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Strengthening of Plain Cement Concrete with Carbon Fibre

Kanishk Kanskar[1], Prof. Charan Singh Thakur[2]

[1] *Research Scholar, Department of Civil Engineering, Shri Ram Group of Institutions, Jabalpur, Madhya Pradesh India*

[2] *Professor, Department of Civil Engineering, Shri Ram Group of Institutions, Jabalpur, Madhya Pradesh India*

***Abstract*—Plain concrete possess very low tensile strength, limited ductility and little resistance to cracking. Internal micro cracks are inherently present in concrete and its poor tensile strength is due to propagation of such micro cracks. Fibers when added in certain percentage in the concrete improve the strain properties as well as crack resistance, ductility, flexure strength and toughness. Mainly the studies and research in fiber reinforced concrete has been devoted to carbon fibers. In recent times, carbon fibers have also become available, which are free from corrosion problem associated with steel fibers. The present paper outlines the experimental investigation conducts on the use of carbon fibers with structural concrete. Carbon fiber of diameter 5–25 micron, having an aspect ratio 1000-1500 was employed in percentages of 0.5, 1.0 and 1.5 by weightin fine aggregate and the properties of this FRC (fiber reinforced concrete) like compressive strength, flexure strength, toughness, modulus of elasticity was studied.**

***Index Terms*—Ductility Flexural Strength, FRC Micro cracks, Tensile Strength**

I. INTRODUCTION

Plain concrete is known to have low strength and low strain capacity; however, these structural properties could be improved by addition of fibres. There are different fibres that are used in the concrete namely carbon fibre, glass fibre, steel fibre, synthetic fibres and natural fibres (jute fibres). The improvement in the material behaviour of the fibre reinforced concrete depends on dosage and characteristics of the used fibres. Addition of randomly distributed carbon fibre improves concrete properties, such as compressive strength, static flexural strength, ductility and flexural toughness. The large number of fibres used for concrete members enables a uniform distribution of fibres through the compound, there by creating a composite material and the concrete

possessing homogeneous mechanical behaviour. They provide a cohesive mix. The important characteristic in FRC material is the bond between the fibers and the matrix. Fibres are designed in different geometries to increase the bond and interfacial friction between fine aggregates and cement paste. In addition, the deformation at peak stress is much greater than plain concrete. Fibres help to alter the behaviour of concrete after the initiation of cracking. The forces induced in CFRC when subjected to load are redistributed within the concrete, which restrains the formation and extension of cracks. The result is a more ductile reinforced concrete which is able to maintain a residual capacity in the post-cracking phase. Thus, resulting in an increased load-carrying capacity, improved shear and bending strength of concrete, superior flexural ductility, toughness, and fatigue endurance.

Navya HA, Patil Nayana N. (2018), in this research work the strength and durability behavior is investigated which was performed on M25 grade concrete mixed with carbon fiber with different volume fractions i.e. 0%, 0.75%, 1.00% and 1.25% of the concrete volume, there was also to find out the differential characteristic’s behaviour. Compressive strength has recorded increased by 46.80%, 59.90% and 32.40% while mixed with carbon fibre of volume fraction 0.75%,1.00% and 1.25% respectively of concrete mass than conventional concrete. Jingjing Zhang1 and colleagues (2017), to determine the mechanical properties of the fibres in concrete and analysis study of carbon fire used concrete durability of reinforced cement conrete structures. This research work has been proposed a analytical tests of chopped carbon, aramid and hybrid carbon-aramid fibers (1:1) used concrete to enhance the properties of concrete and to achieve the greater strength and toughness of the fibers.When the concrete is mixed with 1% fibres, results shows the increment of compressive strength and modulus of elasticity among all the tests conducted on fibre reinforced concrete samples, and it is also observed that 1% used carbon fibre in concrete, anti-carbonation capacity found better than conventional concrete. M. Yakhlaf, Md. Safiuddin, K.A. Soudki (Spt. 2013), the research work examined the effects of discrete pitch-based carbon fibres on self-consolidating concrete fresh properties. Different carbon fibre reinforced in self-consolidating concrete, carbon fibre mixes in proportion of 0%, 0.25%, 0.5%, 0.75% and 1% by concrete volume with two water-to-binder ratios (0.35 and 0.40). After research work it is found that as carbon fibres increases, the filling ability and passing ability of concrete decreases. There are no adverse effects as well on the segregation resistance of concrete due to carbon fibre mixing.

II. MATRIAL USED

Cement
Using Ordinary Portland Cement (grade 43) of specific gravity 3.14 conforming to IS 8112:2013, "ORDINARY PORTLAND CEMENT-SPECIFICATION", has been used.

Aggregates
Fine aggregates conforming to IS383:1970, "SPECIFICATIONS FOR COARSE AND FINE AGGREGATES FROM NATURAL SOURCES FOR CONCRETE" has been used.
Coarse aggregates conforming to IS383:1970, "SPECIFICATIONS FOR COARSE AND FINE AGGREGATES FROM NATURAL SOURCES FOR CONCRETE" has been used.

Water
Normal portable water fit for drinking purpose has been used to prepare fresh concrete. Specification confirming to IS 456:2000.

Concrete
The concrete is mixture of four main constituents: cement, water, coarse aggregate, and fine aggregate. The concrete was prepared of M20 for a characteristic compressive strength of 20MPa in 28 days from manufacturing.

Carbon Fibre
Carbon fiber is produced by carbonizing the organic fibre at high temperaturer. They have a diameter of 5–25 μm and are coated with a "sizing" to improve the adhesion with the matrix material.

Figure 1: Carbon Fibre

III. EXPERIMENTAL SETUP

A. Specimen layout
A total of 36 concrete specimens were prepared and tested in the experimental program having the size of 150mm×150mm×150mm. M20 grade of concrete has been as per the requirement for axial load design. Each cube specimen consists of a 150 mm square cross section and a depth of 150 mm. 9 plain concrete specimens (no replacement) were prepared and 27 carbon fibre mixed concrete with different percentage of replacement were prepared. These specimens were prepared for 7, 14 and 28 days of curing respectively. The specimens were numbered as PC11, CC11, CC12 and so on, where the letter "P" indicates Plain and first "C" is indicating Carbon Fibre respectively. "C" indicates concrete which is the second word in abbreviation and the numeric value indicates the sequence in which they were tested in different group.
In this study, the carbon fibres were mixed homogeneously in the concrete mixture where they were integrated into the cube to form a full composite action. The first step in the strengthening process involved sizing, shaping, dressing, cleaning and removal of moisture (by drying) from the carbon fibre. During mixing we ensured the uniform distribution and shape of carbon fibre. Accurate percentage weight has been taken during the preparation of specimens. These all parameters have been maintained in every specimen preparation.

Figure 2: Shaping & Sizing of Carbon Fibre

Figure 3: Uniform Distribution of Carbon Fibre

B. Testing Programme

These specimens were subjected to axial compressive load using compressive testing machine of 2000KN capacity. The surface area of each specimen was 22500mm2. Ultimate load readings were taken to study the compression performance of the specimens. Prior to testing, all specimens were wiped off the water by a cloth and cleaned the surfaces of concrete and leave them at the room temperature for drying. After all these actions, putting the specimen by possessed a thick layer of paper fixed at the top and bottom surface of the specimen in order to ensure that the contact surface remained parallel and that the applied load remained concentric. The results of tested specimens were tabulated below, these results were recorded in ultimate loads at which the failures of specimens occurred and further these loads are converted in ultimate stress that is ultimate load divided by cross sectional (surface area) area in which the load was applied.

Figure 4: Arrangement & Failure of Specimen

IV. EXPERIMENTAL RESULT

Table 1: Results obtained for concrete specimen7 Days Curing

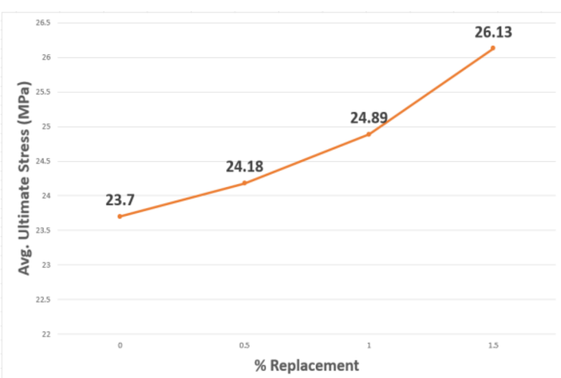
Specimen Name	Percentage Replacement	No. of Cube	Pult(KN)	σult(Pult/A)(MPa)
Plain Concrete(PC) (PC$_{11}$+PC$_{12}$+PC$_{13}$)/3	0	3	534	23.7
Carbon Fibre Concrete(CC$_{11}$)	0.5	3	544	24.18
Carbon Fibre Concrete (CC$_{12}$)	1.0	3	560	24.89
Carbon Fibre Concrete (CC$_{13}$)	1.5	3	588	26.13

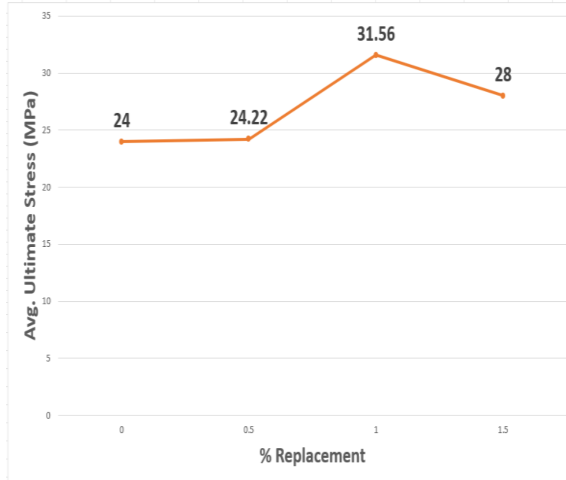
14 Days Curing

Specimen Name	Percentage Replacement	No. of Cube	P_{ult}(KN)	σult(Pult/A)(MPa)
Plain Concrete(PC) (PC$_{21}$+PC$_{22}$+PC$_{23}$)/3	0	3	540	24.00
Carbon Fibre Concrete(CC$_{21}$)	0.5	3	545	24.22
Carbon Fibre Concrete (CC$_{22}$)	1.0	3	710	31.56
Carbon Fibre Concrete (CC$_{23}$)	1.5	3	630	28.00

28 Days Curing

Specimen Name	Percentage Replacement	No. of Cube	P_{ult}(KN)	σult(Pult/A)(MPa)
Plain Concrete(PC) (PC$_{31}$+PC$_{32}$+PC$_{33}$)/3	0	3	560	24.89
Carbon Fibre Concrete(CC$_{31}$)	0.5	3	610	27.11
Carbon Fibre Concrete (CC$_{32}$)	1.0	3	930	41.33
Carbon Fibre Concrete (CC$_{33}$)	1.5	3	725	32.22





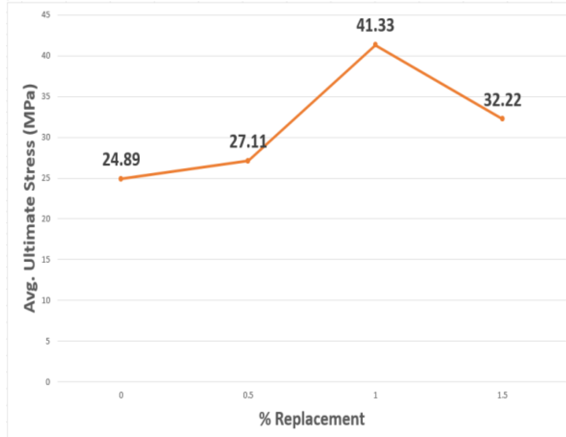


Figure 5: % Replacement VS Ultimate Stresses fo 7, 14 & 28 Days Cured Concrete

Stresses for Replaced & Without Replaced Concrete The concrete specimens, when replaced with carbon fibre up to 1.0% recorded the higher stress than plain concrete stress. Beyond this limit concrete was notable to bear the same stress.

V. CONCLUSION

36 concrete specimens designated as PC11, PC12, CC11, CC12 and so on were tested under axial compressive loading in compression testing machine of 2000KN capacity having the surface area 22500mm2. Comparative study has been carried out between plain concrete and carbon fibre mixed concrete (PC & CC). This research work shows the following results.

1. Specimens mixed with carbon fibres, shows the good increment in strength as we replace the carbon fibre by 0.5% and 1.0%.
2. Up to this limit concrete shows the good

compressive as well as flexural strength.

3. Beyond 1.0% limit i.e. 1.5% replacement of carbon fibre starts reducing the strength.

4. Mixing of carbon fibre up to 1.0%, concrete shows the good cracking resistance and bonding strength.

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