

1 Research Article

2 Mechanical Performance of Fiber-Reinforced Bendable 3 Concrete Incorporating Coir and Jute Fibers

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8 Abstract

9 The aim of this research was to improve the flexural strength and crack resistance of con-
10 crete using waste material fibers such as coir and jute. Coir and jute fibers were added as
11 an environmentally friendly alternative which can increase the crack resistance, tensile
12 and flexural behavior of concrete. Jute and coir fibers were incorporated at the dosage of
13 3% of the total binder volume while fly ash was substituted at 30% of total cement content
14 to reduce shrinkage in order to provide consistent readings which were only affected by
15 the addition of fibers. According to the findings, the tensile and flexural strength were
16 improved by an average of approximately 10% and compressive strength was improved
17 by a slight margin of 2%.

18 **Keywords:** Fiber-reinforced Concrete; Bendable Concrete; Coir Fibers; Jute Fiber; Fly Ash;
19 Tensile Test; Flexure Test.

20 1. Introduction

21 Concrete remains the backbone of construction industry; its versatility and ease of
22 placement has made it an essential part of building materials that cannot be ignored. Con-
23 crete is strong in compression and weak in tension, which causes brittle failure and small
24 cracks whenever tensile abilities are tested. "Modern approaches have targeted concrete
25 large tensile strains and distributed microcracking by combining tailored cementitious
26 materials with crack-controlling fibers, demonstrating strain-hardening behavior and
greatly improved post-crack ductility compared with ordinary or conventional fiber-rein-
forced concrete." [1]

27 Coir and jute fibers are easily available; with sustainable resources it makes this pro-
28 ject easier in application. These fibers have strong abilities in tension and can also boost
29 tensile abilities of concrete, as concrete is generally weaker in tensile strength. [2]

30 Concrete usually follows the same blueprint that has existed for many decades, the
31 prolonged reliance on the same constituents has played a major role in increasing the
32 overall carbon emission footprint. Considering this trend we have carefully examined and
33 put together a project that will benefit the industry.

34 Fly ash with cement replacement and addition of jute fibers have given us adequate
35 strength to increase tension abilities while also subjugating the compressive strength of
36 concrete.
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39 Partial replacement of Portland cement with fly ash provides both environmental
40 benefits (reduced CO₂ footprint) and often also increases strength of concrete.[3]

41 Our work explores the enhancement of concrete in both tension and flexure while
42 addition of fly ash will be reducing carbon footprint created during production of the
43 cement which is expected to increase even more till 2050.[4]

44 2. Literature Review

45 It is evident that the low tensile strain capacity of traditional concrete is a major lim-
46 itation, as it typically fractures with almost no warning because of brittleness. while, bend-
47 able concrete is reported to achieve higher strain capacities, allowing it to bend and sus-
48 tain load even after cracking. The reviewed papers collectively emphasize that this en-
49 hanced behavior comes from the material's ability to form numerous fine micro-cracks
50 rather than one dominant crack. This controlled cracking behavior is the main reason on
51 which bendable concrete retains strength and integrity under tension or bending. The
52 findings across the referenced studies also show that the incorporation of suitable fibers
53 is central to achieving this ductile response, demonstrating that bendable concrete is not
54 simply a stronger version of concrete, but a fundamentally different composite engineered
55 for flexibility and durability.[5], [6]

56 2.1. Composition and Reinforcement Mechanism

57 The performance of bendable concrete results from a matrix design that relies heavily
58 on micro-synthetic and natural fibers. The cementitious matrix often incorporates fine ag-
59 gregates and additives like fly ash. The composite typically includes fibers such as Poly-
60 vinyl Alcohol (PVA) or natural fibers like jute and coir (coconut)[7]. The main function of
61 adding these fibers is to improve the tensile properties and improve crack resilience of the
62 concrete [6]. The fibers act as crack arresters[8]. When ECC is subjected to tensile or flex-
63 ural stress, it exhibits multiple-cracking behavior and strain-hardening [9].The fibers
64 bridge the cracks, leading to the formation of many fine, distributed micro-cracks instead
65 of a single major fracture. This mechanism limits the crack width to a very small size, often
66 less than 100 µm [8]. This controlled cracking pattern is what allows the material to con-
67 tinue bearing load and achieve flexible properties.

68 2.2. Research Gap

69 Previous research only tested small amounts of natural fibers (usually less than 2%).
70 There is very little information on what happens when we use a higher dosage of fibers
71 (3%) combined with a large amount of Fly Ash (30%). This study fills that gap by testing
72 this specific combination to see if it can produce a truly bendable, crack-resistant concrete
73 that reduces the need for expensive steel reinforcement.

74 3. Materials

75 3.1. Jute Fiber

76 Jute fiber is a natural and biodegradable fiber that is derived from the plant known
77 as *Corchorus capsularis*. Because of its sustainability and good ductile properties, it be-
78 comes a very good option to be used in concrete structures to enhance their tension bear-
79 ing capacity[10]. The length of the fiber used in this research is 2 to 3 cm.

80 3.2. Coir Fibers

81 Coir Fiber or coconut fiber is another sustainable fiber that is extracted from the co-
82 conut and incorporated into the concrete mix to enhance their tensile properties. It has
83 some very good elastic properties that can be a very reliable option in freeze and thaw
84 conditions where high tensile strength is required. Like that of jute fiber it also has good

ductile and insulation properties that can play a vital role in enhancing the tensile strength of the concrete[10]. The length of the fiber used in this research is 2 to 3 cm.

3.3. Fly Ash

Fly ash is a byproduct from the combustion of coal in the power plant that is powered by the coal. The fly ash acts as pozzolanic material. During the hydration process calcium hydroxide is released. The fly ash reacts with the released COH and creates Calcium Silicate Hydrate gel that helps in contributing toward the strength and durability of the concrete mix[11]. It creates a "ball bearing effect" in the fresh concrete mix that increase the workability of the concrete, reducing the water content required for the slump.[12]

3.4. Cement

Conventional Portland cement is used that acts as main binding agent for the making of the concrete specimens. It reacts with the other admixtures to make a more hardened concrete matrix.

3.5. Fine Aggregate

The fine aggregate consists of the fine particles that can pass through the 4.75 mm sieve according to the standard specifications. (ASTM C125)

4. Methodology

The research aims for the development of Bendable Concrete that can have an increased tensile strength compared to conventional concrete.

4.1. Selection of Fibers

The two main fibers that we selected for their incorporation in the mix were jute fiber and coir fiber. Cost effectiveness, availability and sustainability were the main factors that governed fiber selection.

4.2. Making of Concrete Mix

The mix ratio used is 1:0.5 (cement: sand). Fly ash was 30% of the cement weight. This mix has the maximum compressive, flexure and tensile strength[13]. In addition to this the fibers were added as 3% of the total volume of the sample.

4.3. Making of Jute Fiber

A jute tangled rope was bought from the local market that can serve as a raw material for the formation of jute fiber. The rope has three thin jute ropes tangled to each other.



Figure 1. Tangled jute rope



Figure 2. Untangled jute rope

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The thin tangled ropes were untangled into separate jute ropes by untangling the jute rope into various sections. The various sections were then tied into bundles in order to make sure they do not tangle back again.



Figure 3. Single jute rope



Figure 4. Rope cut into jute fibers

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The separate jute ropes were dipped into water for 2 to 3 hours to make them softer so that they can be cut easily according to our desired length. Then the soaked jute rope was cut into small fibers of 2 to 3 cm. Then the fibers were again dipped into the water for 8 hours, so they do not agglomerate while mixing with the concrete.



Figure 5. Jute fibers soaked in water



Figure 6. Rope cut into jute fibers

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All the fibers were laid openly for 5 to 6 hours for drying.

4.4 Making of Coir Fiber



Figure 7. Coconut waste



Figure 8. Coconut waste dipped in water

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The coconut waste was soaked into the water for 24 hours to make sure the fibers were easily separable



Figure 9. Drained waste for separation



Figure 10. Separated coir fiber

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The fibers were then untangled and separated into the single fiber after which they were cut into the desired length of 2 to 3 cm. Then they were laid in similar fashion to that of jute fiber for drying in order to avoid agglomeration.

4.5. Sample Casting

Three types of samples were cast that are controlled, jute fiber and coir fiber sample. Mix Ratio for the controlled samples was 1:0.5 (cement: sand). Mix Ratio for Jute & Coir Fiber sample was 1:0.5. Fly ash was 30% of the total cementitious content. Fibers were 3% of the total cementitious content. Water to Cement Ratio in both the samples was 0.45.

Table 1. Mix Ratios

Batch Type	Sample Type	Dimensions (Inches)	Quantity per Batch	Cement (kg)	Sand (kg)	Fly Ash (kg)
Controlled Samples	Beam	30"x 6"x 3"	3	27.51	21.9	11.79
	Cylinder	4" (dia) x 8"	3	4.95	4.05	2.25
Jute Fiber Samples	Beam	30"x 6"x 3"	3	27.51	21.9	11.79
	Cylinder	4" (dia) x 8"	3	4.95	4.05	2.25
Coir Fiber Samples	Beam	30"x 6"x 3"	3	27.51	21.9	11.79
	Cylinder	4" (dia) x 8"	3	4.95	4.05	2.25

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The Coir and Jute fibers were added at 3% of the total cementitious content.

4.6. Testing of the Samples

The specimens were subjected to the compressive, flexure and tensile test. The beams were evaluated through flexure testing and supplementary the cylinder was tested under both compression and tensile loading test. The results were gathered and thoroughly analyzed via different data analyzing techniques that helped in drawing out some constructive findings.

5. Results

5.1. Comparison of Mechanical Properties.

A comparative analysis of the mechanical properties of the fiber reinforced concrete was studied against the control mix. All samples were tested after a curing period of 28 days.

Table 2. Strength comparison table

Mix Type	Compressive Strength (MPa)	Split Tensile Strength (MPa)	Flexural Strength (MPa)
Control	32.53	2.91	4.77
Coir (3%)	33.12	3.34	5.39
Jute (3%)	33.45	3.08	5.16

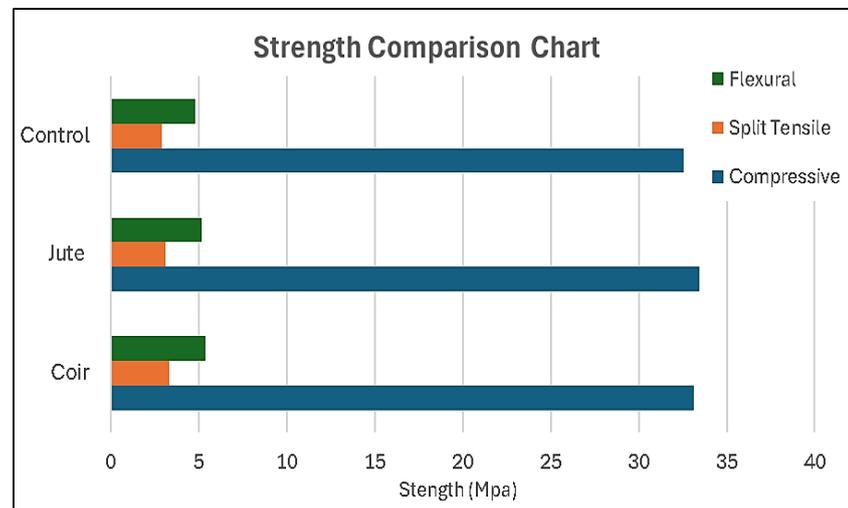


Figure 11. Graphical comparison of strengths.

5.2. Compressive strength

The coir fiber specimens had a small gain of 1.81 % and the Jute fiber specimens had an increase of 2.83% in comparison with the control specimens. Even though natural fibers are credited mainly with affecting tensile and flexural behavior of concrete, they also increased the compressive strength by a small margin.

5.3. Split tensile strength

The addition of 3% Coir fibers increased the tensile strength by 14.78% compared to the control specimens while the addition of 3% of Jute fibers had an increase of 5.84%. This demonstrates that coir fibers contributed more effectively to tensile capacity through enhanced crack-bridging action.

5.4. Flexural strength

The flexural strength of coir fiber specimens increased by 12.99% as compared to the jute fiber specimens which increased by 8.18% in comparison with the control specimens. Coir fibers have higher ductility and elasticity, which increases the energy absorption and slows crack propagation, resulting in a more ductile failure mode and higher post-peak load-carrying capacity than the brittle failure of the control specimens as well as the experimental conclusions that can be drawn.

6. Discussion

Experimental research shows that the incorporation of natural fibers that are jute and coir together with a partial replacement of cement with fly ash improves the mechanical properties of concrete without reducing the compressive strength. The same observations can be attributed to the general aim of creating a composite which demonstrates greater ductility and better crack-resistance.

The slight increase in compressive strength in both fiber-reinforced mixes signifies that the dosage of the fibers used did not produce significant voids in the cementitious matrix. The compressive strength has been slightly higher in the jute-fiber mix may indicate a more favorable fiber-matrix interfacial contact, but the pozzolanic effect of fly ash helped increase the further densification of the matrix.

The split-tensile strength was significantly enhanced and especially with the coir-fiber mix. This improvement may be explained by the fact that coir fibers have more elongation capacity and are inherently elastic, and this is likely to increase the crack-bridging capacity and postpone the onset and propagation of fractures. There was also an increase in tensile strength of the jute-fiber mix, but it could not be used effectively under tensile loading conditions due to its relatively lower ductility.

The results of flexural strength tests were on the same path as the load-bearing capacity and enhanced post-crack behavior were enhanced by both fiber types. The high energy absorption capacity and the shift of the failure modes of coir-fiber concrete to the ductile mode instead of the brittle one is evident in the superior performance of the material in flexural loading. Although quite useful, jute fibers gave a relatively low crack widening resistance.

These results finally confirm the idea that natural fiber reinforcing (especially coir) and fly ash replacement provide an effective and sustainable method of strengthening tensile and flexural properties of concrete. The findings support the future use of coir fiber reinforced concrete in structural and nonstructural components where crack control and ductility are a priority

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