Civil Engineering and Architecture 13(3): 1995-2005, 2025 http://www.hrpub.org
DOI: 10.13189/cea.2025.130339

Effect of Jute Fiber Content on Compressive and Split Tensile Strength of Concrete Utilizing Stone Chips as Coarse Aggregates

Tarikul Islam, Faruk Patowary, Debasish Sen*, Sharmin Reza Chowdhury

Department of Civil Engineering, Ahsanullah University of Science and Technology, Bangladesh

Received December 13, 2024; Revised March 18, 2025; Accepted April 18, 2025

Cite This Paper in the Following Citation Styles

(a): *[1] Tarikul Islam, Faruk Patowary, Debasish Sen, Sharmin Reza Chowdhury , "Effect of Jute Fiber Content on Compressive and Split Tensile Strength of Concrete Utilizing Stone Chips as Coarse Aggregates," Civil Engineering and Architecture, Vol. 13, No. 3, pp. 1995 - 2005, 2025. DOI: 10.13189/cea.2025.130339.*

(b): *Tarikul Islam, Faruk Patowary, Debasish Sen, Sharmin Reza Chowdhury (2025). Effect of Jute Fiber Content on Compressive and Split Tensile Strength of Concrete Utilizing Stone Chips as Coarse Aggregates. Civil Engineering and Architecture, 13(3), 1995 - 2005. DOI: 10.13189/cea.2025.130339.*

Abstract The utilization of sustainable materials in concrete production has attained attention recently. The effect of altering jute fiber content on the workability, compressive, and splitting-tensile strength of concrete prepared using stone chips as coarse aggregate is investigated in this study. In this experimental study, different concrete mixtures were prepared with 25-mm jute fibers in selected proportions (0%, 0.4%, 0.8%, and 1.2% by weight of cement). To determine the workability of the concrete, thorough assessments were performed. Additionally, the jute fiber content was systematically added to identify the optimum proportion for enhancing the mechanical performance (compressive and splitting-tensile strength) of the concrete while maintaining moderate workability. Workability in terms of slump values falls as fiber content increases. The findings show that incorporating jute fibers into concrete improves its compressive and split-tensile strength significantly. For both tests, the optimum fiber content was found to be 0.4%. These improvements are attributed to the reinforcing and bridging effects of the jute fibers within the concrete matrix. However, for higher fiber content (1.2%), the concrete-mix becomes less workable, resulting in improper fiber distribution, difficulty in compaction, and higher voids in the concrete. As a result, fiber aggregation occurs, and compressive and split tensile strength decreases.

Keywords Jute Fiber, Fiber-Reinforced Concrete, Slump, Compressive Strength, Splitting Tensile Strength

1. Introduction

The availability of constituent materials, higher durability, better compressive strength, impressive versatility, and cost-effectiveness have made concrete the most utilized construction material in the world [1]. While concrete is the most widely used construction material, concerns persist in the construction industry due to its weaknesses in tension, ductility, fatigue, toughness, impact, and crack resistance [2, 3]. Natural fibers have the ability to eliminate certain weaknesses in concrete and are abundantly found in nature [4]. Natural fibers, when incorporated in concrete, improve the mechanical and durability performance of concrete and erase the limitations of plain concrete to a great extent [5-9]. Brittleness is a major concern for plain concrete, and this can be effectively overcome by reinforcing it with natural fibers [10, 11]. Fiber reinforcement strengthens the weak matrices of concrete, and the bridging effect of fibers reduces the crack propagation significantly [12, 13]. Microfibers, with increased surface area, have the ability to minimize the plastic shrinkage cracking of concrete [14]. Natural fibers contribute to mitigating the emission of CO_2

into the atmosphere making it more environmentally sustainable [15-17]. Furthermore, natural fibers, sourced from renewable resources like plants, possess the benefit of requiring less energy during their extraction process [18].

Among various natural fibers, jute fibers stand out as highly promising materials for concrete composites due to their widespread commercial availability and affordability [19, 20]. Properties such as biodegradability, high tensile strength, low cost, low density, sustainability, and non-toxicity have made jute fiber a better natural fiber than others [21, 22]. Jute is a rapidly growing herbaceous shrub that belongs to the Malvaceae family, specifically classified under the genus Corchorus [23]. The primary constituents of jute fibers are cellulose (45-65%) and lignin (21-26%) [24]. Studies indicate that jute fibers, weighing roughly seven times less than steel fibers, exhibit a tensile strength in the range of 250 to 300 MPa, making them suitable for a diverse range of applications [25, 26].

Several researchers have reported a significant decrease in the workability of concrete due to the addition of untreated jute fibers. Jute fiber reinforced concrete (JFRC) shows lower slump value than plain concrete due to high water absorption capacity and confinement effect of fibers [27, 28]. It is observed that specific quantity of jute fibers and length yields the maximum mechanical performance of JFRC [20]. But optimum quantity and length of jute fibers varied for different researchers as properties and proportions of constituent's materials of concrete also varied. Faiq [29] reported that the highest splitting tensile strength was observed with 1% fiber content, surpassing the values for 0.5% and 1.5%, across both 2 cm and 4 cm fiber lengths. Sultana et al. [30] found that the highest compressive strength and splitting tensile strength were achieved when incorporating a volume content of 0.2% of jute fiber. Islam and Ahmad [31] incorporated jute fibers in concrete at varying percentages (0.25%, 0.5%, 0.75%, and 1%), and determined that the optimal fiber content for enhanced performance was 0.5%. Dayananda et al. [32] achieved enhanced compressive strength up to a fiber content of 1.4%, while Zhang et al. [33] reported an increased attainment of both compressive and splitting tensile strength for concrete with jute fiber content up to 3%. Zakaria et al. [20] carried out an investigation utilizing jute fibers measuring lengths of 10 mm, 15 mm, 20 mm, and 25 mm, along with volume dosages ranging from 0% to 0.75%. Their study revealed a notable enhancement in both strength when the volume contents of 0.1% and 0.25% were employed in conjunction with fiber lengths of 10 mm and 15 mm. The findings indicated a maximum tensile strength increase of 35% for JFRC compared to plain concrete. Asaduzzaman and Islam [34] examined the fresh and hardened properties of JFRC, incorporating fiber contents of 0.1%, 0.2%, 0.3%, and 0.4%, along with cut lengths of 20 mm and 25 mm. They observed a maximum 7% increase in compressive strength at low fiber content and a maximum 25% increase in tensile strength when the fiber content was 0.4%. Aziz et al. [35] pointed out that the properties of concrete, whether in its fresh or hardened state, are influenced by factors such as the types, shapes, forms, and surface textures of the fibers integrated into the concrete mixture. However, it is underscored that the most significant impact is attributed to the characteristics of the fibers, specifically their type, length, and volume concentration [5]. Additionally, the mechanical properties of the fibers, encompassing aspects like elongation at breakage, tensile strength, modulus of elasticity, and moisture absorption capacity, are identified as playing a pivotal role in governing the concrete's properties [36].

This study aims to expand on prior research by investigating how changes in fiber content affect the mechanical performance of jute fiber-reinforced concrete. The main objective is to identify the optimal fiber content for concrete using natural stone as coarse aggregates. This involves a comprehensive evaluation of both the fresh and hardened properties of the concrete. The outcomes of this research are anticipated to provide guidance for selecting the ideal jute fiber percentage for concrete with comparable mix ratios and aggregate properties.

2. Materials and Methods

2.1. Materials

All the materials used for this study are shown in Figure 1. Portland composite cement (PCC) (CEM-II/A-M) was used as a binder, with a strength class of 42.5 N, a setting time of 165 minutes, and an early (3 days) strength of 20.3 MPa. It contains 80-94% clinker, 6-20% slag, 0-5% limestone, and 0-5% gypsum. Black crushed stone chips (maximum size 19 mm) were utilized as coarse aggregate, whereas coarse river sand (maximum size 4.75 mm) was used as fine aggregate. Table 1 shows physical properties, and Figure 2 depicts the particle size distribution of aggregates. Furthermore, jute fibers (Figure 1d) were collected from local sources, cleaned with water, and cut into 25 mm sizes before drying.

(a) (b) (c) (d)

Figure 1. Materials used in the study: (a) cement, (b) coarse aggregates (stone chips), (c) Fine aggregates and (d) 25 mm jute fibers

Table 1. Physical properties of aggregates (coarse and fine)

Physical Properties	Fine Aggregate	Coarse Aggregate
Unit Weight (Kg/m^3)	1556.00	1695.00
Bulk Specific Gravity (OD)	2.14	2.77
Bulk Specific Gravity (SSD)	2.32	2.80
Apparent Specific Gravity	2.60	2.85
Absorption Capacity (%)	8.10	0.96
Voids (%)	27.14	38.75
Fineness Modulus	3.10	7.00

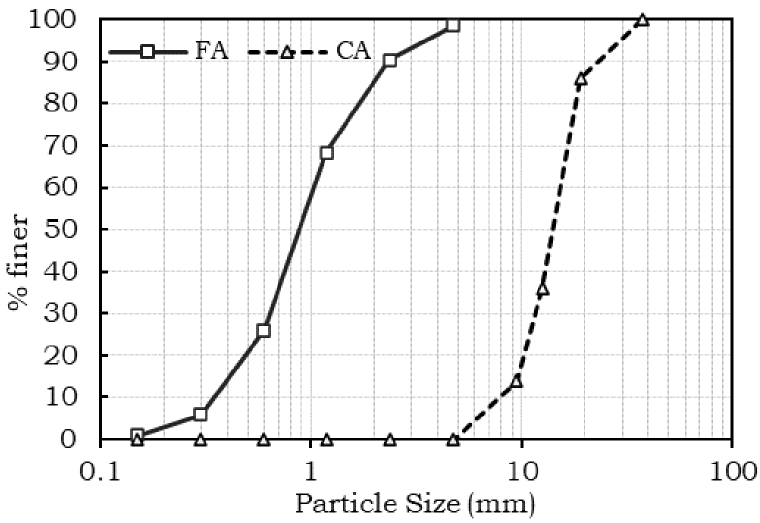


Figure 2. Grain size distribution of coarse and fine aggregates

2.2. Mix Proportions

The mix design was performed according to ACI 211.1 [37] for a target compressive strength of concrete of 20 MPa, and the material proportions are shown in Table 2. Tap water was used for the concrete mix with a water-to-cement ratio of 0.5. A total of five types of mixtures were prepared, containing jute fibers at 0%, 0.4%, 0.8%, and 1.2% by weight of cement. For the compaction of concrete, a mechanical vibrator was used. A total of 24 cylindrical samples, each measuring Ø100 mm × 200 mm, were prepared for performing compressive and splitting tensile strength tests.

2.3. Methods for Testing Fresh and Hardened Properties of Concrete

With the provisions of ASTM C143/143M [38], the slump test was conducted to determine the workability of concrete using a slump cone (Figure 3). Triplicate specimens were prepared for both compressive strength ASTM C39/C39M [39] and splitting tensile strength tests ASTM C496/C496M [40], and all samples were cured with water for 28 days before conducting the tests.

Table 2. Mix proportion of concrete for 20 MPa target strength

Mix No	Mixing Type	Fiber length (mm)	Jute Fiber (%)	Mix Proportion (Kg/m^3)				
				Water	Cement	Stone chips [SSD]	Sand [SSD]	Jute Fiber
1	Control	-	-	249.17	498.34	1230.90	1166.12	-
2	JFRC 1	25	0.4	248.85	497.69	1229.30	1164.60	2.0
3	JFRC 2	25	0.8	248.50	497.00	1227.58	1162.97	4.0
4	JFRC 3	25	1.2	248.17	496.35	1225.98	1161.45	6.0

(a) (b) (c)

Figure 3. Tests on concrete: (a) slump, (b) compressive strength and (c) splitting tensile strength tests

3. Result and Analysis

3.1. Influence of Jute Fiber on Workability of Concrete

Slump is reduced when jute fibers are added, as shown in Figure 4. When jute fiber is added to the concrete matrix, the non-uniform distribution of fibers due to agglomeration, water absorption from the mixture, and the hydrophilic nature of jute fiber, causes this decrement in workability [41]. When 0.4% jute fiber was incorporated to the concrete, workability decreased by 31%. Adding 0.8% jute fiber resulted in a 52.5% reduction in slump (Figure 4). The addition of 1.2% jute fiber led to a nearly 69% decrease in workability, as measured by the slump value in the concrete mix. Reduced workability makes it challenging to ensure proper fiber dispersion within the matrix and achieve effective compaction of the concrete. A comparison of the workability reduction trend found in this study and other available studies in the literature is shown in Figure 5. There are large variations in the trend of workability reduction which might be attributed to the variation of water absorption capacity of the utilized jute fibers by different researchers. For instance, the inclusion of 1.2% jute fiber decreased workability (i.e., slump value) by 69% in this study. In contrast, Tiwari et al. [41] reported a workability reduction of 20-28% (as shown in Figure 5) when using 1.2% jute fibers with lengths of 25-50 mm in concrete for M25-M40 mixes. Furthermore, Islam and Ahmad [31] reported a 100% loss of workability when 1% of 20 mm jute fibers was added to the concrete mix (Figure 5).

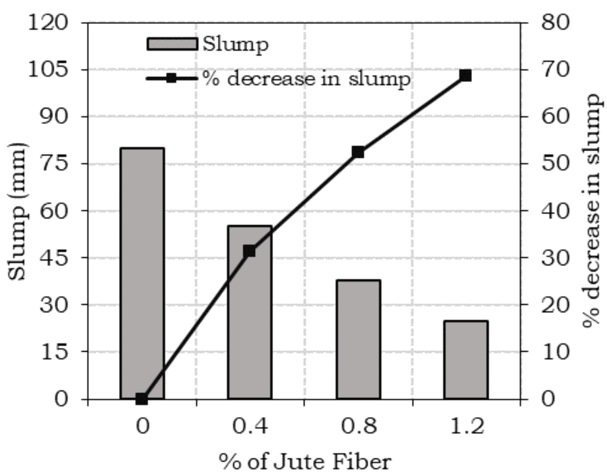


Figure 4. Comparison of workability of concrete (slump) for various jute fiber content

3.2. Influence of Jute Fiber Content on Compressive Strength

The compressive strength of concrete increased with the rise in jute fiber content, up to 0.4% fiber content,- for concrete specimens containing stone chips as coarse aggregates (ref. to Figure 6a). This increment is attributed to the function of fibers, which bridge the micropores and also fill concrete voids [41]. Figure 7(a-d) shows the failure patterns of all the tested specimens including the bridging effect of fibers under compressive loads. The optimal content of jute fiber is observed at 0.4%, indicating nearly a 28% strength increment compared to the control concrete specimens concerning compressive strength. From the failure pattern of concrete specimens (refer to Figure 7b) containing 0.4% fiber, it can be observed that the fibers resisted crack development, requiring additional strength to cause the collapse of the specimens. However, the addition of jute fiber over this percentage resulted in a loss in compressive strength. When 1.2% jute fibers were added to the concrete, the compressive strength decreased to 19.5 MPa, which is lower than the control concrete. The presence of fibers up to a specific amount aids in the more effective control of fracture development and propagation, resulting in an improvement in compressive strength [42]. Again, an increase in fiber content beyond the optimum percentages in the mixture results in higher porosity in the matrix due to poor compaction and less workable concrete, leading to obstruction in the cohesion of the concrete matrix. This obstruction results in the balling effect and reduces the compressive strength [20, 42, 43]. With a 1.2% addition of jute fibers into the concrete mix, lower workability was observed (Figure 5), which led to fiber aggregation, as depicted in Figure 7d. This aggregation resulted in more air voids in the concrete mix, contributing to a decreased compressive strength, as reported in previous studies on fiber-reinforced concrete [44, 45].

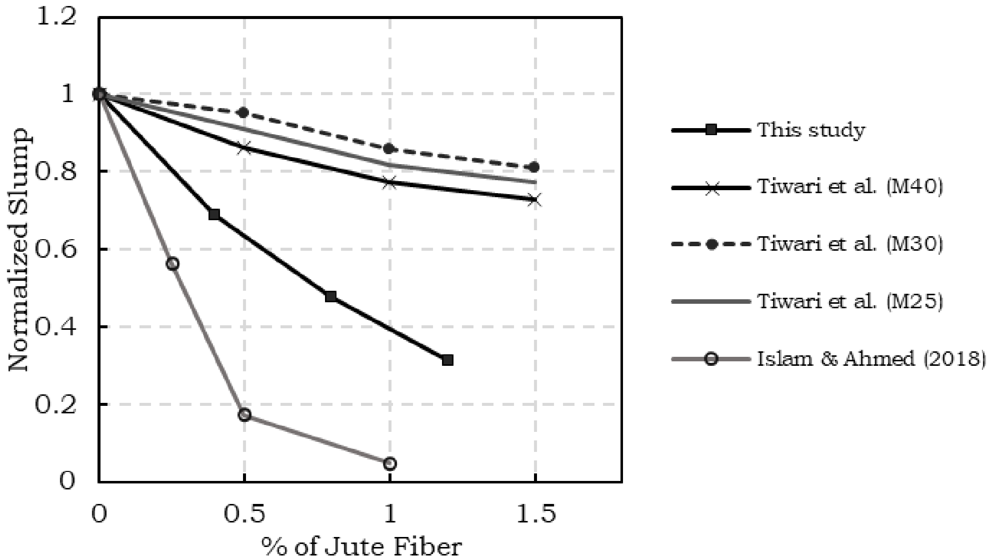


Figure 5. Comparison of normalized slump of concrete for the current study and study contacted by Islam & Ahmed for different percentages of 20 mm jute fiber

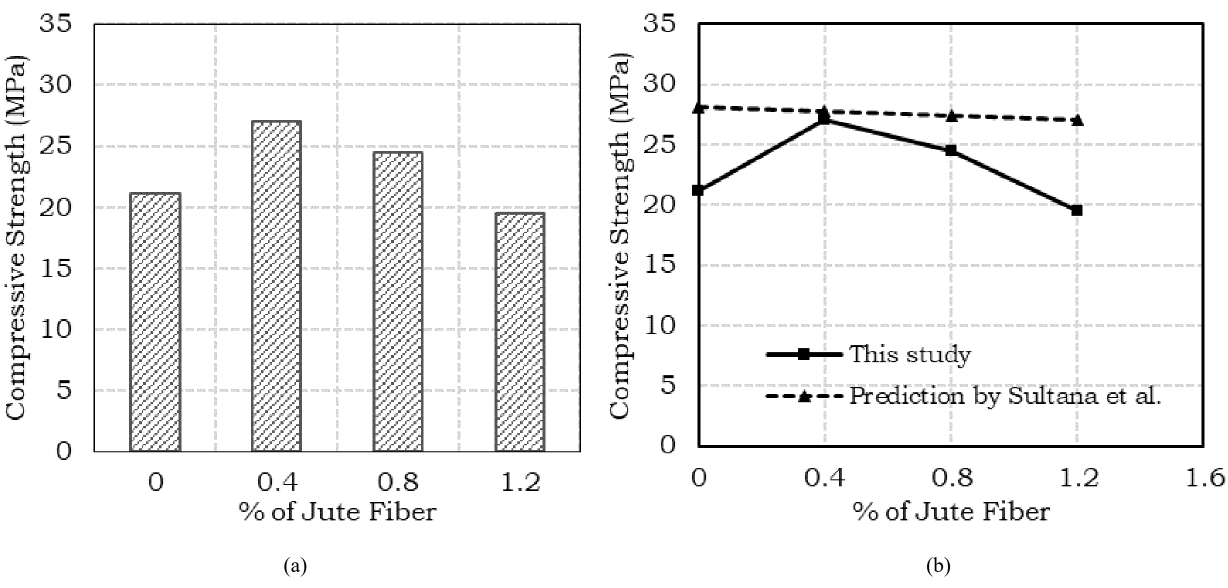
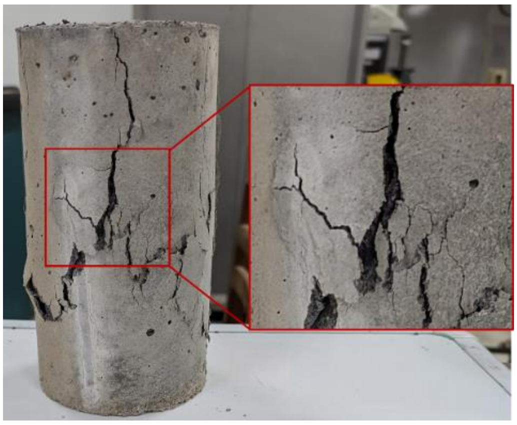
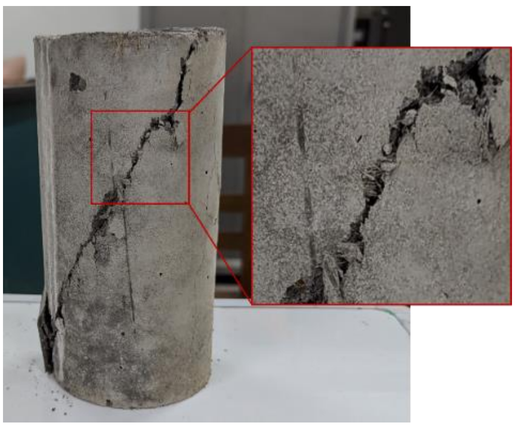


Figure 6. (a) Effect of jute fiber content on compressive strength of concrete and (b) Comparison of experimental value of compressive strength with the predicted values by Sultana et al.



(a) Control specimen

(b) JFRC 1 (0.4% fiber)



(c) JFRC 2 (0.8% fiber)

(d) JFRC 3 (1.2% fiber)

Figure 7. Failure pattern of all types of concrete samples

The experimentally found compressive strengths of the specimens are compared, as shown in Figure 6b, with a prediction model proposed by Sultana et al. [30]. The prediction model by Sultana et al. [30] has been proposed using soft computing approaches where water-to-cement ratio, fiber length, and fiber volume are considered as different variables to predict compressive strength. From the comparison, it can be observed that the addition of jute fiber content tends to decrease compressive strength. However, for 0.4% jute fiber content, the predicted value appears similar to the experimental value from this study (Figure 6b). Beyond a 0.4% addition, the decrement rate is higher in the experimental case than the predicted one. Meanwhile, the normalized compressive strengths (f_c/f_{c0}) of concrete with the jute fiber content from previous studies and this study are compared and shown in Figure 8, where f_c and f_{c0} are compressive strengths with a specific jute fiber content, and without any jute fiber, respectively. Most studies show an increment in normalized compressive strength compared to the control concrete up to a certain amount of jute fiber added and a decreasing trend after reaching the optimum value of jute fiber content [31, 41, 46, 47]. However, Faiq [29] reported a gradual decrement in normalized compressive strength with the addition of jute fibers.

3.3. Effect of Jute Fiber Content on Splitting Tensile Strength

A similar pattern is observed in the case of splitting tensile strength, where the addition of jute fibers into the concrete mix increased the splitting tensile strength (Figure 9) up to a certain fiber content i.e., 0.4%. Specifically, when 0.4% and 0.8% jute fibers were added to the concrete mix, an increment of 30% and 27% in splitting tensile strength was observed, respectively. However, with a 1.2% addition of jute fiber, only a 7% increment was observed. Jute fibers help to improve the brittle behavior of concrete, thereby increasing the splitting tensile strength [41]. Furthermore, the suitability of physical and chemical connections (i.e., bonds) between the jute fibers and the concrete matrix allows them to prevent the spreading of microcracks, which is another factor contributing to the strength increment. On the other hand, concrete with a higher percentage of jute fiber tends to exhibit a balling effect or fiber aggregation and improper bonding, as discussed in the previous section, leading also to a reduction in splitting tensile strength. Similarly, a higher percentage of fiber reinforcement contributes to a decrease in splitting tensile strength during cracking due to the smaller density of concrete [42].

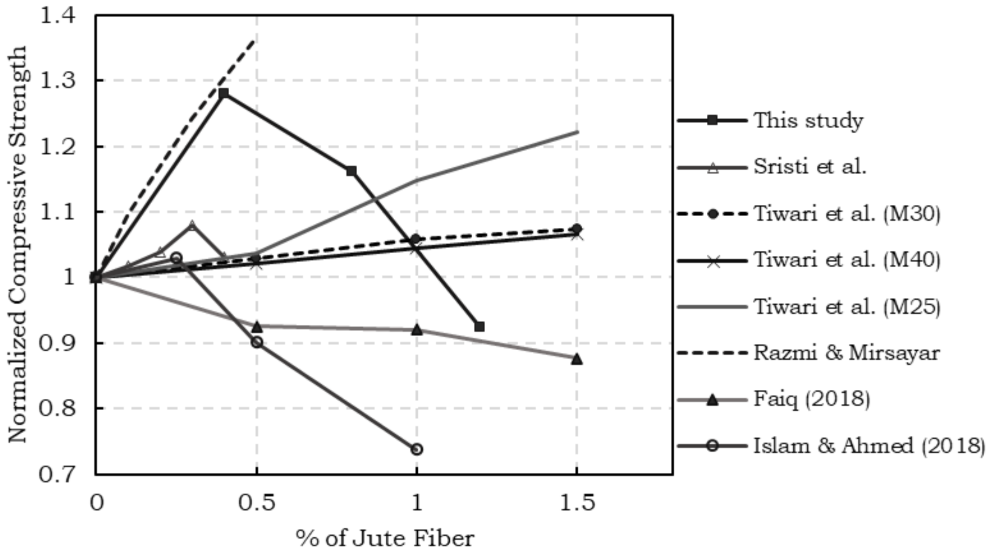
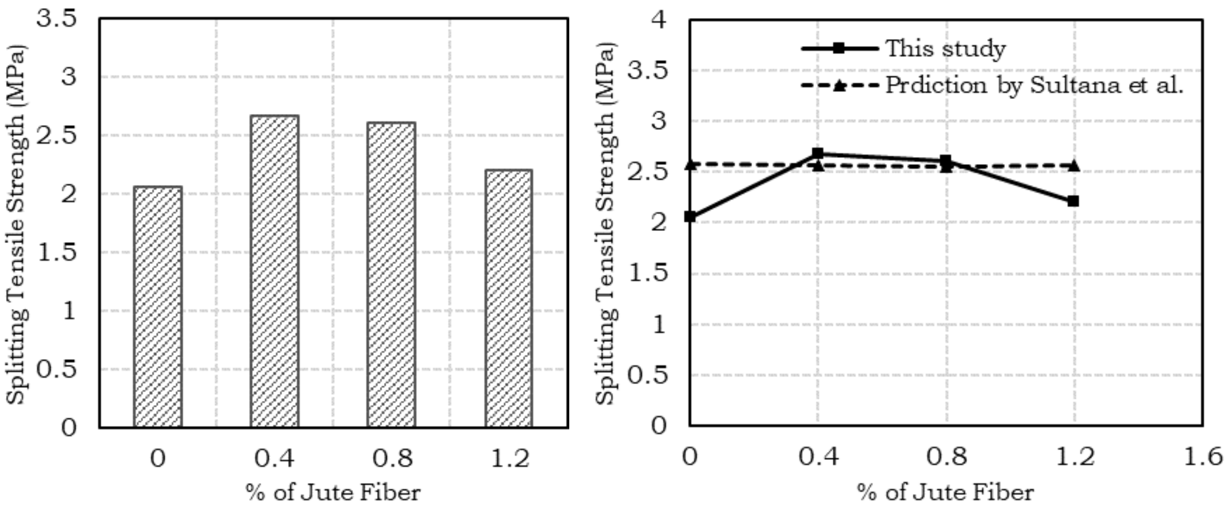


Figure 8. Comparison of normalized compressive strength (f_c/f_{c0}) of concrete with other studies containing 20 mm jute fiber



(a) (b)

Figure 9. Effect of jute fiber content on splitting tensile strength of concrete and (b) Comparison of experimental value of splitting tensile strength with the predicted values by Sultana et al.

The experimentally determined splitting tensile strengths of the specimens, shown in Figure 9b, are compared with a prediction model proposed by Sultana et al. [30]. Referring to the prediction equation proposed by Sultana et al. [30] using soft computing approaches, it is evident that the addition of jute fiber content has a minimal effect on the increment of splitting tensile strength. Nevertheless, the predicted values closely align with the experimentally observed values for 0.4% and 0.8% jute fibers, as illustrated in Figure 9b. Meanwhile, the normalized splitting tensile strength of concrete with jute fiber content from previous studies and this study is compared and shown in Figure 10. Normalized splitting tensile strength refers to the ratio of the splitting tensile strength of concrete with a specific jute fiber content to that without any jute fiber. Most of the previous studies [29, 31, 41, 46, 47] that incorporated 20-25 mm length of jute fibers into concrete concluded that the inclusion of jute fibers increases the splitting tensile strength up to a certain fiber content; however, there are some exceptions. The optimum percentage of jute fibers varies between 0.3% and 1%, as seen in Figure 10. Some inconsistencies are found in the optimum jute fiber content due to different mix designs, mixing and compaction processes, the use of admixtures, types of coarse aggregates, and curing.

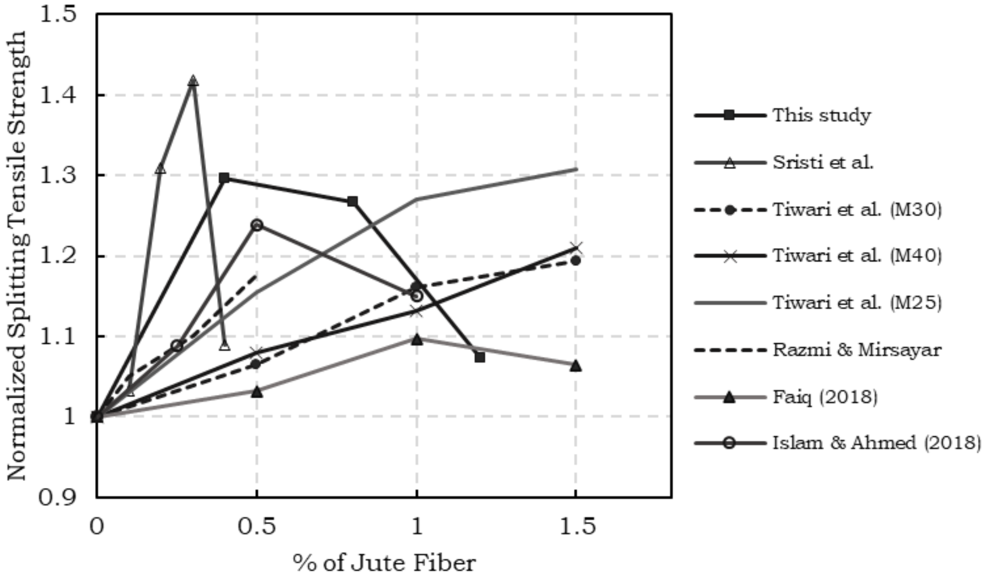


Figure 10. Comparison of normalized splitting tensile strength (f_t/f_{t0}) of concrete with other studies containing 20 mm jute fiber

4. Conclusions and Recommendations

The optimal content of jute fibers is crucial for achieving a balance between enhancing mechanical properties and maintaining workability in concrete. The study underscores the importance of carefully determining fiber content in concrete mixtures to attain desired performance characteristics. Based on the experimental analysis, the following findings can be addressed.

- The introduction of jute fibers led to a noticeable reduction in workability, evident in decreased slump values (i.e., 31 ~ 70% reduction with 0.1~1.2% JF content). This decline is attributed to challenges in achieving uniform fiber distribution due to agglomeration and water absorption, a characteristic of the hydrophilic nature of jute fiber. As workability decreased, difficulties arose in ensuring proper fiber dispersion and concrete compaction, aligning with findings from previous studies.
- The compressive strength of concrete exhibited an increase with an increase in jute fiber content up to an optimal level of 0.4%, resulting in a remarkable strength increment compared to control concrete. The fibers played a role in bridging micropores and filling voids. However, beyond this optimal percentage, compressive strength experienced a decline, reaching a lower level at a 1.2% fiber addition. This decrease beyond the optimum was attributed to higher porosity resulting from poor compaction, decreased workability, and fiber aggregation, consistent with observations in previous studies on fiber-reinforced concrete.
- The inclusion of jute fibers demonstrated an enhancement in splitting tensile strength up to 0.4% fiber content. Incremental additions of 0.4% and 0.8% jute fiber- resulted in remarkable increases, whereas a 1.2% addition led to a comparatively smaller increase. The improved splitting tensile strength is linked to the suppressed brittle behavior in concrete and the prevention of microcrack spreading through physical and chemical connections between jute fibers and the matrix. Conversely, higher fiber percentages caused issues such as a balling effect, fiber aggregation, and improper bonding, contributing to reduced splitting tensile strength.

This study marks the authors' initial exploration into the effects of untreated jute fiber content. As a natural material, jute fiber has low bonding strength to concrete due to smooth surfaces. Therefore, chemical treatment is necessary to achieve greater surface roughness which would be a scope of future work. In addition, durability test, sulphate resistance test, freeze-thaw test, scanning electron microscopy (SEM) can be conducted in further researches to get a comprehensive idea about the performance of jute fiber reinforced concrete. The authors are considering conducting further research to enhance the fresh properties of jute-fiber-reinforced concrete by incorporating admixtures. This is particularly crucial as higher amounts of jute fiber negatively impact concrete workability. Admixtures can be employed to maintain medium to high workability levels. Additionally, this study employs 25 mm jute fibers, but there is a need to investigate jute fibers with varying aspect ratios, ranging from low to high, and their impact on concrete. Furthermore, it is recommended to examine the effect of jute fibers on concrete containing different types of coarse aggregates, including brick chips.

Acknowledgements

The experimental work was conducted in Concrete Laboratory and Strength of Material Laboratory of AUST, Bangladesh. Hence authors extend their thanks to all of the technical staffs of the concerned laboratories.

Statements & Declarations

Funding

This research is supported and funded by AUST Internal Research Grant (AIRG) (Research Project ID: ARP/2022/CE/02/08, Principal Investigator: Prof. Dr. Sharmin Reza Chowdhury, AUST, and Co-Principal Investigator: Dr. Debasish Sen, AUST).

Competing Interests

The authors have no competing interest to declare that are relevant to the content of this article.

Authors Contribution

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Tarikul Islam and Faruk Patowary. The first draft of the manuscript was written by Tarikul Islam, Faruk Patowary and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

REFERENCES

[1] Neville, A.M., “Properties of concrete,” Pearson, 1995.

[2] Chandramouli, K., Srinivasa, R.P., Pannirselvam, N., Seshadri, S.T. and Sravana, P., “Strength properties of glass fiber concrete,” ARPN journal of Engineering and Applied sciences, vol. 5, no. 4, pp. 1-6, 2010.

[3] Gagg, C.R., “Cement and concrete as an engineering material: An historic appraisal and case study analysis,” Engineering Failure Analysis, vol. 40, pp. 114-140, 2014. doi: 10.1016/j.engfailanal.2014.02.004

[4] Bogoeva-Gaceva, G., Avella, M., Malinconico, M., Buzarovska, A., Grozdanov, A., Gentile, G. and Errico, M.E., “Natural fiber eco-composites,” Polymer composites, vol. 28, no. 1, pp. 98-107, 2007. doi: 10.1002/pc.20270

[5] Ahmadi, M.A., Alidoust, O., Sadrinejad, I. and Nayeri, M., “Development of mechanical properties of self compacting concrete contain rice husk ash,” International Journal of Computer, Information, and Systems Science, and Engineering, vol. 1, no. 4, pp. 259-262, 2007. doi: 10.5281/zenodo.1334602

[6] Kumar, P., “Self-compacting concrete: methods of testing and design,” Journal of the Institution of Engineers. India. Civil Engineering Division, vol. 86, pp. 145-150, 2006.

[7] Mohammadi, Y., Singh, S.P. and Kaushik, S.K., “Properties of steel fibrous concrete containing mixed fibres in fresh and hardened state,” Construction and Building Materials, vol. 22, no. 5, pp. 956-965, 2008. doi: 10.1016/j.conbuildmat.2006.12.004

[8] Şahmaran, M., Christianto, H.A. and Yaman, İ.Ö., “The effect of chemical admixtures and mineral additives on the properties of self-compacting mortars,” Cement and concrete composites, vol. 28, no. 5, pp. 432-440, 2006. doi: 10.1016/j.cemconcomp.2005.12.003

[9] Yazıcı, Ş., İnan, G. and Tabak, V., “Effect of aspect ratio and volume fraction of steel fiber on the mechanical properties of SFRC,” Construction and Building Materials, vol. 21, no. 6, pp. 1250-1253, 2007. doi: 10.1016/j.conbuildmat.2006.05.025

[10] Boulekbache, B., Hamrat, M., Chemrouk, M. and Amziane, S., “Flexural behaviour of steel fibre-reinforced concrete under cyclic loading, Construction and Building Materials, vol. 126, pp. 253-262, 2016. doi: 10.1016/j.conbuildmat.2016.09.035

[11] Brandt, A.M., “Fibre reinforced cement-based (FRC) composites after over 40 years of development in building and civil engineering,” Composite structures, vol. 86, np. 1-3, pp. 3-9, 2008. doi: 10.1016/j.compstruct.2008.03.006.

[12] Sor, N.H., Ali, T.K.M., Vali, K.S., Ahmed, H.U., Faraj, R.H., Bheel, N. and Mosavi, A., “The behavior of sustainable self-compacting concrete reinforced with low-density waste Polyethylene fiber,” Materials Research Express, vol. 9, no. 3, pp. 035501, 2022. doi: 10.1088/2053-1591/ac58e8

[13] Karim, M.A., Abdullah, M.Z., Deifalla, A.F., Azab, M. and Waqar, A., “An assessment of the processing parameters and application of fibre-reinforced polymers (FRPs) in the petroleum and natural gas industries: A review,” Results in Engineering, vol. 18, pp. 101091, 2023. doi: 10.1016/j.rineng.2023.101091

[14] Vandewalle, L., "Design of steel fibre reinforced concrete using the sigma-w method: principles and applications,” Materials and Structures, vol. 35, no. 249, pp. 262-278, 2002.

[15] Girijappa, Y.G.T., Rangappa, S.M., Parameswaranpillai, J. and Siengchin, S., “Natural fibers as sustainable and renewable resource for development of eco-friendly composites: a comprehensive review,” Frontiers in Materials, vol. 6, pp. 226, 2019. doi: 10.3389/fmats.2019.00226

[16] Hasan, K.F., Horváth, P.G. and Alpár, T., “Lignocellulosic fiber cement compatibility: a state of the art review,” Journal of Natural Fibers, vol. 19, no. 13, pp. 5409-5434, 2022. doi: 10.1080/15440478.2021.1875380

[17] Waqar, A., Othman, I., Shafiq, N. and Mansoor, M.S., “Applications of AI in oil and gas projects towards sustainable development: a systematic literature review,” Artificial Intelligence Review, vol. 56, no. 11, pp. 12771-12798, 2023. doi: 10.1007/s10462-023-10467-7

[18] Li, Z., Wang, L. and Wang, X., “Compressive and flexural properties of hemp fiber reinforced concrete,” Fibers and Polymers, vol. 5, pp. 187-197, 2004. doi: 10.1007/BF02902998

[19] Song, H., Liu, J., He, K. and Ahmad, W., “A

comprehensive overview of jute fiber reinforced cementitious composites," Case Studies in Construction Materials, vol. 15, pp. e00724, 2021. doi: 10.1016/j.cscm.2021.e00724

[20] Zakaria, M., Ahmed, M., Hoque, M.M. and Islam, S., "Scope of using jute fiber for the reinforcement of concrete material," Textiles and Clothing Sustainability, vol. 2, pp. 1-10, 2017. doi: 10.1186/s40689-016-0022-5

[21] Ali, A., Shaker, K., Nawab, Y., Ashraf, M., Basit, A., Shahid, S. and Umair, M., "Impact of hydrophobic treatment of jute on moisture regain and mechanical properties of composite material," Journal of Reinforced Plastics and Composites, vol. 34, no. 24, pp. 2059-2068, 2015. doi: 10.1177/0731684415610007

[22] Hossain, M.M. and Abdulla, F., "Jute production in Bangladesh: a time series analysis," Journal of Mathematics and Statistics, vol. 11, no. 3, pp. 93-98, 2015. doi: 10.3844/jmssp.2015.93.98

[23] Shukla, S. and Mittal, A., "Effect of jute fibre reinforcement on strength, thickness and cost of low-volume rural roads," Materials Today: Proceedings, vol. 62, pp. 6749-6754, 2022. doi: 10.1016/j.matpr.2022.04.848

[24] Rowell, R.M., "Characterization and factors effecting fiber properties," Natural polymers and agrofibers based composites, 2000.

[25] Ahmad, J., Arbili, M.M., Majdi, A., Althoey, F., Farouk Deifalla, A. and Rahmawati, C., "Performance of concrete reinforced with jute fibers (natural fibers): A review," Journal of Engineered Fibers and Fabrics, vol. 17, pp. 15589250221121871, 2022. doi: 10.1177/15589250221121871

[26] Kundu, S.P., Chakraborty, S., Roy, A., Adhikari, B. and Majumder, S.B., "Chemically modified jute fibre reinforced non-pressure (NP) concrete pipes with improved mechanical properties," Construction and Building Materials, vol. 37, pp. 841-850, 2012.

[27] Kim, J., Park, C., Choi, Y., Lee, H. and Song, G., "An investigation of mechanical properties of jute fiber-reinforced concrete," High Performance Fiber Reinforced Cement Composites 6: HPFRCC 6, pp. 75-82, 2012.

[28] Zia, A. and Ali, M., "Behavior of fiber reinforced concrete for controlling the rate of cracking in canal-lining," Construction and Building Materials, vol. 155, pp. 726-739, 2017. doi: 10.1016/j.conbuildmat.2017.08.078

[29] Faiq, L.S., "Study of the mechanical properties of jute fiber reinforced cement composites," Engineering and Technology Journal, vol. 36, no. 12A, pp. 1244-1248, 2018. doi: 10.30684/etj.36.12a.5

[30] Sultana, N., Hossain, S.Z., Alam, M.S., Islam, M.S. and Al Abtah, M.A., "Soft computing approaches for comparative prediction of the mechanical properties of jute fiber reinforced concrete," Advances in Engineering Software, vol. 149, pp. 102887, 2020. doi: 10.1016/j.advengsoft.2020.102887

[31] Islam, M.S. and Ahmed, S.J., "Influence of jute fiber on concrete properties," Construction and Building Materials, vol. 189, pp. 768-776, 2018. doi: 10.1016/j.conbuildmat.2018.09.048

[32] Dayananda, N., Keerthi Gowda, B.S. and Easwara Prasad, G.L., "A study on compressive strength attributes of jute fiber reinforced cement concrete composites," In IOP Conference Series: Materials Science and Engineering, vol. 376, p. 012069, IOP Publishing, 2018.

[33] Zhang, T., Yin, Y., Gong, Y. and Wang, L., "Mechanical properties of jute fiber-reinforced high-strength concrete," Structural Concrete, vol. 21, no. 2, pp. 703-712, 2020. doi: 10.1002/suco.201900012

[34] Asaduzzaman, S.M. and Islam, G.S., "Using jute fiber to improve fresh and hardened properties of concrete," Journal of Natural Fibers, vol. 20, no. 2, pp. 2204452, 2023. doi: 10.1080/15440478.2023.2204452

[35] Aziz, M.A., Paramasivam, P. and Lee, S.L., "Prospects for natural fibre reinforced concretes in construction," International Journal of Cement Composites and Lightweight Concrete, vol. 3, no. 2, pp. 123-132, 1981. doi: 10.1016/0262-5075(81)90006-3

[36] Gupta, T., Chaudhary, S. and Sharma, R.K., "Mechanical and durability properties of waste rubber fiber concrete with and without silica fume," Journal of cleaner production, vol. 112, pp. 702-711, 2016. doi: 10.1016/j.jclepro.2015.07.081

[37] ACI 211.1-91 "Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete (Reapproved 2009)," American Concrete Institute, Farmington Hills, MI, 48331-3439 USA, 2009.

[38] ASTM C143/143 M. "Standard Test Method for Slump of Hydraulic-Cement Concrete," ASTM International, West Conshohocken, PA, USA, 2010.

[39] ASTM C39/C39M. "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens," ASTM International, West Conshohocken, PA, USA, 2021. doi: 10.1520/C0039_C0039M-21

[40] ASTM C496/C 496M. "Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens," ASTM International, West Conshohocken, PA, USA, 2004. doi: 10.1520/C0496-96

[41] Tiwari, S., Sahu, A.K. and Pathak, R.P., "Mechanical properties and durability study of jute fiber reinforced concrete," In IOP Conference Series: Materials Science and Engineering, vol. 961, no. 1, p. 012009, IOP Publishing, 2020.

[42] Bheel, N., Tafsirojjaman, T., Liu, Y., Awoyera, P., Kumar, A. and Keerio, M.A., "Experimental study on engineering properties of cement concrete reinforced with nylon and jute fibers," Buildings, vol. 11, no. 10, pp. 454, 2021. doi: 10.3390/buildings11100454

[43] Kanagavel, R. and Arunachalam, K., "Experimental investigation on mechanical properties of hybrid fiber reinforced quaternary cement concrete," Journal of Engineered Fibers and Fabrics, vol. 10, no. 4, pp. 139-147, 2015. doi: 10.1177/155892501501000407

[44] Islam, T., Safiuddin, M., Roman, R.A., Chakma, B. and Al Maroof, A., "Mechanical Properties of PVC Fiber-Reinforced Concrete—Effects of Fiber Content and Length," Buildings, vol. 13, no. 10, pp. 1-19, 2023. doi: 10.3390/buildings13102666.

[45] Mastali, M. and Dalvand, A., "The impact resistance and

mechanical properties of self-compacting concrete reinforced with recycled CFRP pieces," Composites Part B: Engineering, vol. 92, pp. 360-376, 2016. doi: 10.1016/j.compositesb.2016.01.046

[46] Gupta, S.D., Aftab, M.S., Zakaria, H.M. and Karmakar, C., "Scope of improving mechanical characteristics of concrete using natural fiber as a reinforcing material," Malaysian Journal of Civil Engineering, vol. 32, no. 2, 2020. doi: 10.11113/mjce.v32.16204

[47] Razmi, A. and Mirsayar, M.M., "On the mixed mode I/II fracture properties of jute fiber-reinforced concrete," Construction and Building Materials, vol. 148, pp. 512-520, 2017. doi: 10.1016/j.conbuildmat.2017.05.034