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STRENGTH IMPROVEMENT OF CONCRETE BY USING CHOPPED CARBON FIBRE

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ABSTRACT

Concrete is the most widely used construction material. It is difficult to point out another material of construction, which is as versatile as concrete. It is the material of choice where strength, performance, durability, impermeability, fire resistance and abrasion resistance are required. Concrete is seemingly simple but actually complex material. Cracking in reinforced concrete members also causes a significant increase in deflection. This is a result of the reduction in bending stiffness at cracked section. Reinforced concrete structures with high strength deformed bars and designed using limit state method was found to have larger crack widths. Bending is one of the reasons for flexural cracks. These cracks appear in the tension face & extend vertically in a small region over interior supports & in mid span regions of continuous beams. One viewpoint is that cracks reduce the service life of structures. The tensile strength of concrete is about 10 percent of the compressive strength, but in the design of reinforced concrete structural elements, this strength is neglected. Steel reinforcement is provided to carry the tensile stresses in a member due to applied loads. It is expected that cracks will develop in a reinforced concrete member under service loads. In tension zone, the steel reinforcement is engaged primarily when a crack occurs, and design of reinforced concrete structures is carried out based on the fact that significant portions of the structure are cracked.

To overcome this difficulty of cracking and to enhance other physical parameters of concrete now a day concrete is reinforced with various fibres. Compared with all other fibres Carbon Fibres have higher Tensile Strength due to which Concrete is benefited. The scope of my project is to assess Characteristic of concrete by using chopped Carbon Fibre. The objective of the project is to study the effect of aspect ratio & different volume fractions of CF on Mechanical Properties of CFRC.

Keywords: Carbon Fibre, CFRC, Compressive Strength, Flexural Strength, High Strength Concrete

I INTRODUCTION

The use of fibres in concrete to improve pre- and post-cracking behavior has gained popularity. Since 1967, several different fibre types and materials have been successfully used in concrete to improve its physical properties and durability. This is supported by an extensive number of independent research results showing the ability of fibres to improve durability and physical properties of concrete. Regardless of origin, cracking, when induced by chemical, mechanical, or environmental processes, results in deteriorated and less-durable concrete. In addition, the increased permeability caused by cracking can accelerate other deterioration processes such as freezing-and-thawing damage, again resulting in less-durable concrete. Fibre-reinforced concrete (FRC) is concrete with the addition of discrete reinforcing fibres made of steel, glass, synthetic (nylon, polyester, and polypropylene), and natural fibre materials. At appropriate dosages, the addition of fibres may provide increased resistance to plastic and drying shrinkage cracking, reduced crack widths, and enhanced energy absorption and impact resistance. The major benefit derived from the use of FRC is improved concrete durability.

1.1 Objectives

1 To assess the flexural strength of CFRC

2 To assess the compressive strength of CFRC

3 To compare the structural behavior of the CFRC with that of the conventional concrete of similar grade.

1.2 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.

II CARBON FIBRE BASICS

Carbon fibre is a long thin strand of Carbon atoms that are bonded together in a honeycomb crystal lattice called Graphene.Some of the Graphene layers are folded around each other in random orientations but most are aligned parallel to the long axis of the strand. This makes the fibre incredibly strong along the axis of the strand.(highest APF) The strands are usually wound into a yarn then woven into a fabric. (By altering the weave pattern the fabric can be stronger in one direction or be equally strong in all directions). The fabric is then mixed with epoxy and molded to form the desired shape.

2.1 Properties of Carbon Fibre

1) Carbon Fibre has High Strength to Weight Ratio (also known as specific strength)

Strength of a material is the force per unit area at failure, divided by its density. Any material that is strong and light has a favourable Strength/weight ratio. Materials such as Aluminium, titanium, magnesium, Carbon and glass fibre, high strength steel alloys all have good strength to weight ratios. It is not surprising that Balsa wood comes in with a high strength to weight ratio.

2) Carbon Fibre is very Rigid

Rigidity or stiffness of a material is measured by its Young Modulus and measures how much a material deflects under stress. Carbon fibre reinforced plastic is over 4 times stiffer than Glass reinforced plastic, almost 20 times more than pine, 2.5 times greater than aluminum.

3) Carbon fibre is Corrosion Resistant and Chemically Stable.

Although Carbon fibre themselves do not deteriorate, Epoxy is sensitive to sunlight and needs to be protected. Other matrices (whatever the Carbon fibre is imbedded in) might also be reactive.

4) Carbon fibre is Electrically Conductive

This feature can be useful and be a nuisance. In Boat building It has to be taken into account just as Aluminum conductivity comes into play. Carbon fibre conductivity can facilitate Galvanic Corrosion in fittings. Careful installation can reduce this problem.

5) Fatigue Resistance is good

Resistance to Fatigue in Carbon Fibre Composites is good. However when Carbon fibre fails it usually fails catastrophically without much to announce its imminent break. Damage in tensile fatigue is seen as reduction in stiffness with larger numbers of stress cycles, (unless the temperature is high). The orientation of the fibres and the different fibre layer orientation, have a great deal of influence on how a composite will resist fatigue (as it has on stiffness). The type of forces applied also result in different types of failures. Tension, Compression or Sheer forces all result in markedly different failure results.

6) Carbon Fibre has good Tensile Strength

Tensile strength or ultimate strength is the maximum stress that a material can withstand while being stretched or pulled before necking, or failing. Necking is when the sample cross-section starts to significantly contract. If you take a strip of plastic bag, it will stretch and at one point will start getting narrow. This is necking. It is measured in Force per Unit area. A brittle material such as Carbon fibre does not always fail at the same stress level because of internal flaws. They fail at small strains.

7) Fire Resistance/Non Flammable

Depending upon the manufacturing process and the precursor material, Carbon fibre can be quite soft and can be made into or more often integrated into protective clothing for firefighting. Nickel coated fibre is an example. Because Carbon fibre is also chemically very inert, it can be used where there is fire combined with corrosive agents.

8) Thermal Conductivity of Carbon Fibre

Thermal conductivity is the quantity of heat transmitted through a unit thickness, in a direction normal to a surface of unit area, because of a unit temperature gradient, under steady conditions. In other words its a measure of how easily heat flows through a material. There are a number of systems of measures depending on metric or imperial units.

$1W/(m.K) = 1\ W/(m.^{o}C) = 0.85984\ kcal/(hr.m.^{o}C) = 0.5779\ Btu/(ft.hr.^{o}F)$

It is not possible to pinpoint exactly the thermal conductivity. Special types of Carbon Fibre have been specifically designed for high or low thermal conductivity. There are also efforts to enhance this feature.

9) Low Coefficient of Thermal Expansion

This is a measure of how much a material expands and contracts when the temperature goes up or down. Units are in Inch / inch degree Carbon fibre can have a broad range of CTE's, -1 to 8+, depending on the direction measured, the fabric weave, the precursor material, Pan based (high strength, higher CTE) or Pitch based (high modulus/stiffness, lower CTE). Low Coefficient of Thermal expansion makes Carbon fibre suitable for applications where small movements can be critical. Telescope and other optical machinery is one such application.

10) Non Poisonous, Biologically Inert, X-Ray Permeable

These qualities make Carbon fibre useful in Medical applications. Prosthesis use, implants and tendon repair, x-ray accessories surgical instruments, are all in development. Although not poisonous, the Carbon fibres can be quite irritating and long term unprotected exposure needs to be limited. The matrix either epoxy or polyester, can however be toxic and proper care needs to be exercised.

11) Carbon Fibres are brittle

The layers in the fibres are formed by strong covalent bonds. The sheet-like aggregations readily allow the propagation of cracks. When the fibres bend they fail at very low strain.

12) Carbon Fibre is Relatively Expensive

Although it offers exceptional advantages of Strength, Rigidity and Weight reduction, cost is a deterrent. Unless the weight advantage is exceptionally important, such as in aeronautics applications or racing, it often is not worth the extra cost. The low maintenance requirement of Carbon fibre is a further advantage. It is difficult to quantify cool and fashionable. Carbon fibre has an aura and reputation which makes consumers willing to pay more for the cachet of having it. You might need less of it compared to fibreglass and this might be a saving.

2.2 Advantages of Strengthening With Carbon Fibre

1) Fibres are electrolitically non-corrosive
2) They possess high strength
   - under short term loading
   - under long term loading and
   - under repeated loading
3) Owing to low specific weight (i.e., 17-18 KN/m^3 depending on the fibre to matrix ratio) fibres:
   - have low transportation costs
   - are easy to apply even in restricted spaces
   - have no need for scaffolding to support the strengthening strips or fabrics during hardening of the adhesive l They have no limitation in length
4) Due to their thickness (1 to 1.4 mm) fibres:
   - Contribute to no significant decrease in structural height
   - Strips can be crossed
   - Applications are easy to cover, thus fulfilling aesthetic requirements
5) Economical solution (considering the entire cost of strengthening).

2.3 Disadvantages of Carbon Fibre

1) Carbon fibres themselves are relatively expensive
2) Mechanical protection is to be provided if vandalism is not excluded Service temperature in the vicinity of strengthening is not allowed to exceed around 50 °C owing to the embedding matrix of fibres

III SELECTION OF INGREDIENTS

The main ingredients of concrete are as follows,

1) Cement.

2) Fine aggregates (i.e. sand)

3) Coarse aggregate.

4) Water.

5) Carbon fibre.

1) Cement

Cement consists of four major compounds Tricalcium Silicate (C_3S), Dicalcium Silicate (C_2S), Tricalcium Aluminates (C_3A) & Tetra calcium Aluminoferrite (C_4AF). Tricalcium Silicate (C_3S) and Dicalcium Silicate (C_2S) are the most important compound responsible for strength. Together they constitute 70 to 80 percent of cement. The average C_3S content in modern cement is about 45 percent and that of C_2S is about 25 percent. During the course of reaction of C_3S and C_2S with water, calcium silicate hydrate (C-S-H) and calcium hydroxide ($Ca(OH)_2$) are formed. Calcium silicate hydrates are the most important products and determines the good properties of concrete. C_3S readily reacts with water and produces more heat of hydration. It is responsible for early strength of concrete.

2) Fine Aggregate (Sand)

Concrete is an assemblage of individual pieces of aggregate bound together by cementing material, its properties are based primarily on the quality of cement paste. This strength is dependant also on the bond between the cement paste and aggregate. If either the strength of the paste or the bond between the paste and aggregate is low a concrete of poor quality will be obtained irrespective of strength of the aggregate, for making strong concrete, strong aggregate are an essential requirement and naturally available mineral aggregate are strong enough for making normal strength concrete.

3) Coarse Aggregate

The nominal maximum size of coarse aggregate should as large as possible within the specified limits but in no case greater than one fourth of the minimum thickness of the member, provided that the concrete can be placed without difficulty so as to surround all reinforcement thoroughly and fill the corners of the form. Locally available crushed stone aggregates are used

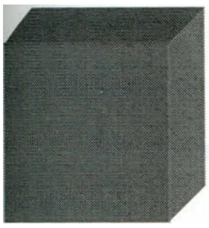
4) Water

Water is an important ingredient of concrete as it actively participates in the mix design consideration. It is generally stated in the concrete codes and also in the literature that the water chemically reacts with cement. The strength of cement concrete mainly due to the binding action of the hydrated cement gel. The requirement of water should be reduced to that required for chemical reaction of anhydrate cement as the excess water would end up in only formation of undesirable voids in the hardened cement paste in concrete.

IV METHODOLOGY

Properties of Concrete

Testing of hardened concrete plays an important role in the controlling and confirming quality of raw material, which help to achieve higher efficiency of material used and greater assurance of performance of concrete.



Cube (150 x 150x 150 mm)

Beam (150 x 150 x 700 mm)

Figure 4.1 Specimens Details for Casting

Curing

1. After moulding the test specimens are stored on the site at a place free from vibration under damp matting, sacks or other similar materials for 24 ± 0.5 hours from the time of addition of water to the other ingredients.

2. The temperature of the place of storage should be within the range of 22ºC to 32ºC. After a period of 24 hours, they should be marked for later identification and removed from the moulds, stored in clean potable water at a temperature of 24ºC to 30ºC until they are transported to the testing laboratory.

Testing:

1. After the required curing (i.e. 7 & 14 days etc.), the specimens are tested under the compression testing machine.

2. The load should be applied gradually at the rate of 14 MPa per minute till the specimen fails.

The testing shall be done on at least three specimens at each selected age. If the strength of any specimen varies by 15 % of the average strength, the results should be rejected

V TEST REPORT

Testing of hardened concrete plays an important role in controlling and confirming the quality of cement concrete work. Tests are made by casting cubes and cylinder from the actual concrete.

Size of cube	=	150 mm x 150 mm x 150mm
Size of Beam	=	150mm x 150mm x 700mm
Mix Proportion		1: 1.5 : 3
W/C ratio	=	0.5

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Type of Cement	=	PPC Ultratech Cement
Type of fibre	=	Carbon Fibre

Table 5.1 For M20 grade of CFR Concrete

In present study, compression test on cube for 7 days & 14 days, flexural test on beams for 7 days & 14 days and plain and varying percentage of Carbon fibre reinforced concrete are carried out. The experimental results and discussion for various tests is described below.

Result of Compressive Strength of CFRC at 7 Days

The variation of compressive strength with respect to Weight of fibre is shown in the graph.

Sr. No.	Identification Mark	% Weight of Fibre	Crushing load ($x10^3$N)	Comp. Strength (N/mm^2)	Avg. Comp. Strength (N/mm^2)
1	C1	0 %	431.64	19.18	18.89
	C1	0 %	431.64	19.18	
	C1	0 %	412.02	18.31	
2	C2	1 %	432.62	19.23	19.17
	C2	1 %	449.30	19.97	
	C2	1 %	412.02	18.31	
3	C3	2 %	491.48	21.84	22.10
	C3	2 %	490.5	21.80	
	C3	2 %	510.12	22.67	
4	C4	3 %	431.64	19.18	19.92
	C4	3 %	463.03	20.58	
	C4	3 %	451.26	20.00	

Table 5.2 Compression Test Results for 7 Days

Sr. No.	Identification mark	% Weight of Fibre	Crushing load (x10^3N)	Comp. Strength (N/mm^2)	Avg. Comp. Strength (N/mm^2)
1	C1	0 %	498.34	22.15	23.14
	C1	0 %	525.81	23.37	
	C1	0 %	537.58	23.89	
2	C2	1 %	521.89	23.20	26.39
	C2	1 %	588.60	26.16	
	C2	1 %	671.00	29.82	
3	C3	2 %	765.18	34.01	30.52
	C3	2 %	706.32	31.39	
	C3	2 %	588.60	26.16	
4	C4	3 %	568.98	25.29	24.88
	C4	3 %	529.74	23.54	
	C4	3 %	580.75	25.81	

Table 5.3 Compression Test Results for 7 Days

VI CONCLUSION

Total 24 cubes, and 24 beams, were cast and tested for different tests of hardened concrete. After testing of all specimens the following conclusions were drawn,

1. The compressive strength of concrete is increases by 31.89 % as compared to the normal concrete at the age of 14 days by the addition of 2% Carbon fibre; further increase in percentage of Carbon fibre compressive strength of CFRC is not increased.

2. The flexural strength of CFRC increases 42.87 % as compared to the normal concrete at the age of 14 daysby the addition of Carbon fibre. The flexural strength of CFRC is increased with increased in % of Carbon fibre up to 2%.

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