

A Study of Flexural and Bending Strength of Steel, Polypropylene and Hybrid Fibre Reinforced Concrete without Adding Admixture

M. Tamil Selvi¹, Dasarathy A K², T.S. Thandavamoorthy, FIE, FIITArb³, S.PonkumarIlango⁴

^{1,2}Professor, Department of Civil Engineering, Veltech Multitech
Dr.Rangarajan Dr.Sakunthala Engineering College, Avadi, Chennai, India
³Professor, Department of Civil Engineering, Adhiparasakthi Engineering College
Melmaruvathur and Past Vice-President, ICI,
⁴Assistant Professor, Department of Civil Engineering,
Dr. M.G.R. Educational and Research Institute University, Chennai, India
*Corresponding Author Email: ¹tamilselvi_05@yahoo.com

Abstract

The present study has been taken up for evaluating the different types of concrete. Emphasis has been given to the strength and deformation properties of reinforced concrete beams. This paper presents the results of an experimental investigation carried out on four different types reinforced concrete beams, 150 mm × 150 mm × 700 mm in size. The beams were tested under one-third point loading. The results exhibited that the flexural strength of concrete are meaningfully improved by adding steel, polypropylene and hybrid fibers. Out of the three different types of fibers used in this study, the fibers with steel and hybrid showed better efficiency in improving the flexural response.

Keywords: Fiber Reinforced Concrete, Steel, Polypropylene and Hybrid Flexural Properties.

1. Introduction

Concrete is currently the most widely used building material. Although many structures are built of concrete, there are still some limitations related to the use of conventional concrete, such as low tensile strength and almost no ductility. Fibers such as polypropylene when added to concrete reduce the compressive strength, but increases both split tensile strength and flexural strength [3].

They are more porous compared to the plain concrete. Steel fiber reinforced concrete (SFRC) offers good tensile strength, ultimate strength, flexural strength, shock resistance, fatigue resistance, ductility and crack arrest [7, 8, 9, 10]. Some researches shows that SFRC shows a slight tendency to reduce the young's modulus as the fiber content decreases [4].

Some of the experimental results show that the beams reinforced with steel fibers shows a similar or even better post cracking behavior than beams with minimum amount of transverse reinforcement [5]. Researches shows that when the fibers are used in the hybrid form-steel and polypropylene, increases ductility [11].

Steel fiber bridging across cracks in concrete mix will increase joint shear strength. It is the concrete characteristics that influence the time to initiation of corrosion initially and later the cracking of concrete due to corrosion of steel is of importance.

The reinforcement is generally in a passive state up to initiation of corrosion and after initiation it is influenced by the environment in concrete up to cracking and later by the environment itself.

The relationships between these have a lot of bearing on the performance of structures. In the last few years, many researchers [6,7] have begun to realize that strain localization also occurs for concrete specimens loaded in compression; however, the compressive failure mechanism is more complex than the tensile failure mechanism.



a) Steelfibre (Crimped)



(b) Polypropylene fiber

Fig. 1: Different fibres

1.1 Objective

The purposes of the present investigation is to find out the durability properties of M₃₀ grade of concrete mix with four percent with respect to weight of cement (2.14% with respect to volume of cement) of steel, polypropylene fibers, and hybrid

fibers. Hybrids consisting of two percent steel and two percent polypropylene fibers, respectively, to calculate their strength at 7 days and 28 days. Also, addition of more fibres reduces cracking and improves corrosion resistance. Moreover, fibre reinforcement also serves to improve the shear resistance of concrete.

2. Experimental Programme

To determine the strength properties of fibre reinforced concrete the following tests were planned and conducted.

2.1 Materials used

In this experimental study, Portland Pozzolanicement, fine aggregate, coarse aggregate, water and steel, polypropylene fibers were used. Types of fibres are shown in Fig. 1. Cement conforming to IS: 12269 (1987) was used in the experimental investigation. Also locally available 20mm and down coarse aggregates with specific gravity 2.70 were used. Locally available sand conforming to zone III as per IS: 383 (1970) with specific gravity 2.65, water absorption 2 per cent and fineness modulus 2.8, was used. Potable water was used for the experimentation. In this experimentation, crimped steel fiber and Polypropylene fiber consisting of Endura - 600 Macro synthetic were used. Properties of the steel fibre and polypropylene fibres are shown in Table 1.

Table 1: Fibre Properties

Fibre type	Steel Fibre	Polypropylene fibre
Length (mm)	50	50
Density (g/cm ³)	7.84	0.9
Tensile strength (MPa)	966-1242	550
Melting point °C	1200	164

2.2 Concrete Mix Design

Concrete mix of grade M30 was designed as per the recommendation of IS: 383 (1970) and IS: 10262 (2009). The

proportions and quantities of various materials for the concrete mix are presented in Table 2.

Table 2: Mix Proportions

Sl. No	Material	Quantity per m ³ in kg			
		Traditional Concrete	Steel fiber reinforced concrete	Polypropylene fiber reinforced concrete	Hybrid fiber reinforced concrete
1	Cement	420 kg/m ³	420 kg/m ³	420 kg/m ³	420kg/m ³
2	Fine aggregate	420 kg/m ³	420 kg/m ³	420 kg/m ³	420kg/m ³
3	Coarse aggregate	840 (kg/m ³)	840 kg/m ³	840 kg/m ³	840 kg/m ³
4	W/C ratio	0.45 %	0.45 %	0.45 %	0.45 %
5.	Steel fiber		16.8kg		
6.	Polypropylene fiber			16.8 kg	
7.	Hybrid fiber		8.4 kg	8.4 kg	Total = 16.8 kg

3. Experimental Programme

3.1 Compressive strength

The compression test, samples were cast using M₃₀ grade of concrete with four per cent of steel fibre, four percent of Polypropylene fiber, and four percent of hybrid fibers. Shaking was given by vibrating equipments. The surface of the samples are smoothly finished. After 24 hours, the samples are remove from the mould and immersed in to the curing tank for 7,14,21,28

days. These cubes were tested on digital compression testing machine as per IS: 516 (1959) as shown in Fig. 2. The collapse load was noted. Three cubes were tested in each type, and their standard load was reported.

The compressive strength was considered as follows:

$$\text{Compressive strength (MPa)} = \text{Collapse load} / \text{C.S.A}$$

Outcome of compressive strength for M₃₀ grade of concrete on cube samples are exposed in Table 5.

Table 5: Compressive Strength of C1 Vs C2,C3,C4

S no	Nature of concrete	Compressive strength Days) (N/mm ²)			
		7	14	21	28
1.	C ₁	18.0	20	33	35
2.	C ₂	25.4	32	32	36
3.	C ₃	20.0	22	28	31
4.	C ₄	18.0	21	26	30

Note:

- C1 - Normal Concrete
- C2 - Steel Fiber Reinforced Cement Concrete
- C3 - Poly Propylene Fiber Reinforced Cement Concrete
- C4 - Hybrid fiber Reinforced cement Concrete



Fig. 2: Cube testing in CTM

3.2 Flexural test of plain concrete

Standard plain concrete prisms of size 150mm×150mm×700mm were used for standard flexural strength tests. These prisms are tested on digital UTM was shown in the report (Bureau of Indian standards, IS:516:1959) and it was shown in Fig.3. The flexural strength of the specimen shall be expressed as the modulus of rupture f_b ,

$$f_b = \frac{P \times l}{b d^2}$$

b = Measured width in cm of the specimen;

d = Measured depth in cm of the specimen at the point of failure;

l = Length in cm of the span on which the specimen was supported, and

P = Maximum load in kg applied to the specimen.

The flexural test results for M₃₀ grade of concrete are given in table 6.

Table 6: Flexure test at 28 days

Sl. No.	Nature of concrete	Flexural strength (N/mm ²)	
		7 days	28 days
1.	C1	3.8	4.1
2.	C2	4.7	6.5
3.	C3	4.4	5.3
4.	C4	2.8	4.8



Fig. 3: Showing testing Arrangements

3.3 Design details of prisms

The details are furnished below. Cross-sectional dimension of the prism: 150 mm×150mm and length of the prism: 700mm. Prisms were cast with and without longitudinal reinforcement and with fibre reinforcement in all cases.

❖ Plain cement concrete beam : Here, no longitudinal reinforcement bar.

❖ Singly reinforced: 2 numbers of 12mm diameter main reinforcement bars with Fe415 steel on the tension side with nominal stirrups of 6 mm.

❖ Doubly reinforced: Main reinforcement bars: 2Nos.12mm dia with Fe415 steel on the tension side; 2Nos.8mm dia with Fe415 steel on the compression side; stirrups of 6mm dia at 75mm c/c. The Design details of the Prisms are shown in Figs4 and 5.

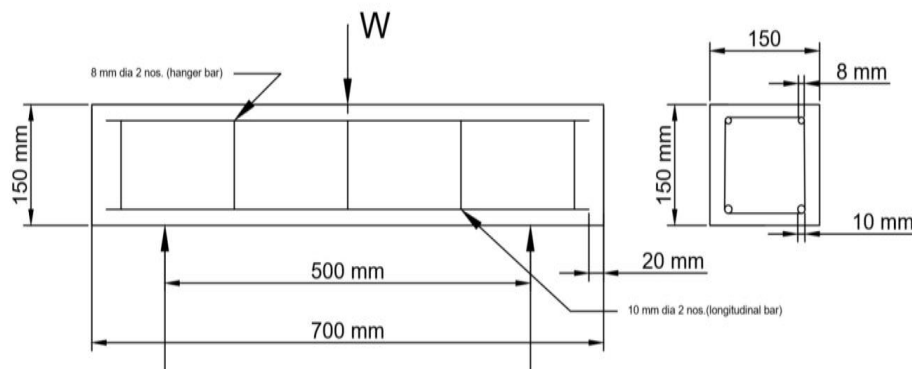


Fig. 4: Singly reinforced R.C.C. beam

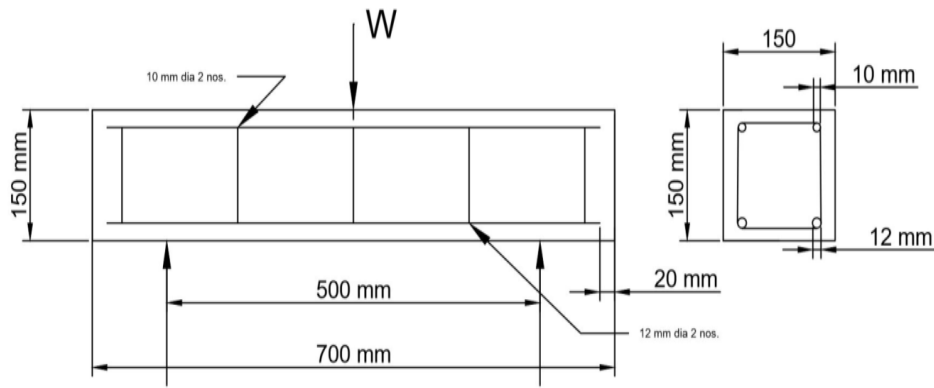


Fig. 5: Doubly reinforced R.C.C. beam

3. 4 Bending Strength of Beam with Reinforcement

Singly reinforced and doubly reinforced concrete beams of size 150 mm × 150 mm × 700 mm were cast. For singly reinforced beams, 10 mm diameter bars at bottom side with nominal stirrups were provided as shown in Fig. 4 and doubly reinforced concrete beams were provided with stirrups and with 12 mm diameter bar on bottom side and 10 mm diameter bars at top as shown in Fig. 5. Three specimens were tested in flexure after 28 days.

Results of tested beams with singly and doubly reinforced sections for M₃₀ grade of concrete are exposed in Table 7.

The specimen used in standard mould and the size of 150 mm × 150 mm and 750 mm long. Thus the paper forms a part of a larger investigation being conducted to investigate the flexural characteristics of concrete containing steel, polypropylene and hybrids of steel and polypropylene fibers. Singly reinforced and doubly reinforced concrete beams were casted.

Table 7: Result of Bending test

Sl. No.	Nature of concrete	Ultimate load (kN)		
		Without reinforcement	Singly reinforced	Doubly reinforced
1.	C ₁	60	70	97
2.	C ₂	65	99	118
3.	C ₃	60	76	95
4.	C ₄	60	82	145

4. Results and Discussion

4.1 Compressive strength

The relative results for compressive strength of concrete between normal concrete, steel fiber reinforced concrete, polypropylene fiber reinforced concrete, and hybrid fiber specimens are shown in Fig. 6.

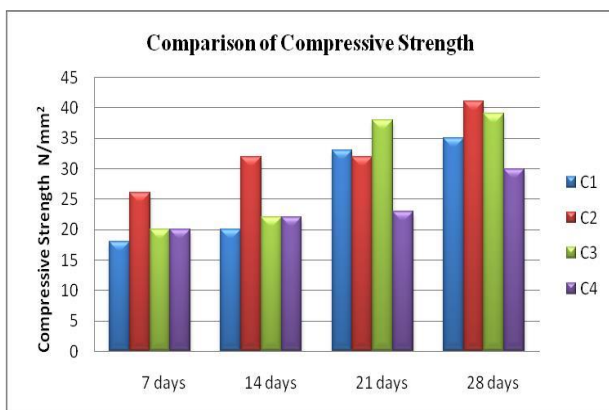


Fig. 6: Compressive strength of concrete with different fibers

An assessment of the 7 and to 28 days compressive strength outcomes are given, C₂ at 7 days there is 41% increase in compressive strength, 60% increase at 14 days, 3% decrease at 21 days and 3% increase at 28 days when compared to C₁

C₃ at 7, to 28 days compressive strength outcomes are demonstrate. Increase in compressive strength for percentage of 11,11,11.5 and 11% decreased at 21&28 days when compared to C₁ for M₃₀ grade.

C₄ at 7 to 28 days compressive strength results demonstrates a decrease in compressive strength for % equal to 5 and an increase at 7,14 and 21 days & 14% decreased at 21 and 28 days, when compared to normal concrete for M₃₀ grade of concrete.

4.2 Flexural Strength in plain concrete

The relative results for flexural strength of plain concrete beams of normal concrete, steel fiber reinforced concrete, polypropylene fiber reinforced concrete, and hybrid fibers samples are given in Fig.7.

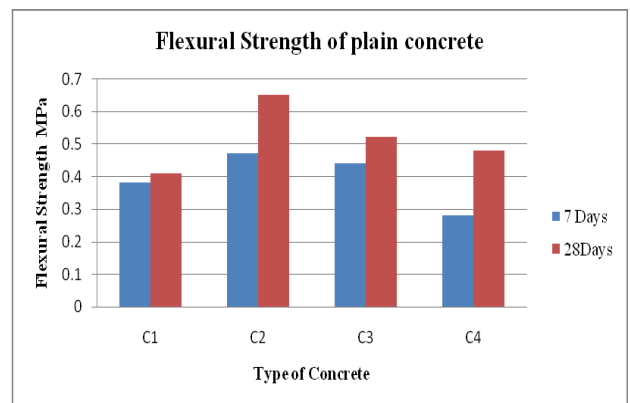


Fig. 7: Flexural strength of plain concrete

The assessment of the 7 to 28 days flexural strength of plain concrete outcomes shows,

- In the concrete C₂, 23% and 58% increase in flexural strength after compared to C₁.
- In the concrete C₃ 16% and 29% increase in flexural strength after compared to C₁.
- In the concrete C₄ 26% decrease and 17% increase in flexural strength after compared to C₁

4.3 Bending strength with reinforcement bars

Bending strength of concrete beams without reinforcement, singly reinforced and doubly reinforced was listed for reference and comparison. Results of tested beams without, singly and doubly reinforced sections for M30 grade of concrete are given in Fig. 8.

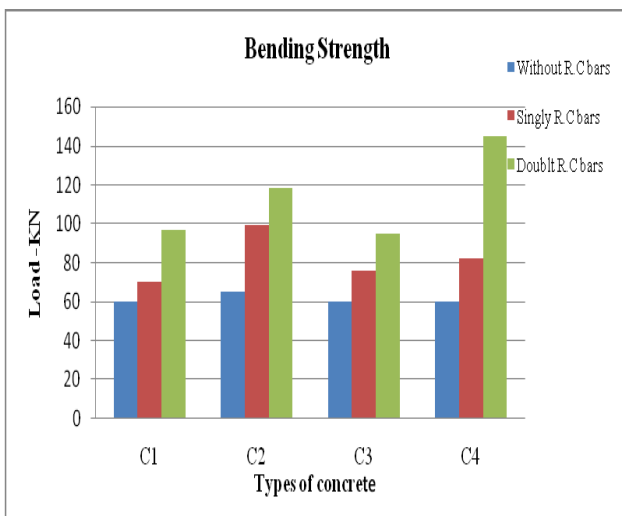


Fig. 8: Bending strength of different fibers

The value of bending strength for C₂ was 8% more for the plain cement concrete beam, 41% increased for singly reinforced beam and 22% increased, for doubly reinforced concrete beam than C₁. In the concrete of C₃, the value of bending strength was equal for the case of beam Without reinforcement, 9% higher for singly reinforced case and 2% decreased, for doubly reinforced concrete beam than C₁.

The experimental value of bending strength for C₄ was equal to the plain cement concrete beam, 17% higher for singly reinforced beam and 49% increased, for doubly reinforced concrete beam than C₁

5. Conclusion

The behavior of beam in tension cracks on fiber reinforced cement concrete with under loaded areas. The ultimate deflection for the Hy.FRC beams was found to be increasing when compared to the control specimen, which is due to the increase in ductility of the beams by the introduction of fibers.

5.1 Compressive Strength of cubes

- Compressive strength of C₂ 7, 14, 21 and 28 days strength is 41%, 60%, equal, and 3%, increased.
- Compressive strength of C₃ 7, 14 days strength was 11%, and 10%, increased 21 and 28 days are 15% and 11% decreased.
- Compressive strength C₄ 7, 14 days strength was equal, and 5% increased 21 and 28 days are 21% and 14% decreased when compared to C₁

5.2 Flexural Strength of Plain concrete

Flexural strength of plain concrete prisms of C₂, 23% and 58% increase, C₃, 16% and 29% increase and C₄ 26% decrease and 17% increase at 7 and 28 days after compared to C₁.

The value in bending strength for C₂, was 8% more for the plain cement concrete, 41% higher for singly reinforced case and 22% increased, for doubly reinforced concrete beam, C₃, was equal on plain cement concrete, 9% higher for singly reinforced case and 2% decreased, for doubly reinforced concrete beam and C₄, was equal to the plain cement concrete, 17% higher for singly reinforced case and 49% increased, for doubly reinforced concrete beam than C₁.

References

- [1] Hillerborg A. Fracture mechanics concepts applied to moment capacity and rotational capacity of reinforced beams. In: Proceedings, international conference on fracture and damage mechanics of concrete and rock, Vienna; 1988; p. 233–40.
- [2] Bazant ZP. Identification of strain-softening constitutive relation from uniaxial tests by series coupling model for localization. *CemConcr Res* 1989;19:973–7.
- [3] A.A. Ramezani pour, M. Esmaili, S.A. Ghahari, M.H. Najafi Laboratory study on the effect of polypropylene fibre on durability and physical and mechanical characteristic of concrete for application in sleepers, *Construction and Building Materials* 44 (2013) 411–418.
- [4] R.D. Neves, J.C.O. Fernandes de Almeida, Compressive behaviour of steel fibre reinforced concrete. *Structural concrete* 1464-4177 2005
- [5] A. Meda, F. Minelli, G.A. Plizzari and P. Riva, Shear behaviour of steel fibre reinforced concrete beams, *Materials and structures* 38(April 2005) 343-351
- [6] A.A. Ramezani pour, M. Esmaili, S.A. Ghahari, M.H. Najafi Laboratory study on the effect of polypropylene fibre on durability and physical and mechanical characteristic of concrete for application in sleepers, *Construction and Building Materials* 44 (2013) 411–418.
- [7] Mukesh Shukla, Behaviour of Reinforced Concrete Beams with Steel Fibres under Flexural Loading, ISSN 0974-5904, Volume 04, No 06 SPL, October 2011, pp 843-846
- [8] Hyun-Ho Lee, Shear strength of steel fibre reinforced concrete columns under seismic loading, *Engineering structures* 29(2007) 1253-1262
- [9] Serkan Tokgoz, Cengiz Dundar, A. Kamil Tanrikulu, Experimental behaviour of steel fibre high strength
- [10] Vikrant S. Vairagade, Kavita S. Kene, Introduction to steel fibre reinforced concrete on engineering performance of concrete, *International journal of scientific & Technology research* volume 1, issue 4 may 2012
- [11] Dr. Perumal, B. Thanukumari, Use of fibre cocktails to increase the seismic performance of beam-column joints, *International journal of engineering science and technology* vol.2(9), 2010, 3997-4006