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EXPERIMENTAL STUDY ON RANDOMLY DISTRIBUTED CARBON FIBER REINFORCED CEMENT CONCRETE BEAMS

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Abstract—: **As for brittle materials is concerned, concrete is strong under compression and weak under tension or flexure. This problem may be alleviated by the addition of short carbon fibers. Extensive applications of the fiber-reinforced polymer (FRP) materials as new construction materials have been recently accomplished FRP materials are lightweight, high strength, non-corrosive and nonmagnetic materials. By virtue of these advantages, there is a wide range of recent, present, and potential applications of these materials that covers both new and existing structures. Among different types of FRP materials, a carbon fiber-reinforced polymer is used extensively in the structural engineering field. Bonding of carbon fiber reinforcement to reinforced concrete members is widely accepted and is considered to be an effective and convenient method of reinforcing among many methods of strengthening different construction, due to excellent mechanical properties of the fiber; high strength at tension ,resistance to aggressive environment, light weight. Carbon fibers are not harmful to workers health, not required skill labors.**

In this research work flexural test and ductility test is conducted for the carbon fibers concrete. The optimum percentage of carbon fiber in plain concrete is to find from 1%, 2%, 3%, 4% and 5% of carbon fiber of 10mm length by weight of the cement and to find the optimum length of the carbon fiber in concrete from 10mm, 20mm, 30mm, 40mm and 50 mm length of the carbon fiber by 1% weight of cement. The specimen size of 150mm×150mm×700mm is subjected to one point loading in flexural test. The present study also aims at finding the behavior of carbon fiber reinforced concrete and optimum percentage of fibers which gives the best results both in terms of enhanced properties and economy.

Keywords— Fiber Length, Fiber Percentage, Random Fiber Reinforced Concrete

I. Introduction

Concrete is a brittle material which is strong in compression and weak in tension or flexure. Findings on the reinforcement of these brittle matrixes in search of improving their mechanical properties are a continuous process since ancient periods. This problem may be alleviated by the addition of carbon fibers. Concrete is probably the most widely used man-made construction material in the world. Concrete is second highest consumptive material after water, which is used worldwide for most of constructions. As from 1960's the modern development of fiber-reinforced concrete has experienced rapid growth. The development of new high-performance composite materials that are stronger and more durable than conventional materials (e.g., Portland cement concrete, steel, wood, and masonry) is important to the construction industry.

To use concrete as a load-bearing element, therefore, it is necessary to impart tensile resistance properties to a concrete structural member. This has been achieved, long before, by the use of reinforcing bars, and more recently by the application of prestressing. Although both these methods provide tensile strength to the concrete member, they do not increase the inherent tensile strength of concrete itself. Thus the overall performance of the traditional reinforced concrete composite material is still effectively dictated by the individual performance of the concrete phase and the steel phase. This has lead to the search for the new materials particularly two-phase composite materials in which the weak matrix is reinforced with strong stiff fibers to produce a composite of superior properties and performance.

Fibers are intended to improve tensile strength, flexural strength, toughness, and to control cracking. Corrosion of reinforcing steel in concrete structure is a major problem affecting infrastructure. Carbon fiber reinforced concrete has outstanding properties such as high strength, durability, and resistance to electrochemical corrosion. Carbon fibers do not corrode, have superior fire resistance and possess long term durability in an alkaline medium such as cement paste, thus making them superior to steel, polymeric and glass fibers. carbon fiber-reinforced concrete are structural materials that are gaining an importance quite rapidly due to the decrease in carbon fiber cost and the increasing demand of superior structural and functional properties. In relation to most functional properties, carbon fibers are exceptional compared to other fiber types. The small closely spaced fibers act like crack arresters substantially and improve static and dynamic strengths. FRC has found interesting applications due to inherent superiority over conventional plain and reinforced concrete in the properties like higher flexural strength, higher shear strength, shock resistance, better ductility and fatigue resistance. The properties of such fiber reinforced concrete will depend upon the properties of the fiber used. As more research and development progresses, short-fibers now possess more complex shapes and dimension in search of optimizing performance of the short-fibrereinforced concrete.

1. EXPERIMENTAL DETAILS

1.1. Methodology:

Experimental studies: Carbon fiber reinforced concrete is an important development in the field of concrete technology. Available literature is an indicator to the tremendous interest and enthusiasm shown in adoption of carbon fiber reinforced concrete for construction. Finding the mix proportion for M_{20} concrete by conducting the physical properties test, flexural and ductility tests are carried out. Finally the experimental results are collected and analyzed.

1.2. Materials:

The materials used for investigation are as follows, the physical properties of material is tested as per IS method

- Cement
- Fine aggregate
- Coarse aggregate
- Carbon fiber sheet

1.2.1. Cement

Ultra-Tech 53-grade cement was used in the present investigation. It was tested as per IS-4031-1988 recommendation for hydraulic cement.

1.2.2 Fine aggregate:

The locally available river sand has been used as fine aggregate. Physical test on fine aggregate have been conducted.

1.2.3. Coarse aggregate:

For coarse aggregate, 10 mm and down size grit metal has been used Carbon Fiber Sheet.Carbon fiber alternatively called graphite fiber, graphite fibre or carbon graphite) is a material consisting of extremely thin fibers about and composed mostly of carbon atoms. The carbon atoms are bonded together in microscopic crystals that are more or less aligned parallel to the long axis of the fiber. The crystal alignment makes the fiber incredibly strong for its size. The density of carbon fiber is also considerably lower than the density of steel, making it ideal for applications requiring low weight. The properties of carbon fiber such as high tensile strength, low weight, and low thermal expansion make it very popular in aerospace, civil engineering, military, and motorsports, along with other competition sports.

Table 1: Properties of one layer of fiber-reinforced polymer materials

Fiber orientation	Weight of Fiber	Density	Fiber thickness	Tensile modulus	Tensile strength	Ultimate elongation
unidirectional	200 g/m^2	1.80 g/cm^3	0.3mm	28500 N/mm^2	3500 N/mm^2	1.5 %

Modulus of elasticity: 1.65×10^5 N/mm^2
Poisson's ratio: 0.25

1.2.4 Mixing of Concrete

The primary requirement when a mix was carried out was to ensure that the mix ingredients was mixed thoroughly, where fresh concrete produced consists of aggregates which were covered thoroughly by cement paste. Furthermore, the importance of achieving uniformity in the mix was also stressed. In the project, the mix ingredients involve cement, water, sand, aggregates and fibres.

1.2.5. Specimens

Specimens which were prepared consist beams (150mm x 150mm x 700mm) are used.
The concrete was poured into the specimens. After that, the specimens were
Compacted, leveled and finally placed into the curing room for 7, 14, 21 and 28 days.

Figure.1: Specimens Used In the Project

Table 2: Comparison of Concrete and Carbon-Fiber Reinforced Concrete

Factor	Conventional Concrete	Carbon Fiber Reinforced Concrete
Weight	Difficult to transport	Easier to transport with 50% less weight
Damage	Quality control problems, corner damage and cracking during handling	Better quality control, tougher and hence easier to handle
Formability	Bar arrangement is difficult, formation of ribs is difficult	Casting and molding of complex architectural forms is possible, increased used in decorative outcrops

2. Flexural Test

Flexural strength of a concrete is a measure of its ability to resist bending. Flexural strength can be expressed in terms of 'modulus of rupture'. Concrete specimens for flexural strength were cross sectional area of 150mm width with 150mm depth and length of 700mm concrete beam. The specimen is subjected to bending; using one - point loading until it fails. The distance of the loading point (*l*) is 350 mm and the supporting point (L) is 60mm. Figure shows the setting up of the concrete beam specimen. The test was carried out under computer-controlled conditions, which measures the load and deflection of concrete beam specimens. As an accurate load/deformation curves can be plotted to obtain the toughness of the concrete with the computer software. In this test, the load/deformation behavior is much more important than the modulus of rupture. It tells more information about the behavior and effect of each type of the short fibres applied in the concrete, once it reaches to the post-crack condition. Because of this perspective, the test is desirable to conduct under a computer-controlled condition.

The task of this test was performed to find the increase and differences of strength according the increasing percentage of fibre in the concrete, as fundamental to assess and evaluate the effects of the additional of short carbon fibres on the behavior of concrete. The flexural strength test was conducted in the material laboratory of universal testing machine after 7, 14, 21 and 28 days of curing. Flexural strength was determined using the equations 1 and 2. As per IS

$$F = \frac{PL}{BD^2} \quad \text{Equation (1)}$$

$$F = \frac{3Pa}{BD^2} \quad \text{Equation (2)}$$

Where,

F = Flexural Strength (N/mm^2)
P = Failure Load (N)
L = Effective Length (mm)
B = Breadth of specimen (mm)
D = Depth of specimen (mm)
A = Average distance between the line of fracture and the nearest support measured on the tension surface of the beam. (mm)

Equation (1) is considered when the fracture in the tension zone surface occurs within the half of the span length i.e, a > 29cm.

Equation (2) is considered when the fracture in the tension zone surface occurs outside the half of the span i.e. < 29cm but > 23cm.

If fractured in the tension zone occurs outside the half by more than 5% of the span, i.e, < 23cm, then the results shall be discarded.

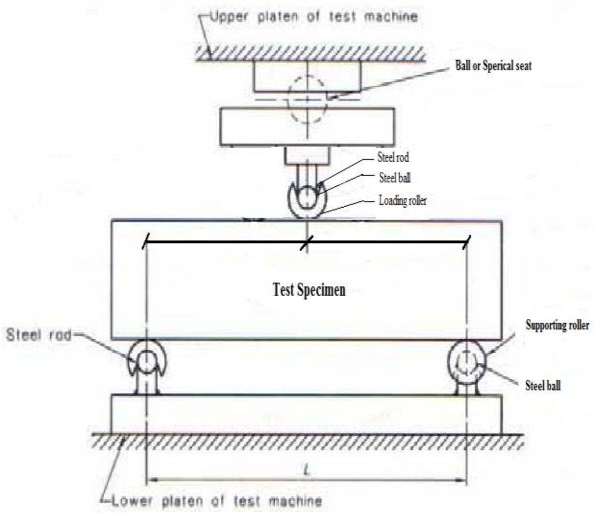


Figure 2: Flexural Test for One Points Loading**.**

3. Ductility Test:

Ductility can be defined as the “ability of material to undergo large deformations without rupture before failure”. This is beneficial to the users of the structures, as in case of overloading, if the structure is to collapse, it will undergo large deformations before failure and thus provides warning to the occupants. This gives a notice to the occupants and provides sufficient time for taking preventive measures. This will reduce the loss of life.

Ductility index of the composite was measured for single point and two point loading bending tests. The deflection ‘Δ85’ corresponding to ultimate load, ‘P max’ and deflection ‘Δ85‘corresponding to 85% of peak load were recorded. The ratio of deflection corresponding to maximum load to that of deflection corresponding to 85% of peak load gives the value of Ductility Index.

Ductility Index, DI = $\Delta max / \Delta 85$

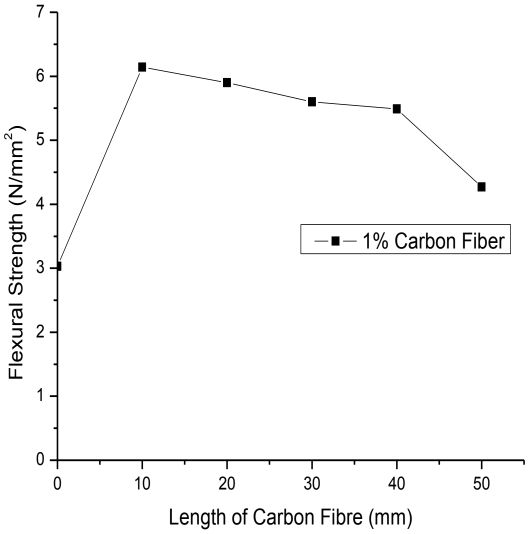
4. RESULTS AND DISCUSSION

4.1. Flexural Strength

The experimental load deflection curves for the beams of random carbon fiber shown in figure where the critical deflections of all the beams occurred at mid span. From the results it is concluded that the flexural strength increased with increasing fiber content up to 3.0 %.The increase of the flexural strength was 35.5%, 36.89%, 34.05% and 31.23% for the 10.0 mm fibers and 30.40%, 29.22%, 27.22% and 21.33% for the 3.0 % fibers of 7, 14, 21 and 28 days respectively.

Table 3: Effect of Carbon Fiber Length on Flexural Strength for 1.0 % Carbon Fiber of Specimen size 150×150×700 mm. (7 days)

Sr.No.	Length of the Fiber (mm)	Load (KN)	Flexural Strength (N/mm^2)	Deflection (mm)
01	Plain	18.85	3.96	2.15
02	10	29.64	6.14	2.10
03	20	28.40	5.90	2.20
04	30	27.01	5.60	1.85
05	40	26.50	5.49	1.70
06	50	20.63	4.27	1.89

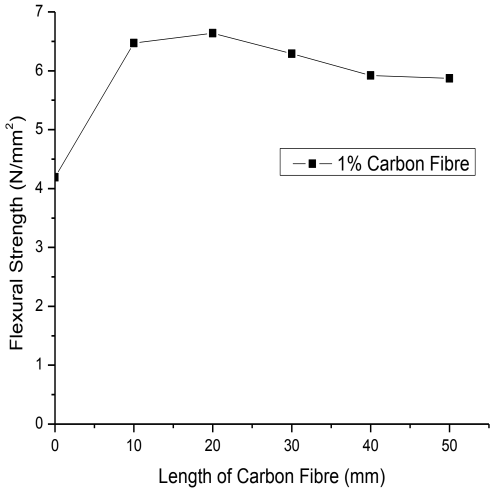


Graph 1: Flexural Strength v/s Fiber Length

Table4: Effect of Carbon Fiber Length on Flexural Strength for 1.0 %

Carbon Fiber of Specimen size 150×150×700 mm.(14 days)

Sr.No.	Length of the Fiber (mm)	Load (KN)	Flexural Strength (N/mm^2)	Deflection (mm)
01	Plain	20.23	4.19	2.30
02	10	32.05	6.64	2.35
03	20	31.23	6.47	2.21
04	30	30.36	6.29	1.96
05	40	28.50	5.92	1.85
06	50	28.33	5.87	1.95

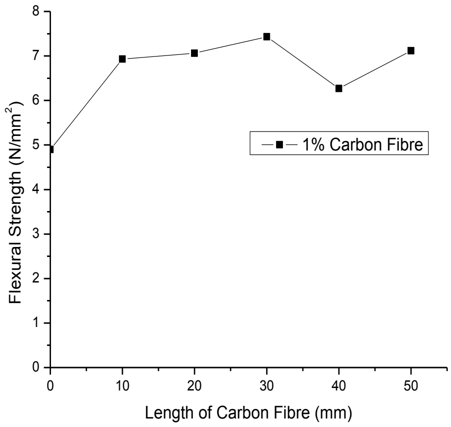


Graph 2: Flexural Strength v/s Fiber Length

Table 5: Effect of Carbon Fiber Length on Flexural Strength for 1.0 %

Carbon Fiber of Specimen size 150×150×700 mm.(21 days)

Sr.No.	Length of the Fiber (mm)	Load (KN)	Flexural Strength (N/mm^2)	Deflection (mm)
01	Plain	23.65	4.90	2.40
02	10	35.83	7.43	2.44
03	20	34.06	7.06	2.23
04	30	33.46	6.93	2.06
05	40	30.24	6.27	1.95
06	50	29.27	6.12	2.22

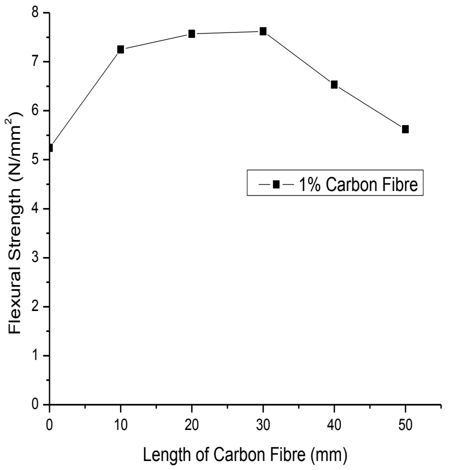


Graph 3: Flexural Strength v/s Fiber Length

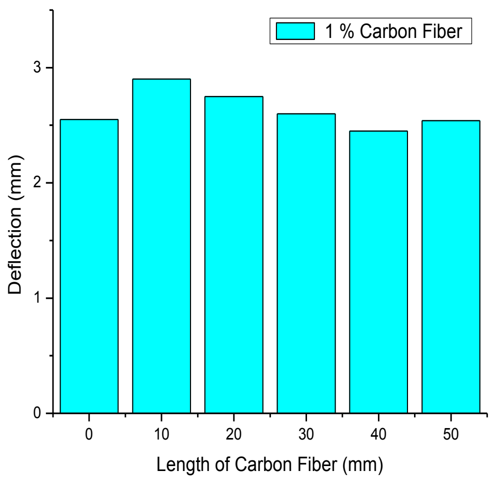
Table 6: Effect of Carbon Fiber Length on Flexural Strength for 1.0 %

Carbon Fiber of Specimen size 150×150×700 mm.(28 days)

Sr.No.	Length of the Fiber (mm)	Load (KN)	Flexural Strength (N/mm^2)	Deflection (mm)
01	Plain	25.30	5.24	2.55
02	10	36.75	7.62	2.90
03	20	36.50	7.57	2.75
04	30	35.00	7.25	2.60
05	40	31.50	6.53	2.45
06	50	30.35	5.62	2.54



Graph 4: Flexural Strength v/s Fiber Length



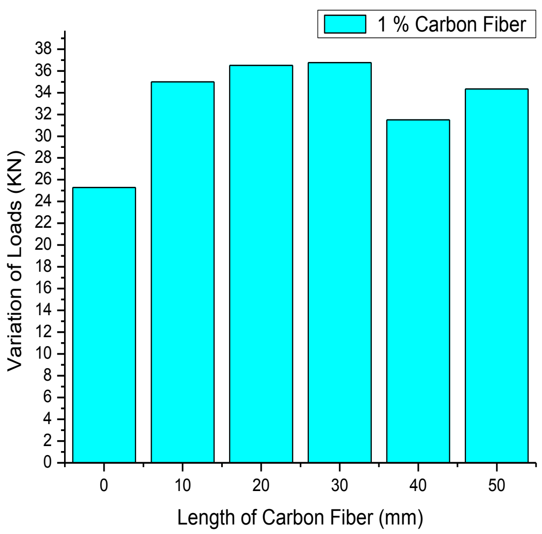
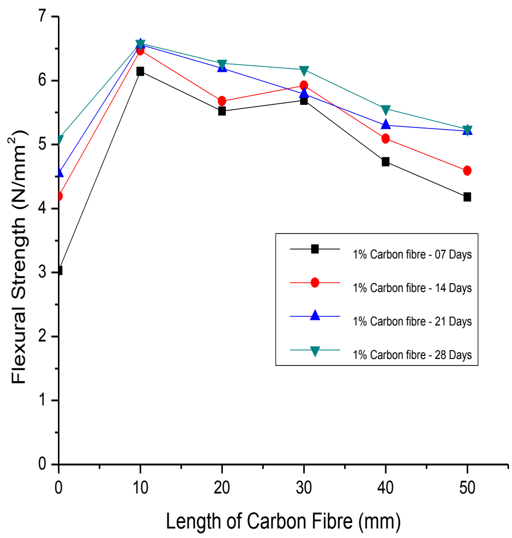


Table 7:Effect of Carbon Fiber Length on Flexural Strength

Sr.No.	Length of Carbon Fiber (mm)	Flexural Strength (N/mm^2)			
		7 Days	14 Days	21 Days	28 Days
01.	Plain	3.96	4.19	4.90	5.24
02.	10	6.14	6.64	7.43	7.62
03.	20	5.90	6.47	7.06	7.57
04.	30	5.60	6.29	6.93	7.25
05.	40	5.49	5.92	6.27	6.53
06.	50	4.27	5.82	6.12	5.62



Graph 5: Flexural Strength v/s Fiber Length

CONCLUSIONS:

The carbon fiber reinforced concrete (CFRC) composites with six different lengths and five different percentage of fiber. The results have shown that CFRC strength increase with the addition of carbon fiber.

- Carbon fibers contributed to the improvement of flexural strength of the concrete.
- From the results it is concluded that the flexural strength increased with increasing fiber content up to 3.0 %. The increase of the flexural strength was 35.5%, 36.89%, 34.05% & 31.23% for the 10.0 mm fibers.
- The increase of the flexural strength was 30.40%, 29.22%, 27.22% & 21.33% for the 3.0 % fibers of 7, 14, 21 and 28 days respectively.

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