ORIGINAL RESEARCH PAPER

Engineering

Parametric Study of High Performance Fibre Reinforced Concrete

KEY WORDS: Concrete, Steel fibers, Polypropylene fibers, Carbon fibers, Compressive Strength, Flexural strength, Split Tensile strength, Percentage Increase

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ABSTRACT

The interest in the use of fibers for the reinforcement of composites has increased during the last several years. In this study, the results of the Strength properties of fiber reinforced concrete have been presented. Steel fibers, Polypropylene fibers and carbon fibers have been used in different combinations in this study. The various strength parameters studied are Compressive strength, Flexural strength and the Split tensile strength as per the relevant IS standards. The samples which are added with all three fibers (Steel fibers, Polypropylene fibers and Carbon fibers) showed better results in comparison with the other combinations. Result data clearly shows percentage increase in Compressive strength, Flexural strength and Split Tensile strength for M-60 Grade of Concrete. In comparison with normal concrete the fiber reinforced concrete (FRC) which is reinforced with all three fibers (Steel fibers, Polypropylene fibers, Carbon fibers) showed **19.58%** increase in compressive strength, **46.72%** increase in Flexural strength, **43.36 %** increase in Split Tensile Strength at 28 days respectively.

1. INTRODUCTION

Concrete is most widely used construction material in the world due to its ability to get cast in any form and shape. It also replaces old construction materials such as brick and stone masonry. The strength and durability of concrete can be changed by making appropriate changes in its ingredients like cementatious material, aggregate and water and by adding some special ingredients. Hence concrete is very well suitable for a wide range of applications.

Though Concrete is most commonly used structural material, it has some deficiencies such as Low tensile strength, Low post cracking capacity, Brittleness and low ductility, Limited fatigue life, Incapable of accommodating large deformations and Low impact strength. In plain concrete and similar brittle material, structural cracks (micro cracks) develop even before loading, particularly due to drying shrinkage or other causes of volume change. The width of these initial cracks seldom exceeds a few microns. When loaded these micro cracks propagate and open up and due to stress concentration, additional micro cracks are formed. The micro cracks are the main cause for elastic deformation in concrete. Fibre reinforced cement and concrete were developed to overcome these problems. The presence of micro cracks in the mortar-aggregate interface is responsible for the inherent weakness of plain concrete. The weakness can be removed by inclusion of fibres in the mixture. Different types of fibers, such as those used in traditional composite materials can be introduced into the concrete mixture to increase its toughness, or ability to resist crack growth. The fibres help to transfer loads at the internal micro cracks. Such a concrete is called fibre-reinforced concrete (FRC). Several types of fibres are now being used like steel, Glass, Carbon, Polypropylene fibres, choir and jute. Woven meshes, continuous meshes and long wire or rods are not considered as discrete fibres. There is a vast scope for application of fibre reinforced concrete in the present construction and in in-situ repair works. In addition to this silica fume (8 to 10 %) and GGBS (10 to 50 %) can be added to concrete which improves the durability of concrete and also helps in protecting the embedded steel from corrosion.

2. LITERATURE REVIEW

Cement mortar and cement concrete undergoes significant changes when admixtures and fibres are used in concrete resulting in changes in structural properties. Thus the behaviour of structural members after being reinforced with fibers is upgraded. In the recent years much of the research is emphasized on the use of one type of fiber at a time. It was noticed that the steel fibre reinforced concrete containing different percentage of Steel fibers (A.M.Shende, A.M.Pande, M.Gulfam Pathan, 2012), showed an increase in the compressive strength, flexural strength and the split tensile strength. Notable increase in compressive strength was reported with the addition of polypropylene fibers. The failure is gradual and ductile in polypropylene fiber reinforced concrete. Also the problem of low tensile strength of concrete can be overcome by addition of polypropylene fibers to concrete (Dr.T.Ch.Madhavi, L.Swamy Raju, Deepak Mathur, 2014). Experimental results showed that the tensile, compressive, and flexural strengths and flexural toughness were all increased by latex addition for any fiber type. Carbon fibers gave mortar of higher tensile strength, lower modulus, higher flexural strength, and lower flexural toughness than polyethylene fibers at the same volume fraction (Pu-Woei Chen and D.D.L.Chung, 1994). Very few studies have used two different types of fibres in concrete at a time. But no attempt has been made to use three different fibers along with the admixtures. Hence in this project, an attempt has been made to select the best combination of fibers that can be used in concrete. Compressive strength, flexure strength and the split tensile strength of concrete specimens are determined experimentally.

3. EXPERIMENTAL PROGRAMME

3.1 Material:

In this present investigation Ordinary Portland Cement of 53 Grade with a brand name Ramco has been used. Tests were conducted in accordance with the Indian standards confirming to IS-12269:1987. Locally obtained natural river sand passing through 4.75 mm sieve and retaining on 150 micrometer sieve with specific gravity 2.631, water absorption 2% and fineness modulus 2.29 conforming to I.S. – 383-1970 has been used. Tests on fine aggregate were conducted in accordance with IS: 650-1966 & IS: 2386-1968. Coarse aggregates passing 12.5 mm sieve size and retained on 10 mm sieve having specific gravity of 2.63, conforming to IS 383-1970 were used. The sieve analysis of combined aggregates confirms to the specifications of IS 383: 1970 for well graded aggregates. Silica Fume and Ground Granulated Blast Furnace (GGBS) has been used as Mineral admixtures. The dosage of Silica fume was limited to 10% of total cementatious material and GGBS was limited to 15 to 20 % of total cementatious material. Glenium - Ace 31 has been used as Chemical Admixtures (Super plasticizer) to impart additional workability (0.6 % by weight of cementatious material was used). Potable water was used for the experimentation. Crimped steel fibres with Aspect ratio (L/D) =50 has been used in the experimental program. Polypropylene fibers (PF) used were of length of 12mm. The dosage of the poly fibre was limited to 900gm per volume of concrete. The filament Carbon fibre is cut to the required length of 6mm.

3.2 Test Specimens:
In each category 3 specimens were casted.

Mix Design:
Cement: SF: GGBS: FA: CA: Water::
1: 0.137: 0.251: 0.957: 2.46: 0.386
Dosage of the fibers was limited to: Steel fibres (0.65% of concrete volume or 51 Kg/m^3), Polymer fibres (900 gms/m^3), and Carbon fibres (0.5 % of concrete volume or 8 Kg /m3).

The details of total number of cement concrete cubes (150mm*150mm*150mm), cement concrete prisms (100mm*100mm*500mm) and cement concrete cylinders (150mm diameter, 300mm depth) specimens casted:

3.3 Casting the Specimens:
In casting of specimen Weigh batching is used for the experimental study. The coarse aggregate was spread evenly on a large tray. Sand, cement and admixtures was dry mixed in the mixer and spread evenly over the coarse aggregates. The dry ingredients were then hand mixed thoroughly for about 3min. Fibres (if any) are added to the dry mixture. It must be ensured that fibres are evenly distributed. Estimated amount of water is first mixed with calculated amount of super plasticizer in chemical mixer and then added to the dry mixture and mixed for 4 min. The assembled mould was filled with the cement concrete mix in 3 layers and compacted using table vibrator and needle vibrator. The cubes/prisms/cylinders were removed from the moulds after 24 hours of casting and cured for 28 days.

4. EXPERIMENTAL METHODOLOGY
In the present study Compressive strength, flexural strength and the split ensile strength are taken into account. The specimens were tested for 3 days, 7 days and 28 days as per Indian Standard Specifications.

4.1 Test Procedure:
Compressive strength test:
For compressive strength test, cube specimens of dimensions 150 x 150 x 150 mm were used. After 28 days curing, these cubes were tested on Compression testing machine as per I.S. 516-1959.
Rate of Loading- 14N/mm^2/min
The failure load was noted. In each category three cubes were tested and their average value is reported. The compressive strength was calculated as follows.
Compressive strength (MPa) = Failure load / cross sectional area.

Flexural strength test:
For Flexural strength test beam specimens of dimension 100x100x500 mm were used. These flexural strength specimens were tested under two point loading as per I.S. 516-1959, over an effective span of 400 mm on Flexural testing machine. Rate of Loading is kept such that minimum rate of increase of extreme fiber is 0.7 N/mm^2. Load and corresponding deflections were noted up to failure. In each category three beams were tested and their average value is reported. The flexural strength was calculated as follows.

Table 1: Details of number of specimens

SL. NO	Description	Number of concrete Cubes casted	Number of concrete Prisms casted	Number of concrete Cylinders casted
1	CS	9	9	9
2	CS + PF	9	9	9
3	CS + SF	9	9	9
4	CS + CF	9	9	9
5	CS+PF+SF	9	9	9
6	CS+PF+CF	9	9	9
7	CS+CF+SF	9	9	9
8	CS+PF+CF+SF	9	9	9

Flexural strength (Mpa)= $\frac{WL}{bd^2}$

Where, b = width of prism (mm), d = depth of prism (mm), L = supported length (mm), P = Maximum Load (N)

Split Tensile strength test:
For Split tensile strength test, cylinder specimens of dimension 150 mm diameter and 300 mm length were cast. The specimens were demoulded after 24 hours of casting and were transferred to curing tank wherein they were allowed to cure for 28 days. These specimens were tested under compression testing machine.

Rate of Loading- 12 N/mm2/min.

In each category three cylinders were tested and their average value is reported. Split Tensile strength was calculated as follows

Spilt Tensile strength (Mpa) = $\frac{2P}{\Pi dl}$

Where, P = Maximum Load (N), d = diameter of cylinder (mm), L = Length of cylinder (mm)

5. RESULTS AND DISCUSSION
5.1 General:
Among all strengths, the compressive strength is generally considered as the most important property of concrete and gives overall picture of quality of concrete. In this present study Compressive strength, flexural strength and the split ensile strength are taken into account.

5.2 Compressive Strength results:
After obtaining the Ultimate Load value from Compressive testing machine (CTM) the Compressive strength is calculated using the formula. The Cubes were tested at 3 days, 7 days and 28 days as per Indian Standard Specifications. In each category 3 specimens are tested its mean value is taken.

Table 2: Compressive strength results of concrete cubes

Sl. NO	Concrete Type	Mean C.S after 3 days	Mean C.S after 7 days	Mean C.S after 28days
1	CS	**27.69**	**37.03**	**64.29**
2	CS+CF	**32.29**	**45.18**	**68.40**
3	CS+PF	**29.47**	**42.81**	**69.07**
4	CS+SF	**37.47**	**50.51**	**70.07**
5	CS+SF+PF	**40.29**	**55.38**	**69.18**
6	CS+CF+PF	**36.57**	**49.66**	**68.32**
7	CS+CF+SF	**40.84**	**51.44**	**73.03**
8	CS+SF+CF+PF	**42.79**	**55.84**	**76.88**

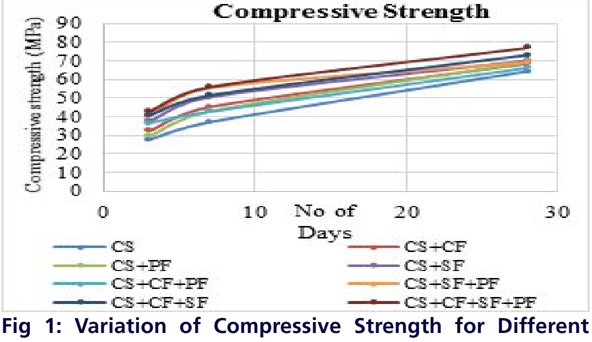

Fig 1: Variation of Compressive Strength for Different combinations of FRC

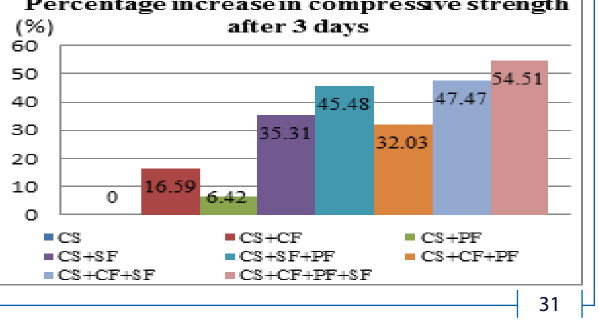

Fig 2: Percentage Increase in Compressive Strength after 3 days

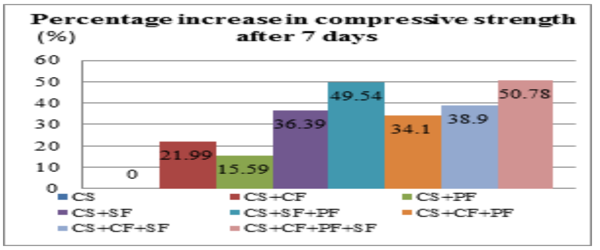

Fig 3: Percentage Increase in Compressive Strength after 7 days

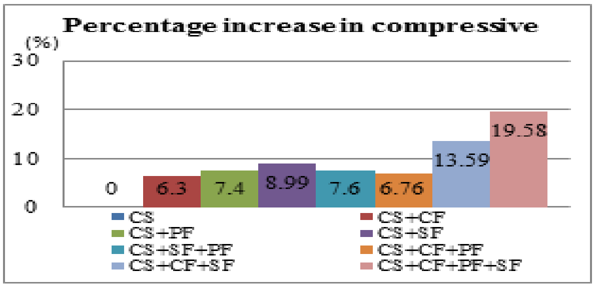

Fig 4: Percentage Increase in Compressive Strength after 28 days

5.3 Flexural Strength results

The Prisms were tested at 3 days, 7 days and 28 days. In each category 3 specimens are tested its mean value is taken.

Table 3: Flexure strength of concrete Prisms

Sl. NO	Concrete Type	Mean F.S after 3 days	Mean F.S after 7 days	Mean F.S after 28days
1	CS	**4.13**	**5.73**	**8.13**
2	CS+CF	**4.73**	**6.46**	**10.8**
3	CS+PF	**4.26**	**6.06**	**8.93**
4	CS+SF	**4.36**	**6.4**	**10.4**
5	CS+SF+PF	**4.93**	**7**	**10**
6	CS+CF+PF	**5.06**	**7.8**	**11.46**
7	CS+CF+SF	**4.8**	**7.86**	**11.86**
8	CS+SF+CF+PF	**5.33**	**8.53**	**11.93**

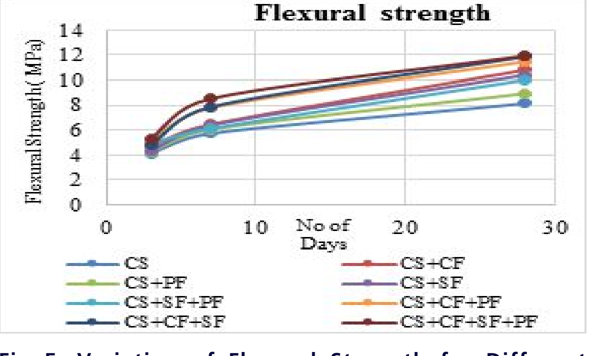

Fig 5: Variation of Flexural Strength for Different combinations of FRC

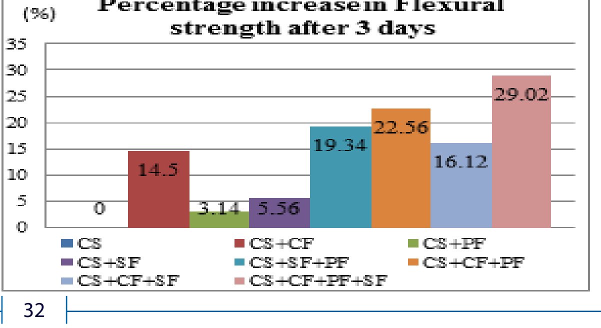

Fig 6: Percentage Increase in Flexural Strength after 3 days

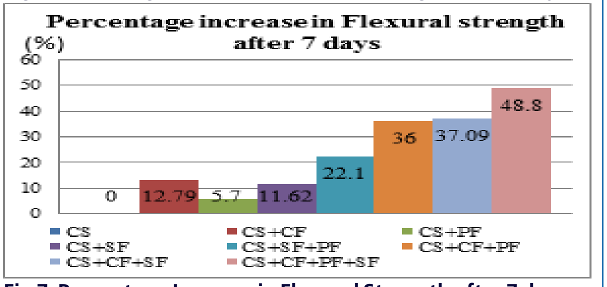

Fig 7: Percentage Increase in Flexural Strength after 7 days

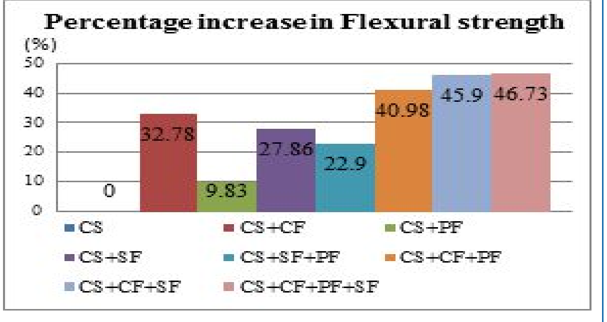

Fig 8: Percentage Increase in Flexural Strength after 28 days

5.4 Split Tensile Strength results:

The Cylinders were tested at 3 days, 7 days and 28 days as per Indian Standard Specifications. In each category 3 specimens are tested its mean value is taken.

Table 4: Split Tensile strength results of concrete Cylinders

SL. NO	Concrete Type	Mean S.T.S after 3 days	Mean S.T.S after 7 days	Mean S.T.S after 28 days
1	CS	**2.2**	**3.10**	**4.04**
2	CS+CF	**2.29**	**3.13**	**4.83**
3	CS+PF	**2.23**	**3.26**	**4.76**
4	CS+SF	**2.33**	**3.44**	**4.94**
5	CS+SF+PF	**2.41**	**3.67**	**5.60**
6	CS+CF+PF	**2.34**	**3.44**	**5.03**
7	CS+CF+SF	**2.41**	**3.65**	**5.51**
8	CS+CF+ PF+SF	**2.45**	**3.91**	**5.79**

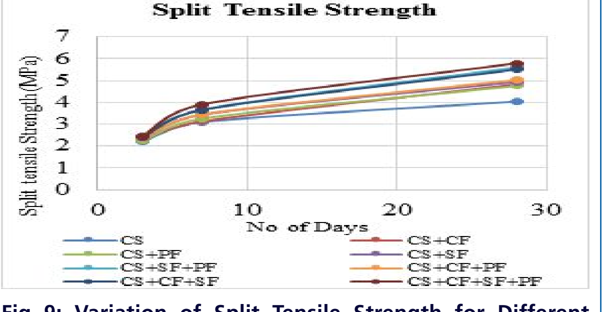

Fig 9: Variation of Split Tensile Strength for Different combinations of FRC

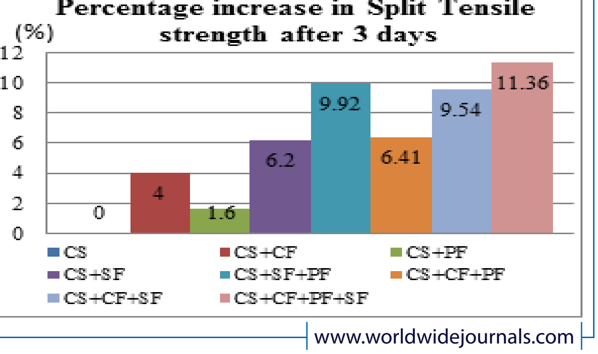

Fig 10: Percentage Increase in Split Tensile Strength after 3 days

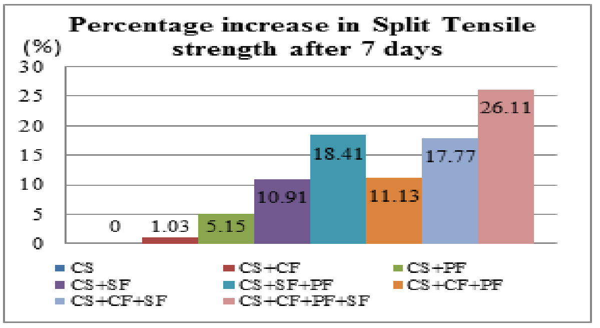

Fig 11: Percentage Increase in Split Tensile Strength after 7 days

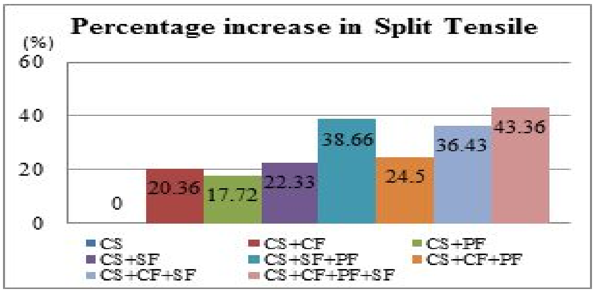

Fig 12: Percentage Increase in Split Tensile Strength after 28 days

6. CONCLUSIONS:

- The Compressive strength, the Flexural strength and the Split Tensile strength of Concrete with no fibers (Control Specimens) has the least value.
- In comparison with Control Specimens, the fiber reinforced concrete (FRC) composed of all three fibers (Steel fibers, Polypropylene fibers, Carbon fibers) showed 19.58% increase in compressive strength, 46.72% increase in Flexural strength, 43.36 % increase in Split Tensile Strength at 28 days respectively.
- It can be noted that the FRC in which Steel fibers when used with Polypropylene fibers or carbon fibers shows growth in its Compressive strength and Split Tensile Strength considerably compared to the other combinations in which steel fibers are not used.
- The FRC in which Carbon fibers when used with Polypropylene fibers or Steel fibers shows growth in its Flexural strength considerably compared to the other combinations in which Carbon fibers are not used.
- Hence Steel fibers, Carbon fibers, Polypropylene fibers are viable addition in concrete which increases the Compressive strength, Flexural strength and the Split tensile strength considerably.

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