

## EFFECT OF JUTE FIBER ON THE MECHANICAL PROPERTIES OF CONCRETE

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### ABSTRACT

*The presence of micro cracks in mortar-aggregate interface is responsible for the inherent weakness of plain concrete, which can be removed by inclusion of fibers in concrete mixture. At present "Fiber Reinforced Concrete" is one of the most promising construction techniques. Among different types of fibers, jute fiber can pose a great impact in the revolution of construction material in the context of Bangladesh, because of its availability and cheap price. In this study, various dosages of Jute fiber (0.5%, 1% and 1.5%) with different values of w/c ratio (0.40, 0.45 and 0.55) were used to accomplish the testing of "Compressive Strength", "Splitting Tensile Strength" & "Flexural Strength" of concrete. The "Fresh Concrete Properties" were also investigated. The results of the compression and split tensile test indicated that the presence of jute fiber tends to increase the strength at lower fiber percentage (maximum compressive strength 28.68 MPa at 0.4 w/c and 0.5% fiber, maximum splitting tensile strength 3.24 MPa at 0.45 w/c and 0.5% fiber). But it decreases at higher fiber percentage. Despite the minimal reduction in the compressive strength at higher jute fiber content, there is an improvement of ductility after cracking of concrete. Similarly, the flexure test results indicated that the maximum modulus of rupture of concrete is 7.44 MPa at 1.0% jute fiber content. In spite of the limited scope of the thesis work and the shortcomings associated with jute fiber, the thesis work results raises a hope that (Jute Fiber Reinforced Concrete) JFRC can be used in areas where small tensile reinforcement is expected and also in the construction of temporary structures. The least cost of jute fiber, its being renewable resources, the reduced weight of the JFRC composite and the reduction in consumption of other constituents of the concrete matrix would indicate its economic advantage.*

Keywords: Fiber reinforced concrete, Jute fiber, Mechanical strengths, Ordinary Portland Cement.

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### 1. INTRODUCTION

Concrete is the most essential building material all over the world. The modern research works in construction material have introduced us to improved concrete such as highly durable polymer concrete, fiber reinforced concrete to overcome cracks in concrete, high- and ultra-high strength concrete, light weight concrete to reduce foundation loads, and high performance concrete for special performance requirements. In the developing countries like Bangladesh, there has been a shortage of durable and low cost housing construction materials. The design of durable, low-cost building is technological challenge in present days. With appropriate use of fiber in cement composites seems feasible to control the inherent problems of cement composites and also for the effective construction. As we all know cement composites lacks in some characteristics such as cement composites behaves brittle with low tensile strength and due to its poor resistance to cracks opening, need of increase in durability of such composites must be taken in to account with some kind of modification in it. There are various types of fibers are present in market which can be used as reinforcement in cement concrete such as steel fiber, polymer fiber, carbon fiber and there are some natural fiber also like jute, sisal, sugarcane, rice husk etc. For the safety of the structures, many researches had been done so far to measure the mechanical strength of concrete with fiber. There are various works regarding the strength of concrete with steel fiber (Altun et al., 2007; Aydın, 2013; Dahake and Charkha, 2016; Song and Hwang, 2004; Sukumar and John, 2014; Velayutham and Cheah, 2014). Research on glass fiber reinforced concrete has been done (Singh and Kumar, 2014). Synthetic fiber like polypropylene also got the attention of researchers (Alhozaimy et al., 1996; Aulia, 2002; Balaguru and Khajuria, 1996; Myers, Kang, Ramseyer, 2008). Natural fibers were used for research purpose as well (Codispoti, 2013). For our experimental purpose we have taken Jute fiber because as a natural fiber it possess several advantages such as low cost, easily available and eco-friendly and they also offer high strength and toughness when mixed in cement composites. Jute is abundantly grown in Bangladesh and it is extracted from a plant which grows about 2m in height and with a diameter of stem ranges in between 20mm to 30 mm. Jute fiber proves to be cheap, durable and strong and also an effective reinforcing material for cement based composites. Several studies were done to investigate the feasibility of using jute fiber in concrete mix. The length of jute fiber has an effect on the mechanical properties of concrete (Zakaria et al. 2016). Performance, workability and strength comparison of JFRC with plain concrete showed the scope of using jute fiber to improve concrete strengths (Pooja Warke and Shrinkhala Dewangan 2016; T. Sai Vijaya Krishna, B. Manoj Yadav 2016; Bal Gopal Guru, Sangeeta Swain, Swapna Seth, Madhusudan

Sahu 2018).

The above review indicates that more studies are required on the behavior of JFRC for more insights. This study was done to explore the feasibility of using this indigenous reinforcing material, jute to improve the mechanical properties of concrete. The objective of the study is to evaluate 3 strength parameters: 1) compressive strength, 2) split tensile strength and 3) flexural strength and compare the change in strengths with respect to different w/c (0.4, 0.45, 0.55), and fiber percentages (0.5%, 1.0%, 1.5%)

## 2. MATERIALS

### 2.1. Course Aggregate

The size of coarse aggregate used in this study was 10 mm and the aggregate gradation was well- graded.

### 2.2. Fine Aggregate

The Sylhet sand used as fine aggregate in this study which was collected from the local market. The fineness modulus of the fine aggregate was 2.47 and the gradation was well-graded.

**Table 1. Various properties of course and fine aggregate**

Aggregate Properties		
Properties	Course Aggregate	Fine Aggregate
Apparent Specific Gravity, $S_a$	2.68	2.69
Bulk Specific Gravity (O-D basis), $S_d$	2.65	2.55
Bulk Specific Gravity (SSD basis), $S_s$	2.66	2.6
Absorption Capacity (D) in %	0.4	1.94
Unit Weight ( $\text{kg/m}^3$ )	1522.23	1508.07
Gradation	Well graded	Well graded

### 2.3. Jute Fiber

Jute fiber was collected from the local market and then cut into desired length (15-25 mm). No chemical treatment was done prior to the use of fiber. The properties jute fiber used are given below:

**Table 2. Properties of Jute Fiber**

Properties of Jute	Value
Specific Gravity	1.49
Length of Fiber	15-25 mm

### 2.4. Cement

Ordinary Portland Cement (OPC) was used as binding material.

## 3. METHODOLOGY

### 3.1. Mix Design

Different types of mix design have already been tested in various studies. For this study, M 30 concrete was designed according to ACI 318 Method and used for the tests of the specimens.

### 3.2. Specimen Types

Two types of specimens were used. For compression and splitting tensile strength test cylindrical specimen of 200 mm length and 100 mm diameter and for flexural strength test square concrete beam of 225 mm length and 75 mm × 75 mm cross section were casted as per the standards with different jute contents such as 0.5%, 1% and 1.5%. The casted specimens are then cured for a period of 28 days.

### 3.3. Test Procedures

After the curing period is completed, the specimens are tested for the following tests:

a) Compressive Strength Test: The test was done according to the standard test method as issued by ASTM (C 39/C 39M – 03). The compressive strength of the specimen was calculated by dividing the maximum load carried by the specimen during the test by the average cross-sectional area of specimen. The compressive strength of the specimen was calculated by following equation:

$$C = \frac{P}{\pi d^2 / 4} \quad (1)$$

Where, C = Compressive strength, psi [MPa], P = maximum applied load indicated by the testing machine, lbf [N], and d = diameter, in. [mm].

b) Split Tensile Strength Test:

The test was conducted in accordance with the standard test method as issued by ASTM (C 496/C 496M – 04). The splitting tensile strength of the specimen was calculated by following equation:

$$T = \frac{2P}{\pi ld} \quad (2)$$

Where, T = splitting tensile strength, psi [MPa], P = maximum applied load indicated by the testing machine, lbf [N], l = length, in. [mm], and d = diameter, in. [mm].

c) Flexural Strength Test: The test was done in accordance with the standard test method as issued by ASTM (C 293– 02). The center point loading method was used in flexure tests of concrete specimen, which ensured that forces applied to the beam, was be perpendicular to the face of the specimen and applied without eccentricity. The modulus of rupture was calculated by following equation:

$$R = \frac{3PL}{2bd^2} \quad (3)$$

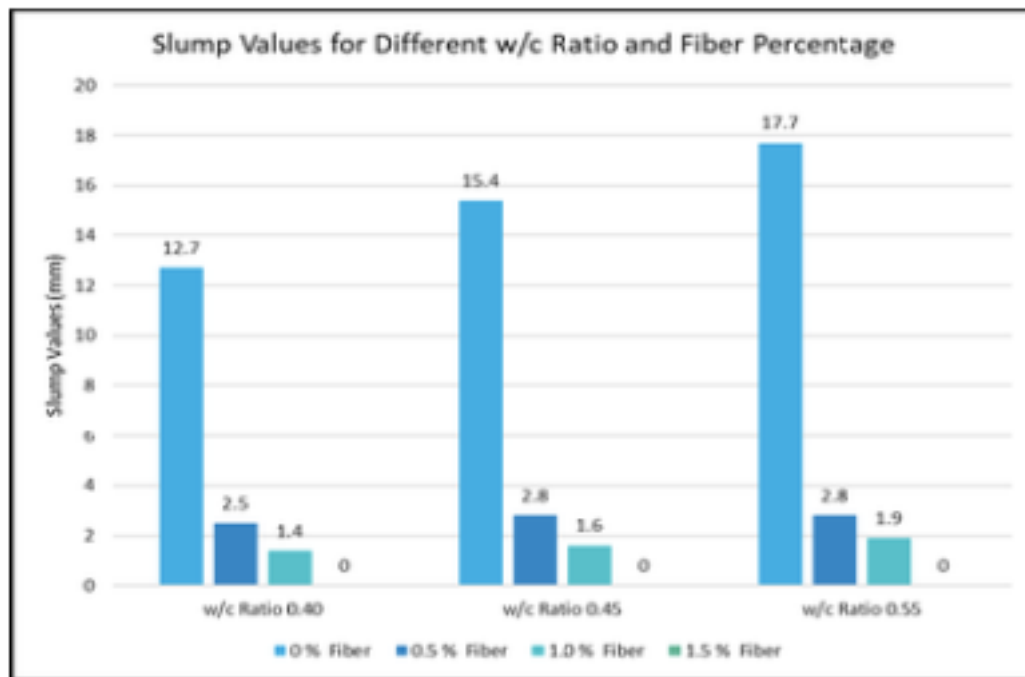
Where, R = modulus of rupture, psi, or MPa, P = maximum applied load indicated by the testing machine, lbf, or N, L = span length, in., or mm, b = average width of specimen, in., or mm, at the fracture, and d = average depth of specimen, in., or mm, at the fracture.

## 4. RESULTS & DISCUSSIONS

The following are the results obtained from the above explained tests:

### 4.1. Slump test for the workability of concrete

Slump test is conducted for testing the workability of plain concrete and JFRC



**Figure 4.1 Slump values**

The result clearly indicates that the workability of concrete reduces with the inclusion of higher fiber percentages.

#### 4.2. Compressive strength test

The results of the compressive strength test of different type of specimens are given below:

**Table 4-1 Result of compressive strength test**

w/c Ratio	Fiber Percentage	Average Compressive Strength (MPa)
0.4	0.5	28.68
	1	18.71
	1.5	23.19
0.45	0.5	26.99
	1	18.11
	1.5	7.54
0.55	0.5	13.46
	1	13.04
	1.5	8.82

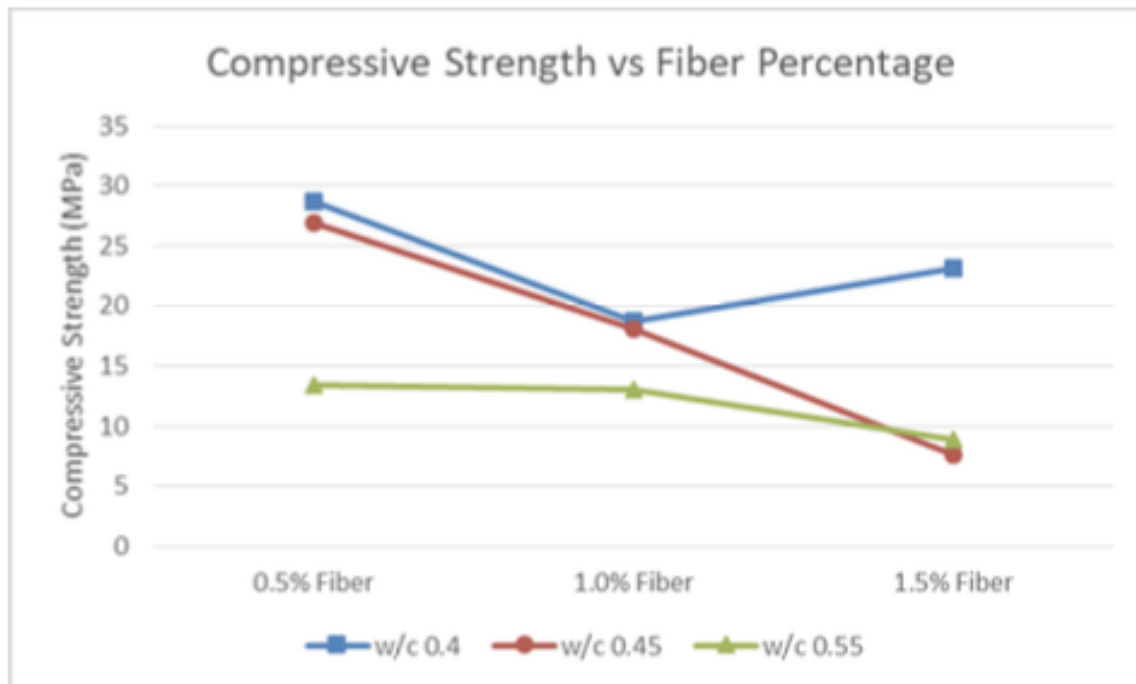


Figure 4.2 Compressive strength vs fiber percentage curve

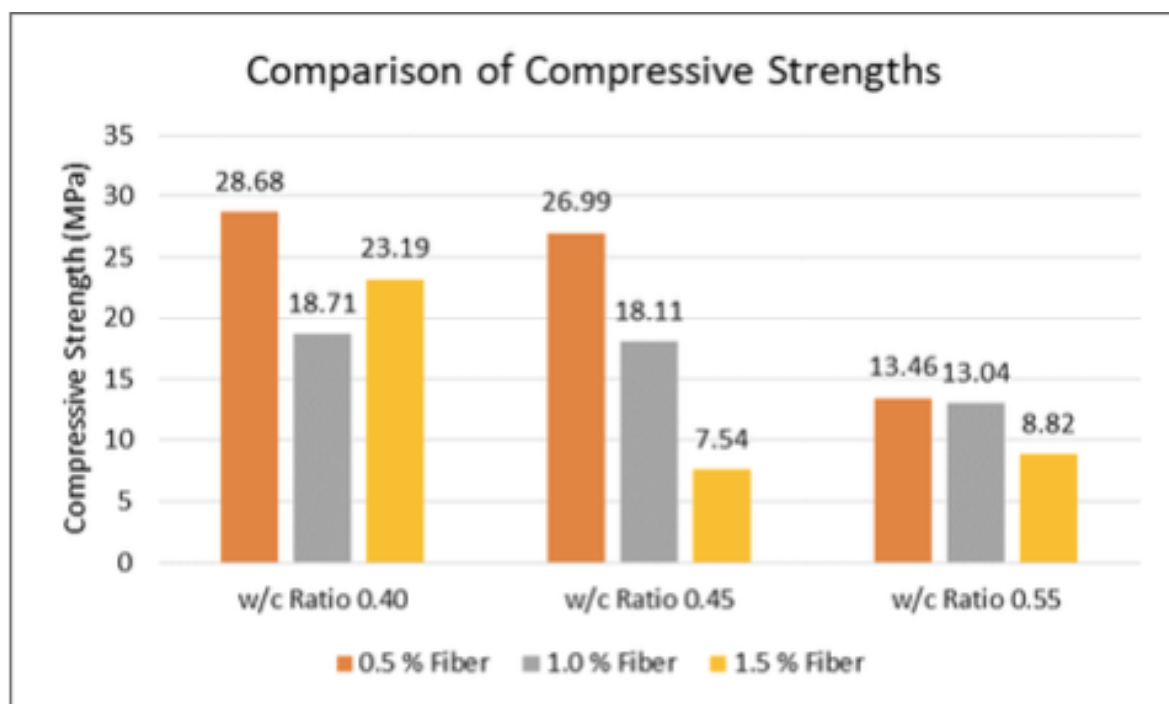
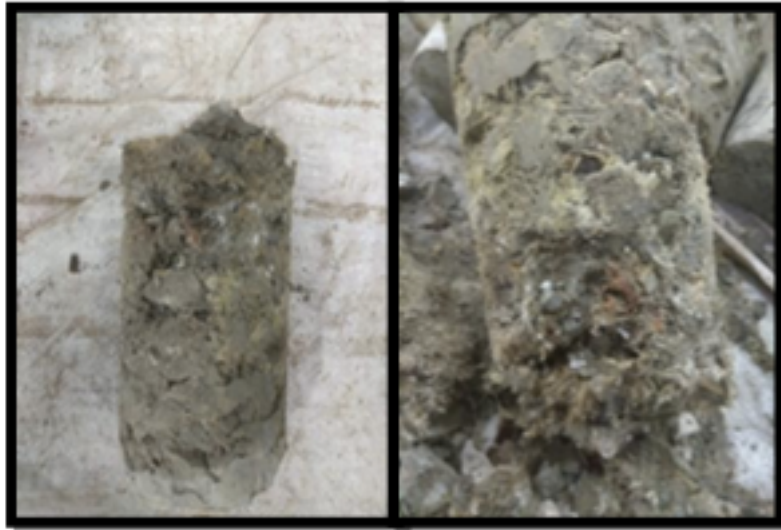


Figure 4.3 Comparison of compressive strengths



**Figure 4.4 Cone and split failure of cylinder**

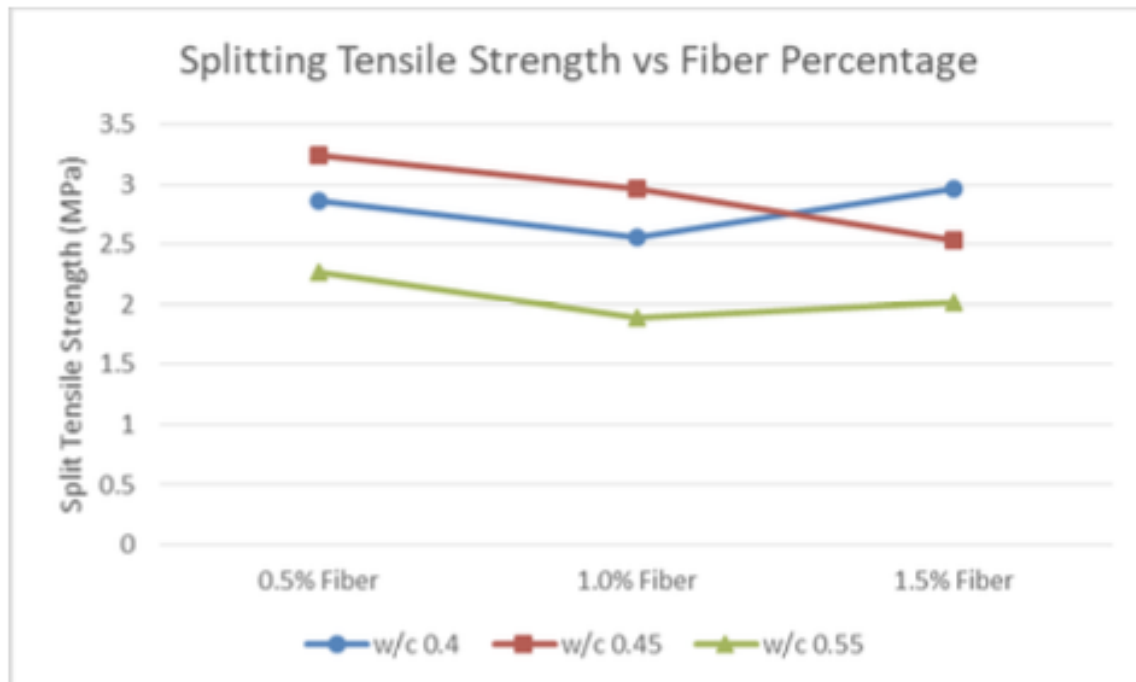
Observations: The results obtained from this experiment showed that the compressive strength decreased for higher fiber content. With the increment of w/c, strength tended to decrease. Crushing pattern of concrete under compression for various fiber contents did not vary. The fracture was similar kind of cone and split type. The optimum w/c and fiber percentage were found to be 0.4 and 0.5% where the compressive strength was 28.68 MPa.

#### **4.3. Split tensile strength test**

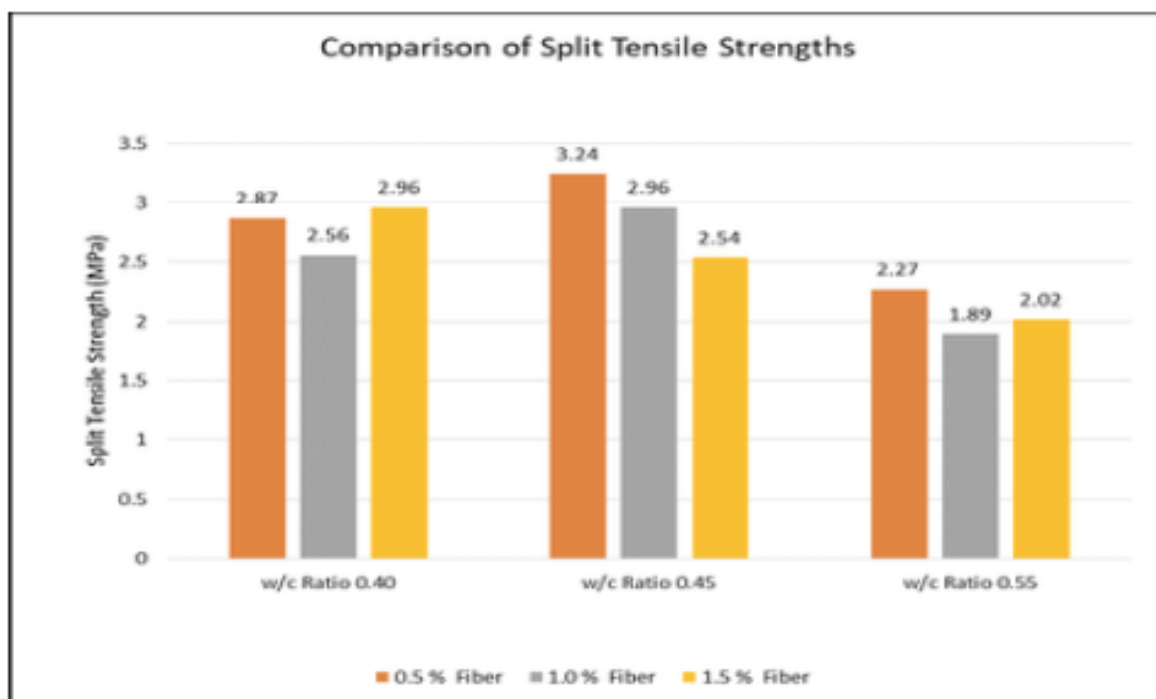
The results of the split tensile strength test of different type of specimens are given below:

**Table 4-2 Result of split tensile strengths**

W/C RATIO	FIBER PERCENTAGE	AVERAGE SPLIT TENSILE STRENGTH (MPA)
0.40	0.50	2.87
	1.0	2.56
	1.5	2.96
0.45	0.50	3.24
	1.0	2.96
	1.5	2.54
0.55	0.50	2.27
	1.0	1.89
	1.5	2.02



**Figure 4.5 Split tensile strength vs fiber percentage curve**



**Figure 4.6 Comparison of split tensile strengths**



**Figure 4.7 Columnar failure of cylinder**

**Observations:**

Reduction in splitting tensile strength with the increase of fiber percentage. An irregular change pattern is observed. With the change in w/c, split tensile strength did not follow the same pattern for various fiber contents. After applying tensile load, specimens split into two parts showing columnar fracture. Moreover, specimen with fiber content showed some resistance due to the pull out effect of fiber. The optimum w/c and fiber percentage were found to be 0.45 and 0.5% where the split tensile strength was 3.24 MPa.

**4.4. Flexural strength test**

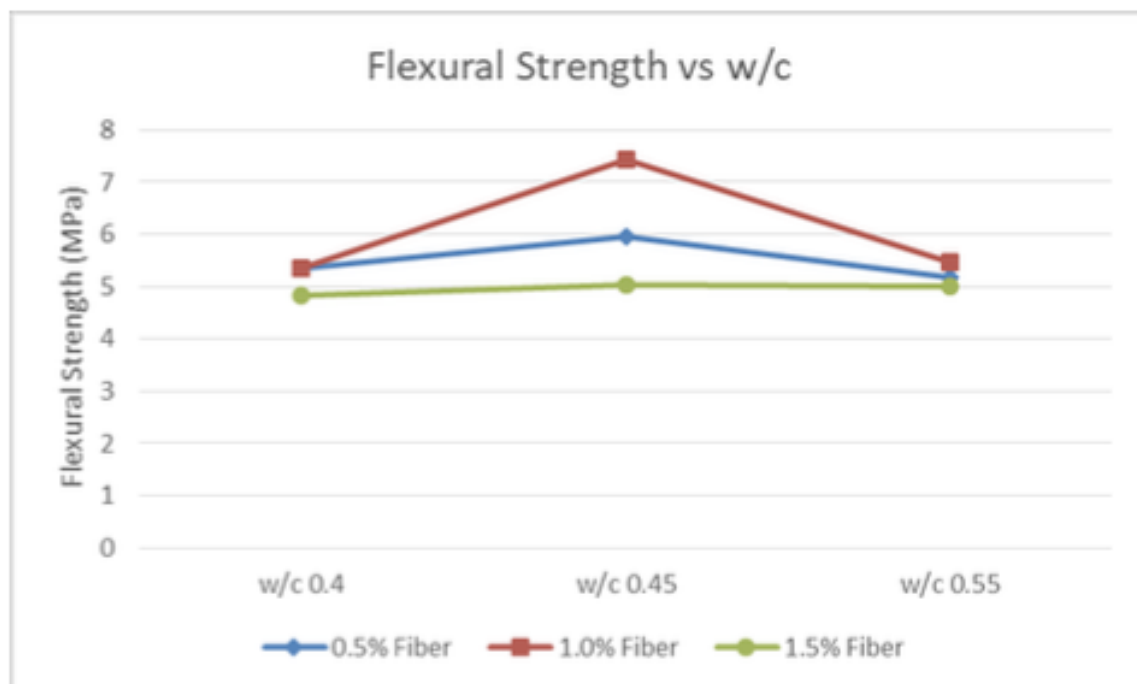
The results of the split tensile strength test of different type of specimens are given below:



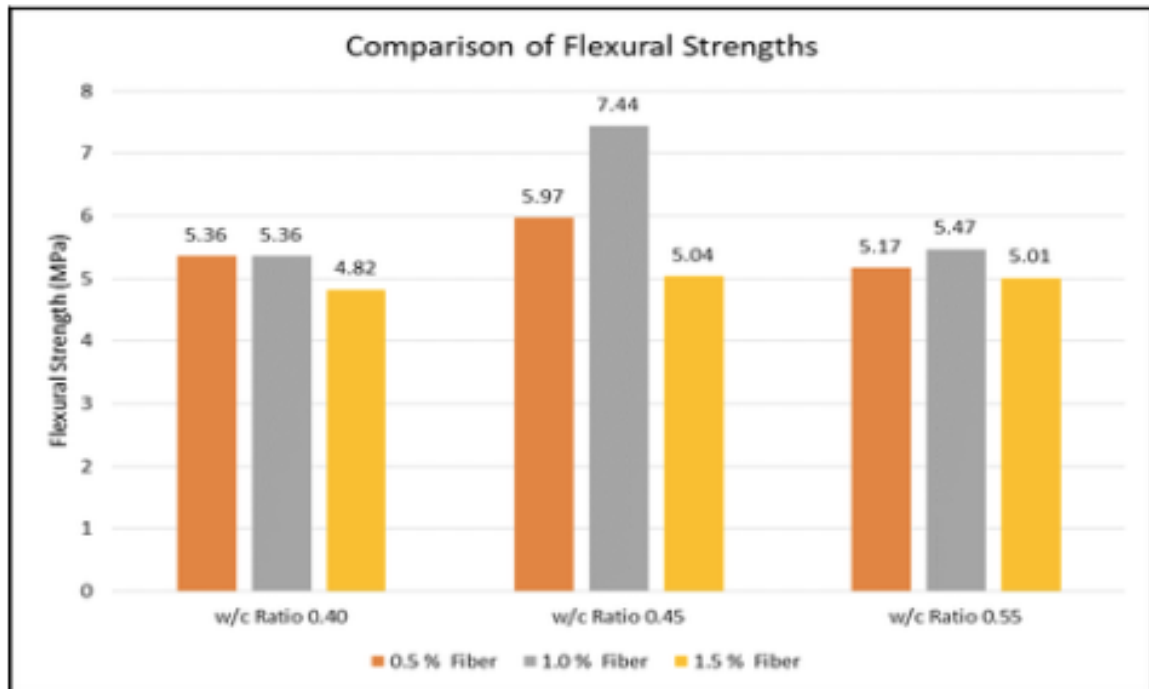
**Table 4-3 Result of Flexural strength tests**

W/C RATIO	FIBER PERCENTAGE	AVERAGE FLEXURAL STRENGTH (MPa)
0.40	0.50	5.36

0.45	1.0	5.36
	1.5	4.82
	0.50	5.97
0.55	1.0	7.44
	1.5	5.04
	0.50	5.17
0.55	1.0	5.47
	1.5	5.01
	0.50	5.17



**Figure 4.8 Flexural strength vs fiber percentage curve**



**Figure 4.9 Comparison of flexural strengths**



**Figure 4.10 Flexure failure of prism**

**Observations:**

For a fixed fiber percentage, the flexural strength at first increased but then decreased after 0.45 w/c. Under flexural test loading, specimens broke in tension on the convex tension surface of the concrete beam. Specimen with fiber content showed some resistance due to the pull out effect of fiber. The optimum w/c and fiber percentage were found to be 0.45 and 1.0% where the flexural strength was 7.44 MPa

## 5. CONCLUSIONS

In this study mechanical properties of JFRC was estimated by 3 parameter tests. The compressive, split tensile, and flexural strength test results of for different w/c (0.4, 0.45 & 0.55) and different fiber percentages (0.5%, 1.0% & 1.5 %) were compared to get the optimum dosage of fiber & w/c for different strengths. The results can be pointed out below:

(1) The incorporation of jute fiber as a constitutive material of concrete affects the rheological properties of the fresh concrete at different w/c. High fiber content in the concrete matrix reduces workability and unit weight.

(2) Significant increase in the compressive strength at lower fiber content. Maximum compressive strength is 28.68 MPa (w/c ratio 0.4 & fiber percentage 0.5%). Reduction in the compressive strength of concrete has been observed at higher fiber content.

(3) Significant increase in the splitting tensile strength at lower fiber content. Maximum splitting tensile strength is 3.24 MPa (w/c ratio 0.45 & fiber percentage 0.5%)

(4) Jute fiber significantly improves the flexural strength of concrete. Maximum flexural strength is 7.44 MPa (w/c ratio 0.45 & fiber percentage 1.0 %)

(5) The test results have shown that fiber content in the JFRC composite is an essential parameter that influences both the rheological and mechanical properties of concrete. Therefore, it is worth noting that fiber content along with other composite parameters has to be closely viewed in the study of JFRC.

These results support the previous outcomes of different studies (Zakaria et al. 2016, Pooja Warke and Shrinkhala Dewangan 2016; T. Sai Vijaya Krishna, B. Manoj Yadav 2016; Bal Gopal Guru, Sangeeta Swain, Swapna Seth, Madhusudan Sahu 2018) that inclusion of jute fiber at a sufficient dosage can enhance the mechanical properties of concrete.

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