Effect of Addition of Carbon Fibre on Mechanical Properties of Concrete

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Abstract: Fibers have the characteristics to enhance the endurance of concrete. One of them is carbon fiber. These carbon fibers have superb mechanical properties and maybe utilized more effectively. This study is focused towards analyzing the variation in strength of carbon fiber concrete at variable fiber contents and to establish it with that of conventional concrete. The mechanical properties analyzed are compressive strength, split tensile strength, flexural strength of carbon fiber concrete at (0%, 0.25%, 0.5%, 0.75%, 1%, 1.25%) percentages by volume of concrete. Result data clearly shows percentage increase in compressive strength, split tensile strength and flexural strength for M25 grade of concrete in 7 days and 28 days with respect to the variation in % addition of carbon fibers. Maximum increase in strength was achieved at 1% addition of fiber content and it can be considered as optimum dosage.

Key words: Carbon fibers, Reinforced concrete, compressive strength, split tensile strength, flexural strength

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Introduction:

Concrete is the most widely used construction material. It is popular due to its compressive strength, resistance to fire, durability, relatively low cost, sustainability, and its can be formed to any shape. However concrete has some deficiencies such as low tensile strength, low post cracking capacity, brittleness and low ductility, limited fatigue life, not capable of accommodating large deformations, low impact strength. The strength and durability of concrete can be changed by making appropriate changes in its ingredients like cementitious material, aggregate and water and by adding some special ingredients. Hence concrete is very well suited for a wide range of applications. In order to overcome these weaknesses, concrete is often reinforced. Apart from the common steel reinforcement, there is a growing trend in fiber reinforcement of concrete (FRC). Generally, natural and manmade fibers incorporated into reinforced concrete structures can improve the durability and toughness and can reduce the shrinkage of concrete. Recently, carbon-fiber-reinforced concrete (CFRC) are usually being used in the repair, rehabilitation, and rebuilding work of civil engineering infrastructures.

Fibre Reinforced Concrete:

Fiber reinforced concrete is a "concrete incorporating relatively short, discrete, discontinuous fibers". Although the fibers added to fiber reinforced concrete (FRC) are not meant to increase strength, tests have shown that some moderate strength increases occur. Fibre Reinforced Concrete (FRC) is cement concrete reinforced mixture with randomly distributed discrete fibres. In the FRC, a numbers of small fibres are dispersed and distributed randomly in the concrete at the time of mixing, and thus improve concrete properties in all directions. Addition of loosely spaced and uniformly dispersed fibres to concrete acts as crack reducer and improves its properties. It has been used in construction with its higher flexural, tensile strength, resistance to splitting, impact resistance and excellent permeability and frost resistance.

Fibers in FRC are mainly used to modify the post-cracking behavior of concrete. The fibers act as "bridges" between cracked surfaces to improve the post-cracking ductility of concrete. FRC has seen an increase in applications in recent years. More than 76 million cubic meters of concrete was produced for use in surface slabs, precast concrete members, and other structural forms. There are many different types of fibers that are used in reinforcing concrete. The properties of the concrete composite vary with the volume of fiber fraction. High fiber volume increases the air void content in the composite. High air voids has negative effects on concrete properties such as compressive strength. Additionally, high fiber content can reduce the workability of the concrete. The cost of the concrete also increases with addition of carbon fibers. Therefore, the fiber fraction should be maintained at the minimum desirable content. In practice, the fiber content of between 0.2% and 1% by volume is commonly used. The fiber content is varied with the size of the aggregate. Large aggregates require higher fiber content. However the flexural strength of a concrete composite decreases with the size of the aggregates.

Necessity of Carbon Fibre:

Concrete is considered a brittle material, primarily because of its low tensile strain capacity and poor fracture toughness. Reinforcement of concrete with short randomly distributed fibres can address some of the concerns related to concrete brittleness and poor resistance to crack growth. Fibres, used as reinforcement, can be effective in arresting cracks at both micro and macro-levels. At the micro-level, fibres inhibit the initiation and growth of cracks, and after the micro-cracks coalesce into macro-cracks, fibres provide mechanisms that abate their unstable propagation, provide effective bridging, and impart sources of strength gain, toughness and ductility. Concrete can be modified to perform in a more ductile form by the addition of Carbon fibres in the concrete matrix.

Selection of Ingredients:

Cement: Cement is a binder, a substance that sets and hardens and can bind other materials together. When mixed with water, the silicates and aluminates in the cement undergo a chemical reaction; the resulting hardened mass is then impervious to water. It may also be mixed with water and aggregates to form concrete. Portland Pozzolana Cement of 43 Grade conforming to IS 1489:1991 with specific gravity 3.119 was used. The percentage of cement particles passing through IS 90-micron sieve was 96%.

Fine and Coarse Aggregates: Manufactured sand (M-Sand) is a substitute of river sand for concrete construction. Manufactured sand is produced from hard granite stone by crushing. M-sand passing through 4.75mm was used as fine aggregate and crushed stone of size 20mm was used as coarse aggregates. The properties of fine and coarse aggregates used in the study are tabulated in Table 1.

Table 1: Properties of M-sand and Coarse Aggregate

Properties	Fine Aggregate	Coarse Aggregate
Fineness modulus	2.63	5.23
Specific gravity	2.65	2.81
Water absorption	0.45%	0.3%

Superplasticizer: Super plasticizer is used as a chemical admixture in liquid form to develop a concrete by reducing water, producing good workability, increased strength, minimization of segregation and bleeding, less porosity.Conplast SP430 is a chloride free, superplasticising admixture based onselected sulphonated napthalene polymers. It is supplied as a brown solution which instantlydisperses in water and it gives good workability to fresh concrete.

Water: Clean tap water was used for mixing and curing ofconcrete.

Carbon Fibers: 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. The Material properties of Chopped carbon fibre obtained from Inspire Aero Technologies, Bangalore is listed in Table 2 below. Figure 1 shows the carbon fibers used for the present study.

Table 2: Properties of Carbon Fibre used in the study

Material Property	Value
Tensile strength (MPa)	4900
Tensile modulus (GPa)	250

Elongation (%)	2.0
Density (g/cm3)	1.78
Fiber diameter (µm)	7
Appearance	Black

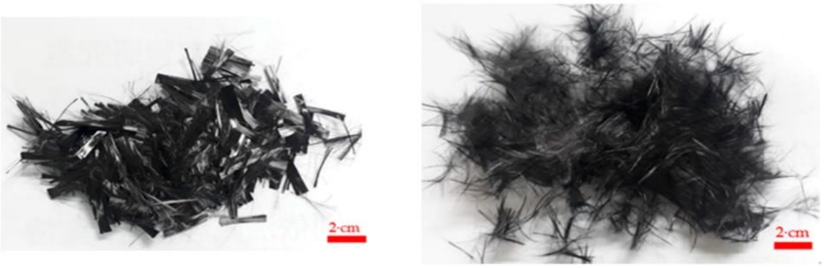

Fig.1. Carbon Fibers Used**:**

Concrete mix proportion:

Mix Proportions: M30 grade concrete was designed as per IS 10262-2009. Quantity of materialsper cubic meter of concrete and dosages of carbon fibers used are listed below. A constantwater cement ratio of 0.43 was used.

Cement = 354 kg/m3

Water = 152 kg/m3

Fine aggregate = 711 kg/m3

Coarse aggregate = 1306 kg/m3

Chemical admixture = 3.54 kg/m3 (1.0% by the weight of cement)

Density of concrete = 2430 kg/m3

Water-cement ratio = 0.43

Mix Proportion By weight **=**1 : 2 : 3.68

Results and Discussions:

All the tests have been performed in standard procedures and the results and load values obtained were tabulated and calculated in following sections.

Compressive Strength:

Compressive strength tests were conducted on cured cube specimen at 28 days age using a compression testing machine. The cubes were fitted at center in compression testing machine and fixed to keep the cube in position. The load was then slowly applied to the testecube until failure.

Sl.No	Percentage of carbon fibre added	Compressive Strength N/mm^2 at 28 days
1.	0	31.37
2.	0.25	35.42
3.	0.5	40.42
4.	0.75	43.44
5.	0.1	45.44
6.	1.25	36.08

Split Tensile Strength:

The split tensile test were conducted as per IS 5816:1999The size of cylinder is 300mm length with 150mmdiameter.The specimen were kept in water for curing for28 days and on removal were tested in wet condition by wiping water and grit present on the surface. The test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine and the load is applied until failure of the cylinder along the vertical diameter.

Sl.No	Percentage of carbon fibre added	Split Tensile Strength N/mm^2 at 28 days
1.	0	3.35
2.	0.25	3.71
3.	0.5	4.09
4.	0.75	5.024
5.	0.1	5.77
6.	1.25	3.72

Flexural Strength:

The Flexural tests were conducted as per IS 516:1959. The size of beam is 150mm*150mm*700mm. The specimen were kept in water for curing for 28 days and on removal were tested in wet condition by wiping water and grit present on the surface. The test is carried out by placing a Beam specimen horizontally such that the load shall be divided equally between the two loading rollers, and all rollers shall be mounted in such a manner that the load is applied axially and without subjecting the specimen to any torsional stresses or restraints.

Sl.No	Percentage of carbon fibre added	Flexural Strength N/mm^2 at 28 days
1.	0	7.23
2.	0.25	8.82
3.	0.5	11.26
4.	0.75	12.68
5.	0.1	13.48
6.	1.25	11.28

Conclusions:

The following important conclusions were drawn based on the results obtained from theexperimental studies:

1. The maximum percentageincrease in compressive strength was achieved at 1.0% of fibre dosage and was foundto reduce for 1.25% of fibre content.
2. The maximum percentageincrease in split-tensile strength was achieved at 1.0% of fibre dosage and was found toreduce beyond 1%.
3. The maximum percentage increase inflexure strength was achieved at 1.0% of fibre dosage and was found to reduce beyond1%.
4. From the results it is observed that there is an increase in strengths (Compressive,Flexural and Split tensile) for CFRC up to 1% of fibers by weight of concrete anddecreases for 1.25% addition of carbon fibres.

Finally it can be concluded that addition of 1% of carbon fibres increases strengths(Compressive, Flexural and Split tensile) to the maximum extent when compared to0.75% and 1.25% addition of carbon fibers. The durability of concrete can be enhancedby adding carbon fibres to concrete.

Reference:

1. Banshkar, B. K., & Rajpoot, A. A Review Study on Mechanical Properties and Fracture Behavior of Chopped Fiber Reinforced Self-Compacting Concrete. Journal homepage: www. ijrpr. com ISSN, 2582, 7421.
2. Li, Y. F., Lee, K. F., Ramanathan, G. K., Cheng, T. W., Huang, C. H., & Tsai, Y. K. (2021). Static and dynamic performances of chopped carbon-fiber-reinforced mortar and concrete incorporated with disparate lengths. Materials, 14(4), 972.
3. Soupionis, G., &Zoumpoulakis, L. (2021). Reinforced Concrete Structures Containing Chopped Carbon Fibers with Polymer Composite Materials. Polymers, 13(21), 3812.
4. K. N., M. A. Khan, M. R., & M. S. F (20021). An Experimental Study on Mechanical Properties of Carbon Fiber Reinforced Concrete. International Research Journal of Engineering and Technology (IRJET)
5. AL-Ridha, A. S. D., Abuzaid, E. K. M., & Abbood, A. A. R. (2018). Effect of addition of chopped carbon fiber on the behavior of reinforced concrete beams with variable (shear distance to effective depth) ratios. Journal of Engineering and Sustainable Development, 22(1), 137-148.
6. Thakur, P., & Singh, K. (2018). A review: effect of carbon fiber on different mixes of concrete. Int. Res. J. Eng. Technol, 5(3), 3996-3999.
7. Navya, H. A., & Nayana, N. P. (2018). Experimental studies on behaviour of carbon fiber reinforced concrete. International Journal of Civil Engineering and Technology, 9(7), 1461-1469.
8. Muley, P., Varpe, S., &Ralwani, R. (2015). Chopped carbon fibers innovative material for enhancement of concrete performances. Int. J. Sci. Eng. Appl. Sci, 1, 2395-3470.
9. S. S. Dusane. (2016). STRENGTH IMPROVEMENT OF CONCRETE BY USING CHOPPED CARBON FIBRE. International Conference on Recent Trends In Engineering, Science &Management(ICRTESM-16)
10. Xu, W., Jalal, M., Zakira, U., & Wang, L. (2021, April). Study on the Mechanical Properties and Durability of Carbon Fiber Reinforced Lime-Based Mortar. In IOP Conference Series: Earth and Environmental Science (Vol. 719, No. 3, p. 032032). IOP Publishing.