Behaviour of Carbon Fiber Reinforced Concrete Beams by Partially Replacing Cement by Rice Husk Ash

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***Abstract:-* Carbon fibers are excellent mixing materials for mortar or concrete because they can prevent the generation of fracture inside the material. Carbon fibers have low specific gravity, high strength, and high elastic modulus; further, they are inert to many chemical substances and also have excellent heat resistance. For these reasons, carbon fibers can be used as excellent mixing materials for mortar or concrete. This paper presents results which indicate that carbon fiber reinforced concrete has the ability to serve as a smart structural material capable of providing information as to internal stress condition and extent of crack propagation. The present invention relates to a carbon fiber-reinforced concrete having excellent strength and durability used mainly in civil engineering and architectural field.**

RHA is a carbon neutral green product. Lots of ways are being thought of for disposing them by making commercial use of this RHA. RHA is a good super-pozzolan. This super-pozzolan can be used in a big way to make special concrete mixes. There is a growing demand for fine amorphous silica in the production of special cement and concrete mixes, high performance concrete, high strength, low permeability concrete, for use in bridges, marine environments, nuclear power plants etc. This market is currently filled by silica fume or micro silica, being imported from Norway, China and also from Burma. With RHA replacement of cement, the compressive strength of concrete is increased evidently; the average pore radius of concrete is greatly decreased, especially the portion of the pores greater than 20 nm in radius is decreased while the amount of smaller pores is increased, and the more the RHA replacement, the less the amount of $Ca(OH)_2$ in concrete.

CHAPTER 1
INTRODUCTION

1.1. GENERAL

A carbon fiber-reinforced concrete containing a cement, a coarse aggregate, a fine aggregate, a carbon fiber and water, wherein the carbon fiber is dispersed in the carbon fiber-reinforced concrete in an amount of from 0.1 to 20 vol % and has an average length in the range of from 30 mm to 100 mm, and not less than the maximum size of the coarse aggregate, a tensile strength of at least 300 kgf/mm^2 and a ductility of at least1%. When a carbon fiber is used, degradation of the fiber can be prevented and durability can be improved.

However, it was only rod-like or mesh-like long fibers that have been therefore used for a carbon fiber-reinforced concrete. In order to improve strength, it was tried to cure carbon fibers with an epoxy resin, thereby forming rod-like short fibers. But the rod-like short fibers were slipped out from a matrix when a bending load was applied and the aimed reinforcing effect could not be achieved. The carbon fiber-reinforced concrete of the present invention can be produced by dispersing and curing a mixture comprising a cement, a coarse aggregate, a fine aggregate, water and a carbon fibers having an average length of not less than the maximum size of the coarse aggregate and a tensile strength of not less than 300 kgf/mm^2. The pitch based carbon fiber used in the present invention is not specially limited, provided that it has a tensile strength of at least 300kgf/mm2, preferably at least 350 kgf/mm2, and such carbon fibers as prepared from as starting material including polyacrylonitrile, coal tar pitch, petroleum pitch, coal-liquefied material or the like, can be used. It is essential for the present invention that the carbon fibers should have an average length of not less than the substantial maximum size of coarse aggregate. In order to efficiently bind coarse aggregates to achieve an effect for strengthening a concrete structure, carbon fibers should preferably have an average length of at least 30 mm, more preferably at least 35 mm, and at least two times as long as the maximum size of coarse aggregate, but should not have an average length of more than 100 mm in view of dispersibility of the carbon fibers in concrete.

Pitch based carbon fibers should preferably be used in the form of a chopped strand inview of dispersibility of carbon fibers in concrete. Also, if carbon fibers are kneaded with cement, a coarse aggregate and the like and are dispersed therein in the form of single fibers, they are liable to be cut by the coarse aggregate. Therefore, it is preferable to knead the carbon fibers in the form of a chopped strand with a cement, a coarse aggregate and the like while maintaining the strand form, and it is also preferable to get a cement gel invaded into the strand and to maintain the strand form in the cured concrete wherein concrete is present between fibers. The carbon fiber-reinforced concrete of the present invention can be produced by dispersing and curing a mixture comprising a cement, a coarse aggregate, a fine aggregate, water and a chopped strand of carbon fibers having an average length of not less than the maximum size of the coarse aggregate and a tensile strength of not less than 300 kgf/mm^2.

Rice milling industry generates a lot of rice husk during milling of paddy which comes from the fields. This rice husk is mostly used as a fuel in the boilers for processing of paddy. Rice husk ash (RHA) is about 25% by weight of rice husk when burnt in boilers. It is estimated that about 70 million tones of RHA is produced annually worldwide. During milling of paddy about 78 % of weight is received as rice, broken rice and bran. Rest 22% of the weight of paddy is received as husk.

1.2. APPLICATION OF CARBON FIBER

Carbon fiber can be used as

1. Corrugated units for floor construction
2. Single and double curvature membrane structures
3. Boat hulls
4. Scaffold boards

1.3. APPLICATION OF RICE HUSK ASH

Rice milling industry generates a lot of rice husk during milling of paddy which comes from the fields. This rice husk is mostly used as a fuel in the boilers for processing of paddy. Rice husk ash (RHA) is about 25% by weight of rice husk when burnt in boilers. It is estimated that about 70 million tones of RHA is produced annually worldwide. During milling of paddy about 78 % of weight is received as rice, broken rice and bran .Rest 22 % of the weight of paddy is received as husk .This husk is used as fuel in the rice mills to generate steam for the parboiling process This husk contains about 75% organic volatile matter and the balance 25 % of the weight of this husk is converted into ash during the firing process, is known as rice husk ash. RHA acts as a very good insulator. RHA is also used for insulation of molten metal in tundish and ladle in slab caster. The temperature of molten metal in the ladle is around 1400 degrees centigrade and above. When this metal flows from ladle to tundish, the temperature drops to around 1250 degrees. This reduction in temperature leads to choking and causes breakdown in the slab caster. When this RHA is spread as a coating over the molten metal in the tundish and in ladle, it acts as a very good insulator and the temperature is maintained and does not cool down quickly, hence reducing the breakdown time of the casting.

1.4. LITERATURE REVIEW

1) Zheng and Chung, Carbon fiber reinforced concrete, Strategic highway research program by national research council.

This paper focused on the concrete containing carbon fibers in the amount of 0.2vol%.In this study isotropic pitch based carbon fibers are used. The result shows that use of this type of fibers increase the flexural strength by 37%,33%and 21% respectively after 7,14 and 28 days. Compared to plain concrete fiber reinforced concrete yields a flexural strength increase of 85% at 28 days curing.

2) Chuan Mein Wong, Use of short fibers in structural concrete to enhance mechanical properties, University of southern Queinsland.

In flexural test it showed that specimens with fibers have high strength from specimens without fibers. By increasing the fiber volume dosage rate tends to lead the high tensile strength. The most remarkable changes in the increasing of strength by the use of short concrete fibers to concrete occur in bending. This change includes the increase of flexural strength in pre cracking stage.

3) Khosrow Ghavami, Porosity and water permeability property of rice husk ash, Journal of materials science vol.41, Springer Netherlands publisher.

It was observed that the incorporation of RHA in the composites could cause an extensive pore refinement in the matrix and in the interface layer thereby decreasing water permeability. The results indicate that the partial replacement of cement by RHA can improve the durability characteristics of cement composites.

4) Farhad Reza, Phd., Smart behaviour of carbon fiber cement composite in compact tension, ASCE,16th engineering conference , july 16/8/2003.

In this paper the smart behaviour was evaluated by performing frequency electrical resistance measurements during compact tension tests on carbon fiber reinforced concrete specimens. The result shows that smart material capability existed volume contents between 0.2% to 0.6%.

5) K.Sakr, Effect of silica fume and rice husk ash on heavy weight concrete, ASCE journal vol.18.

Concrete mixed with RHA has good resistance to sulphate attack. High mechanical and physical properties than that mixed without any additives. RHA is a pozzolanic material. It acts as an insulator. It helps to improve the microstructure of the interfacial transition zone between the cement paste and the aggregate in concrete. The relative strength is high when compared to the concrete made with plain cement.It also exerted significant influences on the blending coefficient.

6) N.Banthia, P.Guptha, and C.Yan, Impact resistance of fiber reinforced concrete part1: beam test, Journal of materials and science.

Based on the beam test it is clear that fiber reinforcement is highly effective in improving the fracture energy absorption and toughness under impact loading. Carbon fiber also increases the flexural strength and compressive strength.

7) Keiichi Okuyama, Application of carbon fiber to concrete, Journal of environmental science for sustainable society vol.2, 2008.

Carbon fibers are excellent mixing materials for concrete because they can prevent the generation of fracture inside the materials. It has high strength and elastic modulus, they are inert to many chemical substances, for these reasons they are used as excellent mixing materials.When a carbon fiber is used, degradation of the fiber can be prevented and durability can be improved.

1.5. OBJECTIVE OF THE PROJECT

The main objective is

- To study the flexural behaviour of the reinforced concrete beams by partially replacing cement by rice husk ash.
- To study the behaviour of carbon fibre reinforced concrete beam (pitch based carbon fiber).

1.6. SCOPE OF THE PROJECT

In this project the flexural behaviour of carbon fiber reinforced concrete beams (pitch based carbon fiber) are to be studied. The structures are subjected to flexural loading until failure. Therefore the flexural performance of concrete with adding carbon fiber and partial replacement of cement by rice husk ash is to be studied carefully. Comparing the flexural behaviour of control RC beam with partial replacement (rice husk ash) RC beam is studied. The characteristic studies that are possible in this paper is as follows.

- Load-Deflection characteristics
- Ultimate load carrying capacity
- Crack propagation and its development
- Stress- Strain relationship

CHAPTER 2

EXPERIMENTAL INVESTIGATION

2.1.1 Cement:

Ordinary locally available Portland cement (53 grade cement) was used in the casting of specimens.

Specific Gravity of Cement

Table 2.1. Test Results for specific gravity of cement

Description	Weights(gms)	
	Trial1	Trial2
Wt. of empty bottle (w_1)	19.12	19.12
Wt. of bottle +water (w_2)	46.56	46.56
Wt. of bottle+ kerosene (w_3)	41.33	41.33
Wt. of bottle+cement + kerosene(w_4)	50.91	50.93
Wt. of cement(w_5)	32.14-19.12=12.94	

Trial no:1

$$\text{The specific gravity of cement} = \frac{w_5}{w_5 + w_3 - w_4} x \frac{w_3 - w_1}{w_2 - w_1}$$

$$= \frac{12.94}{12.94 + 41.33 - 50.91} x \frac{41.33 - 19.12}{46.56 - 19.12} = 3.13$$

Trial no:2

$$\text{The specific gravity of cement} = \frac{w_5}{w_5 + w_3 - w_4} x \frac{w_3 - w_1}{w_2 - w_1}$$

$$= \frac{12.94}{12.94 + 41.33 - 50.93} x \frac{41.33 - 19.12}{46.56 - 19.12} = 3.14$$

Average specific gravity of cement = 3.15

2.1.2. Fine Aggregate:

The Fine Aggregate used is clean dry river sand. The sand is sieved to remove all pebbles. The Material properties of the fine aggregate are given in **table 2.2.** The result of the sieve analysis, particulars of the fine aggregate is given in the **table 2.3**.

Specific Gravity of Fine Aggregate

Table 2.2. Specific Gravity Test Results for Fine Aggregate

Description	Weight(kg)	
	Trial 1	Trial 2
Empty weight of the mould (w_1)	2.96	2.96
Weight of the mould + Fine aggregate (w_2)	4.97	4.76
Weight of the mould + fine aggregate + water(w_3)	7.16	7.01
Weight of the mould + water (w_4)	5.9	5.9

Trial 1:1

$$\text{Specific gravity of fine aggregate} = \frac{w_2 - w_1}{(w_2 - w_1) - (w_3 - w_4)}$$

$$= \frac{4.96 - 2.96}{(4.96 - 2.96) - (7.16 - 5.9)} = 2.68$$

Trial no: 2

Specifiic gravity of fine aggregate = $\frac{w_2 - w_1}{(w_2 - w_1) - (w_3 - w_4)}$

$$= \frac{4.76 - 2.96}{(4.76 - 2.96) - (7.01 - 5.9)} = 2.608$$

Average specific gravity of fine aggregate = 2.64

Sieve Analysis

Table 2.3. Sieve Analysis Test Results for Fine Aggregate

I.S.Sieve (mm)	Wt.Retained	%Wt Retained	%Wt passing	Cumulative % Wt Retained
4.75	0	0	100	100
2.36	110	5.5	2.5	97.5
1.18	610	60.5	12	88
600µ	580	29	35	65
300µ	460	23	64	36
150µ	190	9.5	94.5	5.5
pan	50	2.5	100	0

Initial weight: 2 kg

Fineness modulus = $\frac{\sum F}{100}$

$$= \frac{292}{100}$$

= 2.92

2.1.3. Coarse Aggregate:

Hard Granite broken stone is used as coarse aggregate. The material property of the coarse aggregate is given in **table 2.4.**The sieve analysis test results are shown in **table 2.5.**

Specific Gravity of Coarse Aggregate

Table 2.4. Specific Gravity Test Results for Coarse Aggregate

Description	Weight(kg)	
	Trial 1	**Trial 2**
Empty weight of the mould (w_1)	12.59	12.59
Weight of the mould + Coarse aggregate (w_2)	19.67	21.89
Weight of the mould + Coarse aggregate + water(w_3)	31.71	33.1
Weight of the mould + water (w_4)	27.16	27.16

Trial 1:1

Specific gravity of coarse aggregate = $\frac{w_2 - w_1}{(w_2 - w_1) - (w_3 - w_4)}$

$$= \frac{19.67 - 12.59}{(19.67 - 12.59) - (31.71 - 27.16)} = 2.79$$

Trial no: 2

Specifiic gravity of coarse aggregate = $\frac{w_2 - w_1}{(w_2 - w_1) - (w_3 - w_4)}$

$$= \frac{21.89 - 12.59}{(21.89 - 12.59) - (33.1 - 27.16)} = 2.76$$

Average specific gravity of Coarse aggregate = 2.78

Sieve Analysis

Table 2.5. Sieve Analysis Test Results for Coarse Aggregate

I.S.Sieve (mm)	Wt.Retained	%Wt Retained	%Wt passing	Cumulative % Wt Retained
80mm	0	0	0	100
40mm	0	0	0	100
20mm	0	0	0	100
10mm	1.59	53	53	47
4.75mm	1.28	42.67	95.67	4.33
2.36	0.13	4.33	100	0
1.18mm	0	0	100	0
600	0	0	100	0
300mm	0	0	100	0
150mm	0	0	100	0
pan	0	0	100	0

Initial weight: 3kg

Fineness modulus = $\frac{\sum F}{100}$

$$= \frac{748.67}{100}$$

= 7.48

2.1.4. Steel:

In all beams tested two numbers of 10 mm diameter bars was provided for tension side and two numbers of 8 mm diameter in compression side and 8 mm diameter bars are used as stirrups @ 100mm spacing.

2.1.5. Water:

Water of good quality was used throughout the work.

2.1.6. Fiber

The fiber used in this study is of Carbon fiber. The form of Carbon Fiber used in this investigation is pitch based Carbon fiber. High tensile strength, high elastic modulus, low thermal expansion and low weight are some of the advantages of the pitch based carbon fiber. Carbon fibers are excellent mixing materials for concrete because they can prevent the generation of fracture inside the materials. They are inert to many chemical substances and also have excellent heat resistance. For these reason they are used as excellent mixing material for concrete. The Properties of pitch based carbon fiber is shown in **table 2.6.** The Carbon fiber used in the investigation is shown in **photo 2.1**

2.1.7. Rice Husk Ash:

Rice milling generates a byproduct know as husk. This surrounds the paddy grain. During milling of paddy about 78 % of weight is received as rice, broken rice and bran .Rest 22 % of the weight of paddy is received as husk. This husk is used as fuel in the rice mills to generate steam for the parboiling process. This husk contains about 75 % organic volatile matter and the balance 25 % of the weight of this husk is converted into ash during the firing process, is known as rice husk ash (RHA). Rice husk collected from nagercoil paddy mill is burnt and used in this investigation. The properties of rice husk ash are shown in

Table 2.7. Properties of Rice Husk Ash

Moisture content	3.68%
Specific gravity	2.08
Fineness	12.5%
Silica	93.15%
Alumina	0.21%

2.2. Mix Design and Mix Proportions

Mix proportions are arrived for M20 grade of concrete based on IS code method. Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible.

Data

a) Characteristics compressive strength required = 15 Mpa
b) Max. Size of aggregate = 20mm
c) Degree of workability = 0.9
compaction factor
d) Degree of quality control = good
e) Type of Exposure = mild
f) Specific Gravity of cement = 3.15
g) Specific Gravity of coarse aggregate = 2.78
h) Specific Gravity of fine aggregate = 2.64
i) Free surface moisture – coarse aggregate = nil
j) Free surface moisture – fine aggregate =2%

Solution

1) Target Mean Strength

$F_{ck} = 20.78$ N/mm^2

2) Selection of water cement Ratio

From Fig.1 of Is: 10262-1982 for target mean strength 20.78N/mm^2

W/c ratio = 0.42

3) Selection of Water and cement content

From table 4. Of Is: 10262-1982 for coarse aggregate of size 12mm

Water content = 186 Kg/m^3

Sand = 35%

4) Correction

Correction	Water content	Sand %
Compaction factor	3	0
W/c ratio	0	-3.6%

Weight of water = 191.58 Kg

$$\text{Weight of Cement} = \frac{Weightofwater}{w/cratio}$$

$$= \frac{191.58}{0.42}$$

$$= 456.14 \text{ Kg}$$

5) Sand Weight

$$V = [w + \frac{c}{s_c} + \frac{1}{p} \text{ x } \frac{f_a}{s_{fa}}] \text{ x } \frac{1}{1000}$$

$F_a = 563.84$ Kg

6) Coarse Aggregate Weight

$$V = [w + \frac{c}{s_c} + \frac{1}{1-p} \text{ x } \frac{c_a}{s_{ca}}] \text{ x } \frac{1}{1000}$$

$C_a = 1280$ Kg

Table2.8. Mix Proportion

Cement	Fine aggregate	Coarse Aggregate
456.14	563.84	1280

Ratio: *1: 1.23: 2.81*