose volume, the restrained inhibits movements, which then induces tensile stress in concrete. Once the tensile strength has been exceeded, it will crack. Uniform distribution of fibers throughout the concrete discourages the development of large capillaries caused by bleed water migration to the surface. Fiber reinforced concrete is less likely to crack than standard concrete. The use of fiber can enhance mechanical performances as reinforcement in a cement based matrix has shown to be a promising opportunity. Fibers are long standard of molecules interwoven to form a linear, string like structures. The use of fibers in concrete become more and more a current practice in rehabilitation of structures and the applications are more and more developed. In the recent years, a great deal of interest has been created worldwide on the potential applications of fiber reinforced concrete composites. Investigations have been carried out in many countries on various mechanical properties, physical performance and durability of cement based matrices reinforced with fibers such as polymers, polypropylenes, coir, sisal etc. This fiber reinforced mortar has been reported to have better properties than plain mortar. The main objective of using fiber as an additive in concrete is to improve tensile strength and flexural strength. It also helps to limits and controls the cracks and improves the shock resistance.

B. Fiber

Fiber is a small piece of reinforcing material possessing certain characteristic propertiesThey can be circular or flat. The fiber is often described by a convenientparameter called “aspect ratio”.The aspect ratio of the fiber is the ratio of its lengthto its diameter. Typical aspect ranges from 30 to 150.

1) Types of Fibers

Fibers are produced from different materials in various shapes and sizes. Typical fiber materials are,

Steel Fibers

Straight, crimped, twisted, hooked, ringed, and paddled ends. Diameter range from 0.25 to 0.76mm.

Polypropylene Fibers

Plain, twisted, fibrillated, and with buttoned ends.

2) *Effect of fibers in concrete*

Fibers are usually used in concrete to control cracking due to plastic shrinkage and to drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibers produce greater impact,abrasion, and shatter–resistance in concrete. Generally fibers do not increase the flexural strength of concrete, and so cannot replace moment–resisting or structural steel reinforcement. Indeed, some fibers actually reduce the strength of concrete.

The amount of fibers added to a concrete mix is expressed as a percentage ofthe total volume of the composite (concrete and fibers), termed "volume fraction" (Vf). Vf typically ranges from 0.1 to 3%. The aspect ratio (l/d) is calculated by dividing fiber length (l) by its diameter (d). Fibers with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. If the fiber's modulus of elasticity is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. Increasing the aspect ratio of the fiber usually segments the flexural strength and toughness of the matrix. However, fibers that are too long tend to "ball" in the mix and create workability problems.

C. *Fiber Reinforced Concrete*

Fibers have been used in construction material for many centuries. The lastthree decades have seen a growing interest in the use of fibers in ready mixed concrete, precast concrete and shorcrete. Fiber reinforced concrete is a composite material consisting of hydraulic cement, sand, coarse aggregate, water and fibers. In this composite material short discrete fibers randomly distributed throughout the concrete mass. The behavior and efficiency of this composite material is far superior to that of plain concrete and many of other construction material of equal cost. Due to this benefit, the use of fiber reinforced concrete had steadily increased during last three decades and its current field ofapplication includes airport andhighway pavements, earth-quake resistant and explosive resistant structures, minesand tunnel linings, bridge deck overlays, hydraulic structures and rock slope stabilization. Extensive fiber reinforcement is done by using different type of fibers such as glass, carbon, polypropylene, coir, sisal etc.

Structural Behaviour of FRC

Fibers combined with reinforcing bars in structural members will be widelyused in the future. The following are some of the structural behaviour

1) *Flexure*

The use of fibers in reinforced concrete flexure members increasesductility, tensile strength, moment capacity, and stiffness. The fibers improve crack control and preserve post cracking structural integrity of member.

2) *Torsion*

The use of fibers eliminates the sudden failure characteristic of plain concrete beams. It increases stiffness, tensional strength, ductility,rotational capacity, and the number of cracks with less crack width.

3) *Shear*

Addition of fibers increases shear capacity of reinforced concretebeams up to 100 percent. Addition of randomly distributed fibersincreases shear-friction strength, the first crack strength, and ultimate strength.

4) *Column*

The increase of fiber content slightly increases the ductility of axiallyloaded specimen. The use of fibers helps in reducing the explosive type failure for columns.

5) *High Strength Concrete*

Fibers increase the ductility of high strength concrete. The use of highstrength concrete and steel produces slender members. Fiber addition will help in controlling cracks and deflections.

6) *Cracking and Deflection*

Fiber reinforcement effectively controls cracking and deflection, inaddition to strength improvement. In conventionally reinforced concrete beams, fiber addition increases stiffness, and reduces deflection.

II. MATERIALS AND PROPERTIES

A. *General*

This chapter will explain in detail about the materials and tests that will be conducted in this study. It also included explanation about materials will be used, and also the methods to determine the engineering properties of reinforced concrete studied. This chapter also will give us a clear picture about this study and shows how to achieve the objective of the study.

In the primary stage the data was collected from the researches and fromother resources such as journals, research papers, book, symposium papers, articles, magazines and also from the internet. Other than that is including the resources from discussion to improve the knowledge about the topic.

B. *Materials Used*

1) Cement

Ordinary Portland cement of 53 Grade was used for casting all thespecimens. To produce a high strength concrete, the usage of high strength cements is necessary. The selection of brand and type of cement is the most important to produce a good quality concrete. Different types of cement needs different quantities of water to produce pastes of standard consistence. Different types of cement also will produce concrete have a different rates of strength development. The type of cement affects the rate of hydration, so that the strengths at early ages can be considerably influenced by the particular cement used. It is also important to ensure compatibility of the chemical and mineral admixtures with cement

2) Polypropylene Fiber

Fig. 3.1 shows the crimpled steel fibers used in this study. The fibers were purchased from M/S. MJ suppliers, Madurai. The properties of polypropylene fibers are given in Table 3.12.

Fig. 2.1: Polypropylene fiber

Table 2.12: Properties of polypropylene fiber

SI.NO	NAME OF THE PROPERTIES	PROPERTIES PROVIDED
1	Material	Virgin synthetic polypropylene fibers
2	Length	3,4,5,12,15,18,20,24,26,40,110 mm
3	Form	Mono Filament
4	Dispersion	Excellent
5	Color	Brilliant white
6	Melt point	1600C
7	Specific gravity	0.91
8	Alkali resistance	Very good
9	Absorption	Nil
10	UV Stability	Excellent

3) Steel Fiber

Fig. 3.2 shows the crimpled steel fibers used in this study. The fiber is purchased from M/S. MJ suppliers, Madurai. The properties of polypropylene fibers are given in Table 3.13.

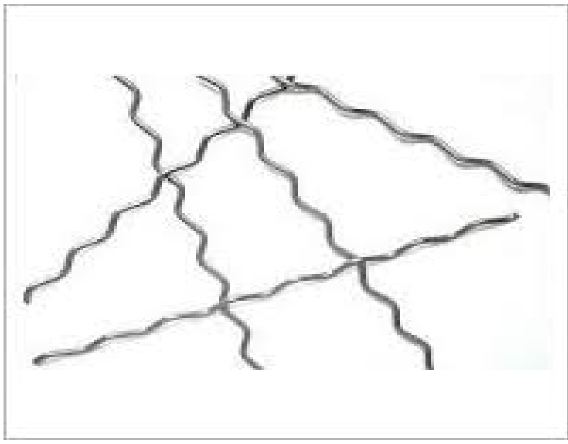


Fig. 2.2: Steel fibers

Table 2.13: Properties of steel fiber

SI.NO	NAME OF THE PROPERTIES	PROPERTIES PROVIDED
1	Fiber type	Steel
2	Length	36mm
3	Equivalent Diameter	0.6mm
4	Tensile strength	1100Mpa

4) Super Plasticizer

The super plasticizer is purchased from M/S. MJ suppliers, Madurai.Conplast SP 430 is used to reduce the frictional properties of concrete.

III. EXPERIMENTAL WORK

A. General

This chapter will explain in detail about the experimental works that will beconducted in this study. It also included explanation about the methods to determine the engineering properties of reinforced concrete studied. This chapter also will give us a clear picture about this study and shows how to achieve the objective of the study.

In the primary stage the data was collected from the researches and from otherresources such as journals, research papers, book, symposium papers, articles, magazines and also from the internet. Other than that is including the resource from discussion to improve the knowledge about the topic

B. Mixing Process

It is essential that the mix ingredients such as cement, fine aggregate, coarseaggregate, water and fibers are properly mixed. The first problem we encountered inthe mixing is that the balling effect of fibers. If the fiber does not mix properly, theproblem will occur and fiber does not dispersed randomly. By using concretemixture and by hand mixing problem will be reduced.

Fig. 4.1: Preparation of concrete mixture

C. Casting

The freshly mixed concrete was poured into the mould and the top surfacefinished smooth with trowel. The specimens were left in the mould for 24 hours andthen it is de-moulded. Identification marks were made on the exposed face ofspecimens.

Fig. 4.2: Casting of concrete specimens

D. Curing

After 24 hours from casting, the specimens were totally immersed in water.The specimens were taken out from the curing tank after 7th and 28th day of curingand tested for compressive and split tensile strength and the flexural behavior ofbeam.

Fig. 4.3: Curing of concrete specimens

E. Tests On Hardened Concrete

1) Compressive Strength

The compressive strength of concrete is one of the most important and usefulproperties of concrete. In most structural applications concrete is employed primarily to resist compressive stress. Compressive strength is also used as aqualitative measure for other properties of hardened concrete. The compressive strength of concrete was determined at the age of 7 and 28 days. The specimenswere cast and tested as per IS 456-2000. The cubes for testing were casted with fiber having a volume fraction of 0%, 1%, and 2%. The cubes were casted for each proportion.

The test were carried out on 150x150mm size cube, as per IS 456-2000.Remove the specimen from water after specified curing time and wipe out excess water from the surface. Apply the load gradually without shock and continuously at the rate of 140kg/cm2/minute till the specimen fails. Record the maximum load and note any unusual features in the type of failure. The test setup for compressive strength is shown in fig. 4.4.

2) Split Tensile Strength

It is the method of determining the tensile strength of concrete using acylinder which splits across the diameter. It is expressed as the minimum tensilestress (force per unit area) needed to split the material apart. Cylinder should beplaced in the middle of the machine with their axis horizontally between two piecesof steel. The position of the steel must be correct. The load is subjected to thecylinder until it is split into two. The maximum load, P recorded. The indirecttensile strength, f for the cylinder is calculated using the formula below. The testsetup for strength is shown in fig. 4.5.

Where, P- applying load, D - Diameter of the cylinder, L- Length of theCylinder

IV. RESULTS AND DISCUSSION

A. Introduction

The present study aims to investigate the engineering properties of Hybrid fiber reinforced concrete with steel and polypropylene fibers. The specimens were cured and tested at 7th and 28th days. The fiber content added to the concrete was based on volume fraction. This information may be very useful for future study and future development of building materials.

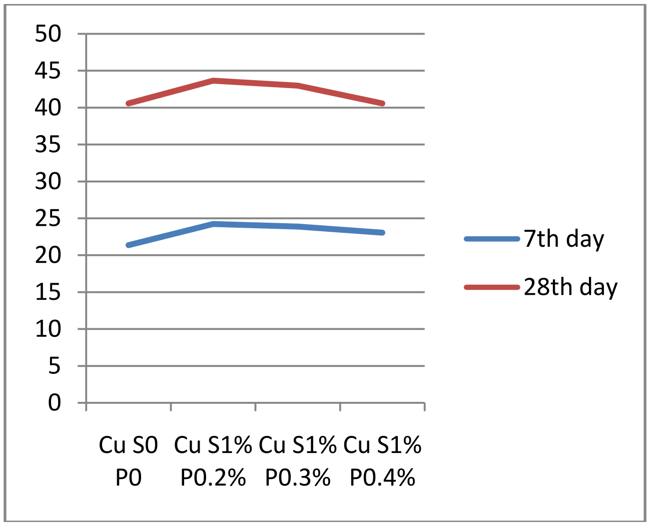
B. Compressive Strength

Determination of compressive strength of the concrete is an importantparameter. For each volume fraction four standard cubes were cast to determine $7^{th}$and 28thdays compressive strength after curing. And also four number of control cubes are casted to know the original strength of the concrete. The cube size is 150X150X150mm as per the IS 10086 – 1982. The compressive strength of concrete cubes are given in

Compressive Strength of Concrete cubes

SI.NO	Specimen designation	Percentage Of Fiber Adding In Conrete	Compressive StrenthIn N/Mm2	
			7th day	28th day
1	Cu S0 P0	0%(C.C)	**21.36**	**40.57**
2	Cu S1% P0.2%	1%SF+0.2%PP	**24.23**	**43.66**
3	Cu S1% P0.3%	1%SF+0.3%PP	**23.88**	**42.98**
4	Cu S1% P0.4%	1%SF+0.4%PP	**23.05**	**40.56**

Note: C.C- Control Concrete



Compressive strength for various mix proportion

From the fig., it is clear that the compressive strength of concrete at 28thday of curing in water, we are clear from the graph that the Compressive strength ofPolypropylene added by 2% of volume fraction was greater as compared to others.The values decreases in the order that polypropylene 2% gives higher value as43.52 N/mm2, Combination of both in 2% gives 42.98 N/mm2, Natural Fiber 2%gives 42.7 N/mm2, Artificial Fiber 1% gives 42.68 N/mm2, Combination 1% gives41.89 N/mm2, Natural Fiber 1% gives 41.62 N/mm2, and control cube gives 41.46N/mm2. Like this way all the values of compressive strength is decreasing thisorder. And we can obtain more strength as compared to control cube.From the above figures it is clear that the compressive strength of concreteget reduced as the volume fraction of fiber get increased. And the value ofcompressive strength for S S1% P0.2% is always greater as compared to the volumefraction of S S1% P0.3%. The values decreases in the order that polypropylene fibersin a volume fraction of 0.2%, 0.3% and 0.4% along with 1% of steel fibers gives43.07 N/mm2, 41.74 N/mm2 and 40.32 N/mm2. The control cube gives thecompressive strength of 40.68 N/mm2. The usage of fibers in concrete improves the strength of the cube. One of the main observations while adding fibers to theconcrete is to control cracking and changing the mode of failure. However, thecracks do not have much influence in compressive strength.

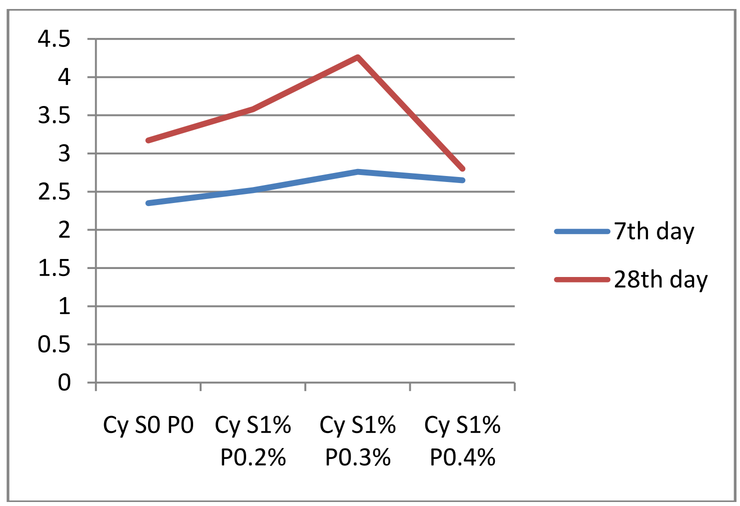
C. *Tensile Strength*

It is very difficult to directly measure the tensile strength of concrete; therefore the splitting tensile test, an indirect method, was adopted. To determine the split tensile strength the cylinders were cast. The size of the cylinder is 150mm of diameter and 300mm of length. The cylinder are cured properly and tested on 7thand 28th day. Control concrete cylinder specimen is also cured and tested as per IS specification. Combinations of test results are compared with control concrete specimens.

Split Tensile Strength of Cylinders

SI.NO	Specimen Designation	Percentage Of Fiber Adding In Conrete	SPLIT TENSILE STRENTH IN N/mm2	
			7th day	28th day
1	Cy S0 P0	0%(C.C)	**2.35**	**3.17**
2	Cy S1% P0.2%	1%SF+0.2%PP	**2.52**	**3.58**
3	Cy S1% P0.3%	1%SF+0.3%PP	**2.76**	**4.26**
4	Cy S1% P0.4%	1%SF+0.4%PP	**2.65**	**4.03**

Note: C.C- Control Concrete



Split tensile strength for various mix proportion

From the fig. it is clear that the split tensile strength shows a gradualincrease as the volume fraction increase. The value of split tensile strength for S S1%P0.3% is always greater as compared to the volume fraction of S S1% P0.4%. The values decreases in the order that polypropylene fibers in a volume fraction of 0.2%, 0.3% and 0.4% along with 1% of steel fibers gives 3.49 N/mm2, 4.14 N/mm2and 3.85 N/mm2. The control cube gives the tensile strength of 3.25 N/mm2. So the mixing of fibers also affects the tensile strength of concrete. Volume fraction is other factor to increase the tensile strength the increase in the volume fraction also increases the tensile strength.

V. CONCLUSIONS

Based on experimental investigation and analysis of results obtained, thefollowing conclusions may be drawn broadly:

i. Steel – polypropylene hybrid fiber reinforced concrete shows a slight increase in the compressi8ve strength and significant increase in tensile strength as compared with the plain or control concrete.
ii. Among the Hybrid fiber combination, 1% steel fiber and 0.2% polypropylene fiber combination gives higher compressive strength than other combinations reported in this study.
iii. Similarly, among the hybrid fiber combinations, 1% steel fiber and 0.3% polypropylene fiber combination gives higher tensile strength than other combinations reported in this study.
iv. The maximum gain in compressive strength of concrete achieved for 0.2% of polypropylene fiber along with 1% of steel fiber at the age of 7 and 28 days of curing are 9.34% and 5.88%, respectively.
v. Similarly, the maximum gain in tensile strength of concrete achieved for0.3% of polypropylene fiber along with 1% of steel fiber at the age of 7 and 28 days of curing are 21.98%% and 27.38%, respectively.
vi. From the beam tests, it is evident that the fiber volume has little or no effect on the load-deflection response of the beam. But, there is relatively stiffer response after the first cracking stage for all the beams tested in this study when compared with reference or control beam.

REFERENCE

[1] IS 10262 – 1982, "Recommended guidelines for concrete mix design", PP 5 – 15, Bureau of Indian Standards, New Delhi.
[2] IS 5515-1983, "Indian standard specification for compacting factor apparatus", pp3-6, Bureau of Indian Standards, New Delhi.
[3] IS 7320-1974, "Indian standard specification for slump test apparatus", pp3- 6, Bureau of Indian Standards, New Delhi .IS 3495 (Part 1) – 1976, "Part 1- Determination of compressive strength", PP 28 – 35, Bureau of Indian Standards, New Delhi.
[4] IS 5816-1999, "Indian standard specification for splitting tensile strength of concrete-method of test" pp 1-4, Bureau of Indian Standards, New Delhi.

APPENDIX

CONCRETE MIX DESIGN

General

In this chapter the design mix for the study will be prepared and discussed.Design procedure from "Recommended Guidelines for Concrete Mix Design" (IS: 10262-1982).

Design Stipulations

1. Characteristic compressive strength required in the Field in 28 days - 30MPa
2. Max size of aggregate - 20mm
3. Degree of workability - 0.9
4. Degree of quality control - good
5. Type of exposure - mild

Test data for material

i) Specific gravity of cement - 3.14
ii) Specific gravity
a. coarse aggregates - 2.84
b. fine aggregates - 2.65
iii) Water absorption:
a. Coarse aggregates - 0.5%
b. Fine aggregates - 1%
iv) Free moisture:
a. Coarse aggregates - nil
b. Fine aggregates - 2%
The zone of the coarse aggregates is II

Target mean strength of concrete

fck = fck+ t s
fck = characteristic compressive strength in 28 days
t = 1.65 (risk factor)
S= Standard deviation as per IS 456-2000
= 30 + (1.65x6)= 39.9 MPa

Selection of w/c ratio

w/c ratio = 0.4

Selection of Sand and Water Content

20mm aggregate size
Water content including surface water per cubic = 186 ml
Sand as percent of total aggregate by absolute volume = 3

Adjustment of values in water content and sand percentage for otherConditions

Change In Condition	Adjustment Required In	
	Water Content	% Sand In Total Aggregate
For decrease in w/c ratio by (0.6 – 0.4) then in 0.2	0	-4%

For increase in compacting factor (0.9-0.8) that is 0.1	3%	–
For sand conforming to zone II	–	–
Total	3%	-4%

Total sand content required as percentage of total aggregate =35%-4%

3

Water content

= 186+3%

3

Determination of Coarse and Fine Aggregate Content

$$0.98^{m3} = \left(191.61 + \frac{479}{3.14} + \frac{1}{0.295} X \frac{fa}{2.66}\right) X \frac{1}{1000}$$

$$0.98^{m3} = \left(191.61 + \frac{479}{3.14} + \frac{1}{0.295} X \frac{Ca}{2.83}\right) X \frac{1}{1000}$$

or fa = 522 $Kg/^{m3}$

ca= 1249.58 $Kg/^{m3}$

Water : cement : fine aggregate : coarse aggregate

191.6 : 479 : 500.7 : 1269.16

` 0.403 : 1 : 1.097 : 2.625