Feasibility of Improving Impact Resistance and Strength Properties of Sustainable Concrete Composites by Adding Kenaf Fibres

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Abstract

Waste materials utilization is one of the central concerns of waste management approaches in recent years. The developments in cement and concrete technology towards the production of sustainable concrete by using waste materials and cellulosic fibre is gradually attaining acceptance because of its technological, economic and ecological advantages. This research presents the potential use of a natural fibre known as Kenaf fibre and Rice Husk Ash (RHA) from agricultural waste towards achieving a bio fibrous concrete with enhanced impact resistance and strength properties. Four mixes with varying percentage of RHA from 0% to 15% at 5% step intervals without fibre was used as a basis for comparison against another four mixes made with 50 mm length fibre of 0.5% volume fraction. The drop weight impact test method was adopted in determination of the impact resistance strength and energy absorption of the RHA based kenaf fibrous concrete. At later ages, the compressive strength of the fibrous concrete mixtures containing 15% RHA significantly increased, and the obtained values were higher than the mix with Portland Cement (PC) alone. The positive interaction between Kenaf fibres and RHA leads to high tensile strength, flexural strengths and impact resistance, thereby increasing the concrete energy absorption capacity. It is concluded that concrete containing 0.5% volume fraction of 50 mm length Kenaf fibre and 15% RHA can be used as building materials in the construction of sustainable concrete.

Keyword(s): Agricultural waste, concrete, kenaf fibre, natural fibre, rice husk ash

1. Introduction

The low tensile strength and the low rigidity of concrete, subsume it as brittle materials. Higher impact resistance and energy absorption capacity are therefore needed in different applications like industrial floors, highway paving, bridge decks, etc. Additional components are necessary to enhance these properties of concrete where these requirements are essential (Hsie *et al*., 2008; Ogunbode *et al*., 2016). Fibre reinforced concrete (FRC) is a composite material made of Portland cement (PC), coarse and fine aggregates, and a dispersion of discontinuous short fibres. Among others, the most common fibres utilized in FRC are metallic fibres, polymeric fibres (for example nylon and polypropylene), glass fibres, natural fibres and fibres from pre- and post-consumer wastes (Babafemi and Boshoff 2015). As the introduction of FRC in the construction industry emerged, a great deal of challenges has been encountered during the evaluation of the real properties and advantages of different types of fibres. Over the years, various kinds of natural fibres have been successfully used in concrete mixtures. Kenaf fibres with volume fractions ranging from 0.5% to 1.0% have commonly been used as a subsidiary reinforcement in concrete and have been reported for enhancing tensile and flexural strength (Lam and Jamaludin, 2015; Ogunbode *et al*., 2018). But there is a dearth of literature on its effect on impact resistance and energy absorption of concrete.

Generally, the ductility of concrete can be enhanced by introducing different types of fibres in it. Fibre permits for crack bridging action, taking advantage of a mechanism that restrains crack opening and improve the energy absorption of the concrete mixtures (Tejchman *et al.*, 2010; Arango, 2012). Many studies have been undertaken to investigate the ductility of FRC by the impact test, and it has been found that the addition of fibres considerably develops the impact resistance of the mixture (Razavi, 2017).

Fibrous concrete containing pozzolanic materials have been previously fabricated and studied with conventional concrete (Hossein and Jamaludin, 2016). In recent decades, detection and recognition of pozzolanic ashes as supplementary cementious materials (SCMs) used in concrete rapidly increased for practice in research and concrete industries. One of the inclusions in the ash family is RHA, which is obtained by burning rice husks deposited as waste from rice mills. This waste ash is usually available in African Sub-Sahara and South-East Asia regions where production of rice plays a significant role in the national economy. This study seeks to experimentally find out the combined effect of kenaf fibre and RHA in enhancing the impact resistance and strength of concrete.

Waste materials utilization is one of the central concerns of waste management approaches in recent years. The developments in cement and concrete technology towards the production of sustainable concrete by using waste materials and cellulosic fibre is gradually attaining acceptance because of its technological, economic and ecological advantages. In past years synthetic fibres such as carbon, glass, aramid and steel fibres are commonly used for strengthening of RC structures due to their mechanical properties (i.e. high modulus of elasticity, relative low extension coefficient, and corrosion resistance). However, these materials are expensive in terms of costs and material production. Besides, they are also not biodegradable materials. Kenaf fibres have dramatically received attention to be used in different applications.

This acceptance is due to its being environmental friendly and its desirable characteristics such as high specific strength and high specific stiffness.

In the last decades, researchers have investigated the influence of kenaf fibres on various properties of concrete and generally concluded that kenaf fibre reduced the workability and compressive strength of concrete. However, kenaf fibres have been shown to exhibit a positive response in terms of flexural strength and toughness of concrete (Lam and Jamaludin, 2015; Ogunbode *et al*. 2016). The study of Nagrale *et al.* (2012) reported that addition of 15% RHA influences the density of concrete by reducing the weight concrete to about 72-75%. Thus, RHA concrete can be effectively used in the production of light weight concrete for the construction of structures where the weight of structure is of supreme importance. Nagrale *et al.* (2012) study further explained that the Compressive Strength of concrete will increase with the addition of

RHA and noted that the inclusion of RHA in concrete considerably reduces the water absorption of concrete. Thus, concrete containing RHA can be effectively used in places where the concrete can come in contact with water or moisture. RHA has the potential to act as an admixture, which increases the strength, workability & pozzolanic properties of concrete. Also, Habeeb & Mahmud (2010) described the effect of RHA on strength properties of concrete to be significant. The outcome of their investigation shows that compressive strength of blended concrete with 10% RHA increased significantly. They reported that up to 20% replacement of cement with RHA produced a valuable strength without adversely affecting the concrete strength.

The combined effect of kenaf fibres and RHA on the properties of concrete is a new concept of study which needs extensive consideration. While a few research works have been conducted on the use of these fibres in concrete to improve general properties of concrete, it is essential to conduct an in-depth study on the behaviour of concrete with the wide range of mix proportions. Since a small quantity of short fibres has been recommended for the enhancement of the strength properties of concrete, it paves the way to use kenaf fibres to obtain more detail on impact resistance of concrete containing this fibre. This study seeks to investigate the potential use of a natural fibre known as Kenaf fibre and Rice Husk Ash (RHA) from agricultural waste towards achieving a bio fibrous concrete with enhanced impact resistance and strength properties.

2. Materials and Test Methods

2.1. Materials

ASTM Type I Portland Cement used in this study attained the necessities of ASTM C150 (2007). In addition, the rice husk used in this research work was collected from a local grain mill in Garatu village along Minna-Bida road, Bosso Local Government Area, in Niger State. The collected rice husk was then burnt in open air with a locally fabricated incinerator. The resulting RHA was dried and sieved to eliminate larger materials and to lessen the carbon content. A local milling device was used to ground the resulting burnt RHA particles to a size smaller than 150 µm. Finally, the grounded ash was sieved with a 75 µm sieve and particles passing through were used as the RHA for the experiment. The obtained RHA followed to the provisions of BS 3892: Part 1 (1997). According to ASTM C618 (2017), it can be characterised as class C and F. However, based on the type, source and comparatively low CaO (1.26%) content, this ash was classified as low calcium content ash. The physical properties and chemical compositions of Portland Cement (PC) and RHA are given in Table 1.

Table 1: Oxide Composition of RHA

Material	Physical properties		Chemical composition (%)									
	Specific gravity	Al_2O_3	CaO	SiO_2	Fe_2O_3	MgO	K_2O	P_2O_5	TiO_2	M_2O_5	SO_3	Loss on Ignition
RHA	3.15	0.54	1.26	83.76	1.38	1.55	1.56	6.29	0.20	0.29	-	2.93

PC	2.64	5.65	5.10	61.6	8.62	3.52	9.05	-	-	-	1.16	6.25

River sand with a maximum sieve size of 4.75 mm and a specific gravity of 2.67, fineness modulus of 2.34, and 0.68% water absorption was used as the fine aggregates. Coarse aggregate used was crushed granite with a relative specific gravity of 2.90, 1.59% water absorption, and maximum size of 10 mm. For mixing and curing purposes, tap water was used.

Additionally, to increase the concrete flowability of fresh concrete, a polymer-based superplasticizer (CONPLAST SP 430) conforming to ASTM C494 (2018) requirement at a dosage of 1.0% by total mass of binders was used. Also, Kenaf fibre used was collected from kenaf plant and retting for two weeks and passed through mercerization treatment using Sodium Hydroxide to remove lignin, pignin, cellulose, hemicellulose and other impurities. In this study, the treated kenaf fibre was chopped to a length of 50 mm, as shown in Figure. 1.

Figure 1: Treated Chopped Kenaf Fibre

2.2. Mix proportioning and sample preparation

Various mixes were done for the different materials and in relation to their varying proportions. The mixes carried out includes: Plain concrete and RHA-based concrete based concrete with varying percentage of RHA (0%, 5%, 10%, 15%). Prisms (100 mm x 100 mm x 500 mm) were cast for impact test at 7, 28 and 56 days of curing age. 30% waste was added to every mix because of possible shortage from the mixing machine.

2.3. Testing methods

There are various methods of carrying out impact test of concrete, but for this work, the drop weight method was used according to the provisions of ACI 544.1R-96. Impact test on the prism was performed to determine the potential energy of the RKFC. In this test, prisms of 100 mm × 100 mm × 500 mm size (three specimens per mix) were tested with a centre to centre span of 400 mm at the centre of prism used. A 10 mm × 100 mm × 5 mm thick angle bar is placed at the centre of the prism to transfer and distribute the load from point load to line load. A hammer of 1.3 kg weight was dropped on the mid span of the beam from a height of 500 mm and 1000 mm. Number of drops (blows) up to cause initial crack (N_i) or failure (N_u) was determined and energy absorbed by the specimen (the impact energy), U was calculated by expression presented in Equation (1) given by Gupta *et al*. (2009):

$$U = N_i mgh \tag{1}$$

Where:

U= impact energy absorbed

m = mass of drop hammer (1.3kg),

h = drop height,

g = acceleration due to gravity (9.81 m/s), and

N_i = Number of drops up to failure,

(a) Initial Set-up (b)Failure after Impact

Figure 2: Operational Procedure for Drop Weight Impact Resistant Test

3. Results and Discussion

3.1 Tests on Hardened Concrete

With regards to the scope and objective of this work, some selected mechanical properties tests are to be carried out on the hardened concrete specimens, this includes: Compressive strength test, splitting tensile strength test, flexural strength test and impact resistance strength test.

3.1.1 Results and Analysis of Compressive Strength Test

The compressive strength result was obtained from the laboratory using the crushing machines at the various curing ages of 7, 28 and 56 days respectively. The average compressive strengths at various curing times of the five concrete mixes evaluated are presented in Table 2.

Table 2: Compressive Strength of the Concrete Mixtures Evaluated (N/mm^2)

Mix Type	RHA (%)	KF (%)	7 days	28 days	56 days
			Compressive Strength (N/mm^2)		

PCC	0	0	36.4	46.12	49.95
RPC1	5	0	32.7	43.9	53.3
RPC2	10	0	33.4	45.3	57.9
RPC3	15	0	34.6	46.1	54.3
PKFC	0	0.5	31.4	42.71	46.8
RKFC1	5	0.5	29.8	44.8	51.2
RKFC2	10	0.5	32.7	48.7	56.4
RKFC3	15	0.5	30.8	47.1	53.9

From the result indicated in Table 2, the compressive strength values for concrete mixes without fibre (RPC) is higher than mixes containing fibre (KFC) at the curing age of 7 days, while mixes containing fibre (0.5%) and RHA (10% and 15%) at 28 days exhibited higher strength than the control mix. The KFC and RKFC mixture cured at 56 days showed a more interesting higher strength when compared to the controlled mixture; this is due to the pozzolanic activity that boosts the concrete strength at later hydration period of 56 days. All concrete containing RHA from 5% to 15% displayed a corresponding higher strength than the Plain Concrete (PCC) and RKFC as illustrated in Table 2. Generally as the RHA content increased, the compressive strength also increased for all ages.

Admixtures such as pozzolans is one of the factors that have great influence on concrete strength at a given age and cured in water at a prescribed temperature in engineering practice and concrete materials technology. In this research work, five selected concrete mixtures were prepared using Nigerian based RHA and Kenaf fibre. The effects of varying RHA content was evaluated on the compressive strength of both the KFC at ages of 28 days and 56 days as illustrated in Table 2. Fibre content is another important factor influencing the strength of concrete because the higher the fibre content of natural fibre such as Kenaf fibre used in this research work, the more porous the hardened concrete tends to be and lesser the compressive strength of the concrete. This behaviour is as a result of the hydrophilic nature of kenaf fibre. As shown in Table 2, Compressive strength of concrete decreases dramatically as the fibre content was introduced into the concrete at 0.5%.

3.1.2 Results and Analysis of Splitting Tensile strength Test

Analysis of tensile strength of concrete is of great importance for some purpose such as, the design of airfield pavements and highway, shear strength and resistance to cracking. Tensile strength of concrete is much lower than compressive strength, due to ease with which cracks can propagate under load (Mindess *et al.*, 2003). Concrete is known to be weak in tension, and for normal strength concrete, tensile strength is only 10% of its compressive strength and for high strength concrete tensile strength ratio further reduces (Mindess *et al.*, 2003). Hence, appreciating the tensile strength manners and the relationship between compressive strength and tensile strength of concrete with and without different SHA content for both fibrous and non-fibrous concrete is imperative. The influence of RHA content on the splitting tensile strength of kenaf fibrous concrete and plain concrete is demonstrated in Figure 2.

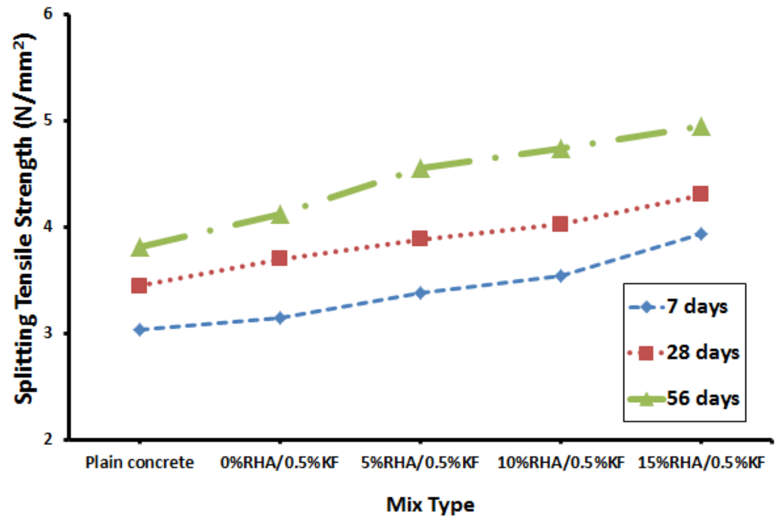


Figure 2 Splitting tensile strength of PC and kenaf fibrous RHA based concrete

The average splitting tensile strength obtained for Plain and RHA fibrous concrete cured for 7, 28 and 56 days indicated the tensile strength of the concrete to be between 3.04 to 3.96 N/mm^2 at 7 days for the entire specimen. In general, splitting tensile strength increased with age, for both fibrous and non-fibrous concretes made with both Portland cement and RHA as presented in Figure 2. However, the tensile strength improved with increase in RHA content up to 15% in the concrete. Nonetheless, the rate of increase in splitting tensile strength became lower at a later age for the entire test specimens. From the figure it can be observed that at 28 days the splitting tensile strength of plain concrete (0%), 5%, 10% and 15% SHA concrete with 0% fibre and 0.5% kenaf fibre respectively is within the limit of 2.0 – 2.5 N/mm^2 set by BS 5328 1981 (1981). Similarly, the specification of the splitting tensile strength of concrete for bridge and road construction is 1.85 MPa at 7 days. Nevertheless, Concrete containing 15% RHA develop up to 2.0 N/mm^2 at 7 days. Meanwhile, all other specimens fulfilled the same requirement at 56 days. Although there are scares literatures of splitting tensile strength of KFC containing RHA, the comparative result of those concrete with only RHA without kenaf (RPC1 to RPC3) or only kenaf fibre without RHA (PKFC)) showed a similar trend with control.

3.1.3 Results and Analysis of Flexural Strength Test

Concrete used for construction of beams or slabs either for structural or road pavement purposes are in most cases subjected to tensile stresses as a result of bending action in their applications. In any case, flexural tensile strength plays an important role in rigid pavement. Flexural strength of RHA based concrete containing kenaf fibre having similar mixture proportions with compressive strength was also evaluated for the same period of curing. An average of three values was obtained at each data point and the values are presented in Figure 3.

Similar to compressive strength, the flexural strength of concrete mixtures increased with increase in duration of curing and RHA content for both plain and fibrous concrete. As it can be seen, the early strength gain of the plain and fibrous concrete containing 0% RHA was not superior to those containing 5, 10 and 15% RHA. But at the age of 56 days, fibrous concrete containing 15% RHA was found to develop the highest flexural tensile strength compared to the with that of control (plain and fibrous concrete containing 0% RHA). This phenomenon which was found to be the same with the compressive strength, demonstrated the potential benefit of both kenaf fibre and rice husk ash in flexural behaviour of concrete. In general, plain concrete and fibrous containing RHA showed higher rates of flexural strength development after the age of 7 days. For example, flexural strength at the age of 28 and 56 days was found to be 4.82, 5.02, 5.49, 5.95 N/mm^2 and 5.44, 5.73, 6.19, 6.84 N/mm^2 for 0, 5, 10 and 15% RHA content of kenaf fibrous concrete, respectively. These values demonstrated higher increase in flexural strength for RHA concrete at 56 days; this shows that RHA based fibrous concrete may develop superior flexural strength beyond the age of one year. The reason for this conclusion was explained in an extensive study conducted by Huang, *et al.* (2013) on the contribution of fly ash to flexural strength development of concrete to be the interaction between fly ash and calcium hydroxide. This results to recrystallization of carbonate in the cementitious matrix, which causes a decrease in the porosity of the matrix and the transition zone (Nassar, *et al.*, 2013). The flexural tensile strength of PC and RHA concrete showed a somewhat similar trend to compressive strength. As the compressive strength increased, flexural strength also increased, but at a decreasing proportion for both categories of specimen.

As mentioned earlier, the higher values of flexural strength can be attributed to the higher contact area between fibres and the paste-aggregate matrix resulting from the increased amount of hydrated products such as C-S-H gel, due to the higher pozzolanic action of RHA with increasing curing time. The increase in flexural strength mainly resulted from the fibres intersecting the cracks in the tension zone of the prism specimens. Kenaf fibres act as crack arresters and hold the crack face separation through their stretching; therefore, these fibres provide a higher energy absorption capacity and stress relaxing for the micro-crack area adjoining the tip of the crack. The inter-particle friction between kenaf fibres and between fibres and aggregates also affects the orientation and distribution of the fibres and therefore the strength properties of the concrete composite. The increase in porosity may be linked to the sealing-up of micro cracks and poor fibre-matrix bonding.

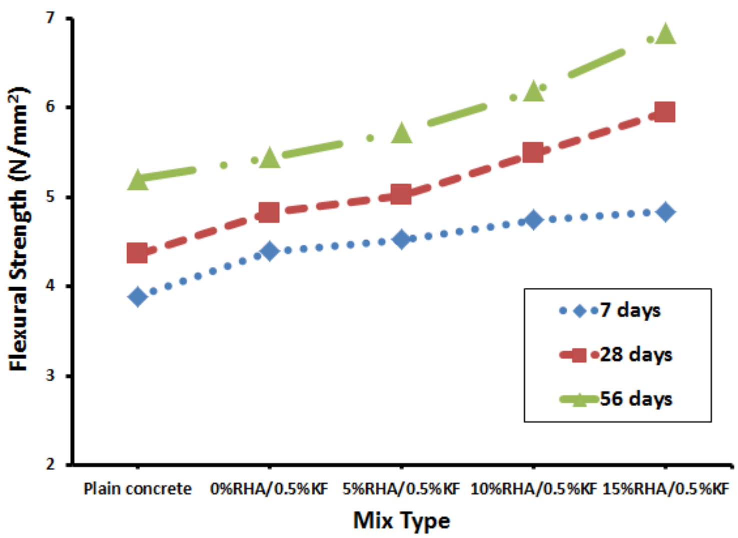


Figure 3: Flexural strength of PC and kenaf fibrous RHA based concrete

4. Impact Resistance

In this paper, the impact resistance of KF concrete containing different RHA content (0%, 5%, 10%, 15%) was investigated through the number of hammer blows necessary to obtain the initial crack (N_1) and failure (N_2) of the concrete prism (100 mm x 100 mm x 500 mm). The variance between the number of blows at ultimate crack (failure) and first crack (initial crack) (N_2-N_1) and the percentage rise in the number of post first crack blows to ultimate failure (N_2-N_1/ N1) are presented in Table 3. This study as shown that, with the addition of RHA into the KFC mixtures, the blows number of first crack was increased by 3%, 5%, 8%, and 10% for PKFC, $RKFC_1$, $RKFC_2$, $RKFC_3$ mixes, respectively.

The addition of RHA also raised the percentage rise in the number of post-first-crack blows to failure (N_2-N_1/N_1) value over the specimens not containing RHA. This indicates that RHA greatly enhanced the toughness and rigidity of the concrete mixture, thus promoting the ductility comportment of the fibrous concrete. The combined effect of RHA and KF on the impact resistance is shown in Figure 5. A confident interaction has been also created between the RHA and fibres, in the sense that combination of fibre and RHA exhibited a higher resistance in terms of the number of blows and energy absorption when compared with fibrous concrete containing no RHA or fibreless concrete containing no RHA. Table 3 further demonstrates the impact energy of initial crack and failure for concrete mixtures containing RHA and KF. It can be seen that, by the increasing RHA content in the fibreless concrete and fibrous concrete mixtures, an imperative increase in the blow number to attain the first crack and ultimate failure crack as compared to the control specimens without RHA or KF is witnessed.

Table 3: Impact resistance and energy of concrete mixtures at first crack and at failure for 0.5 m

and 1.0 m drop height

Mix ID		Impact resistance						Impact energy (Energy Absorption (kNmm)					
		Initial (First) Impact Crack (N_1)		Ultimate (Failure) Impact Crack (N_2)		N_2-N_1		Initial (First) Impact Crack (N_1)		Ultimate (Failure) Impact Crack (N_2)		(N_2-N_1/N_1)*100	
Fibre (%)	RHA (%)	0.5 m	1.0 m	0.5 m	1.0 m	0.5 m	1.0 m	0.5 m	1.0 m	0.5 m	1.0 m	0.5 m	1.0 m
0	0	523	116	526	120	3	4	3331.51	1477.84	3350.62	1528.8	0.57	3.45
	5	528	119	536	130	8	11	3363.36	1516.06	3414.32	1656.2	1.52	9.24
	10	536	125	554	141	18	16	3414.32	1592.5	3528.98	1796.34	3.36	12.80
	15	545	145	565	165	20	20	3471.65	1847.3	3599.05	2102.1	3.67	13.79
0.5	0	540	141	559	160	19	19	3439.8	1796.34	3560.83	2038.4	3.52	13.48
	5	549	157	566	179	17	22	3497.13	2000.18	3605.42	2280.46	3.10	14.01
	10	568	168	577	182	9	14	3618.16	2140.32	3675.49	2318.68	1.58	8.33
	15	580	175	593	198	13	23	3694.6	2229.5	3777.41	2522.52	2.24	13.14

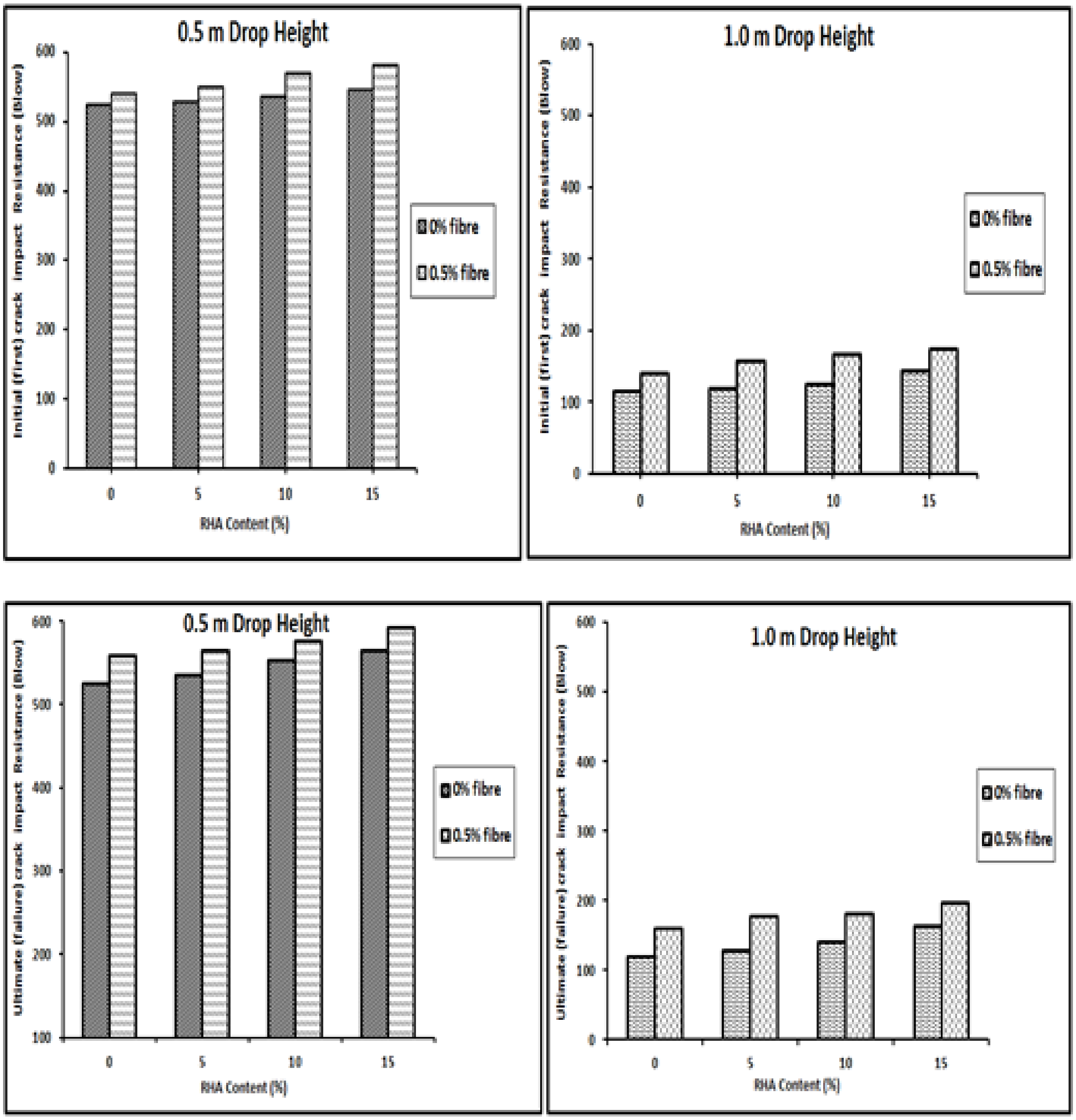


Figure 4 Impact resistance of kenaf fibrous concrete mixtures at varying RHA at first crack and at failure for 0.5 and 1.0 metre drop height

Figure 5 describes the relation among impact energy and RHA content in fibrous concrete. It has been establish that the addition and further increase in volume fraction of RHA occasioned higher impact energy compared to that of the plain concrete. For instance, a mixture containing 15% RHA exhibited highest impact energy of 3472 kN mm for 0% fibre, 3695 kN mm for 0.5% fibre for 0.5 m drop height and 1847 kN mm for 0% fibre, 2230 kN mm for 0.5%

fibre for 1.0 m drop height for first crack failure respectively. Also, for ultimate crack failure, a mixture containing 15% RHA exhibited highest impact energy of 3599 kN mm for 0% fibre, 3777 kN mm for 0.5% fibre for 0.5 m drop height and 2102 kN mm for 0% fibre, 2523 kN mm for 0.5% fibre for 1.0 m drop height respectively. A similar tendency like that of 0% (fibre less) mixtures has also been observed in the specimens containing 0.5% KF; the higher the amount of RHA, the higher the impact energy. The results of impact energy obtained from the present research work are similar to that reported by Nili and Afroughsabet (2010), Mastali *et al*. (2016) and Hossein *et al*. (2018) for concrete containing polypropylene and waste glass fibres and pozzolan.

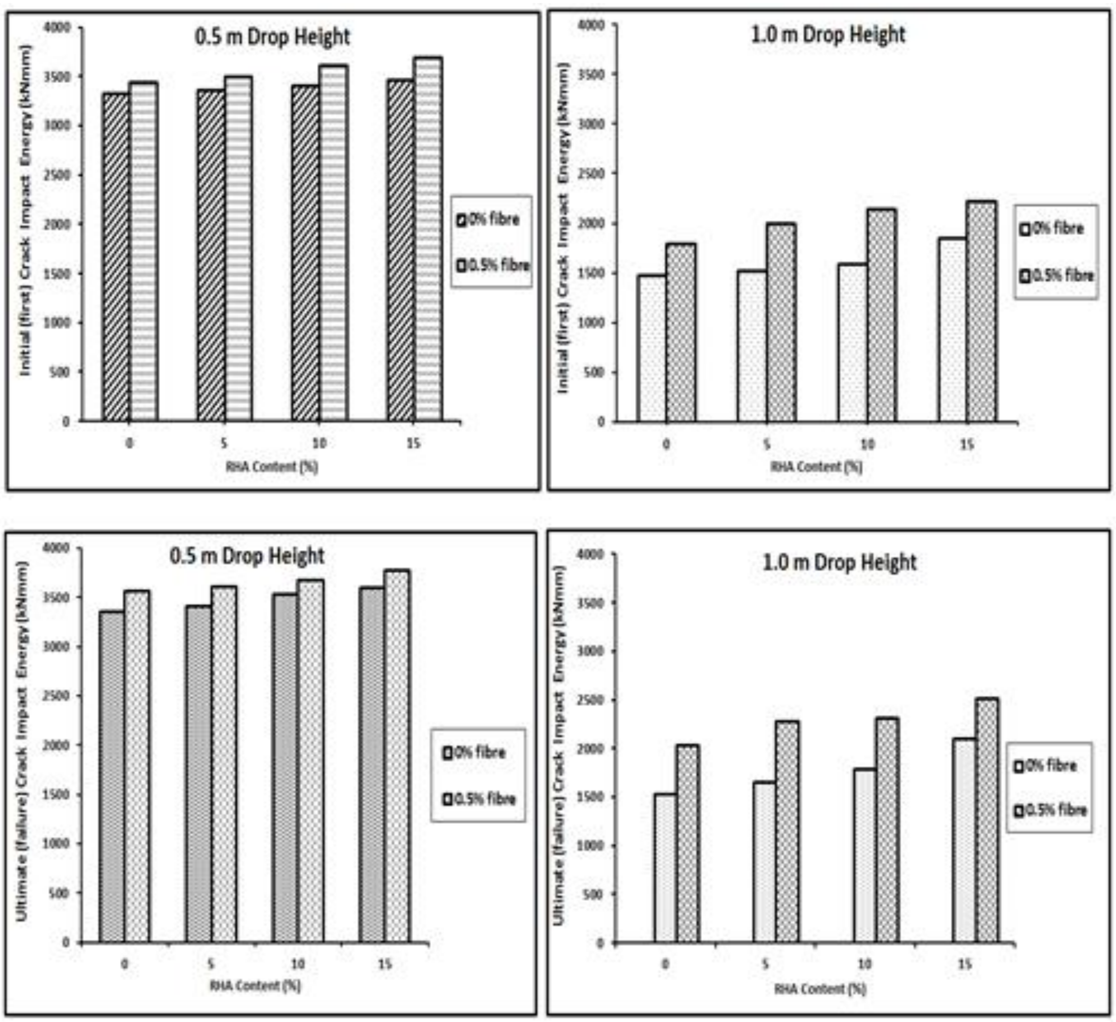


Figure 5: Impact energy of kenaf fibrous concrete mixtures containing RHA at varying volume fraction at first crack and at failure for 0.5 and 1.0 metre drop height

Variation of (N_2 - N_1) values are illustrated in Figure 6. It represents the post-peak resistance of the PCC and the RKFC mixtures. It can be seen that for 0.5 metre drop height test, the maximum value of 20 blows for 0% fibre and 15% RHA, and 19 blows for 0.5% fibre and 0% RHA content mixes respectively. Also, It can be seen that for 1 metre drop height test, the maximum value of 20 blows and 23 blows for both 0% and 0.5% fibre content mixes respectively, containing 15% RHA content. The obtained results indicate that higher amount of RHA content significantly increase the difference in number of blows between first crack and failure of the concrete specimens. It is due to the interconnection behaviour among the RHA content and fibrous concrete particles and therefore prevents the sudden failure of the concrete composite**.**

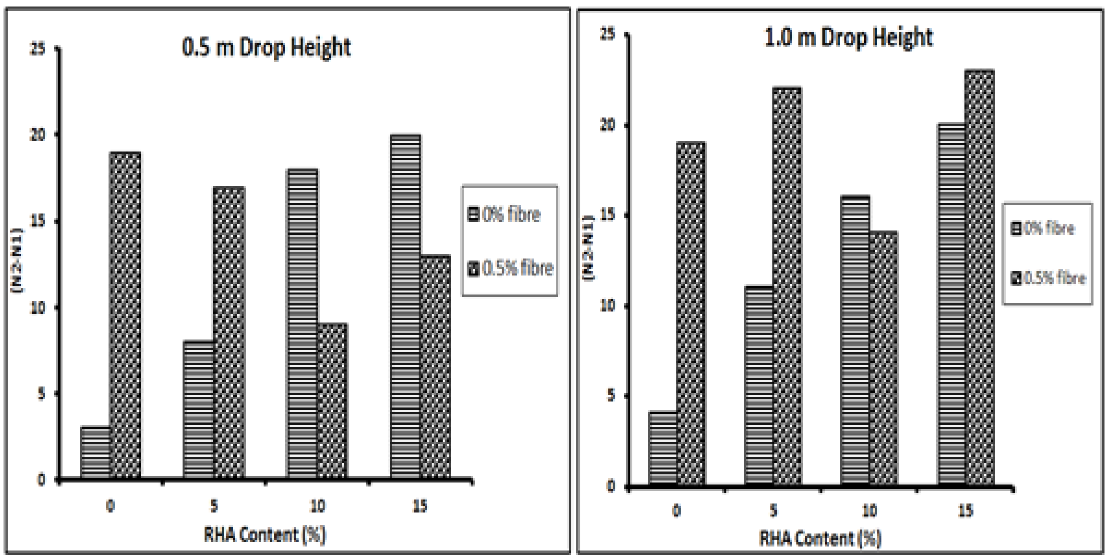
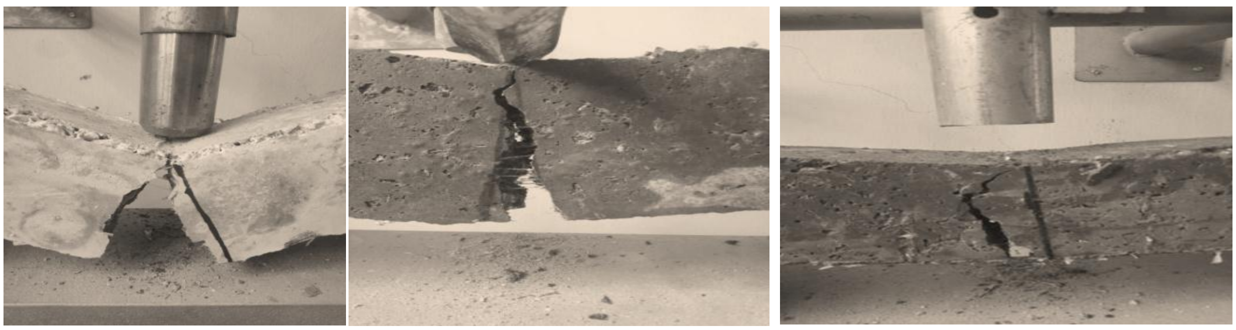


Figure 6: Variation of (N2 - N1) with RHA content

The results indicate that the combination of kenaf fibres and RHA can significantly improve the post-peak resistance and ductility performance of the concrete. Figure 7(a)-(f) shows a prism specimen for impact resistance test before and after the failure. Increasing RHA content resulted in increase in the toughness and ductility of the concrete as higher number of blows was experienced before the first crack and failure crack occurred when compared to the plain concrete without RHA content. A catastrophic failure crack was observed in concrete prism without fibre compared to the fibrous concrete prisms, as revealed in Figure 7(d), (e). The cracks developed on the surface of the fibrous concrete prism are due to the bridging action delivered by KF which absorbed more energy and prevented the sudden failure of the specimens. A fractured surface is also illustrated in Figure 7(e), where portions of the kenaf fibres are clearly visible. According to the given fractured surface, it is clear that kenaf fibres are uniformly distributed along the section. These results confirm the findings of Hossein *et al.* (2018) and Mastali *et al.* (2016).

(a) 0% fibre concrete without RHA (b) 0.5% fibre and 5% RHA (c) 0.5% fibre and 15% RHA



(d) Failure mode of sample with 0% fibre concrete without RHA (e) Failure mode of sample with 0.5% fibre and 5% RHA (f) Failure mode of sample with 0.5% fibre and 15% RHA

Figure 7: Impact Test Prism Samples and their Failure modes

5.0 Conclusion

This study is largely intended at assessing the effects of RHA on the impact resistance property of kenaf fibrous concrete. Although, the effects of these additives (RHA) on some selected strength properties of the concrete was not overlooked since it is the prime determinant of concrete usefulness. The environmental benefit of efficiently using these wastes (Rice husk) cannot be over-emphasized as it provides means for effective waste management and the efficiency of utilizing and recycling materials already termed to be wastes. However, it is noteworthy to conclude this work by highlighting the all-round effects of RHA and KF on concrete fresh and hardened properties. In the fresh fibreless and fibrous concrete mixtures, the addition of RHA at varying percentage replacement of cement resulted in lower workability of the fresh concrete. Addition of both kenaf fibre and RHA to concrete mixes reduces the unit weight of concrete thereby making the concrete more of a lightweight concrete as compared to concrete mixes without fibre and RHA. The cube compressive strength of the concrete increase with increase in the volume of RHA added to the mix. At 56 days of curing, the compressive strength of RHA based concrete mixtures exceeded the values of PC based concrete mixtures.

The results obtained and the observation made in this study indicate that concrete incorporating KF and RHA can be used with satisfactory engineering properties in the construction of building slabs, road pavements and other structural and non-structural applications.
With the results and analysis from this work, it is recommended that RHA and KF should be incorporated into concrete mixes aimed at improving the impact resistance of concrete but extreme consideration should be given if there is need to obtain maximum compressive strength, in which, high strength concrete should be used for the mix. For effective waste management, use of waste materials such as RHA can be effectively put to use and the recycling of these materials can help in the production of a sustainable concrete material and thus provide optimum economic benefit. Further study should be carried out to investigate the effect of high temperature on the compressive strength or impact strength.

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