International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 03 | Mar-2018 www.irjet.net p-ISSN: 2395-0072

A Review: Effect Of Carbon Fiber On Different Mixes Of Concrete

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Abstract: *Concrete is the most widely used in construction material. It is the material of choice where strength, performance, durability, fire resistance and abrasion resistance are required. Reinforced concrete structures with high strength deformed bars and designed using limit state method was found to have larger crack widths. The present review paper mainly focuses on research papers carried in the field of carbon fiber reinforced concrete, which includes experimentation studies, strength and, effect on carbon fibers etc.Compared with all other fibers Carbon Fibers have higher Tensile Strength due to which Concrete is benefited. The experimental investigation was performed to evaluate the strength of concrete, in different percentages of fibers were added with respect to weight of cement. Tests were performed for various percentages (0.10%, 0.20%, 0.25%, 0.30%, 0.40%, 0.50%, 0.60%, 0.75%,1.00%) of carbon fiber for M30, M40, M60 grade concrete at different curing periods (3,7,14 and 28 days). The paper represents a complete collection of the studies carried out in the field of carbon fiber reinforced composites. The review article would give an updated material for the researchers in the field of carbon fiber reinforced concrete. This helps them to carry out the research related to carbon fibers, fiber composite etc, and can furnish in their studies and help them to arrive at feasible outcomes.*

Key words: Carbon Fiber, CFRC, Compressive Strength, Flexural Strength, Tensile Strength

1. INTRODUCTION

The use of fibers in concrete to improve pre- and post-cracking behavior has gained popularity. Since 1967, several different fiber types and materials have been used in concrete to improve its physical properties and durability. This is supported by large number of independent research results showing the ability of fibers to improve durability and physical properties of concrete [10].

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 [5].

Concrete has very low tensile strength. Cracks formed with application of load, leads to fracture of concrete. Cracks are formed in concrete during hardening stage. The new technology of using carbon fibers made the invention of carbon fiber reinforced concrete to overcome these problems associated with cement based materials such as low tensile strength, poor fracture toughness of cementitious composites. Cracks and weak in tension are the limitations of conventional concrete. Thus recent years have show the extensive use of fibers like glass, steel, carbon etc. in order to face the challenges of the growing civil engineering industry. Addition of such carbon fibers increases fire resistance, impact, compressive, erosion, split tensile and flexural strength, durability, fracture and shrinkage characteristics of cracks. Objective of this work is to present the information accumulated from various researches and to show the benefit out of using carbon fibers [4].

Carbon fibers have low density, high thermal conductivity, good chemical stability and excellent abrasion resistance, and it can be used to reduce cracking and shrinkage. These fibers increase structural properties such as tensile and flexural strengths, flexural toughness and impact resistance. Carbon fibers also increase durability and dry shrinkage. However, the addition of carbon fibers decreases the electrical resistance [1,2,3].

Fibres with different volume fractions have been used to study the effect of carbon fibers on mechanical properties (compressive strength, splitting tensile strength and flexural strength) of concrete. Carbon fiber, is a material consisting of fibers 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 shape gives the fibre high strength-to-volume ratio (making it strong for its size)[6,7,8].

The properties of carbon fibers, such as high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion, make them very popular in aerospace, civil engineering, military, and motorsports, along with other competition sports. However, they are relatively expensive when compared to similar fibers, such as glass fibers or plastic fibres [6, 9].

1.1 ADVANTAGES OF FIBERS

Addition of carbon fibers improves the following properties of Concrete;

1. Fire resistance.
2. Compressive strength.
3. Split tensile strength.
4. Flexural strength.
5. Durability.
6. Erosion strength.
7. Serviceability of concrete.
8. Fracture characteristics.
9. Reduce cracking.

2. EXPERIMENTAL STUDIES ON MECHANICAL PROPERTIES

Many researchers have carried out experiments related to strength properties with addition of different size and volume of carbon fibers. Below are some recent research articles received, in order to get clear results and understanding of carbon fibers.

E.Mello,C.Ribellato,E.Mohamedelhassan[11]:This paper shows study of carbon fiber reinforced concrete by using 6mm length of carbon fiber with different percentage of carbon fiber content (0.20% to 0.50%) with M30 grade of concrete. Cement (OPC53), coarse aggregate having maximum size of 16mm, fine aggreagate, water and super plasticizer were used. Mechanical properties were calculated for different percentage of carbon content. In table2.1 all the results are given;

Table 2.1 Test results for CFRC for 28 days;

Carbon Fiber Content (%)	Compressive Strength(MPa)	Flexural Strength(MPa)	Tensile Strength(MPa)
0.20	43.1	7.42	2.98
0.30	43.6	6.82	3.78
0.40	42.0	9.37	4.17
0.50	47	6.94	4.11

While plain concrete has compressive strength of 42.8 MPa, flexural strength 6.46MPa and tensile strength is 3.75MPa after 28 days. While the addition of carbon fibers increased the compressive strength by 2%, flexural strength by 45% and tensile strength by 11%.

S.M.Deore, J.S.Bodke, A.R.Pendhari [5]: This paper shows the effect of addition of carbon fiber in concrete with partial replacement of sand by waste foundry sand. This investigation finds results only for flexural strength shown in table2.2.

Cement(OPC53),coarse aggregates(max. size 20mm),fine aaggregates,water,foundry sand and carbon fiber(5-10mm).Results are carried out after 3,14,28 days for different carbon fiber content(0.25%,0.50%,0.75%,1.0%) with 30% replacement of sand by waste foundry sand.

Table2.2 Flexural strength of CFRC after 3,7,28 days in MPa;

Sr. no.	WFS content (%)	Carbon fiber content (%)	Flexural strength (after 3 days)	Flexural strength (after 7 days)	Flexural strength (after 28 days)
1	30	0.25	4.20	4.80	6.45
2	30	0.50	4.70	6.55	7.55
3	30	0.75	6.05	7.35	9.05
4	30	1.0	5.55	7.30	8.65

Maximum flexural strength 9.05MPa achieved for WFS concrete with 0.75% carbon fiber at 28 days. As comparison with CFRC concrete, conventional concrete shows 7.51MPa flexural strength after 28 days.
The maximum flexural strength 6.05Mpa(3 days),7.35Mpa (14days),9.05Mpa(28days) were obtain at 30% replacement of sand by WFS with 0.75% carbon fibre addition in concrete.

S.M.Kinayekar,Dr.V.D.Gundakalle,KishorKulkarni[12]:

In this paper, cement content in the HSC mix is replaced with fixed percentages of fly ash (10%) and carbon fiber are added in volume fraction (0 to 0.60%).

Cement: Ordinary Portland cement (OPC) (53 grade) with specific gravity of 3.15 and fineness of 292 m2/kg Confirming to IS 8112:1989 is being used.

Fine aggregate: The sand used for the experimental program was locally procured and was confirming to Zone-III. The specific gravity of fine aggregate was 2.58 and bulk density 1600 kg/m3.

Coarse aggregate: Locally available crushed angular coarse aggregate having maximum size of 12.5 mm were used in the present work. The specific gravity of coarse aggregate was 2.90 and bulk density 1553kg/m3.

Fly ash (FA): Fly ash from Raichur thermal power station, Karnataka has been used as cement replacement material with a specific gravity of 2.2 and blains fineness of 229 m2/kg.
Carbon fiber: The carbon fiber used is obtained from engineering India, Pune. The density of carbon fiber is about 1800 kg/m3 and tensile strength of fiber is 4137 N/mm2.

Water: Potable tap water was used for the preparation of specimens and for the curing of specimens.

Superplasticizer: The super plasticizer used is Conplast SP430, which is obtained from FOSROC chemicals, Bangalore.

Hydroxy Ethyl Cellulose (HEC): The Hydroxy Ethyl Cellulose used as in this experiment was obtained from FOSROC chemicals, Bangalore. The viscosity of HEC is 4.75 % in water at 20oC

Epoxy: Epoxy is the resin based bonding agent, which is obtained from FOSROC chemicals, Bangalore.

This study works on M60 grade of concrete mix. Carbon fiber having different length of 10, 20, and 30 mm strip with different % content of carbon fibre.

Table2.3 Harden properties of HSC using Carbon Fiber (10mm) for 28 days

Length of CF(mm)	CF content (%)	Compressive Strength(MPa)	Flexural Strength(MPa)	Tensile Strength(MPa)
10	0	61.49	7.08	5.12
	0.10	61.64	7.22	5.24
	0.20	61.79	7.32	5.40
	0.30	62.08	7.50	5.56
	0.40	62.23	7.60	5.70
	0.50	62.68	7.79	5.87
	0.60	62.82	7.88	6.06

Hardened properties were determined by conducting compressive strength on cubes, splitting tensile strength on cylinders, flexural strength response on beams. The compressive strength test on cube specimens is conducted as per IS 516-1959. Split tensile test is carried out on compression testing machine as per IS 5816-1999. To determine flexural properties of concrete beams two point loading system is adopted and testing is carried out by as per IS 516-1959.Now table2.4 given below shows the harden properties of 20mm length of carbon fiber in HSC.

Table2.4 Harden properties of HSC using Carbon Fiber (20mm) for 28 days

Length of CF(mm)	CF content (%)	Compressive Strength(MPa)	Flexural Strength(MPa)	Tensile Strength(MPa)
20	0	61.49	7.08	5.12
	0.10	61.79	7.27	5.34
	0.20	61.93	7.41	5.52
	0.30	62.23	7.60	5.71
	0.40	62.53	7.74	5.85
	0.50	63.12	7.88	6.04
	0.60	63.27	8.03	6.24

Table2.5 Harden properties of HSC using Carbon Fiber (30mm) for 28 days

Length of CF(mm)	CF content (%)	Compressive Strength(MPa)	Flexural Strength(MPa)	Tensile Strength(MPa)
30	0	61.49	7.08	5.12
	0.10	61.93	7.36	5.40
	0.20	62.68	7.55	5.62
	0.30	63.12	7.74	5.82
	0.40	63.56	7.88	5.96
	0.50	64.15	7.93	6.23
	0.60	64.45	8.12	6.44

The addition of carbon fiber as fiber reinforcing material in HSC with 10 percent fly ash show improved mechanical strength properties. As comparing the length of carbon fiber (10,20,30mm), 30mm shows the higher harden properties of HSC using carbon fibre.

Prashant Muley,ShrikantVarpe,Rahul Ralwani[13]:This paper shows that to alter and further the effects of carbon fiber reinforced concrete, fiber dosage rates of 0.25%, 0.5%, 0.75% and 1.0% by volume were selected. Summary of Mix design is based on IS codes [14, 15,16].This investigation is based on M50 grade of concrete mix. Cement, sand, coarse aggregate, water and carbon fibre (5-10mm) were used for this concrete mix. There are two different curing period of 7 and 28 days.After curing mechanical strength can be checked of CFRC by using carbon fibre as shown in table below;

Table2.5 Test results for CFRC for 7 days;

Sr.No.	CF content (%)	Compressive Strength(MPa)	Flexural Strength(MPa)	Tensile Strength(MPa)
1	0.00	38.3	4.6	2.9
2	0.25	42.2	5.2	3.3
3	0.50	44.0	5.9	3.6
4	0.75	47.9	6.4	3.9
5	1.00	51.0	7.1	4.2

Table2.5 Test results for CFRC for 28 days;

Sr.No.	CF content (%)	Compressive Strength(MPa)	Flexural Strength(MPa)	Tensile Strength(MPa)
1	0.00	50.5	6.1	3.8
2	0.25	54.7	6.9	4.3
3	0.50	56.9	7.9	4.7
4	0.75	62.0	8.3	5.0
5	1.00	69.9	9.3	5.4

The comparisons of mechanical properties and behavior include the compressive strength, tensile strength and flexural strength. With the discussions and results obtained from the experimental tests, it is clearly to know the effect of carbon fibers used in the structural concrete shows in the above results in tables.

CONCLUSION

The current review paper shows the studies carried out on carbon fibers reinforced concrete. The paper mainly focuses on strength properties of concrete by addition of carbon fiber with different dosages. The optimality and effect of fibers on concrete properties are studied and behavior of concrete is experimentally verified by casting cubes, cylinders and beam specimen.

Studies have shown that the addition of carbon fibers in a concrete matrix in proves all the mechanical properties of concrete, especially tensile strength, impact length and toughness. The resulting material possesses higher compressive, tensile strength.

From the literature papers referred on carbon fibers, its properties, significance, effect, impact on strength properties are focused and brought into picture for the study and future research. Following conclusions could be drawn from present papers.

1. The Mechanical properties such as compressive strength, tensile strength, toughness, impact, flexural etc are greatly influenced by addition of carbon fibers, optimum dosage of carbon fibers governs these properties and must carry out optimality study on carbon fibers.

2. Selection of carbon fibers, properties like length, diameter aspect ratio, its effect on properties of concrete changes with addition of dosage. The prime importance must be given for selection of carbon fibre, etc.

3. The carbon fiber used in concrete significantly improves many properties of concrete. The combination of fibers thus shows advanced improvement and great changes in properties of concrete.

4. The Addition of fibers with additional supplementary cementations material such as fly ash, silica fumes,waste foundry sand etc should better performance by improving workability of concrete and inherent properties of concrete.

5. The Addition of carbon fibres is carried out for special category such as self-compacting concrete, high performance concrete, high strength concrete etc.

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