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Effects of Jute Fiber Length and Dosage on the Workability and Fresh Density of Concrete: An Experimental Investigation

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Abstract:
Background:
Jute fiber can alter concrete placement behavior, but reduced fresh density alone does not demonstrate lightweight concrete. This study examined the effects of jute fiber length and dosage on slump and fresh density.
Materials and Methods:
Concrete mixtures were prepared using volumetric mix proportions of 1:1.5:3 and 1:2:4, incorporating jute fibers of three lengths (10, 15, and 20 mm) at four contents (0, 0.25, 0.50, and 1.00% by weight of cement). Three w/c ratios (0.45, 0.50, and 0.55) were investigated. Workability and fresh-density tests were carried out to evaluate the workability and unit weight of the jute-fiber-modified concrete (JFC). The mix proportions of 1:1.5:3 with w/c ratio of 0.55 were chosen for fresh-density testing based on the slump test results.
Results:
Results of the experiments showed that the workability reduced gradually as the jute-fiber length and content increased. An increase in w/c ratio from 0.45 to 0.55 resulted in a decrease in slump while an increase in the mix proportion from 1:1.5:3 to 1:2:4 resulted in an increase in slump. Similarly, for fiber length and content, the fresh density decreased as length increased. The maximum decrease in fresh density was at 20 mm fiber length and 1.00% fiber content and was 2.23% from the control concrete.
Conclusion:
The use of jute fibers decreased the workability and fresh density of the concrete, and the amount of decrease increased with the increase of the fiber length and fiber content. Under the tested conditions, the mix proportion of 1:1.5:3 and w/c ratio of 0.55 gave comparatively good workability, and when 20 mm jute fibres were added at 1.00% content, the workability was found to be the lowest due to fresh density. The results are experimental evidence that has been used to select the parameters for jute-fiber to obtain the desired fresh properties of concrete.
Key Words: *Jute fiber; fiber-modified concrete; workability; slump; fresh density; water-to-cement ratio.*

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I. Introduction

Concrete is the backbone of the modern infrastructure because of its abundance, durability and economy (Neville, 2011; Yang et al., 2011). But, its fragility and low tensile characteristics make it challenging for structural performance. To overcome these drawbacks, researchers in the concrete field have focused on adding fibers in concrete which enhances its ductility, crack resistance and tensile strength for the last few decades (Mohammadi et at., 2008; Yazici et al., 2007). Various types of fibres are available, such as industrial by-products (polyvinyl alcohol, polyvinyl chloride, polyethylene terephthalate, and nylon) and natural by-products (kenaf, hemp, coir fiber and sisal). The following are some of the applications of these fibers in concrete construction where they have been incorporated: tunnel lining, blast-resistant concrete, concrete overlay, high-strength concrete, high-performance concrete, pozzolanic concrete and even rigid pavements (Islam et al., 2023; Kaliyavaradhan and Ling, 2019; Kanda and Li, 1998; Meena et al., 2022).

In this list, Natural Fiber is receiving special attention from the researchers; among these, jute fiber is getting more popularity as it is environmentally friendly, low cost and regionally available, especially in South Asian countries; in particular, jute fiber is available in Bangladesh. Jute fiber (JF) is one of the natural fibers which

can be obtained from the Corchorus plant, is biodegradable, recyclable, renewable, and widely cultivated. About 3.1534 million tons of jute fibre is being produced all over the world, out of which nearly 1.533 million tons is produced in Bangladesh after peeling. Bangladesh is the second largest jute producer in the world (FAO, 2024), but the primary applications of jute are in the production of bags, textiles, home decoration, agriculture and packaging.

The use of jute in construction is not new concept but concrete is rarely used with jute because of the lack of knowledge regarding it. Aziz et al. (1981) stated that jute fiber possesses good tensile strength, moderate elasticity and high-water absorption property which would make it worthy of use as a reinforcement material in concrete. However, fresh properties of the concrete, especially workability are very important in guaranteeing proper mixing, transporting, placing and finishing the concrete before it sets. The presence of jute fiber in concrete decreases the fluidity of concrete, because of the high water absorption capacity, rough surface, and increase in the surface area of fiber in the concrete (Ahmad et al., 2022; Vajje and Murthy, 2013). Islam et al. (2018) showed that the workability of the concrete reduces as the length of JF increases. Moreover, increasing the amount of jute fiber (by weight of cement) reduces the fresh density of concrete (Hossain et al., 2023; Mohammadi et al., 2008). Thus, the type, length, shape, form and surface of the fibers could affect the fresh properties of concrete (Aziz et al., 1981).

Although many studies (Ahmad et al., 2022; Aziz et al., 1981; Islam et al., 2023; Jarabo et al., 2012; Khan et al., 2023; Vajje and Murthy, 2013) have explored the properties of concrete with jute fiber, comparatively limited research has examined its fresh properties in combination with varying fiber lengths, mix proportions, and water-to-cement ratios. There is also a significant research gap related to a proper mix design that balances fresh properties and the lightweight nature of concrete incorporating jute fiber. To minimize these gaps, this study aims to contribute to the development of a mix that achieves this balance. Therefore, the study focuses on the effect of JF on the fresh properties (workability and unit weight) of concrete.

II. Materials And Methods

(i) Constituent materials

Locally available tossa jute fiber was used with ordinary Portland cement (OPC) supplied locally. Coarse aggregate was crushed gravel from Sylhet, Bangladesh, passing a 19 mm sieve. Fine aggregate was river sand obtained from the same supplier. Laboratory drinking water was used for mixing. Material properties reported in the source manuscript are retained in Table 1.

(ii) Material characterization and verification

Table 1 preserves the reported measurements and comparison entries. Its reported methods and benchmark values require confirmation against laboratory records. In particular, the 28-day cement mortar strength is blank, and the table alone does not establish ASTM Type I cement compliance. The reported cement unit weight of 1440 kg/m³ must be distinguished from particle density measured using ASTM C188. The applicability and adaptations of plastics standards to jute fiber also need explanation.

Table 1. Properties of materials.

Materials	Properties		Test standard	CA		FA		JF		OPC	
				Present study	Hossain et al. (2021)	Present study	Hossain et al. (2021)	Present study	Chanu et al. (2024)	Present study	ASTM C150 (2022)
Aggregates	Fineness modulus (FM)		ASTM C136 (2001)	7.33	-	3.04	-	-	-	-	-
	Unit weight (kg/m^3)		ASTM C29 (1997)	1563	1672	1611	1564	-	-	-	-
	Specific gravity (dry)		ASTM C127/128 (2001)	2.65	2.72	2.4	2.36	-	-	-	-
	Water absorption (%)		ASTM C127/128 (2001)	0.66	1.18	3.35	1.62	-	-	-	-
	Moisture content (%)		ASTM C566 (2013)	1.63	1.79	2.55	1.3	-	-	-	-
Cement	Normal consistency (%)		ASTM C187 (1998)	-	-	-	-	-	-	27	30%
	Setting time (min)	initial	ASTM C191(2021)	-	-	-	-	-	-	150	>45
		final	ASTM C191(2021)	-	-	-	-	-	-	300	<375
	Compressive strength (MPa)	7d	ASTM C109 (2016a)	-	-	-	-	-	-	25.24	>19.3
		28d	ASTM C109 (2016a)	-	-	-	-	-	-		>26.9
	Unit weight (kg/m^3)		ASTM C188 (2017)	-	-	-	-	-	-	1440	1440
Jute fiber	Bulk density (kg/m^3)		ASTM D1895 (2010)	-	-	-	-	1300	1500	-	-
	Specific gravity (dry)		ASTM D792 (2008)	-	-	-	-	1.5	1.5	-	-
	Water absorption (%)		ASTM D570 (1998)	-	-	-	-	302.7	-	-	-

CA = coarse aggregate; FA = fine aggregate; JF = jute fiber; OPC = ordinary Portland cement. Original cell contents, merged structure and blank entries are retained; a blank is not a zero. Comparison columns and standard labels are retained for traceability and are not endorsements of compliance.

(iii) Mixture proportions and batching

The nominal OPC: FA:CA proportions were 1:1.5:3 and 1:2:4 by volume, with water-to-cement ratios of 0.45, 0.50 and 0.55 by mass. Fiber lengths were 10, 15 and 20 mm, and nonzero dosages were 0.25, 0.50 and 1.00% by cement mass. JFC0 denotes the fiber-free control; JFC0.25, JFC0.50 and JFC1.0 denote increasing fiber dosage. Table 2 retains the source mixture quantities, described there as quantities for one cubic meter. These quantities are nominal until the batching conversion and actual yield are verified.

A drum-type mixer was used. Fiber was added to the mixtures rather than explicitly identified as a replacement for cement or aggregate. The source does not report the addition sequence, mixing time, batch capacity, fiber dispersion assessment or use of admixtures. Their absence from the report must not be interpreted as confirmation that a particular procedure was followed.

(iv) Experimental matrix and replication

The stated factor levels imply 60 distinct slump conditions if the full matrix was completed: two mix proportions × three water-to-cement ratios × (one fiber-free control + three lengths × three nonzero dosages). Fiber length is not a meaningful factor for the zero-fiber control. Density testing was restricted to the 1:1.5:3 mixture at w/c 0.55, implying ten conditions if all lengths and nonzero dosages were tested. These counts are reconstructed design conditions, not confirmed batch or replicate counts.

(v) Slump measurement

The source cites ASTM C143 (2020). It reports a cone with bottom diameter 200 mm, top diameter 100 mm and height 300 mm; filling in three equal layers; 25 strokes per layer using a 16 mm rod; and vertical mold removal in 5 ± 2 s. These details are retained as reported. The source describes measuring to the highest point of the slumped concrete; this requires correction or disclosure because the reference is the displaced original center of the specimen top surface (ASTM C143/C143M-20; ACI, n.d.-b). The description of equal layers must also be confirmed as equal volume rather than equal depth.

(vi) Fresh density measurement

Fresh density was measured only at a 1:1.5:3 proportion and w/c 0.55 after comparison of slump results. The source cites ASTM C138 (2008), describes 100 × 200 mm cylindrical molds filled in two or three equal layers, and reports 25 strokes per layer with a 16 mm rod. After consolidation and leveling, the filled container was weighed. Fresh density was calculated as $\rho = (M_{filled} - M_{empty})/V$, where the two masses are in kg and calibrated container volume V is in m^3.

The described mold and ambiguous layer count do not establish compliance with ASTM C138/C138M-08. The mold dimensions imply a nominal volume of about 1.57 L if they are internal diameter and height; that calculated value is not a calibration result. The suitability and required capacity of the measure must be checked against aggregate size and the cited edition. Container calibration, tare and filled masses, consolidation method, balance resolution and actual layer count were not supplied.

Table 2 Nominal mixture quantities fiber

Mix designation	Mix proportions: 1:1.5:3 (by volume)							Mix proportions: 1:2:4 (by volume)						
	CA (kg)	FA (kg)	OPC (kg)	JF (kg)	Water (kg)			CA (kg)	FA (kg)	OPC (kg)	JF (kg)	Water (kg)		
					w/c = 0.45	w/c = 0.50	w/c = 0.55					w/c = 0.45	w/c = 0.50	w/c = 0.55
JFC0 (control)	1270.64	659.05	392.73	0.00	176.73	196.36	216.00	1331.14	690.43	308.57	0.00	138.86	154.29	169.71
JFC0.25	1270.64	659.05	392.73	0.98	176.73	196.36	216.00	1331.14	690.43	308.57	0.77	138.86	154.29	169.71
JFC0.50	1270.64	659.05	392.73	1.96	176.73	196.36	216.00	1331.14	690.43	308.57	1.54	138.86	154.29	169.71
JFC1.0	1270.64	659.05	392.73	3.93	176.73	196.36	216.00	1331.14	690.43	308.57	3.09	138.86	154.29	169.71

Original table contents and merged structure retained. Quantities are stated by the source as kg per one cubic meter; actual yield and moisture corrections require author verification. Fiber dosage is by cement mass, not concrete volume. The original JFC1.0 label denotes 1.00% dosage.

(vii) Data treatment

The reported relative density reduction is expressed as 100(ρcontrol − ρfiber)/ρcontrol. The source provides no independent replicate count, standard deviation, confidence interval or inferential analysis. Accordingly, trends are described without claims of statistical significance. No error bars, ANOVA results or p values have been created. Plot values have not been digitized and presented as raw measurements.

III. Result And Discussion

(i) Slump trends

Figure 1 preserves the original slump plots. The reported trends show lower slump with increasing fiber dosage and length, greater slump at higher water-to-cement ratio, and greater slump for the 1:1.5:3 mixture than the 1:2:4 mixture. The combination of 1:1.5:3 and w/c 0.55 was consequently selected for fresh-density testing. This is a selection based on relative slump, rather than a demonstrated optimum or a placement specification: no target slump or application-specific acceptance criterion was provided.

Fiber water absorption, obstruction of aggregate movement and interactions between fibers are plausible explanations for slump loss. A greater paste fraction is a plausible explanation for the difference between nominal mix proportions. These mechanisms were not isolated experimentally. In particular, longer fibers do not automatically create greater total surface area at constant mass and diameter; the source explanation is therefore replaced by possible geometric interference and dispersion effects. The observed direction agrees with Islam and Ahmed (2018), but their dosage basis differs from this study, so equal percentage labels cannot be compared directly.

Figure 1 Slump of jute fiber concrete

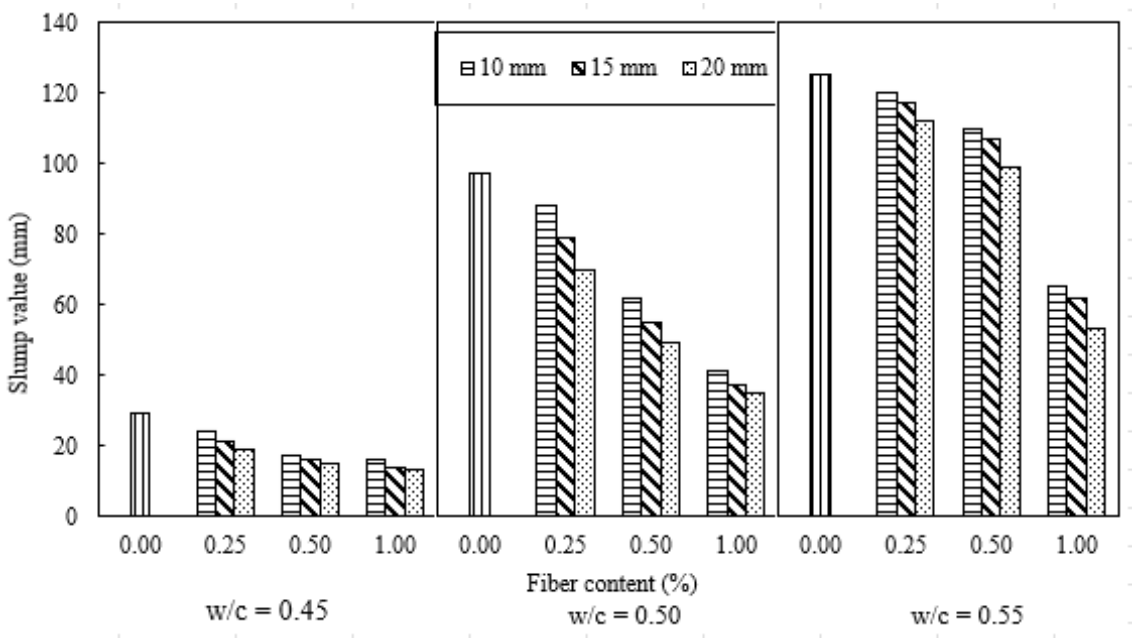


Figure 1(a). Original slump plot for the 1:1.5:3 volumetric mixture.

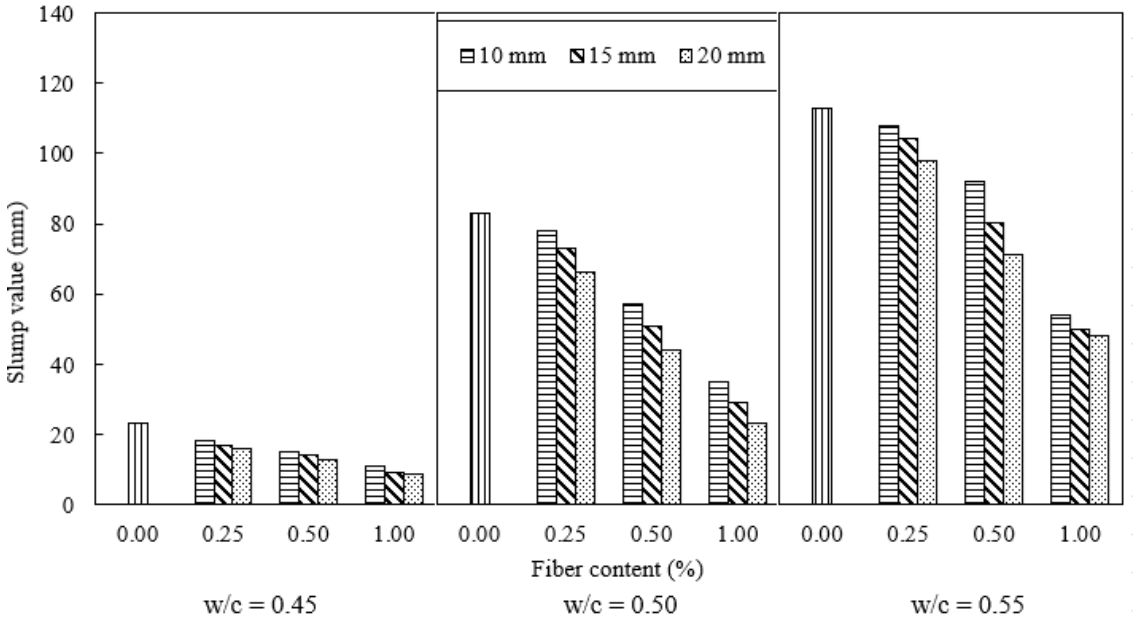


Figure 1(b). Original slump plot for the 1:2:4 volumetric mixture.

(ii) Fresh Density

Fresh density is the mass of freshly mixed concrete per unit volume, including the air present in the mixture. It is influenced by constituent densities, mixture proportions and the degree of consolidation. Figure 2 preserves the original fresh-density plot for the 1:1.5:3 mixture at w/c 0.55. The reported control density was 2293.69 kg/m³. At dosages of 0.25, 0.50 and 1.00%, respectively, reported reductions were 0.36, 1.10 and 1.78% for 10 mm fibers; 0.71, 1.35 and 2.15% for 15 mm fibers; and 1.25, 1.52 and 2.23% for 20 mm fibers. All these source values are retained.

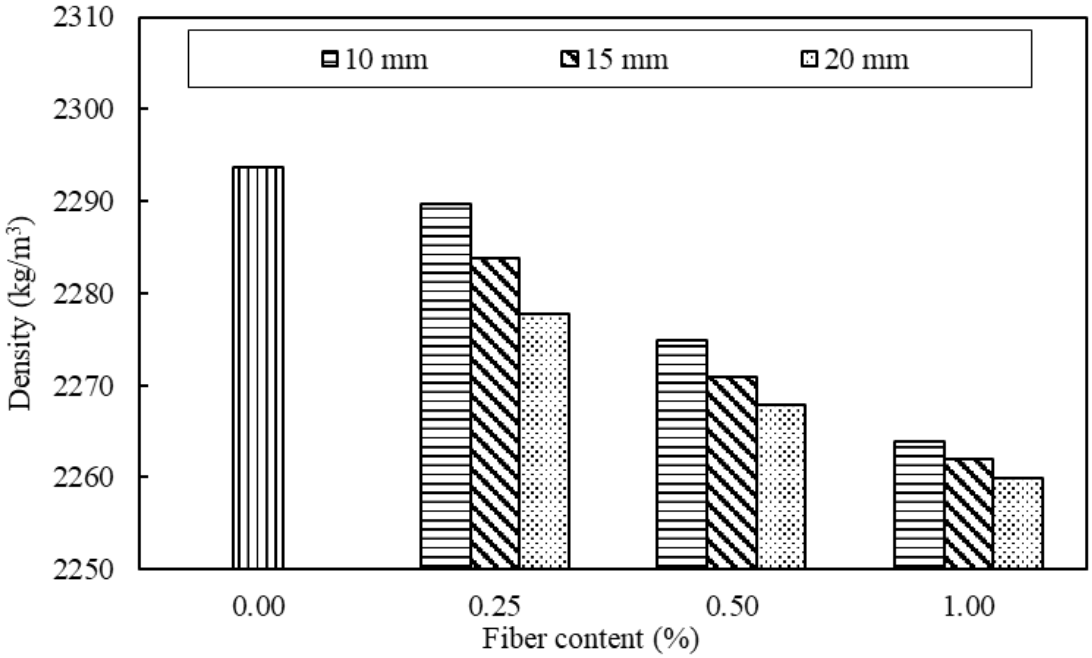


Figure 2. Original fresh-density plot for the 1:1.5:3 mixture at w/c 0.55.

The maximum reported reduction corresponds to approximately 2242.54 kg/m³, calculated from 2293.69 × (1 − 0.0223). This is a derived estimate from a rounded percentage, not an additional measurement. The reductions are modest, and their separation from experimental variability cannot be assessed without replication and calibrated density measurements. Lower fiber particle density may contribute to the density trend, but addition of fibers without documented replacement does not isolate a dilution effect. Entrapped air,

incomplete consolidation, fiber dispersion, moisture condition and actual mixture yield may also affect the result. Air content and compaction quality were not measured or reported, so these explanations remain hypotheses.

(iii) Scope of interpretation

Fresh density is not equilibrium or oven-dry density. ACI lightweight-concrete terminology generally refers to equilibrium densities of 1120–1920 kg/m³ and aggregate composition (ACI, n.d.-a). The present fresh-density measurements do not establish that classification. No hardened concrete strength, durability, thermal performance or structural assessment is reported. Cement mortar strength entries in Table 1 are constituent characterization and cannot substitute for concrete strength tests. The study also provides no life-cycle inventory, cost analysis or comparison at equal structural performance. Jute availability motivates investigation but does not demonstrate environmental superiority or commercial feasibility. Increasing water content to recover slump can affect hardened performance; this trade-off cannot be evaluated using the present fresh-property measurements alone.

(iv) Limitations and further validation

The principal limitations are unreported replication and uncertainty, incomplete batching and moisture records, unresolved density-measure suitability, and absence of a complete numerical slump dataset. Density conclusions apply only to the selected mixture. Selection after observing slump also limits interpretation as a balanced factorial study of both responses. Statistical interactions among factors, application-specific workability and an optimum dosage cannot be established from the reported record.

Further work should prioritize confirming or repeating the fresh-property tests with calibrated equipment and independent batches. A prospective analysis should distinguish batch variation from repeat readings and account for mix proportion, water-to-cement ratio, length and nonzero dosage without assigning a length to controls. Additional hardened, durability and environmental tests are needed only if corresponding performance claims are to be pursued.

IV. Conclusion

Within the investigated conditions, reported slump decreased with increasing jute fiber length and dosage and increased with water-to-cement ratio. The 1:1.5:3 mixture at w/c 0.55 showed comparatively greater slump and was selected for density testing; acceptable placement performance was not established against a specified target.For that selected mixture, the control fresh density was 2293.69 kg/m³ and the largest reported reduction was 2.23%, at 20 mm length and 1.00% fiber dosage by cement mass. The result describes a modest fresh-density reduction and does not demonstrate lightweight concrete. The observations remain descriptive pending confirmation of independent replication, uncertainty, batching yield and measurement procedures. They do not establish statistical significance, a universally recommended dosage, structural suitability or environmental benefit.

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