

Chopped Carbon Fibers Innovative Material for Enhancement of Concrete Performances

, Prashant Muley¹, Shrikant Varpe², Rahul Ralwani³,

¹ Assistant Professor, Civil Engineering Dept, Datta Meghe College of Engineering, Airoli, Navi Mumbai, India

² Deputy Manager, Ambuja Cements Ltd, Andheri East India

³ Graduate Student, Datta Meghe College of Engineering, Airoli, Mumbai, India

Abstract— the purpose of this research is based on the investigation of the use of short fibres in structural concrete to enhance the mechanical properties of concrete. The objective of the study was to determine and compare the differences in properties of concrete containing no fibres and concrete with fibres, as well as the comparison on the effects of different volume of fibres to the concrete. This investigation was carried out using several tests, which included workability test, compressive test, split tensile test and flexural test.

A total of five mix batches of concrete containing 0%, 0.25%, 0.5%, 0.75% and 1.0% fibre volume dosage rate on carbon fibres were tested to determine the enhancement of mechanical properties of concrete. The workability of concrete significantly reduced as the fibre dosage rate increases. This was assessed through standard slump test. Results of compressive strength test indicated that the use of fibre in concrete increase the strength and help in early strength gain. In flexural and split tensile test showed specimens with fibres that drastic increase in strength from specimens without fibres.

The usage of fibres were fully utilized in split tensile test as the fibres don't allow splitting of concrete specimens after the first crack. Flexure test results showed us that the concrete with fibres didn't have brittle failure after first crack and the concrete could take further load after first crack indicating increase in ductility of concrete.

As to create a cost efficient fibre reinforced structure, these changes on fibres are vital to the design and construction. However, further investigations are recommended and could be carried out to understand more mechanical properties of fibre reinforced concrete.

Keywords—Fibers, Chopped Carbon Fiber, Fiber reinforced concrete, The minimum or critical fibre volume dosage rate, fibres volume dosage. Split tensile test.

I. INTRODUCTION

Fibre Concrete is acknowledged to be a relatively brittle material when subjected to normal stresses and impact loads, where 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, majority on concrete beams and slabs.

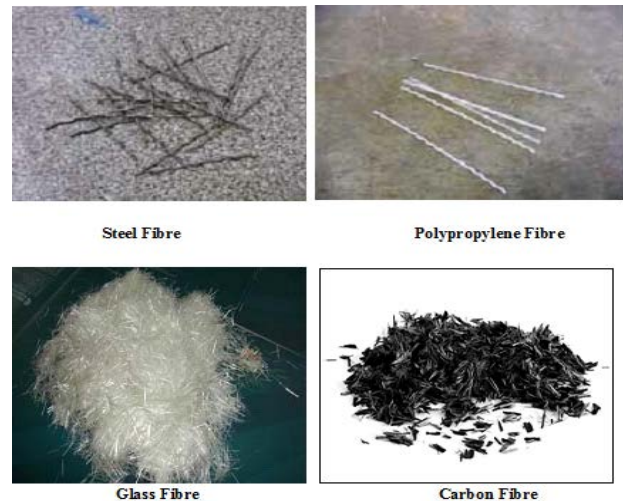


Figure 1: Types of fibres available in market.

In the early stage of fibre development, steel and glass fibres with geometry of straight and smooth were used, as these fibres improve in ductility, flexural strength and fracture toughness of concrete matrix [1, 2, 3]. Figure 1 shows various fibres available in market. The primary factors that controlled for this composition were fibre volume fraction and length/diameter. However, the problems faced were difficulty in mixing and workability. Fibres that are long and at higher volume fractions were found to ball up during

the mixing process^[8]. The process called ‘balling’ occurs, causes the concrete to become stiff and a reduction in workability with increased volume dosage of fibres. This has a tendency to influence the quality of concrete and strength.^[4, 6, 15]

The introduction of fibres was brought in as a solution to develop concrete in view of enhancing its flexural and tensile strength, which are a new form of binder that could combine Portland cement in the bonding with cement matrices^[5, 13, 19]. Fibres are most generally discontinuous, randomly distributed throughout the cements matrices. The term of ‘Fibre reinforced concrete’ (FRC) is made up with cement, various sizes of aggregates, which incorporate with discrete, discontinuous fibres.^[7, 9, 14]

II. CARBON FIBER DETAILS.

Carbon Fiber Chopped		GC-700T-PU6
Chop Length	mm	6
Carbon Content	%	95
Electrical Resistivity	Ω.cm	1.6 X 10 ⁻³
Elongation	%	1.8
Tensile Strength	MPA	4,300
Tensile Modulus	Gpa	230
Bulk Density	g/liter	350
Filament Diameter	um	7
Sizing agent	Poly urethane %	1.2

Table 1. Properties of carbon fibres Short pitch chopped carbon fibres: (source: Ramesh carbon suppliers)

These fibres with different volume fractions have been used in this study to study the effect of short chopped carbon fibres on mechanical properties (compressive strength, splitting tensile strength and flexural strength) of concrete. Carbon fibre, is a material consisting of fibres about 5–10 μm in diameter and composed mostly of carbon atoms.

To produce carbon fibre, the carbon atoms are bonded together in crystals that are more or less aligned parallel to the long axis of the fibre as the crystal alignment gives the fibre high strength-to-volume ratio (making it strong for its size). Several thousand carbon fibres are bundled together to form a tow, which may be used by itself or woven into a fabric.^[10, 11, 13]

The properties of carbon fibres, such as high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion, make them very popular in aerospace, civil engineering, military, and motorsports, along with other competition sports.

However, they are relatively expensive when compared to similar fibres, such as glass fibres or plastic fibres.^[10, 12]

III. EXPERIMENTAL WORK

A. The minimum amount

Carbon fibres should add in the concrete mix was therefore 0.2% by volume. The value obtained corresponds to the minimum volume percentage used in the past research.^[16] To alter and further the effects of fibre reinforced concrete, fibre dosage rates of 0.25%, 0.5%, 0.75% and 1.0% by volume were selected. Summary of Mix design in table no 2.^[17, 18, 19]. As a result, a total of 5 mix batches were required for this project, which involves 4 different volumes of carbon fibres and a control mix batch. From current information, when fibre volume dosage is around 2%, the concrete is not workable and too stiff.

B. Summary Of Mix Design

GRADE	M40
SLUMP	25mm -75mm
A/C	3.6
W/C	0.4
F.A.	47%
C.A.-I	16%
C.A.-II	37%

Table 2: Summary of mix design

IV. FIBER VOLUME DOSAGE RATE AND MIX BATCHES AND VOLUME AND WEIGHT OF CARBON FIBRE

Carbon fibers (%)	Volume of fibers (in lit)	Weight of fibers(in kg)
0.00%	Control mix	
0.25%	2.5	0.875
0.50%	5	1.75
0.75%	7.5	2.625
1.00%	10	3.5

Table 3 Carbon fibres by weight required per cum. of concrete.

V. PRACTICAL WORK

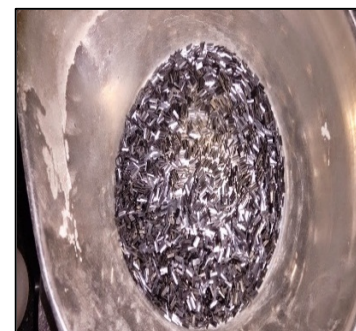


Figure 2 chopped Carbon fiber sample



Figure 3 Drying of River sand before sieve analysis.



Figure 4 : Compacting cube using rubber hammer &



Figure 5: Slump measuring during concrete trails.

VI. RESULTS AND DISCUSSION.

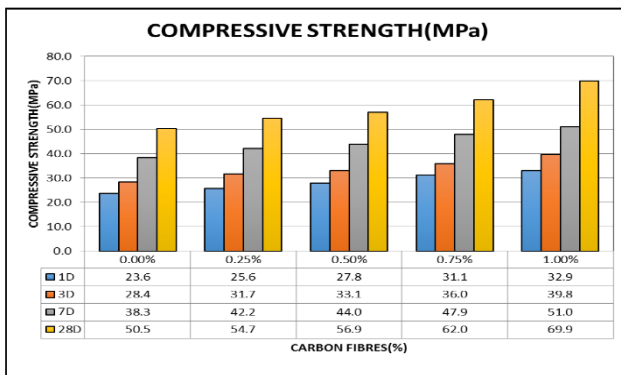


Chart 1 Compressive strength of concrete at 1d, 3d, 7d & 28d for different volume dosage of carbon fibers

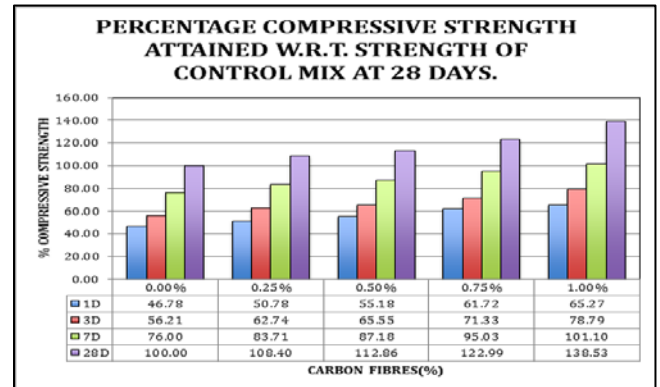


Chart 2. Percentage of compressive strength attained with respect to compressive strength of control mix at 28 days

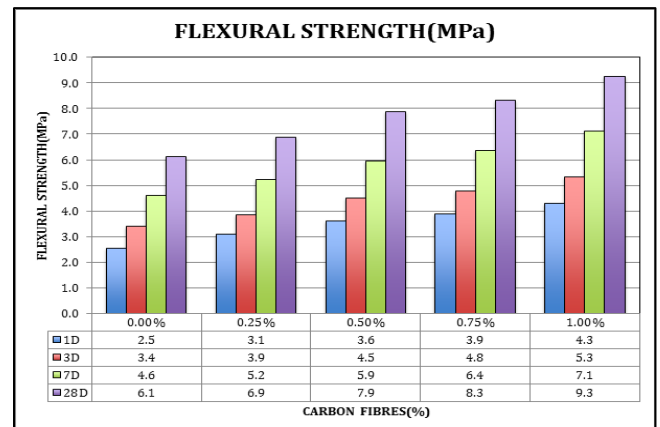


Chart 3 flexural strength of concrete at 1d,3d,7d & 28d for different volume dosage of carbon fibers.

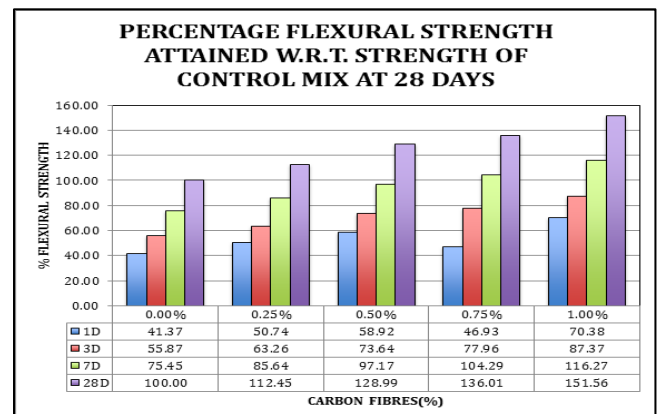


Chart 4. Percentage of flexural strength attained with respect to compressive strength of control mix at 28 days

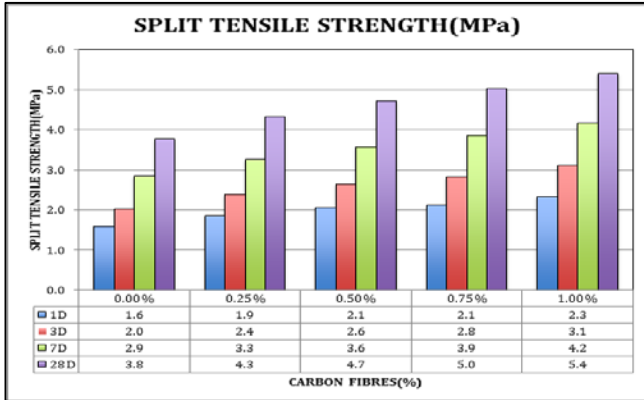


Chart 5 Split tensile strength of concrete at 1d, 3d, 7d & 28d for different volume dosage of carbon fibers

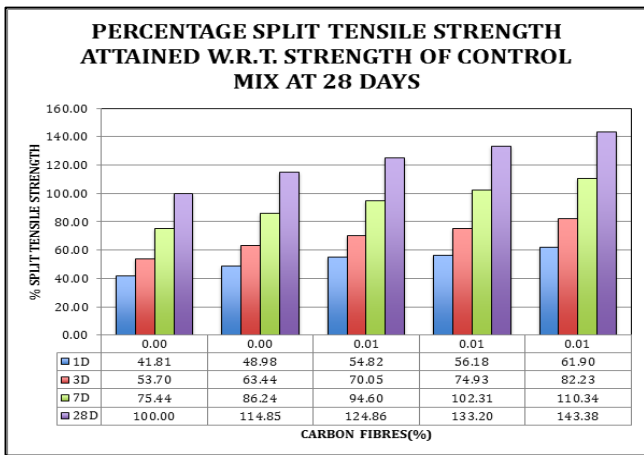


chart 6 Percentage of split tensile strength attained with respect to compressive strength of control mix at 28 days

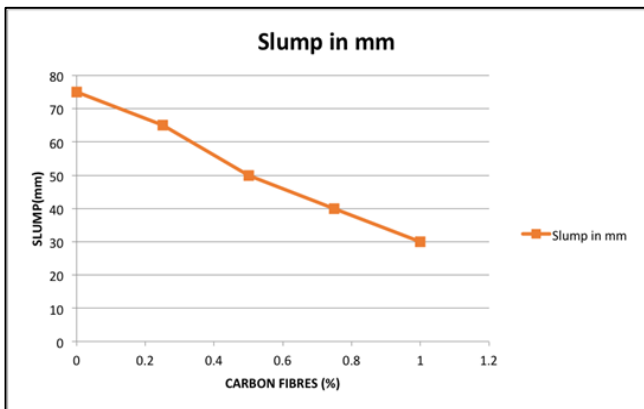


Chart 7. Average slump height vs. fiber volume dosage rate of each batch.

VII. RESULTS DISCUSSION AND CONCLUSION

The comparisons of mechanical properties and behaviour include the workability, compressive strength, indirect tensile strength and flexural strength. With the discussions and results obtained from the experimental

tests, it is clearly to know the effect of carbon fibres used in the structural concrete.

A. Compressive Strength (Chart 1 & 2)

It is observed that the rate of increase is higher when the volume dosage rate exceeds 0.5%. Maximum compressive strength of 69.9 MPa is observed at fibre volume of 1.00% which indicates an increase of 19.4 MPa when compared with control mix.

The percentage increase in compressive strength at different fibre volume rate with respect to control mix. A linear percentage increase in strength is over served up to a fibre volume of 0.75%. The percentage increase in strength is higher when the fibre volume is increased from 0.75% to 1.00%. There is an increase of about 38.5% in compressive strength at 1.00% fibre volume dosage as compared to control mix. The percentage compressive strength gained with respect to the compressive strength gained by control mix at 28 days. This bar graph shows us that concrete with fibres at 1.00% volume dosage gain equal strength to the strength of control mix at 28 days in 7 days. The strength of concrete having carbon fibres at 0.75% also is seen to gain 95% strength of control mix at 28 days in 7 days. Hence this shows that concrete with carbon fibres at volume of 0.75% can be used economically where faster rate of construction is required.

B. Flexural Strength (Chart 3 & 4)

The percentage increase in compressive strength at different fibre volume rate with respect to control mix. A linear percentage increase in strength is over served up to a fibre volume of 0.75%. The percentage increase in strength is higher when the fibre volume is increased from 0.75% to 1.00%. There is an increase of about 38.5% in compressive strength at 1.00% fibre volume dosage as compared to control mix.

The percentage compressive strength gained with respect to the compressive strength gained by control mix at 28 days. This bar graph shows us that concrete with fibres at 1.00% volume dosage gain equal strength to the strength of control mix at 28 days in 7 days. The strength of concrete having carbon fibres at 0.75% also is seen to gain 95% strength of control mix at 28 days in 7 days. Hence this shows that concrete with carbon fibres at volume of 0.75% can be used economically where faster rate of construction is required.

C. Split tensile Strength (Chart 5 & 6)

The indirect tensile test results have an increasing trend of average tensile strength for fibre reinforced concrete when the fibre volume dosage rate increased. This increase in tensile strength was due to the nature of binding of fibre available in concrete. When the reinforced concrete was force to split apart in the tensile strength test, the load was

transferred into the fibres as pull-out behaviour when the concrete matrix began to crack where it exceeded the pre-crack state. The control batch specimens containing no fibres failed suddenly once the concrete cracked, while the fibre reinforced concrete specimens were still intact together. This shows that the fibre reinforced concrete has the ability to absorb energy in the post-cracking state.

The increase in strength is not predominant in the first 7 days at any fibre volume dosage rate. The tensile strength for control mix at 28 days was 3.8 MPa and the tensile strength when fibre volume dosage is 1.00% was 5.4 MPa. Hence, an increase of 1.6 MPa in strength was observed. Tensile strength increases linearly as the fibre dosage rate increases hence. There is no sudden increase in tensile strength at any fibre volume hence, 0.50% fibre volume rate may be adopted as the best economical dosage rate. It is observed that the rate of increase is higher when the volume dosage rate exceeds 0.5%. Maximum compressive strength of 69.9 MPa is observed at fibre volume of 1.00% which indicates an increase of 19.4 MPa when compared with control mix.

D. Slump cone test (Chart 7)

The experimental results showed that the slump of the fibre reinforced concrete has a decreasing trend when the fibre volume dosage rate increases. Considering a slump value of 75mm for control mix with no fibre added to the concrete. Once the fibre was added into the concrete, an average slump drop of 10mm was observed for every 0.25% increase in fibre volume dosage.

VIII. FUTURE SCOPES

Further investigations can be carried out to understand more mechanical properties of fibre reinforced concrete. Several recommendations for further studies are mentioned below:

The problem on the workability of the fresh fibre reinforced concrete can be reduced by adding chemical admixture such as super plasticiser, silica fume or blast furnace slag. Hence, with high workable fresh concrete can demote the quick stiffening effects from the fibres.

More investigations and laboratory tests can be done to study on the mechanical properties of fibre reinforced concrete. Such application of fibres can be done in testing on concrete slabs, beams and walls or conducting more tests such as abrasion, impact, blasting, shatter, shear or creeping of concrete.

The combination of short fibres may tend to provide more efficient mechanical properties of structure. Further investigation can be carried out by combination of different types of short fibres into the concrete mix.

To widen the use of fibre reinforced concrete, different or more complicated geometry of fibre can be used to investigate the effects of short fibres in the concrete through fresh and hardened properties.

The mechanical properties of fibre reinforced concrete may be different in various temperatures. Test on hot weather and cold weather concreting can be performed.

References

- [1] ACI committee, "State - of - the art report in fiber reinforced concrete" ACI 554 IR – 96 Detroit Michigan 1996.
- [2] ACI Committee 544, 1984, Guide For Specifying, Mixing, Placing, and Finishing Steel Fiber Reinforced Concrete, ACI Journal, Volume 81, Number 2, March-April 1984, p.140-147.
- [3] ACI Committee 544, (1993) Guide for proportioning, mixing, placing and finishing steel fiber reinforced concrete, ACI Materials Journal, 90 (1), pp. 94-101.
- [4] Banthia N. and Dubey A., 2000, Measurement of flexural Toughness of Fiber- Reinforced Concrete Using Technique – Part 2: Performance of various Composites, ACI Materials Journal, Volume 97, Number 1.
- [5] James J. Beaudoin, 1990, Handbook of Fiber-Reinforced Concrete: Principles, Properties, Development and Applications, Noyes Publications, New Jersey, United State of America.
- [6] Nanni A., and ACSE, 1992, Properties of Aramid-Fiber Reinforced Concrete and SIFCON, Journal of Materials in Civil Engineering, Volume 4, Number 1, February 1992, p.1-13.
- [7] Toutanji, H. A. and Saafi, M., "Flexural Behavior of Concrete Beams Reinforced with Glaass Fiber-Reinforced Polymer (GFRP) Bars," ACI Structural Journal, Vol. 97, No. 5, September-October 2000, pp. 712-719.
- [8] Balaguru, P. (1994). Contribution of fibers to crack reduction of cement composites during the initial and final setting period. ACI Materials Journal. V. 91, No. 3, May-June, 280-288.
- [9] Johnston C. D., 1982, Steel Fiber Reinforced and Plain Concrete: Factors influencing Flexural Strength Measurement, ACI Journal, Volume 79, Number 14, March-April 1982, p.131-138.
- [10] Johnston C. D. and Skarendahl A., 1992, Comparative flexural performance evaluation of steel fiber-reinforced concretes according to ASTM C1018 shows importance of fiber parameters, Materials and Structures, Volume 25, Number 148, May 1992, p.191-200
- [11] P. Rathish Kumar and K. Srikanth a Department of Civil Engineering, NIT Warangal, India, (2008), "Mechanical Characteristics Of Fiber Reinforced Self Compacting Mortars" Asian journal of civil engineering (building and housing) vol. 9, no. 6 (2008) pages 647-657
- [12] Dragica Jevtić, Dimitrije Zakić, Aleksandar Savić, (2008), "Modeling Of Properties Of Fiber Reinforced Cement Composites" University of Belgrade, Faculty of Civil



Engineering, Serbia facta universities Series: Architecture and Civil Engineering Vol. 6, No 2, 2008, pp. 165 - 172

- [13] Wang Y., Wu H. C. and Victor C. Li, 2000, Concrete Reinforcement with Recycled Fibers, Journal of Materials in Civil Engineering, Volume 12, Number 4, November 2000, p.314-319.
- [14] D.D.L. Chung, 1999, Cement reinforced with short carbon fibers: a multifunctional material.
- [15] Malvar, L.J., "Tensile and Bond Properties of GFRP Reinforcing Bars," ACI Materials Journal, vol. 92, no. 3, May-June 1995, pp. 276-285.
- [16] Perumalsamy N. Balaguru, Sarendra P. Shah, "Fiber reinforced cement composites", Mc Graw Hill International Editions 1992.
- [17] Indian Standard 10262: 2009, Concrete Mix Proportioning: Guidelines.
- [18] Indian Standard 1199: 1959, Methods of Sampling and Analysis of Concrete.
- [19] Indian Standard 516: 1959, Methods of tests for Strength of Concrete.