A STUDY ON THE STRENGTH PARAMETERS OF CONCRETE WITH POLYPROPYLENE FIBERS AS A REINFORCING MATERIAL

By

GOURISHETTY RUTHVIK * CHALLA DATTA KARTHIK ** G. SIVA VIGNAN ***

*-*** Department of Civil Engineering, St. Martin's Engineering College, Hyderabad, Telangana, India.

Date Received: 21/01/2020 Date Revised: 11/03/2020 Date Accepted: 24/04/2020

ABSTRACT

Concrete is basically a brittle material and possesses very low tensile strength. To overcome this weakness, we generally introduce reinforcement to the concrete. For this study, we are aiming to analyze the strength parameters of concrete under the influence of fibers as a reinforcing material. During the last 30 years, different types of fibers and fiber materials were introduced and are being continuously produced in the market as new applications. Usage of fibers in concrete helps to improve resistance to cracking and fragmentation. For this study, Polypropylene fiber is used as a reinforcing material. We have used M40 and M25 concrete and a comparative study on strength parameters is made with and without the presence of these fibers. The compressive, flexural strength tests were performed by using fiber weight content from 5%.

Keywords: Compressive Strength, Concrete, Fiber Reinforced Concrete, Flexural Strength, Polypropylene Fibers.

INTRODUCTION

Concrete is one of the most versatile and has been leading building materials. It can be casted in to fit any structural shape. It is readily available in urban areas simply at an affordable cost (Shetty, 2005). Though, Concrete is strong under compression but weak under tension. Practice of concrete provides the following advantages as, high durability, good fire resistance, negligible maintenance and most importantly grater compressive strength. Concrete also offers some limitations as, poor tensile strength (which could be altered by providing reinforcement) and formwork requirement (which is un-ignorable).

Concrete material is very weak in tension (Bureau of Indian Standards, 2000). So, to add tensile property to concrete, reinforcement is added.

Tensile strength of concrete is typically 8% to 15% of its compressive strength. This weakness has been dealt with over many decades by using a system of reinforcing bars to create reinforced concrete, so that concrete primarily resists compressive stresses and steel bars resist tensile and shear stresses (Wafa, 1990).

Generally, we use HYSD (High Yielding Strength Deformed Steel) bars (Raju & Pranesh, 2003), mild steel, steel fibers (Ghaffar et al., 2014; Shende et al., 2012) and other materials to reinforce the concrete in-situ. This process of reinforcing is greatly efficient of increasing the tensile and flexural strength of concrete. It also brings many disadvantages along with it including increasing the self-weight of the structure, being non-economical, demanding resources like transportation, cost for bar bending etc.

Whereas, few studies stated that few fibers are capable of replacing the regular reinforcement with few special fibers. Such concretes can be simply called as Fiber Reinforced Concrete.

Fiber Reinforced Concrete (FRC) is a concrete containing fibrous material as a reinforcing material to enhance the tension developing in the concrete (Arunakanthi & Kumar, 2016). These fibers act as an alternative material to the reinforcing materials like HYSD bars.

This concrete contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, synthetic and natural fibers each of which lend varying properties to the concrete. The characteristics of fiber-reinforced concrete are influenced by the type of concrete, fiber materials geometrics and other factors (Rai & Joshi, 2014).

This study primarily aims to use Polypropylene fibers as a reinforcing material for the concrete.

1. Literature Review

Kandasamy and Murugesan (2011), in their study on "Fiber Reinforced Concrete Using Domestic Waste Plastics as Fibers" and have presented their results as, using 0.5% of polythene fibers to concrete, there is an increase in the cube compressive strength of concrete in 28 days to an extent of 5.12%, increase in the split tensile strength to an extent of 1.63%, and increase in the various mechanical properties of the concrete mixes with polythene fibers is not in same league as that of the steel fibers.

Shende et al. (2012) have worked on the concept of "Experimental Study on Steel Fiber Reinforced Concrete for M-40 Grade" and have vividly explained their results as, compressive strength, split tensile strength and flexural strength are on higher side for 3% fibers as compared to that produced from 0%, 1% and 2% fibers. All the strength properties were observed to be on higher side for aspect ratio of 50 as compared to those for aspect ratio 60 and 67. Finally, it was observed that compressive strength increased from 11 to 24%, flexural strength increased from 12 to 49%, split tensile strength increased from 3 to 41% with addition of steel fibers.

Rai et al., (2014) have worked on the concept of "Applications and Properties of Fiber Reinforced Concrete", and have stated their results as, fiber addition improves ductility of concrete and its post-cracking load-carrying capacity. In FRC crack density is increased, but the crack size is decreased. The addition of any type of fibers to plain concrete reduces the workability. Fibers are also capable of enhancing the toughness of Concrete.

Krishna and Rao (2014), have done research on "Experimental study on behavior of fiber reinforced concrete for rigid pavements", and have attained the following results. Compressive strength enhancement ranges from 8.38% to 16.37% when % of fiber increases from 0.1% to 0.3% for PFRC compared to the conventional concrete at 28 days. At the age of 28 days, there is a significant improvement in the flexural strength with the addition of fibers. The increment in the flexural strength is from 12.42% to 41.13% when % of fibers varied from 0.1% to 0.3% respectively. 0.3% is observed as the optimum value. By addition of polyester fiber in concrete, the pavement thickness is decreased by 20%, which is economical when compared to plain cement concrete.

Ghaffar et al. (2014) have done an intensive research on "Steel Fiber Reinforced Concrete", and have found that, workability decreases with increase in fiber content. The wet and dry density (7 and 28 Days) goes on decreasing as the percentage fiber volume fraction increases and ductility of concrete is found increasing with inclusion of fibers at higher fiber content.

Gupta & Malhotra (2018), have done "A Case Study on Fiber Reinforced Concrete", and have attained the following results. There was an increase in compressive strength of 10% upon increase of 0.25% of fibers in the concrete. High quantities of fiber produced concrete with poor workability and segregation, higher entrapped air and lower unit weight. The fiber concrete fails in more ductile mode opposite the plain concrete that shattering into pieces.

2. Objectives

- To use polypropylene fibers as a reinforcing material to concrete and compare its properties with nominal concrete.
- To analyze the properties of fiber reinforced concrete
- To study the effect of using polypropylene fiber on concrete compressive and flexural strength.
- To increase the flexural strength of concrete.

2.1 Materials Used

2.1.1 Cement

Cement is one of the basic construction material that will be generally in powdered form and hardens upon the addition of water to it. It can serve as a binding material to aggregates to obtain strength. It possesses cohesive and adhesive properties. The cement used for this study is Portland Pozzolana Cement of 53 Grade (BIS, 2013).

The properties of the cement used for this study are presented in Table 1.

S. No	Property of Cement	Value
1	Grade of Cement	53
2	Fineness	390 m^2/kg
3	Standard Consistency	33.5%
4	Setting Time	
	a) Initial	30 minutes
	b) Final	550 minutes
5	Soundness in Le-Chat Expansion	0.5 mm
6	Compressive Strength	
	a) 72 +/- 1hour (3 days)	28.6 MPa
	b) 168 +/- 2 hour (7 days)	38.6 MPa
	c) 672 +/- 4 hour (28 days)	58.0 MPa

Table 1. Properties of Cement Used

2.1.2 Fine Aggregate

The aggregate passing through IS: 4.75 mm sieve could be called as fine aggregate. Generally, fine aggregate is a filling material for the concrete. The fine aggregate used for this project is river sand collected from local RMC plant. The specific gravity of the fine aggregate used for this study is 2.65.

2.1.3 Coarse Aggregate

The aggregates passing through IS: 20 mm sieve and retained on IS: 4.75 mm sieve could be called as coarse aggregate (BIS, 2016). Generally, coarse aggregate is a material that enhances the strength and stability for the concrete. The coarse aggregate used for this study is collected from Miyapur Quarry. The specific gravity of coarse aggregate used is 2.83.

2.1.4 Water

Water is the main ingredient used to mix all the contents. Potable water is used, as usage of any other water may contain salts and cause decrease in strength of concrete.

2.1.5 Polypropylene Fibers

Recron 3s fibers are manufactured in an ISO 9001:2000 facility for use in concrete as a "Secondary Reinforcement" at a rate of dosage varying from 0.1% to 0.4% by 0.9 kg/m^3 - 3.6 kg/m^3. Fibers comply with ASTM C 1116, Type 111 Fiber Reinforced Concrete. All the properties of Polypropylene fibers are shown in Table 2.

3. Methodology

For this project, initially we have adopted 2 concrete mixes. They are M40 concrete (Design Mix) which is made with respect to BIS (2009), and M25 Concrete (Traditional Mix).

S. No	Properties of Fiber	Value
1	Shape	Triangular
2	Cut Length	3/4.8/6/12/ 18/24 mm
3	Effective Diameter	25-40 microns
4	Specific Gravity	0.90-0.91
5	Melting Point	160-165°C
6	Tensile Strength	4-6 * GPa
7	Elongation	60-90 %
8	Young's Modulus	> 4000 MPa
9	Alkaline-Stability	Very Good

Table 2. Properties of Fibers

The proportions for these mixes are, M40 (1:1.67:2.92) and M25 (1:1:2) and the water cement ratio is 0.5 for both the mixes. The process of mixing is done by hand mixing. Mixing of reinforced concrete is shown in Figure 2 and the applying is shown in Figure 3.

For fiber reinforced concrete, 5% of fibers are added to the mix on the weight of cement and are casted in the form of cubes and prisms. After hardening, they are proceeded for curing and testings.

4. Results and Discussions

After the specimens are done with the certain period of curing, they are subjected to compressive strength and flexural strength tests. For this study, we have adopted immersion curing for the concrete specimens. Each test result is tabulated and analyzed.

4.1 Compression Test Results

Compression Test is done by subjecting compression load on the concrete cube surface in Digital Compression testing machine, as shown in Figure 4 and the cube specimen after testing is presented in Figure 5.

Size of cube for compression testing = 150 x 150 x 150 mm.

Compressive strength of concrete = Compressive Load/ (Surface Area of cube).

The results of this test are shown in table 3, and the variation in compressive strength for M40 & M25 are shown in Figure 6 & 7 respectively.

4.2 Flexure Test Results

Flexure test is done on concrete prism, by subjecting the flexural load in flexure testing machine, as shown in Figure 8. The prism specimen looks as shown in Figure 9.

According to BIS (2000), the flexural strength of concrete at

Figure 2. Mixing of Fiber Reinforced Concrete

Figure 3. Freshly Mixed Fiber Reinforced Concrete

Figure 4. Compression Testing for Cube specimens

Figure 5. Cube Specimen After Compression Testing

Grade of Concrete	Type of Concrete	Average Compressive Strength (MPa) 7 Days	14 Days	28 Days
M40	Nominal Concrete	20.26	32.65	40.13
	Fiber Reinforced Concrete	42.26	49.87	53.18
M25	Nominal Concrete	19.01	21.57	33.84
	Fiber Reinforced Concrete	29.88	33.23	39.39

Table 3. Compression Test Results for Various Concretes and Concrete Grades

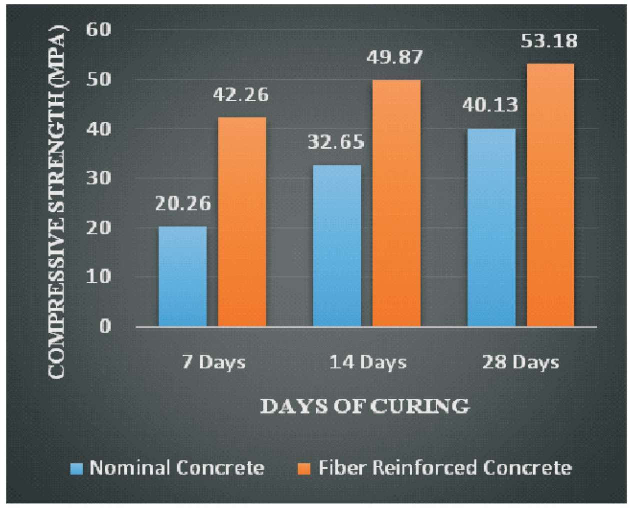

Figure 6. Variation of Compressive Strength in M40 Concrete for Nominal and Fiber Reinforced Concretes

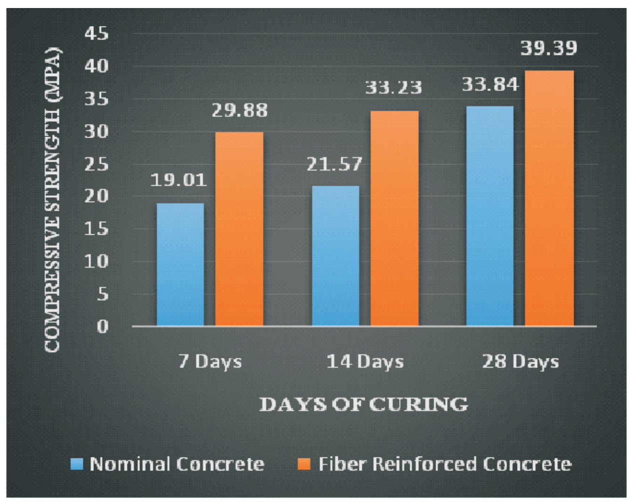

Figure 7. Variation of Compressive Strength in M25 Concrete for Nominal and Fiber Reinforced Concretes

28 days age would be 0.7* $(f_{ck})^{0.5}$ MPa. (where, f_{ck} is the grade of concrete).

Size of prism for flexure testing = 500 x 100 x 100 mm.

Flexure Strength of concrete = (Maximum Flexure Loadx length of prism/ width x depth^2).

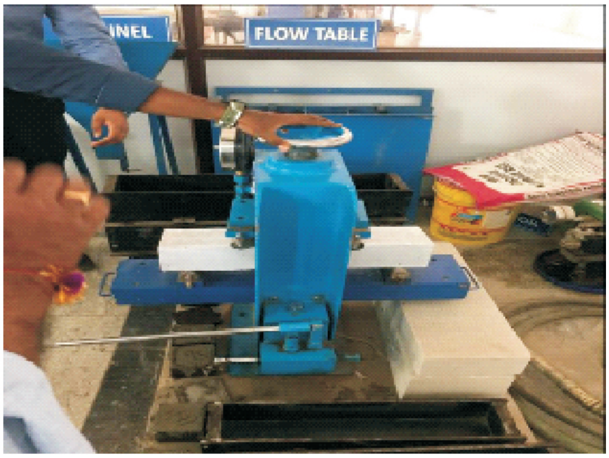

Figure 8. Flexure Testing Machine

Figure 9. Concrete Prism Specimen after Flexure Testing

Grade of Concrete	Type of Concrete	Average Compressive Strength (MPa) 7 Days	14 Days	28 Days
M40	Nominal Concrete	2.58	3.20	4.97
	Fiber Reinforced Concrete	5.80	6.30	7.10
M25	Nominal Concrete	2.98	3.46	3.70
	Fiber Reinforced Concrete	4.10	5.75	6.75

Table 4. Flexure test Results for Various Concretes and Concrete Grades

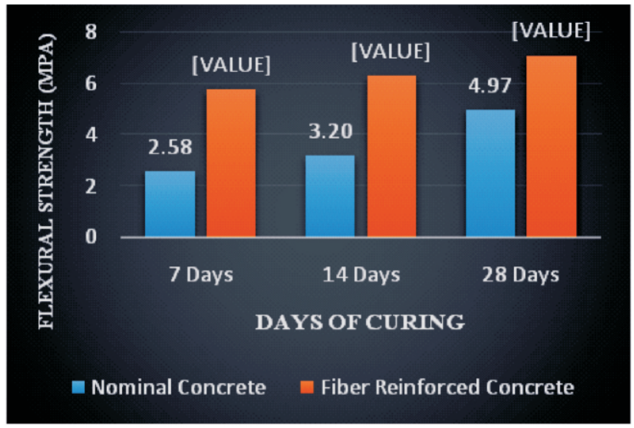

Figure 10. Variation of Flexural Strength in M40 Concrete for Nominal and Fiber Reinforced Concretes

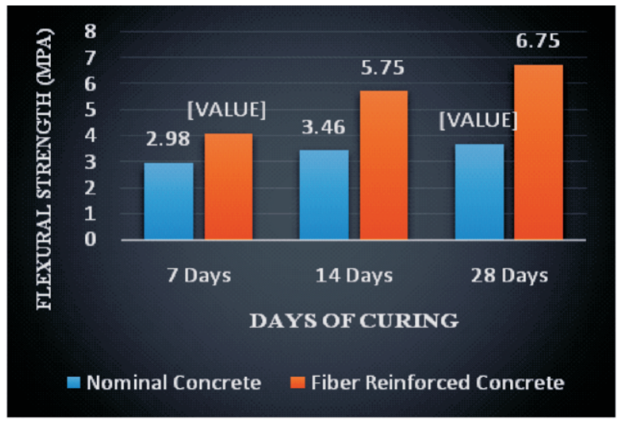

Figure 11. Variation of Flexural Strength in M25 Concrete for Nominal and Fiber Reinforced Concretes

The results for this test are presented in Table 4 and the variation in flexural strength for M40 and M25 are shown in Figure 10 and 11 respectively.

Conclusion

- Adoption of fiber reinforced concrete have given us higher compressive and flexural strengths in both the concretes.
- We have achieved on an average of about 20% higher compressive strength in both the grades by the usage of fiber reinforced concrete.
- There is also an increase of flexure strength for about more than 50% in fiber reinforced concrete than nominal concrete in both the grades.
- Polypropylene fibers are very economical compared to normal reinforcement, and are also time saving.

- It is observed that there is an increase in flexural strength in FRC compared to nominal concrete. So there are much favorable chances to decrease the amount of steel reinforcement practically.
- Since we are reducing the amount of reinforcement in concrete, the dead load of the structure decreases, hence the dimensions of the entire structure can be reduced. Thus we can ultimately minimize the cost of construction.
- The only disadvantage that fiber reinforced concrete offers is that, the mixing could be done only by hand mixing, which offers concrete in limited quantities.
- So further developments could be made to prepare this fiber reinforced concrete using machine mix to attain higher quantities of concrete.

Acknowledgement

We, Challa Datta Karthik and Gourishetty Ruthvik, would like to take this opportunity to thank our Project Guide Mr. G. Siva Vignan for helping us throughout this study. We would also like to thank our Department of Civil Engineering, St. Martin's Engineering College for supporting us. We like to thank our parents for imposing so much of faith and love on us.

References

[1]. **Arunakanthi, E., & Kumar, J. C. (2016).** Experimental studies on fiber reinforced concrete (FRC). *International Journal of Civil Engineering and Technology,* 7(5), 329-336.

[2]. **BIS. (2000).** *Plain and Reinforced Concrete - Code of Practice [CED 2: Cement and Concrete]* (Standard No. 456). Bureau of Indian Standard, New Delhi. Retrieved from https://www.iitk.ac.in/ce/test/ IS-codes/is.456.2000.pdf

[3]. **BIS. (2009).** *Guidelines for Concrete Mix Design Proportioning [CED 2: Cement and Concrete]* (Standard No. 10262). Bureau of Indian Standard, New Delhi. Retrieved from https://law.resource.org/pub/in/bis/S03/is. 10262.2009.pdf

[4]. **BIS. (2013).** *Ordinary Portland Cement, 53 Grade Specification (First Revision) Code of Practice.* (Standard No. 12269). Bureau of Indian Standard, New Delhi. Retrieved from https://www.iitk.ac.in/ce/test/IS-codes/is. 122 69.2013.pdf

[5]. **BIS. (2016).** *Specification for Coarse and Fine Aggregates from Natural Sources for Concrete Code of practice.* (Standard No. 383). Bureau of Indian Standard, New Delhi.

[6]. **Ghaffar, A., Chavhan, A. S., & Tatwawadi, R. S. (2014).** Steel Fiber Reinforced Concrete. *International Journal of Engineering Trends and Technology (IJETT),* 9(15), 791-797. https://doi.org/10.14445/22315381/IJETT-V9P349

[7]. **Gupta, G., Malhotra, S. (2018).** A Case Study on Fiber Reinforced Concrete. *International Journal for Research in Applied Science & Engineering Technology (IJRASET),* 6(VI), 3253-3255. https://doi.org/10.22214/ijraset.2018.454 1

[8]. **Kandasamy, R., & Murugesan, R. (2011).** Fibre reinforced concrete using domestic waste plastics as fibres. *ARPN Journal of Engineering and Applied Sciences,* 6(3), 75-82.

[9]. **Krishna, K. V., & Rao, J. V. (2014).** Experimental study on behavior of fibre reinforced concrete for rigid pavements. *IOSR Journal of Mechanical and Civil Engineering,* 11(4).

[10]. **Rai, A., & Joshi, Y. P. (2014).** Applications and properties of fibre reinforced concrete. *International Journal of Engineering Research & Application,* 4(5), 123-131.

[11]. **Raju, N. K., & Pranesh, R. N. (2003).** *Reinforce Concrete Design: IS: 456-2000: Principles and Practice.* New Delhi, India: New Age International.

[12]. **Shende, A. M., Pande, A. M., & Pathan, M. G. (2012).** Experimental study on steel fiber reinforced concrete for M-40 grade. *International Refereed Journal of Engineering and Science,* 1(1), 043-048.

[13]. **Shetty, M. S. (2005).** *Concrete technology.* New Delhi, India: S. Chand Publishing.

[14]. **Syal, I. C., Goel, A. K. (2008).** *Reinforced Concrete Structures.* New Delhi, India: S. Chand Publishing.

[15]. **Wafa, F. F. (1990).** Properties & applications of fiber reinforced concrete. *Engineering Sciences,* 2(1), 49-62.

[16]. **Zaidi, S. F. A., Khan, M. A., & Kumar, A. (2016).** Fiber Reinforced concrete using waste material: A review. *International Research Journal of Engineering and Technology (IRJET),* 3(3), 534-536.

ABOUT THE AUTHORS

Gourishetty Ruthvik is a student who is currently pursuing his final semester in Bachelors of Technology in Civil Engineering from St. Martin's Engineering College (SMEC), Hyderabad, Telangana, India. He holds a Diploma in Civil Engineering from TRR College of Technology, Telangana, India. His areas of interests include Structural Engineering and Project Management.

Challa Datta Karthik is a student who is currently pursuing his final semester in Bachelors of Technology in Civil Engineering from St. Martin's Engineering College (SMEC), Hyderabad, Telangana, India. He holds a Diploma in Civil Engineering from VNR Vignana Jyothi Institute of Engineering and Technology, Telangana, India. He has published a total of 03 Papers in reputed National and International Journals. His areas of interests include Structural Engineering, Water Resources and Environmental Engineering.

G. Siva Vignan is currently working as an Assistant Professor in the Department of Civil Engineering at St. Martin's Engineering College (SMEC), Hyderabad, Telangana, India. He holds his M. Tech Degree in Structural Engineering from Vellore Institute of Technology, Tamil Nadu, India. He has published 6 papers in reputed National and International Journals. His main research area includes Sustainable Construction Material for building and Light Weight Concrete.