

Effects of High Performance Carbon Fiber Addition on Mechanical Properties of Concrete

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ABSTRACT: Concrete is a composite material, which is strong in compression but weak in flexure. Various fibers are used to increase the flexural strength. Among all the fibers, carbon fibers are considered to be more effective. This study focus on adding carbon fibre in M30 grade of concrete in which 15% of Ordinary Portland Cement is replaced with flyash. To increase workability Super Plasticizer is used. Carbon fibers are incorporated into concrete at the levels of 0%, 0.25%, 0.5%, 0.75% and 1%. A detailed experimental study on compressive strength, split tensile strength and flexural strength are carried out at an age of 3,7,14 and 28 days. Compressive strength of Fiber infiltrated concrete at 28th day is 28.8N/mm² which is 2.5times greater than conventional concrete. Flexural strength of conventional concrete is 3.83 N/mm² at 0% and the strength increases to 4.09N/mm² at 0.5%.Use of carbon fiber in concrete has improved the performance of concrete in flexural strength at 0.5%.

KEYWORDS : Concrete, flyash, Superplasticizer, Carbon fiber, Mechanical properties.

I.INTRODUCTION

Concrete is a composite material which is widely used as a manmade construction material. It is composed of fine and coarse aggregate bonded together with cement and water. Here cement (cement paste) act as a bonding material. Concrete is used widely for the construction of various types of structures due to its structural stability and strength. The usage, behavior as well as the durability of concrete structures are improving day by day. These concrete materials are strong in compression but week in flexural strength due to its non-homogeneous materials in it. The steel bars present in the reinforced concrete are homogeneous material which is stronge in both compression and tension. There are two types of cement present in market one is Ordinary Portland Cement and the other is Portland Pozzolana Cement. The ordinary Portland cement does not contain any pozzolonic materials. For the better strength, OPC of 53 grade is used in this project. Concrete provides superior fire resistance and also it is non-combustible. It is economical when the industrial byproducts are partially replaced for cement. Flyash is one of the byproduct and it is used as the filler material and it is partially replaced for the cement. In this study we have used High Performance Carbon Fiber to increase the flexural and tensile strength of the concrete. Carbon fibers are polymers of graphite and are about 5-10 micrometers in diameter and composed mostly of carbon atoms. When compared to steel and glass fibers the carbon fibers give high tensile and flexural strength. The strength, durability and other characteristic of concrete depends on the properties of its ingredients, proportion of mix, method of compaction and other controls during placing and curing.

II.MATERIAL PROPERTIES

2.1. Materials

In the conventional concrete design the proper ingredients must be selected and their properties must be evaluated and used according to their performance. The ingredients used in the concrete are cement as a binding

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material, manufacture sand, carbon fiber, flyash, course aggregate, water and super plasticizer. These materials have the following properties they are:

- Long term mechanical properties.
- Early strength.
- Toughness
- Long service life.
- Long term durability properties.
- Easy to place and compact without segregation and bleeding
- Volume stability.

2.2. Carbon fiber

Carbon fibers are polymers of graphite and are about 5-10 micrometer in diameter and composed mostly of carbon atoms. When compared to glass and steel fiber the carbon fiber gives high tensile and flexural strength. Carbon fibers have several advantages including high tensile strength, high chemical resistance, low thermal expansion, high stiffness, low weight, high temperature tolerance. These properties have made carbon fiber popular in the field of aerospace, civil engineering, military and motorsports. Carbon fibers are usually combined with other materials to form a composite. Carbon fibers composite with other materials, such as graphite to form reinforced carbon-carbon composite, which have heat tolerance highly.

Table 2.1: Properties of Carbon fiber

Physical properties	Result
Diameter (micrometer)	7
Physical form	Thin wire
Length (cm)	2.5
Color	black



Figure 1: Carbon fiber

2.3 Flyash

Flyash is a coal combustible product. It is composed with the fine particles of fuel that are driven out of coal-fired boilers together with the flue gases. Flyash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys. Depending upon the source of the coal being burned, the

components of fly ash vary considerably, but all fly ash includes significant amounts of silicon dioxide (SiO₂) (both amorphous and crystalline), aluminum oxide (Al₂O₃) and calcium oxide (CaO), the main mineral compounds in coal-bearing rock strata.

Table 2.2: Properties of fly ash

Physical properties	Result
Specific gravity	2.12
Physical form	Powder
Size (Micron)	0.1
Colour	Dark grey

2.4. Super plasticizers

Super plasticizers are used to reduce the water cement ratio up to 30%. By using the super plasticizers the compressive strength of the concrete is increased. The main advantage of adding super plasticizer is to increase the workability by not increasing the water content. Super plasticizer named Conplast SP 430.

Table 2.3 Properties of super plasticizer

Physical Property	Value
Solid content	42%
Specific gravity	1.22

2.5. Mix design

Mix design is done for finding the correct proportion of materials to be used in concrete for which we could attain the required strength. The mix design is done as per IS 10262 - 2009.430 is used.

3.2 MIX PROPORTIONS

Cement	= 425 kg/m ³
Flyash	= 70 kg/m ³
Water	= 160 kg/m ³
Fine aggregate	= 740 kg/m ³
Coarse aggregate	= 1140 kg/m ³
Chemical admixture	= 17 kg/m ³

Table 1: shows the mix proportion of concrete.

Mix proportions	Cement kg/m ³	Fine Aggregate kg/m ³	Coarse Aggregate kg/m ³	Water kg/m ³	Chemical Admixture kg/m ³	Fly ash kg/m ³	Carbon fiber gms
Mix 1 (0%)	425	740	1140	160	17	70	0
Mix 2 (0.25%)	425	740	1140	160	17	70	85.64
Mix 3 (0.5%)	425	740	1140	160	17	70	171.29
Mix 4 (0.75%)	425	740	1140	160	17	70	256.93
Mix 5 (1%)	425	740	1140	160	17	70	342.58

IV. EXPERIMENTAL PROGRAM

4.1 MECHANICAL PROPERTIES

4.1.1 Compression Test (IS: 516-1959)

Compression test is the most common test conducted on hardened concrete. It is an easy test to perform because most of the desirable characteristics properties of concrete are qualitatively related to its compressive strength. Compressive strengths were attained by testing the cube specimens of size 150mm x 150mm x 150mm. Cube was placed on the platform of the compression testing machine. The load was applied gradually till the concrete cubes get failed. The specimens are subjected to compressive loads in compression testing machine as per IS: 516-1969 and the crushing load is noted, which gives the compressive strength of that cube. The compressive strength is the ratio of crushing load to the surface area of the specimens expressed in N/mm². Similarly the compression strength values of all the cubes are found.

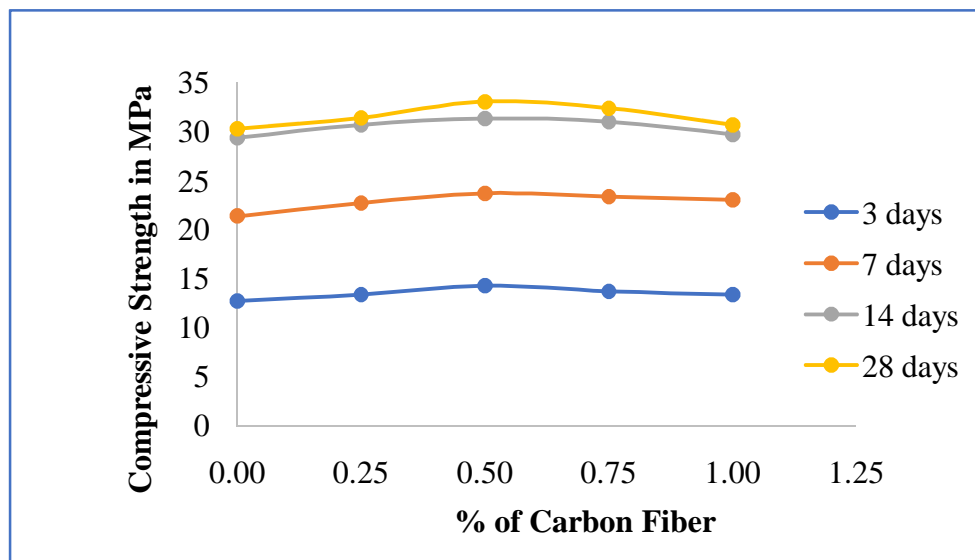


Figure 2: Compressive strength of concrete Vs % of Carbon Fiber

4.1.2 Flexure Strength Test (IS: 516-1959)

The flexural strength represents the moment of rupture of the material and also the highest stress experienced within the material. It is measured in terms of stress. The symbol is f_{cr} . The flexural strength of the respective specimens have been obtained from the flexural tests performed on the prism specimens of size 150mm x 150mm x 500mm. The flexural strength are tested using a two point loading frame machine as per standards. The loading must be applied centrally. The specimen must not be subjected to any tensional stresses and restraints. The axis of the specimen shall be carefully aligned with the axis of the loading device. The load shall be applied without any shock and increasing continuously at specified rate.

The modulus of rupture can be determined by using the formula:

$$f_{cr} = (P_{max} \times l) / bh^2$$

Where, f_{cr} = Flexural strength
 P_{max} = Maximum load in kg

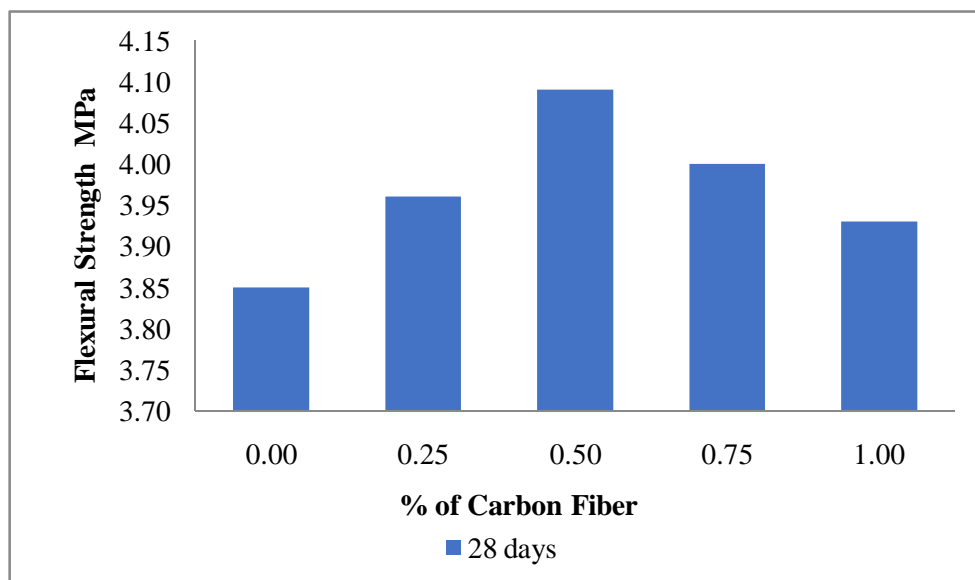


Figure 3: Flexural Strength Vs % of Carbon Fiber.

4.1.3 Split tensile strength Test (Ref: IS: 5816-1999)

Split tensile strength of concrete is usually found by testing plain concrete cylinders. Cylinders of size 150mm x 300 mm were casted using M30 grade concrete. Specimens with Conventional Concrete and carbon fibers with four different percentages were casted. During casting the conventional concrete cubes were manually compacted using tamping rods. After 24hours, the specimens were removed from the mould and subjected to water curing for 3, 7, 14 and 28 days. After curing, the specimens were tested for compressive strength as per IS: 5816-1999 using a calibrated compression testing machine of 2000KN capacity.

Two packing strips of plywood 3mm thick were provided between the specimen one at top and another at bottom. The specimen was placed on the plywood strip and aligned so that, the central horizontal axis of the specimen is exactly perpendicular to the load applying axis. The second plywood strip was placed length wise on the cylinder and the top platen was brought down to touch the plywood. The load was applied without shock and increased continuously until the resistances of the specimen is reached. At one point load broke down and no greater load can be sustained.

$$\text{Tensile strength of concrete } f_t = \frac{2p}{\pi dl}$$

Where, f_t = Split tensile strength in N/mm^2
 p = Maximum load in N applied to the specimen
 l = Measured length in cm of the specimen.
 d = Measured diameter in cm of the specimen

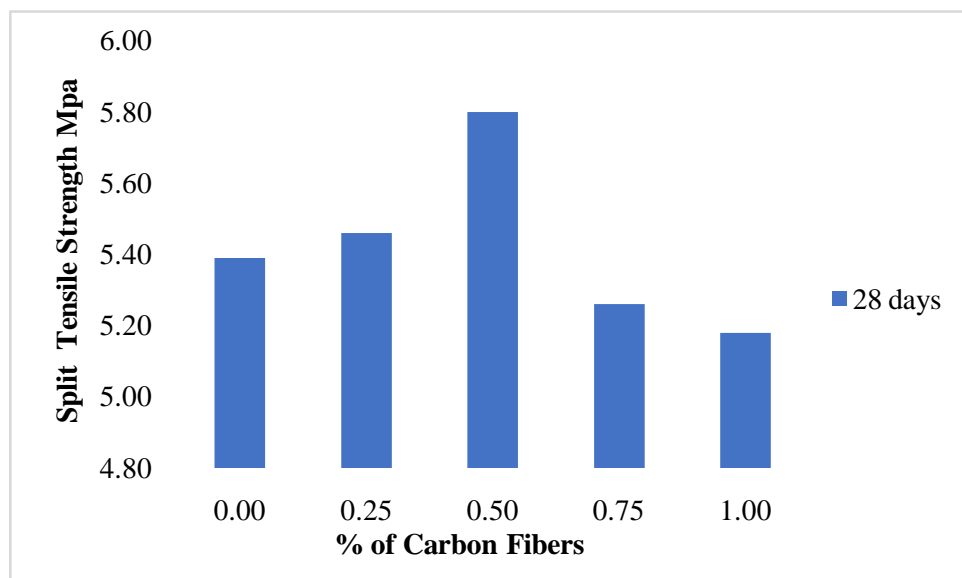


Figure 4: Split Tensile Strength Vs % of Carbon Fiber.

V.RESULTS AND DISCUSSION

5.1 GENERAL

The results obtained from the various experiments conducted to access mechanical properties. The aim of this study is to determine the compressive strength, flexural strength and split tensile strength of both the conventional concrete and the fiber infiltrated concrete. So, the results of test specimens are graphically presented in above.

VI. CONCLUSION

Carbon fiber possesses very high flexural strength and high modulus of elasticity. Even though they are expensive their strength and stiffness characteristics have been found to be superior when compared to steel fibers. The stress strain curves are confined and it has good resistance to high temperature and controls seepage failure in concrete. They are widely used for repairing purpose as they resist chemical attack and corrosion. Based on this experimental result, the following conclusions are made. By testing the cylinder we came to a conclusion that the flexural strength of concrete is increased by adding the carbon fiber to M30 grade of concrete at 0.5%. From the test results of the cube and prism we can understand that the addition of carbon fiber at 0.5% gives the good compressive and split tensile strength for the conventional concrete.

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