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Research Article

Mechanical properties of kevlar and jute fiber reinforced concrete

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ABSTRACT

Concrete, due to its inherent brittleness, exhibits relatively low tensile strength. Fibers have been used extensively to improve their mechanical properties as they helped to reduce the crack width. Textile industries produce a lot of natural and synthetic fiber waste, which can be utilized to produce better-performing fiber-reinforced concrete. Therefore, in this study, a detailed experimental investigation has been carried out to study the compressive, tensile, and flexural properties of the Kevlar and jute fiber reinforced concrete. Concrete specimens with a mix design ratio of 1:1.43:1.89 and a water-cement ratio of 0.6 were cast. Jute fibers with lengths of 10 mm, 15 mm, and 25 mm and three different concentrations of 0.1%, 0.25%, and 0.5% by volume of concrete were used. In contrast, Kevlar fibers with lengths of 10 mm, 15 mm, and 20 mm and three different concentrations of 1%, 1.5%, and 2.5% by volume of concrete were used. It was found that both Kevlar and Jute fibers contributed positively towards controlling the crack initiation and propagation, suggesting using fibers in concrete for enhanced mechanical properties and performance.

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1. INTRODUCTION

Concrete is a brittle material exhibiting minor strains and deficient tensile capacity. To reduce the effect of this brittleness, incorporating short, discrete, discontinuous fibers into the concrete matrix has become increasingly popular [1]. The fibers used in concrete may be commonly classified as metallic, textile, and natural fibers [2]. The metallic fibers in concrete include steel, amorphous, etc. In contrast, textile and natural fibers include Kevlar, Jute, coconut, palm tree, etc.

It has been a well-established fact that when concrete is reinforced with short, discrete, and discontinuous fibers, the addition of fibers results in the formation of bridges across the crack, thus reducing the inherent brittleness associated with concrete. When the load is applied and cracks are formed, the randomly oriented fibers arrest the crack formation and propagation, thus improving strength and ductility [3]. It has been observed that the cracks of textile-reinforced concrete are thinner than those of steel-reinforced concrete, making the surface more durable [4].

Textile-reinforced concrete originated from a German institute focusing on Textile technology. The initial work on textile-reinforced concrete structures began in the 1980s. In 1982, the first patent for textile-reinforced concrete design was granted for transportation-related safety items meant to be reinforced with materials other than steel. In 1996, two concrete canoes using textile reinforcement were created by students of German University. In 1996, a boat competition, Concrete Canoe Regatta, was held in Dresden, Germany, during which the textile-reinforced concrete gained public attention [5].

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Walton and Majumdar [6] conducted an experimental investigation to study the properties of cement composites reinforced with Kevlar fibers under different curing conditions. Based on the study, it was found that Kevlar-reinforced concrete specimens exhibited good strength and ductility even in adverse environments.

Chaudhary conducted an experimental investigation to study the mechanical properties of Kevlar fiber-reinforced concrete (KFRC) [7]. For this purpose, KFRC, which has a fiber content of 2%, 4%, 6%, 8%, 10%, 12%, and 14%, was used in preparing concrete specimens. It was found that with the increase in the Kevlar fiber, the concrete compressive strength of up to 16% was observed.

Uchida et al. [8] also conducted an experimental investigation to study the mechanical properties of ultra-high-strength fiber-reinforced concrete using aramid fibers. Aramid fibers of different shapes and sizes were incorporated into the concrete mixture to examine the properties of fresh and hardened fiber-reinforced concrete. Based on the study, it was found that the concrete reinforced with aramid fibers of 3 mm length and 3% fiber content had the highest compressive and flexural strength when compared with different lengths and concentrations of aramid fibers.

Zakaria et al. [9] carried out an experimental study to examine the mechanical properties of jufiber-reinforced concrete (JFRC). For this purpose, jute fibers with lengths of 10 mm, 15 m, and 2 mm and three concentrations of 0.1%, 0.25%, 0.50%, and 0.75% were used to evaluate the compressive, tens,ile, and flexural strength. The concrete was prepared with two different ratios of cement/ sand/ brick chips (1:2:4, 1:1.5:3) and water/cement ratios (0.60 and 0.55). It was observed that for both ratios, the concrete compressive strength increased for the case of the concrete specimen having 15 mm jute fiber with 0.10% concentration. However, the concrete compressive strength decreased when fiber lengths of 20 mm and 25 mm with a fiber content of 0.25, 0.50 and 0.75% were used.

Dayananda et al. [10] also investigate the behavior of JFRC. The specimens were prepared with jute fibers having fiber concentrations of 0.5%, 1%, and 2% and were tested after 7, 28, 56, and 90 moist curings. It was observed that the concrete compressive strength decreased with the increase in the Jute content, and after 7 and 28 moist curing, the concrete compressive strength of the JFRC specimen decreased with the rise in jute content. However, the concrete compressive strength of Jute fibers increased when specimens were cured for 56 days, in the case of specimens with fiber contents of up to 1%. This trend of increase in compressive strength again shows a decline when the specimen was cured for 90 days.

Zhang et al. [11] investigated using jute fibers on the mechanical properties of high-strength concrete. It was observed that using the jute fibers in high-strength concrete proved to be efficient in reducing the micro-cracks and porosity and delaying the initiation and crack propagation. Kim et al. [12] investigated using regular strength and high-fluidity concrete using jute fibers. It was found that the influence of the use of the jute fiber was more prominent in the high fluidity concrete compared to the normal strength concrete when comparing compressive and tensile strength. Razmi and Mirsayar [13] invested in the fracture properties of JFRC specimens. Based on the detailed experimental investigation, it was found that the use of the jute fiber possesses a positive influence against crack growth in addition to the improved compressive and tensile splitting strength when compared with plain specimens. Rahman and Azad [14] investigated the impact of jute fiber length on the mechanical properties of concrete. He concluded that jute fibers with a length of 10 mm were most influential in increasing the concrete compressive and tensile strength compared to the plain concrete specimens. In contrast to the above findings, however, Faiq [15] concluded the decremental pattern in concrete compressive and tensile strength using the jute fibers.

Li et al. [16] investigated the influence of kevlar, carbon, and hybrid fiber-reinforced concrete specimens under static and quasi-static loading. It was found that using Kevlar fiber with carbon fiber significantly improved both static and dynamic compressive strength of concrete specimens as compared to when the specimens were prepared separately with Kevlar and carbon fibers. Li et al. [17] also investigated the influence of using Kevlar fibers in concrete specimens under static and high-rate loading. They found that the specimens prepared with 12 mm and 24 mm fiber lengths show similar static properties. However, under high rate loading, the specimens prepared with fibers having 24 mm length exhibited higher strain energies than those prepared with 12 mm fibers. Konczalski and Piekarski [18] investigated the influence of Kevlar fibers on the tensile properties of ordinary Portland cement and found that using Kevlar significantly improves the elastic modulus and fracture energy.

Pakistan, whose economy is mainly boosted by the export of its textile products, has an abundance of textile-related wastage, which, if not correctly recycled, goes to already polluted landfills. Therefore, this investigation studies the uniaxial compressive, splitting tensile, and flexural tensile strength of Kevlar and JFRC. Furthermore, the influence of jute and kevlar fiber lengths and percentage of fiber content (by volume) on the properties of jute and KFRC was also studied. As discussed above, few studies have focused on using jute and Kevlar fibers in concrete.

2. MATERIALS AND METHODS

2.1. Kevlar Fiber Reinforced Concrete Specimens

The investigation presented herein aims to investigate the mechanical properties (compression and tension) of concrete reinforced with Kevlar fibers. For this purpose, concrete was prepared with Kevlar, which has fiber lengths of 10 mm, 15 mm, and 20 mm. Furthermore, to study the influence of the fiber quantity on the mechanical properties of concrete, three different concentrations of Kevlar fibers, 1%, 1.5%, and 2.5% concentration by volume of concrete were used in concrete casting.

To study the behavior of KFRC under uniaxial compression and splitting tensile, cylinders having a diameter of 100 mm and height of 200 mm were used and tested as per C39

Table 1. Constituents of concrete mix

Constituent	Quantity
Water	272.4 kg/m^3
w/c ratio	0.6
Coarse aggregates	858 kg/m^3
Fine aggregates	649 kg/m^3
Cement	454 kg/m^3
Super plasticizer	222 mL

Table 2. Physical properties of coarse and fine aggregates

Properties	Coarse aggregates	Fine aggregates
Loose density	1886 kg/m^3	2002 kg/m^3
Saturated bulk specific gravity	2.66	2.4
Dry rodded density	1905 kg/m^3	2120 kg/m^3
Absorption	0.78	0.968

and C496 ASTM Standards [19, 20], whereas prisms having a cross-section of 75 mm × 75 mm and length of 300 mm were used to study the flexural behavior as per C78 ASTM standard [21]. A total of sixty (60) cylindrical specimens, 30 each for uniaxial compression and splitting tension, were cast such that three specimens for concrete without Kevlar fibers and a set of 3 for each fiber length and fiber concentration. Similarly, 30 prism specimens with varying percentages and concentrations of Kevlar fibers used for compression and splitting tensiles were also cast and tested under three-point bending.

The specimens used in this study were prepared with concrete with a mix proportion of 1:1.43:1.89 and a water-to-cement ratio (w/c) of 0.6. The details of the concrete mix are provided in Table 1. The concrete was prepared with ordinary Portland cement coarse and fine aggregates. As discussed above, percentages and concentrations were used for specimens with Kevlar fibers. The physical properties of coarse and fine aggregates and the chemical properties of the ordinary Portland cement used in the study are provided in Table 2 and Table 3, respectively. The Kevlar fibers used in this study have a yarn count of 20/2 NeC, 1440 kg/m^3 tensile modulus density, and tenacity of 70500 MPa and 2920 MPa, respectively. All specimens were tested after 28 days of moist curing as per ASTM standards [19].

2.2. Jute Fiber Reinforced Concrete Specimens

Uniaxial compression and splitting tension tests were carried out per ASTM standards to study the mechanical properties of concrete made with jute fibers. Cylinders with a diameter of 100 mm and a height of 200 mm were used and tested as per ASTM Standards.

The specimens were cast from concrete, having a mixed proportion of 1:1.43:1.89 and a w/c of 0.6. Initially in yarn or twine form, a locally available jute was used for preparing concrete with three different yarn lengths of 10 mm, 15 mm, and 25 mm and three different concentrations of 0.1%, 0.25%, and 0.5%. In total, sixty (60) specimens were cast out of which

Table 3. Chemical composition of cement

Component	Content (%)
Lime (CaO)	60.9%
Silica (SiO_2)	20.8%
Alumina (Al_2O_3)	5.1%
Iron Oxide (Fe_2O_3)	3.2%
Magnesia (MgO)	3%
Sulphur trioxide (SO_3)	1.7%

Table 4. Properties of Jute yarn used in preparing concrete specimens

Parameters	3-Plied yarn
Diameter (mm)	0.1
Weight (lb)	0.27
Spindle count (lb / one spindle of 14400)	77
Linear density (tex)	2651
Count (Ne)	0.22
Twist per inch (TPI)	1.87
Moisture content (%)	2.76
Moisture regain (%)	2.85
Force (N)	366
Extension (%)	6.04
Stress value (N/ m^2)	28152307
Strain value	0.06
Elastic modulus (GPa)	0.46

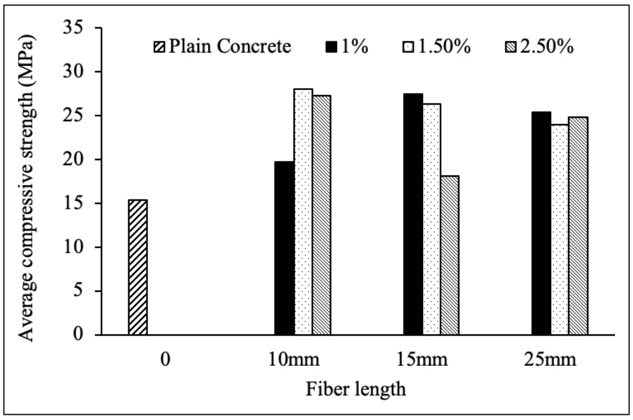

Figure 1. Relationship exhibiting the influence of the fiber volume and length on the average compressive strength of KFRC specimens.

27 cylinders were used for uniaxial compression tests and 27 for the splitting tensile test. Three specimens were cast and tested for each fiber length and volume after 28 days of moist curing. Plain concrete specimens 3 for each compressive and tensile testing were also used for comparison.

Two different types of jute yarn in twine were locally available: 3-plied and 4-plied. The three plied twine yarns were used in the experimental program, and their properties are provided in Table 4. The properties of the 3-plied yarn were determined as per ASTM standards [14].

Table 5. Average uniaxial compressive strength of KFRC

	Fiber length				Fiber length		
	0	10 mm	15 mm	25 mm	10 mm	15 mm	25 mm
	Average concrete compressive strength (MPa)				% Increase w.r.t Plain concrete		
Fiber percentage							
0%	15.35	–	–	–	–	–	–
1%	–	19.8	27.5	25.3	28.70	79.3	65.1
1.50%	–	28.1	26.3	24.0	82.9	71.3	56.5
2.50%	–	27.3	18.1	24.8	77.8	18.1	61.6

Table 6. Average splitting tensile strength of KFRC

	Fiber length				Fiber length		
	0	10 mm	15 mm	25 mm	10 mm	15 mm	25 mm
	Average splitting tensile strength (MPa)				% Increase w.r.t. Plain concrete		
Fiber percentage							
0%	1.81	–	–	–	–		
1%	–	2.32	1.56	1.53	28.2	-13.8	-15.5
1.50%	–	2.35	2.14	1.62	29.8	18.2	-10.5
2.50%	–	2.30	1.63	2.72	27.1	-9.9	50.3

3. RESULTS AND DISCUSSION

Results of experimental investigations carried out during the study on KFRC and JFRC are presented in terms of uniaxial compressive strength, splitting tensile strength, and flexural tensile strength.

3.1. Kevlar Fiber Reinforced Concrete Specimens

3.1.1. Compressive Strength

The concrete compressive strength of plain concrete and KFRC specimens prepared with different fiber contents and fiber lengths are shown in Figure 1. In general, the positive influence of the use of the Kevlar fibers was observed on the concrete compressive strength as the specimens having Kevlar fibers exhibited higher compressive strength as compared to the plain concrete without any fibers, irrespective of the fiber lengths and fiber content used in preparing concrete specimens. An increase in concrete compressive strength was observed in specimens with the increase in the fiber contents for 10 mm long Kevlar fibers. In contrast, it was the opposite for 15 mm fibers, as concrete specimen strength decreased with increased fiber content. However, when a fiber length of 25 mm was used, the effect of fiber content was insignificant as almost similar strengths were observed. Maximum strength was obtained when 10 mm fibers were used at 1.5% content by volume. Strengths in a similar range were observed for the cases of 10 mm fibers at 2.5% and 15 mm fibers at 1%.

Table 5 compares the concrete compressive strength of specimens with 1%, 1.5%, and 2.5% Kevlar fibers concerning the plain concrete specimens. Maximum strength gain compared to plain concrete without fibers was 78% to 83% for the cases mentioned in the preceding paragraph. This shows a significant increase in the compressive strength of KFRC, and it can be implied that Kevlar fibers can be used in concrete to improve its stability.

Figure 2 shows the failure patterns exhibited by KFRC specimens under uniaxial compression. It was observed that, as expected, the plain concrete specimen under uniaxial compression exhibited excessive crushing before failure. However, with the addition of Kevlar fibers, a significant reduction in crushing was observed with the failure of the specimen, resulting in the rupture of junk pieces from the concrete specimen, as seen in Figure 2.

3.1.2. Splitting Tensile Strength

The experimentally exhibited splitting tensile strengths of plain and KFRC specimens are shown in Figure 3. Figure 3 shows that, in general, KFRC specimens exhibited higher splitting tensile strength than plain concrete specimens. It was also observed that no definite relationship was demonstrated between the fiber content and length of Kevlar fibers on the tensile strength of the KFRC specimens.

It was further observed that the inclusion of the fibers positively influences the splitting tensile strength of the concrete for all the percentages of 10 mm long fibers, 1.5% of 15 mm long fibers, and 2.5% of 25 mm long fibers. For the case of 10 mm long fibers, the gain in splitting tensile strength was similar, showing no effect on the percentage of fibers used.

In addition to the strength, the inherent brittleness of concrete was also improved as the inclusion of the fibers

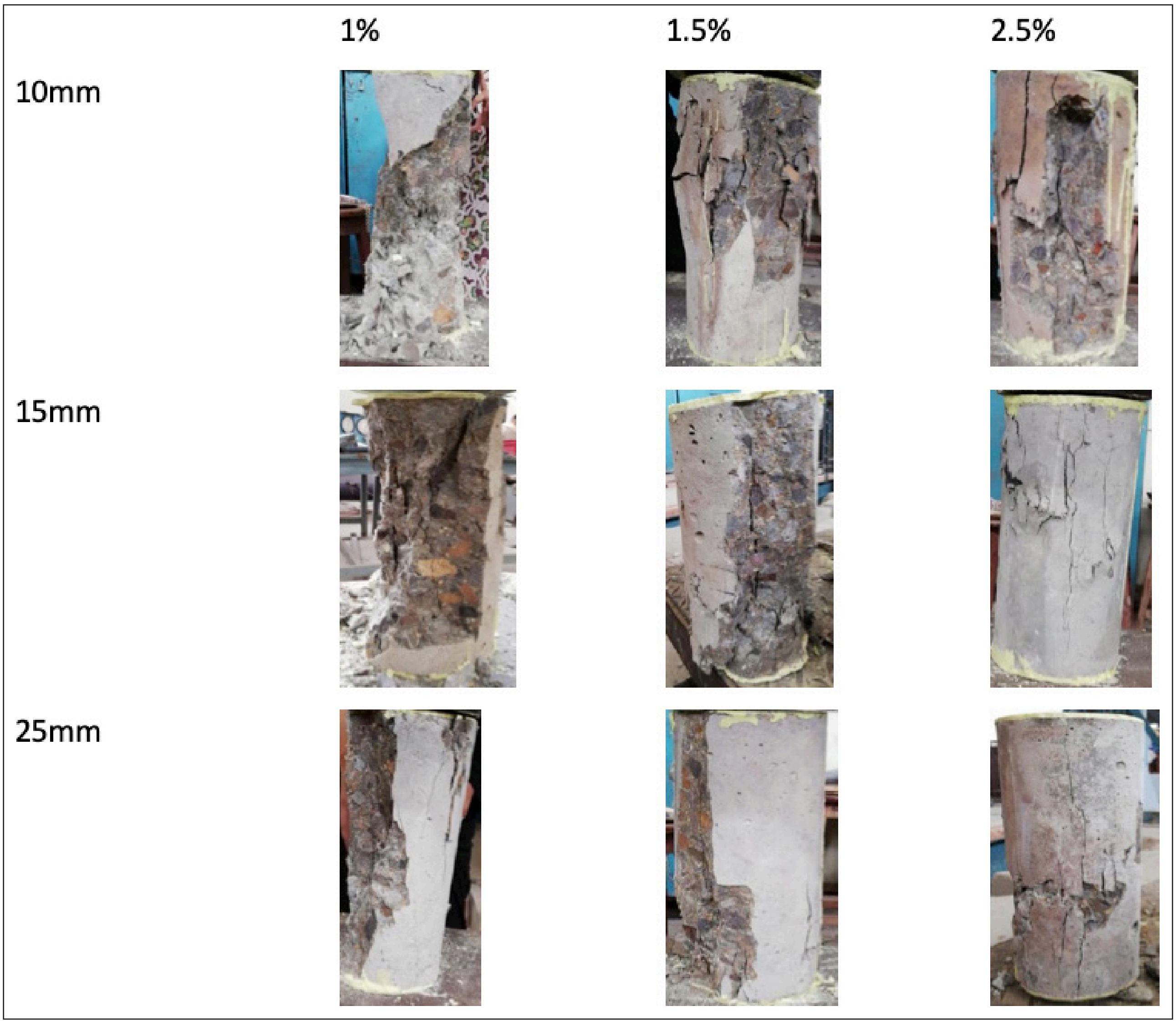

Figure 2. Failure pattern exhibited by KFRC specimens made with different fiber content and fiber lengths under uniaxial compression.

delayed the failure of the specimen, as several cracks were observed before complete failure, reflecting the effectiveness of the Kevlar fibers used. The failure pattern of the KFRC specimens under splitting tensile can be seen in Figure 4.

Table 6 compares the concrete splitting tensile strength of KFRC with 1%, 1.5%, and 2.5% Kevlar fibers concerning the plain concrete specimens. Maximum strength gain compared to plain concrete without fibers was 30% to 50% for the cases mentioned in the preceding discussion. This shows a significant increase in the splitting tensile strength of KFRC, and the use of Kevlar fibers delayed the initiation of cracking and, ultimately, the failure.

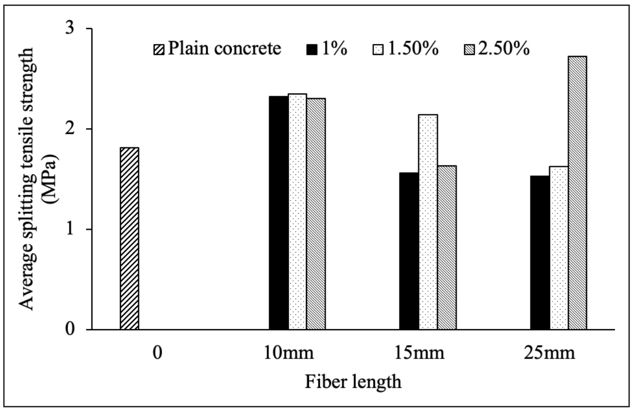

Figure 3. Relationship exhibiting the influence of the fiber volume and length on the average splitting tensile strength of KFRC specimens.

3.1.3. Flexural Tensile Strength

The flexural strengths of the plain concrete and KFRC specimens are shown in Figure 5. It was found that Kevlar fibers significantly reduced the concrete flexural strength, irrespective of the fiber contents and fiber lengths used in preparing the specimens when compared with the plain concrete specimens. Only marginal gain in strength was noted in the case of 25 mm fibers at 1% and 1.5% concentration.

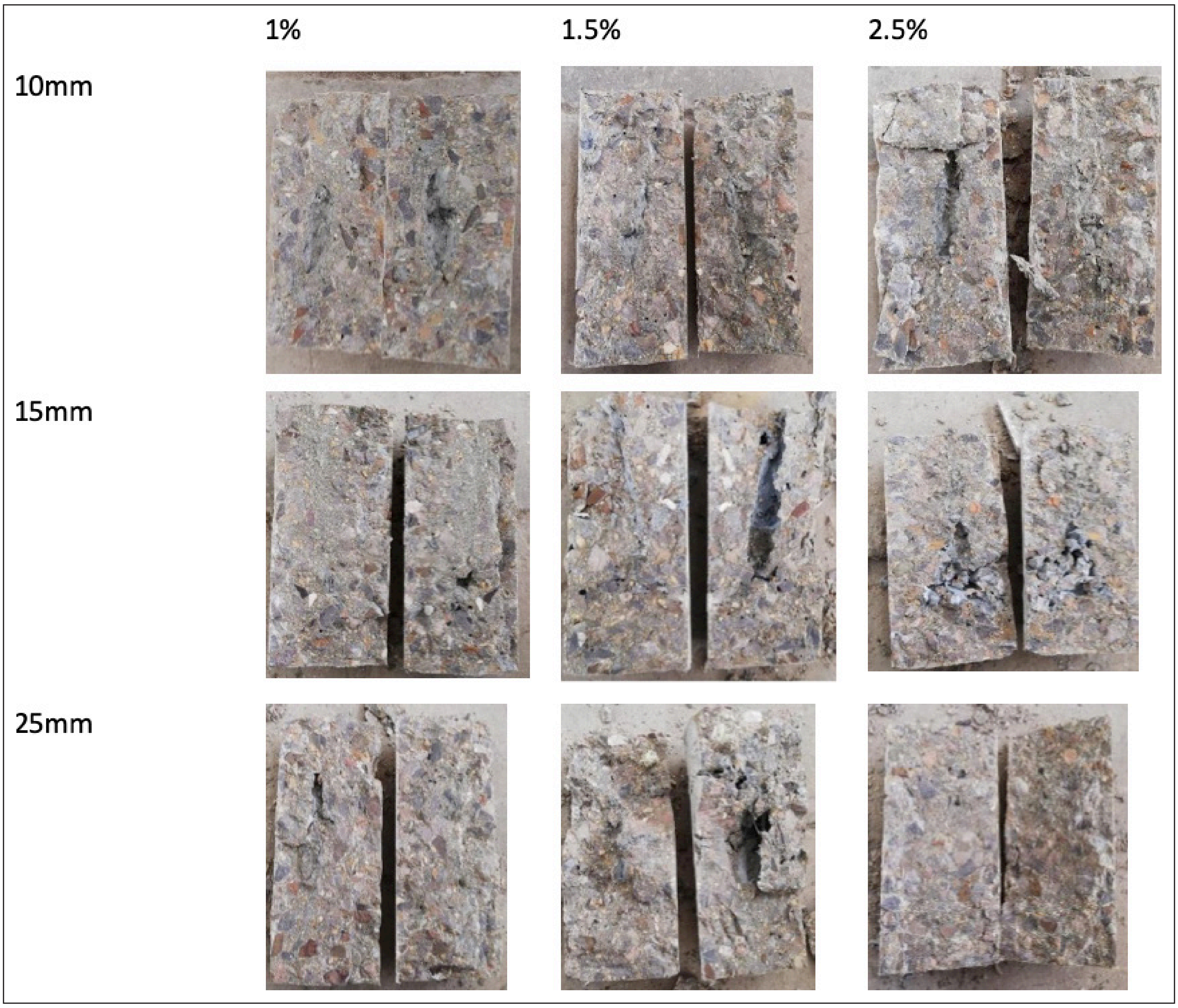

Figure 4. Failure patterns were exhibited by KFRC specimens made with different fiber content and fiber lengths under splitting tensile.

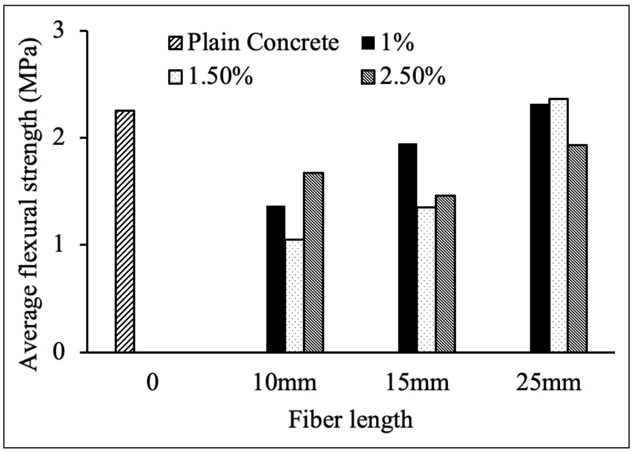

Figure 5. Relationship exhibiting the influence of the fiber volume and length on the average flexural strength of KFRC specimens.

Table 7 compares the concrete flexural strength of specimens with 1%, 1.5%, and 2.5% Kevlar fibers concerning the plain concrete specimens. In general, no significant influence of Kevlar fibers used in the study was observed on the flexural strength of the specimens investigated when compared with plain concrete specimens, except 25 mm fibers specimens having fibers content of 1.0% and 1.5%, in which a marginal increase of 2.7% and 4.9% respectively was observed in the flexural strength. This is in contrast to the splitting tensile strengths observed. This may be due to the uneven distribution of Kevlar fibers during the casting of specimens to be tested in flexure, as the gain in strength and overall behavior of fiber-reinforced concrete depends on the uniform distribution of fibers in concrete.

3.2. Jute Fiber Reinforced Concrete Specimens

3.2.1. Compressive Strength

The compressive strength of plain concrete and JFRC specimens is shown in Figure 6. As can be seen, in general, using the Jute fibers in concrete proved beneficial in increasing the concrete compressive strength irrespective of the fiber length and concentrations used in preparing the

Table 7. Average flexural strength of KFRC

	Fiber length				Fiber length		
	0	10 mm	15 mm	25 mm	10 mm	15 mm	25 mm
	Average flexural strength (MPa)				% Increase w.r.t Plain concrete		
Fiber percentage							
0%	2.25	–	–	–	–		
1%	–	1.37	1.95	2.31	-39.1	-13.3	2.7
1.50%	–	1.05	1.35	2.36	-53.3	-40.0	4.9
2.50%	–	1.67	1.46	1.953	-25.8	-35.1	-13.3

Table 8. Average uniaxial compressive strength of JFRC

	Fiber length				Fiber length		
	0	10 mm	15 mm	25 mm	10 mm	15 mm	25 mm
	Average compressive strength (MPa)				Increase w.r.t Plain concrete		
Fiber percentage							
0%	14.82	–	–	–	–	–	–
0.1%	–	26.75	38.44	25.77	80.50	159.4	73.9
0.25%	–	25.97	36.79	22.83	75.2	148.2	54.0
0.50%	–	25.25	28.32	22.45	70.4	91.1	51.5

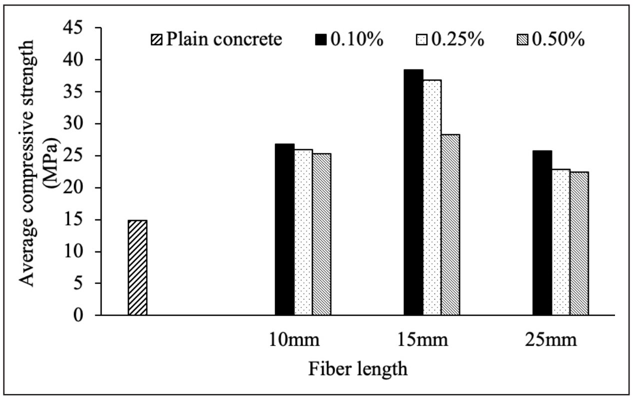

Figure 6. Relationship exhibiting the influence of the fiber volume and length on the average compressive strength of JFRC specimens.

Figure 7. Typical failure pattern exhibited by **(a)** plain concrete and **(b)** JFRC specimens under uniaxial compression.

specimens. However, the gain in strength reduces with the increase in fiber content for all lengths. A maximum increase in the concrete compressive strength was observed for specimens with Jute fibers with a length of 15 mm at all concentrations of fibers. Strength gain is reduced with the increase in the percentage of fibers used. A similar trend was observed when 10 mm and 25 mm fiber lengths were used, with the highest strength at 0.1%. Reduction in strength for 0.25% and 0.5% fibers was found to be marginal compared to 0.1% fibers, indicating that the influence of the percentage of fibers used is insignificant for 10 mm and 25 mm long fibers.

Table 8 compares the concrete compressive strength of specimens with 0.1%, 0.25%, and 0.5% jute fibers concerning the plain concrete specimens. Maximum strength gain compared to plain concrete without fibers was 159% to 148% for 15 mm long fibers at 0.1% and 0.25% fiber contents, respectively. For fiber lengths of 10 mm and 25 mm, gain in strength is in the range of 51% to 80%, which is less than strength gain for 15 mm fibers but is still significant. This significant increase in the compressive strength of JFRC demonstrates that jute fibers can be used in concrete to have performance in terms of compressive strength.

The increase in concrete compressive strength with the inclusion of the Jute fibers may be attributed to the fact that plain concrete specimens under uniaxial compression fail due to excessive lateral deformations, resulting in concrete crushing, as seen in Figure 7. However, the inclusion of the

Table 9. Average splitting tensile strength of JFRC

	Fiber length				Fiber length		
	0	10 mm	15 mm	25 mm	10 mm	15 mm	25 mm
	Average tensile strength (MPa)				% Increase w.r.t Plain concrete		
Fiber percentage							
0%	2.01	–	–	–			
0.1%	–	3.47	3.12	3.46	72.6	55.2	72.1
0.25%	–	3.66	2.35	2.78	82.1	16.9	38.3
0.50%	–	2.85	3.79	3.28	41.8	88.6	63.2

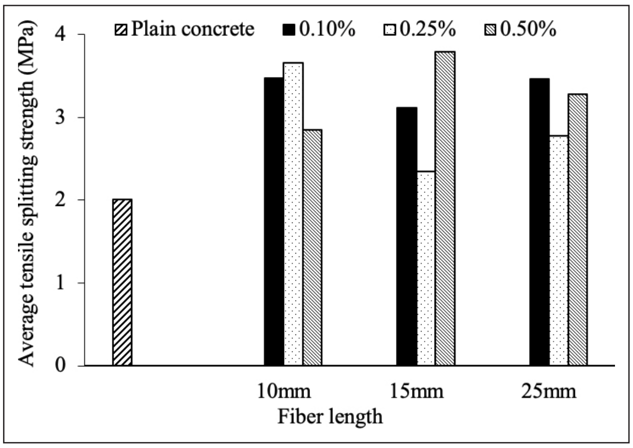

Figure 8. Relationship exhibiting the influence of the fiber volume and length on the average splitting tensile strength of JFRC specimens.

Figure 9. A typical failure pattern is exhibited by **(a)** plain concrete and **(b)** JFRC specimens under tensile splitting.

Jute fibers controlled excessive lateral deformations. As such, a higher magnitude of the force is required to fail the specimen, thus increasing the concrete compressive strength.

3.2.2. Splitting Tensile Strength

The splitting tensile strength of plain and JFRC specimens is shown in Figure 8. In general, it was found that with the addition of the Jute fibers, the splitting tensile strength also increased irrespective of the length of fibers and their percentages. However, no definite relationship was observed between the fiber lengths and concentration on the splitting tensile strength of concrete with the addition of the jute fibers.

For 10 mm long fibers, tensile strength was almost similar, at 0.1% and 0.25%, while it decreased by 0.5%. For 15 mm and 25 mm long fibers, strength decreased at 0.25% and then increased again at 0.5%. Strengths for 15 mm and 25 mm fibers were almost similar.

Table 9 compares the splitting tensile strength of specimens with 0.1%, 0.25%, and 0.5% jute fibers concerning the plain concrete specimens. Maximum strength gain compared to plain concrete without fibers was 89% in 15 mm fibers at 0.5%, followed by 82% in 10 mm fibers at 0.25%, 72.6 in 10 mm fibers at 0.1%, and 72.1% in 15 mm fibers at 0.1%. The minimum strength gain was 17% in 15 mm fibers at 0.25%. Gain in splitting tensile strength followed a trend similar to the one KFRC and again indicated that using Jute fibers delayed the initiation of cracking in tension and, ultimately, the failure.

Figure 9 shows the typical failure pattern of plain concrete and JFRC specimens with different fiber content and lengths under tensile splitting. As can be seen with the inclusion of the fibers, the number of cracks increases on the surface, indicating that higher resistance to tensile cracking was provided by the jute fibers used in concrete specimens, which was delayed, and the cracks were fine and distributed.

4. CONCLUSIONS

The investigation presented aimed at studying the behavior of JFRC and KFRC specimens under uniaxial compression, splitting tension, and flexure. Based on the detailed experimental investigation, it was observed that adding Kevlar fibers increased the compressive, tensile, and flexural strength of concrete specimens when compared with plain concrete specimens. In this investigation, the effect of the Kevlar and Jute fibers on the compressive and tensile strengths was studied using varying lengths of the fibers, the fiber content, and the volume of concrete. Conclusions drawn from the study are as follows:

- The use of Kevlar and Jute fibers in concrete was found to have a positive influence on the compressive and tensile (splitting and flexural) strengths of concrete.

- For KFRC, fibers of 10 mm length performed better under uniaxial compression and splitting tension. No strength gain was noted in flexural tension for all the fiber lengths and proportions. Therefore, using 10 mm long fibers at 1.5% content by volume is recommended for KFRC.
- For JFRC, fibers of 15 mm length performed better under uniaxial compression, while fibers of 10 mm and 15 mm length performed better-splitting tension. Therefore, 10 mm and 15 mm long fibers at 0.1% content by volume are recommended for use in JFRC.
- Both Kevlar and Jute fibers contributed positively towards controlling the crack initiation and propagation compared to plain concrete specimens, suggesting using fibers in concrete for enhanced mechanical properties and performance.

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ETHICS

There are no ethical issues with the publication of this manuscript.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

FINANCIAL DISCLOSURE

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USE OF AI FOR WRITING ASSISTANCE

Not declared.

PEER-REVIEW

Externally peer-reviewed.

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