Assessment on Fracture Behaviour of Carbon Fiber Reinforced Concrete using Micro Silica

Pasupuleti Tilak Surya Varma[1], P. Narendra Babu[2]
[1]PG Student, Department of CE, NRI Institute of Technology, Agiripalli, A.P, India.
[1]Associate Professor & HOD, Department of CE, NRI Institute of Technology, Agiripalli, A.P, India.

***Abstract*— 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.**

***Index Terms*— Cement, Carbon fibers, Fiber Reinforced Concrete, Cracks in Concrete, Carbon Fibers in Concrete, Crack Propagation.**

I. INTRODUCTION

Carbon Fibre is one of the most recent developments in the field of composite materials and is one of the strongest fibres known to man. It is usually the first choice of fibre if some thin very strong and very light is required. Carbon fibre was originally developed in space technology, but has now been adopted in many other areas of manufacture. Racing car monocoques and aero plane wings are usually constructed of carbon. Generally, the term "carbon fibre" is used to refer to carbon filament thread. Carbon fibre is one of the latest reinforcement materials used in composites. It's a real hi-tech material, which provides very good structural properties

Carbon fibers or carbon fibres (alternatively CF, graphite fiber or graphite fibre) are fibers about 5 to 10 micrometers (0.00020–0.00039 in) in diameter and composed mostly of carbon atoms. Carbon fibers have several advantages: high stiffness, high tensile strength, high strength to weight ratio, high chemical resistance, high-temperature tolerance, and low thermal expansion. These properties have made carbon fiber very popular in aerospace, civil engineering, military, motorsports, and other competition sports. However, they are relatively expensive compared tosimilar fibers, such as glass fiber, basalt fibers, or plastic fibers.

Beyond Overall, these technical advantages make carbon fiber reinforced concrete a promising material for a wide range of structural applications where strength, durability, and lightweight properties are desired. To produce a carbon fiber, the carbon atoms are bonded together in crystals that are more or less aligned parallel to the fiber's long axis as the crystal alignment gives the fiber a high strength-to- volume ratio (in other words, it is strong for its size). Several thousand carbon fibers are bundled together to form a tow, which may be used by itself or woven into a fabric.

II. EXPERIMENTAL PROGRAM

The primary stage includes the preliminary re-search on selecting the raw materials. Number of conventional trails is prepared and the mix proportions for M25 grade is selected. By replacing the Carbon fiber in control mix 0%, 1.0%, 1.5%, 2.0% optimum percentage is selected for main trails. The Fresh and Hardened properties are studied in this work by M25 grade. The Fracture behavior of concrete was also investigated in terms of Crack Width Measurement and CMOD (Crack Mouth Opening Displacement) Studies.

The Main Objectives of the present investigation are:

- Examining how various carbon fiber percentages affect the fresh and hardened characteristics of concrete.
- To examine the effectiveness of using carbon fiber in concrete studying strength parameters depends on carbon fiber percentages.
- To use carbon fiber as an admixture in concrete which gives more strength and less in weight.
- To obtain optimum percentage of carbon Fiber reinforced concrete.

B. Materials:

Concrete is a composition of three raw materials. They are Cement, Fine aggregate and Coarse aggregate. These three raw materials play an important role in manufacturing of concrete. By varying the properties and amount of these materials, the properties of concrete will change. The main raw materials used in this experimental work are cement, fine aggregate, coarse aggregate and carbon fiber.

C. Carbon Fiber:

The Carbon fibers are of 5–10 micron diameter. Carbon fibers can be used as an addition of percentage in concrete. It can improve the workability and durability of concrete, Carbon fiber represents a significant advancement in material science, offering exceptional strength and lightweight properties that have revolutionized various industries, from aerospace to automotive and sports. It embodies the quest for stronger, lighter, and more durable materials for modern engineering and design challenges. The Carbon fibers are of 1 Inch length approximately.

Table -1: Properties of Carbon Fiber

S.NO	Physical Property	Value
1	Specific gravity	1.9
2	Physical form	Filaments
3	Colour	Black

III. MIX DESIGN

Mix proportioning is done according to the guidelines of IS – 10262: 2019. The detailed mix quantities are as follows.

Table -2: Mix Proportions as Per IS 10262 – 2019

Mix	% Percentage	Cement (kg/m^3)	Silica Fume	CF (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Water (kg/m^3)
Control Mix	0	380	0	0	724	1287	138
Trial 1	0.5	361	19	1.9	724	1287	138
Trial 2	1.0	361	19	3.8	724	1287	138
Trial 3	1.5	361	19	5.7	724	1287	138
Trial 4	2.0	361	19	7.6	724	1287	138

IV. RESULTS AND DISCUSSIONS

A. Fresh Properties(Slump Cone Test):

Slump cone method consist a cone of 300mm height, 200mm bottom diameter and 100mm top diameter. For doing slump test concrete is poured into the cone in 3 layers and tamped at 24 times for each layer with a tamping bar. After total compaction the cone will removed and height of cone will measured. The difference between actual height and formed cone height will give slump value. The Average Slump Value of the concrete is shown in Table 4.

Table -3: Workability of Concrete

MIX	SLUMP (mm)
Trial 1 (0% CF)	65
Trial 2 (0.5% CF)	60
Trial 3 (1% CF)	56
Trial 4 (1.5% CF)	55
Trial 5 (2% CF)	40

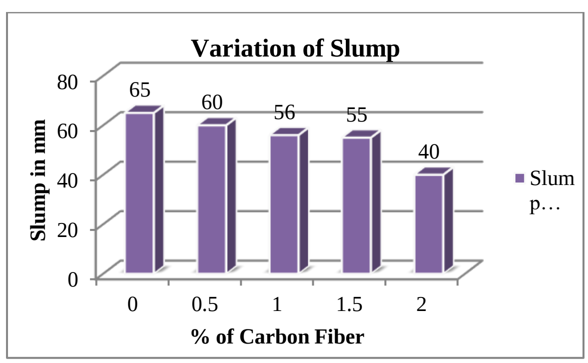

Fig. 1 Variation of Slump

B. Hardened Properties:

One of the most crucial characteristics of hardened property is its compressive strength, which is frequently utilized as a gauge of the material's general quality. We can determine the compression strength by utilizing a compression test machine. Count of laboratory tests done on varying concrete percentages over 7 and 28 days. The Variation of Split Tensile Strength and Flexural Strength were also investigated.

Table -4: Compressive Strength of Concrete

Mix	Compressive Strength (N/mm²)	
	7 Days	28 Days
Trial 1 (0% CF)	18.0	36.7
Trial 2 (0.5% CF)	24.4	44.0
Trial 3 (1% CF)	23.5	32.3
Trial 4 (1.5% CF)	23.0	31.2
Trial 5 (2% CF)	20.0	29.1

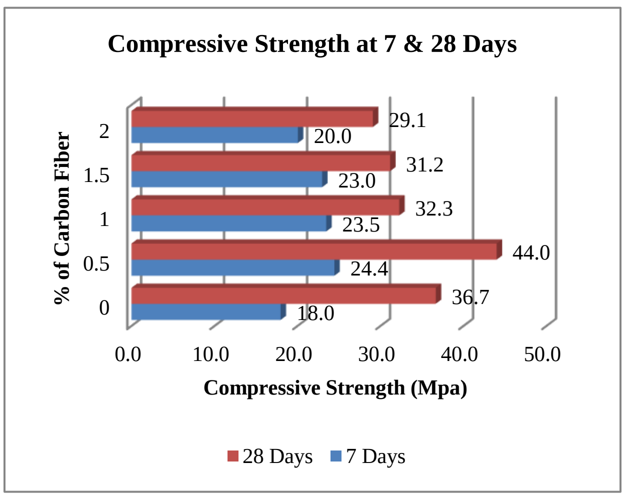

Fig. 2 Variation of Compressive Strength

Table -5: Split Tensile Strength of Concrete

Mix	Split Tensile Strength (N/mm²)	
	7 Days	28 Days
Trial 1 (0% CF)	1.82	3.19
Trial 2 (0.5% CF)	2.53	3.41
Trial 3 (1% CF)	2.40	3.14
Trial 4 (1.5% CF)	2.26	3.06
Trial 5 (2% CF)	2.09	2.86

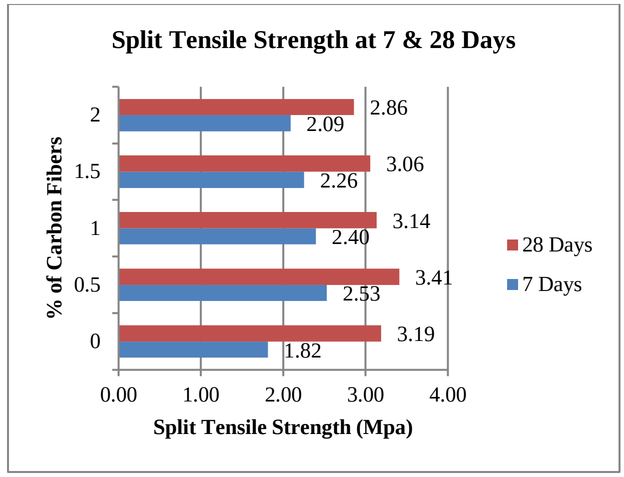

Fig. 3 Variation of Split Tensile Strength

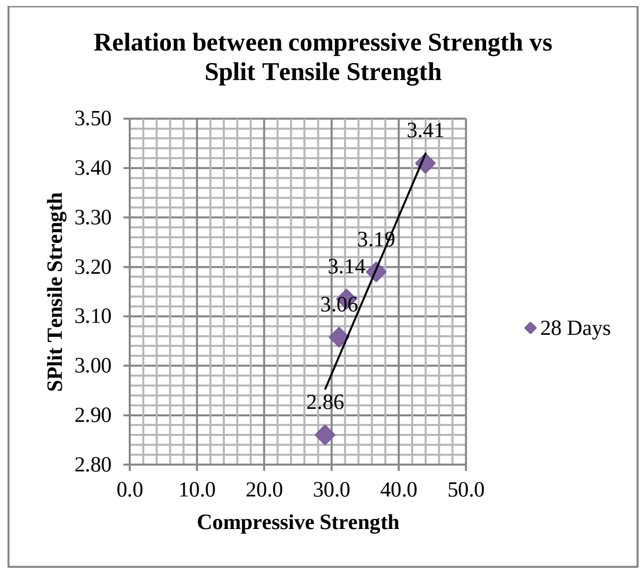

Fig 4 Relation between Compressive Strength vs Split Tensile Strength

Table -6: Flexural Strength of Concrete

Mix	Flexural Strength (N/mm²)	
	7 Days	28 Days
Trial 1 (0% CF)	1.82	3.19
Trial 2 (0.5% CF)	2.53	3.41
Trial 3 (1% CF)	2.40	3.14
Trial 4 (1.5% CF)	2.26	3.06
Trial 5 (2% CF)	2.09	2.86

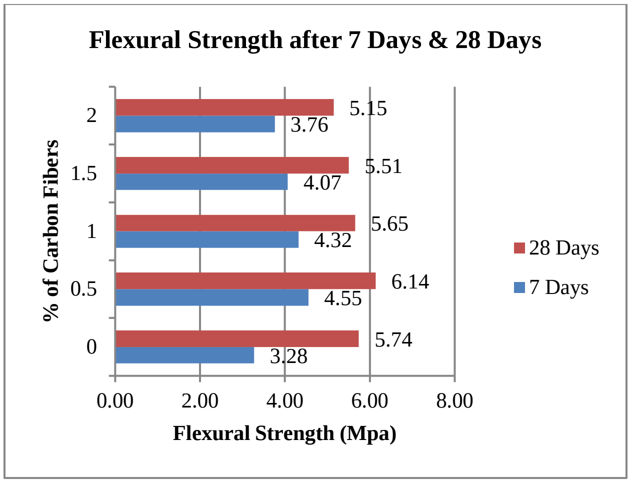

Fig. 5 Variation of Flexural Strength

V. CRACK PROPAGATION STUDIES

An experimental evaluation of crack propagation and post-cracking behavior in Carbon fiber reinforced concrete (CFRC) beams, using full-field displacements obtained from the Physical Width Measurement technique using Crack Width Measuring Gauge are presented. Surface Crack Widths of CFRC beams with volume fractions (V_f) of steel fibers equal to 0.5%, 1%, 1.5% and 2% are analyzed. An analysis procedure for determining the crack opening width over the depth of the beam during crack propagation in the flexure test is presented. The crack opening width is established as a function of the crack tip opening displacement. The Values of CMOD were presented in Table 6,

Table - 7: Crack Mouth Opening Displacement of CFRC Cubes

Mix	Crack Width in mm	
	Face 1	Face 2
Trial 1 (0% CF)	4	3
Trial 2 (0.5% CF)	1.2	1
Trial 3 (1% CF)	1.5	1.5
Trial 4 (1.5% CF)	2	1.6
Trial 5 (2% CF)	1.5	1.8

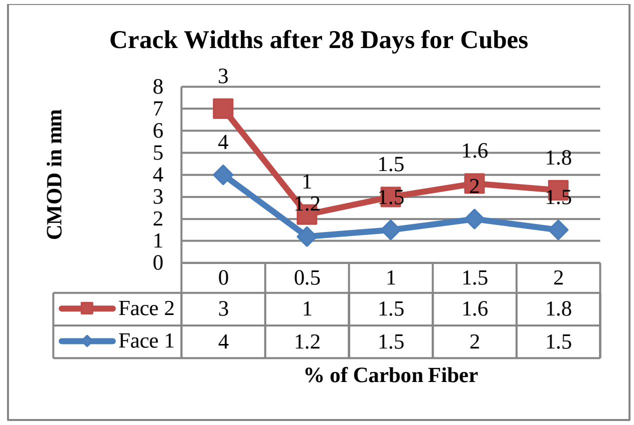

Fig 6 Crack Mouth Opening Displacement of Cubes after 28 Days

Table – 8: Crack Mouth Opening Displacement of CFRC Beams

Mix	Crack Width in mm	
	Face 1	Face 2
Trial 1 (0% CF)	3.5	2.8
Trial 2 (0.5% CF)	0.5	1
Trial 3 (1% CF)	1	1.2
Trial 4 (1.5% CF)	1.5	1.6
Trial 5 (2% CF)	1.8	2

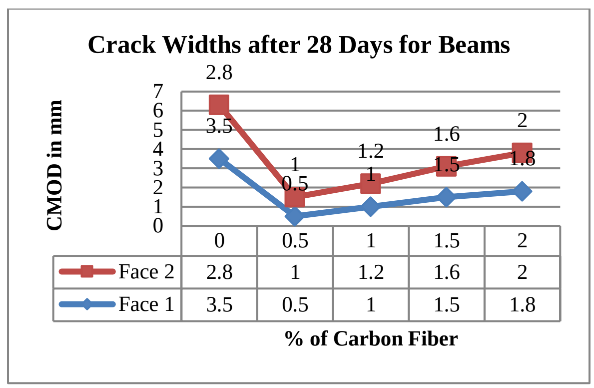

Fig 7 Crack Mouth Opening Displacement of Beams

VI. CONCLUSIONS

Based on the limited study carried out on the strength behavior of Ferrocement the following conclusions are drawn.

- In the present investigation the fresh and Hardened Properties are successfully achieved their desired values.
- The material carbon fiber is a good composite material to the concrete that satisfies all the requirements and it can be used for all constructional purposes.
- Maximum compressive strength of 40 Mpa for M25 Grade had occurred for 0.5% of carbon fibre for 28 days.

- Maximum Split tensile strength of 3.1 Mpa had occurred for 0.5 % of carbon fibre for 28 days.
- Workability of carbon fiber reinforced concrete is decreased compared to control mix in slump cone Test.
- It was observed that the workability of concrete is gradually reducing while increasing the carbon fibres.
- The optimum percentage of carbon fibres is 0.5 % for M25 grde concrete.
- The minimum Crack widths are observed for concrete cubes with 0.5% Carbon Fiber and the average width is 1.1 mm.
- The minimum Crack widths are observed for concrete beams with 0.5% Carbon Fiber and the average width is 0.75 mm.
- The Silica Fume used in this experimental investigation has improved the internal bonding of concrete by filling micro voids and 5% Silica Fume is optimum for the mix.

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