ASSESSMENT OF THE IMPACT RESISTANCE BEHAVIOUR OF RHA BASED KENAF FIBROUS CONCRETE

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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 investigated 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 an interval of 5% without fibre was used as a basis for comparison against another four mixes made with 50 mm length fibre of 0.5% volume fraction and RHA of 0% to 15% as supplementary cementing material. 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. It was found that the addition of Kenaf fibre decreased the slump values and increased the VeBe time of fresh concrete. Also, the inclusion of RHA at

varying percentage had a reducing effect on the workability of both the fibreless and the fibrous concrete. At later ages, the compressive strength of the fibrous concrete mixtures containing RHA significantly increased and the obtained values were higher than the mix with OPC alone. The positive interaction between Kenaf fibres and RHA leads to high tensile strength, flexural strengths and impact resistance, thereby increasing the concrete ductility with higher energy absorption and improved crack distribution. The study established that Kenaf Fibre (KF) at 5% and 10% Rice Husk Ash (RHA) resulted in; 12%, 26.3%, 30.8% and 3.9% in compressive strength, splitting tensile strength, flexural strength and energy absorption values respectively compared to the control. It is concluded that Kenaf fibre and rice husk ash can be used as building materials in the construction of sustainable concrete.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Concrete with its low durability and rigidity has been subsumed as a brittle and frail material (Ogunbode *et al*., 2016). Therefore, the urgent commitment of a greater energy absorption and impact defiance is required in various applications like deck of bridges, industrial floors, highway paving etc. Enhancing the properties of concrete can be achieved by further incorporation of some additional components. (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. Natural fibres, Polymeric fibres (polypropylene, nylon etc), glass fibres, metallic fibres, and fibres from consumer waste have emerged as common fibres employed in FRC (Babafemi & 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 time, natural fibres of different kinds have been outstanding and applied in concrete mixtures. Kenaf fibres with volume fractions ranging from 0.5% to 1.0% has been frequently used as a supplementary reinforcement in concrete and have reported an enhanced tensile strength (Lam & Jamaludin, 2015; Ogunbode *et al*., 2018). But there is a dearth of literature on its effect on energy digestion and impact defiance of concrete.

Ordinarily, incorporating various types of fibres in concretes can enhance its ductility. Tejchman *et al.,* 2010; Arango, 2012 also worked on exploiting the importance of a system that fights against the development of cracks as well as enhancing how much work the concrete matrix can take. Quite a number of studies have been done to examine

how ductile FRC can be by the impact test, and results have shown that when fibres are added, the impact defiance of this mixture is improved. (Razavi, 2017). Fibrous concrete containing pozzolanic materials have been previously fabricated and studied with conventional concrete (Hossein, 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.

1.2 Statement of the Research Problem

Despite several approaches, waste materials utilization has become an emerging interest for waste management. The advancements concrete and cement technology has taken towards the production of sustainable concrete by using waste materials and cellulosic fibres is gradually attaining acceptance due to the advantages it possesses in the ecological, technological and economic advantages. In the past years, some fibres (glass, carbon, steel fibres etc.) are frequently being 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 considerably received attention to be used in different applications. This acceptance is due to its being environmentally friendly and its desirable characteristics such as a great and excellent stiffness and strength in particular.

Over the past decades, researches on the impact and clot of kenaf fibres on concrete and concluded that kenaf fibres curtails the compressing force and workability of concrete. However, kenaf fibres have demonstrated a positive reaction with respect to its toughness coupled with its strength (Lam & 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%. Hence, an effective use of RHA concrete is in the production of concrete with low weight where they can be applied in building up of structures where the weight is very significant. Nagrale *et al.* (2012) further explained the incorporation of RHA with results showing an increase in strength of concrete with a reduction in how much water the concrete absorbs. Therefore, with the presence of RHA in concrete, it can be used in areas where concrete can get in touch with water. In addition, with a significant increase in strength, pozzolanic properties and workability of membranes, RHA offers the possibility act as an admixture. Habeeb & Mahmud (2010) described the impact RHA has on the resilience characteristics of concrete to be significant. Results showed that the extensive strength of composite concrete with 10% RHA was substantially improved. They also reported that having about 20% of cement with RHA produced a valuable strength with no negative impact on concrete strength.

A recent notion of study that requires a comprehensive review is in the combined effect of RHA and kenaf fibres on the characteristics of concrete. With little research being done on the utilization of these fibres in enhancing concrete performance, conducting a detailed study on concrete having a broad range of mixing ratio is very vital. Considering the fact that a small amount of short fibres has been considered in improving the

properties of concrete, this makes it easier to utilize kenaf fibres in order to achieve a greater defiance effect of concrete with fires in them.

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.

1.3 Aim and Objectives of Research

This research aims to study the influence of Rice Husk Ash (RHA) on the impact resistance of Kenaf Fibrous Concrete (KFC) with a view of producing a concrete with enhanced ductility and ability to withstand impact load. The specific objectives of this work are to:

i. Determine the physiochemical properties of the constituent materials.
ii. Evaluate the influence of RHA on the fresh properties of KFC.
iii. Determine the effects of RHA content on compressive, tensile and flexural strength properties of KFC.
iv. Assess the influence of RHA content on the impact resistance of the KFC.

1.4 Scope and Limitation of Study

This work would be tested and experimented in nature and majorly focus on applying developed KFC composite containing RHA at replacement levels of 0 to 15% at 5% step intervals of Portland Cement (PC) and kenaf fibre at fibre length and content is 50 mm and 0.5% respectively. Kenaf fibre was used as an addition while RHA was used as supplementary cementing material. Therefore, an essential number of investigations and

analysis were performed. This study emphasizes on the properties of concrete (mechanical and physical) considered to be within specified limits set by the objectives.

The kenaf fibre used in the study is Nigeria based and obtained from manchock local government area in Kaduna State to be precise. In order to removed pectin, cellulose and lignin, the fibres were treated with Sodium Hydroxide (NaOH). The RHA was initially acquired in the husk state and then burnt to ash form in a locally fabricated incinerator. The study emphasizes on the impact resistance of the composite using drop weight impact test methods. KFC specimen testing for impact resistance was conducted on standard size specimens. 100 mm x 100 mm x 500 mm prism were in use while undergoing the drop weight impact test as given in the work of Razavi (2017). The focal variables considered are the effect of RHA inclusion in 0.5% KFC (0% to 15% at 5% interval) and Height of Drop weight (500 mm and 1000 mm) on concrete sample. The specimens had been tried at hydration days (7, 28 and 56) respectively.

1.5 Justification for the Study

Elimination of the huge amounts of agricultural waste and synthetic waste materials generated in our environment has been a very difficult task to achieve in the past years. Nevertheless, the environmental defects can be reduced by providing more sustainable usage of these waste materials. This is known as the Waste Hierarchy''. Its objective is to reduce, recycle, or reuse waste, the latter being the desired option of waste disposal as illustrated in Figure 1.1.

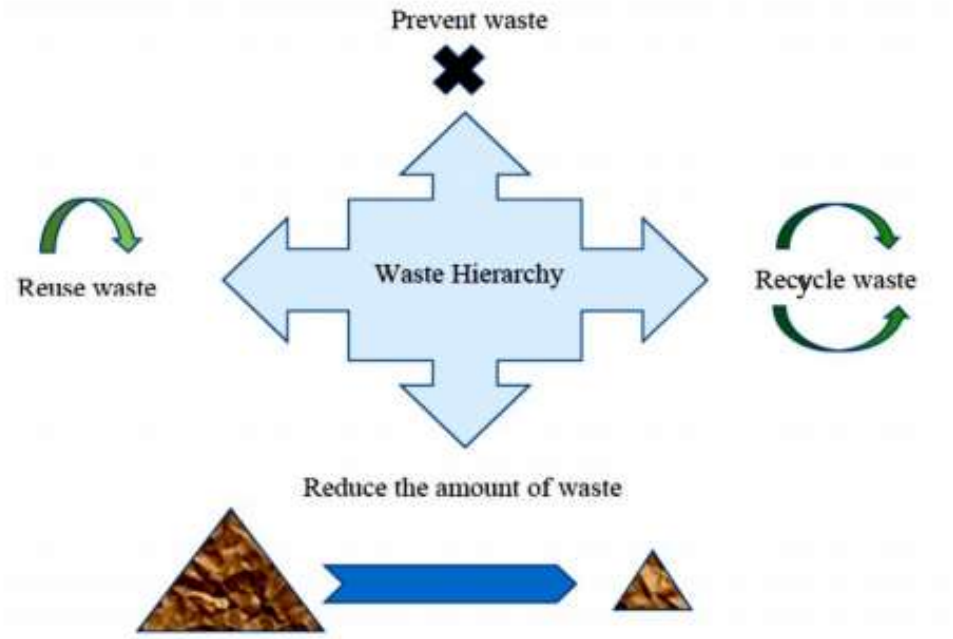


Figure 1.1 The waste hierarchy

Since short discontinues fibres has been proposed for the development of the concrete performance, the use of kenaf fibres will result in a reduction of the amount of synthetic fibre used which is generated from petroleum product. This will help to reduce the generation of CO_2 that have relative effect on the ozone layer of the earth leading to global warming. Promoting the use of kenaf fibre as a fibre material in fibrous concrete production will increase the plantation of kenaf plant which contributes to our environment by reducing the CO_2 in the atmosphere and achieving a cleaner environment. The change aimed in achieving a renewable and long-term improvement due to the effects of strains placed on reducing CO_2 and greenhouse gases which gives an increase in the demand in the fibre market. Switching into a renewable and biological inclined system demands alternating certain resources (Plant or animal based) materials.

On ecological grounds products should then be preferred that are based on photosynthetic CO_2 fixation. The benefit of those sustainable resources is that they can be regrown within the foreseeable future, without negative side-effects on global bio-diversity. Therefore, competitive products based on renewable resources need to be developed that

have high quality, show excellent technical performance and harm the environment less than current products based on petrochemical materials (van Dam, 2009).

The inclusion of kenaf fibre and replacing Portland cement with RHA helps to enhance the brittleness properties of concrete. Appropriate use of SHA in the concrete product will significantly develop the mechanical properties of concrete which will in turn decrease the pressure on the industrial and domestic consumption of Portland cement. As both SHA and kenaf fibre are from agricultural source requiring minimal spending, their use will considerably decrease the overall cost of construction, thereby justifying the name of "Green Concrete Composite". Consequently, the mixture of SHA and Kenaf fibre to produce concrete composite will open up new research opportunities.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Concrete

Concrete constitutes a mass of loose inert particles of aggregates (mostly of gravel and sand) held together in solid form by a binding agent, the loose particle consists of mineral fibres, industrial waste, wood chips and synthesis material. The binding agents could be gypsum, coal tar, Portland cement or various synthetic materials (Hossein, 2017). Concrete is a composite material which is made up of fillers and binder. The binder (cement paste) glues the filler together to form a synthetic conglomerate. The constituents used for the binder are cement and water, while the filler can be fine or coarse aggregate, (Chudley & Greeno, 2006, Falade, 2009 and Hossein, 2017).

Piasta and Sikora (2015) also added that, with the diversity in nature, concrete comprises of numerous materials that influences its characteristics in respect of both toughened and fresh state (NIS-ISO 9004). Therefore, the primary goal is to know the suitable amount of materials which would yield a good concrete of a good workability and durable strength (NIS-ISO 9004). Admixture (e.g. pozzolan, plasticizers, air entraining agents etc.), coarse and fine aggregates, and water are principal components of a concrete (Piasta & Sikora, 2015). Several virgin materials are being absorbed including principal materials listed above which has being a major danger to the environment.

2.2 Cement

Cement with its grey finely divided texture comprises of an extremely complex mineral component. Specifically, Portland cements hold a very good cohesive and adhesive properties that has made it capable in binding mineral substances together (Neville, 2011).

The rate and level of cohesion allows the cement in becoming very homogenous while the rate of adhesion enables it binds together with other several materials. Silica Oxide (SiO_2), Iron (Fe_2O_3), Aluminium oxide (Al_2O_3) and Limestone coupled with clay through Calcium oxide (CaO) are major raw materials employed in the manufacturing of cement. Oxides of some other elements like Sodium, magnesium, potassium and sulphur are also present in small percentage. All materials put together would be heated in what is called a kiln at temperature of about 1400 - 1600^oC where all materials chemically react together to give a homogenous compound called a clinker. A specific amount of gypsum is then grounded together with the clinker to give a Portland cement (Neville, 2011).

2.3 Pozzolans

ASTM C618 (2017) explained Pozzolans as siliceous and aluminous materials in finely divided state that exhibits a little or no cementitious properties but with the presence of water, it chemically reacts with Calcium hydroxide at room temperature to give a product with cementitious properties. Pozzolan can be used in enhancing the properties of cement as stated below:

i. Water tightness increment
ii. Enhanced chemical attack resistance.
iii. Enhanced workability.

iv. Decrease in amount spent on concrete material especially cement.

v. Although, when pozzolan is added into cement, this would not add to the concrete's comprehensive strength until it is heated for an ample period of time (Neville & Brooke, 2010).

Table 2.1: Physical and Chemical Requirement of Pozzolans as Offered by ASTM

S/NO	Property of Pozzolana	ASTM Requirement (%)
(i)	Water-soluble solution	10.0
(ii)	Fines: Amount retained when wet sieve Number 30 Sieve (600ῳm) Max% Number 200 Sieve (75 ῳm) Max%	2.0 30.0
(iii)	Drying shrinkage (Max)%	0.15
(iv)	Increase in drying shrinkage of Portland pozzolana cement mortal bars at 28days (Max)%	0.03
(v)	Water requirement (Max % of control)	115
(vi)	Silicon dioxide (SiO_2) + Aluminum oxide (Al_2O_3) + Iron oxide (Fe_2O_3)	70
(Viii)	Pozzolanic activity index with Portland cement at 28days(Max % of control)	75
(ix)	Magnesium oxide (MgO) Max%	5.0
(x)	Loss of ignition (LOI) Max %	12.0

Source: ASTM C618 (2017)

2.3.1 Rice Husk Ash (RHA)

Recently and. Based on high silica content, Rice Husk Ash (RHA) has gained and has started to show superior characteristics in its application to concrete and so many researches have been done in utilizing RHA as a co-reactant with cement. The optimum replacement of PC with RHA to produce grade 30 and 40 concrete at 28 days strength is 30% while for the production of grade 50 is 20%. This replacement was also done in order curtail how much

water enters into the cement (Kartini *et al.*, 2006) and such RHA replacement results in nan enhanced strength (Habeeb *et al.,* 2010). From this various research report, it was observed that there are variant optimum replacement percentages. This variance could be due to the properties, source, and treatment of RHA and method of production of the RHA. Also, the smoothness of the RHA has a great influence on concretes strength (Magnani *et al*., 2014).

2.3.2 Effects of RHA in Concrete

Containing about 87% silica, Rice husk exists mainly in an amorphous pattern having a definite surface area about 36.47 mm^2 blended together alongside the cement. With a displacement of about 30%, there was no adverse effect on permeability and strength of cement Nagrale *et al.* (2012). Replacing cement with RHA is possible without any compelling difference in strength (Habeeb & Mahmud 2010). Ikpong *et al*, (1993) also worked on the alteration observed in concrete strength when cement is partially replaced with RHA. Results showed that strength can be increased up to of 30 N/mm^2 after 28 days if about 405 is replaced with RHA. Furthermore, Saraswathy and Ha-Won (2007) also explained that, with the rate at which RHA reacts with pozzolanic, RHA blended with cement also applies a compelling influence on how the strength is enhanced.

2.4 Fibres

There are majorly two types of fibre, the artificial and natural fibre. Environmental and financial issues have highlighted the importance of natural fibres to be used for manufacturing such as automotive products and construction materials (Bernard et al 2011; Pervaiz & Sain 2003; Sreekala *et al.,* 2002; Saheb *et al.,* 1999). These fibres have certain

advantages such as biodegradability and being free from health issues. The physical characteristics of natural fibres are based on their components which includes, how much cellulose is present, climatic and planting conditions, architecture of the fibre and also fibre mode of extraction and storage (Mohanty *et al*., 2005; Jawaid & Khalil, 2011). Figure 2.1 shows some natural fibres and their classification.

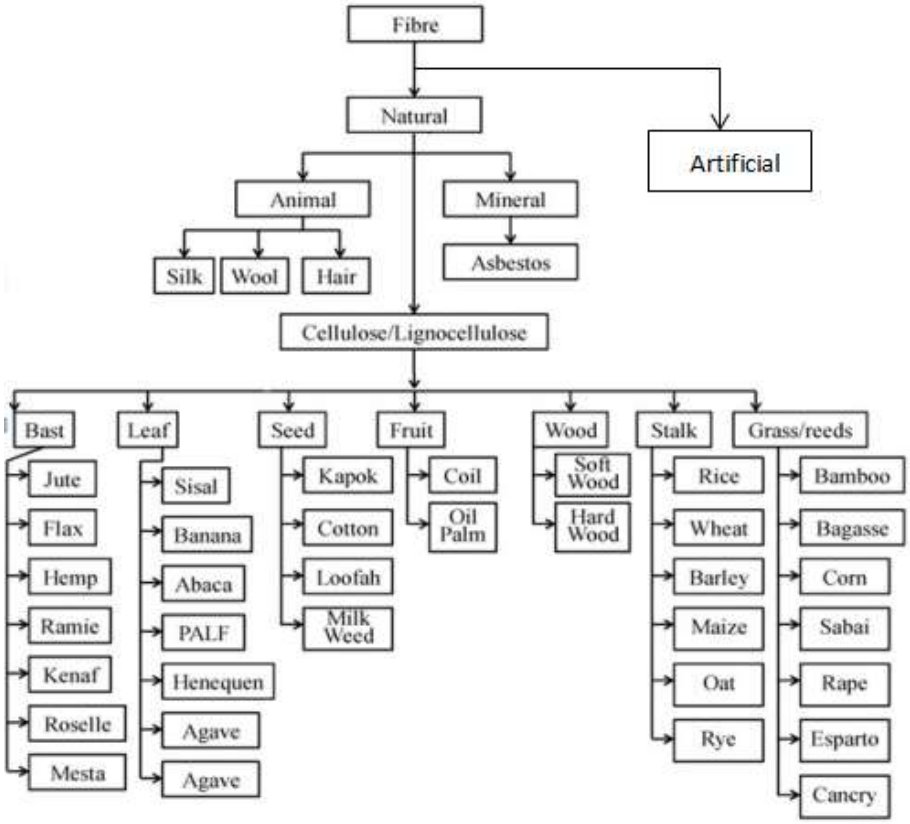


Figure 2.1 Natural fibres classification

Cellulose, lignin, pectin and hemicellulose are constituents of a vegetable fibre. Natural fibres are mostly composed of Lignin and cellulose. Quantity of cellulose might alter based on the age and type of plant. Containing a polysaccharide hydrophilic group, cellulose is an

anhydroglucose having a hydroxyl and an alcohol functional group. Therefore, every natural fibre has a good hydrophilicity.

2.4.1 Kenaf fibre

Using the core (inner) and the bast (outer) of a kenaf plant also known as ("Hibiscus Cannabinus L."), Kenaf fibres can be made. This fibre has been one of the ancient natural fibres specially used (Ogunbode *et al.*, 2015). The kenaf plant is one of the most commercially cultivated plants in the United States and applied for various purposes (feed for animals) and also being eaten in Ghana (Ogunbode *et al.*, 2015). Recently, this fibre has been focused as a different mode of substituting synthetic fibres for the augmentation of composites (Akil *et al*., 2011).

2.5 Fibre reinforced concrete

Unreinforced concretes with a drawback low strain capacity and tensile strength has been removed and strengthened by the use of pre-stressing steel bars. Most fibres which are normally dispersed all through the matrix of a concrete are usually applied for increasing and augmenting the strength of materials. Straw and horsehair respectively applied for reinforcing sun-baked bricks and masonry mortar are used as the traditional reinforcing method. Asbestos cement construction is widely used in material construction. However, because of the health problems stemming from asbestos fibres, other alternative fibre materials were applied in 1960s and 1970s. Fibres are also used in modern engineering materials such as ceramics, plastics, cement, and gypsum as a way of improving the composite properties. Some major properties which are going to be improved by using fibres

includes, durability, resistance to crack and impact, fatigue life extension, strength (Tensile and comprehensive), resistance to shrinkage or contraction, and thermal properties.

By using fibres,

2.5.1 Natural Fibre Reinforced Concrete

Most commonly used fibres used for FRC application are short discontinuous fibres. In addition, natural fibre reinforced concrete (NFRC) are concretes that are being augmented using natural fibres. Items usually used for reinforcement are easily found at low cost, and don't need specialized technical manpower. These fibres are applied in producing FRC with reduced fibre content also with a FRC with a thin sheet with an increased fibre content. Such kinds of fibres are considered as unprocessed natural fibres (UNF) (Hossein *et al*., 2018).

Mohammed *et al*. (2015) put it succinctly that In spite of applying unprocessed natural fibres, natural fibres can also be processed to improve their characteristics making them usable for reinforcement. One type of applied processing is called Kraft process which leads to emergence of Kraft pulp fibres being applied in complicated production processes. The fibres produced through such procedure are called processed natural fibres (PNF). The concretes derived from such PNFs are named processed natural fibre reinforced concretes (PNFRC) which are receiving attention these days (Mohammed *et al*., 2015)

2.5.2 Fresh State Properties of FRC

Plastic or fresh state concrete are newly blended components that can be shaped to a desirable form. Some components which governs the characteristics of concrete in either the

hardened or plastic state includes; rate of distribution of cement, aggregates, and mixing ratio of water and fibre. The concrete should be designed accordingly in a manner by which by FRC properties (workability with respect to vebe and slump time) would be appropriately fulfilled.

2.5.2.1 Workability

As reported by ASTM C125/C125M (2012), the Property that ascertains the attempt to manipulate or influence a freshly mixed concrete with the slightest decline in homogeneity is called concrete workability. Manipulate or influence as stated above refers to the process of mixing, compacting and conclusion. Workability of fresh concretes as described by (Mindess *et al.* (2003) is the level of energy or work needed in generating a complete compression in a concrete with the absence of partitions. Concrete workability is one of the major properties that must be fulfilled in concrete technology. In spite of the complications in the steps for mix design, a concrete that is no well mixed may not be possible to hard enough to give the desired strength and endurance. It has been an established knowledge that when any short fibre is added to concrete, the workability is reduced. In spite of what kind of fibre, decrease in workability correlates to how much fibre is utilized while mixing the concrete (Bentur & Mindess, 2007). In agreement with ACI544, instances of workability test include; compacting factor, slump, inverted cone and vebe time.

2.5.2.2 Unit Weight of Fibrous Concrete

A major parameter in concrete is the unit weight (UW) which is usually applied in ascertaining how much yield and unit weight of concrete that are newly mixed. UW is also

referred to as mass per unit volume of a concrete. Concretes UW is influenced by material components, water/binder proportion along with mixing ratio (Neville & Brooks 2010). When a SCM or a slightly soft fibre is employed, then UW of FRC reduced significantly (Tapkin 2008; Akça *et al.* 2015). As reported by Karahan and Atis (2011), Fibres enhanced concretes comprising of polypropylene fibres exhibits a lower UW compared to those not enhanced. It has as well been discovered that UW decreases as the polypropylene fibres rises. This is because of polypropylene fibres has a small specific gravity of about (0.90-0.94). A confirmation of this work is in accordance to results from Hsie *et al*. (2008).

2.5.3 Hardened State Properties of FRC

As earlier stated above, concrete is a material prone to stress and pressure in which crack developed is linked with its hardness and level of shrinking etc. This crack develops in the course stress and time hereby making its durability detrimental and inner surface prone to destruction by acid or water. Consequently, for the purpose of nullifying cracks, it is best advised to use a method that enables the concrete mix together by introducing short fibres. Furthermore, as fibres impacts resistance to chemical attack and heavy loads, they also improve performance based on pressure, tension and compaction (Zollo 1997; Song *et al.* 2005; Hsie *et al.* 2008).

2.5.3.1 Compressive Strength

One of the most important property of a concrete is its strength. Concrete is applied in order to resist excess pressure. In such circumstances where force is excessive, its pressure is of great importance. Therefore, constituents used in mixing cement are evaluated by their strength. In addition, they are also applied as a standard for some other addition components

used in enhancing performance. By no means is there any connection existing between fire resistance, flexibility, tear and ear resistance or permeability. Nonetheless, relationships that gives vital details to researchers and engineers have been acknowledged (Shetty, 2012). With regards to situation of concrete enhanced with fibres, they exhibit little or no influence on concretes strength. Identical methods utilized in concretes strength can also be applied to FRC (Bentur and Mindess, 2007).

There is no substantial way to distinguish the strength of concrete enhanced with polypropylene fibres and those with just plain mixtures (Chan *et al.* 2000; Song *et al.,* 2005; Nili & Afroughsabet, 2010; Yew *et al.* 2016) due to the fact that it has little or no fibre in it. Certainly, when the fibre content is increased, the strength of concrete is reduced to about 10% because of the problems with compaction in the matrix (Beaudoin, 1990). Nevertheless, it has been outlined that there is an improvement in performance when polypropylene fibres are used (Sun & Xu 2009; Ueno *et al.* 2017). Conflicting results have been recorded by various researchers on how polypropylene fibres influences FRC strength (Zollo 1997; Nili & Afroughsabet 2010; Serrano *et al.* 2016). Quality of production, formulation of matrix and type of fibre used are major causes in the variation of this results. Concretes having pozzolanic substances and enhanced with fibre has furthermore been investigated (Alhozaimy *et al.* 1996; Nili & Afroughsabet 2010; Zhang *et al.* 2011; Aldahdooh *et al.* 2013). Another discovery shows that blending pozzolanic substances like fly ash, silica fume, or palm oil fuel give a better strength that made of normal concrete especially during the subsequent stage. Furthermore, very little studies have been done on how waste carpet fibres (WCF) affect concrete strength. As indicated by Wang *et al.* (2000),

supplementing a concrete mixture with WCF caused a decline in the compact strength. Reason for this is due to the reduced quality and strength of thread used. Despite the fact that significant studies on how PP fibres influences the strength of FC, no details on how the combined effect of pozzolanic substances and WCF affects performance has been recorded.

2.5.3.2 Splitting Tensile Strength

A major characteristic of a concrete is its tensile strength. Also, in order to evaluate the tensile strength, the splitting test method can be applied. As earlier explained, concrete cannot repel tension imposed directly due to its poor tension and fragile nature. For this reason, there is great advantage if its tensile strength is assessed so as to ascertain how much load is required before cracks starts to show up (Bentur & Mindess 2007). Some other essential materials like FRC are required and have shown good results in improving tensile strength (Zollo, 1997; Hsie *et al.,* 2008). Li and Cai (2011) also stated that tensile strength, hardness and tensile behaviours and failure mode are properties that are being improved with the incorporation of fibres. Usually, with respect to their reaction to tensile strength, FRC are majorly classified into strain hardening and strain softening. Strain hardening refers to a type of FRC which is usually enhanced using a large quantity of short fibres. Occurrence of cracks in this type of FRC is usually noticed for concrete enhanced with short fibres as well as in composites enhanced with continuous fibres. While strain softening, a reduced amount of short fibres containing as low as 1% fibre applied for a large amount of concrete. In addition, mode at which both changes are through strain-softening to strain-hardening. Increase in concrete tensile strength is also possible if the fibres are concentrated in the position where the tensile strength is more (Alhozaimy *et al.,* 1996; Hsie *et al.,* 2008).

Notwithstanding, there is a reduction in strength with concrete where the fibres are evenly distributed but still very much greater than that made of ordinary concrete (Aslani & Nejadi 2013). Nili & Afroughsabet (2010) also demonstrated that tensile strength can be improved to as high as 14% for 0.5% fibre content by splitting tension test of FRC having PP fibres in contrast to ordinary concrete alone. Whereas, it was observed by Li *et al.* (2006) that tensile strength was drastically improved as high as 41% with 0.95% PP fibre. Increasing the content of fibre is more beneficial in enhancing tensile strength than improving compression. By splitting tensile strength with a fibre content above 2%, Sivakumar and Santhanam (2007) explained that tensile strength increases. As the fibre content increases, the concretes splitting tensile strength also is improved.

2.5.3.3 Flexural Strength

Most cases of application of concrete impinged to tensile strength are mostly in construction of roads, slabs or beam purposes which is because of how much bending activity is done on them. Frequently, concretes enhanced with fibres are very ductile and possesses a very excellent strength which is a very important factor in constructing a firm ground. For more improvement in the flexural strength of FRC, natural fibres have proven to be best applied.

Improving this strength is not as a result of just increasing fibre content but by carefully taking note of its ratio which is proportional to the increase in strength. Hence, flexural strength is denoted with the expression *Wl/d. W* being the percentage weight of fibres and *l/d* is the aspect ratio (Bentur & Mindess 2007). This improvement is due to the fact that fibres

are standing in places with cracks at the area with more tension by stretching further hereby taking in all additional energy. Results gotten from some other work supports the above claim as stated (Alhozaimy *et al.* 1996; Song *et al.* 2005; Nili & Afroughsabet 2010). In addition, some other work also supported the proof that the incorporation of waste and pure PP fibres into concrete improves its flexural strength (Wang *et al.* 2000; Martínez-Barrera *et al.* 2005; Choi & Yuan 2005; Yin *et al.* 2016).

2.5.4 Impact Resistance of Concrete

For the purpose of identifying how FRC affects and influences concrete, various work on the proportion of stress have been carried out. (Razavi 2017) also stated that certain characteristics like flexural, comprehensive and tensile impact test have been employed in reviewing how fibres influences concrete. Incorporation of short fibres can significantly enhance the effect on concretes reduced resistance. Fibres in general, such as polypropylene fibres, increase both the fracture energy and generally the peak loads under impact (Mindess *et al.* 2003). Examining the impact of loads on concretes with natural fibres is very important. However, there is at present no standard impact test for FRC, similar results are obtained with several tests that have been practically used such as test on explosive loading, Charpy impact and also drop weight (ACI 544.2R: 1999). According to ACI 544.2R (1999), drop weight test is the easiest test amongst all that can be carried out.

All test as stated above are used to give how much number of hits the concrete can take be getting to an undesired degree of worry. In contrasting the various importance of various blend of FRC into concrete and also to point out the development in performance with

comparison to plain mixture, this test can also be applied. In addition, this test can also be applied to test how much resistance a concrete can take based on various thickness of substances used. Chapter 3 presents the equipment for drop-weight test and the test procedure. Several works have been done in other to review how ductile a FRC sample but this test has proven to be the most popular way of evaluating how ductile a concrete can be (Banthia *et al.* 1989; Badr *et al.* 2006; Yahaghi *et al.* 2016).

Nili & Afroughsabet (2010) also stated that, the impact resistance test by drop weight method was used for concrete that were enhanced using samples of PP and ordinary fibres. They found that incorporating silica fumes improves its strength, resistance and accelerates its dispersion rate (Ogi *et al.* 2005; Siddique *et al.* 2008; Mastali *et al.* 2016). Concretes strength with fibres that are being reused has found great potential in enhancing how durable and how much force it can resist. Nevertheless, such development is dependent on its mechanical properties, type, amount and constituents of fibres. However, there still remains a lacunar in knowledge of the potential of natural fibre on concrete and how it can improve its impact resistance.

2.5.4.1 Impact Test

A study on concretes impact test carried how by Swamy & Jojagha, (1982), where it was enhanced using steel fibres in order to identify its resistance. Another example of the impact test on concretes enhanced with fibres was also done by Gopalaratnam & Shah, (1985) while Sridharan *et al.* (1989) as well examined to what extent a concrete enhanced with fibre possesses impact resistance. Several researches as initially stated has come to come to a conclusion that concrete with good fibre content exhibiting good impact strength has

increased up to about 350% unlike those with plain concrete. In an effort by Wu *et al.* (1989) to determine how much strength a concrete enhanced with concrete with various percentage amount of fibres (0.5%, 1.0%, 1.5%), results showed a significant increase in strength up to about (251%, 583%, 730%) with a steel fibre content of (0.5%, 1.0%, 1.5%).

Kohno *et al*. (1992) also carried out a research and results showed that incorporating fibres made of steel into significantly improves the mixture. Ukrainczyk & Rak (1992) in a separate work also proved that concrete enhanced with fibres made of steel showed an impact resistance more than three times larger unlike those with plain concretes. With proof of concept, Siddique (1993) tested how much natural fibres can affect concretes strength by using a concrete mixture having about (0.25, 0.50, 0.75) % natural fibres with length ranging from (20 to 30) nm. Also, there was a Contrast among plain concrete and concrete enhanced with fibres with a percentage amount of (20 x 300 x 300) mm having a magnitude about (25 x 100 x 300) mm. Results showed an increase in concretes impact strength up to about (25 to 26.73) % with fibre content of 0.75% and length of 25mm. In another work according to Natraja *et al*. (1999), a test showing the difference in impact resistance of concrete enhanced with fibres and impinged with a kind of weight. Having a width about 150mm and breadth 64mm chopped away from a 150 x 300mm size cylinder having a fibre proportion 0.5%. There was a noticeable difference in results observed at different ratio percentage (46 and 57) % for initial and final resistance accordingly.

$$H = \frac{gt^2}{2} \tag{2.2}$$

$$V = gt \tag{2.3}$$

impact energy

$$U = \frac{mv^2}{2} \tag{2.4}$$

Expression above indicates how the impact energy for every strike of hammer (Mohammad *et al.,* (2009).

Figure 2.2 and 2.3 below shows a graphical expression of number of strikes at first crack against the amount of fibres applied respectively whereas, Figures 2.4 and 2.5 shows a graphical expression of first crack/ energy failure plotted against the amount of fibres used respectively (Mohammad *et al.,* (2009):

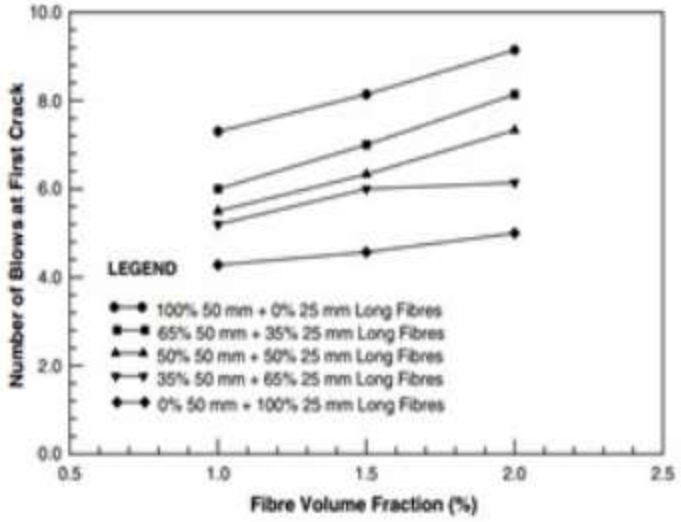


Figure 2.2: Impact of first crack resistance of concrete having mixed fibres

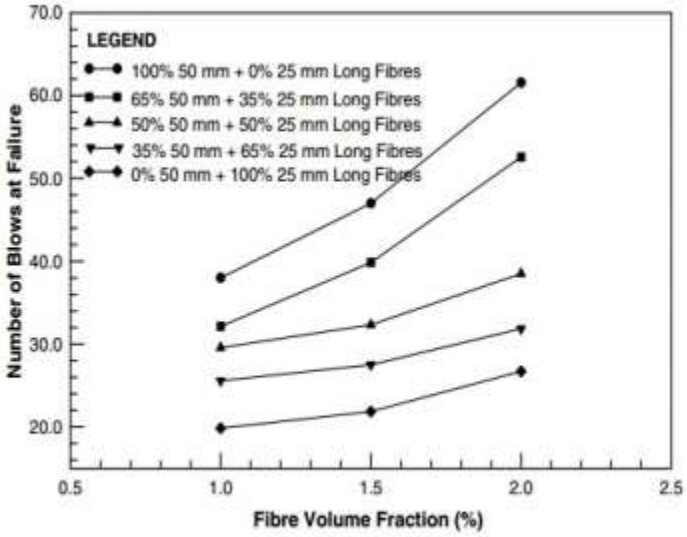


Figure 2.18: Failure impact resistance of fibrous concrete containing mixed fibers

Figure 2.3: Impact resistance failure of fibrous concrete having mixed fibre

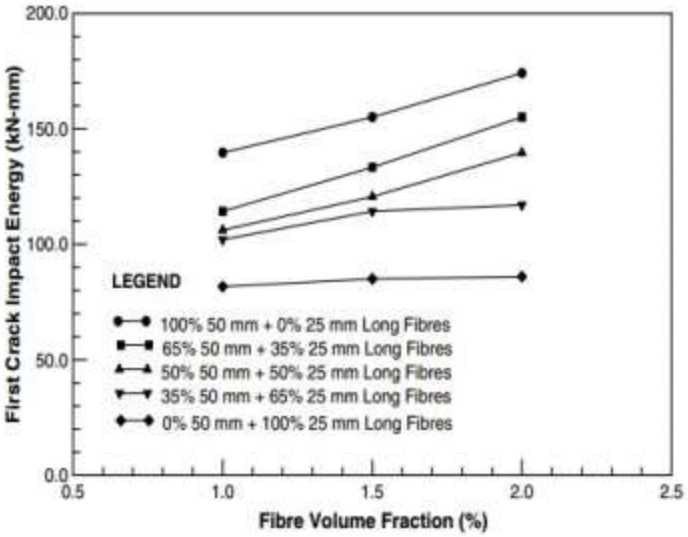


Figure 2.19: first crack impact energy of fibrous concrete containing mixed fibers

Figure 2.4: First crack impact energy of fibrous concrete containing mixed fibre

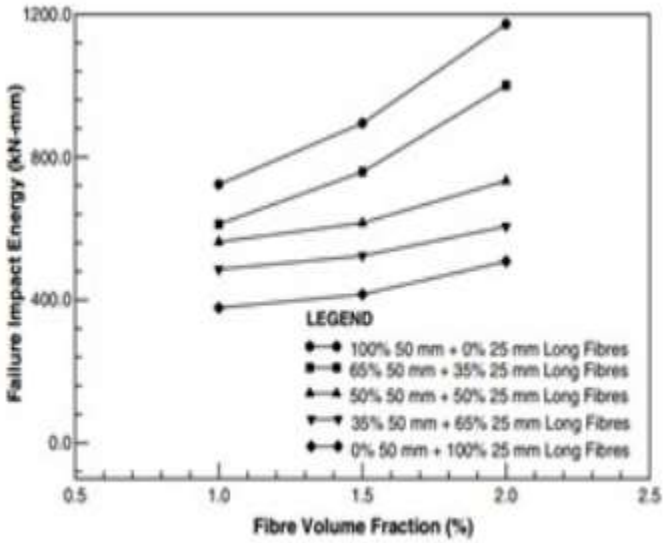


Figure 2.20: Failure impact energy of fibrous concrete containing mixed fibers

Figure 2.5: Failure impact energy of fibrous concrete containing mixed fibre

The expression below was primarily applied in evaluating impact energy E*p*: *dwi* upon first crack. Where *p* indicates what kind of energy taking in (e.g. potential energy), and *dw* indicates what kind of test was performed (Gupta *et al*. 2015):

$$E_{p:dwi} = N_1 mgh \tag{2.5}$$

Similarly, the impact energy at ultimate crack, $E_{p:dwu}$ was calculated by the equation 2.6 given :

$$E_{p:dwu} = N_2 mgh \tag{2.6}$$

where, N_1 and N_2 are the number of blows at initial and ultimate crack level, m is the mass drop hammer, g is acceleration due to gravity (9.81 m/s2) and is the releasing height of drop hammer.

Impact Resistance Loading:

Equation 2.7 gives an expression to evaluate the amount of blows until failure N*f*, in addition with how much energy is taken in by d sample E*p*:*fl (fl indicates flexural upload)*

$$Ep{:}fl = €m_i g h_i \tag{2.7}$$

Given that: m_i indicates the weight of hammer dropped while h_i is the total weight being dropped down (Gupta *et al*., 2015).

CHAPTER THREE

3.3.3 MATERIALS AND METHOD

3.3.3 Materials

Components and concrete materials employed during this research; RHA, Kenaf fibre, cement, aggregate, water, and superplasticizer.

3.3.3 Kenaf Fibre

Kenaf raw fibres used in this work are gotten from Manchock village, in Kaduna State. The fibres were separated from their stalks by water retting for about 20 days. After which water the fibres were then cleaned with water and dried under the sunlight. Plate I presents a typical cut fibre to length





(a) Untreated Curled kenaf fibre (b) Treated Chopped Kenaf Fibre

Plate I: Curled and Chopped Kenaf Fibre

3.3.1 Kenaf Fibre Pre-treatment and Chemical Treatment

Kenaf fibre used in this work was passed through two stage of treatment. That is the pre-treatment and the chemical treatment (alkalinisation of natural fibre or mercerization of

cellulose fibre). This process is meant for surface treatment of cellulose fibres. For the kenaf fibre in this test, this treatment aimed to decrease the fibre characteristics of water intake. The lignin, pectin and dirt's in fibre were removed to make the fibre less hydrophilic, which is the major drawback in the use of cellulose fibre in concrete composite production. Also, the fibre matrix surface bonding of the kenaf fibre is improved by the treatment.

3.3.2 Chemical Treatment of Natural Fibre

At room temperature, kenaf fibre for chemical treatment was immersed and soaked in 5% concentration of NaOH solution for three hours at room temperature. Afterwards, fibre immersed will be withdrawn and washed with clean water until free of all impurities of dirt and alkali. The resulting fibre was then soaked for 24 hours in clean water and later dried under ambient temperature. The dried fibre was then cut to required fibre length for use.

3.3.3 Cement

Type II Cement (brand name Dangote 3x) 42.5R as illustrated in Plate II was utilized for all several tests carried out in this work. For a proper storage method, Portland cement used in this work was carefully kept in a laboratory vessel. The physical properties as well as chemical composition of the portland cement are given in Chapter 4.



Plate II: Portland Cement

3.4 Aggregate

The aggregates used are fine and coarse. Details on the aggregate are described in the preceding subsections.

3.4.1 Fine Aggregate

Before characterizing the fine granulates which was used in this research, it was allowed to pass over a dry sieve analysis. The standard sieve size applied in order to get a desired result are (1.18, 2.36, 4.75) mm and (75, 150, 300, 600) µm from a mass of 500g while a container is kept below the sieve in order to gather masses that passes through the tiniest sieve. The fine aggregate retained within 1.18 mm and 75µm (simulated reference sand) sieved out from the available natural sand obtained from Bosso Local Government Area, Minna, Niger State in accordance with BS EN 196-1 (2016) reference sand prescription for strength test on cement was used for the experiments.

3.4.2 Coarse Aggregate

Locally available, air-dried crushed granite of 10 mm maximum size was used as coarse aggregate in all the mixes. Care was taken to ensure that the aggregate is free from organic matters such as dry muds, leaves and other deleterious materials.

3.5 Water

Portable tap water obtained from the laboratory was utilized all through this work and also for curing and blending purposes.

3.6 Admixture

A water reducing admixture was used in order to achieve a target slump. Superplasticiser (SP) of trade name CONPLAST SP 430 conforming to ASTM C 494 (2019) requirement was used as a water reducing admixture to enhance the workability of concrete. Owing to the high viscosity, the super plasticiser was added to the mixing water.

3.7 Rice Husk Ash

The RHA used in this research work was collected from a local grain mill in Garatu village along Minna-Bida Road, Bosso LGA, in Niger State. The collected Sorghum 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.

3.8 Methods

Production of test specimen and test procedure for evaluating fresh and hardened state properties and the standards adopted in conducting various test on strength and durability of concrete are presented and discussed. KFC that thus consistently meet the requirements of workability and strength are only achieved through the application of stringent requirements on selection of material. In this study, targeted strength of the concrete was achieved through a well-considered material proportioning and also through the use of quality materials in the concrete production. A mix proportion which is suitable for the production of plain concrete and KFC were determined through the preliminary test.

3.8.1 Concrete Mixes

Based on various substances that were utilized, blends of concretes in different percentage were made. Various blends that were made consist of; KFC incorporated concrete having varying percentage of RHA (0%, 5%, 10%, 15%), Cubes (100mm in length, breath and height) was used to mould and various mixes that would be used for testing, (100mm x 200mm) length cylinder were cast for tensile strength, (100 mm x 100 mm x 500) prisms were cast with regards to its influence and flexural test after 1, 4 and 8weeks, and clear concrete. Waste of about 30% was supplemented into all mix due to the potential of have a reduction during the mixing process.

3.8.2 Fresh Properties of Concrete

The properties of the concrete examined in the fresh state are described in the succeeding sub section.

3.8.3 Measurement of Workability

The workability was measured in terms of Slump, Vebe and Compacting factor of concrete. The objective of the test is to determine the water cement ratio that satisfied the design mix, for concrete made without fibre and those containing fibre. The tests were conducted under the influence of water reducing admixture at constant quantity.

3.8.3.1 Slump of Plain Control Concrete (PCC), RHA-based fibreless Plain Concrete (RPC) and RHA-based KFC (RKFC)

According to Plate III below, the concrete operability and work done were evaluated with respect to slumps. As such, this test was practically applied in order to guarantee a stable work is being done. The target slump of the concrete is in the range of 80 - 120 mm. The procedure followed, in measuring the slump is in accordance with ASTM C 143 (2018). Slump readings were taken as soon as the concrete was mixed. With the purpose of acquiring a good and acceptable slump, previously stated CONPLAST SP 430 was applied not only in RHA-based fibreless plain concrete or Plain Control Concrete (PCC) but also in RHA-based kenaf fibrous concrete (RKFC)



Plate III: Test for Slump in progress

3.8.3.2 Vebe Test (BS EN, 12350-3: 2018)

As outlined by BS EN 12350-3 (2018), vebe test is a technique applied to evaluate how concrete react when exposed to outside forces and influences so as to ascertain how much work is done on the concrete as a result of the external forces and vibration. This test successfully determines FRC flow and action in concrete, in other words knowing is capability with the influence of vibration as well as helping to easily detect how entrapped air could possibly be expelled.

3.8.3.3 Compacting Factor Test

Test on compaction factor is employed to determine to what proportion compaction takes place. In agreement with BS 1881-103 (1993), this has been taken to be a very dependable way of determining how much work is done by the concrete. Following the completion of the test, Equation (3.1) was used to evaluate its compaction factor as in the weight ratio of

incomplete and completed concrete. The standard specifies that for concrete to be considered normal, the compacting factor should be within the range of 0.8 to 0.92. Plate IV illustrates the operational procedure of Compacting factor test.

$$CF = \frac{weight\ of\ partially\ compacted\ concrete}{weight\ of\ fully\ compacted\ concrete} \tag{3.1}$$



Plate IV: Operational procedure of compacting factor test in progress

3.8.3.4 Fresh Density of Concrete

With the help of a vessel connected to the instrument used to evaluate compacting factor, density would be estimated. Firstly, before pouring the mixed concrete into the vessel, the load and size is measured. Plate V illustrates the process of determining the Fresh density of concrete.



Plate V: Measuring wet concrete mass to determine Fresh density

3.9 Tests on Hardened Properties of Concrete

Concrete hardening characteristics to be evaluated includes; Splitting tensile, flexural and comprehensive strength. Details of this test procedure are described in the succeeding sub section.

3.9.1 Compressive Strength

Compressive strength test was conducted in accordance with BS EN 12390-3 (2019), provision. Prior to the testing, 100 mm x 100 mm x 100 mm cube, specimens were duly prepared (cleaned and weighed), the loading machine cleaned and the digital unit of the machine programmed with the required sample information (Plate VIa & b). A constant loading rate was selected and applied until failure of the specimen. Plate VIc & d presents the mode of specimen before failure and after failure. The following stress equation was also used to determine the compressive strength of specimen.

$$f_c = F/A_c \quad (3.2)$$

Where:

f_c = the compressive strength, in newtons per mm^2

F = the maximum load at failure, in newtons

A_c = the cross-sectional area of the specimen, in mm^2



(a) Cleaning and weighing of concrete cube sample



(b) Setting and programming the crushing machine



(c) Placing concrete cube under the maching before crushing



(d) Failure mode of concrete cube after testing

Plate VI: Operation procedure for determining the compressive strength test of hardened concrete cube

3.9.2 Splitting Tensile Strength

In agreement with requirement ASTM C496 (2017) will splitting tensile strength be examined. Specimens used in examining is a cylinder container of (100 x 200mm) in accordance with ASTM C496 (2017) would be employed. Flexible plywood of dimension 10±1 mm x 4±1 mm would be employed in the finishes in order to have a consistent weight spread (Plate VII). Steady charge load ratio would be employed longitudinally until it is divided into half. Splitting strength was determined through the equation below;

$$f_{ct} = 2F/\pi Ld \quad (3.3)$$

Where:

f_{ct} = splitting tensile strength, in newtons per mm^2

F = maximum load, in newtons

L = length of the specimen, in mm

d = cross-sectional dimension, in mm



Plate VII: Splitting tensile test of hardened concrete

3.9.3 Flexural Strength

Flexural strength test conducted using the British Standard specification of ASTM C78 (2018). Cubes with dimension (100x100x100mm) had been charged inside with the absence of any shock in a steading flow. The arrangement of the testing of flexural strength is shown in Plate VIII below;

$$f_{cf} = FLr / d1\ (d2)^2 \quad (3.3)$$

Where:

f_{cf} = flexural strength in N/mm^2

F = maximum load, in Newton

Lr = distance between the lower roller, in mm

d1 and d2 = lateral dimension of the specimen, in mm



Plate VIII: Operational Procedure for flexural strength test

3.9.4 Impact Resistance Strength Test (ACI 544.1R-96)

Several ways of evaluating concrete impact test have been reviewed. Nevertheless, as stated by ACI 544.1R-96, drop weight approach shall be employed. Impact test on the prism was performed to determine the potential energy of the SFRC. 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. Hammer weighing about 1.3 kg thrown down from a height (500 mm x 1000 mm) at the beams centre. Count of drops that resulted in causing break (N_i) or breakdown (N_u) was determined and calculations on impact energy were premeditated by expression presented in Equation (3.4) given by Gupta *et al*. (2015):

$$U = N_i mgh \tag{3.4}$$

Where:

U= impact energy absorbed

m = weight 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

Plate IX shows the set up and procedure for Drop Weight Impact Resistance Test method of concrete.



(a) Initial Set-up



(b) Failure after Impact

Plate IX: Operational Procedure for Drop Weight Impact Resistant Test

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Chemical Composition of RHA

After subsequent analysis conducted at the Department of Works at Ewekoro Lafarge cement factory, chemical constituents of Rice Husk Ash (RHA).

Table 4.1: Oxide Composition of RHA

Oxide Composition (%)	**Value**
CaO	1.26
SiO_2	83.76
Al_2O_3	0.54
Fe_2O_3	1.38
MgO	1.55
SO_3	0.00
Na_2O	0.00
K_2O	1.56
P_2O_5	6.29
TiO_2	0.20
ZnO	-----
M_2O_5	0.29
Loss on Ignition	2.93
$SiO_2 + Al_2O_3 + Fe_2O_3$	**85.71**

Having silica content of 83.76%, the table above shows that pozzolan containing agro waste have an overall amount of SiO_2+Al_2O_3+Fe_2O_3 greater than 70%, SO_3 less than 4% and loss on ignition (LOI) with loss of 10% maximum, which is an evidence to show the calcination process was effective.

4.2 Characteristics of Fine Aggregate

Fineness modulus =∑ cumulative % retained up to 150 µm/ 100 = 258.6/100= 2.586 from this result, it can be deduced that the fine aggregate is a (fine sand) (Shetty, 2012).

4.2.1 Grading of Fine Aggregate

Figure 4.1 below shows the Particle Size Distribution curve for the fine aggregate sample.

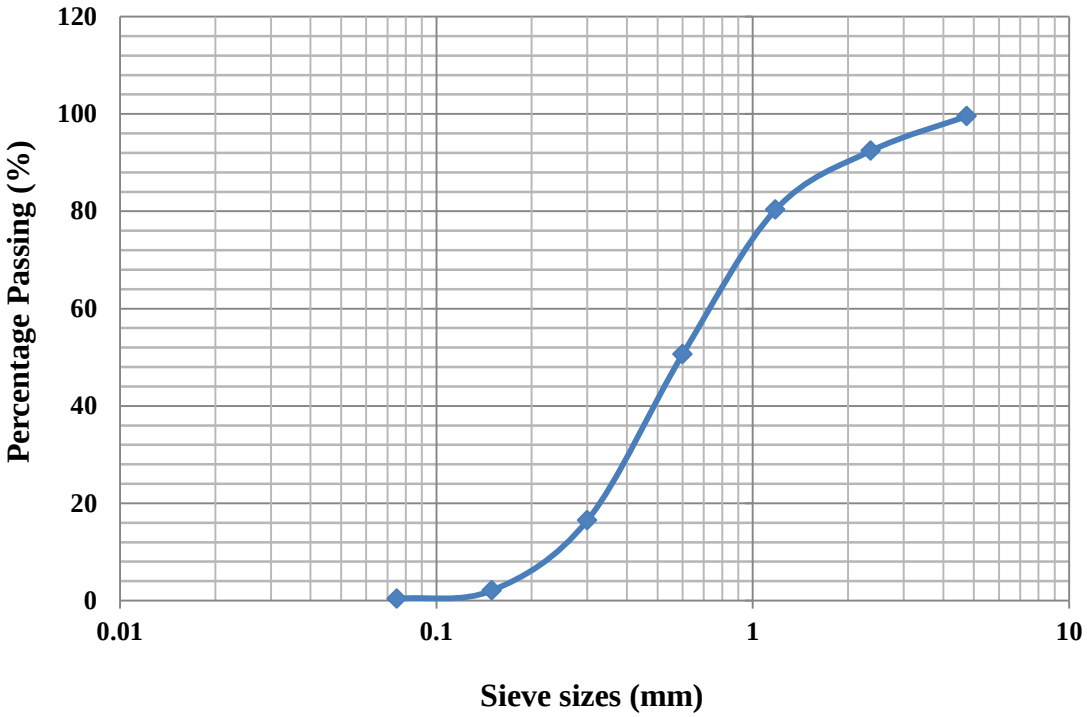


Figure 4.1: Particle Size Distribution Curve for Fine Aggregate.

The curve above represents the relationship between the percentages of fine aggregate passing through each sieve and the sizes of the sieves. From the curve above, the coefficient of uniformity, Coefficient of curvature and fineness modulus for the natural sand (fine aggregate) was calculated. The values of D_{60}, D_{30} and D_{10} gotten from the graph were computed as and the result obtained is as shown below:

D_{60} = 0.74mm, D_{10} = 0.25mm, D_{30} = 0.41mm and

Coefficient of uniformity (Cu) = D_{60} /D_{10} = 2.96

Coefficient of curvature (Cc) = (D_{30}^2)/ (D_{60} x D_{10}) = 1

4.2.2 Physical Properties of Fine Aggregate

Table 4.2 below shows the various properties of the fine aggregate used for the work as obtained through several laboratory tests.

Table 4.2: Physical Properties of Fine Aggregate

Properties	Test Value	Max. Allowable Value	Relevant Standards
Material finer than 75um	0.4%	3%	ASTM C33 (2018)
Oven dry Bulk density (unit weight)	1641 kg/m^3	1600-1700	Kosmatka *et. al.* (2002)
Specific gravity on sat surface dry basis	2.67%	2.4-3.0%	Neville (2011)
Evaporated Moisture content	0.12%	0.05-0.80%	Neville (2011)
Water Absorption	1.59%	0.2-3.15%	Neville (2011)

4.2.3 Characterization of Coarse Aggregate

Just as it is for the fine aggregate, the characterization coarse aggregate used for this work was obtained through sieve analysis. Different sizes of sieves were used to obtain the sieve

analysis result. A pan is placed under the sieves to collect samples that passed through the smallest sieve. A sample weight of 1000g was weighed using a weighing balance and used for the work. Figure 4.2 Shows the percentage passing through each sieve on the Y axis against the corresponding sieve sizes on the X axis of the graph.

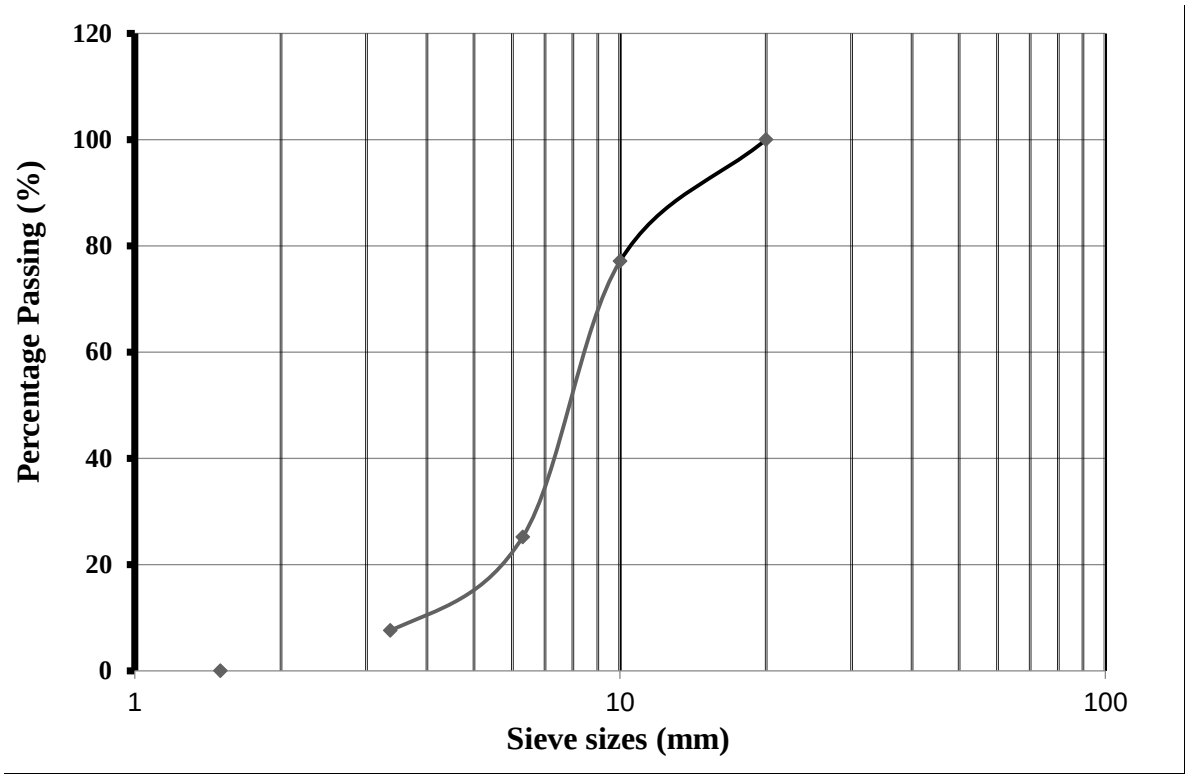


Figure 4.2: Particle Size Distribution Curve for Coarse Aggregate.

4.2.4 Physical Properties of Coarse Aggregate

As shown below, Table 4.3 outlines several characteristics of coarse masses that were utilized in this research following a few numbers of tests.

Table 4.3: **Physical Properties of Coarse Aggregate**

Properties	Test Value	Max. Allowable Value	Relevant Standards
Bulk density (unit weight)	1432 kg/m^3	1200-1750	Kosmatka *et al.*, 2002
Specific gravity on sat surface dry basis	2.90%	2.4-2.90%	Neville, 2011
Evaporated Moisture Content	0.65%	1.0-1.13%	Neville, 2011
Water Absorption	1.59%	0.2-4.5%	Neville, 2011

4.3 Properties of Fresh Concrete

Concretes properties with respect to fresh density as well as workability (Vebe, Slump and Compacting factor) were all tested.

4.3.1 Workability Test

The workability tests were carried out on the RPC and RKFC sample are Slump test, Vebe test and Compacting factor tests. Table 4.4 presents the result obtained for the workability tests. It was observed that as the RHA content increases, the workability of the concrete reduces both for the slum, vebe and compacting factor test. The slump tests compacting factor test, and vebe test were carried out according to ASTM C 143 (2018), BS 1881 and ASTM C1170 respectively.

Table 4.4: Workability Test Results for Fresh Concrete

Specimen ID	RHA Content (%)	Fibre Content (%)	Slump (mm)	Vebe (Sec.)	Compacting Factor
PCC	0	0	165	3.30	0.95
RPC1	5	0	80	4.56	0.92
RPC2	10	0	70	7.54	0.91
RPC3	15	0	135	9.66	0.90
PKFC	0	0.5	65	12.42	0.89
RKFC1	5	0.5	60	15.46	0.87
RKFC2	10	0.5	50	18.80	0.84
RKFC3	15	0.5	45	23.10	0.81

4.3.2 Fresh density of concrete

The fresh density of concrete was obtained after full compaction of the concrete in a cylinder of 6.03 m^3. Table 4.5 below shows the fresh density values for all the mixes. The density for the wet concrete mix is primarily affected by the density of the aggregate, the varying quantity of the cementitious material and the fibre content. The decrease in the density of the wet concrete implies that the higher the fibre content, the lesser the concrete weight. And the higher the RHA content the higher the weight of the concrete. This reduced weight compared to the plain concrete makes the concrete to be fit for use for special structures where light weight concrete is needed.

Table 4.5: Fresh density of concrete

Specimen ID	RHA Content (%)	Fibre Content (%)	Density (kg/m^3)
PCC	0	0	2370
RPC1	5	0	2361
RPC2	10	0	2347
RPC3	15	0	2326
PKFC	0	0.5	2285
RKFC1	5	0.5	2278
RKFC2	10	0.5	2270
RKFC3	15	0.5	2266

4.4 Tests on Hardened Concrete

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

4.4.1 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 4.6.

Table 4.6: 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

Results got as shown above in Table 4.6 explains that compression strength is increases for concrete matrixes not having PRC fibre unlike that having KFC fibre after a week of drying. while mixes containing fibre (0.5%) and RHA (10% and 15%) at 28 days showed an increased strength compared to the ordinary mix. The KFC as well as 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 4.6. Generally, as the RHA content increased, the compressive strength also increased for all ages.

4.4.2 Effects of RHA Content on Compressive Strength of KFC

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 4.6. 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 behavior is as a result of the hydrophilic nature of kenaf fibre. As shown in Table 4.6 Compressive strength of concrete decreases intensely as the fibre content was introduced into the concrete at 0.5%.

4.4.3 Results and Analysis of Splitting Tensile strength Test

Analysis of concretes tensile strength is of great importance for some purpose such as, the design of airfield pavements and highway and cracking resilience. Concretes comprehensive strength is greater than concrete tensile strength as a result of how much load it can take even when cracked (Mindess *et al.,* 2003). One characteristics of a concrete is its weakness after being stressed by a lot of pressure and for normal concrete, comprehensive strength is 10times greater than tensile strength (Mindess *et al.,* 2003). Hence, appreciating the manners and the tie that binds concrete tensile and comprehensive strength relationship between compressive strength and tensile strength of concrete with or without different SHA content for both concrete containing fibres and those without fibres is imperative. Amount of SHA

influencing the concrete strength with kenaf fibres and plain concrete as demonstrated in Figure 4.3

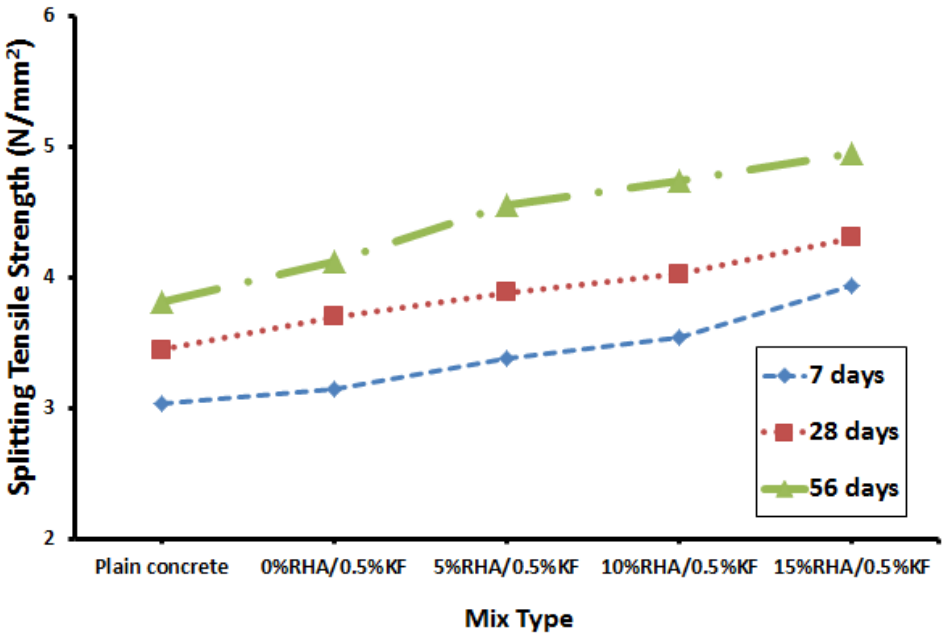


Figure 4.3: Splitting tensile strength of PC and kenaf fibrous RHA based concrete

Concrete with and without RHA fibres cured for (1,4 and 8) weeks shows concrete tensile strength to be between 3.04 to 3.96 N/mm^2 at 7 days for the entire specimen. In general, as time goes by, tensile strength improves for both fibrous and non-fibrous concretes made with both RHA as well as for Portland cement as shown by Figure 4.3 above. However, the tensile strength improved as RHA content incorporated in the concrete rises to 15%. Nonetheless, the rate of increase in splitting tensile strength became lower at a later age for the entire test specimens. From the figure, after about 4weeks (28days), it was noticed that strength of ordinary concrete (0%), 5%, 10% and 15% SHA concrete with no fibre is within limit of 2.0 – 2.5 N/mm^2 set by BS 5328-1 (1997). Similarly, the specification for concrete strength used applied in 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.

4.4.4 Results and Analysis of Flexural strength Test

Before construction of sidewalk ways or major roads, concrete mixture to be utilized are first allowed to go through some test (e.g. tensile strength) in order to evaluate its usefulness. Severally, evaluating tensile of a solid walkway is very significant. Compressive strength and flexural strength of RHA based concrete containing kenaf fibre have similar mixture proportions after being evaluated within same period of drying time. An average about three values was obtained at each data point and the values are presented in Figure 4.3. very close to flexural and comprehensive strength of mixed matrixes which is improved in accordance to the increase in duration of curing and RHA content for both plain and fibrous concrete. As observed, initial work done by the fibre enhanced concrete and plain concrete was not superior to those containing 5, 10 and 15% RHA. But after about 8 weeks (56days), concrete enhanced with fibre 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 kenaf fibre in concrete matrix and its flexural

behaviour. Generally, plain concrete and fibrous containing RHA showed higher rates of flexural strength development after 7 days. As an illustration, flexural strength after 4 weeks and 8weeks 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 might begin to grow as long as up to 12 months. This conclusion was extensively studied by Hossein (2017), how concrete flexural strength is developed after the incorporation of palm oil fuel ash. Due to this interaction, carbonates present in the mix recrystalize resulting in a reduction in mixtures porosity.

Concrete enhanced with RHA and PC showed close tendencies in flexural and comprehensive strength. As previously stated, a high contact area between fibres and aggregate mix is attributed to an increased flexural strength resulting out of an increased number of products that are hydrated and having a higher volume of RHA and pozzolanic action as curing time increases. As fibres are crosslinked in areas stressed with cracks, there is an increase in concrete flexural strength. Kenaf fibres apprehend slits and giving an increased rate of energy intake for such area with so much stress. Relationship between concrete mix and kenaf fibres used in enhancing it significantly affects the characteristics of the concrete mixture. As major cracks are being sealed off with fibres matrixes, permeability is also improved accordingly.

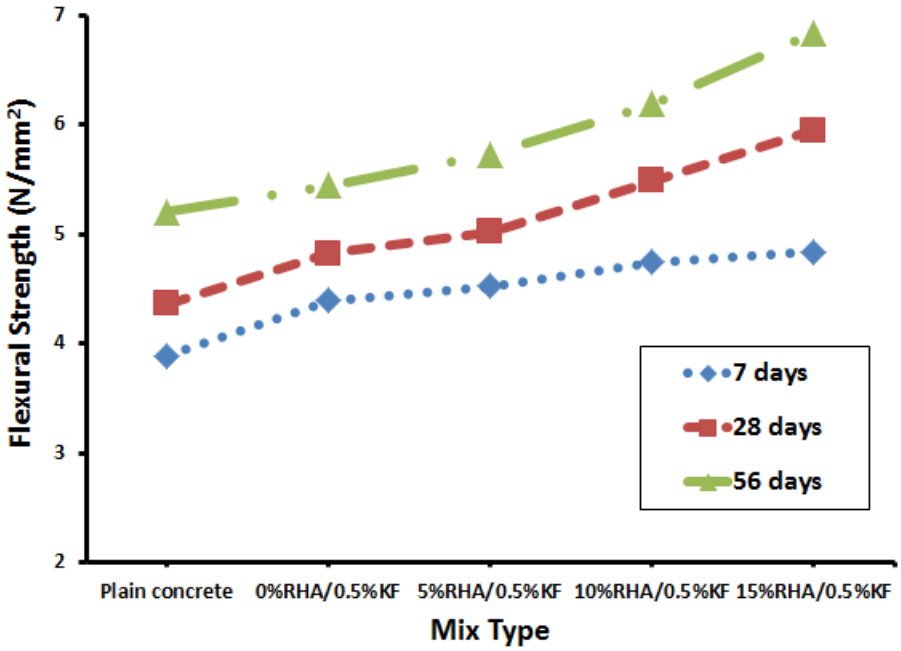


Figure 4.4: Flexural strength of PC and kenaf fibrous RHA based concrete

4.4.5 Impact Resistance

Concrete enhanced with several RHA and KF content as well as their impact resistance were thoroughly reviewed by several hammer hits required to get its first crack (N1) as well as its failure (N2) with a concrete prism of diameter (100 x 100 x 500 mm). Difference observed among how many hits causes the ultimate crack (failure) as well as its initial crack (N_2-N_1) as well as its proportion increase in amount of initial crack hits to failure (N_2-N_1/ N_1) as shown below (Table 4.5). This study has shown that incorporating RHA with KFC matrixes, number of blows for initial crack went up to 3%, 5%, 8%, and 10% for PKFC, $RKFC_1$, $RKFC_2$, $RKFC_3$ matrixes accordingly. Introducing RHA is also another way of increasing percentage rate of initial cracks leading into collapse (N_2-N_1/ N_1) ratio unlike those not containing RHA. It means that RHA greatly enhanced the toughness and rigidity of the concrete mixture, thus promoting the ductility comportment of the fibrous concrete. Cumulative impact applying KF

with RHA in enhancing impact defiance is shown in Figure 4.5. A confident interaction has been also created among fibres as well as with RHA, in terms of combining RHA with fibres showing an increased resistance with respect to number of cracks and work done in comparative with fibrous concrete containing no RHA or fibreless concrete containing no RHA.

Table 4.5 further demonstrates the characteristics of concretes having RHA and KF with respect to how its impact energy influences first and failure crack. As stated above, with a rise in the amount of fibreless concrete and concretes with fibres as hits on concrete rises before cracking in comparison with mix without RHA or KF is witnessed.

Table 4.5: Impact resistance and energy of concrete mixtures at first crack and at failure for 0.5 and 1.0 metre 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

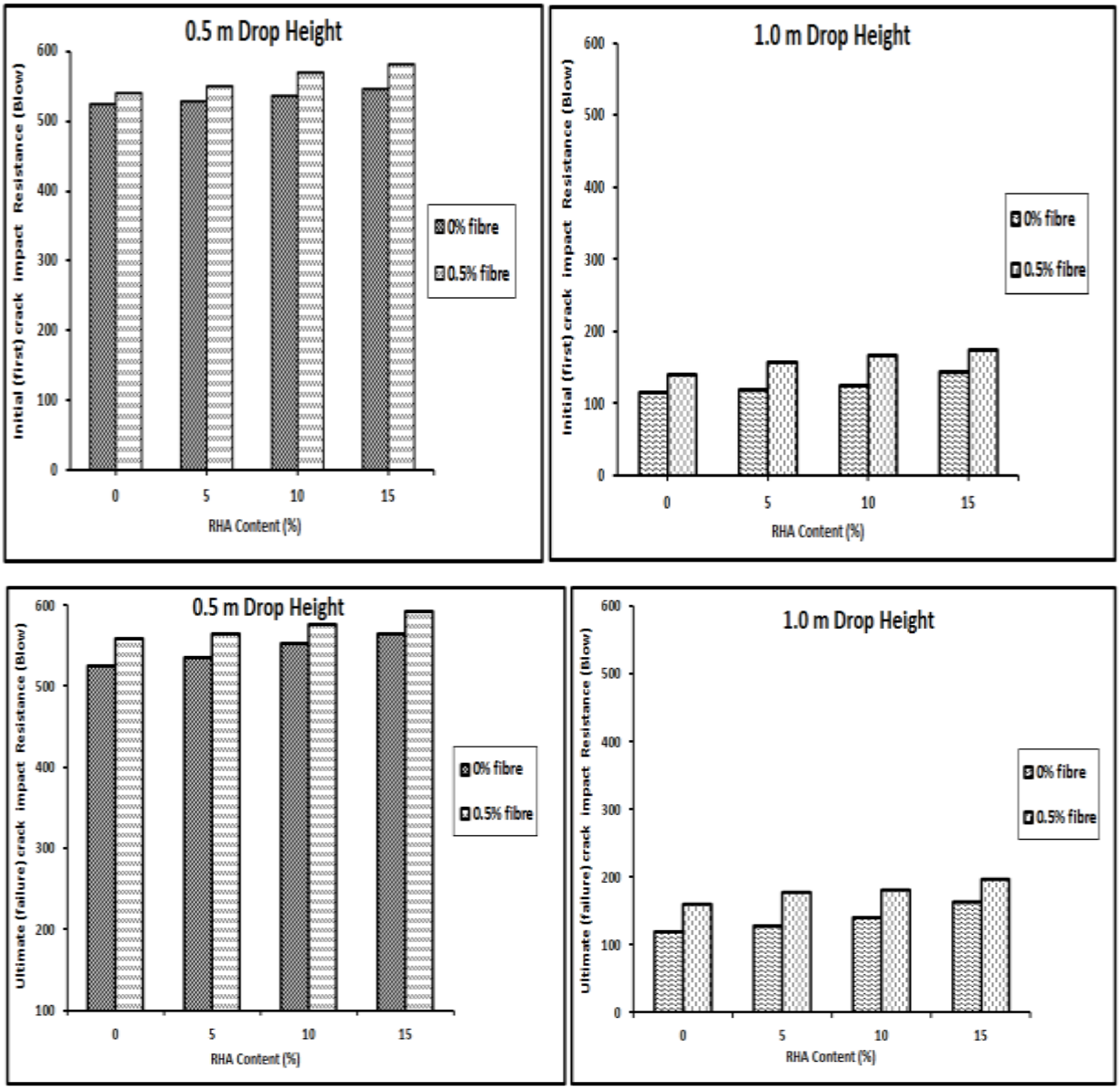


Figure 4.5 Impact resistance of kenaf fibrous concrete mixtures at varying RHA at first crack and at failure for 0.5 and 1.0 metre drop height

Figure 4.6 describes the relation among impact energy and RHA content in fibrous concrete. After establishing the fact that increasing the incorporation of RHA occasion a greater increase in impact energy unlike those made with ordinary concrete. As an example, a blend having 15% RHA showed a greater energy about 3472kN 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 accordingly. Identically to fibreless blends, those having 0.5%KF; the greater the RHA content as well as its energy impact.

Rate of impact energy outcome in this work is closely related to a research done by Nili & Afroughsabet (2010) and Hossein *et al*. (2018) with the incorporation of pozzolan and polypropylene enhanced concretes.

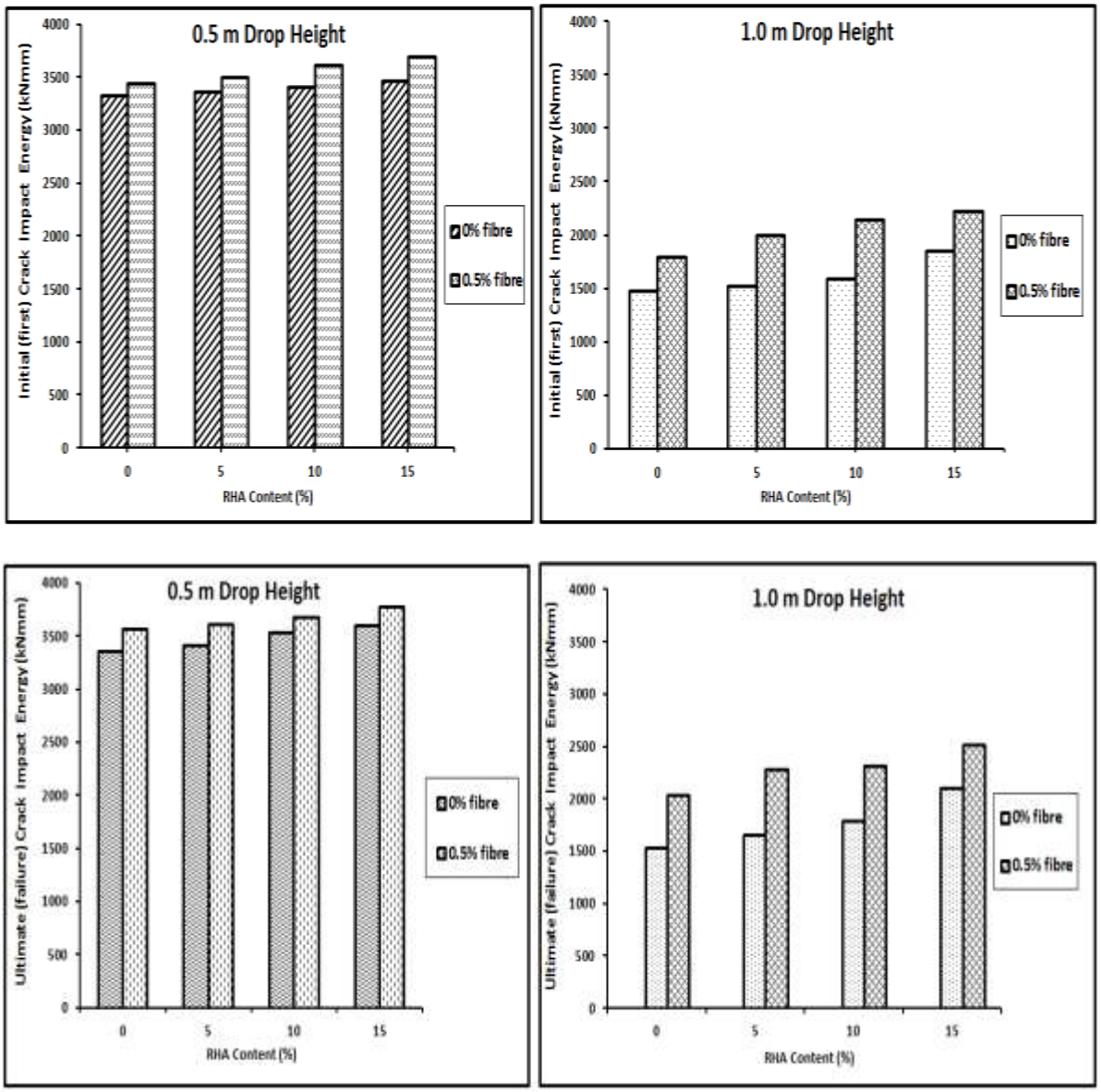


Figure 4.6: Impact energy of kenaf fibrous concrete mixtures containing RHA at varying volume fraction at first crack and at failure for 0.5 and 1.0 metre drop height

As shown in Figure 4.7, variation in amount of (N_2 - N_1) portrays how much resilience the PCC and the RKFC mixtures possess. 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 concretes initial and final collapse. It is as a result of interconnection behaviour among the RHA content and fibrous concrete particles and therefore avoids the concrete from collapsing unexpectedly.

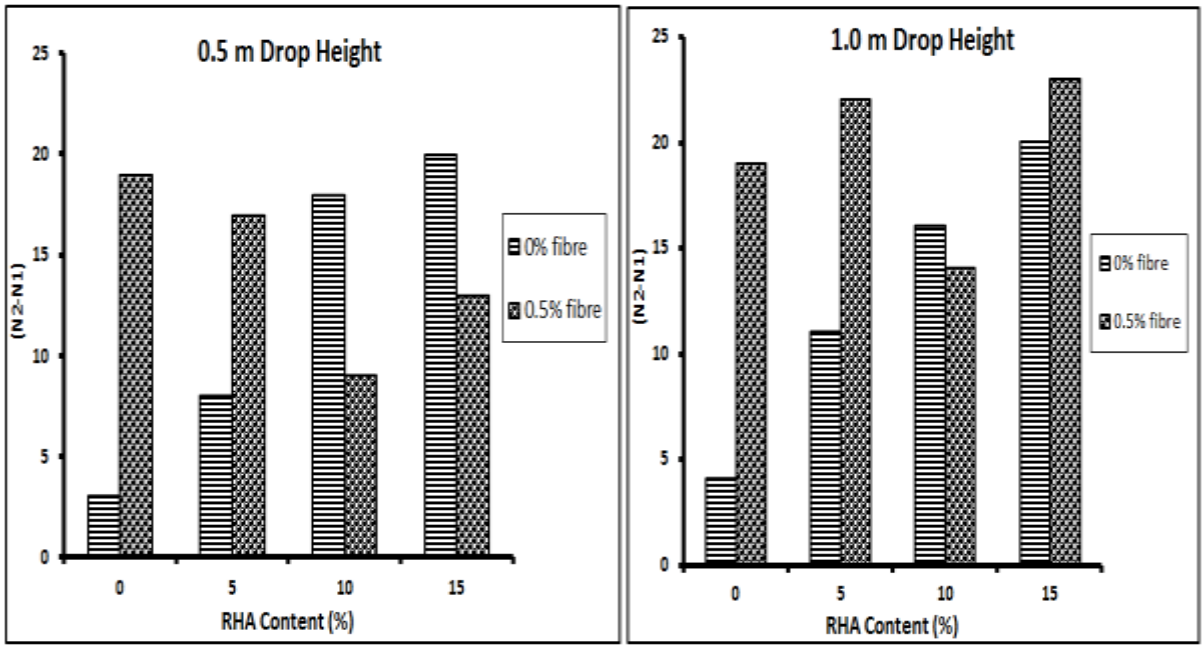


Figure 4.7 Variation of (N2 - N1) with RHA content

Performance shows that blending kenaf fibres with RHA enhances concretes efficiency based on its elasticity and strength. Figure 4.8 shows a sample prism used in testing concrete strength and resistance initially and after it fails. Increasing the amount of RHA leads to an improvement in concretes ductility and toughness as higher number of blows was experienced before the initial and last crack before it collapses occurred unlike 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 4.8(d), (e). The cracks developed on the surface of the fibrous concrete prism are as a result of the extra linking activity in which KF causes by taking it all extra energy and work done avoiding an unexpected collapse of the objects. Figure 4.8(e) also shows a cracked area where kenaf fibres were clearly present. With regards to the broken area, it clarly turns out that the kenaf fibres uniformly circulated all through. Outcome of this work is in confirmation with that done by 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

Plate X: Impact test prism samples and their failure modes

4.5 Summary of Findings

i. It is experiential that the workability of RKFC decreases as the volume of RHA increases, and as the fibre content was introduced at a constant volume fraction of 0.5%. This is due to the large surface area of uneven KF, absorbing cement paste and the sand, making the matrix more viscous.

ii. Higher values of fresh concrete unit weight were noticed in concrete specimens without RHA or KF (Plain Concrete-PCC) compared to those containing either only KF fibre or RHA and KF.

iii. The cube compressive strength of the fibrous concrete increases with the introduction of RHA to the mix at ages beyond 7 days. The development in the strength of RHA based mixtures at early ages was lower to that of plain concrete mixtures. But however, 10% RHA based concrete with 5% kenaf fibre produced the highest compressive strength value of 56.4 N/mm^2 at 56 days.

iv. The combination of kenaf fibres and RHA enhanced the ductility of concrete composites and energy absorption capacity, and led to a uniform crack distribution.

v. Impact Resistance Strength of concrete is increased with the addition of kenaf fibres. The highest value of Impact Resistance Strength was noticed in concrete samples containing 15% RHA with 0.5 KF content across samples tested under 0.5 metre and 1 metre drop heights.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study is largely intended at assessing the effects of RHA on the impact resistance property of kenaf fibrous concrete. Despite the fact that concrete properties with the addition of RHA additives weren't ignored, its influence is a major determinant of its usefulness. A major importance of applying this waste is because it gives several ways for effectively employing substances that are already regarded as waste. Although, this research points out all surrounding consequences KF as well as RHA possesses when applied on concretes. In the fresh fibreless and fibrous concrete mixtures, the addition of RHA at varying percentage replacement of cement caused a decrease in strength and properties of a newly made concrete. Addition of both kenaf fibre and RHA blends with concretes decreases specific gravity thus produces an underweight concrete unlike those enhanced with RHA and fibres. As the amount of RHA incorporated rises, concretes cube compressive also improves. After about 8 weeks of drying (56days), the strength of concrete enhanced with RHA surpasses that concrete enhanced with PC. The outcome achieved as well as remarks of this study explains that the addition of RHA and KF into concrete is very much acceptable as it fulfils major engineering characteristics and can be applied in several cases like road and sidewalk constructions, as well as in several architectural processes.

5.2 Recommendations

i. Considering all outcomes and reviews from this research, RHA and KF are recommended to be added and mixed with concretes with the sole aim of enhancing concretes comprehensive strength but as well as carefully considering if need be for having a high impact strength where a concrete with an increased strength is applied.

ii. Using substances like RHA in efficient waste treatment system and retraining waste substances assists in the making of long-lasting substances that can be used to enhanced concrete properties.

iii. Further study should be performed in order to investigate how much impact high temperature has on upon impact strength.

5.3 Contribution to Knowledge

The research established that Kenaf Fibre (KF) at 5% and 10% Rice Husk Ash (RHA) resulted in; 12%, 26.3%, 30.8% and 3.9% in Compressive Strength, Splitting Tensile Strength, Flexural Strength and Energy Consumption Values respectively compared to the control

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