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An Experimental Study on the Performance of Carbon Fiber Concrete (CARBOCRETE)

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ABSTRACT: Concrete is a composite construction material composed primarily of aggregate, cement and water. Generally Concrete is strong in compression and weak in tension. The aggregate is generally coarse gravel or crushed rocks such as limestone, or granite, along with a fine aggregate such as sand. The cement, commonly Portland cement, and other cementitious materials such as fly ash and slag cement, serve as a binder for the aggregate. Various chemical admixtures are also added to achieve varied properties. Water is then mixed with this dry composite which enables it to be shaped (typically poured) and then solidified and hardened into rock-hard strength through a chemical process known as hydration. The water reacts with the cement which bonds the other components together, eventually creating a robust stone-like material. Carbon reinforced concrete is a composite material consisting of two high-performance materials. The innovative combination of carbon fibre fabrics or bars with fine-grained concrete simultaneously enables significantly more varied shapes and a high load-bearing capacity. Due to the corrosion resistance of the fabrics and rebars, the concrete cover and thus the use of resources can be reduced to a minimum. Carbon reinforced concrete can be used for sustainable, resource-saving, less material-intensive and lighter construction.

A cement concrete of M30 grade is chosen as it is usable in most of the constructions. The mix design for the concrete will be designed as per IS 10262 code. The behaviour of M30 grade carbon fibre concrete is studied with respect to compressive strength, flexural strength and split tensile strength. The effect of temperature on these parameters is also studied.

Key words: Carbon fibres, cement, compressive strength, split tensile strength, flexural strength

1. INTRODUCTION:

Fiber-reinforced concrete (FRC) is a type of concrete that incorporates fibers, such as steel, glass, or synthetic fibers, to enhance its performance. These fibers provide additional strength, durability, and crack resistance to the concrete mix. FRC is commonly used in construction to improve the structural properties of concrete elements like slabs, beams, and columns. Carbon fibers are high-strength, lightweight materials composed mostly of carbon atoms. They are known for their exceptional tensile strength, low weight, and resistance to temperature and corrosion. Their properties make them valuable for creating strong and lightweight structures in applications ranging from aircraft components to sports gear.

2. LITERATURE REVIEW:

2.1. Iaochu Wang, Xiaomei Nie and Long Xiong – "Experimental Study on Carbon Fiber Concrete Beams X", The influence of the length of carbon fibre on the deflection and strain of carbon fibre concrete beams was studied by testing the flexural capacity of the normal section of four carbon fibre concrete beams. The results show that the length of carbon fibre has a certain influence on the strength of reinforced concrete beams. The failure deflection of fibre concrete beams increases with the increase of the length of carbon fibre. Carbon fibre can improve the brittle failure of concrete beams. No matter how long the carbon fibre is, the cracking load and ultimate load of CFRC beam are not different from that of ordinary concrete beam.

2.2. Gao-Jie Liu, Er-Lei Bai, Jin-yuXu and Ning Yang – "Mechanical Properties of Carbon Fiber-Reinforced Polymer Concrete with Different Polymer–Cement Ratios"
In carbon fibre-reinforced concrete (CFRC), the cohesion between carbon fibre and the cement paste matrix is mainly dependent on the surface energy of the materials. Combined with mechanical meshing, CFRC is strengthened and toughened to limit the crack generation [3,4]. However, due to the bond property between carbon fibres and the cement paste matrix, the carbon fibres can easily be pulled out or slip when the concrete is damaged

2.3. Zhan-Yang Chen and Jun Yang – "Experimental Study on Dynamic Splitting Characteristics of Carbon Fiber Reinforced Concrete"

The results indicated that incorporation of short carbon fibres could improve high brittleness, low tensile strength, and result in far less stress-strain curve of HPC than that of ordinary concrete. Zhou divided the static stress-strain curve of carbon fibre concrete based on the laboratory basic mechanical property test, established the mathematical expressions of the stress-strain curve with different contents, and determined the relationship between corresponding parameters and carbon fibre volume ratio. Giner V.T studied the influence of carbon fibre on the damping ratio and dynamic elastic modulus of concrete containing micro-silicon powder and showed that the dynamic elastic performance of concrete is higher than that of static, and the compressive strength of concrete slightly decreases with the addition of carbon fibre.

2.4. Yuhang Du1, Song Lu1, Jinyu Xu1, Wei Xia1, TengjiaoWang1 & ZhihangWang1 - "Experimental study of impact mechanical and microstructural properties of modified carbon fibre reinforced concrete

This paper investigated the preparation method and the dispersion behaviour of Modified Carbon Nanotube-fibre Reinforcements (MCNF), the change laws and the effect mechanisms of dynamic compressive strength of MCNF concretes. Electrophoresis method was used to prepare MCNF and its interfacial shear performance was tested by interfacial shear strength (IFSS) test. In addition, the dispersion behaviour of MCNF in simulated concrete solution was verified by turbidity method. Split Hopkinson Pressure Bar (SHPB), Scanning Electron Microscope (SEM) and Mercury Intrusion Porosimeter (MIP) tests were carried on concrete samples with different volume fractions (0%, 0.1%, 0.2%, 0.3%, 0.4%) of MCNF. The results show that carbon nanotubes are easier to deposit to the negative electrode, and the higher the content of polycarboxylate superplasticizer, the more obvious the dispersity of MCNF in alkaline environment. The dynamic compressive strength of MCNF concrete was 14.0–35.5% higher than that of untreated concrete, and reached the maximum when the MCNF content was about 0.3%. The MCNF was wrapped in concrete matrix and promoted hydration reaction of interface between cement and MCNF from microscopic observation. The addition of MCNF could increase the porosity. The volume percentage of ≥100 nm pore decreased first and then increased. Reasons for the improvement strength of MCNF concrete is that the bridging effect is stronger with the increase of MCNF content (≤ 0.3%) and limited when the MCNF content is equal to 0.4%. MCNF concrete could be used in actual engineering with high requirements for dynamic load.

3. OBJECTIVES:

To identify the basic properties of Carbon fibres (Aspect ratio, Specific gravity etc.). To derive the mix proportion for M30 grade cement concrete. To test the fresh concrete for workability. To determine the compressive strength of carbon fibre reinforced concrete at different ages of curing. To determine the flexural strength of carbon fibre reinforced concrete at different ages of curing. To determine the split tensile strength of carbon fibre reinforced concrete at different ages of curing. To identify the behaviour of Carbon fibre concrete at elevated temperatures w.r.t compressive and split tensile strengths.

4. METHODOLOGY:

The preliminary experiments are conducted on the in-gradients of concrete as well as on carbon fibres. The mix proportion for M30 concrete is derived by considering the steps involved in the code IS:10262 – 2019. The optimal % of carbon fibres is identified to get the ultimate strength. The compressive strengths of carbon fibre reinforced concrete are identified at different ages of curing. The split and flexural strengths of carbon fibre reinforced concrete are also identified at different ages of curing. The behaviour of carbon fibre concrete at elevated temperatures w.r.t compressive, split tensile and flexural strengths is also studied in the investigation.

5. MIX PROPORTION OF CARBON FIBRE CONCRETE:

Cement = 438 kg/ m^3

Water = 197 kg/ m^3

Fine Aggregate = 798 kg/ m^3

Coarse Aggregate = 979 kg/ m^3

Water Cement ratio = 0.45

Mix Proportion → ***1 : 1.82 : 2.23 : 0.45***

6. OPTIMUM % OF CARBON FIBERS: The required percentage of carbon fibres is identified in the study to get the maximum compressive strength.

Table.1: Optimum % of Carbon fibres

MIX	% OF FIBERS	COMPRESSIVE STRENGTH (N/mm^2)	
		7 DAYS	28 DAYS
1	0	23.89	36.38
2	0.25	28.40	43.25
3	0.5	33.80	51.48
4	0.75	37.76	57.51
5	1	24.69	37.60
6	1.5	10.24	15.59

Therefore, the optimum % of carbon fibres = 0.75 %

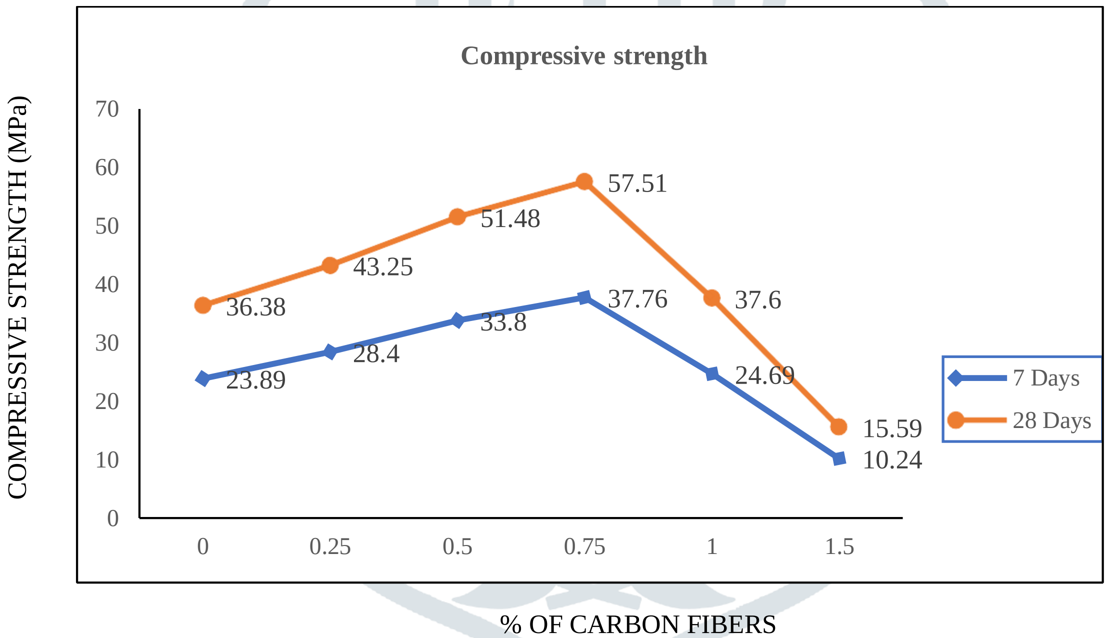

Fig: 1 The variation of Compressive strength of concrete with % of Carbon fibers

7. CASTING AND TESTING OF CONCRETE SPECIMENS: The cubes of 150 x 150 x150 mm size, the cylinders of 150 mm diameter with 300 mm hight and the beams of 500 x 100x100 x100 mm are used in this investigation.

Fig. 2 Casted Cubes, Cylinders and Beams

Testing of Specimens: The concrete specimens are tested for compressive strength, split tensile strength and flexural strength

Fig. 3 Testing of Cubes, Cylinders and Beam

8. RESULT AND DISCUSSION:

8.1:COMPRESSIVE STRENGTH:

As the strength is achieved by applying crushing load on surface of cube, it is also named as Crushing strength. The specimens are tested by compression testing machine after 7 and 28 days of curing.

Table.2: Compressive Strength of Concrete with % Carbon Fibers

MIX	% OF FIBERS	COMPRESSIVE STRENGTH (N/mm^2)	
		7 DAYS	28 DAYS
1	0	23.89	36.38
2	0.25	28.40	43.25
3	0.5	33.80	51.48
4	0.75	37.76	57.51
5	1	24.69	37.60
6	1.5	10.24	15.59

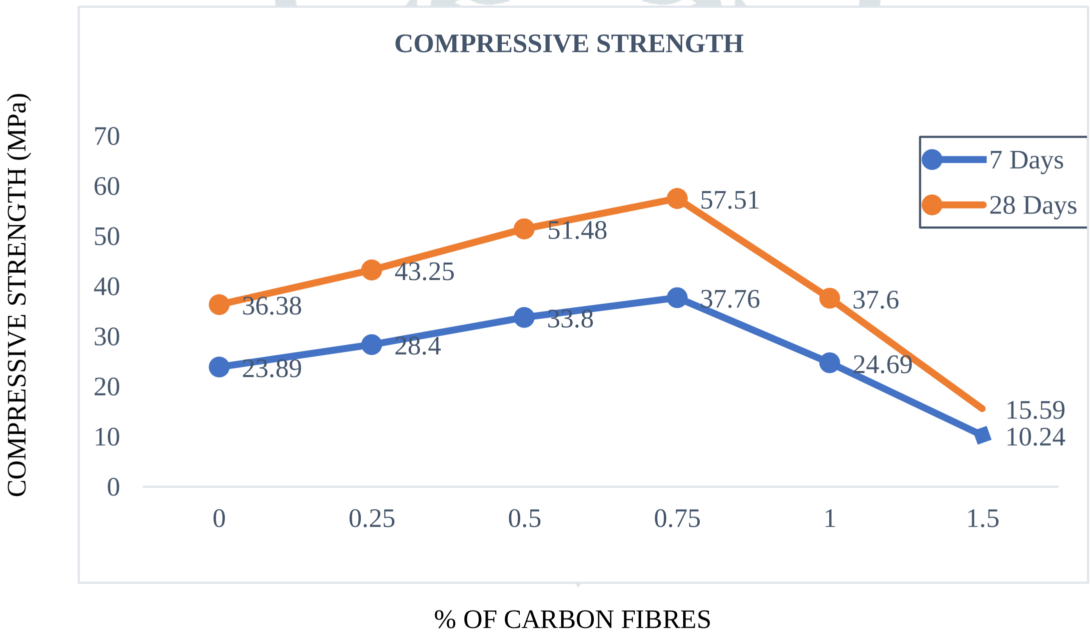

Fig: 4. The variation of Compressive strength of concrete with % of Carbon fibers

As the strength is achieved by applying crushing load on surface of cube, it is also named as Crushing strength. The specimens were cured at 7 and 28 days. The specimens are kept in oven for time period of 3 hours at 50, 100 and 150^{0}C temperature and then tested for compressive strength.

Table.3: Compressive Strength of concrete at different Temperature (^{0}C)

S.NO.	TEMPERATURE (^{0}/C)	COMPRESSIVE STRENGTH (N/mm^2)	
		7 DAYS	28 DAYS
1	0	37.76	57.55
2	50	38.07	58.01
3	100	42.57	64.84
4	150	38.57	58.753

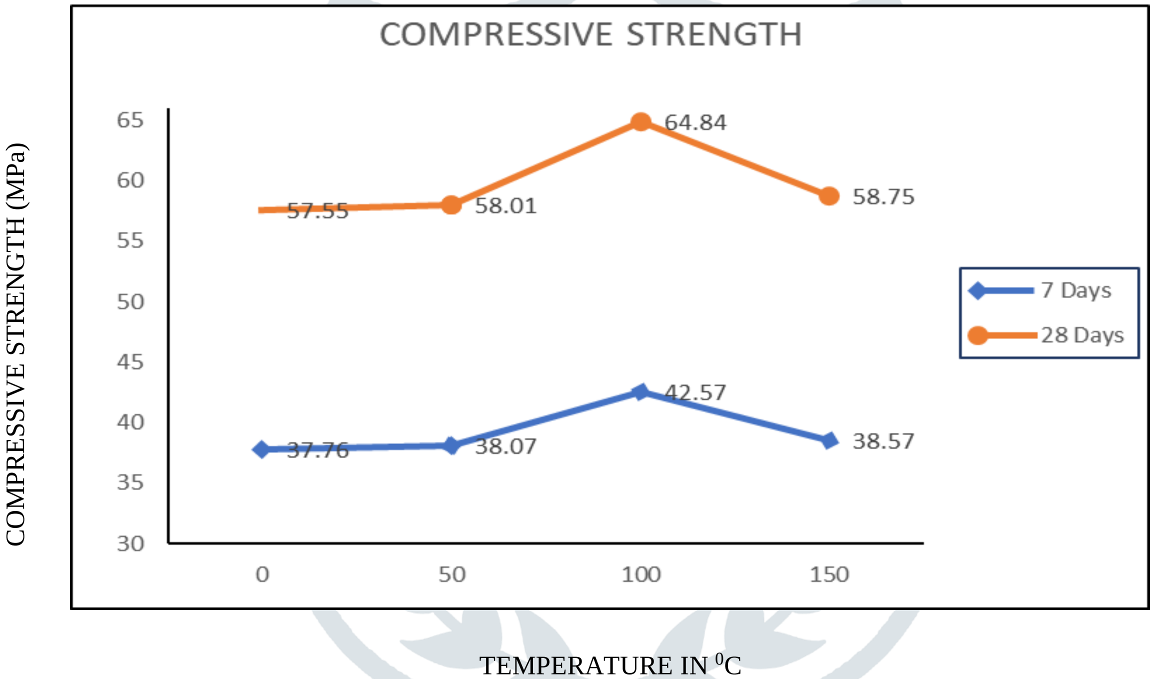

Fig:5 The variation of Compressive Strength of concrete with Temperature in ^{0}C

8.2: SPLIT TENSILE STRENGTH:

Cylindrical specimens of concrete are helpful for accurate tensile strength value. The specimens are after 7 and 28 days of test period. Specimens are kept in horizontal direction in the testing machine between two steel plates. This arrangement is made to make that the load is applied on axial side only. The load at which the cylinder failures is noted as **P.** The value of "P" is further used to calculate the tensile strength of concrete by using the below formula.

Table.4: Split Tensile Strength of concrete with Temperature in ^{0}C

S.NO.	TEMPERATURE (^{0}/C)	SPLIT TENSILE (N/mm^2)	
		7 DAYS	28 DAYS
1	0	4.35	6.62
2	50	5.57	8.48
3	100	6.66	10.14
4	150	4.38	6.67

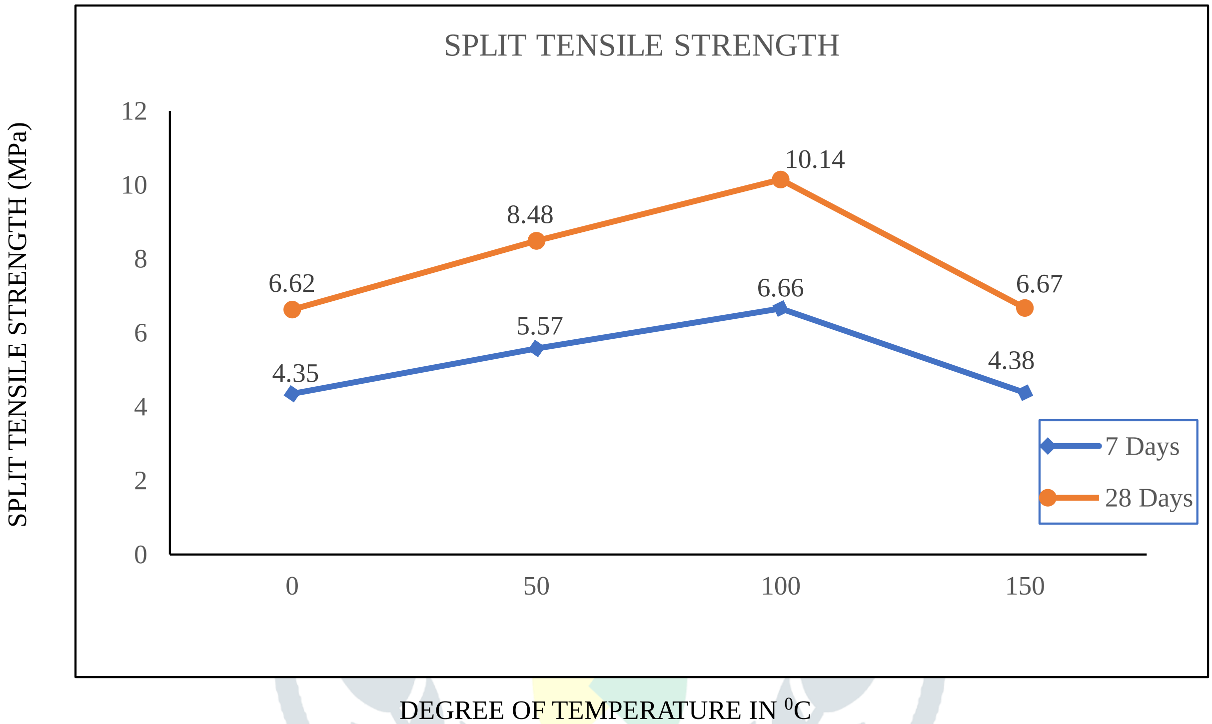

Fig.6 The variation of Split Tensile Strength of concrete with Temperature in ^{0}C

8.3: FLEXURAL STRENGTH:

To get the flexural value of concrete, beam specimens are placed in the testing machine parallel to the direction of application of load. The load at which the beam failures is notes as **P**. The load value "P" is used to determine the flexural load by using below formula

Table.5: Flexural Strength of concrete with Temperature in ^{0}C

S.NO.	TEMPERATURE (^{0}/C)	FLEXURAL STRENGTH (N/mm^2)	
		7 DAYS	28 DAYS
1	0	8.78	13.37
2	50	8.58	13.06
3	100	11.42	17.39
4	150	8.86	13.49

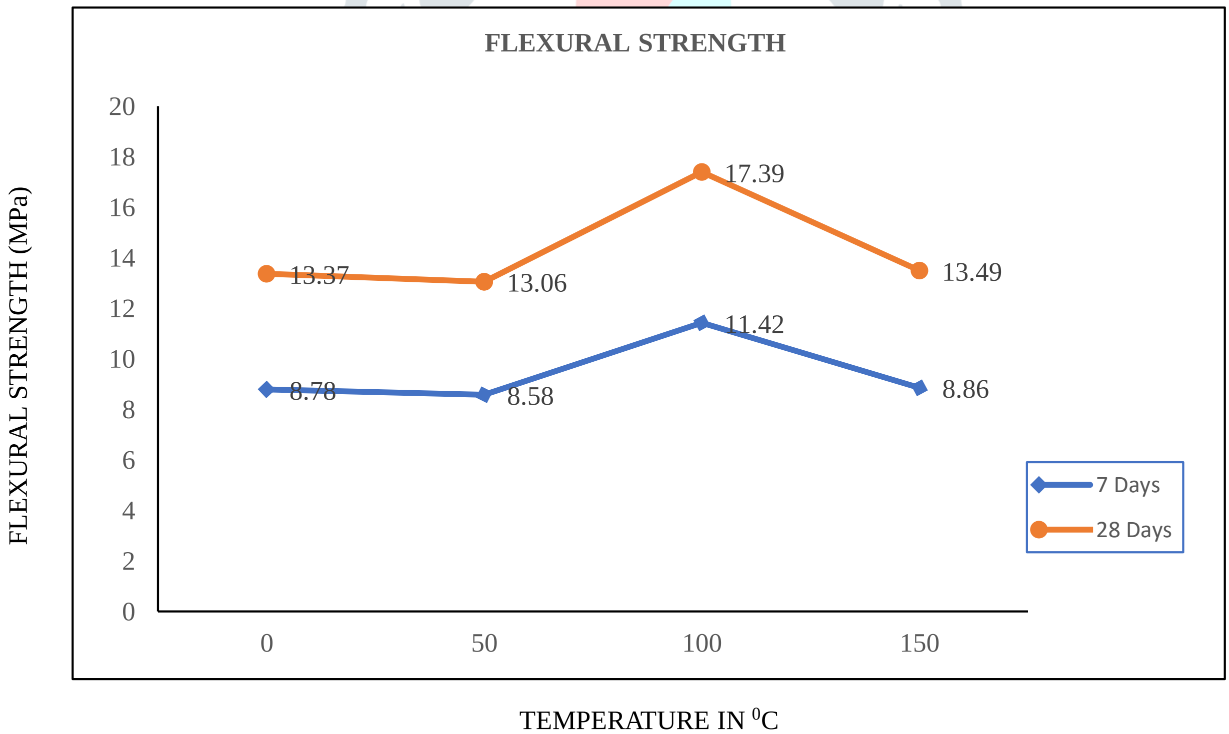

Fig.7 The variation of Flexural Strength of concrete

with Temperature in ^{0}C

Conclusions:

1. The optimum percentage of carbon fibers to get the maximum 7 days compressive strength (37.76 N/mm^2) for M30 grade concrete is observed as 0.75%

2. The maximum 28 days Compressive strength of M30 concrete is noticed as 57.51 N/mm^2 @0.75% of Carbon fibers.

3. The maximum 28 days Compressive strength of M30 concrete is noticed as 64.84 N/mm^2 when heated @100^0C

4. The maximum 28 days Split tensile strength of M30 concrete is noticed as 10.64 N/mm^2 when heated @100^0C.

5. The maximum 28 days Flexural strength of M30 concrete is noticed as 17.39 N/mm^2 when heated @100^0C.

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