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Effect of Jute Fibre Reinforcement on Shear Strength of Concrete

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P A P E R I N F O

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A B S T R A C T

This research work examined the effect of jute fibre on the shear strength of concrete. Fibre volume fractions of 0%, 0.25%, 0.5%, and 0.75% for grades 25, 30, 35 and 40 N/mm^2 respectively were used. A total of 32 beams and 96 cubes were prepared. 16 beams and 48 cubes were cured at room temperature for 28 days, while the other 16 beams and 48 cubes were cured for 28 days and kept for a period of 6 months to be observed for durability with respect to strength after testing. All the beams were tested under three-point loading system with a shear span, av = 2.5d. The results of the compressive strength showed that concrete made with 0.5% jute fibre for 28 days and 6 months gave percentage increase in compressive strength by 12%, 12.5%, 9.7% and 10.1% for grades 25, 30, 35 and 40 N/mm^2 respectively compared to the control samples. Percentage increase in shear strength were by 24.5%, 16.1%, 27.9% and 16.5% for concrete grades 25, 30, 35 and 40 N/mm^2 respectively compared to the control samples. The addition of the fibre to the concrete slightly reduced the workability of the concrete and increased the crack resistance of concrete.

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INTRODUCTION

In view of the poor tensile strength of concrete, concrete is generally known to collapse and crumble abruptly under flexure (in the absence of reinforcement). This has brought about the conventional reinforcement of concrete using steel rebar to take care of the tensile force acting below the neutral axis as well as the shear along the section. In most developing nations, it is, however, expensive for many people however, due to the sudden nature of shear failure without warning, many researchers consider natural fibres an alternative to steel fibre to enhance the shear properties of concrete. Natural fibres are widely available in tropical areas, and when used in building, they can lower costs and boost efficiency [1]. The increasing demand for sustainability in the building sector emphasizes the need of employing natural materials in the production of concrete. Plant-based natural fibres are low-cost renewable materials that have the potential to help sustainable development in both urban and rural areas [2]. Concrete is an important building material all around the world however, the use of concrete as a structural material is due to flaws such as brittleness, low tensile strength and resistance to impact strength, fatigue, and low ductility [3]. Fibre addition to concrete is thought to be a good approach for increasing tensile strength, fatigue resistance, toughness, and ductility. Although natural fibres do not prevent fracture development, they rather reduce crack propagation [4].

Steel rebar, though conventionally used as reinforcement in concrete, has not been found cost effective for many in most developing nations. The amount of rebars used can be reduced and the performance of reinforced concrete elements also greatly improved if the strength and quality of the concrete matrix is improved by the use of natural fibres especially for the purpose of inhibiting crack generation and propagation in the matrix. [1]. Fibre reinforcement is one of the methods which has been discovered to improve the strength and cracking characteristics/toughness of concrete. Though various types of fibres have been explored and utilized in the production of fibre-

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reinforced-concrete, fibres with the best prospects in tropical Africa and other developing countries of the world are natural fibres. In tropical areas, natural fibres are accessible in large quantities which when utilized will reduce the cost of construction and enhance performance [1].

Concrete shear strength is its capacity to withstand forces that cause one part to slide relative to another at an internal plane. Shear strength is affected by the grade of concrete, the number of fibres, and the percentage of tension steel in beams [5]. Shear failures in concrete beams are usually caused by the formation of diagonal cracks near the support, provided there is no shear reinforcement. Beams fail suddenly upon the formation of critical cracks in the high-shear region near the concrete beam supports. Any time the value of the actual shear stress exceeds the permissible shear stress of the concrete used, shear reinforcement must be provided. The purpose of shear reinforcement is to prevent failure in shear, and to increase beam ductility, and subsequently, the likelihood of sudden failure will be reduced. Shear failure of reinforced concrete beams is usually sudden and occurs without sufficient warning. This type of shear failure is considered a high-risk type of failure. The cost and safety of shear reinforcement in reinforced concrete beams has led to the study of other alternatives. Due to the sudden nature of shear failure, designers try to avoid the shear mode of failure when designing reinforced concrete beams [6]. Fibres generally improve the structural integrity of concrete and are usually used in concrete to control cracking due to plastic and drying shrinkage. It also produces greater impact and abrasion resistance and the use of micro fibres gives a better impact resistance to the concrete [7].

According to some researchers, the density of jute fibre reinforced concrete was slightly reduced by the addition of jute fibre to the mix. The experimental result shows that 0.5 % volume fraction of jute fibre was considered the optimal percentage for this type of concrete with respect to the highest compressive strength. The percentage increase when compared to the control sample at 28 days compressive strength was found to be 10.2 %. While a 0.75 % volume fraction of jute fibre is considered the optimal percentage with respect to the highest tensile strength. A percentage increase of 68.13% was found at 28 days tensile strength using a fibre volume fraction of 0.75% [8]. The addition of fibre reinforcement to concrete has now been considered an effectual way to achieve the global demand for sustainable development, due to their sustainability, bio-degradability, and environmental friendliness, natural fibres are preferred as compared to synthetic fibres [9]. According to findings, adding 1% sisal fibre to concrete increases the compressive and shear strengths by 16.9% and 9.5%, respectively, when compared to normal concrete. It was also reported that the inclusion of sisal fibre in the concrete increased the concrete resistance to cracking [10]. Though little or no attention has been drawn to the shear strength of natural fibre-reinforced concrete, it is obvious that the shear resistance of a fibre-reinforced concrete would may be high or greater than that of normal concrete of corresponding compressive strength. Therefore, this study aims to investigate the effect of jute fibre on the shear strength in concrete to aid proper specification when in use.

MATERIALS AND METHODS

Materials

Dangote Portland Limestone Cement (PLC) grade 42.5 conforming to British standard [11], fine aggregate passing British Standard (BS) sieve size of 5mm, coarse aggregate of crushed granite ranging between 10mm – 20mm maximum aggregate size, Jute fibre reinforcement, high yield 12mm and 8mm reinforcement and portable drinking water free from impurities were all used in this research work.

Mixing of concrete and specimens' preparation

The mixing of the composite materials (cement, fine and coarse aggregate, jute fibre and water) was carried out by manual hand, and the batching is by weight and grade 25-40N/mm^2 was used for the jute fibre reinforced concrete beams and cubes. All the materials, i.e., fine and coarse aggregate, cement, water, and fibre, were measured as per the different grade of concrete using a weighing scale. The fine aggregate was first measured, followed by the cement in the right proportion. The fine aggregate and cement were thoroughly mixed to achieve a homogeneous mixture before the measured fibres were added, and they were dispersedly oriented and spread evenly to prevent balling when water was added. The coarse aggregate was the last material to be added and thoroughly mixed before the water measured was added and finally mixed to produce jute fibre-reinforced concrete. The jute fibre reinforced concrete beams, cubes and percentage of fibres are shown in Tables 1, 1a and 2, 2a. Each of the beam is reinforced with 2Y12 reinforcement at the bottom.

Table 1. Showing percentage of Jute fibre, grades of concrete and total number of beams.

Jute fibre volume fraction	Grade of concrete			
	25N/mm^2	30N/mm^2	35N/mm^2	40N/mm^2
0%	1 beam	1 beam	1 beam	1 beam
0.25%	1 beam	1 beam	1 beam	1 beam
0.5%	1 beam	1 beam	1 beam	1 beam
0.75%	1 beam	1 beam	1 beam	1 beam
Total of 16 beams	4 beams	4 beams	4 beams	4 beams

Table 1a. Showing percentage curing period and numbers of beams.

Curing age	No. of beams
28 days	16 beams
6 months	16 beams
Grand total	32 beams

Table 2. Showing the percentage of Jute fibre, grades of concrete and total number of cubes

Fibre volume fraction /grades of concrete	No. of cubes
0 % (25-40n/mm^2)	12 cubes
0.25% (25-40n/mm^2)	12 cubes
0.5% (25-40n/mm^2)	12 cubes
0.75% (25-40n/mm^2)	12 cubes
Total	48 cubes

Table 2a. Showing percentage curing period and numbers of beams

Curing age	No. of beams
28 days	48 beams
6 months	48 beams
Grand total	96 beams

Methods

Specific gravity of fine and coarse aggregate was determined according to British standard [12], workability and density of concrete was determined according to British standards [13, 14], the concrete compressive strength was tested according to ASTM [15], the jute fibre and steel reinforcement tensile strength were determined according to British standard [16, 17].

The beam shear test was carried out according to British standard [17]. The beam was subjected to three-point loading system with a shear effect span/effective depth ratio of 2.5. The load was applied gradually until the beam fail in shear. Figure 1 shows the loads detail of reinforced concrete beam.

RESULTS AND DISCUSSION

Specific gravity

The fine and coarse aggregate have a specific gravity of 2.65 and 2.75, respectively which fall between the ranges of 2.5 to 3.0 as recommended [18].

Jute fibre and steel reinforcement tensile strength

Table 3 summarized the result of the tensile strength test of jute fibre which agreed to the test result conducted by

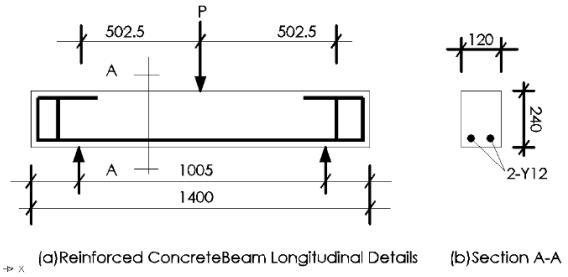

Figure 1. The detail of reinforced concrete beam

Da Costa Santos and Archbold [19], they had a tensile strength of 362N/mm^2.

From the test conducted of Y12mm the average yield strength of the reinforcement is 397.85N/mm^2 and the ultimate strength is 409.86N/mm^2, which is below the target strength of 460N/mm^2 as specified in British standard [17] for high yield reinforcement.

Workability and density of concrete

This shows that the slump test results for both normal and Jute fibre reinforced concrete (JFRC) fall between low and medium workability as indicated in Figure 2.

The density of concrete ranges between 2300 and 2400kg/m^3 for cubes made from the same sample of concrete as stated in the British standard [13], which

Table 3. Tensile strength of jute fibre

Sample	Tensile Strength (N/mm^2)	Young Modulus (N/mm^2)	Elongations (%)
A	365	0.0107	12.9
B	355	0.01	12
C	362	0.01	11
Average	360.67		

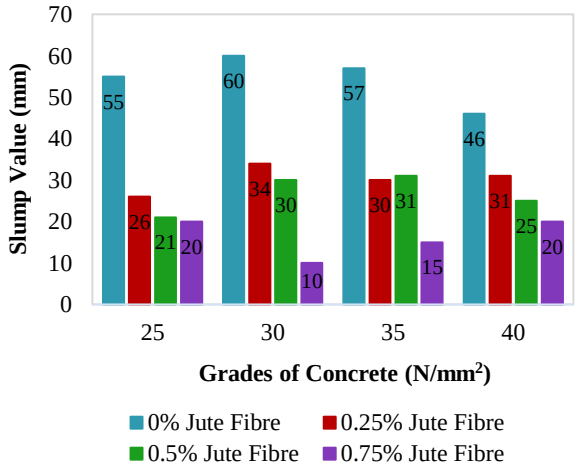

Figure 2. The difference in workability values for different grades of concrete and fibre percentage using slump test

implies that the density of the concrete from the experimental results falls within the standard (see Table 4).

Compressive strength

The experimental results show that concrete made with jute fibre has a higher compressive strength at a 0.5% jute fibre volume fraction compared to normal concrete. The strength of concrete made with jute fibre had an average percentage increase of 12%, 12.5%, 9.7%, and 10.1% for concrete grade 25–40 N/mm^2. This implies that the addition of jute increased the compressive strength of concrete, as shown in Figure 3. The second batch of the cubes was kept for an observation period of six months before crushing, and the result obtained was similar to the results of the 28-day compressive strength test, which implied the durability nature of jute fibre in concrete, since the strength was maintained over the period of six (6) months (see Figure 4).

Shear failure of beam

The Jute fibre and the conventional concrete beams were all subjected to a three-point loading test, and all of them failed when a diagonal tension/shear crack developed (see Figure 5). However, the failure behaviour of

Table 4. Density of concrete for normal and Jute fibre concrete (kg/m^3)

Fibre volume fraction	Grades of Concrete (N/mm^2)			
	25	30	35	40
0% Jute fibre	2405	2412	2416	2426
0.25% Jute fibre	2357	2362	2402	2378
0.5% Jute fibre	2389	2344	2397	2345
0.75% Jute fibre	2365	2410	2368	2409
Percentage difference between the highest and lowest density	1.99%	2.82%	1.98%	3.34%

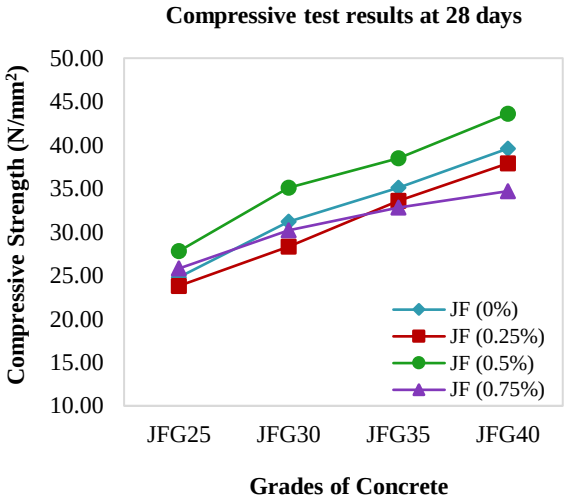

Figure 3. Compressive strength values for different grades of concrete and fibre percentage at 28 days

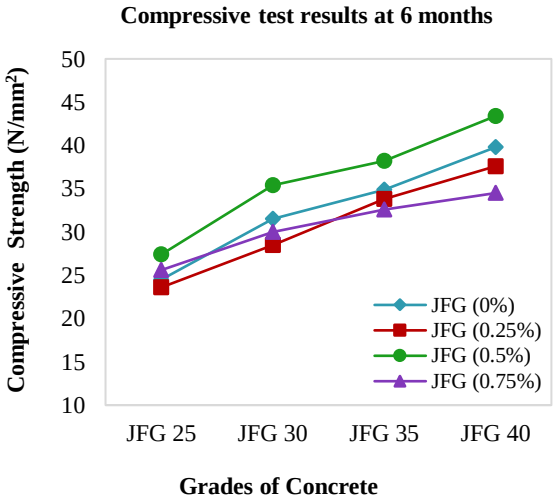

Figure 4. Compressive strength values for different grades of concrete and fibre percentage at 28 days

Figure 5. The diagonal crack developed during the Shear beam test

conventional concrete and that of the jute fibre reinforced concrete beams differed slightly. The shear failure of the conventional concrete occurred practically instantly following the development of the diagonal tension crack. The failure of the jute fibre reinforced concrete beams, on the other hand, was slow and gentle because of the fibre content, which formed a resistance and slowed down the crack propagation.

Shear strength results

The results of the shear strength of jute fibre-reinforced concrete show that the peak shear strength was achieved at 0.75% of jute fibre as compared to 0% in the control sample. The percentage increase in shear strength was 24.5%, 16.1%, 27.9%, and 16.5% for concrete grade 25–40 N/mm^2 with jute fibre reinforcement, respectively, compared to the control samples as shown in Figure 6. Figure 7 also shows the shear strength of the jute fibre-reinforced concrete beams that were kept for 6 months before testing, and it was observed from the result that there is no reduction in the strength of the concrete. A theoretical calculation was carried out based on the equation provided by British standard [20] for the calculation of the shear capacity of concrete without shear reinforcement, and the result was compared with the shear strength test results as obtained from the experiment. It was observed that the result fell within the limit provided by the concrete shear capacity equation in British standard [20], for normal concrete and higher for jute fibre reinforced concrete (Figure 8). Figure 9 shows the comparison in the test results for 28 days and 6 months.

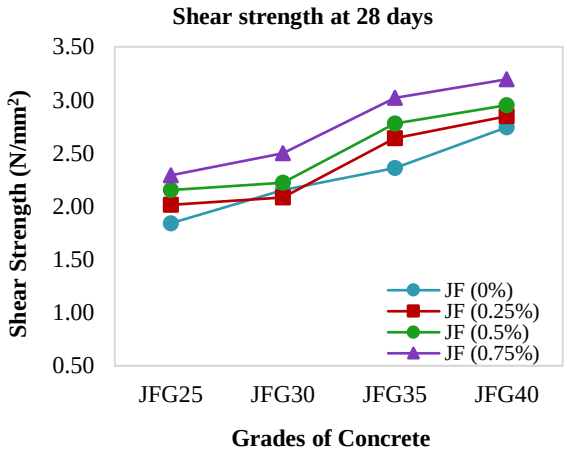

Figure 6. Shear strength test results of jute fibre reinforced concrete for 28 days

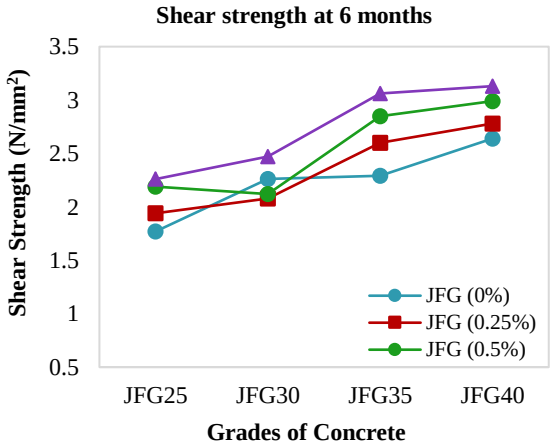

Figure 7. Shear strength test results of jute fibre reinforced concrete for 6 months

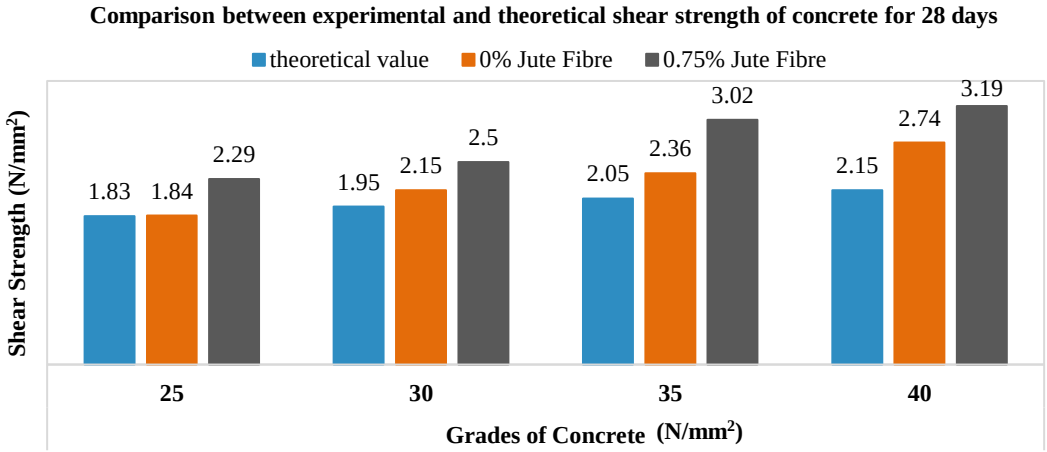

Figure 8. Comparison between the experimental shear strength test results and the theoretical shear strength results of concrete

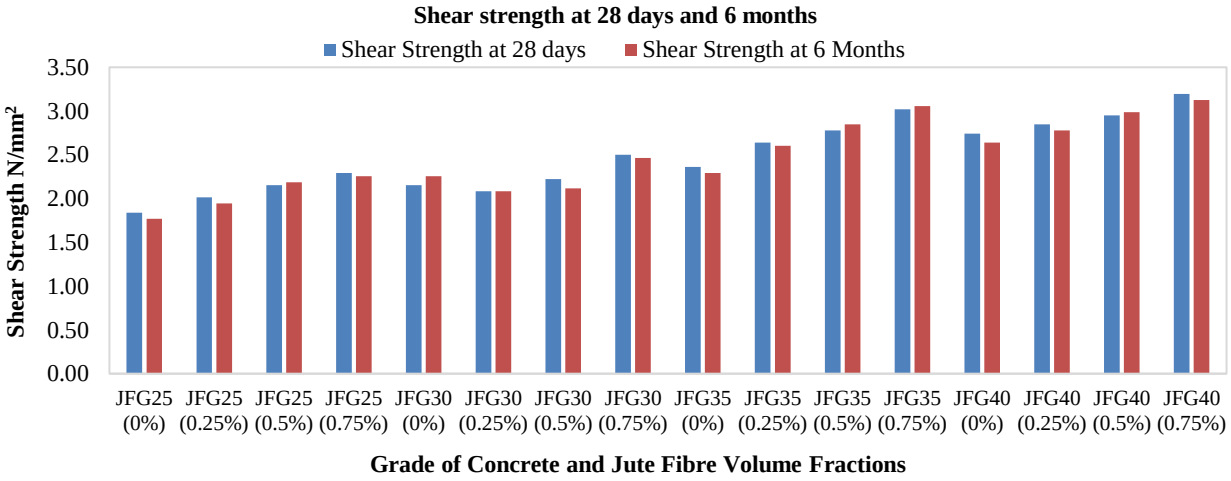

Figure 9. Comparison between 28 days and 6 months shear strength results of concrete

CONCLUSION

From the study, a number of deductions can be made. The addition of the jute fibre reinforcement to the concrete mix has effects on the following:

1. Workability was slightly reduced, but it had no negative effect on the strength of the concrete.
2. The jute fiber-reinforced concrete has slightly reduced in density but still falls within the acceptable limit.
3. The compressive strength of the concrete was found to have increased by 12%, 12.5%, 9.7%, and 10.1% for grades 25, 30, 35 and 40 concrete respectively using a 0.5% volume fraction of jute fiber.
4. Its shear strength increased by 24.5%, 16.1%, 27.9%, and 16.5% using a 0.75% volume fraction of jute fiber for grades 25, 30, 35 and 40 concrete respectively.
5. The strength remained constant even after six months of testing.
6. Furthermore, jute fibre in concrete improved the mechanical properties of concrete, such as impact strength, brittleness, and resistance to cracks.

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Persian Abstract

چکیده

این کار تحقیقاتی به بررسی اثر الیاف جوت بر مقاومت برشی بتن پرداخته است. در این تحقیق از کسر حجمی الیاف ۰٪، ۰/۲۵٪، ۰/۵٪ و ۰/۷۵٪ برای گرید ۴۰-۲۵ N/mm^2 استفاده شد. برای آزمایش، ۳۲ پرتو و ۹۶ مکعب تهیه شد. ۴۸ نمونه مکعب و ۱۶ پرتو در دمای اتاق به مدت ۲۸ روز تیمار شدند، در حالی که مجموعه دیگری از ۱۶ پرتو و ۴۸ مکعب به مدت ۲۸ روز تیمار و به مدت ۶ ماه نگهداری شد تا از نظر دوام و استحکام پس از آزمایش مشاهده شود. تمامی تیرها تحت سیستم بارگذاری سه نقطه‌ای با دهانه برشی av=2.5d آزمایش شدند. نتایج مقاومت فشاری نشان داد که بتن ساخته شده با الیاف جوت ۰/۵ درصد به مدت ۲۸ روز و ۶ ماه، درصد افزایش مقاومت فشاری ۱۲، ۱۲/۵، ۹/۷ درصد و ۱۰/۱ درصد را به ترتیب برای گرید ۲۵، ۳۰، ۳۵ و ۴۰ N/mm^2 با تقویت فیبر جوت در مقایسه با نمونه های شاهد به همراه داشت. درصد افزایش مقاومت برشی برای بتن با عیار ۲۵، ۳۰، ۳۵ و ۴۰ نیوتن بر میلی‌متر مربع با الیاف جوت نسبت به نمونه‌های شاهد به ترتیب ۲۴/۵، ۱۶/۱، ۲۷/۹ و ۱۶/۵ درصد افزایش یافت. افزودن الیاف به بتن کارایی بتن را اندکی کاهش داد و مقاومت بتن در برابر ترک خوردگی را افزایش داد.