DETERMINATION OF THE COMPRESSIVE STRENGTH OF PALM KERNEL SHELL CONCRETE

BY

OKECHUKWU PETER OTI (B.Eng.)

REG NO: 20114771058

A THESIS SUBMITTED TO

THE POSTGRADUATE SCHOOL,

FEDERAL UNIVERSITY OF TECHNOLOGY, OWERRI

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR

THE AWARD OF MASTER OF ENGINEERING (M.Eng.) IN AGRICULTURAL

ENGINEERING

OCTOBER, 2015

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CERTIFICATION

This is to certify that this project work on the **“Determination of the Compressive Strength of Palm Kernel Shell Concrete”** was done by **Oti, Okechukwu Peter (20114771058)** (B.Eng) in partial fulfilment of the requirement for the award of Master of Engineering Degree (M.Eng) in Soil and Water Engineering in the Department of Agricultural Engineering, Federal University of Technology, Owerri, Imo State, Nigeria, under my supervision.

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External Examiner

DEDICATION

This work is dedicated to the Almighty God who has provided me with the necessary strength and wisdom to have started and completed this programme.

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ABSTRACT

This study is on the determination of the Compressive Strength of Palm Kernel Shell Concrete. The effect of percentage replacements (0, 25, 50, 75 and 100%) of crushed granite with palm kernel shell on density and compressive strength of concrete is presented. Concrete cube specimens of mix 1:2:4 were prepared with water-cement ratio of 0.6. The cubes (150mm×150mm×150mm) were cured using water-submerged curing until testing ages of 7, 14, 21 and 28 days when their densities and compressive strengths were determined.The 28day compressive strength ranged from 12.71 to 16.63N/mm^2, whereas the density ranged between 1562 to 2042 kg/m$^{3.}$. A replacement of 25 and 50% of Crushed Granite with palm kernel shell resulted in a cost reduction of 5.69% and 11.37% respectively. Tests conducted include sieve analysis, bulk density, and specific gravity to characterize aggregates. The Specific gravities of Sharp Sand, Crushed Granite and Palm Kernel Shell were found to be 2.5, 2.76 and 1.301 while their bulk densities were 1650, 1545 and 634 kg/m^3 respectively. Water absorption capacities of crushed granite in 1 and 24hrs was 6% while palm kernel shell was found to be 11% in 1hr and 21.5% in 24hrs.Compressive strength decreased as well as density with percentage increase in palm kernel shell content. Curing is very important for the strength development of concrete. In general, Crushed Granite could be replaced in concrete with Palm Kernel Shell up to 25%.Palm kernel shell being a lightweight aggregate could be used for structural lightweight concrete production for small load bearing farm structures.Reduced cost of construction arising from the use of locally available agricultural waste materials such as palm kernel shell will reduce pollution associated with the waste disposal and enhance infrastructural development as well.

Keywords: Compressive Strength, lightweight aggregate, Palm kernel shell, percentage replacements and Curing.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

Previously, Agricultural and Industrial wastes have created waste management and pollution problems. In the effort to put these waste materials in use, a lot of research has been done and still on-going to investigate their properties when employed in the replacement of conventional ingredients in concrete production. In spite of the fact that the use of such replacement materials would contribute to construction cost reduction and proper waste management, they should be readily available.

The main palm oil producing states in Nigeria include Anambra, Enugu, Imo, Abia, Ogun, Ondo, Oyo, Edo, Cross River, Ekiti, Akwa-Ibom, Delta and Rivers.Palm kennel fibres are derived from oil palm tree (*Elaeis guneensis*), an economically valuable tree, and native to West Africa and widespread throughout the tropics (Akpe, 1997).Oil palm tree grows to about 9metres in height and characterized with a crown of feathery leaves that are up to 5mm long. Flowering is followed by the development of cluster of egg-shaped red, orange or yellowish fruits, each about 3cm long .Palm kernel shells are hard, carbonaceous, and organic by-products of the processing of the palm oil fruit (Alengaram, *et al*., 2010). They consist of small, medium, and large sized particles in the range 0-5mm, 5-10mm and 10-15mm respectively .They are organic waste materials obtained from crude palm oil producing factories in Asia and Africa (Alengaram, *et al*., 2010). According to Okly, (1987), palm kernel shell is made up of 33% charcoal, 45% pyroligneous liquor, and 21% combustible gas. Palm kernel shell is hard in nature and does not deteriorate easily once bound in concrete and therefore, it does not contaminate or leach to produce toxic substances (Basri *et al.*, 1999).

Concrete is defined as an artificial material resulting from a carefully controlled mixture of cement, water, fine and coarse aggregates, which takes the shape of its container or formwork when hardened and forms a solid mass when cured at a suitable temperature and humidity (Alawode *et al.*, 2011).Concrete is brittle and weak in tension but its compressive strength is about 8times greater than the tensile strength (Mosley and Bungey, 2000).

Fine aggregate is generally natural sand and is graded from particles 5mm in size down to the finest particles but excluding dust. Coarse aggregate is natural gravel or crushed stone usually larger than 5mm and usually less than 16mm in ordinary structure (Mohd *et al*., 2008). Natural aggregate deposits consist of gravel and sand that can be readily used in concrete after minimal processing. Natural gravel and sand are usually dug or dredged from a pit, river, lake, or seabed. Crushed stone is produced by crushing quarry rock, boulders, cobbles, or large-size gravel. According to Alexander *et al*. (2005), aggregate occupies between 70 to 80 % of the total volume of concrete and is essential in making concrete into an engineering material. They tend to give concrete its volumetric stability; they also have a unanimous influence on reducing moisture related to deformation like shrinkage of concrete. With this large proportion of the concrete being occupied by aggregate, it is expected for aggregate to have an enormous influence on the properties of concrete as well as its general performance.

1.2 STATEMENT OF PROBLEM

The increasing cost of construction materials and the environmental degradation caused by the high utilization of aggregates for concrete is a global challenge in civil engineering construction. The high demand and continuous use of crushed granite for concrete in construction will overtime deplete the natural stone deposits and this will affect the environment thereby causing ecological imbalance. Earthquakes have been reported to have occurred as a result of activities relating to continuous production of chippings from natural stone deposits. Similarly, the continuous production of palm kernel shell waste promotes environmental pollution and nuisance with reference to its disposal. Recently, research has been conducted by Alengaram *et al* (2011, 2013), Shafigh *et al* (2010, 2011, 2012), and Mahmud (2008, 2010), on palm kernel shell and its concrete. Palm kernel shells are underutilized and are usually abandoned as waste materials or used in a small scale as fuel in furnaces and materials for filling potholes. There is need, therefore, to explore and find suitable replacement material to substitute for the coarse aggregate in the production of light weight concrete.

1.3 OBJECTIVES OF STUDY

The aim of this research work is the "Determination of the Compressive Strength of Palm Kernel Shell Concrete". To achieve this research aim, the specific objectives of this work is:

a. To determine the physical properties (Bulk density, Water absorption capacity, Specific gravity and Sieve analysis) of Palm Kernel Shell, Sharp Sand and Crushed granite.

b.To determine the Compressive strength of lightweight concrete containing Palm kernel shell aggregate in percentage replacements.

1.4 JUSTIFICATION OF STUDY

Chippings are usually bought at distant quarries and hauled at high cost to various construction sites across the country, thereby increasing the cost of construction projects. The use of palm kernel shell waste in construction shall promote waste management and it will go a long way in the reduction of cost of aggregate. Additionally, the use of palm kernel shell waste as an alternative to conventional aggregates will reduce the size of structural members and this will bring immense change in the development of high rise structures using lightweight concrete.Hence, the frequency of land slide or earthquakes will decrease due to a reduction in the mining of chippings from its natural deposit. Alengaram *et al.,* (2013) reported that Palm kernel shell is one kind of organic aggregate with better impact resistance compared to normal weight aggregate. Additionally, considering that Palm kernel shell is cheap and available in large quantities in Nigeria the engineering properties of cracked Palm kernel shell was chosen to be analyzed so as to ascertain its suitability as a substitute for gravel and crushed granite in the production of concrete for construction. From the various kinds of concrete, lightweight concrete is one of the most interesting subjects for researchers because of its advantages such as the savings on reinforcement, formwork and scaffolding , foundation costs as well as the savings derived from the reduced cost of transport and erection (Shafigh *et al,* 2010).

1.5 SCOPE OF STUDY

This thesis is focused on experimental tests to determine the compressive strength of concrete using Palm kernel shell as coarse aggregate in concrete. It is also aimed at characterization and determination of the properties of these shell that make them suitable for concrete works in the stead of conventional aggregate and the effects of percentage replacement of this waste material on the strength characteristics of concrete. The study also investigated absorption rates of water on prepared concrete samples for the seepage properties of the concrete made from palm kernel shell.

1.6 LIMITATIONS OF STUDY

The Cost of crushing the specimen cubes was high. Additionally, the curing tank used for this research was for the entire students in the department which necessitated the labelling of specimen cubes; in fact, finding and bringing out the cubes from the tank for crushing became a very rigorous task.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 OVERVIEW

Several recent studies have been directed toward the strength and behaviour of concrete made from replacement of crushed granite with palm kernel shell. A few other research areas where palm kernel shell has been used are: Automobile disk brake pad (Dagwa *et al*., 2006; Koya *et al*., 2008), Carbon activation for water purification; concrete ingredient in building industry and fuel for heat generation (Okly, 1987) etc. As a matter of fact, palm kernel shell has been used as aggregate in light and dense concretes for structural and non-structural purposes (Uviasah, 1976; Akpe, 1997; Nuhu-Koko, 1990). Abdullah (1984) was the first to use palm kernel shell as lightweight aggregate (LWA) in Malaysia and proved that complete replacement of normal weight aggregate (NWA) with palm kernel shell is a possibility.

2.2 PHYSICAL PROPERTIES OF PALM KERNEL SHELL CONCRETE

Among the research carried out on the physical properties of palm kernel shell concrete are those done by Okafor (1988), Okpala (1990), Ayanbadefo (1990) Ata *et al*. (2006), Mannan and Ganapathy (2004), Alengaram *et al*., (2008), Jumaat (2009), Alengaram *et al*. (2010), Acheampong *et al*. (2013) and Newman (1993).

Okafor (1988) and Okpala (1990), reported that palm kernel shell consists of 60 to 90percent particles in the range of 5 to 12.7mm, specific gravity between 1.17 and

1.37, maximum thickness of the shell was found to be 4mm and density to vary in the range of 1,700 to 2,050kg/ m^3.They also reported a 28days cube compressive strength in the range of 15 to 25MPa. In the same study Okafor (1988) conducted a study using palm kernel shell as aggregate replacement in concrete and discovered that similar to normal weight concrete (NWC), water to cement (w/c) ratio affects the mechanical properties of palm kernel shell concrete. He reported that the 28day compressive strength of palm kernel shell concrete varied depending on the mix ratio employed. Also Ayanbadefo (1990) in his research on the investigation into the use of palm kernel shell as light weight aggregate for concrete reported that the Aggregate impact value (AIV) and the Aggregate crushing value (ACV) ,were approximately 46percent and 58percent lower respectively compared to granite aggregates, which shows that palm kernel shell is a good shock absorbing material. Also Alengaram et al (2010) investigated the physical and mechanical properties of different sizes of palm kernel shells as lightweight aggregates (LWA) and theirinfluence on mechanical properties of palm kernel shell concrete reported that the 28day compressive strengths were in the range of 21 to 26MPa.They further showed that palm kernel shell consists of about 65 to 70percent of medium size particles in the range of 5 to 10mm. The other two sizes, namely, small (0-5mm) and large (10-15mm) sizes were found to influence the mechanical properties of palm kernel shell concrete. The concrete mix that was made with medium size palm kernel shell only produced lower compressive strength of about 11percent compared to the mix that contained all sizes of palm kernel shell. Acheampong et al, 2013, investigated the Comparative Study of the Physical Properties of Palm kernel shells Concrete and Normal Weight Concrete using different cement types in Ghana and reported that the density of the palm kernel shell concrete was about 22percent lower than that of the normal weight concrete for both cement types. Compressive strengths of both palm kernel shell and normal weight concretes with

Portland-limestone cement and Ghacem Extra cement evaluated at 7, 14 and 28days showed that Ghacem Extra cement produced concretes of higher compressive strengths than Portland-limestone cement for palm kernel shell concrete and normal weight concrete. The authors reported that in general, the compressive strength of palm kernel shell concrete using Ghacem Extra cement compared well with those obtained from other materials used for structural lightweight concrete. Also Newman, 1993, in his research into the properties of structural lightweight concrete reported that the behaviour of the palm kernel shell aggregates is beneficial to concrete structures that require good impact resistance properties. The author observed that the physical and mechanical properties of the palm kernel shell aggregates are satisfactory for producing structural concrete, and that the type of aggregate influences the unit weight and compressive strength of the corresponding concrete. In the same research, the author also reported that the strength of lightweight aggregates was the primary factor controlling the upper strength limit of lightweight aggregate concrete. He observed that the smooth convex surface of palm kernel shell aggregates resulted in weak bonds between palm kernel shell aggregates and cement matrix. Thus, the strength of palm kernel shell concrete is usually governed by the strength of the mortar. He further stated that the mode of failure of the palm kernel shell concrete observed suggests the dependence of the strength of palm kernel shell concrete on the strength of the mortar and the interfacial bond between the palm kernel shell and the cement matrix. It was also observed that for the normal weight concrete, failure was explosive, resulting in full disintegration of the test specimens (failure of the granite aggregates).However, failure was gradual for the palm kernel shell concrete as the specimens were capable of retaining the load after failure without full disintegration. He reported that this may be attributed to the good energy absorbing quality of the palm kernel shell aggregates derived from the low aggregate impact value (AIV) and low aggregate crushing value (ACV) (Teo *et al.*, 2007).

2.3 DENSITY OF PALM KERNEL SHELL CONCRETE

On density of concrete and percentage replacement of palm kernel shell in concrete, Alengaran *et al.*, 2010; Olutoge *et al.*, 2010, 1995 and Okpala (1990), investigated among other things the density of palm kernel shell aggregate as well as its concrete and discovered that when palm kernel shell is completely used as coarse aggregate, the density of the palm kernel shell concrete is less by over 20percent with reference to normal weight concrete. Olutoge *et al.,* (1995), found the density of palm kernel shell concrete to be 740kg/m^3. They concluded that the materials have properties which resembled those of lightweight concrete materials. Generally, when the density of concrete is lower than 2000kg/m^3, it is categorized as lightweight concrete (LWC).

Neville (2000) also reported that the use of palm kernel shell as a material of construction could have other advantages in concrete aside from serving as lightweight concrete. He further stated that one of the major advantages is the reduction in concrete density, which consequently reduces the total dead load of the structure. He also stated that when lightweight concrete is employed in the construction process, the formwork is subjected to lower pressure than would be the case with normal or heavy weight concrete.

2.4 EFFECT OF MINERAL ADMIXTURE ON PALM KERNEL SHELL CONCRETE

Several researches in the past have shown that the cube compressive and flexural strengths could be improved with the addition of mineral admixtures like silica fume and fly ash to mention a few. Among studies done in this area include the works of Neville (1995 and 1996); Alengaram *et al.*, 2008; Teo *et al.*, 2006; Alengaran *et al.*, 2010; Robert *et al.*, 2003 and Alengaram *et al.*, 2008).

Neville (1995) had reported that Silica fume (SF) has the ability to localize at the surface of the aggregates to enhance the bond between an aggregate and the cement matrix. This addition of silica fume strengthens the zone of weakness being the zone between the aggregate and the cement paste interface. The weaker bond between aggregate-matrix contributes to the lower tensile strength in palm kernel shell concrete. In Normal weight concrete (NWC), the rough surface of aggregates increases the bond and thereby increasing tensile strength. According to Neville (1996), Silica fume (SF) is always employed in the production of palm kernel shell concrete of grade 30 and above mainly to improve the bond between the smooth convex surfaces of palm kernel shell and cement matrix., He further reported that Silica fume (SF) particles are 100 times smaller than cement particles and the extremely very fine Silica fume (SF) particles have the ability to be located in the very close proximity of the aggregate particles. Alengaram *et al*. (2008) and Teo *et al*. (2006) respectivelyinvestigated the flexural behaviour of palm kernel shell concrete with and without mineral admixture and reported that for structural concrete using palm kernel shell as lightweight aggregate, the compressive strength was between 25 to 28.1MPa at 28days curing**.** They also concluded that lightweight concrete from palm kernel shell has dry density of 1950kg/m^3 and that the performance of beams made from palm kernel shell concrete of dimension

(3000mm ×250mm × 150mm) was superior with respect to ductility. Alengaran *et al*. (2010) also observed that when mineral admixtures of silica fume (SF) and fly ash (FA) were added to a concrete mix with palm kernel shell aggregate, the compressive strength at 28days was improved to 37N/mm^2. Similarly, Robert *et al*. (2003) reported that the extremely fine Silica fume (SF) particles would produce calcium silicate and aluminate hydrates in Concrete on reacting with liberated calcium hydroxide. This chemical reaction increases strength and reduces permeability by increasing the density of the concrete matrix. Also Alengaram *et al*. (2008), from his research paper on the influence of sand content and silica fume on mechanicalproperties of palm kernel shell concrete observed improvement of palm kernel shell concrete by the use of Silica fume (SF). The authors reported that one of the ways to improve the bond is to check the influence of sand content as mechanical properties, in which is governed by density of concrete. The fresh densities of palm kernel shell ranged between 1852 and 1940kg/m^3. It was observed that oven dry densities were about 220 to 260kg/m^3 lower than water cured densities. The highest density of 1971kg/m^3 was reported for mix containing sand/cement (s/c) ratio of 1.6. Alengaram *et al*. (2008) also observed that an increase in sand content beyond s/c ratio of 1.6 might have resulted in higher density than the limit for lightweight concrete (LWC) of 2000kg/m^3 and hence mixes containing s/c ratio higher than 1.6 was not considered. The authors reported 10 to 15percent increase in strength for mixes containing silica fume. It was further reported that the silica fume plays a major role in early strength development of palm kernel shell concrete.

2.5 INFLUENCE OF COMBINATION OF COCONUT SHELL, SAWDUST AND PALM KERNEL SHELL IN CONCRETE

Previously, authors like Ata *et al*. (2006) and Olutoge *et al*. (2010), have also characterized other organic waste materials like coconut and sawdust when used as aggregate replacement for crushed granite in concrete. Ata *et al*. (2006) investigated the properties of palm kernel shell and coconut shell as coarse aggregate in concrete. Palm kernel shell and coconut shell were crushed and substituted for conventional coarse aggregates in gradation of 0 to 100percent in steps of 25percent. Two mix ratios (1:1:2) and (1:2:4) were used for the research. They noted that the compressive strength of concrete decreased as the percentage of the shells increased in the two proportions. Their results also indicated a 30percent and 42percent cost reduction in concrete produced from coconut shells and palm kernel shells respectively. The coconut shell was more suitable than palm kernel shells when used as a substitute for conventional aggregates in concrete production. They further concluded that replacement of 8percent crushed granite with palm kernel shell by volume batched concrete can be used in reinforced concrete construction whereas replacement of 13percent crushed granite by weight batched concrete can be used in reinforced concrete construction. Thus, palm kernel shell concrete batched by volume performed better than that batched by weight. Olutoge *et al*. (2010) investigated the suitability of sawdust and palm kernel shell as replacement for fine and coarse aggregate respectively in the production of reinforced concrete slabs. They concluded that 25percent sawdust and palm kernel substitution reduced the cost of concrete production by 7.45percent. They also indicated the possibility of partially replacing sand and granite with sawdust and palm kernel shell respectively in the production of lightweight concrete slabs.

2.6 CURING MEDIA EFFECT ON PALM KERNEL SHELL CONCRETE

Several researches had been conducted on palm kernel shell concrete in the past by evaluating their properties with a view to predicting and ascertaining their performance in practical applications. Curing is very important for strength gain in concrete. Different authors have conducted research on the influence of curing media on the compressive strength of palm kernel shell concrete.Basri *et al*. (1999) investigated the effect of different curing conditions for a period of up to 56days.They also studied the workability, density, and compressive strength when fly ash is used as cement replacement in palm kernel shell concrete. They reported a reduction of up to 29percent on the compressive strength of the concrete and also stated that compressive strength of palm kernel shell concrete was within the range for structural lightweight concrete (LWC). This was about 50percent less than the Normal weight concrete (NWC). They concluded that palm kernel shell concrete attained the highest strength within a 56days water curing period. Similarly, Adewumi*et al*. (2012) reported the effect of three curing conditions on the 28day compressive strength of palm kernel shell concrete at three levels of coarse aggregate sizes and five replacement levels of granite with palm kernel shell. The curing media investigated were complete immersion in water for 28days strength test, complete immersion in water for an initial 7 days before open air curing in the laboratory under room temperature for the remaining 21days, and open air curing for 28days in the laboratory. They observed that at 25percent palm kernel shell replacement, the slump values were highest (22-40mm), specimens were of dense weight for all aggregate sizes and optimum strength at 28days was obtained for the 5-20mm aggregate size specimen. Aggregate size of 5-20mm also had the highest de-moulded density. However, at 50percent palm kernel shell content, which is lightweight, compressive strength, was 18.43 N/mm^2 for 5-20mm aggregate specimen which is above the minimum value of 17 N/mm^2 for lightweight concrete. At 50-100percent palm kernel shell contents, densities of specimens were lightweight. At 100percent palm kernel shell content the slump values reduced to zero. They therefore concluded that similar to normal weight concrete (NWC), specimens cured by complete immersion in water for the test period gave the highest compressive strength at all aggregate sizes and palm kernel shell contents. Also, according to Teo *et al*. (2006), palm kernel shell concrete was found to have water absorption and water permeability of about 11percent and 6.4×10^{-10} cm/s respectively when cured in water at an age of 28day, and they concluded that it is comparable to other lightweight concretes such as those made from pumice aggregates (Guduz and Ugur, 2005; Hossain, 2004).

2.7 EFFECT OF PROPORTION AND AGGREGATE SIZE ON PALM KERNEL SHELL CONCRETE

Nuhu-Koko (1990), Akpe (1997), Olusola and Babafemi (2013) and Abang (1982) have studied the effects of proportion and aggregate sizes on palm kernel shell concrete. Aggregates have an overwhelming influence on the properties of concrete considering the percentage occupied in the mix. According to Nuhu-Koko (1990), Akpe (1997), Olusola and Babafemi (2013), the compressive strength of concrete varies between 0.3 N/mm^2 and 22.97N/mm^2 depending on the proportion of the palm kernel shell in the mix. Olusola and Babafemi (2013) also showed that both compressive and splitting tensile strengths increased with increase in aggregate sizes. Both strengths however decreased with increase in replacement levels of granite with palm kernel shell. Optimum replacement level of granite with palm kernel shell was 25percent with compressive and tensile strengths of 22.97N/mm^2 and 1.89N/mm^2 respectively at maximum coarse aggregate size of 20mm. However, at 50percent palm kernel shell content, which results in lightweight concrete, compressive strength, was 18.13N/mm^2 which is above the minimum value of 17MPa for lightweight concrete. Abang (1982) reported that a higher proportion of Palm kernel shell in a mix lowers the workability and compressive strength of palm kernel shell concrete. He also observed that the strength of the shell also plays a significant role in the strength of the concrete.

2.8 BOND CHARACTERISTICS OF PALM KERNEL SHELL CONCRETE

Some research had been done in assessing the bond characteristics of the palm kernel shell in concrete matrix like works of Raheem *et al*. (2008) and Jumaat *et al*. (2009). According to Raheem *et al*. (2008) and Jumaat *et al*. (2009), the poor bond between palm kernel shell aggregate and the concrete matrix produced a poorly compacted concrete because of the smooth and convex nature of the shell. However, higher sand content has been reported to improve significantly the bond strength of palm kernel shell concrete (Babafemi and Olawuyi, 2011). Previously, researchers like Okafor (1988), Mannan and Ganapathy (2002) and Jumaat *et al*. (2009) have shown that a poor bond between palm kernel shell and the cement matrix resulted in bond failure. This contributed to lower mechanical properties in palm kernel shell concrete. They reported that bond failure may be attributed to the smooth and convex surface of palm kernel shell. Jumaat *et al*. (2009) reported that the ordinary failure in tension occurs as a result of breakdown of bond between the matrix and the surface of the aggregate or by fracture of the matrix itself, and not as a result of fracture of the aggregate. Since gravel stone have rough surface compared to palm kernel shell, it tends to have better bonding with the cement paste (Jumaat *et al*., 2009). The behaviour of palm kernel shell concrete in a marine environment had been previously reported by Mannan and Ganapathy (2001) and they revealed that the compressive strength of palm kernel shell concrete was 28.1MPa at an age of 28days.They also observed that the bond property of palm kernel shell concrete is comparable to other types of lightweight concretes.

2.9 UTILISATION OF PALM KERNEL SHELL CONCRETE IN BUILDING.

Aside from the environmental gains in the utilization of palm kernel shell as a natural lightweight aggregate (LWA), there is also an economical achievement in the production of low cost houses. Palm kernel shell concrete has been successfully used in the construction of buildings. A model low-cost house of 58.68m^2 area which was built in Sarawak-Malaysia using palm kernel shell hollow blocks for walls and palm kernel shell concrete for footings, lintels and beams was performing well and has no structural problems at all (Teo *et al*., 2006). According to Kankam (2000), a residential building in Ghana that was constructed using palm kernel shell aggregate concrete and palm kernel shell aggregate blocks was completed in 1990 and has been occupied. Regular monitoring over the years indicates that the building has not suffered any particular structural distress from usage of palm kernel shell as aggregates in the concrete. Bergert (2000), however, reported that palm kernel shell could be mixed with mud and formed into blocks for the construction of traditional homes. Bernasco (2004) investigated the use of palm kernel shells as chippings in terrazzo flooring and concluded that it could be used alone in low traffic areas or replaced with about 30percent volume of marble chippings in high traffic areas**.** Similarly, Owolabi (2012), in his research work on the assessment of palm kernel shells as aggregate in concrete and laterite blocks reported that the strength of laterite cubes increased linearly with age and that laterite cubes reinforced with palm kernel shells in appropriate proportion of 1:4 (kernel shells: laterite) by volume had higher strength than plain laterite cubes (about 15percent difference). The author encouraged the use of kernel shells as aggregate in laterite blocks. Further tests on palm kernel shells revealed low specific gravity, high moisture content and water absorption rate. However,replacement of crushed stone aggregate with kernel shells in concrete blocks resulted in astrength reduction of about 50percent. According to Owolabi (2012), concrete with crushed stone as coarse aggregate has higher strength than concrete with palm kernel shells as aggregate. This shows that palm kernel shells cannot be substituted for crushed stones as coarse aggregate in concrete except for aesthetic purposes. However, concrete with palm kernel shells as aggregate could be used for lightweight construction work. The strength of laterite cubes (whether plain or reinforced with kernel shells) compare favourably with the strength of sandcrete blocks popularly used in day to day building construction work as partitions. However, he concluded that laterite blocks are good substitutes for sandcrete blocks.

2.10 PALM KERNEL SHELL IN ROAD CONSTRUCTION

Ndoke (2006) investigated the performance of Palm kernel shells as a partial replacement for Coarse Aggregate in Asphalt Concrete. It was observed that palm kernel shells can be used to replace coarse aggregate up to 30percent before drastic reductions in strength became noticeable. He went further to report that the 28day compressive strength of concrete with palm kernel shell aggregate range between 0.3 and 20.5N/mm^2 depending on the proportion in the mix. He concluded that Palm kernel shells can be used as partial replacement for coarse aggregate up to 10percent for heavily trafficked roads and 50percent for light trafficked roads. For the very lightly trafficked roads in the rural communities palm kernel shells can be used as full replacement for the coarse aggregates.

2.11 WORKABILITY AND COMPRESSIVE STRENGHT OF PALM KERNEL SHELL CONCRETE

Saman and Omidreza (2011) reported the influence of Palm kernel shell on workability and compressive strength of high strength concrete. They noted that the general strength of palm kernel shell concrete samples produced high strength concrete with compressive strength reaching up to 52.2N/mm^2 at 28days.They also noted that concrete made with nominal mixes of 1:3:6 and 1:4:8 generally gave poor results. Similarly, Emiero and Oyedepo (2012) investigated the strength and workability of concrete using palm kernel shell (PKS) and palm kernel fibre (PKF) as a coarse aggregate. Concrete batching was by volume and two mix ratios of 1:1.5:3 and 1:2:4 were used. They reported that for Lightweight concrete obtained using Palm kernel shell and Palm kernel Fibre respectively as partial replacement for coarse aggregate the concrete mix ratio PKS: PKF of 50:50 for 1:1.5:3 and 1:2:4 had compressive strength of 12.29N/mm^2 and 10.38N/mm^2 after 28days, which confirms light weight concrete. It was also observed that the rate of absorption for water increase from 7days to 28days was about 9.2 percent for the combination of PKS and PKF for mix 1:1.5:3 while mix 1:2:4 was 13.0 percent.

The percentage absorption of water for the combination of crushed granite (CGN) and PKF of mix 1:1.5:3 was 4.3percent while mix 1:2:4 was 6.8 percent. It was therefore discovered that PKF with PKS concrete absorbed more water compared to concrete made with partial replacement of crushed granite with PKF. They concluded that organic materials are subject to deterioration over time hence concrete made with PKS plus PKF and GN plus PKF should be regularly maintained and replaced as the need arises.

The introduction of artificial and natural lightweight aggregates (LWA) to replace conventional aggregates for the production of concrete in many developed countries, has brought immense benefits in the development of infrastructure, especially, high rise structures using lightweight concrete (Jumaat *et al*.,2009). In addition, in developed countries, the construction industries have identified the use of waste natural material as the potential alternative to conventional aggregates by reducing the size of structural members. This has brought immense change in the development of high rise structures using Lightweight Concrete. However, the manufacture and use of lightweight aggregates from wastes such as expanded pelletized fly ash aggregates, sintered fly ash aggregates, expanded slag gravel, palm kernel shell, coconut shell, blast furnace slag etc. have in fact demonstrated the effectiveness of waste utilization in industrially advanced countries. Additionally, production of lightweight aggregates from the municipal and dredging wastes in the USA, Russia, Japan and other developed nations is a very significant development (Chandra and Berntsson, 2003). According to Ndoke (2006), the use of palm kernel shell as construction material is not common in the Ghanaian construction industry and this may be attributed to the non-availability of technical information to support their use or the low resource base of palm kernel shell in the past compared with the conventional sand and gravel aggregate.

However, Alengaram *et al*. (2010) and Teo *et al*. (2006) have reported that in Asia the construction industry is yet to utilize the advantage of Lightweight Concrete (LWC) in the construction of high rise structures. Recent research has shown that the utilization of palm kernel shell in construction shall provide immense benefit and also bring significant development. Furthermore ,Ramli (2003) stated that nearly 5million hectares of oil palm trees is expected by the year 2020 in Malaysia alone and that the requirement of vegetable oil is constantly increasing and more cultivation of palm oil is forecast in the near future. Similarly, Anon (2011) reported that for every 10tons of palm oil, about 1ton of palm kernel oil is also obtained while Ndoke, 2006, reported the annual generation of Palm kernel shell in Nigeria to be about 1.5million tons. With this background information, if palm kernel shell is found suitable for construction, their large supply could be harnessed to reduce construction cost without undermining the strength and integrity of concrete structures especially for irrigation and drainage canals.

2.12 LIGHT WEIGHT AGGREGATE CONCRETE

Mu'azu *et al*. (2001) investigated the properties of palm kernel shell aggregate concrete and observed that with lightweight aggregate, concrete produced are light in weight, thereby reducing the total dead load of the structure. The authors further reported that the sound absorption coefficient of lightweight concrete is about twice that of normal weight concrete.

According to the American Concrete Institute-ACI, 1998, Structural lightweight aggregate concrete is defined as concrete which:

(i) Is made with lightweight aggregates conforming to the American Standard Test Method-ASTM C330, (2004).

(ii) has a compressive strength in excess of 17.25MPa at 28days of age when tested in accordance with methods stated in the American Standard Test Method-ASTM C330,(2004) and

(iii) has an air dry density not exceeding 1,840 kg/m^3 as determined by the American Standard Test Method-ASTM C567(2003).

Neville (2000) stated that lightweight aggregate concrete should be classified according to the purpose for which it is to be used. In the same research the author reported structural lightweight concrete to have density value in the range of 1900 to 1950Kg/m^3 with a minimum compressive strength of 17N/mm^2 at 28days hydration and consists of lightweight aggregate. The author also classified Concrete into three major categories based on density. The density of heavy weight concrete being more than 3600kg/m^3 and normal weight concrete about 2400kg/m^3. Neville (1995) classified lightweight concrete as one with density of 2000kg/m^3 or less. The practical range of densities of lightweight concrete is between 300kg/m^3 and 1800kg/m^3.Lightweight concrete has unique benefits in construction .Besides the advantage of reduction of self-weight of structures lightweight concrete also gives better thermal insulation compared with normal weight concrete (Short and Kinniburgh, 1978).

In recent years, due to the numerous advantages of using lightweight aggregate concrete in construction, there has been an increasing interest in production and also investigation of properties of these materials (Kan and Demirbog, 2009; Gennaro *et al.*, 2008; Hossain, 2004; Teo *et al.*, 2007; Subasi, 2009 and Alengaram *et al.*, 2010). According to the American concrete institute (ACI), 1987, there are many types of aggregates available that are classified as lightweight, and their properties cover wide ranges. Structural lightweight aggregate concrete is an important and versatile material in modern construction. It has many and varied applications including multi-story building frames and floors, bridges, offshore oil platforms, and pre-stressed or precast elements of all types. Many Architects, Engineers, and contractors recognize the inherent economies and advantages offered by this material, as evidenced by the many impressive lightweight concrete structures found today throughout the world (American concrete institute -ACI, 1987).Structural lightweight aggregate concrete has strengths comparable to normal weight concrete, yet is typically 25 to 35percent lighter and it also solves weight and durability problems in buildings and exposed structures(American concrete institute -ACI, 1987).

2.13 CURING OF CONCRETE

According to Neville (1981), Curing is the process used for promoting the hydration of cement and consists of a control of temperature and of the moisture movement from and into the concrete; with the aim of keeping the concrete saturated or as nearly saturated as possible until the originally water-filled space in the fresh cement paste has been filled to the desired extent by the products of cement hydration. The goal of curing is to ensure that air-filled void is filled with the products of hydration of cement as time progresses (Mannan *et al*., 2002). Previously, investigations from the researches done by Gonnerman and Shuman (1928) and Price (1951) have shown that concrete continuously cured in air had lower compressive strength compared to water cured concrete at all the ages tested. Increase in compressive strength, permeability, durability and other mechanical properties of concrete by continuous water curing are attributable to improved gel/space ratio in concrete (Neville, 1981). Mannan *et al*. (2002) observed that among the factors influencing the strength development of concrete is the curing environment where the specimens are put after being de-moulded. They stated that curing is usually done in a fully saturated environment to ensure proper hydration of the cement over time thereby leading to significant strength development. The authors observed that for concrete to achieve best performance, the temperature and humidity under which it is cast and cured are part of the major considerations. The authors also reported that at higher temperatures, the rate of cement hydration is negatively affected and lower temperatures retard the hydration process leading to poor strength development. Çakir and Akoz, 2008; Mannan *et al.* (2002) have also shown that the method employed in curing concrete also has significant effect on its mechanical properties.Price (1991) refers to curing as the process of protecting concrete for a specified period of time after placement, to provide moisture for hydration of the cement, to provide proper temperature and to protect the concrete from damage by loading or mechanical disturbance. Curing is designed primarily to keep the concrete moist by preventing loss of moisture from it during the period in which it is gaining strength. Curing can be achieved by keeping the concrete element completely saturated or as much saturated as possible until the water-filled spaces are substantially reduced by hydration products (Gowripalan *et al.*, 1992). The chemical reaction which curing aims at continuing, termed hydration of cement, virtually ceases when the relative humidity within capillaries drops below 80percent(Neville, 1996). Nilsson (1980) in his experimental investigation into hygroscopic moisture in concrete had observed a substantial decrease in the rate of hydration when the ambient humidity fell below 80percent. It's important to note that if concrete is not cured and is allowed to dry in air, it will gain only 50percent of the strength of continuously cured concrete. As a result, if concrete is cured for only three days, it will reach about 60percent of the strength of continuously cured concrete; if it is cured for seven days, it will reach 80percent of the strength of continuously cured concrete. If curing stops for some time and then resumes again, the strength gain will also stop and reactivate (Mamlouk and Zaniewski, 2006). However, long period of moist curing has been reported to reduce the incidence of cracking (Kong and Evans, 1994). If concrete is not well cured, particularly at the early age, it will not gain the required properties at desired level due to a lower degree of hydration, and would suffer from irreparable loss (Ramezanianpour and Malhotra, 1995; Zain *et al*., 2000). Wojcik and Fitzgarrald (2001) also observed that improper curing would entail insufficient moisture and this has been found to produce cracks, compromise strength, and reduce long-term durability. The strength development and permeability of concrete is greatly affected by the processes of hydration, leaching and curing.

2.14 PROPERTIES OF PALM KERNEL SHELL

Ndoke (2006) andTeo*et al*. (2007) has shown that palm kernel shell has different bulk physical and chemical characteristics as presented in tables 2.1 and 2.2.

Table 2.1 Bulk physical and chemical characteristics of palm kernel shell

PROPERTY	PARAMETER	VALUE	
		Ar	Db
Physical	Moisture Content (%)	6.11	-
	Ash Content (%)	8.68	-
	*Bulk density (kg-m^{-3})	740	9.24
	*Porosity (%)	28	650
Chemical	C (%)	46.75	49.79
	H (%)	5.92	5.58
	O (%)	37.97	34.66
	N(%)	0.68	0.72
	S(%)	<0.08	<0.08
	CI(ppm)	84	89
Structural Carbohydrates	Hemi cellulose (%)	26.16	
	Cellulose (%)	6.92	
	Lignin (%)	53.85	

Ar (as received), db (dry basis)

Source, Ndoke,(2006).

Table 2.2 Chemical composition of palm kernel shell aggregate.

Elements	Results (%)
Ash	1.53
Nitrogen (as N)	0.41
Sulphur (as S)	0.000783
Calcium (as CaO)	0.0765
Magnesium (as MgO)	0.0352
Sodium (as Na_2O)	0.00156
Potassium (as K_2O)	0.00042
Aluminium (as Al_2O_3)	0.130
Iron (as Fe_2O_3)	0.0333
Silica (as SiO_2)	0.0146
Chloride ((as Cl^-)	0.00072
Loss on Ignition	98.5

Source, Teo *et al.(*2007).

CHAPTER THREE

MATERIALS AND METHODS

3.1 MATERIALS SELECTION

3.1.1 Preparation of Palm Kernel Shell

Palm kernel shell used in this study was collected from a local palm oil processing factory at Mbarakpaka village in Ihiala town, Ihiala Local Government Area of Anambra State. Preparation of Palm kernel shell was done first by soaking them overnight in detergents after which the shells were washed and then spread to dry. Pre-treatment is necessary to remove impurities such as oil coating and mud particles which stick onto the surface of fresh palm kernel shell during processing. In this investigation, boiling in water as well as washing with detergent was adopted. After washing, they were rinsed thoroughly in order to ensure that all particles of detergent were removed as these can lower the performance of cement or even be a contaminant in concrete. The shells were finally spread to dry in a shed and then kept in waterproof sacks.
Alengaram *et al*. (2010) observed that with varying palm kernel shell sizes, water absorption also varies in the range of 8-15% and 21-25% for 1 h and 24 h, respectively. Alengaram *et al*. (2011) proposed that due to the high water absorption property of Palm kernel shell pre-soaking of aggregates for about 45 minutes to 1hour is mandatory before use in concrete production. The absorption during this period of pre-soaking was therefore determined in this research and was found to be 11%.

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3.1.2 Sharp Sand and Crushed Granite

Naturally occurring clean river sharp sand (fine aggregate) and Crushed Granite (coarse aggregate) were used in this research. They were sourced from a construction site along Chime Avenue, Enugu in Enugu State of Nigeria. BS 812 (2002) that deals with “Testing Aggregates” was used in carrying out laboratory tests on the aggregates.The crushed granite was seen to have maximum aggregates size of 12mm, specific gravity of 2.76, and a fineness modulus of 5.74.The sharp sand was sun dried to control the moisture content during usage to conform with the requirements of BS 882 (1992).It had maximum aggregates size of 4.75 mm, specific gravity of 2.5, and a fineness modulus of 2.69

3.1.3 Cement

Ordinary Portland cement with specific gravity of 3.0 was used for this study. The bags were observed to be airtight from the manufacturer and free from moisture related fluids. The cement thereby conforms with BS 12 (1996).

3.1.4 Water

Portable water supplied by Enugu state Water Co-operation was used in mixing the materials. The water was tested using basic sense of smell and taste and observed to be clean and free from any visible impurities hence was in conformity with BS 3148 (1980).

3.2 RESEARCH PROCEDURE

The physical properties studied for palm kernel shell and other aggregates were gradation test/sieve analysis, specific gravity, water absorption capacity and bulk density.The palm kernel shell and granite aggregates used in the study were sampled from portions passing 14mm sieve size and retained on the 10mm sieve size. The water absorption of the palm kernel shell and crushed granite were determined in accordance with the recommendations for testing aggregates in BS 812 (2002) by measuring the decrease in mass of a saturated and surface dry sample after drying under the shed for 24 hours. The water absorption was estimated as the ratio of the decrease in mass to the total mass of the sample expressed as a percentage.

3.3 PHYSICAL PROPERTIES TEST ON AGGREGATES

3.3.1 Specific Gravity (SG).

The specific gravity of the materials was determined in accordance with the requirement of ASTM C 127-07, (2007).

The specific gravities of sand and cement were determined using the density bottle while the pycnometer was used to estimate the specific gravities of palm kernel shell and crushed granite.

For the sand and cement,the density bottle was initially weighed in a weighing balance,W_1; after which it was half-filled with sample. Weight of sample with density bottle was also noted,W_2. Water was now introduced into the bottle with sample and weight determined from the balance once more,W_3. Finally, water was drained from the density bottle after which remnants of sample were washed off completely from the inside and surfaces of the density bottle. The density Bottle was dried with absorbent cloth and was water-filled to determine weight of water and bottle,W_4. Experiment was replicated thrice for values of W_1,W_2, W_3 and W_4 and the average values used for the estimation of the specific gravities of sand and cement. Using the pycnometer, same procedure was repeated to determine the specific gravities of crushed granite and palm kernel shell. Specific gravity is given by Equation 3.1.

$$\frac{(W_2-W_1)}{(W_4-W_1)-(W_3-W_2)} \qquad (3.1)$$

Where,

W_1= Weight of density bottle empty.

W_2= Weight of density bottle +Sample.

W_3= Weight of density bottle + Sample +Water.

W_4= Weight of density bottle + Water.

3.3.2 Sharp Sand

W_1 = 33grams.

W_2 = 48grams

W_3 = 92grams

W_4 = 84grams

3.3.3 Crushed Granite

W_1 = 480grams

W_2 = 1492grams

W_3 = 2011grams

W_4 = 1366grams

3.3.4 Palm Kernel Shell

W_1 = 480grams

W_2 = 942grams

W_3 = 1467grams

W_4 = 1360grams

3.3.5 Cement

W_1 = 34grams

W_2 = 43grams

W_3 = 84grams

W_4 = 88grams

Using Equations 3.1 the specific gravities of Sharp Sand, Crushed Granite, Palm Kernel Shell and Cement are 2.5, 2.76, 1.301 and 3.0 respectively.

3.4 BULK DENSITY

Test carried out on the samples of aggregates used for the research was in accordance with the procedures described in ASTM C 29/C29M (2003). Bulk Density was estimated in this research using a Mould with dimensions: length = 17.3cm, width = 8.8cm and depth = 11.4cm

Volume of Mould =1735.5cm^3

The mould was filled to the brim each time to determine the bulk densities of sharp sand, crushed granite and palm kernel shell. One side of the mould was gently tapped to consolidate the sample height in the mould.The weighing balance was used to estimate the Weight of empty mould, W_1, after which the mould filled to the brim with sample was weighed, $W_{2.}$ .Weight of Sample, W_3 was determined by subtracting W_1 from W_2. Experiment procedures were repeated thrice for values of W_1,W_2, and W_3 .Average for these values were then used for the estimation of the bulk densities of sharp sand, crushed granite and palm kernel shell.

Bulk Density is given by equation 3.2.

<u>Weight of Sample</u> (3.2)

Volume of Mould

Where,

W_{1}=Weight of empty mould

W_{2}=Weight of mould + Sample

$W_{3} = (W_{2} - W_{1})$ =Weight of Sample,

Volume of Mould used = (length = 17.3cm, width = 8.8cm, depth = 11.4cm = 1735.5cm^3)

Volume in m^3 = 0.0017355m^3

3.4.1 Sharp Sand

W_1 = 622g

W_2 = 3486g

W_3 = (3486-622) =2864g=2.864kg

3.4.2 Crushed Granite

W_1 = 611g

W_2 = 3293g

W_3 = (3293 -611) =2682g=2.682kg

3.4.3 Palm Kernel Shell

W_1 = 611g

W_2 = 1712g

W_3 = (1712 -611) =1101g=1.101kg

Using Equations 3.2 the Bulk Densities of Sharp Sand, Crushed Granite and Palm Kernel Shell are 1650, 1545 and 634kg/m^{3}respectively.

3.5 WATER ABSORPTION

Water Absorption test on materials was carried out in accordance with BS

1881(1983)-Part 122 and the equation is given by equation 3.3.

1000grams of samples of crushed granite and palm kernel shells was Washed, sundried and weighed; these weights were noted as being W_1 for crushed granite and palm kernel shell samples. The samples were later immersed in water for a period of 24hrs after which the weights were estimated as W_2. The weight of water absorbed within this 24hr period being the difference between the weight of sample soaked in water for 24hrs and the weight of sun-dried sample. The water absorption capacity was now estimated using equation 3.3.

$$\frac{(W_2 - W_1)}{W_1} \qquad (3.3)$$

Where,

W_1=Weight of Sun dried sample.

W_2=Weight of Sample after 1hr/24hrs immersion in water.

$(W_2 - W_1)$=Weight of water absorbed.

3.5.1 Palm Kernel Shell

1HR

W_1 = 1000grams

W_2 = 1110grams

$(W_2 - W_1)$ = 110grams

24HOURS

W_1 = 1000grams

W_2 = 1215grams

$(W_2 - W_1)$ = 215grams

3.5.2 Crushed Granite

1HR

W_1 = 1000grams

W_2 = 1006grams

$(W_2 - W_1)$ = 6grams

24HOURS

W_1 = 1000g

W_2 = 1006g

$(W_2 - W_1)$ = 6g

Using Equations 3.3 the Percentage Water Absorption of Palm Kernel Shell in 1hour and 24 hours are 11% and 21.5% respectively while the Percentage Water Absorption of Crushed Granite in 1hour and 24 hours is 6%.

3.6 SIEVE ANALYSIS

Sieve analysis was performed on a weighed sample of crushed granite, sand and palm kernel shells to determine their grading. Samples were washed with water and sun dried for 12 hours before analysis. The aggregate samples were shaken through a set of sieves of successively smaller openings and the mass of sample retained by each sieve was recorded. Thereafter, grain size distribution curves were drawn. Sieve analysis provides information on the gradation of aggregates. Experimental procedure conformed with the specifications of ASTM C 136 (2003).

Coefficient of Curvature (Cc) may be estimated as:

$C_c = \underline{(D_{30})^2}$ (3.4)

$D_{10} \times D_{60}$

Coefficient of Uniformity (Cu) is given by equation 3.5

$$C_u = \frac{D_{60}}{D_{10}} \quad (3.5)$$

Where,

D_{60} = particle size at 60% finer.

D_{30} = particle size at 30% finer.

D_{10} = particle size at 10% finer.

Fineness Modulus (FM) is calculated as the sum of the cumulative percents retained divided by 100:

$$FM = \frac{(\sum \text{Cumulative percent retained})}{100} \quad (3.6)$$

Note: Dry Weight of Original Sample for Sand, Crushed granite and palm kernels are all 1000g.

3.6.1 Sharp Sand

D_{60} = 1.10

D_{30} = 0.513

D_{10} = 0.181

C_c=1.3

C_u =6.0

FM=2.69

3.6.2 Crushed Granite

D_{60} = 19

D_{30} = 20

D_{10} = 13

C_c=1.6

C_u =1.4

FM=5.74

3.6.3 Palm Kernel Shell

D_{60} = 7

D_{30} = 9

D_{10} = 6.0

C_c=2.0

C_u =1.2

FM=3.81

Using equations 3.4, 3.5 and 3.6 Coefficients of Curvature (C_c), Coefficients of Uniformity (C_u) and Fineness Modulus (FM) respectively was computed for Sharp sand, Crushed Granite and Palm Kernel Shell.

3.7 STRENGTH PROPERTIES

3.7.1 The Slump Test

The Slump test was conducted on fresh concrete for all percentage replacements of crushed granite with palm kernel shell as well as the control to ascertain workability of concrete. Procedures from BS 1881: Part 102: (1983) was adopted in carrying out the slump test. The apparatus consists of a mould in the shape of a frustum of a cone with a base diameter of 20.32cm, a top diameter of 10.16cm, and a height of 30.48cm. The mould is filled with concrete in three layers of equal volume. Each layer is compacted with 25 strokes of a tamping rod. The slump cone mould is lifted vertically upward and the change in height of the concrete is measured.

3.7.2 Batching and mixing of materials

Absolute volume method of calculation was adopted to determine the quantities of materials required for the production of the specimen cubes. Palm kernel shell was soaked for 45mins before producing concrete. This practice has been shown to overcome the phenomena of diluting the concrete with increased water (Mannan & Ganapathy, 2002, 2004; Olanipekun *et al*., 2006).Palm kernel shell was used in percentages of 25 to replace granite from 0 to 100% i.e. (0, 25, 50, 75 and 100%) in the mix to study the effect and influence on palm kernel shell concrete. The batching was done by volume because of the differences in apparent specific gravities of Palm kernel shell- 1.30 and Crushed granite- 2.76.Standard Steel moulds with internal dimensions of 150mm by 150mm by 150mm were used for casting test samples for compressive strength test. The inner parts of the moulds were smeared with used engine oil to ensure easy de-moulding and smooth surface finish. Immediately after thorough mixing, the wet and fresh mixture was used for slump test before being cast into the moulds using hand trowel. The concrete in the mould was compacted in 3layers of 50mm each using the rammer (25mm diameter steel rod). Each 50mm layer of concrete in the 150mm mould was compacted manually by uniformly distributing at least 30 blows of the rammer across the cross-section of the mould. The essence of the compaction is to reduce the amount of voids in the concrete.The top of each mould was levelled and smoothened and the outside surfaces cleaned. Each set of three specimen cubes were labeled and identified with a unique number.The moulds and their contents were kept in the materials laboratory for 24 hours before de-moulding.

3.7.3 Concrete Volume Batching

Saman and Omidreza (2011) reported the influence of Palm kernel shell on workability and compressive strength of high strength concrete. They also noted that concrete made with nominal mixes of 1:3:6 and 1:4:8 generally gave poor results. Hence water/cement ratio of 0.5 was used in their research with a mix design of 1:2:4.This informed the use of mix ratio 1:2:4 and water/cement ratio of 0.6 in this research to improve the results on the compressive strength.

In $1m^3$ of concrete,

Sand = $0.42\ m^3$

Crushed Granite = $0.84\ m^3$

Volume of Cement in a 50kg bag of cement = $0.035\ m^3$

6bags of cement makes a concrete of mix ratio 1:2:4 (1bag =50kg).

Quantity of cement in $1m^3$ concrete = 6 bags × 0.035 = $0.21\ m^3$.

Size of Specimen Cube used- (0.15m × 0.15 m × 0.15 m) = $0.003375\ m^3$ of concrete.

Batch of 3 Specimen cubes, $0.003375\ m^3 \times 3 = 0.010125\ m^3$

Include 10% wastage = (0.0010125 + 0.010125)

= $0.011375\ m^3$ of concrete.

6 bags × 0.035 × 0.011375 = $0.00238875\ m^3$ =$2389\ cm^3$.

This is the quantity of cement needed to batch 3 specimen cubes (each measuring 0.15m× 0.15 m× 0.15 m) of concrete mix ratio 1:2:4.

A welded iron mould of dimension 13.4 cm by 13.4 cm by 13.4 cm was prepared for the volume batching of the specimen cubes.

1 part of cement = $2389\ cm^3$

2 parts of Sand = $4778\ cm^3$

4 parts of Aggregate = 9556cm^3

A w/c of 0.6,

Water = 1433.4 cm^3

3.7.4 Density and Compressive Strength Determination

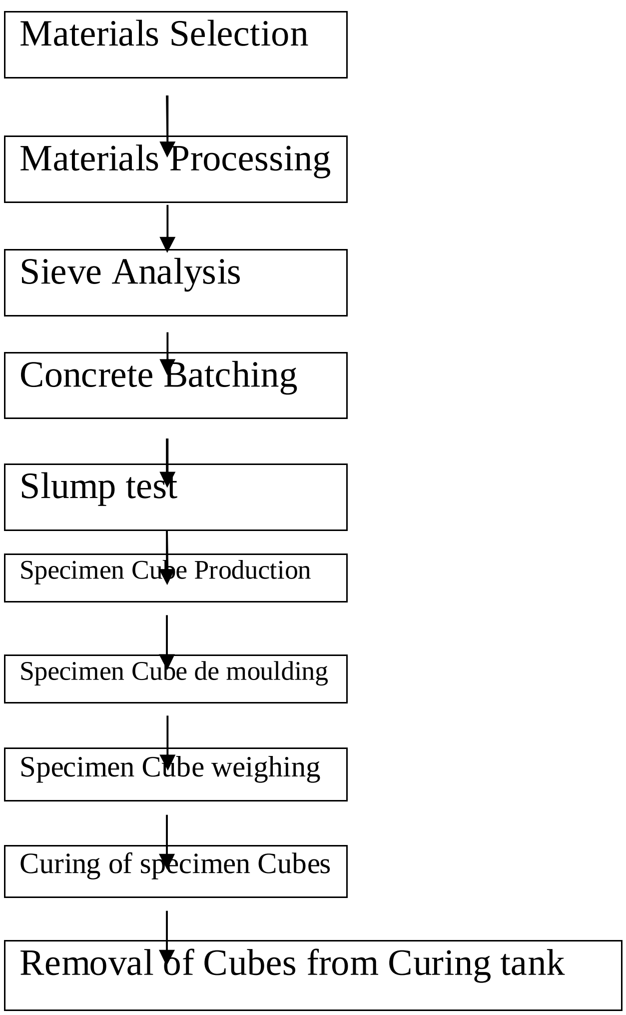
Density of specimens were determined after de-moulding and samples completely immersed in a curing tank of water until crushing test following standard laboratory procedures as outlined in BS and ASTM standards. The specimens were made in accordance with BS 1881:1983 as outlined in section 3.7.2 Batching and mixing of materials.

All specimens were totally immersed in curing tank for 7, 14, 21, and 28days, after which the cubes were brought out of the curing tank and allowed to rest for two hours before crushing to determine the strength properties. The density of each specimen was once more determined before crushing. Three replicates were made for specimens at each curing age for 5 percentage replacements of palm kernel including the control (i.e. 100% granite, 0% palm kernel). This amounted to a total of 60 specimen cubes for the compressive strength test including the control specimen cubes. The average values of the maximum loads, at which each group of the three specimens failed, were used to determine the compressive strength. The compressive test was determined again with reference to the guidelines outlined by the BS and ASTM. Formula for the computation of compressive strength is given below in equation 3.7.

Compressive Strength (N/mm^2)

$$\frac{\text{Crushing Load} \quad (\text{N})}{\text{Effective Area (mm2)}} \qquad (3.7)$$

The compressive strength of the concrete cubes was tested at the Civil Engineering Laboratory of the Institute of Management and Technology (IMT), campus III, Enugu in Enugu State using a SEIDNER Compression Testing Machine of maximum capacity 2000 KN. The weight of each test specimen was determined 30 minutes before the crushing test and density was calculated as the ratio of the weight to the volume of each specimen. Compressive strength on 150mm cube specimens at age of 7, 14, 21, 28days was also tested in accordance to BS EN 12390-3 (2002) and computed using equation 3.7.The experimental procedures for BS EN 12390-3 (2002) are described in sections 3.7.4 Density and Compressive Strength Determination.All tests were carried out at materials laboratory of Civil Engineering Department, IMT, Enugu, Enugu State, Nigeria.



Specimen Cube Weighing

Specimen Cube Crushing to determine Compressive Strength.

Fig 3.1 Sequence involved in the mechanical testing of concrete specimen cubes

3.7.5 Water Absorption Test

The 150mm x 150mm x 150mm sized cubes after casting were immersed in water for 28 days for curing. These specimens were then oven-dried for 24 hours at 85°C until the mass became constant and again weighed. This weight was noted as the dry weight (W_1). After that, the specimen was kept in water for 24 hours. Then this weight was noted as the wet weight (W_2).Recommendations by ASTM (2004) method C1585 were followed to carry out the Water Absorption Test as outlined in section 3.7.5.

$$\% \text{ water absorption} = \frac{W_1}{W_2} \times 100 \qquad (3.8)$$

Where,

W_1 = Oven dry weight of cubes in grams.

W_2 = after 24 hours wet weight of cubes in grams.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 RESULTS

Table 4.1 shows the Comparison of the properties of the aggregates used in the research. The Weights and Densities of Specimen Cubes for 7, 14, 21 and 28days Curing are presented in Tables 4.2 and 4.3 respectively. Tables 4.4 and 4.5 also presents the Weights and Densities of Specimen Cubes after 7, 14, 21 and 28days Curing respectively. The Compressive strength Developments of Specimen Cubes after 7, 14, 21 and 28days Curing are presented in Table 4.6 while Table 4.7 shows the Slump Test results to determine Workability of concrete. GenStat Release 7.2 Discovery Edition 10.3(PC/Windows) was used to statistical analyse result as presented in Table 4.8.Prevailing market prices of aggregates used for the research are presented in Table 4.9.

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Table 4.1 Comparison of properties of aggregates

Properties	Crushed Granite	Palm Kernel Shell	Sharp sand
Thickness (mm)	-	1.0-3.0	-
Bulk density (kg/m^3)	1545	634	1650
Specific gravity	2.76	1.30	2.5
Fineness modulus	5.74	3.81	2.69
Water absorption - 1 h (%)	0.6	11	-
Water absorption - 24 h (%)	0.6	21.5	-
Maximum aggregate size (mm)	12	12	4.75

Table 4.2 Weight of Specimen Cubes for 7, 14, 21 and 28days Curing

S/No	Label	Crushed Granite Replacement (%)	Palm kernel shell Replacement (%)	Mass(Kg)			
				1st	2nd	3rd	Average
1	7A0	100	0	7.674	7.721	7.680	7.692
2	7A25	75	25	5.460	5.320	5.420	5.400
3	7A50	50	50	5.240	5.210	5.150	5.200
4	7A75	25	75	5.020	5.000	4.980	5.000
5	7A100	0	100	4.960	4.870	4.880	4.903
6	14A0	100	0	7.721	7.910	7.660	7.764
7	14A25	75	25	5.490	5.511	5.580	5.527
8	14A50	50	50	5.310	5.111	5.290	5.237
9	14A75	25	75	5.100	5.060	5.080	5.080
10	14A100	0	100	5.005	4.900	4.860	4.922
11	21A0	100	0	7.610	7.980	7.982	7.857
12	21A25	75	25	5.510	5.520	5.470	5.500
13	21A50	50	50	5.300	5.410	5.060	5.257
14	21A75	25	75	5.150	5.210	5.130	5.163
15	21A100	0	100	5.115	5.005	4.900	5.007
16	28A0	100	0	7.640	7.812	7.560	7.671

17	28A25	75	25	5.520	5.410	5.290	5.407
18	28A50	50	50	5.320	5.190	5.450	5.320
19	28A75	25	75	5.100	5.010	5.115	5.075
20	28A100	0	100	4.640	4.790	4.810	4.747

For Density of cube determination the volume of specimen cube is

$(0.15m \times 0.15m \times 0.15m) = 0.003375m^3$

Table 4.3 Density of Specimen Cubes for 7, 14, 21 and 28days Curing

S/No	Label	Crushed Granite Replacement (%)	Palm kernel shell Replacement (%)	Density(Kg/m^3)
1	7A0	100	0	2279
2	7A25	75	25	1600
3	7A50	50	50	1541
4	7A75	25	75	1481
5	7A100	0	100	1453
6	14A0	100	0	2300
7	14A25	75	25	1638
8	14A50	50	50	1552
9	14A75	25	75	1505
10	14A100	0	100	1458
11	21A0	100	0	2328
12	21A25	75	25	1630
13	21A50	50	50	1558
14	21A75	25	75	1530
15	21A100	0	100	1484
16	28A0	100	0	2273

17	28A25	75	25	1602
18	28A50	50	50	1576
19	28A75	25	75	1504
20	28A100	0	100	1407

Table 4.4 Weight of Specimen Cubes after 7, 14, 21 and 28days Curing

S/No	Label	Crushed Granite Replacement (%)	Palm kernel shell Replacement (%)	Mass(Kg)			
				1st	2nd	3rd	Average
1	7A0	100	0	7.770	7.801	7.756	7.776
2	7A25	75	25	5.587	5.413	5.523	5.507
3	7A50	50	50	5.334	5.310	5.270	5.304
4	7A75	25	75	5.154	5.219	5.103	5.159
5	7A100	0	100	5.091	4.992	5.005	5.029
6	14A0	100	0	7.843	8.033	7.785	7.887
7	14A25	75	25	5.613	5.733	5.700	5.682
8	14A50	50	50	5.530	5.340	5.415	5.428
9	14A75	25	75	5.233	5.289	5.232	5.251
10	14A100	0	100	5.221	5.022	4.985	5.076
11	21A0	100	0	7.902	8.112	8.347	8.120
12	21A25	75	25	5.956	5.991	5.890	5.946
13	21A50	50	50	5.711	5.622	5.311	5.548
14	21A75	25	75	5.320	5.442	5.342	5.368
15	21A100	0	100	5.311	5.197	5.112	5.207
16	28A0	100	0	8.311	8.220	7.971	8.167

17	28A25	75	25	6.857	6.790	7.030	6.892
18	28A50	50	50	5.950	5.422	6.934	6.109
19	28A75	25	75	5.704	5.311	5.574	5.530
20	28A100	0	100	5.471	5.129	5.212	5.271

Table 4.5 Density of Specimen Cubes after 7, 14, 21 and 28days Curing

S/No	Label	Crushed Granite Replacement (%)	Palm kernel shell Replacement (%)	Density(Kg/m^3) (Days)			
				7	14	21	28
1	7A0	100	0	2304			
2	7A25	75	25	1632			
3	7A50	50	50	1572			
4	7A75	25	75	1529			
5	7A100	0	100	1490			
6	14B0	100	0		2337		
7	14B25	75	25		1684		
8	14B50	50	50		1608		
9	14B75	25	75		1556		
10	14B100	0	100		1504		
11	21C0	100	0			2406	
12	21C25	75	25			1762	
13	21C50	50	50			1644	
14	21C75	25	75			1591	
15	21C100	0	100			1543	
16	28D0	100	0				2420

17	28D25	75	25				2042
18	28D50	50	50				1808
19	28D75	25	75				1640
20	28D100	0	100				1562

Table 4.6 Compressive strength Development of Specimen Cubes after 7, 14, 21 and 28days Curing

S/No	Label	Crushed Granite Replacement (%)	Palm kernel shell Replacement (%)	Compressive Strength (N/mm^2) (Days)			
				7	14	21	28
1	7A0	100	0	15.10			
2	7A25	75	25	12.11			
3	7A50	50	50	9.16			
4	7A75	25	75	8.44			
5	7A100	0	100	3.90			
6	14B0	100	0		18.97		
7	14B25	75	25		15.19		
8	14B50	50	50		13.70		
9	14B75	25	75		13.03		
10	14B100	0	100		6.58		
11	21C0	100	0			19.44	
12	21C25	75	25			15.57	
13	21C50	50	50			14.77	
14	21C75	25	75			13.88	

15	21C100	0	100			7.94	
16	28D0	100	0				21.73
17	28D25	75	25				16.63
18	28D50	50	50				15.60
19	28D75	25	75				14.62
20	28D100	0	100				12.71

Table 4.7 Slump Test results to determine Workability of concrete

Replacements of Palm Kernel Shell. (%)	Height of Slump(mm)	Description
0	40	(35 – 75 mm) Medium
25	53	(35 – 75 mm) Medium
50	57	(35 – 75 mm) Medium
75	61	(35 – 75 mm) Medium
100	65	(35 – 75 mm) Medium

Table 4.8 STATISTICAL ANALYSIS OF RESULT

DENSITY

******* ANALYSIS OF VARIANCE *******

Variate: Density

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
CA_days	3	308088.	102696.	26.99	<.001
%PKSR	4	5577959.	1394490.	366.54	<.001
CA_days.%PKSR	12	150224.	12519.	3.29	0.002
Residual	40	152181.	3805.		
Total	59	6188452.			

******* TABLES OF MEANS *******

Variate: **Density**

Grand mean 1781.6

CA_days	C14	C21	C28	C7
	1737.8	1789.0	1894.4	1705.2

%PKSR	P0	P100	P25	P50	P75
	2366.7	1524.6	1779.8	1658.5	1578.3

CA_days	**%PKSR**	P0	P100	P25	P50	P75
C14		2336.9	1504.0	1683.6	1608.4	1556.0
C21		2406.0	1542.7	1761.7	1643.9	1590.5

C28	2420.0	1561.7	2042.2	1810.0	1638.4
C7	2303.9	1490.2	1631.9	1571.8	1528.5

***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****

	CA_days	%PKSR	CA_days %PKSR
rep.	15	12	3
d.f.	40	40	40
s.e.d.	22.52	25.18	50.36

*** **LEAST SIGNIFICANT DIFFERENCES OF MEANS (5% LEVEL)** ***

	CA_days	**%PKSR**	**CA_days %PKSR**
rep.	15	12	3
d.f.	40	40	40
l.s.d.	45.52	50.89	101.79

***** **STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *******

Variate: Density

d.f.	**s.e.**	**cv%**
40	61.68	3.5

FOOT NOTES: s.s = sum of squares, m.s = mean squares, v.r = variance ratio, F. pr =F probability, d. f = degree of freedom, C. V. = coefficient of variation, SE = Standard Error, s.e.d = standard error of difference between two means, l.s.d = least significant difference, FPROB = F probability, %PKSR=percentage palm kernel shell replacement, CA_days=curing age in days, (P0, P25, P50, P75, P100=percentage replacements of 0,25,50,75,100 respectively)**.** REPL=replacements**.** The double asterisks that the L.S.D value bears shows that the parameter under consideration was significant at 5% (P<0.05)

COMPRESSIVE STRENGTH

***** **ANALYSIS OF VARIANCE** *****

Variate: COMPRESSIVE STRENGTH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
CA_days	3	333.1686	111.0562	529.97	<.001
%PKSR	4	766.2409	191.5602	914.15	<.001
CA_days.%PKSR	12	30.7408	2.5617	12.22	<.001
Residual	40	8.3820	0.2096		
Total	59	1138.5322			

***** **TABLES OF MEANS** *****
Compressive Strength Analysis Of Variance

Variate: COMPRESSIVE STRENGTH

Grand mean 13.426

CA_days	C14	C21	C28	C7
	13.495	14.204	16.261	9.743

%PKSR	P0	P100	P25	P50	P75
	18.812	7.787	14.878	13.160	12.494

CA_days	**%PKSR**	P0	P100	P25	P50	P75

C14	18.973	6.587	15.190	13.700	13.027
C21	19.440	7.947	15.577	14.177	13.880
C28	21.733	12.710	16.633	15.603	14.627
C7	15.100	3.903	12.110	9.160	8.443

*** **STANDARD ERRORS OF DIFFERENCES OF MEANS** ***

	CA_days	**%PKSR**	**CA_days %PKSR**
rep.	15	12	3
d.f.	40	40	40
s.e.d.	0.1672	0.1869	0.3738

*** **LEAST SIGNIFICANT DIFFERENCES OF MEANS (5% LEVEL)** ***

	CA_days	**%PKSR**	**CA_days %PKSR**
rep.	15	12	3
d.f.	40	40	40
l.s.d.	0.3378	0.3777	0.7554

***** **STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION** *****

Variate: **COMPRESSIVE STRENGTH**

d.f.	**s.e.**	**cv%**
40	0.4578	3.4

FOOT NOTES: s.s = sum of squares, m.s = mean squares, v.r = variance ratio, F. pr =F probability, d. f = degree of freedom, C. V. = coefficient of variation, SE = Standard Error, s.e.d = standard error of difference between two means, l.s.d = least significant difference, FPROB = F probability, %PKSR=percentage palm kernel shell replacement, CA_days=curing age in days, (P0, P25, P50, P75, P100=percentage replacements of 0,25,50,75,100 respectively**).**
REPL=replacements**.** The double asterisks that the L.S.D value bears shows that the parameter under consideration was significant at 5% ($P<0.05$)

Effect of Curing Age (days) and Percentage palm kernel shell Replacement on Density (Kg/m^3)

CURING AGE (days)	**DENSITY** (Kg/m^3)
7	1705.2
14	1737.8
21	1789.0
28	1894.4
$LSD_{0.05}$	45.52**
% PKS REPL.	
0	2366.7
25	1779.8
50	1658.5
75	1578.3
100	1524.6
MEAN	1781.6
$LSD_{0.05}$	50.89**
SE	61.68
CV(%)	3.50

Effect of Curing Age (days) by Percentage palm kernel shell replacement interaction on Density (Kg/m^3)

	% PERCENTAGE PALM KERNEL SHELL REPLACEMENT				
CURING AGE	0	25	50	75	100

(DAYS)					
7	2303.9	1631.9	1571.8	1528.5	1490.2
14	2336.9	1683.6	1608.4	1556.0	1504.0
21	2406.0	1761.7	1643.9	1590.5	1542.7
28	2420.0	2042.2	1810.0	1638.4	1561.7
LSD$_{0.05}$					101.79**

Effect of Curing Age (days) and Percentage palm kernel shell replacement on Compressive Strength (N/mm^2)

CURING AGE(DAYS)	COMPRESSIVE STRENGTH(N/mm^2)
7	9.743
14	13.495
21	14.204
28	16.261
LSD$_{0.05}$	0.3378**
% PKS REPL.	
0	18.812
25	14.878
50	13.160
75	12.494
100	7.787
MEAN	13.426
LSD$_{0.05}$	0.3777**
SE	0.4578
CV(%)	3.40

Effect of Curing Age (days) by Percentage palm kernel shell replacement interaction on Compressive Strength (N/mm^2)

% PALM KERNEL SHELL REPLACEMENT					
CURING AGE (DAYS)	0	25	50	75	100

7	15.100	12.110	9.160	8.443	3.903	
14	18.973	15.190	13.700	13.027	6.587	
21	19.440	15.577	14.177	13.880	7.947	
28	21.733	16.633	15.603	14.627	12.710	
$LSD_{0.05}$						0.7554**

Table 4.9 Prices of Materials from the markets in Enugu in Enugu State and Ihiala in Anambra State as at August, 2014.

Material	Price/m^3 (₦)
Crushed Granite	₦3,192:00
Cement	₦ 10,500:00
Sharp Sand	₦ 342:00
Palm Kernel Shell	Free
Total	₦ 14,034:00

4.2 DISCUSSIONS

4.2.1 Specific Gravity

Specific gravity is used in the estimation of voids in aggregates. The results from Table 4.1 show that the specific gravity obtained for the palm kernel shell is 1.30. The high porosity of palm kernel shell may have contributed to the low specific gravity value obtained compared with the specific gravity obtained for the granite aggregate of 2.76, which is considered adequate for normal weight aggregate (Adom-Asamoah & Russell, 2010).The difference in the specific gravities imply that for a given mix design, the palm kernel shell concrete would contain a much higher volume of coarse aggregate than the normal weight concrete, if batching is done by weight.

4.2.2 Bulk density

The bulk density of the aggregates as presented in Table 4.1 show that the sharp sand has a bulk density of 1650kg/m^3,crushed granite 1545Kg/m^3 and 634Kg/m^3 for palm kernel shell. According to ASTM C330 (1999), these values of the bulk densities for sand and gravel lie within the range of bulk densities for normal weight aggregate which is 1450 – 1600 kg/m^3.The palm kernel shell has a bulk density of 634Kg/m^3. The value satisfied the requirement for lightweight aggregate as recommended by ASTM C330 (1999); and the bulk density of the shell fall within the range of lightweight aggregates which varies from 300 to 1100 Kg/m^3 as proposed by Neville (2000). For this reason, palm kernel shell can be classified as lightweight aggregate.

4.2.3 Density

This research focused on specimen cube production with a mix ratio of 1:2:4 and w/c 0.6.The densities of the hardened concrete as presented in Tables 4.5 indicate that the density decreases as the quantity of palm kernel shell increases in each of the curing age. The density of palm kernel shell concrete depends on various factors such as, the specific gravity of palm kernel shell , water cement (w/c) ratio, sand,palm kernel shell contents and water absorption of palm kernel shell (Alengaram *et al.,* 2013).The densities for 7 ,14,21, and 28 days curing for 0 to 100% palm kernel shell content are in the range 2304 to 1490 Kg/m^3 ,2337 to 1504 Kg/m^3 ,2406 to 1543 Kg/m^3 and 2420 to 1562 Kg/m^3 respectively.The percentage increase of density of the palm kernel shell concrete (i.e. 100% palm kernel shell content) when compared to that of the gravel concrete (i.e. 0% palm kernel shell content) is in the average of 35.75% for 7 ,14,21 and 28 days. The density of concrete having up to 25% palm kernel shell content at 28days was above 2000 Kg/m^3 while those ones containing more than 25% palm kernel shell content have densities in the range of 1490 to 1808kg/m^3. The results of the density tests presented in Table 4.5 show an average density of 1763 Kg/m^3 for the palm kernel shell concrete and 2420Kg/m^3 for normal weight concrete at 28days. This results show that palm kernel shell concrete is about 27% lower in density than the normal weight concrete.This is supported by the reports of Alengaran *et al.*, 2010; Olutoge ., 2010;1995 and Okpala (1990) who reported that when palm kernel shell is completely used as coarse aggregate, the density of the palm kernel shell concrete is less by over 20% with reference to normal weight concrete.Consequently, the palm kernel shell concrete produced in this study is a lightweight concrete. The higher specific gravity of granite aggregate in the normal weight concrete resulted in higher concrete density. On the other hand, the lower specific gravity of palm kernel shell contributed to lower density of the palm kernel shell concrete. From Table 4.5, Density reduces with an increase in Palm kernel shell content in the mix. The unit weight of Palm kernel shell, being a lighter material, is lower than the unit weight of natural aggregates mainly from rock fragments. Consequently, an increase in Palm kernel shell content reduces the overall density of the concrete. The highest density reduction was recorded for full replacement at curing age of 28days giving a density of 1562 kg/m^3 .The range for density for structural lightweight concrete is 1440 to 1850 kg/m^3 (ACI Committee 213R-87 ,2003). According to Clarke (1993) the density of palm kernel shell concrete usually falls in the range of 1600-1900 kg/m^3 due to lower density of palm kernel shell. He also reported that for structural lightweight concrete, the density is between 1200 and 2000 kg/m^3. Neville (1995) observed the density of structural lightweight concrete to be between 350 and 1850 kg/m^3.

In another research Alengaram *et al* (2008) reported the density of palm kernel shell concrete to vary in the range of 1700 to 2050 kg/m and that it depends on factors such as type of sand, sand and palm kernel shell contents. The density of 1562 kg/m^3 recorded for full replacement at curing age of 28days fall within the range for structural lightweight concrete and suggests that palm kernel shell can be used as structural lightweight concrete (ASTM C 330. 2004).

4.2.4 Compressive Strength

From Table 4.7, it is observed that the compressive strength of both palm kernel shell and normal weight concretes directly depend on the unit weight of the corresponding concrete, the lower the unit weight of concrete the lower the compressive strength. According to Alengaram *et al* (2013) palm kernel shell can be termed as lightweight aggregate as it has low specific gravity in the range of 1.17-1.6.According to FIP Manual, (1983) some of the codes of practice stipulate minimum strength of lightweight concrete as 15MPa.

It was also observed that the compressive strength increases with curing age. For all the curing ages, the highest strength was obtained from concrete made without palm kernel shell. The amount of paste required is believed to depend on the amount of void spaces to be filled and the total surface of the aggregate to be coated with paste (Mindess, *et al,* 2003).This amount has great influence on both the density and compressive strength of the specimen cubes. According to Alengaram *et al.,* (2013) the compressive strength of concrete depends on density and it is one of the most important variables to consider in the design of concrete structures

The 28days compressive strength values of all the percentage replacements (0, 25, 50, 75 and 100%) with palm kernel shell are 21.73, 16.63, 15.60, 14.63 and12.71N/mm^2 respectively. This shows that the amount and type of coarse aggregate used in the production of concrete has a tremendous influence on the compressive strength of the corresponding concrete. The results show that concrete mix of 1:2:4 for 25, 50, 75 and 100% content of palm kernel shell with compressive strength of 16.63, 15.60, 14.63 and 12.71 N/mm^2 at 28 days hydration period respectively is similar to previous research findings that the compressive strength of palm kernel shell concrete ranges from 5 to 25 N/mm^2 based on mix design by Okafor (1988).Okpala,(1990) reported Compressive strength of palm kernel shell concrete to be 16.50N/mm^2 using a mix ratio of 1:2:4 with water/cement ratio (w/c) 0.6 while Olanipekun *et al* (2005) reported 14.70N/mm^2 using same mix ratio of 1:2:4 and water/cement ratio (w/c) 0.6.

4.2.5 Slump

According to Neville (1995), Slump is the decrease in height of the concrete. It is a measure of displacement of fresh concrete mass from its original position. The displacement occurs under gravity without any disturbing force and its magnitude reduces with a reduction in overall weight of the fresh paste. In this research, increase in palm kernel shell content in the paste progressively reduced the slump. From the result for slump values in Table 4.7, it is observed that slump reduces (the value of the slump increases) with increase of palm kernel shell content in concrete. The increase in value of slump can be attributed to reduction in aggregate content as the percentage of the palm kernel shell content increases since the batching of the concrete was done by volume and not by mass. Less quantity of aggregate was required to be lubricated by the water and hence higher slump value. Palm kernel shell absorbs water from the mix even though it was soaked 45mins before batching. This reduces the amount of water available for hydration leading to a reduction of slump as the cement paste is drier. Palm kernel shell is also lighter than natural aggregate and as a result as palm kernel shell content increases the overall fresh unit weight of concrete reduces. The slump test results shown in Table 4.7 also indicate that the Palm kernel shell concrete has medium good workability. Mehta and Monteiro (2006) suggested that for structural lightweight concrete slump value of 50-75 mm may be sufficient to obtain workability that is similar to a 100-125 mm slump for normal weight concrete. The workability decreases with increase in the percentage replacement of granite by palm kernel shell. This is due to the increase in the specific surface as a result of the increase in the quantity of palm kernel shell, thus requiring more water to make the specimens workable. However, with reference to Table 4.7, the workability of the mix reduced progressively due to the constant water cement ratio of 0.6 that was used.

This is because the same quantity of water was used to batch the concrete with increasing proportions/percentages of palm kernel shell.

4.2.6 Cost Analysis

The cost of producing 1m^{3}of concrete with different percentage replacements of crushed granite with palm kernel shell were comparatively evaluated for 1:2:4 mix. Table 4.9 shows prices of materials as at August, 2014. The analysis was based on existing market prices of the constituent materials in Enugu and Anambra State where palm kernel shell are in abundance. Cost savings of about 5.69 and 11.37% can be made on 1m^3 of 1:2:4 concrete mix using 25 and 50% palm kernel shell respectively.

4.2.7 Sieve Analysis.

The particle size distribution and particle size distribution curves of Sand, Crushed Granite, and Palm kernel shell are presented in Appendices 4 and 5 respectively. Grading of aggregates is done using values from coefficient of curvature and coefficient of uniformity.

Another important factor is Fineness Modulus which is mainly used for sand. According to ASTMC 33,(2003) the sieves used for sand are typically the 0.150 mm (No. 100), 0.300 mm (No. 50), 0.600 mm (No. 30), 1.18 mm (No. 16), 2.36 mm (No. 8), and the 4.75 mm (No. 4) .

Crushed granite and sands may be either poorly graded (Uniformly graded) or well graded depending on the values of coefficient of curvature and uniformity coefficient. Values for Coefficient of curvature (Cc) should lie between 1 and 3 for well grade gravel and sand while the Uniformity coefficient (Cu) should be more than 4 for well graded gravel and more than 6 for well graded sand(ASTMC 33,2003).

The results from Appendix 4and 5 show that the sand used in this research has a Fineness modulus of 2.69, which falls within the range of 2.3 to 3.1 (ASTMC 33, 2003), and also satisfied the requirement of BS EN 12620: 1 (2007) for sand to be used for concrete production. The

Coefficient of uniformity (Cu) of the sand, gravel and Palm kernel shell is 6.0, 1.4 and 1.2, respectively; while their coefficient of curvatures (Cc) are 1.3, 1.6 and 2.0 respectively. From the result, the aggregates can be classified as well graded, based on having Cc value between 1 and 3 in conformity with the requirements of ASTMC 33, (2003). Hence, it is concluded that the sand, gravel and palm kernel shell used for the study are well graded and suitable for making good concrete. From Appendix 5, the S-shaped curve of sand, granite and palm kernel shell also indicates that the aggregates are well graded.

4.2.9 Statistical Analysis of Result

Table 4.8 presents the statistical analysis of the result where the independent variables are Density, Percentage replacement of granite with palm kernel shell and Curing age. The dependent variable is the Compressive strength. The effect of independent variables on the dependent variable as well as their interactions was statistically analyzed using Statistical Analysis Software GenStat Release 7.2 Discovery Edition 10.3(PC/Windows).

The analysis was focused on determining which of the factors considered had significant effect on the compressive strength of the concrete.

From the Density ANOVA table, there are highly significant differences in the effects of Curing Age and % palm kernel shell replacement ($P<0.01$). It also shows highly significant interaction between curing age and % palm kernel shell replacement (P<0.01). Curing at 28days with 0% palm kernel shell replacement gave the highest density (1894.4kg/m^3 for Curing at 28days, 2366.7kg/m^3 for 0% palm kernel shell replacement and 2420.0kg/m^3 for their interaction).

From the Compressive strength ANOVA table, there are also highly significant differences in the effects of curing age, % palm kernel shell replacement and the interaction of both (P<0.01). Similarly, curing at 28days with 0% palm kernel shell replacement gave the highest compressive strength (16.261N/m^2 for Curing at 28days, 18.812N/m^2 for 0% palm kernel shell replacement and 21.733N/m^2 for their interaction).

Note:"Very highly significant" is used when F- Probability is less than 0.001."Highly significant" was used because F-Probability is less than 0.01 as also shown in the ANOVA Variate table for density and compressive strength. Also on the Variate table for density and compressive strength, "F-cal." means calculated P-values, but it is called "F-calculated".

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The results of the research have shown that palm kernel shell concrete has comparable strength properties and structural behaviour to normal weight concrete. However, it can be concluded that the Palm kernel shell concrete showed superior performance compared to normal weight concrete with respect to cracking.100% crushed granite aggregate concrete cracked explosively unlike gradual crack observed with the specimen cubes that had 25 to 100% palm kernel shell content. This could be attributed to the lower density of Palm kernel shell concrete due to its contribution to the reduction in dead load and the better impact- resistant nature of Palm kernel shell aggregate.

Additionally, the density of the Palm kernel shell concrete was found about 27 % lower compared to the normal weight concrete and that is very noteworthy as far as dead load of the structures is concerned in the design and construction of structural elements. Thus, it can be concluded that Palm kernel shell concrete has advantage in both strength and density. The compressive strengths obtained for the Palm kernel shell concrete at 28days curing for 25, 50, 75, and 100% were 16.63, 15.60, 14.62 and 12.71N/mm^2 respectively. Consequently, Palm kernel shell used in this research met compressive strength requirements with reference to previous research findings that the compressive strength of palm kernel shell concrete ranges from 5 to 25 N/mm^2 based on mix design by Okafor (1988), 16.50N/mm^2 according to Okpala,(1990) ,and 14.70N/mm^2 as reported by Olanipekun *et al* (2005) for same mix design of 1:2:4 and water/cement ratio 0.6. Generally, the compressive strength of 13-22 N/mm^2 was reported for Palm kernel shell concrete by many researchers.This research has shown that Concrete strengths increases with curing age and decreases with increasing palm kernel shell content. The research has also revealed that the physical and mechanical properties of the palm kernel shell aggregates are satisfactory for producing structural concrete and has shown as well the aggregate influence on the unit weight and compressive strength of the resultant concrete. Furthermore, the characterization and use of palm kernel shell in the production of concrete indicated that the palm kernel shell met the requirements for use as aggregates in concrete as prescribed by the American Society for Testing of Materials (ASTM) and British Standards Institution (BS). According to ASTMC 33(2003), range of 2.3-3.1 is prescribed for fineness modules for sharp sand.

5.2 RECOMMENDATIONS

Further studies should be conducted with other water cement ratios and mix designs to further evaluate their influences on concrete strength. Subsequent studies on palm kernel shell concrete should allow a curing age of up to 90 days and above. More research is needed to reduce water absorptive nature of palm kernel shell concrete.

There is need to intensify studies to reduce the density of palm kernel shell concrete without compromising strength so as to produce medium and high strength concrete.

5.3 CONTRIBUTION TO KNOWLEDGE

With the information from the results of the compressive strength of percentage replacements of crushed granite with palm kernel shell, structural lightweight concrete made with palm kernel shell can be predicted at 25, 50, and 75% replacement to be adequate for civil construction.

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APPENDICES

APPENDIX 1

Plate 1: Unprocessed palm kernel shell.

Plate 2: Palm kernel shell dried and ready to be put in waterproof sack.

Plate 3: Slump test to determine workability of palm kernel shell concrete

Plate 4: Specimen Cubes in curing tank.

Plate 5: Crushing of specimen cubes to determine compressive strength.

APPENDIX 2

Mix proportions of concrete specimens

Palm kernel shell Replacement (%)	Cement (cm^3)	Sand (cm^3)	Crushed Granite (cm^3)	Palm kernel shell (cm^3)	Water (cm^3)
0	2389	4778	9556	0	1433
25	2389	4778	2389	7167	1433
50	2389	4778	4778	4778	1433
75	2389	4778	7167	2389	1433
100	2389	4778	0	9556	1433

APPENDIX 3

Identification Labels for Specimen Cubes

S/No	Label	Crushed Granite Replacement (%)	Palm kernel shell Replacement (%)	Description
1	7A0	100	0	Cubes to cure for 7days
2	7A25	75	25	Cubes to cure for 7days
3	7A50	50	50	Cubes to cure for 7days
4	7A75	25	75	Cubes to cure for 7days
5	7A100	0	100	Cubes to cure for 7days
6	14B0	100	0	Cubes to cure for 14days
7	14B25	75	25	Cubes to cure for 14days
8	14B50	50	50	Cubes to cure for 14days
9	14B75	25	75	Cubes to cure for 14days
10	14B100	0	100	Cubes to cure for 14days

11	21C0	100	0	Cubes to cure for 21days
12	21C25	75	25	Cubes to cure for 21days
13	21C50	50	50	Cubes to cure for 21days
14	21C75	25	75	Cubes to cure for 21days
15	21C100	0	100	Cubes to cure for 21days
16	28D0	100	0	Cubes to cure for 28days
17	28D25	75	25	Cubes to cure for 28days
18	28D50	50	50	Cubes to cure for 28days
19	28D75	25	75	Cubes to cure for 28days
20	28D100	0	100	Cubes to cure for 28days

APPENDIX 4

Particles Size Distribution of the Fine Aggregate (Sharp Sand)

Sieve Sizes(mm)	Mass retained (g)	% Mass retained	%Cumulative Mass retained	% Mass Passing(g)
4.75	17	1.7	1.7	98.3
2.36	49	4.9	6.6	93.4
1.18	151	15.1	21.7	78.3
0.600	403	40.3	62	38.0
0.420	136	13.6	75.6	24.4

0.300	89	8.9	84.5	15.5
0.210	42	4.2	88.7	11.3
0.150	35	3.5	92.2	7.8
0.075	11	1.1	93.3	6.7
Pan	67	6.7	100	

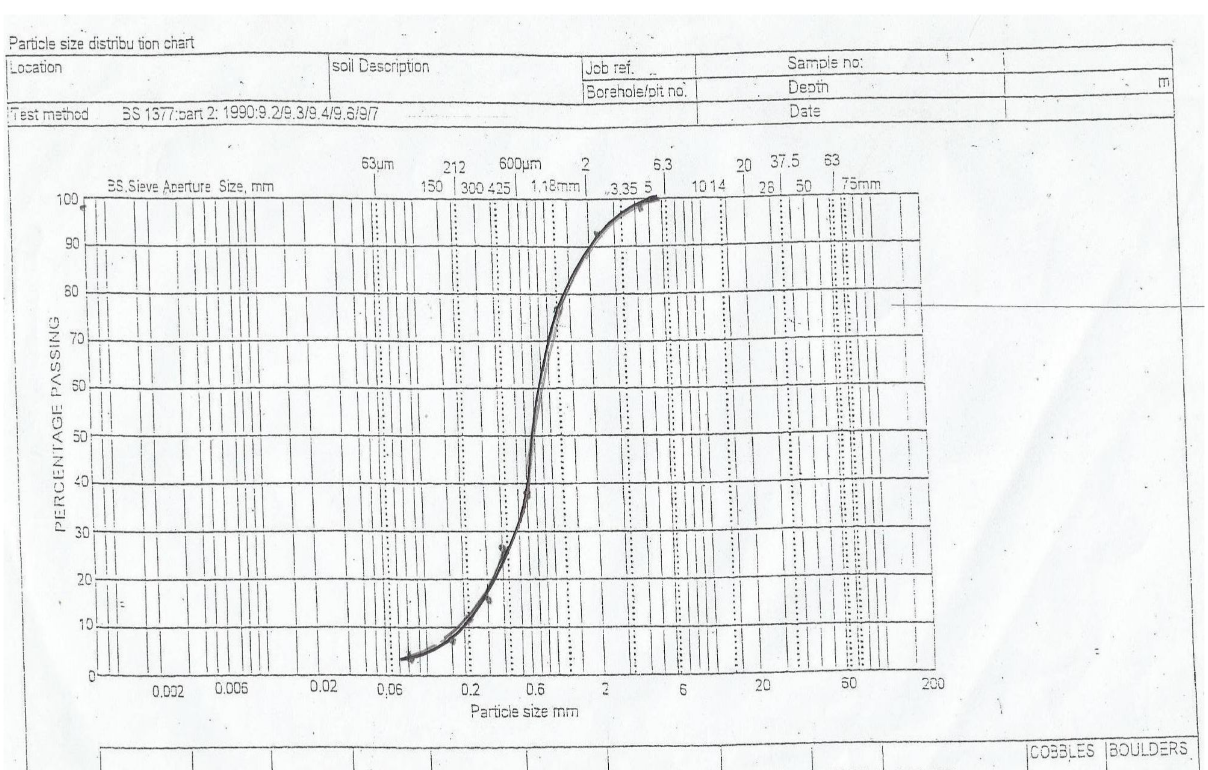
Particle Size Distribution of Coarse Aggregate (Crushed Granite)

Sieve Sizes(mm)	Mass retained (g)	% Mass retained	%Cumulative Mass retained	% Mass passing(g)
26.5	174	17.4	17.4	82.6
19.0	497	49.7	67.1	32.9
13.0	257	25.7	92.8	7.2
6.3	64	6.4	99.2	0.8
5.6	0	0	99.2	0.8
4.75	0	0	99.2	0.8
2.36	0	0	99.2	0.8
Pan	8	0.8	100	

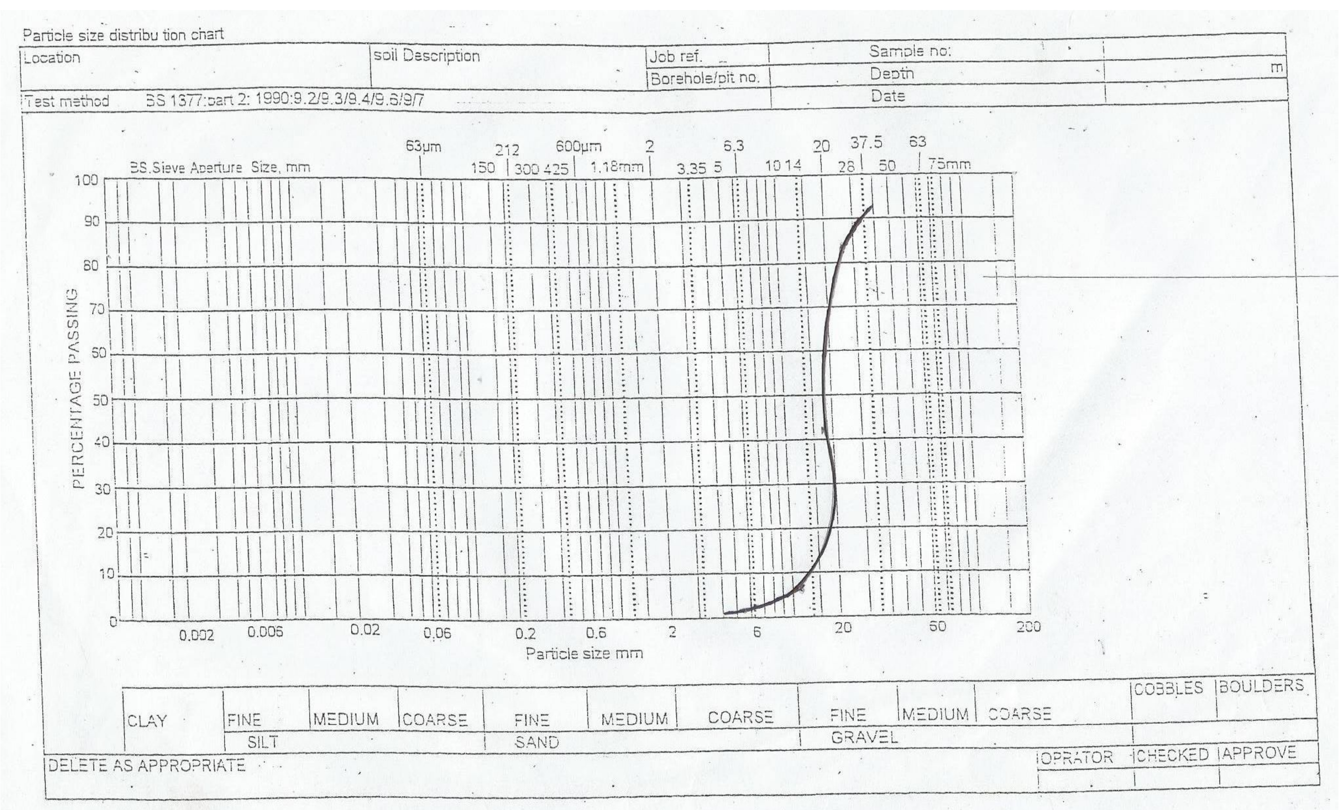
Particle Size Distribution of Palm Kernel Shell

Sieve Sizes(mm)	Mass retained (g)	% Mass retained	Cumulative Mass retained	% Mass passing(g)
26.5	0	0	0	100
19.0	0	0	0	100
13.0	29	2.9	2.9	97.1
6.3	868	86.8	89.7	10.3
5.6	37	3.7	93.4	6.6
4.75	29	2.9	96.3	3.7
2.36	19	1.9	98.2	1.8
Pan	18	1.8	100	

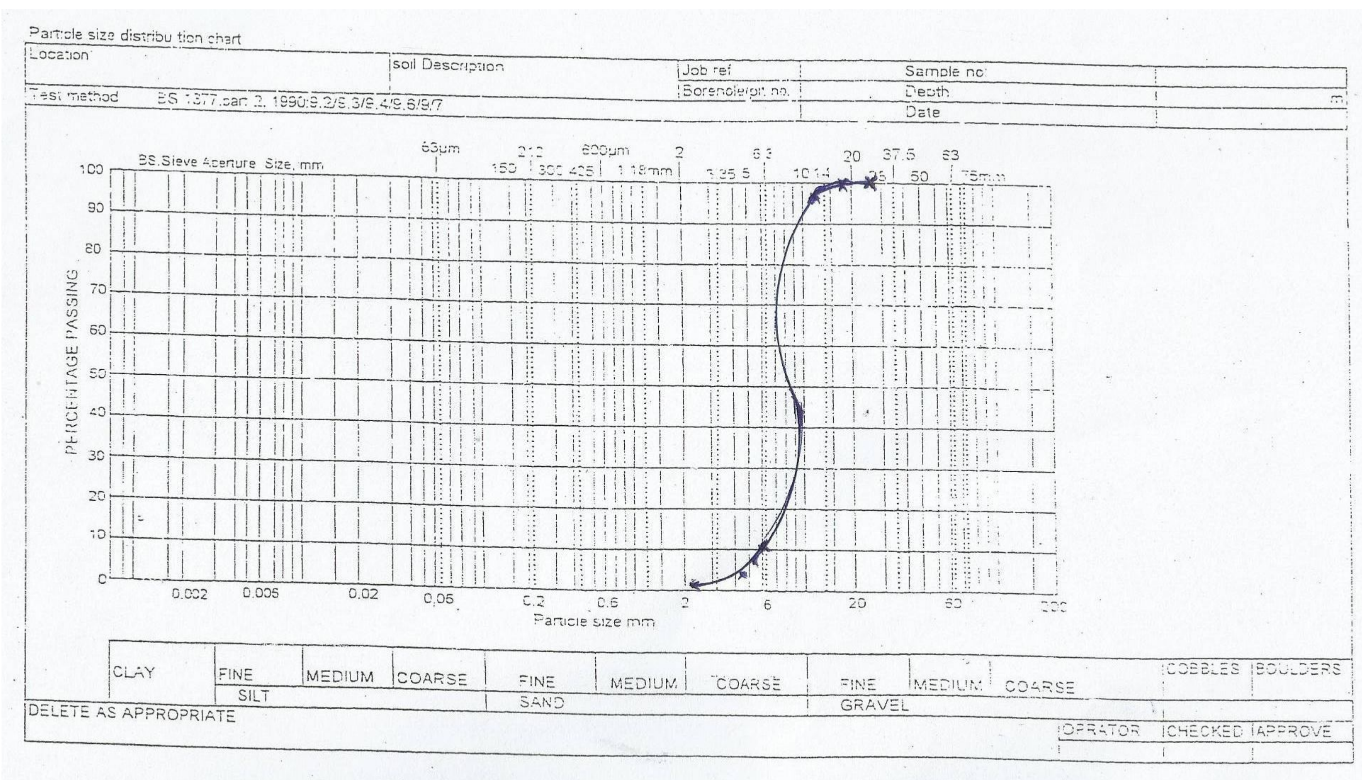
APPENDIX 5



Graph of particle size distribution of Fine Aggregate (Sharp Sand).



Graph of particle size distribution of Coarse Aggregate (Crushed Granite).



Graph of particle size distribution of Palm Kernel Shell.

Graph of particle size distribution of Palm Kernel shell

APPENDIX 6

Cost Evaluation per cubic meter of concrete

Conversion of m^3 to volume ratio is given by

(Volume × 0.45) + Volume***

Where, 0.45 is a conversion constant.

Volume represents volume of concrete and in this case would be $1m^3$.

For a mix design of 1:2:4, a total of 7 represents all the composite aggregates including cement i.e. (1+2+4=7).

Going by equation 3.8 we have (1

For cement,

= 1.45

$\frac{(1.45\times1\times1)}{(1\times7\times0.035)}$
=5.918 = 6bags of cement.

6bags of cement is required to produce $1m^3$ of 1:2:4 mix design of concrete.

(Where $0.035m^3$ is the standard volume of cement in a cubic meter of 1:2:4 mix design).

6bags @ N1, 750:00 =N10, 500:00

Using same equation 3.8

For Sharp Sand,

Where, $3.82m^3$ = 10ton truck volume.

$0.109m^3$ =

= 0.0285 of truck @N12, 000:00

N342:00

For Crushed Granite,

Where, $3.82m^3$ = 10ton truck volume.

$0.217m^3$ =

= 0.057 of truck @N56, 000:00

N3, 192:00

A replacement of 25 and 50% of Crushed Granite with palm kernel shell will bring the total cost of concrete production to N13, 236:00/m^3 and N12, 438:00/m^3 which will amount to a percentage cost reduction of 5.69% and 11.37% respectively.

Note: Equation *** is empirical and used in civil engineering construction practice for calculating quantities of inputs for concrete production.