Investigation on Mechanical Strength of Jute Fiber Reinforced Concrete (JFRC) Compared to Plain Concrete

S. Rahman, A. K. Azad

Abstract— In this study, jute fiber was used as fibrous material in concrete to improve the overall strength. Jute fiber of different lengths and percentages were selected. Three percentages of jute fibers were implemented here, such as 0.1%, 0.25% and 0.5% of the volume of plain concrete. Again, three lengths of jute fiber were selected such as 10 mm, 15 mm and 20 mm for each percentage to find out the best potential percentage along with length. All these were done to compare the compressive strength and split tensile strength of jute fiber reinforce concrete (JFRC) with plain concrete to find out the best results. Total 30 numbers of cube were prepared for compressive strength tests and 30 numbers of cylinder for split tensile strength tests. They were loaded in 7, 14 and 28 days respectively and the strengths were noted and compared with each other. The cube has shown maximum improvement over compressive strength for 0.25% jute fiber of 10 mm length. The compressive strength was increased by 22.51%, 29.56% and 26.15% for 7, 14, and 28 days respectively compared to plain concrete. The cylinder also has shown maximum enhancement over split tensile strength for 0.25% jute fiber of 10 mm length. The split tensile strength was increased by 14.09%, 26.23% and 25.48% for 7, 14, and 28 days respectively compared to plain concrete. Here, the improvement was little for 0.1% jute fiber compared to 0.25%. However, the strengths has been dramatically reduced for 0.5%.

Index Terms— Jute Fiber, JFRC, Concrete, Plain Concrete, Mechanical Strength, Compressive Strength, Split Tensile Strength

1 Introduction

Recent advancements and research in material technology has led to the development of special concretes such as polymer concrete for high durability, fiber reinforced concrete for preventing cracks in concrete, high and ultra-high strength concrete for applications in tall buildings and bridges, lightweight concrete for reducing foundation loads, and high performance concrete for special performance requirements [1].

To overcome the shortcomings of plain concrete (PC), the use of reinforcing fiber has been found very effective [2]. The fibers can insure the post-cracking resistance, high-energy absorption features and increased fatigue resistance of cement based composites [3]. Between two different types of fibers i.e., natural fibers and artificial polymer based fibers, natural fibers are promising to use as reinforcement to overcome the inherent deficiencies in FRCC reinforced with polymer-based fiber [4]. Natural fibers, which are biodegradable, inexpensive, environmental friendly, easy availability, are produced from naturally available resources for instance, coconut tree, banana tree, cotton, jute, etc. [5].

Bangladesh is one of the large jute producing country. Jute can be used as fiber with a number of advantages. Jute has high specific properties, low density, less abrasive behavior to the processing equipment, good dimensional stability and harmlessness. Jute textile is a low cost eco-friendly product, is abundantly available, easy to transport, and has moisture retention capacity. It is widely being used as a natural choice for plant mulching and rural road pavement construction. The biodegradable and low priced jute products merge with the soil after using providing nourishment to the soil. Being made of cellulose, on combustion, jute does not generate toxic gases.

2 Experimental Works

2.1 Materials Used

2.1.1 Cement

In casting of concrete, Ordinary Portland Cement (OPC) was used which was tested for specific gravity as shown in Table 1.

Table 1: Test on cement

Name of test	Code Followed	Found value
Specific gravity	ASTM C188-16 [6]	3.32

2.1.2 Coarse aggregate (CA)

Stone chips were used as coarse aggregate and the sizes were maintained 19mm downgrade. The conducted tests are given in Table 2 with the results.

Table 2. Tests on CA

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Name of tests	Code Followed	Found value
Specific gravity	ASTM C127-15 [7]	2.39
Absorption capacity	ASTM C127-15	1.5%
Dry rodded unit weight	ASTMC 29 - C 29M – 17 [8]	1484 kg/m^3
Gradation	ASTMC 33 - C 33M - 16e1	Fineness Modulus 4.3

2.1.3 Fine aggregate (FA)

Sylhet sand was used in the casting of concrete. Several tests were done on sand as given in the Table 3 with results.

Table 3. Tests on FA

Name of tests	Code Followed	Found value
Specific gravity	ASTM C128-15 [9]	1.64
Absorption capacity	ASTM C128-15	17.65%
Gradation	ASTM C778-13 [10]	Fineness Modulus 2.23

2.1.4 Jute Fiber

Jute was collected from Baharbag village of Magura district, Bangladesh. Jute fiber was made manually by chopping the jutes by 15, 20 and 25 mm lengths as required as shown in Fig. 1 and Fig. 2. The specific gravity of jute fiber was also tested and found as 1.03.

Fig. 1. Collected jutes

Fig. 2. Chopped jute fibers

2.2 Experimental Strategy

Concrete cube of 6″x6″ was elected for compressive strength test and concrete cylinder of 4″ diameter and 8″ height was selected for split tensile strength test. Concrete was casted for different percentages of jute fiber with each percentage having different length as given in Table 4.

Table 4. Jute fiber formation in concrete

Jute fiber percentages (%)	Length of jute fiber (mm)
0 %	-
0.1 %	10, 15, 20
0.25 %	10, 15, 20
0.5 %	10, 15, 20

2.3 Mix Design of Concrete

ACI mix design was carried out from the materials test results as given in Table 5 with results.

Table 5. Mix design

Name	Value
C: FA: CA	1: 1.24: 3.45
W/C	0.48

2.4 Casting and Curing

Total 30 cubes and 30 cylinders were casted as shown in Fig. 3 for compressive strength test and split tensile strength test respectively for 7, 14 and 28 days of curing period.

Fig. 3. Casting of concrete

2.5 Compressive and Split Tensile Strength Test

Universal Testing Machine (UTM) of capacity 1000 KN as shown in Fig. 4 was used for both compressive strength test conferring to ASTM C39-C39M-17 [11] and split tensile strength test conferring to ASTM C496-C496M-11 [12].

Fig. 4. Universal Testing Machine (UTM)

3 Result and Discussion

3.1 Compressive Strength Data

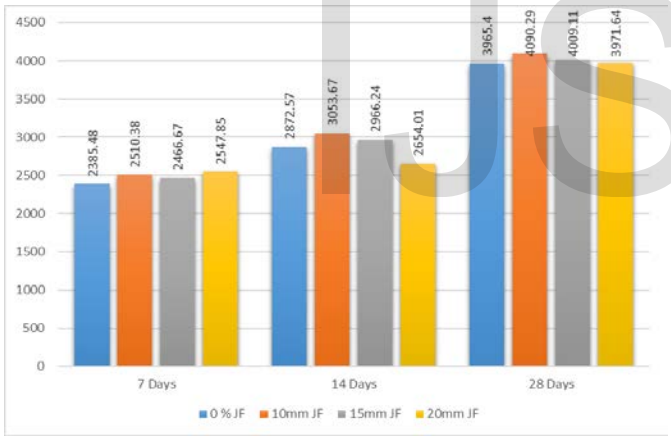

Fig. 5. Bar chart showing comparison between compressive strength for plain concrete and concrete with 0.1% jute fiber of 10, 15, 20 mm lengths with respect to age (days)

Fig. 5 shows that, compared to plain concrete in 7 days, the compressive strength for 10 mm jute fiber was increased by 5.23%, also improved by 3.40% for 15 mm and 6.81% for 20 mm being maximum. In 14 days, the compressive strength was increased by 6.30% for 10 mm being maximum, 3.26% for 15 mm but decreased by 7.61% for 20 mm. Finally, in 28 days, the compressive strength was increased slightly by 3.15% for 10 mm being maximum, 1.10% for 15mm, and 0.16% for 20 mm.

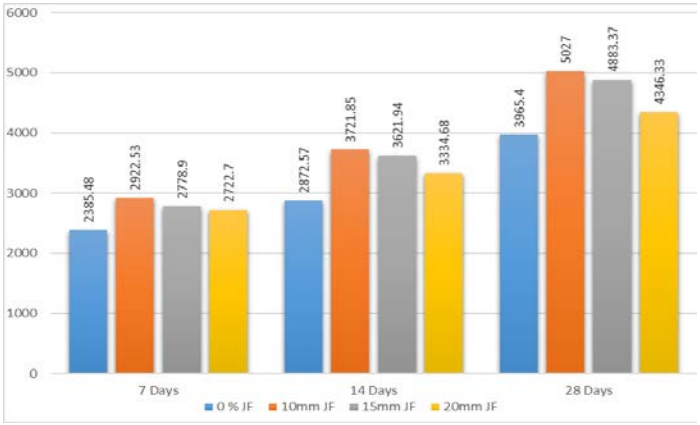

Fig. 6. Bar chart showing comparison between compressive strength for plain concrete and concrete with 0.25% jute fiber of 10, 15, 20 mm lengths with respect to age (days)

Fig. 6 shows that, compared to plain concrete in 7 days, the compressive strength for 10 mm jute fiber was increased by 22.51% being maximum, also improved by 16.49% for 15 mm and 14.14% for 20 mm. In 14 days, the compressive strength was increased by 29.56% for 10 mm being maximum, 26.09% for 15 mm and 16.09% for 20 mm. Finally, in 28 days, the compressive strength was also increased by 26.15% for 10 mm being maximum, 23.15% for 15mm, and 9.61% for 20 mm. Here, for 10 mm jute fiber the compressive strengths were maximum in all ages.

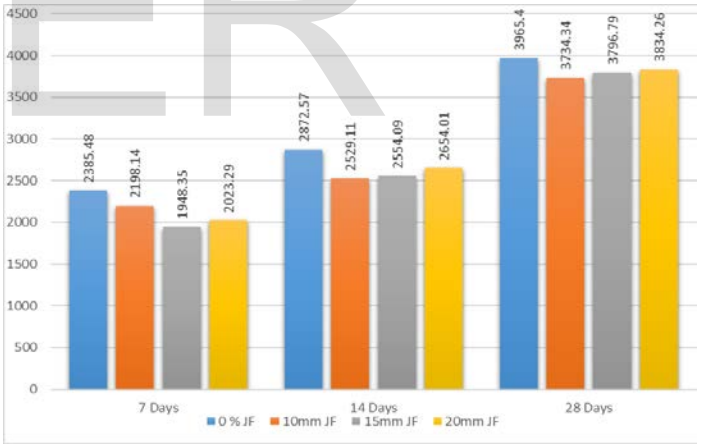

Fig. 7. Bar chart showing comparison between compressive strength for plain concrete and concrete with 0.5% jute fiber of 10, 15, 20 mm lengths with respect to age (days)

Fig. 7 shows that, compared to plain concrete in 7 days, the compressive strength for 10 mm jute fiber was decreased by 7.85% being minimum, also reduced by 18.32% for 15 mm and 15.18% for 20 mm. In 14 days, the compressive strength was decreased by 11.96% for 10 mm, 11.09% for 15 mm and 7.61% for 20 mm being minimum. Finally, in 28 days, the compressive strength was also decreased by 5.83% for 10 mm, 4.25% for 15mm and 3.31% for 20 mm being minimum.

3.2 Split Tensile Strength Data

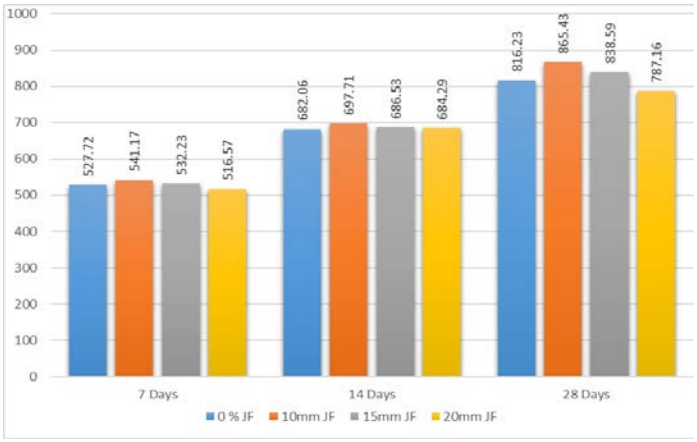

Fig. 8. Bar chart showing comparison between split tensile strength for plain concrete and concrete with 0.1% jute fiber of 10, 15, 20 mm lengths with respect to age (days)

Fig. 8 shows that, compared to plain concrete in 7 days, the split tensile strength for 10 mm jute fiber was increased by 2.64% being maximum, also improved by 0.94% for 15 mm, but decreased by 2.03% for 20 mm. In 14 days, the split tensile strength was increased slightly by 2.30% for 10 mm being maximum, 0.66% for 15 mm and 0.33% for 20 mm. Finally, in 28 days, the split tensile strength was increased by 6.03% for 10 mm being maximum, 2.74% for 15mm, but decreased by 3.57% for 20 mm.

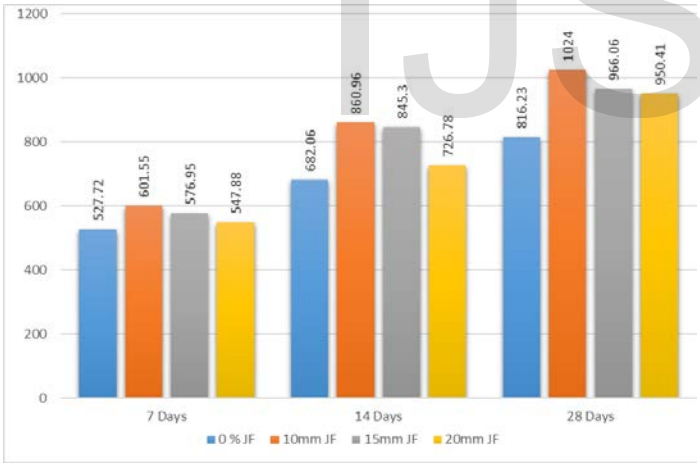

Fig. 9. Bar chart showing comparison between split tensile strength for plain concrete and concrete with 0.25% jute fiber of 10, 15, 20 mm lengths with respect to age (days)

Fig. 9 shows that, compared to plain concrete in 7 days, the split tensile strength for 10 mm jute fiber was increased by 14.09% being maximum, also improved by 9.42% for 15 mm and 3.91% for 20 mm. In 14 days, the split tensile strength was increased by 26.23% for 10 mm being maximum, 23.93% for 15 mm and 6.56% for 20 mm. Finally, in 28 days, the split tensile strength was increased by 25.48% for 10 mm being maximum, 18.36% for 15mm and 16.44% for 20 mm. Here the split tensile strength for 10 mm was increased by maximum in all ages.

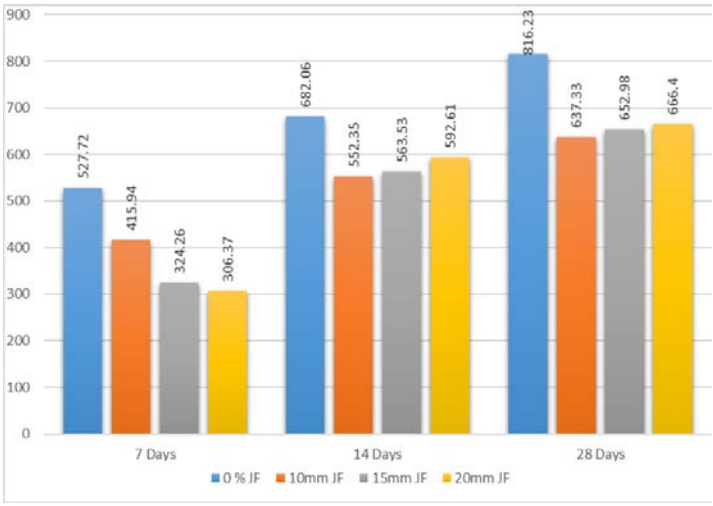

Fig. 10. Bar chart showing comparison between split tensile strength for plain concrete and concrete with 0.5% jute fiber of 10, 15, 20 mm lengths with respect to age (days)

Fig. 10 shows that, compared to plain concrete in 7 days, the split tensile strength for 10 mm jute fiber was decreased by 21.11% being minimum, also reduced by 38.50% for 15 mm and 41.90% for 20 mm being minimum. In 14 days, the split tensile strength was decreased by 19.02% for 10 mm, 17.38% for 15 mm and 13.11% for 20 mm being minimum. Finally, in 28 days, the split tensile strength was decreased by 21.92% for 10 mm, 20% for 15mm and 18.36% for 20 mm being minimum.

4 Conclusion

From the data analysis, the following findings can be seen on compressive strength and split tensile strength.

Compressive Strength

- For 0.1% jute fiber, the compressive strength was improved compared to plain concrete for all lengths in all days except in 14 days for 20 mm length of jute fiber. The improvement was in between 0.16% and 6.81%.
- For 0.25% jute fiber, the compressive strength has shown better performance in all days and lengths compared to plain concrete specimen. The improvement was about 9.61% to 29.56%.
- For 0.5% jute fiber, the compressive strength was reduced for all lengths in all days compared to plain concrete.
- Overall, the most improved compressive strength was found for 0.25% jute fiber of 10 mm length. The strength was increased by 22.51%, 29.56% and 26.15% for 7, 14, and 28 days respectively compared to plain concrete.

Split Tensile Strength

- For 0.1% jute fiber, the split tensile strength was improved compared to plain concrete for all lengths in all days except in 7 and 28 days for 20 mm length of jute fiber. The improvement was within 0.33% and 6.03%.
- For 0.25% jute fiber, the split tensile strength has shown enhancement in all days and lengths compared to plain concrete specimen. The improvement was about 3.91% to 26.23%.
- For 0.5% jute fiber, the split tensile strength was decreased for all lengths in all days compared to plain concrete.
- Overall, the most improved split tensile strength was found for 0.25% jute fiber of 10 mm length. The strength was increased by 14.09%, 26.23% and 25.48% for 7, 14, and 28 days respectively compared to plain concrete

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