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Mechanical and Fresh Properties of Sustainable Kenaf Fibrous Concrete Incorporating Sorghum Husk Ash

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Abstract: This article describes the findings of an experimental investigation on the performance of concrete using Kenaf Fiber (KF) and Sorghum Husk Ash (SHA) (CEM 1). To characterised the SHA (EDS), microstructural studies such as X-ray diffraction (XRD), scanning electron microscopy (SEM), X-ray fluorescence (XRF), and Energy-dispersive X-ray spectroscopy were performed. CEM 1 was used with the KBF (length, L = 50 mm) and five volume fractions ranging from 0 to 1.0 percent (= 0.25 percent). Following that, five concrete mixtures were cast with 10 percent SHA as a substitute for CEM 1. The samples were cured in water and their characteristics were evaluated in both the fresh and hardened stages. In new concrete, the use of Kenaf fibre and SHA lowered slump values while increased VeBe time. When Kenaf fibre was added to either CEM 1 or SHA concrete mixes, it resulted in a good interaction with high tensile and flexural strengths, as well as increased concrete ductility and crack dispersion. When 0.5 percent Kenaf Fibre was added to dry concrete at the age of 56 days, it resulted in the largest increase in tensile and flexural strengths. The research found that utilising KF and SHA to manufacture sustainable green concrete is both technologically and environmentally viable.

Keywords: Building materials, concrete, kenaf fibre, sorghum husk ash, sustainable green

1. Introduction

Due to the extremely increasing quantity of trash created by agricultural goods, there has been a rising interest in using trash to make construction materials to obtain possible advantages and a cleaner environment. In achieving sustainable green construction and environment, cleaner and proficient management of numerous forms of waste generated in our environment have been an issue of concern. This has made government, concrete engineers, material scientists (Mohd, Arifin, Nasima, Hazandy & Khalil, 2014), and researchers in the construction industry (Stevulova, Schwarzova, Hospodarova, & Junak 2016) devote apt responsiveness to the production and utilisation of bio fibre and agro-waste respectively. In many regions of the world, one of the most basic difficulties with waste management practices is the reuse of agricultural waste products (Awal & Mohammadhosseini, 2016). Recycling benefits include

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reduced pollution, reduced landfilling and waste disposal, and the preservation of natural resources (Awal & Mohammadhosseini, 2016). Also, it has been observed that five per cent of global CO_2 emissions are from cement production. This has presented conventional cement production as a process that is harmful to the environment (Banthia, Yan & Sakai, 2014).

Nonetheless, global cement output continues to rise, with 4.3 billion tons estimated in 2014, representing a 6.7 per cent increase over the 4 billion tons produced in 2013. (The European Cement Association, 2014). As a result, the worldwide construction sector is under pressure to reduce CO2 emissions dramatically (Banthia, Yan & Sakai, 2014).

Natural fibre markets have bright prospects due to the shift to a bio-based economy and sustainable development as a result of the Kyoto Protocols on greenhouse gas reduction and CO2 impartial production. Bio fibre's resurgence and growing interest in the building sector is due to its latent to replace synthetic fibre, glass fibre, and metallic fibre in fibrous concrete complex production at low cost with improved properties, low-cost manufacture of fibrous concrete composites with improved characteristics using glass and metallic fibres (Cigasova, Stevulova, Sicakova, & Junak, 2013). Biofiber has been one of the most important strategies to improve concrete's poor tensile strength and significant brittleness negative qualities while also contributing to the drop of greenhouse gases and CO2 in the environment (Pickering, Beckermann, Alam & Foreman, 2016).

The concept of sustainability in the building sector advocates the use of waste or natural resources to replace raw resources such as fibre, cement, fine and coarse aggregates. This results in more sustainable, green, and environmentally friendly buildings by lowering the cost of the components when compared to the cost of disposing of the materials (Onuaguluchi & Panesar, 2014). The utilisation of bio fibre in the construction industry is receiving attention recently due to its prevalent ecological, technological, and economic benefits (Ogunbode, Jamaludin, Yunus, Hamid, Azmahani & Masoud, 2016). The usage of bio-fibre in the building has risen in response to the environmental consequences of getting construction materials from petroleum-based goods. Bio fibres have a higher specific strength, lower cost, and lower density than synthetic fibres since they are renewable and have a lower environmental effect. Therefore, fibres are a far-fetching reason for their wide embracing (Ochi, 2008). To achieve a safer and cleaner environment, it is critical to investigate environmentally friendly, sustainable, and renewable resource materials to substitute materials obtained from global warming contributors such as mineral resources or fossil (petrochemical) fuels. (Stevulova, Schwarzova, Hospodarova, & Junak 2016).

Fibrous Concrete Composite (FCC) is a high-performance concrete made from a traditional concrete mix including coarse aggregates, fine aggregates, cement, and short intermittent fibres spread randomly throughout the freshly mixed concrete. Fibres increase the flexibility, energy absorption, tensile strengths and flexural of concrete mixes, flexural toughness, drying shrinkage reduction, concrete density, and infusing the concrete composite with self-strain sensor devices (Brandt, 2008; Akça et al., 2015). The most common fibres used in FCC are natural fibre, commonly referred to as cellulosic fibre, bio fibre, and plant fibre. Other fibre types are steel fibres, fibres from pre-and post-consumer wastes glass fibres, synthetic fibres (Ogunbode, Jamaludin, Yunus, Hamid, Azmahani & Masoud, 2016; Aldahdooh, Bunnori, Megat & Johari, 2013 and Awal & Mohammadhosseini, 2016) have fabricated and made a comparative study of fibrous concrete containing pozzolanic materials with conventional concrete. Certainly, the progress on concrete production using novel supplementary cementitious materials (SCM) has delivered outstanding mechanical, physical, and durable properties (Awal and Shehu, 2015). According to Ndububa & Nurudeen (2015) and Alkamu, Datok & Jambo (2017), SHA is a potential pozzolanic material receiving widespread attention in concrete technology for its ecological, economic benefits. SHA is obtained by burning sorghum husk. The ash, which was once considered a waste product with little economic use, is today regarded as a useful element capable of boosting the strength and durability of concrete mixes (Ndububa & Nurudeen, 2015 and Alkamu Alkamu, Datok & Jambo, 2017).

The production of sorghum has provided Nigeria with great economic growth and boost over the years. Nigeria farmed over 5.6 million hectares in 2012, with an anticipated yearly yield of 2.8 million tons, as reported by Hannah (2018). Nigeria reached second place in the world for sorghum output between 2015 and 2017. This follows the United States of America, which is ranked #1. Franklin (2017) estimated that the United States output in 2017 would be 8.4 million metric tons.

In contrast, Nigeria's output would be 6.4 million metric tons, based on statistics from the United States Department of Agriculture (USDA). This, together with the output from other sorghum-producing countries, resulted in a global sorghum production of 59.34 million tons in the same year. According to the USDA's 2017 report, sorghum output will increase to 60.6 million tons in 2018, with no changes in the rankings expected. Due to the expanded area of the sorghum plantation, this output rate is expected to increase. Countries that produce sorghum worldwide apart from Nigeria and the USA include Sudan, Ethiopia, Brazil, Mexico, Australia, Burkina Faso, India, Argentina, China.

Towards attaining cleaner production, Kenaf plants from which kenaf fibre is derived have been proven as a potentially valuable natural plant. Kenaf plants have a high carbon dioxide (CO2) absorption rate and the capacity to clean the air by eating huge amounts of CO2, and the ability to absorb nitrogen and phosphorus from the soil, which are the primary causes of the greenhouse effect. As a result, kenaf fibre has become important in terms of environmental friendliness. Currently, kenaf fibres are intended to substitute composites instead of traditional materials or synthetic fibres. Kenaf fibres are suitable for composites due to their inexpensive cost, lack of health risks, high strength and modulus, low density, and availability in some countries (Ogunbode, Yatim, Ishak, Masoud & Meisam, 2015). Agro-waste ash, such as SHA, also has negative environmental consequences due to its delayed disintegrating time. One feasible option for reducing these negative repercussions is to use waste materials as useful resources in other sectors, such as green building construction.. Thus far, there is still a dearth of knowledge on the comportments of concrete composites from Kenaf fibre (Lam and Jamaludin, 2015; Ogunbode, Jamaludin, Yunus, Hamid, Azmahani & Masoud, 2016). This knowledge will provide building material scientists and engineers with the requisite expertise in developing a sustainable concrete composite for structural uses.

Although, no or little research has been done on using kenaf fibre and SHA as partial substitutes for cement in concrete. An extensive study was carried out at the Department of Building, Federal University of Technology Minna, Niger State, Nigeria, taking into account the accessibility of Kenaf fibre and the ash, as well as SHA's pozzolanic behaviour. Its purpose was to investigate the potential advantages of creating sustainable construction materials. This study aims to use 10% sorghum husk ash as supplementary cementitious material in kenaf fibrous concrete with fibre volume fractions of 0%, 0.25 per cent, 0.5 per cent, 0.75 per cent, and 1.0 per cent. Both the fresh and hardened phases, workability, compressive strength, splitting tensile, and flexural strengths were connected to fibreless concrete without sorghum husk ash.

1. Materials and Methods

1.1 Materials

The binder for the control reference concrete mix was CEM I 42.5N (Dangote 3X) (Portland Cement) made by Dangote Cement Company in Obajana. The sorghum husk used in the research came from a local grain mill in Garatu village, Bosso Local Government Area, Niger State, located on the Minna-Bida highway (Fig. 1 a). The recovered Sorghum husk was then burnt at a local open-air incinerator (Fig. 1 b-d).To eliminate larger components and lower carbon content, the SHA was dried and sieved. Using local milling equipment, the charred SHA particles were reduced to fewer than 150 m in size. Lastly, the pulverised ash was sieved through a 75 m sieve to determine whether particles passed the SHA test.

Fig. 1 - (a) sorghum husk collected; (b) set up of the locally fabricated incinerator; (c) burning into ash using the incinerator; (d) sorghum husk ash produced from the incinerator

In this study, Sorghum husk ash was used in producing green concrete containing kenaf fibre. The SEM, X-ray diffraction (XRD), EDS, and X-ray Fluorescent (XRF) analysis of the Sorghum husk ash were conducted. The results of the XRD and XRF of the major elements and minerals of the Sorghum husk ash are shown in Fig. 2 (a &b) and Tables 1, respectively. The summation of SiO_2, Al_2O_3, and Fe_2O_3 content for all Sorghum husk ash is 88.6% which is higher than 70%, the benchmark offered by ASTM standard. The CaO content was less than 8%. Also, the percentage of unburned particles in terms of the Loss on Ignition (LOI) for the Sorghum husk ash is 5.6%. At a magnification of 8000, the SEM micrograph of the SHA revealed marginal holes. Although pore opening proportions indicate a predisposition to absorb water, they may impair the workability of fresh concrete. It might also have an impact on the number of capillaries and voids. As a result, the crowded structure's density is reduced. Fig. 2 (a) presented that the SHA contains spherical particles with a smooth surface. The EDS analysis (Fig. 2c) demonstrated the predominant elements in the tested SHA specimen: Si, Ca, O, C, Mg, and Na in numerous compounds, even though lower amounts of Ti, Al, and K elements are were also detected.

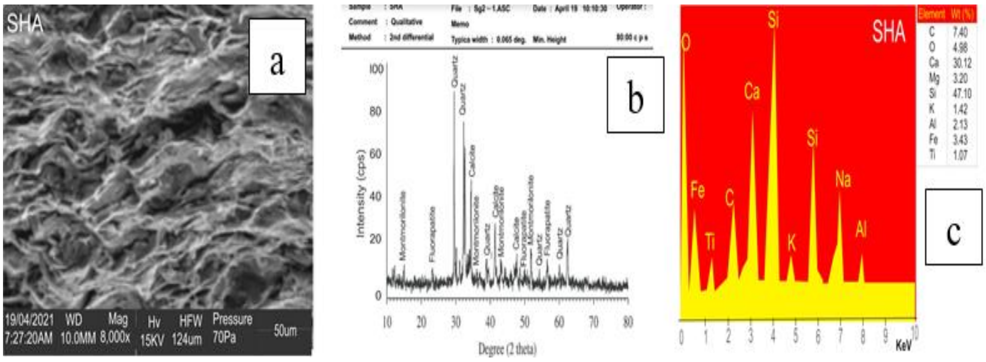

Fig. 2 - (a) SEM image; (b) XRD pattern; (c) EDS image of the SHA specimen used in the experiment

Table 1 - Physical and chemical properties (X-ray Fluorescent (XRF) of the binders

Materials	**Physical property**	**Chemical properties**							
	Specific gravity (kg/m^3)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	SO_2	LOI*
CEM 1 (PC)	3.15	21.5	1.6	1.2	64.0	2.9	0.0	4.5	0.80
SHA	2.32	83.0	2.9	2.7	1.3	0.8	2.8	0.0	5.6

**Loss on ignition*

The fine aggregate utilised in the study was made of river sand, which the greatest aggregate size of 4.75 mm screen when the surface was saturated and dry. The fine aggregate has a fineness modulus of 2.3 and a precise gravity of 2.64, with 0.70% water absorption of 0.70 The coarse aggregate was crushed granite with a maximum particle size of 10 mm, a specific gravity of 2.7, and water absorption of 0.5%. Tap water was utilised for both mixings and curing throughout the investigation. To increase the workability of the concrete, 1.0 percent by weight of cement-based components were treated with a polymer-based superplasticiser (Coloplast SP 430). The water/binder (w/b) ratio of 0.38 was maintained in all batches. Kenaf fibres were collected in the form of a long coiled fibre from Manchok, Kaura Local Government, Kaduna State, Nigeria (Fig. 3 a). As shown in Fig. 3(b), the hydrophilic Kenaf fibres were cut to a length of 50 mm. Figure 3 (c)shows a kenaf fibre micrograph demonstrating the fibre morphology. Table 2 shows the main features of the Kenaf fibre employed.

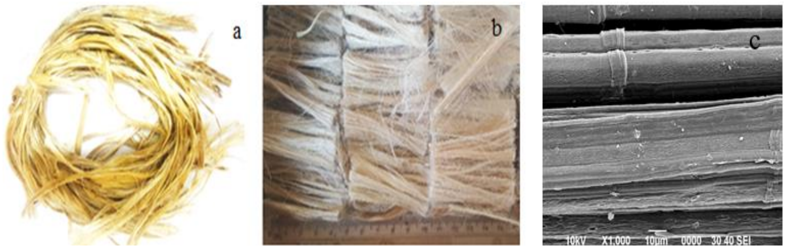

Fig. 3 - (a) Kenaf fibre curl; (b and c) chopped kenaf fibre treated with alkaline

Table 2 - General properties of kenaf fibre

Parameter	**Value**
Fibre	Kenaf
Length (mm)	50
Diameter (µm)	39.7-115.1
Density (g/cm3)	1.2
Tensile Strength (N/mm^2)	135-930
Reaction with water	Hydrophilic
Cellulose (%)	31-57
Hemicellulose (%)	21-23
Lignin (%)	4.79
Pectin (%)	2.0

1.2 Mixture Configuration

Natural fibrous concrete is made in a slightly different way than standard concrete. Ogunbode (2017) developed a natural fibrous concrete mixing method presented and employed in this research. The basic concrete was built following the Department of the Environment's (DOE) concrete design specifications. The fibrous, fine, and coarse aggregates were mixed for 4 minutes in the concrete mixer with one-fifth of the water necessary for mixing. The mixer was turned off for 2 minutes to allow the air-dried aggregate to gather the water needed for saturation. This is necessary to prevent the aggregates from absorbing the superplasticiser. CEM I and SHA cementing materials were also added to the mixture. After adding the second and third quarters of the mixing water, the machine was restarted, and the stirring proceeded for another 6 minutes. To ensure uniform fibre distribution, all the soaking water and fibres were progressively dripped into the matrix. The workability of new concrete was found to be significantly reduced. In addition, the hydrophilic nature of the Kenaf fibre in the mix results in significant water absorption and hydrolysis in the concrete mixture. The SP was then drained from the fourth quarter of the mixing water and mixed with the concrete mix for 5 minutes. The mixing was stopped after 2 minutes. After another 4 minutes of mixing, the liquid was poured and cast into greased steel, plastic, and wooden moulds as required. The concrete mixes were mixed using an oscillating type pan mixer with a capacity of 0.02m3. All of the specimens were cast and water cured following ASTM C192.

The proportions of the fibrous concrete mix are shown in Table 3. The first batch was used as a control mix since it had no fibre or SHA (Plain). Five batches of the ten combinations included CEM I cementing material (plain) with fibre volume fractions of 0 per cent, 0.25 per cent, 0.5 per cent, 0.75 per cent, and 1.0 per cent (A1–A5). As indicated in Table 3, five separate batches were prepared for the relevant fibre volume fractions (A7–A10), with SHA replacing CEM I cementing material by 10%.

Table 3 - Mixture configuration of various concrete components

Mixture	Cement (kg/m^3)	SHA (%)	SHA (kg/m^3)	Vf* (%)	Vf (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Water (kg/m^3)
A1	539	-	-	-	-	832	832	205
A2	539	-	-	0.25	3	832	832	205
A3	539	-	-	0.5	6	832	832	205
A4	539	-	-	0.75	9	832	832	205
A5	539	-	-	1.0	12	832	832	205
A6	485.1	10	53.9	-	-	832	832	205
A7	485.1	10	53.9	0.25	3	832	832	205
A8	485.1	10	53.9	0.5	6	832	832	205
A9	485.1	10	53.9	0.75	9	832	832	205
A10	485.1	10	53.9	1.0	12	832	832	205

**fibre volume fraction*

1.3 Program and Procedure of the Test

The VeBe time consistometre, slump, and compacting factor tests were utilised to investigate the fresh state attributes according to BS EN 12350-3: 2009; BS EN 12350-2: 2009; and BS 1881-103: 1993. In the compressive strength test, 100 mm cube specimens were employed (BS EN 12390-3: 2009). For the splitting tensile strength test, cylindrical specimens of 100 mm x 200 mm were created (ASTM C496-11). Prism specimens with 100 mm x 100 mm x 500 mm dimensions were produced at the ages of 7, 28, and 56 days to measure flexural strength (BS EN 12390-5: 2009).

2. Results and Discussion

2.1 Workability

The VeBe, Slump, and Compacting factor tests were used to assess the workability of new concrete. Figure 4 illustrates the workability test results of the concrete as well as its densities. As demonstrated in Fig. 4(a), the slump values of the concrete mix reduced as the fibre content increased. The slump for the control mixture, which was fibreless and included no SHA, was 160 mm. As shown in Fig. 4(a), the slump value decreased as the fibre content was raised at 0.25 per cent intervals from 0 to 1 per cent. When 10% SHA was utilised instead of only Portland cement, the slump and compacting factor values were lower. For volume concentrations of 0.25 percent, 0.5 percent, 0.75 percent, and 1.0 percent, respectively, slump values of 110 mm, 65 mm, 50 mm, and 25 mm were obtained, while compacting factor values of 0.93, 0.90, 0.88, 0.75 were obtained for volume fractions of 0.25 percent, 0.5 percent, 0.75 percent, and

1.0 percent, respectively. For volume concentrations of 0.25 percent, 0.5 percent, 0.75 percent, and 1.0 percent, respectively, slump values of 110 mm, 65 mm, 50 mm, and 25 mm were obtained, while compacting factor values of 0.93, 0.90, 0.88, 0.75 were obtained for volume fractions of 0.25 percent, 0.5 percent, 0.75 percent, and 1.0 percent, respectively.SHA also observed that the VeBe time increased as the quantity of fibre increased (Fig. 4 b). Because of the large quantity of KF and the associated higher surface area, more sand and cement paste were used around the fibres; this is assumed to be the genesis of the firm fibre-matrix bond in the concrete mixture, which subsequently hampered workability. Because of Lam and Jamaludin's (2016), Ogunbode, Egba, Olaiju, Elnafaty, and Kawuwa's (2017), and Ogunbode, Yatim, Affendi, Aziz, Yunus, and Hamid's (2019) findings on bio/natural fibre in a concrete mixture, this workability behaviour is credible. This also explains the hydrophilicity of natural fibre.

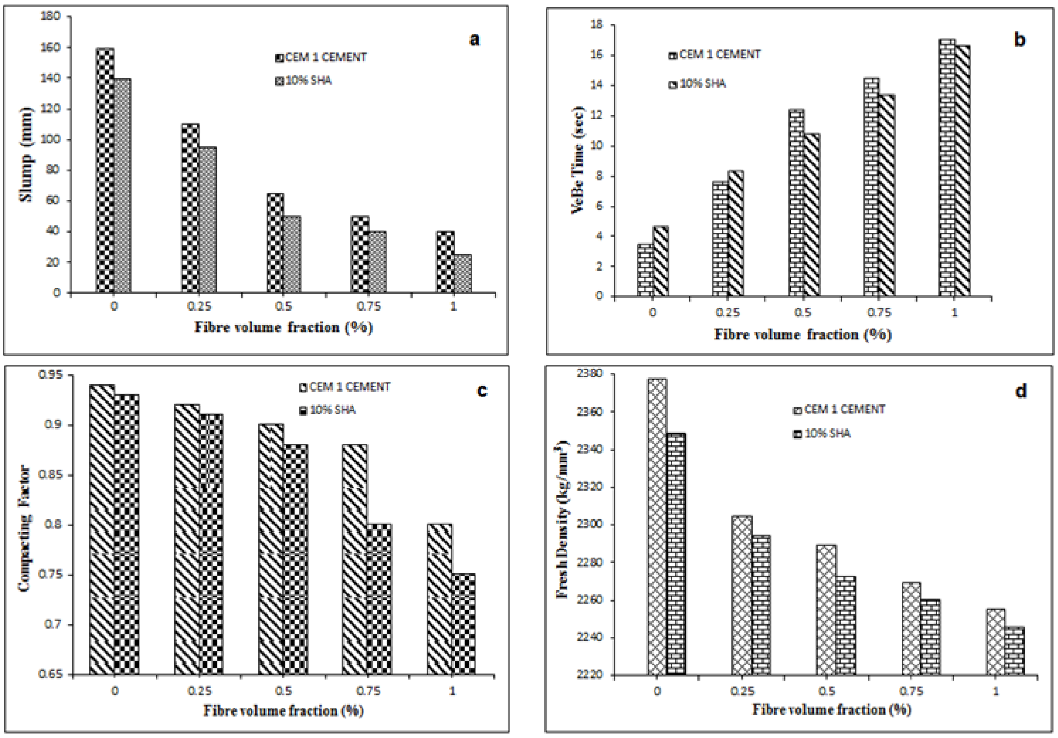

Fig. 4 - The concrete fresh-state properties: (a) Slump; (b) Vebe time; (c) Compacting factor; (d) Fresh density

The fresh-state density of the various concrete mixes declined as the quantity of fibre material increased, as seen in Fig. 4 (d). This was expected because of KF's lesser density (1200 kg/m3) when compared to normal concrete. The density of SHA-containing concrete mixes was likewise lower than that of CEM I cementing material-only concrete mixes (Portland cement). This might be because SHA (2.32) has lower specific gravity than CEM I cementing material (3.15). Figure 4 (d) also shows that the combination of 10% SHA and 1.00% KF had the lowest fresh-state density, which was about 6% lower than the control mix with no fibre or SHA.

2.2 Compressive Strength

Table 4 demonstrates the tensile, compressive, and flexural strengths of various fibre volume combinations and their combinations without and with a SHA component. As indicated, the addition of kenaf fibre reduced the compressive strength of the mixture. As demonstrated in Fig. 5, a 5%, 8%, 11%, and 16% decline in compressive strength was seen at 28 days for 0.25 per cent, 0.5 per cent, 0.75 per cent, and 1 per cent fibre volume, respectively. Fig. 5 further shows that replacing SHA for CEM 1 cement influences concrete strength. In the early days, plain concrete had greater compressive strength than SHA-containing concrete.

On the other hand, increases in fibre volume content of more than 0.5 per cent, on the other hand, reduced compressive strength even more, though to tolerable levels. At 28 days, compressive strength fell by 15 per cent, 18 per cent, 24 per cent, and 27 per cent for 0.25 per cent, 0.5 per cent, 0.75 per cent, and 1.0 per cent fibre volume and SHA content, respectively. Reduced pozzolanic activity, especially at younger ages, the occurrence of gaps due to the inclusion of KF, and the existence of weak interfacial connections between natural fibre and pozzolanic cement particles may all contribute to the lower compressive strength of the SHA fibrous composites (Ogunbode, 2017). The findings of this study, on the other hand, revealed that the inclusion of kenaf fibres had no significant effect on concrete compressive strength and that the failure mode was generally ductile, as shown in Fig. 5. (b). The introduction of discontinuous kenaf fibres in the concrete mixture decreases unequal micro-crack propagation. It improves ductile performance when the fibres can adequately suppress the crack formation and disperse stresses against the adjacent matrix. As a result, the post-failure behaviour of kenaf-fibre concrete is more flexible than plain concrete, with a gradual loss of strength (Fig. 5). As a result of the inclusion of Kenaf fibre, the flexibility of concrete increased, as did the energy absorption and the cracking distribution.

Table 4 - Selected mechanical properties of the concrete mixtures

Mix	**Compressive Strength N/mm^2**			**Tensile Strength N/mm^2**			**Flexural Strength N/mm^2**		
	7 Day	28 Day	56 Day	7 Day	28 Day	56 Day	7 Day	28 Day	56 Day
M1	35.20	46.50	49.95	3.10	4.75	4.90	3.95	4.60	5.25
M2	32.90	43.98	49.10	3.35	4.85	5.10	4.40	5.05	5.70
M3	31.40	42.71	46.80	3.50	5.05	5.35	4.95	5.40	6.55
M4	30.65	41.23	45.20	3.40	5.00	5.20	4.35	5.20	6.00
M5	28.85	38.85	43.65	3.38	4.90	5.15	4.10	4.95	5.65
M6	30.50	43.20	48.05	3.00	4.75	5.00	3.80	4.25	5.35
M7	27.60	39.30	46.20	3.25	4.60	5.05	4.60	4.75	5.50
M8	25.70	37.70	44.70	3.40	4.85	5.15	4.75	5.10	5.90
M9	24.20	35.20	41.30	3.35	4.70	5.25	4.60	4.95	5.60
M10	22.95	33.75	39.40	3.30	4.60	5.10	3.90	4.80	5.40

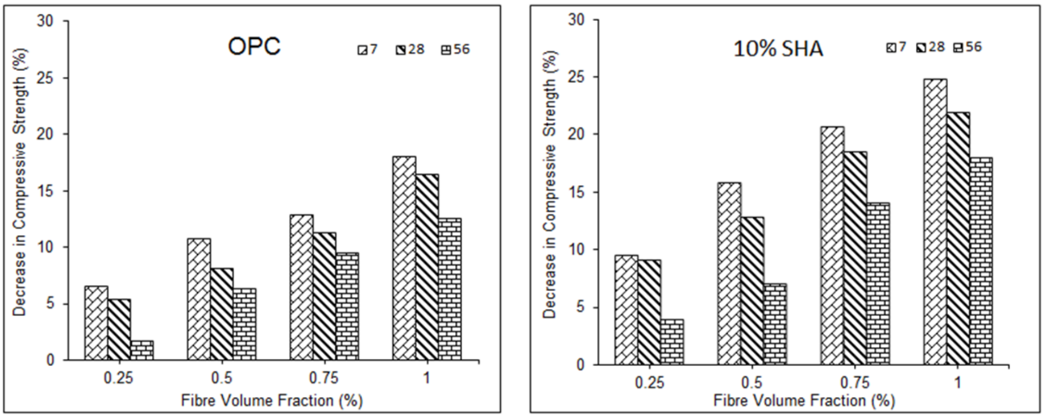

Fig. 4 - Compressive strength variation against control mix

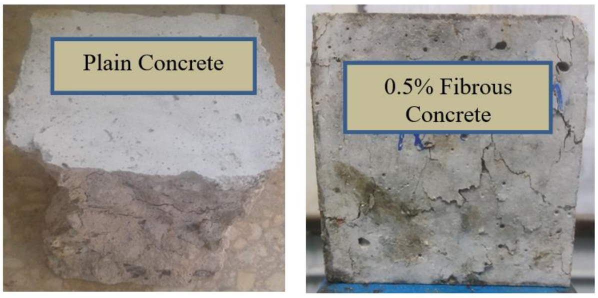

Fig. 5 - Failure patterns of the concrete

2.3 Splitting Tensile Strength

As a result, kenaf-fibre concrete's post-failure behaviour is more flexible than ordinary concrete, with a progressive decrease of strength (Fig. 5). The flexibility of concrete rose due to the addition of Kenaf fibre, as did the absorbed energy and cracking distribution (Fig. 7 b). In addition, the transmitted stress increased the concrete matrix's tensile strain capacity, thereby increasing the tensile strength of fibrous mixtures over non-fibrous counterparts.

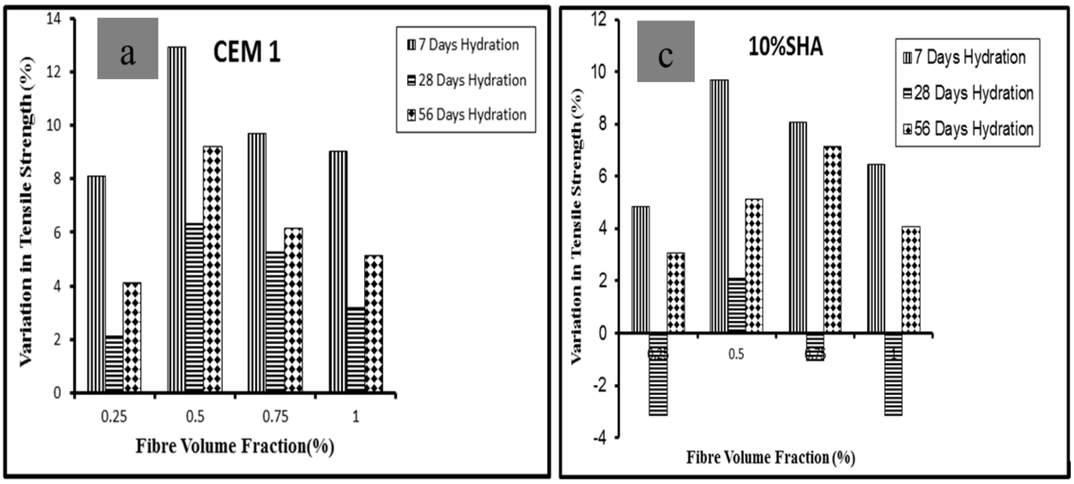

Fig. 6 - Variation in splitting tensile strength to control mix

The transmitted stress boosted the concrete matrix's tensile strain capacity, enabling fibrous mixes to surpass non-fibrous equivalents in terms of tensile strength. Tensile strength of cement-only mixtures rose by 2.11 per cent and 6.32 per cent after 28 days for KF levels of 0.25 per cent, 0.5 per cent, 0.75 per cent, and 1 per cent, respectively. However, it began to fall by 5.26 per cent and 3.16 per cent when compared to ordinary concrete without fibre. The addition of SHA to the fibrous mixes increased the strength of certain fibre volume fractions. However, because of the pozzolanic nature of SHA, the rate of robust growth was low at an early age, say after seven days of therapy. Compared to a combination without SHA and fibre content, the addition of SHA to reinforced concrete fibre mixes enhanced tensile strength by 3.06 per cent, 5.10 per cent, 7.14 per cent, and 4.08 per cent after 56 days. As a consequence of the improved pozzolanic activity of SHA and the improved amount of hydrated products, the improvement might be attributed to an increase in the contact area between the fibres and the aggregate matrix.

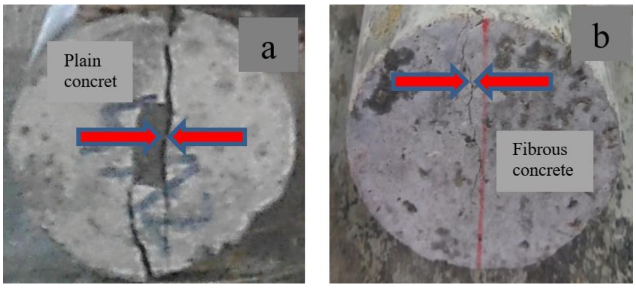

Fig. 7 - Failure modes of concrete cylinder specimen

2.4 Concrete Flexural Strength

Table 5 presents the results of bending strength tests for concrete composite combinations. By increasing the KF concentration from 0% to 1%, the concrete composite mixes achieved flexural strengths of 3.95–4.10 N/mm2, 4.60–4.95 N/mm2, and 5.25–5.65 N/mm2, respectively, after 7, 28, and 56 days. KF concrete has a higher flexural strength than un-fibered concrete. The tensile strength of a fibre-reinforced concrete sample followed a similar pattern to that seen in the previous study. After 56 days, the 0.5% fibre mix had a maximum flexural strength of 6.10 N/mm2, which was 19.5% higher than the control mix, which did not comprise SHA or fibre. SHA displayed enhanced flexural performance as measured by tensile strength in the flexural direction over longer curing durations. Flexural strength improved by 13.4per cent when 0.5 per cent fibre was used instead of a non-fibrous concrete containing 10per cent SHA. The combined impact of SHA and KF increased flexural strength by 13.4 per cent.

The fibres spanning the cracks in the tension zone of the prism samples increased the flexural strength of the prism samples. Kenaf fibres operate as crack arresters, elongating and isolating the crack face from the surrounding area. As a result, these fibres have a greater capacity for energy absorption and stress relaxation in the microcrack region adjacent to the fracture tip than other fibres (Figure 9).

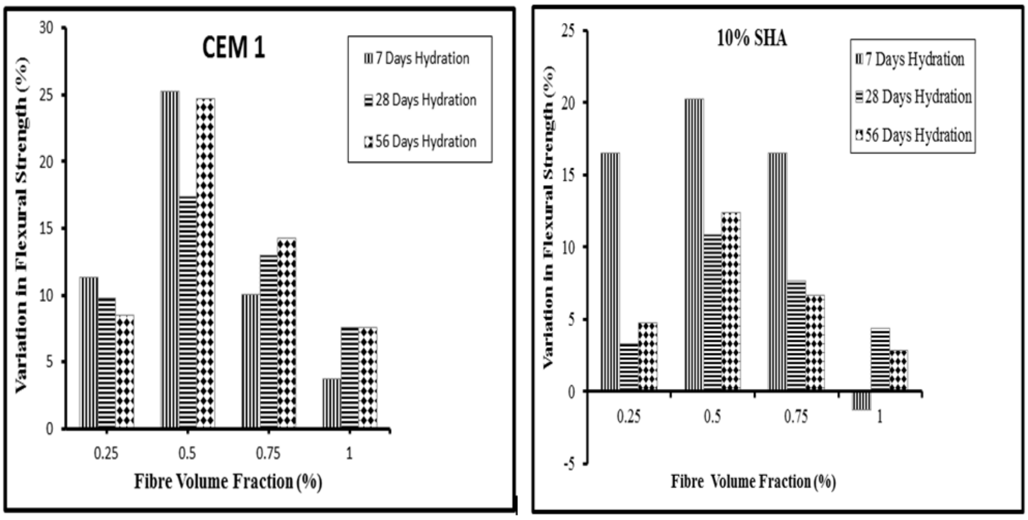

Fig. 8 - Flexural strength variation against respective control mix

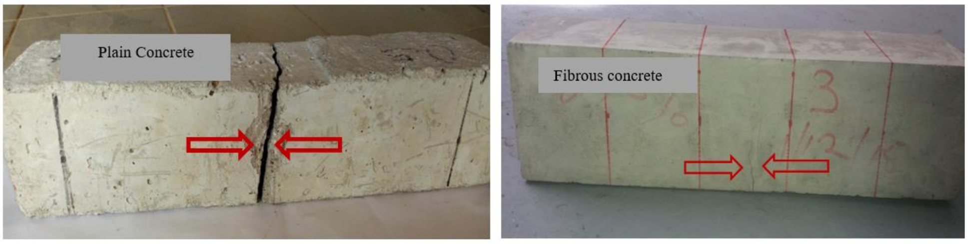

Fig. 9 - Concrete prism specimens failure pattern

3. Conclusions

The influence of Kenaf fibre and sorghum husk ash on the characteristics of concrete composite in both the fresh and hardened phases is investigated in this research. By supporting environmentally friendly fibre and recycling agro-waste, the use of kenaf fibre and sorghum husk ash in concrete composites has aided in meeting the criteria for keeping the environment clean and creating green concrete. The following conclusions have been reached based on the study's findings and observations. First, adding kenaf fibre to concrete made it more difficult to work with. Second, as the fibre content rose, the compressive strength of the fibre matrix dropped. Third, kenaf fibre and SHA concrete have lower cube compressive strengths than plain concrete. The results, however, were within an acceptable range for structural applications. Fourth, although compressive strength did not increase considerably, tensile and flexural strength did. Because of improved fibre-cement matrix interaction and matrix densification, concrete containing kenaf fibre and SHA performed better in developing tensile and flexural strengths at all ages. Finally, in terms of ductility, kenaf fibre concrete outperforms normal concrete due to the bridging activity of the fibres. The study's results and observations suggest that kenaf fibre and sorghum husk ash concrete composites may be utilised to create engineering-quality building slabs, road pavements, and bridge decks. However, greater research into the widespread use of kenaf fibre and its performance in reinforced concrete members is needed in the future.

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