*Research Article* *ISSN: 2319-507X*
*Muhammad Javed, IJPRET, 2012; Volume 1(3): 29-35* *IJPRET*

INTERNATIONAL JOURNAL OF PURE AND APPLIED RESEARCH IN ENGINEERING AND TECHNOLOGY

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# EFFECT OF SHORT CARBON FIBRES ON FLEXURAL TENSILE STRENGTH OF CONCRETE

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**Accepted Date:**

**18/10/2012**

**Publish Date:**

**01/11/2012**

**Keywords**

Tensile strength

Carbon fibress

Modulus of rupture

Plain concrete

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## Abstract

Use of short carbon fibers in concrete improves some important properties (i.e. flexural tensile Strength, toughness etc.). The flexural tensile strength of concrete is specially very important property as it indicates the limitation on the use of concrete in structural elements/members which purely relies on flexural tensile strength e.g., short span slabs, pavements etc. The strength of Plain concrete (P.C) beams is measured from modulus of rupture (MOR) test that is used to determine the strength at which a P.C.C beam in flexural tension. In this research work, four types of concrete mixes with different amount of short carbon fibers were used and a comparative study is devised. Flexural strength was determined using modulus of rupture test for all the four types of concrete with 28 days strength. The effect of variation of the amount of carbon fibres on flexural strength was found and compared to the reference concrete.

## INTRODUCTION

Flexural tensile strength of plain concrete, $f_r$, commonly known as modulus of rupture (MOR) is an important property of concrete and is used in the design of short span slabs, road pavements, etc. In this investigation, results of experimental work to study the effect of short carbon fibers (type of fibers with 98% carbon content and are available in length of 5±1 mm) on $f_r$ is discussed. Beams, moist cured for at least 28 days, were subjected to MOR test. These beams were fabricated using four types of mixes designated as CC, Type A, Type B and Type C on the basis of amount of short carbon fibers. Type CC mix had no carbon fibers, while types A, B and C contained carbon fibers with amount of 0.35%, 0.5%, and 0.65%, respectively, by weight of cement.

## RESEARCH SIGNIFICANCE

Concrete is a material which performs well under compression and is best to use in situation where compressive strength is of prime importance. It also exhibits limited tensile strength. MOR tests are performed to measure flexural strength of plain concrete. If the flexural tensile cracks, during the test, are produced within the middle third portion of the beam's clear span then the modulus of rupture, $f_r$ , is determined by the Equation 1 as follows:

$f_r = Pl/bd^2$ ………… 1

Equation 1 is derived using equilibrium conditions for simply supported beam loaded at third point. Where

$f_r$ = Modulus of rupture ; P = Maximum vertical load applied by the testing machine; l = Length of the specimen between supports; b = width of the beam; and d = depth of the beam

However, if the cracks are produced outside the middle third of the clear span of beam by not more than 5% of the clear span length, then the modulus of rupture is determined by the following equation.

$f_r = 3Pa/bd^2$ ………………… 2

Where 'a' is the average distance between line of fracture to the nearest support measured on tension side of the beam.

The test results of a sample is discarded if the resulting cracks are produced outside the middle third of clear span by more than 5%,

**MIX PROPORTION**

Mix proportions for Normal Concrete were made with a compressive strength of 28 MPa by using ACI 211.1[1]. Results of mix proportions are as follows in Table I:

Table-1 Mix proportion Values

| S. No. | Material | Quantity ($kg/m^3$) |
|---|---|---|
| 1. | Cement | 364 |
| 2. | Fine Aggregate | 831 |
| 3. | Coarse | 906 |
| **4.** | **Water** | **208** |

Other materials that were used in the concrete included Carbon fibers, Silica Fume (8% by weight of cement), Methylcellulose (0.4% by weight of cement) and Plasticizers (1.5% by weight of cement). Methylcellulose was used for dispersing the fibres in the concrete. While silica fume was used to increase the bond strength of concrete with carbon fibers. Whereas, Plasticizers were used to impart proper workability as using the silica fume results in a harsh concrete mix.

Four different types of concrete mixes were used in the experimental work on the basis of varying amount of short carbon fibers. These mixes were designated as Controlled Concrete (CC); Type A, Type B, Type C having Carbon fibres by amount of 0%, 0.35%, 0.5%, and 0.65% respectively by weight of cement. The details of mix proportions are given in the Table II.

**Table I Details of Mix proportions**

| Mix type | Carbon fibers (%) | Fine agg. (kg/m$^3$) | Coarse agg. (kg/m$^3$) | Cement (kg/m$^3$) | w/c | Silica Fume (%) | Plasticizer (%) | Methyl cellulose (%) |
|---|---|---|---|---|---|---|---|---|
| **CC** | 0 | 831 | 906 | 364 | 0.57 | 8 | 1.5 | 0.0 |
| **Type A** | 0.35 | 831 | 906 | 364 | 0.57 | 8 | 1.5 | 0.4 |
| **Type B** | 0.50 | 831 | 906 | 364 | 0.57 | 8 | 1.5 | 0.4 |
| **Type C** | **0.65** | **831** | **906** | **364** | **0.57** | **8** | **1.5** | **0.4** |

**MIXING PROCEDURE**

Mixing of concrete was carried out at normal temperature. Care was taken that during mixing process, all the steps should be taken in accordance with ASTM C1116[2]. The concrete batches were made by a concrete Mixer Machine using following procedure:

Coarse aggregates were first placed in the mixer machine and water was added in a nominal amount to wet the coarse aggregate. Mixer machine was allowed to start rotating.

Then Silica Fume as per ASTM C1240[3] was added an an amount equal to 8% by weight of cement to the mixer machine containing wet aggregates.

Fine aggregates were added to the rotating mixer machine.

Methylcellulose was dissolved in the water and the solution was shaked for 2 minutes. Carbon fibres were then added to the solution. This resulted in a thick black paste as shown in Figure 1.

**Figure 1 Carbon fibres in Methylcellulose**

This paste of methylcellulose and carbon fibres was also added to the mixer machine.

Finally, plasticizers were added to the mixer machine and all the material was allowed to mix for 3 minutes.

**TEST PROCEDURE**

Beam samples with 450 mm x 100 mm x 100 mm size were made in the lab to determine the modulus of rupture as per ASTM C78 standards[4]. All the beam specimens were cast and cured in accordance with ASTM C192 specifications[5]. Beams specimens, tested using universal testing machine (UTM), were supported on both sides. 75 mm length of beam from each face of the support was supported on thick steel plates as shown in Figure 2. The remaining 300 mm length was divided in three equal portions to accomplish the ASTM C78 requirements that the intermediate distance between points should be equal to depth of the beam. Circular rods, with an overlying thick steel plate, were used to equally transfer the point load applied through UTM as shown in Figure 2.

**Figure 2 Setup for MOR test**

**Figure 2 Beam at failure**

Care was taken during the testing to observe the cracks generation i.e. whether the cracks were produced within the middle third of the beam clear span or otherwise. It was observed that tensile cracks were produced within middle third portion of all the tested beams (Figure 3) and, therefore, Equation 1 was used to determine $f_r$

**RESULTS AND DISCUSSIONS**

Results of the experimental work are given in Table III. Results are also compared in

Figures 3 and 4 taking controlled concrete (Type CC) as reference.

Table III: Flexural tensile strength of tested specimens

| Flexural tensile strength, $f_r$, (MPa) | | | | |
|---|---|---|---|---|
| Type of Concrete | Beam 1 | Beam 2 | Beam 3 | Average $f_r$ |
| CC | 5.00 | 4.84 | 5.10 | 4.99 |
| Type A | 5.37 | 5.20 | 5.50 | 5.36 |
| Type B | 5.34 | 5.54 | 5.59 | 5.50 |
| Type C | 5.54 | 5.60 | 5.75 | 5.63 |

It can be seen from Figure 4 that the flexure tensile strength of concrete increases with an increase in the amount of short carbon fibers. A direct relation between percent increase in flexural tensile strength and the amount of carbon fibers[6, 7, 8] can also be seen from Figure 5.

This increase in strength can be attributed to the increase in bond strength of fibers with cement due to silica fume.

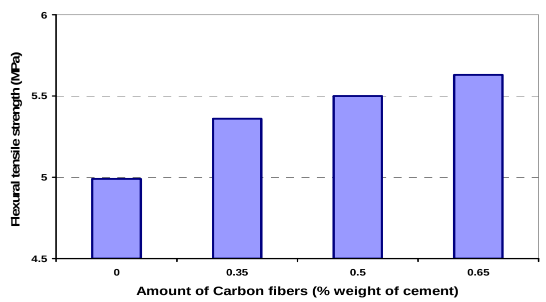


**Figure 3 Variation in flexural tensile strength with amount of carbon fibers**

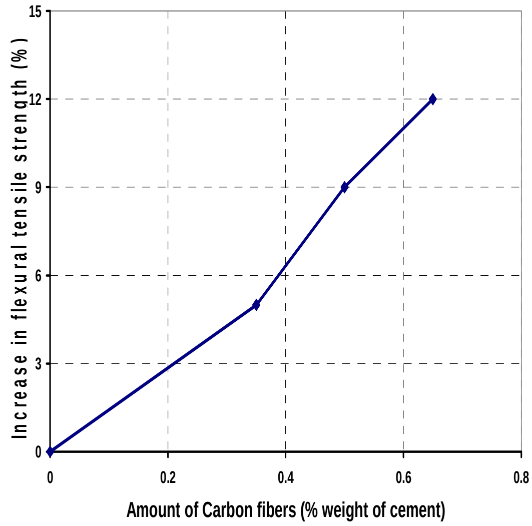


**Figure 4 Percent increase in tensile strength w. r. t controlled specimen**

## CONCLUSSION

On the base of tests results, it can be concluded that use of short carbon fibers in plain concrete increase the tensile strength of concrete. This increase in strength may be credited to the reinforcing action developed by the bond between fibers and concrete. The reinforcing action increases by increasing the amount of fibers that causes the flexural tensile strength to increase further.

## FUTURE WORK

Effect of further increase of carbon fibers amount on the flexural tensile strength shall be investigated. The existing and additional data may be used to develop empirical relation between amount of carbon fibers and flexural tensile strength. Similarly influence of various fibers length on the flexural tensile strength of concrete having same amount of carbon fibers shall also be studied.

**ACKNOWLEDGMENT**

I am thankful to the department of Civil Engineering, University of Engineering & Technology Peshawar for providing the necessary assistance in conducting these tests. I am also grateful to Dr. Deborah L. Chung (Department of Mechanical and Aerospace Engineering, State University of New York at Buffalo) for providing me the proper guidance. I am also thankful to Prof. Dr. Jahangir Mirza, (Hydro Quebec, Montreal, Quebec, Canada) for his amazing help.

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