International Journal of Environmental Studies and Safety Research
ISSN: 2536-7277 (Print) : 2536-7285 (Online)
Volume 3, Number 3, September 2018
http://www.casirmediapublishing.com

EVALUATION OF KERNEL SHELL AS CONSTRUCTION MATERIALS FOR LOW COST HOUSES

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ABSTRACT

The major construction material that cost more are cement and gravel which makes buildings costly. Palm kernel shells are locally available materials which can be used in place of gravel. Previous works on the kernel shell shows that the strength determined have met with the building requirements. Concrete is the most common material used in construction, various research work and experience gained shows that the quality and durability of concrete depend mostly on the properties of its constituent, mix design, method of preparation, curing etc. have their influence on it. Tests results have shown that kernel shell concrete of mix ratio 1:2:4 has average compressive strength of 5.6 N/mm2 at 14days curing while 12.47 N/mm2 at 28days of curing. Palm kernel shell produces a concrete with a lower compressive strength in comparison with normal concrete with gravel.The project in conclusion was a success as it took into consideration the economic status quo of the population. This project help to provide new materials affordable for the low income earners which helps in producing low cost houses and this does not remove the criteria of performance for a material

Keywords: *Evaluation, kernel shells, construction materials, low cost Houses*

INTRODUCTION

In construction site the use of gravel, sand, steel, and other materials are available for successful construction of building houses. The use of these materials put together with understanding of their nature has produced many satisfactory solutions to structural design problems throughout the years. (Owolabi, 1995).Concrete is the most diverse construction material and the effort of infrastructural development of any nation (O. S. Olafusi, F. A. Olutoge, 2012). Concrete is a composite inert material comprising of a binder course (e.g. cement), mineral filler (body) or aggregates and water (V. O. Oyenuga, 2001). Concrete is one of the oldest manufactured construction materials used in construction of various structures around the world. The cost of concrete and other construction materials in Nigeria is currently so high that the majority of individuals find it difficult to afford, with the exception of Government, Industrial and Business Corporations. Concrete is a construction material made by mixing cement, fine aggregate, coarse aggregate, water and admixture where necessary in designed or prescribed proportions. It is usually used in construction works for concreting due to its strength, durability and other properties. Over the years, attention has been mainly focused on the use of gravel or granite as coarse aggregates in concrete. Blocks are strong, dense construction materials made from well-graded natural aggregate, sand and cement. Generally, blocks are classified as load bearing (external walls) for carrying structural loads and non-bearing for interior partitions. The ever increasing demand for these materials in the construction industry coupled with their high production cost has drastically caused increase in their cost and has made owing building unaffordable to many.

This has provided designers and planners with new materials and product with which challenges and requirements of the builders are met. The need for low-cost good quality and readily accessible building materials with adequate strength have led to the technological development of some locally available materials which are abundant in the country and which could be used as alternatives to the expensive conventional materials (D.O Oluyomi Ayidiowu, 2007). Production of concrete depend on the large amount of the availability of cement, sand and coarse aggregates such as granite, the costs of which have risen much over the past few years. Despite the rising cost of production, the demand for concrete is increasing. The undesirable consequences of the increasing demand for concrete include depletion of aggregate deposits; environmental degradation and ecological imbalance (Short & Kinniburg, 1978). The possibility of complete reduction of aggregates resources in the near future can therefore not be over emphasized. Palm Kernel Shells have lightweights and are porous in nature; they have a density of about 1030kg/m3. The nuts are crushed manually by hand or by mechanical means. Most of the times they are set aside as waste or used as fuels and materials for filling potholes in the palm oil producing areas such as Okitipupa, Ode-Aye farm settlement, Araromi-Obu rubber and palm plantation, all in Ondo State, Nigeria Institute for Oil Palm Research (NIFOR) in Edo State and in other towns and villages especially in the southern part of Nigeria (Owolabi, 2001). Many varieties of kernel shells exist depending on the thickness of the shells and fibrous parts. The varieties are classified as Dura (which has a very thick shell and thin fibrous oily parts), Pisifera (where the shells are absent or thin), Tenera (those with medium fibrous and shell thickness). (Ndegwe, 1987).

Palm Kernel Shell (PKS) is a waste material obtained during the crushing of palm nuts in the palm oil mills for palm oil extraction. In South East Asia, it is one of the most quantitative waste materials produced. Malaysia produces about 4 million tons of kernel shells yearly. Hence, using kernel shells would enforce lower construction costs compared to other waste materials like rubber crump, plastic waste, and others. With proper mix design, kernel shells can be used to develop normal strength concrete, which ranges from 20 to 30MPa. Research has been conducted on PKS as lightweight aggregate to produce lightweight concrete since 1984 which brought immense changes in the concrete industry. It was discovered by Imam et. al (2014) that palm nut shell can be used as construction material in low cost buildings since it has attained a compressive strength of 18N/mm2. This can indirectly facilitate in waste reduction (Zarinaltam, SalmiaBeddu, NurLiyana, Mohd Kamal, MdAshrafulAlam, UsamaIssaAyash, 2016). Ndoke (2006) investigated the suitability of palm kernel shells as partial replacement for coarse aggregates in asphaltic concrete. Olutoge (2010) investigated the suitability of sawdust and palm kernel shells as replacement for fine and coarse aggregate in the production of reinforced concrete slabs. He concluded that 25% sawdust and palm kernel replacement reduced the cost of concrete production by 7.45%. He also indicated the possibility of partially replacing sand and granite with sawdust and palm kernel shell in the production of lightweight concrete slabs.

AIM AND OBJECTIVES

The aim of this project is to evaluate the use of kernel shells as construction materials for low cost houses.

OBJECTIVES

1. To compare the strength of coarse aggregate concrete and kernel shell concrete and their compressive strength determined in the laboratory.
2. To reduce the cost of concreting in building works.
3. To show the cost effectiveness of using kernel shells.
4. To study the effect of replacing natural aggregate with kernel shells on weight of concrete and find the optimum replacement of natural aggregate with kernel shells.

SCOPE OF STUDY

The study is limited to the following;

1. To develop a suitable mix design of concrete with kernel shell as aggregate.
2. To determine the compressive strength of the concrete using compressive strength testing machine
3. To determine the crushing strength
4. To determine the workability of the concrete by concrete slump test
5. To determine the workability of concrete mix of given proportions by compaction factor test.

THEORETICAL FRAMEWORK

The construction industry depends greatly on conventional materials such as cement, granite and sand for the production of concrete. The high and increasing cost of these materials has greatly delayed the development of shelter and other infrastructural facilities in developing countries. There arises the requirement for engineering consideration of the use of low-cost and locally available materials to reduce the construction cost for sustainable development (Usman *et al.,* 2012).Historically, agricultural and industrial wastes have created waste management and pollution problems. However, the use of agricultural and industrial wastes to complement other traditional materials in construction provides both practical and economic advantages.

The wastes generally have no commercial importance and being locally available, transportation cost is minimal (Chandra and Berntsson, 2002). Agricultural wastes have advantages over conventional materials in low cost construction. The use of waste materials in construction contributes to conservation of natural resources and the protection of the environment (Osei and Jackson, 2012). The palm oil industry and rice mills produce wastes such as palm kernel shells, palm oil fibres and rice husk respectively which are usually dumped in the open thereby impacting the environment negatively with no economic benefits.

CONCRETE

Concrete is an artificial material comparable in appearance and properties to some natural lime stone rock. It is a man-made composite, the major constituent being natural aggregate such as gravel, or crushed rock, sand and fine particles of cement powder all mixed with water. The concrete as time goes on through a process of hydration of the cement paste, producing a required strength to endure the load (Maninder and Manpreet, 2012). Concrete is defined in student Encarta as a mixture of sand, cement, aggregate and water in specific proportions that hardens to a strong stony consistency over varying length of time. The aggregate in this context refers to rock particles of size above 5mm2. American concrete institute also sees concrete as an engineering material made from a mixture of Portland cement, water, fine and coarse aggregate and small amount of air. Olanipekun (2006) defines concrete as a composite material consisting of a binding medium within which the particles are embedded. Other scholars also define concrete as a combination of aggregates and a paste composed of a Portland cement and water. The aggregate refer to sand and gravels or crushed stones (Mannan and Ganapathy, 2002). Concrete is a widely used construction material in civil engineering projects throughout the world for the following reasons: It has great resistance to water, structural concrete elements can be formed into a variety of shapes and sizes and it is usually the cheapest and most readily available material for the job (Olanipekun, 2006).

HISTORY OF CONCRETE

The first major concrete users were the Egyptians in around 2,500BC and the Romans from 300BC the Romans found that by mixing a pink sand like material which they obtained from Pozzuoli with their normal lime-based concretes they obtained a stronger material. The pink sand turned out to be fine volcanic ash and they had unintentionally produced the first pozzolanic cement. Pozzolanic is any siliceous and aluminous material which possesses little or no cementitious value 8in itself but will, if finely divided and mixed with water, chemically react with calcium hydroxide to form compounds with cementitious properties (http://www.bushywood.com/concrete.htm).

COMPONENTS OF CONCRETE

Cement

The most generally used cement is ordinary Portland cement (OPC), but other additional materials such as pozzolana, silica fume and fly ash can also be included as long as their acceptance has been proven. The manufacture of Portland cement consists of ingredients mainly lime, silica, alumina and iron oxide from limestone and clay/shale which react together on firing to form a series of more complex products. The relative proportions of these oxide compositions are responsible for influencing the various properties of particular cements; in addition to the rate of cooling and fineness of grading which affects the strength of the cement. In many structural applications, the choice of cement has a lesser influence on the long-term performance of concrete than the practical aspects of mix control, cement content, water content, aggregate quality, and compaction, finishing and curing (Newman and Choo, 2003).

(BS EN 197-1, 2000) classifies cements into five main types depending on its constituents. Which are?

- Portland cement.
- Portland composite cement.
- Blast furnace cement.
- Pozzolanic cement.
- Composite cement.

CHEMICAL COMPOUNDS OF CEMENT

Four main compounds are considered as the major constituents of cement and these compounds are presented in Table 2.1. The composition of Portland cement is based on the 'Bogue composition' which are given in the equations below.

$$C_3S = 4.07(CaO) - 7.60(SiO_2) - 6.72(Al_2O_3) - 1.43(Fe_2O_3) - 2.85(SO_3)$$

$$C_2S = 2.87(SiO_2) - 0.754(3CaO.SiO_2)$$

$$C_3A = 2.65(Al_2O_3) - 1.69(Fe_2O_3)$$

$$C_4AF = 3.04(Fe_2O_3)$$

Table 2.1 Compound composition and its contribution to hydration of Portland cement

Chemical formula	Shorthand notation	Weight percent	Reaction rate	Contribution to strength
$3CaO.SiO_2$	C_3S	50	Moderate	High
$2CaO.SiO_2$	C_2S	25	Slow	Low initially and high later
$3CaO.Al_2O_3$	C_3A	12	Fast	Low
$4CaO.Al_2O_3.Fe_2O_3$	C_4AF	08	Moderate	Low

Source: Nawy, 2008; Neville and Brooks, 2008

It is seen that the major products of the hydration reactions, which primarily account for the strength of concrete, are the calcium silicate hydrates (C_3S and C_2S) that make up most of the hydrated cement (Nawy, 2008). These silicates are the most vital compounds responsible for the strength of hydrated cement paste and are formed from the reactions between the two calcium silicates and water. 10

Water

In general, potable water is safe for use in concrete. Water containing harmful substances such as salts, silts, suspended particles, organic matter, oil, or sugar can unfavorably affect the strength and setting properties of cement and disturb the affinity between aggregate and cement paste (Nawy, 2008). Therefore, the suitability of water should be examined before use. As a rule, any water with silt content below 2000 mg/L is suitable for use in concrete (Shetty, 2005).

Coarse Aggregate

Aggregates were originally viewed by Troxell *et al.* (1968) as being inert and dispersed all through the cement paste in concrete, largely due to economic reasons, that is, as a fill material.
Studies have shown that fine and coarse aggregates are very important in concrete because aggregates occupy 60% to 75% of the concrete volume and strongly influence the concrete's freshly mixed and hardened properties, mix proportions, and economy (Quiroga and Fowler, 2004).
The vital requirement of an aggregate for concrete is that it remains constant within the concrete (both in the fresh and hardened states) and in any given environment, throughout the design life span of the concrete (Smith and Collis, 2001). Coarse aggregates are materials retained on 5mm (3/16 inches) test sieve and containing only so much finer material as allowed from the various sizes.

Table 2.2: Type of Coarse Aggregate and Source

Types	**Source**
Uncrushed gravel	From natural disintegration of rock
Crushed stone	From crushing of gravel or hard stone
Partially crushed gravel	Product of the blending uncrushed and crushed gravel

Source: Suryakanta, P. (2014) How to store aggregate on site available at http://civilblog.org/category/construction-materials/aggregate/ (assessed 16/09/2015) Table 2.3 shows the different type of coarse aggregate and their source which all of the fine aggregate are from rock. According to Suryakanta, (2014), commonly, fine aggregate passed 12 4.75mm sieve and contains only so much coarser as is permitted by specification. Normally, river sand and crushed sandstone with fineness modulus of 1.78 were passed through a 2.36 mm sieve analysis. Commonly, materials used are having maximum particle size with 2.36 mm diameter.

PROPERTIES OF AGGREGATE

Aggregate possess certain properties, which directly influences the strength of concrete. Some of these properties cannot be measured qualitatively and some indirect measures are taken sometimes. The main properties of aggregates, which may influence the concrete properties, are:

- Shape
- Texture
- Size gradation
- Moisture content
- Specific gravity
- Bulk unit weight
- Strength of aggregate
- Soundness
- Wear resistance
- Alkali-aggregate reaction
- Impurities
- Unsound particles

CURING PROCESS

Curing is the name given to the procedures used for promoting the hydration of the cement, and consists of a control of temperature and of moisture movement from and into the concrete. Curing allows continuous hydration of cement and subsequently continuous increase in the strength, once curing stops strength increase of the concrete also stops. Proper moisture conditions are critical because the hydration of the cement virtually stops when the relative humidity within the capillaries drops below 80%. With insufficient water, the hydration will not continue and the resulting concrete may not possess the necessary strength and impermeability. The continuous pore structure formed on the near surface may allow the entrance of harmful agents and would cause various durability problems. Moreover due to early drying of the concrete micro-cracks or shrinkage cracks would develop on surface of the concrete. When concrete is exposed to the environment, evaporation of water takes place and loss of moisture will reduce the initial water cement ratio which will result in the partial hydration of the cement and hence lowering the quality of the concrete. Various factors such as wind velocity, relative humidity, atmospheric temperature, water cement ratio of the mix and type of the cement used in the mix will affect the curing of concrete. Evaporation in the initial stage leads to plastic shrinkage cracking and at the final stage of setting it leads to drying shrinkage cracking (Yash Nahata et al., 2013). Curing of the concrete is also governed by the moist-curing period, longer the moist-curing period, higher the strength of the concrete assuming that the hydration of the cement particles will go on. Curing has a strong effect on the properties of hardened concrete; appropriate curing will increase the durability, strength, volume stability, abrasion, resistance, impermeability and resistance to freezing and thawing (Yash Nahata *et al.* 2013).According to Yash Nahata *et al.* (2013), there are three method of curing which includes; air curing, water curing and saturated wet covering. Air curing is a curing method where the concrete cubes are left in open air to be cured at room temperature. Water curing is a curing method where the concrete cubes were cured in water tank at room temperature. Saturated wet covering is a curing method where moisture retaining fabrics such as burlap cotton mats, gunny bag and rugs are used as wet covering to keep the concrete in a wet condition during the curing period.

PROPERTIES OF FRESH CONCRETE USING KERNEL SHELLS

As the result of crushing during extracting the oil from the palm nut, the hard palm oil shells are received as crushed pieces. A lot of fine particles were produced; therefore, the sieving process will be needed to remove the large amount of fine particles. After the sieving process, the shells are then air-dried before use in concrete mixing. (A.A.A., A. 1997). Since the palm oil shells are lighter than the cement matrix, it tends to segregate in the wet concrete mixes. Trial mixes are normally necessary to achieve a good mix design. The workability of freshly mixed concrete depends on the mix proportions, the materials and environmental conditions. The aggregate normally occupy about 70% of the total volume of the concrete. The total specific areas of the aggregate are minimized by proper selection of the size, proportion of the fine and coarse aggregate, and the shape of aggregates. The surface texture and the shape of aggregates affect the void content and the water requirement of the concrete mixing. The fineness modulus of aggregate is a numerical index of the fineness which indicates the mean size of that aggregate. The fineness modulus of aggregate is a prime indication in obtaining the required strength and workability which can give the most economic mix design. (Mannan, M.A., G.C., 2004). 15 The workability of fresh concrete and bonds between the mortar phase and the aggregate are influenced by the physical characteristic of the aggregate such as the roughness, texture and shapes. The surface texture of the aggregate can be smooth or rough; whereas the surface can be glassy, smooth, granular, rough, crystalline, and porous. (M.L., G., 2000). The roughness and the porosity of the surface of the aggregate affect the development of the bond. The porous surface of the aggregate can improve the development of bond by the suction of the paste into its pores. (Mannan, M.A., G.C., 2004). A study was done by a group of researchers on the workability of fresh concrete with palm oil shells as aggregates. The results showed that the POS concrete has better workability than that of the normal concrete. In the same water cement ratio, the smooth surface of the palm oil shells may has led to a better workability, slump and compaction factor when compared with the normal concrete. (Mannan, M.A., G.C., 2004).

This similar trends also being reported that the presence of palm kernel shell as aggregate can lead to better workability for a same water-cement ratio.(FO., O., 1988).However as the percentage of the POS replacement increase, the slump of the concrete will decrease. This may due to the higher shells content combined with the irregular and angular shapes of the shells lead to poor workability. Lower workability might also due to the friction of the angular shapes between the shells and lower fines content. (Alengaram, U.J., J.M.Z., Mahmud H.). Besides, the porosity of the shells can influence the workability. The higher the porosity of the shells, the absorption capacity will be higher, which consequently reduces the workability. The lower compacting values of the shells indicate that less work is done on the shell concrete by gravity. This may due to the lower density of the shell aggregate when compared with granite aggregate. (D.C., O., 1990). 16

PROPERTIES OF HARDENED CONCRETE USING KERNEL SHELLS

Compressive Strength

The proportion of the palm oil shells and the water cement ratio normally affect the workability and the compressive strength of the concrete with palm oil shells as aggregate. The 28 day cube compressive strength of the concrete are found to be vary in the range of 5.0 to 19.5 N/mm2. (A.A.A., A., 1997). The compressive strength of concrete with kernel shells was found continue to increase with age. This shows that the kernel shells do not undergo any degradation after mixed with the concrete matrix. Besides, study was done by other researchers that the compressive strength of the kernel shells concrete at 28 day was higher than the minimum required strength of 17 MPa as required by ACI 318 (1995) for structural purposes. (Teo, D. C. L., L.Y.F.). Even though the compressive strength of the kernel shells concrete continues to develop with age, but still remained below that of the normal concrete. The development of the compressive strength of POS concrete was about 49-55% lower compared with the normal concrete. (Mannan, M.A., G.C., 2004). Although the kernel shell aggregate is a type of organic material, but study was done by other researchers showing that the biological decay was not evident as the concrete cubes gained strength even after 6 months. (Teo, D.C.L., M.M.A., Kurian V.J., 2006).

Flexural Strength

Reinforced concrete beam made from palm oil shells are found to be exhibited satisfactory in structural behavior. With a lightweight concrete mix of 1:1.5:0.5/0.5 cement, sand, palm kernel shells and water-to-cement ratio, a 28 day cube compressive strength are found about 17.5 N/mm2. (A.A.A., A., 1997).Study done by other researchers has shown that the 28 day flexural strength of kernel shell concrete was about 14% to 17% of the compressive strength whereas for normal concrete, the flexural strength is about 13% to 15%. This shows that the behavior of the kernel shell concrete is similar with the normal concrete. (Mannan, M.A., G.C., 2002). However, the flexural strength of concrete with kernel shell is weak in resisting bending stress compared with the normal concrete. (Teo, D. C. L., L.Y.F.). These flexural strength values obtained still fall within the normal range of the conventional concretes, in which the flexural strength is about 10 to 23% of its compressive strength. (S., S., 1995).The flexural strength of concrete depends on physical strength of coarse aggregate to some extent, just like compressive strength. (Mannan, M.A., G.C., 2002). Besides, the flexural strength is influenced by the diffused moisture distribution in the test samples significantly. (Short A., K.W., 1978). As the density decrease, the flexural strength also decrease. (D.C., O., 1990).

CREEP

A load equivalent to a stress of 6.0 N/mm2 are applied on three 150 mm diameter cylinders made from lightweight concrete with palm kernel shell as aggregates in order to perform the creep test according to ASTM. The strain obtained by deducting the initial reading from the final reading immediately after loading. The readings were taken after six hours, then daily for one week, weekly for one month and monthly for nine months. Strain readings of the control sample were taken at the same time schedule. The total strains then divided by the average stress giving the total strain per unit stress. This total strain per unit stress then plotted. The results show that the creep curve for the lightweight concrete with palm oil shells shows a large creep compared with the ordinary 18 concrete. The creep rate for lightweight concrete using palm oil shells did not show a constant value after 3 months, and this property will be concerned when used as structural lightweight concrete. (A.A.A., A., 1997).

DRYING SHRINKAGE

Generally, all the cement products undergo volume changes which are small in values with response to the changes in moisture conditions. Although the volume changes are small, but the effects are considerably important. When a fresh concrete dried, it undergoes shrinkage which is termed as initial drying shrinkage. After that, the concrete will subsequently experience the alternative wetting and drying showing the alternative expansion and contraction which termed as reversible moisture movement. The reversible moisture expansion in lightweight concrete with response to the change in moisture condition is found that more often than but not as great as the initial drying shrinkage. Recent study shows that not only the cement undergo the shrinkage, but a few natural aggregate have shown marked shrinkage that contribute the total shrinkage of the concrete. (Andrew Short, W.K. 1962)

The shrinkage of concrete is about 50% greater than the normal weight concrete. Besides, concrete with the aggregate having opened textured and irregular surface can produce shrinkage of about 1000 micro strain. (Short A., K.W 1978). Tensile stress can be set up in the concrete as the result of drying shrinkage, especially it is restrained. If the shrinkage stress exceeds the tensile strength of the concrete, crack will occurred. (Andrew Short, W.K., 1962). Study was conducted by researchers to study the drying shrinkage of the kernel shell concrete. It was found that the kernel shell concrete experienced more shrinkage of about 14% higher than the normal weight concrete. Shrinkage can be due to the loss of free water in concrete mixture, the settlement of solids, drying of concrete and chemical reaction of the cement paste. (Mannan, M.A., G.C 2002). This drying shrinkage is a long lasting process when the concrete exposed to dry condition, same as the hydration process. There are some factors which govern the drying shrinkage of the lightweight concrete such as the water-cement ratio, curing temperature, moisture content, admixture, aggregate characteristic (with the stiffness, content and volume/surface ratio), relative humidity, and the rate and duration of drying. (Mindess S, Y.J., 1981) (A. M., B., 1995).

SOUND ABSORPTION

Sound absorption was measured through the noise reduction coefficient. The sound absorption coefficient was measured at frequencies of 250, 500, 1000 and 2000 Hz which used in U.S.A moderately some time. (A.S.T.M, 1997).A study was conducted by researchers' shows that the normal weight concrete have a noise reduction coefficient of about 0.02. (F.Y., L., 1975).For the concrete with shell as aggregates, the noise reduction coefficient is about 0.34 for water-cement ratio of 0.5. This shows that the shell concrete which is lightweight concrete has better sound absorption capacity than the normal weight concrete. (D.C., O., 1990).If the water-cement ratio increases, the noise reduction coefficient increased. This may due to the increasing in the water-cement ratio that will cause the porosity of the concrete increase as well. This enable the shell concrete as a porous material act as a good sound absorbent. When sound energy pass through the shell concrete, part of the energy is used up in exciting the air that held in the discrete pores within the structure. 20 Hence, as the porosity increase, more pores will present and this would probably increase the absorption capacity. The sound absorption capacity of shell concrete can be used as sound proofing in some purposes. (D.C., O., 1990)

THERMAL CONDUCTIVITY

A study was conducted to obtain the thermal conductivity of shell concrete which have a value of 0.45 Wm-10C-1, whereas for the shell aggregate, the thermal conductivity is 0.19 Wm-10C-1. These values shows that both the concrete shell and shell aggregate have low thermal conductivity. Hence, the material can be considered as a poor conductor of heat. The thermal conductivity value obtained for the shell concrete were higher when compared with the shell aggregate due to the shell concrete have other constituents such as the fine aggregates, cement or hydration product. These imply that these constituents conduct heat more than the shell aggregate. (D.C., O., 1990)

PALM KERNEL SHELL

Palm kernel shells are derived from the oil palm tree (elaeisguineensis), an economically valuable tree, and native to western Africa and are common throughout the tropics (Omange, 2001). They are used in commercial agriculture in the production of palm oil. The African oil palm (elaeisguineensisis) native to West Africa, occurring between Angola and Gambia. The generic name is derived from the Greek word for oil, (elaion) while the species name has referred to its country of origin (Sulyman and Junaid, 1990). In Nigeria, about 1.5 million tons of Palm Kernel Shells (PKS) are produced annually; most of which are often dumped as waste products (Nuhu-Koko, 1990). The waste could be converted to wealth by using it in the production of asphaltic concrete. Some years ago, the use of local materials in the construction industry has been campaigned by the Nigerian government to limit costs of construction (Mohammed, 2014). There has been a greater call for the findings and development of alternative, agro-based and, non-conventional local construction materials in view to connect the maximum potential of agricultural waste in agricultural sector. Palm oil shells are one of the naturally occurring raw materials and obtained as a byproduct when palm oil is extracted from the palm nuts. The palm oil tree, which the palm oil shell is extracted from, is a type of wet tropical tree, which found mostly around the equatorial zone. (D.C., O., 1990).The agricultural waste as aggregates can be used as an alternative to conventional construction material in producing the aggregate concrete. These agricultural wastes are produced in a large quantity from the palm oil mills and can be used as aggregates in producing lightweight concrete. These agricultural wastes also can be used in production of cementitious materials, its fibers can be used in particle boards or sheets and its shell can be used as aggregates. (A.A.A., A., 1997).IThe material properties and structural performance of lightweight concrete made from palm oil shell are found to be similar with the lightweight concrete made from common aggregates such as clinker, foamed slag, and expanded clay. The palm oil shells are hard and crushed as a result of the process of extracting the oil. Sieving is needed in order to remove the fine particles. After sieving, the shells are air-dried before used in concrete mixing. (Satish Chandra, L.B.)

THE PALM OIL

Elaeisguineensis which is generally known as oil palm is an important species in the genus Elaeis which belongs to the Palmae family. The second species which is

Elaeisoleifera (H.B.K) Cortes is found in the south and central of America, and generally known as American oil palm. (Teoh, C.H. 2002).The palm oil is an erect monoecious plant that produces both separate female and male inflorescences. This palm trees are cross-pollinated and the weevil act as the pollinating agent. The harvesting can started after 24 to 30 months of planting and each palm can produce in the range of eight to fifth-teen fresh fruit bunches per year. Each fresh fruit bunches can contain about 1000 to 1300 fruitlets. Figure 2.1 shows the fresh fruit bunches of oil palm. Each fruitlets consists of a fibrous mesocarp layer and the endocarp which is the shell that contain the kernel. (Teoh, C.H. 2002). The common cultivars are the Dura, Tenera and Pisifera which are classified by the thickness of the endocarp or shell and the mesocarp content. Dura palms have an endocarp thickness of 2-8mm and a medium mesocarp content which consist the 35%-55% of fruit weight. The tenera race has an endocarp thickness of 0.5-3mm thick and high mesocarp content of 60%-95%. The pisifera palms do not have endocarp and have about 95% of mesocarp. Figure 2.2 shows the cross section of the palm oil fruit. Figure 2.3 shows the type of the palm oil fruits.

FIGURE 2.1: TYPES OF THE PALM OIL FRUITS
Source: Google

The palm oil produces two types of oils. The fibrous mesocarp produces the palm oil whereas the palm kernel produces the lauric oil. In the conventional milling process, the fresh fruit bunches are sterilized, then the fruitlets are stripped off, then digested and pressed to extract the crude palm oil. The nuts separated from the fiber in the press cake and cracked to obtain the palm kernels. The palm kernel then 14 crushed in another plant to obtain the crude palm kernel oil and a byproduct, palm kernel cake which is used as animal feed. Palm oil has a balanced ratio of saturated and unsaturated fatty acids whereas the palm kernel oil has saturated fatty acids almost the same with the composition of coconut oil. (Teoh, C.H. 2002).

PROPERTIES OF PALM KERNEL SHELLS

Palm kernel shells is a type of agricultural solid wastes and as being an organic material, it can be biodegradable and decay over a long period of time if the environment is full with moisture and sufficient air are present. (Mannan, M.A., A.J., Ganapathy C., Teo D.C.L. 2006). Presently, the uses of palm oil shell are limited to the fuel for burning and as finishes in mud houses. The shells can provide several advantages if it was found to be structurally adequate. Such advantages include the low density of the shells which can reduce the self-weight of the material, good thermal insulation and good sound absorption. (D.C., O. 1990). Palm oil shells are dark grey to black in color. The shell has two faces that are outer face and inner face. The outer face are from which the fibers and palm oil has been extracted, and this face can be smooth or rough depend on the extraction process. The inner faces are from which the kernel are extracted, and this face is relatively smooth. (D.C., O. 1990). The shells also have irregular shapes such as angular or polygonal, depending on the extraction process. Besides, the thickness of the shells is variable and can range from 0.15 to about 3mm, depend on the species and the time of year. (D.C., O. 1990). 24. Sometimes, the oil coating can present on the surface of fresh palm oil shells, therefore, pretreatment to remove this oil coating are necessary. The pretreatment can be done via various ways, including natural weathering, boiling in water, and washing with detergent. (Teo, D.C.L., M.M.A., Kurian V.J. 2006).

The mechanical properties of palm oil shell, crushed granite and sand are shown in Table 2.2. From the Table 2.2, it shows that the shell has higher water absorption with a capacity of 23.3%. This high water absorption may due to the high porosity in the shell. This shows that the shell need more water compared to the conventional aggregate to attain the same consistency. (D.C., O. 1990). Since the shell has higher water absorption, the shells need to be pre-soaked in potable water for 24 hour to achieve saturated surface dry (SSD) condition before mixing. This is to prevent the absorption from occurring during the mixing. (Teo, D.C.L, M.M.A., Kurian V.J, Ganapathy C 2007). The mechanical properties of palm oil shell, crushed granite and sand are shown in Table 2.2. From the Table 2.2, it shows that the shell has higher water absorption with a capacity of 23.3%. This high water absorption may due to the high porosity in the shell. This shows that the shell need more water compared to the conventional aggregate to attain the same consistency. (D.C., O. 1990) Since the shell has higher water absorption, the shells need to be pre-soaked in potable water for 24 hour to achieve saturated surface dry (SSD) condition before mixing. This is to prevent the absorption from occurring during the mixing. (Teo, D.C.L, M.M.A., Kurian V.J, Ganapathy C 2007).

Table 2.4: Mechanical Properties of POS, Crushed Granite and River SandProperties Palm kernel shell Crushed granite River Sand

Properties	Palm kernel shell	Crushed granite	River Sand
Specific gravity	1.17	2.61	2.60
Flakiness index (%)	65.17	24.94	-
Elongation index (%)	12.36	33.38	-
Bulk unit weight (kg/m3)	590	1470	-
Fineness modulus	6.24	6.33	2.56
Los Angeles abrasion value (%)	4.80	24	-
Aggregate impact value (%)	7.86	17.29	-
Loss on ignition	100	-	-
24-h water absorption (%)	23.30	0.76	0.95

Table 2.5: Chemical Composition of POS Aggregate

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

Source: Teo, D.C.L, M.M.A., Kurian V.J, Ganapathy C. (2007)

WASTE MATERIAL WITH PARTIALLY REPLACEMENT

Attempts have been made by various researchers to reduce the cost of concrete constituents and hence total construction cost by investigating and ascertaining the usefulness of materials which could be classified as agricultural or industrial waste. Some of these wastes include sawdust, pulverized fuel ash, palm kernel shells, rice husk and ash, slag, fly ash which is produced from milling stations, thermal power station and waste treatment plants (Usman et al., 2012, Kumar et al.,2012). The market inflationary trend and the constituent materials used for concrete have led to high cost of construction (Ndoke, 2006). In the same write up, an assessment was carried out on the performance of palm kernel shells as a partial replacement for coarse aggregate in asphalt concrete. It was concluded that palm kernel shells could be used up to 30% in asphalt concrete production. Falade (1992) also investigated into the sustainability of palm kernel shells as aggregate in light and dense concrete for structural and non-structural purposes. He concluded that, palm kernel shell could be used as an aggregate up to 45% in the production of light and dense concrete. As palm kernel shells perform creditably when partially replaced in concrete production, it is anticipated that it could be fully used as lightweight coarse aggregate in concrete production.

Olutoge (1995) in his investigations into the physical properties of rice husk ash, sawdust and palm kernel shell found their bulk densities to be 530kg/m 3 , 614kg/m 3 and 740kg/m 3 respectively. He concluded that these materials had properties which resembled those of lightweight concrete materials. In his findings, it is clearly indicated that palm kernel shells could be used as lightweight coarse aggregate as its bulk density affirms its viability. Sisman et al. (2011) investigated the effects of organic waste (rice husk) on the concrete properties for farm buildings and found that the unit weight of the concrete samples produced varied between 1797 and 2268 Kg/m3 , when the rice husk amount in the mixture was greater than 15%, concrete could be classified as lightweight concrete with respect to their unit weights, the compressive strengths of the samples at days 7 and 28 ranged from 15.2-31.3 Mpa and 18.1- 37.5 Mpa, respectively and the water absorption of the samples on day 28 varied between 3.02 and 5.48%, and the use of rice husk as an aggregate replacement increased the water absorption.

Olanipekun (2006) investigated the properties of coconut shells and palm kernel shells as coarse aggregates in concrete. The coconut shells were crushed and substituted for conventional coarse aggregates in gradations of 0%, 25%, 50%, 75% and 100%. Two mix ratios (1:1:2) and (1:2:4) were used respectively. He noted that the compressive strength of the concrete decreased as the percentage of the shells increased in the two mix ratios. However, concrete obtained from coconut shells exhibited a higher compressive strength than palm kernel shell concrete in the two proportions. His results also indicated a 30% and 42% cost reduction for concrete produced from coconut shells and palm kernel shells respectively. He concluded that coconut shells were more suitable than palm kernel shells when used as substitute for conventional aggregates in concrete production. In Nigeria, Okafor (1988) conducted further study on using Palm kernel shell as coarse aggregate and found out that, the weight of the concrete produced with palm kernel shells is similar to normal weight concrete.

Palm kernel shell for aggregate replacement, it increases the water absorption but decreases the concrete workability and strength. Results however, fall into the range acceptable for lightweight aggregates, hence it can be concluded that there is potential to use kernel shell as aggregate replacement for lightweight concrete. (ZarinaItam, Salmia Beddu et al, 2016). Then, according to Dr. Festus A. Olutoge, et al. (2012), palm kernel shell ash can be used as a replacement of cement. Palm kernel shell which were collected from palm oil mill were burnt and grinded into fine ash particles. Palm kernel shell ash were sieved through 45um sieve in order to remove any foreign material and bigger size ash particles. The result showed the concrete strengths were increased with the increase of curing age but were decrease with increasing percentage of palm kernel shell ash in concrete. Williams *et al.* (2014) in their work titled "Sustainability of palm kernel shell as concrete aggregate in lightweight concrete production found that properties of palm kernel shells fresh concrete are excellent, workable, consistent and easily placed. And that hardened palm kernel shell concrete developed sufficient strength that will help make it suitable for a wide range of uses. However, the flexural and compressive strength values of the normal weight concrete is about twice that of the palm kernel shells which is normal as palm kernel shell is lighter. They concluded that palm kernel shell concrete is useful as coarse aggregate where they are abundant in order to reduce the cost of building construction.

COMPARISONS OF PALM KERNEL SHELLS WITH OTHER AGRICULTURAL WASTES

The strength properties of concrete with palm oil shells as aggregate were compared with other lightweight concrete with other agricultural wastes as aggregates. Four types of agricultural wastes were studied including palm oil shells, palm oil clinkers, rice husks and coconut shells. The palm oil clinkers are the byproducts of the palm oil mills energy generating burners. Both the palm oil clinkers and the coconut shells needed to be crushed and broken into size not larger than 20 mm before use in concrete mixing. Before using these agricultural wastes, these aggregates wastes need to be air-dried. The concrete mixed with a ratio of 1:1:2 of cement, sand and agricultural wastes with water-cement-ratio of 0.55.

MATERIALS AND METHODS

A proper understanding of the methods adopted in this study on the evaluation of kernel shells as construction materials for low cost houses is fully discussed.

This study focused on analyzing the effect of replacing natural aggregate with kernel shells on the workability, compressive strength and how it will help the reduction of the cost of concrete and also be able to build houses for lower cost

In the research, 3-4 batches of different sample will be provided consisting of:

- Two batches of normal concrete
- Two batches of concrete with full replacement of coarse aggregate (gravel) with kernel shells.

Laboratory tests will be performed in Landmark University Omu-aranKwara State to study the effect of replacing natural aggregate (gravel) with kernel shells on weight of concrete, to compare the strength of coarse aggregate and kernel shell concrete, to determine the workability, compressive strength, and also to report on the durability of kernel shells concrete.

MATERIALS

The following materials used in the production of the concrete are;

1. Portland Cement (Dangote)
2. Coarse aggregate (Gravel)
3. Fine aggregate (Sand)
4. Water (Portable)
5. Palm kernel shells
6. Engine Oil (Lubricant)

The raw materials used were Portland cement, Gravel, Kernel shell, Sand, and Portable water. The cement was used as a binder in the production of concrete

International Journal of Environmental Studies and Safety Research
ISSN: 2536-7277 (Print) : 2536-7285 (Online)
Volume 3, Number 3, September 2018
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while the kernel shells served as aggregate and the engine oil served as a lubricant for easy removal of the concrete cube from the mold.

MATERIAL SOURCING

The cement was gotten from a local distributor of Dangote cement along Ipetu road, Omu-AranKwara State. The Kernel shell was gotten from Ijesa-isuEkiti State. The gravel and sand was gotten from Omu-aran community. The water used was gotten from a tap inside the concrete shade in Landmark University while the mold was gotten from concrete laboratory in Landmark University. The engine oil was gotten from Mechanical workshop in Landmark University.

SAMPLE PREPARATION

The kernel shell was washed with detergent to get rid of all contaminant in the shell. After sourcing of materials which included 2bags of cement (50kg each), 3bags each of Gravel and sand, 50kg of kernel shell, 24 concrete mold and water, the inner surface of the mold was lubricated with engine oil. After coating the molds, a mixture of cement, gravel, sand and water which formed a paste was poured into the mold using a hand trowel, and also a mixture of cement, kernel shell, sand and water was also poured into a different mold using a hand trowel. The mixture of the materials was done manually using shovels, head pans and bucket.

Figure 3.1 Mixing process

CURING METHOD

The continuous hydration of cement is necessary in concrete strength. Therefore all the test specimens, after 24hours of setting was carefully removed from their molds and placed them in the curing tank filled with water at a controlled

International Journal of Environmental Studies and Safety Research
ISSN: 2536-7277 (Print) : 2536-7285 (Online)
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temperature. The specimen was removed from the curing tank when it is due for testing.

EXPERIMENTAL TEST PROCEDURES

The test carried out in the course of the project are;
1. Slump test on the concrete
2. Compacting factor test on the concrete
3. Rebound hammer test on the concrete cube
4. Compressive strength test on the concrete cube

SLUMP TEST ON CONCRETE

Slump test is used to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work. The procedures are as follows:

- Clean the internal surface of the mold and apply oil.
- Place the mold on a smooth horizontal non- porous base plate.
- Fill the mold with the prepared concrete mix in 4 approximately equal layers.
- Tamp each layer with 25 strokes of the rounded end of the tamping rod in a uniform manner over the cross section of the mold. For the subsequent layers, the tamping should penetrate into the underlying layer.
- Remove the excess concrete and level the surface with a trowel.
- Clean away the mortar or water leaked out between the mold and the base plate.
- Raise the mold from the concrete immediately and slowly in vertical direction.
- Measure the slump as the difference between the height of the mold and that of height point of the specimen being tested.

Calculation

Slump = Height of the slump cone – Height of the unsupported concrete

Result of slump test on concrete 34

When the slump test is carried out, following are the shape of the concrete slump that can be observed:

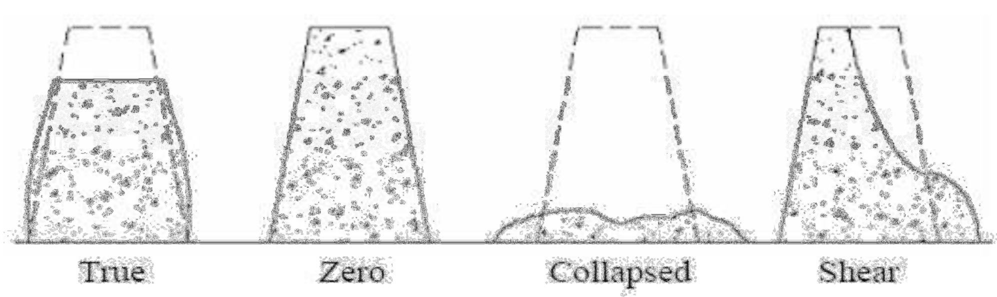

Figure 3.2 Types of Concrete Slump Test Results

• **True Slump** – True slump is the only slump that can be measured in the test. The measurement is taken between the top of the cone and the top of the concrete after the cone has been removed as shown above.
• **Zero Slump** – Zero slump is the indication of very low water-cement ratio, which results in dry mixes. These type of concrete is generally used for road construction.
• **Collapsed Slump** – This is an indication that the water-cement ratio is too high, i.e. concrete mix is too wet or it is a high workability mix, for which a slump test is not appropriate.
• **Shear Slump** – The shear slump indicates that the result is incomplete, and concrete to be retested.

COMPACTING FACTOR TEST

This test also gives the workability of concrete indirectly. This test is appropriate for concrete with the maximum aggregate size of 40mm.

Apparatus

- The compaction factor apparatus shall consist of two conical hoppers mounted above a cylinder.
- Trowels
- One scoop about 150 mm long
- A tamping rod
- A balance
- A compacting rod

Procedures

• Prepare a concrete mix in the ratio of 1:2:4
• With the help of a trowel, fill the freshly prepared concrete in the top upper of the apparatus. The concrete should be filled to the brim of the hopper and level it off with trowel.
• Now open the trap of the upper hopper, so that the concrete falls in the lower hopper.
• After all concrete falls from the upper hopper to lower one. Then again open the trap of the lower hopper. Let the concrete falls on the cylinder.
• Now take the weight of the cylinder in which concrete had felled. Let this weight be "The weight of partially compacted concrete (W_1)
• Empty the cylinder.
• Now again, fill concrete in the cylinder in three layers with 25 blows for each layer using tamping rod. Fill concrete to the top of cylinder and scrape excess concrete above the brim.
• Now take the weight of the cylinder in which concrete we filled. Let this weight be "The weight of fully compacted concrete (W_2)

Calculation

The compacting factor of concrete can be found out using the formula 36

= (Weight of Partially Compacted Concrete W_1 – Weight of empty cylinder)/(Weight of fully Compacted Concrete W_2 – Weight of empty cylinder)

Figure 3.3 Compacting factor apparatus

COMPRESSIVE STRENGTH TEST ON SPECIMEN

This test is carried out to determine the compressive strength of the concrete. The compressive strength of a material is its ability to withstand any gradually applied load acting on it. The machine used for this test is the compressive machine. After the machine is turned on, the cube is placed in the machine and the crushing process begins.

Calculation

Compressive Strength of concrete = Maximum compressive load / Cross Sectional Area

Figure 3.4 Compressive strength machine

International Journal of Environmental Studies and Safety Research
ISSN: 2536-7277 (Print) : 2536-7285 (Online)
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SCHMIDT REBOUND HAMMER TEST ON SPECIMEN

This test is carried out to determine the compressive strength of concrete without destroying the concrete. It is only a test used for estimating the strength of concrete in structure and it can hardly be considered as a substitute for compressive strength test. The rebound of an elastic mass depends on the hardness of the surface against which its mass strikes. When the plunger of the rebound hammer is pressed against the surface of the concrete, the spring-controlled mass rebounds and the extent of such a rebound depends upon the surface hardness of the concrete. The surface hardness and therefore the rebound is taken to be related to the compressive strength of the concrete. The rebound value is read from a graduated scale and is designated as the rebound number or rebound index. The compressive strength can be read directly from the graph provided on the body of the hammer.

Figure 3.6 Rebound hammer39

RESULT AND DISCUSSION

Tests were carried out on the samples of concrete cube after production. The aims of these tests were to determine the strength, durability and other properties of the cube with kernel shell. The tests carried out were slump cone test, compacting factor test, compressive strength test, Schmidt rebound hammer test.

LABORATORY TEST

Slump Cone Test

The slump cone test was carried out and the following result are as follows;
Mix ratio was 1:2:4
Height of the cone = 300mm
Height of the concrete with gravel as coarse aggregate = 270mm
Height of the concrete with kernel shell as coarse aggregate = 286mm.

Compacting Factor Test

Compacting factor test is the test carried out to determine the workability of concrete mix.

Compacting factor value = $W_1 - WW_2 - W$
Where W—Weight of empty cylinder
W_1—Weight of partially compacted concrete
W_2—Weight of fully compacted concrete

Table 4.1 Compacting factor result Batch

	W(kg)	W1(kg)	W2(kg)	Compaction factor
Gravel	7.9	18.6	19.8	0.899
Kernel shell	7.9	16	16.4	0.953

Compressive Strength

Compressive strength test was carried out on the concrete cube sample to determine the compressive strength in N/mm2. The result obtained for 7days, 14days, 21days, and 28days are shown below.

Table 4.2 Compressive strength of gravel as coarse aggregate

GRANITE	7days	14 days	21 days	28 days
GS1	13.56	16.2	24.76	24.3
GS2	18.7	13.16	29.3	28.76
GS3	26.1	11.6	36.6	31.6
Mean	19.45	13.65	30.22	28.22

Figure 4.1 Bar chart showing the compressive strength of concrete 41

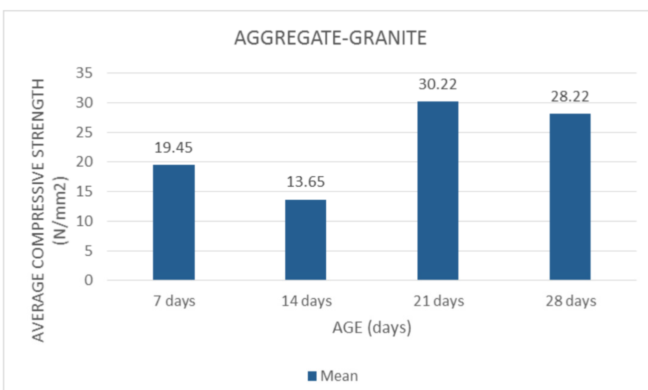
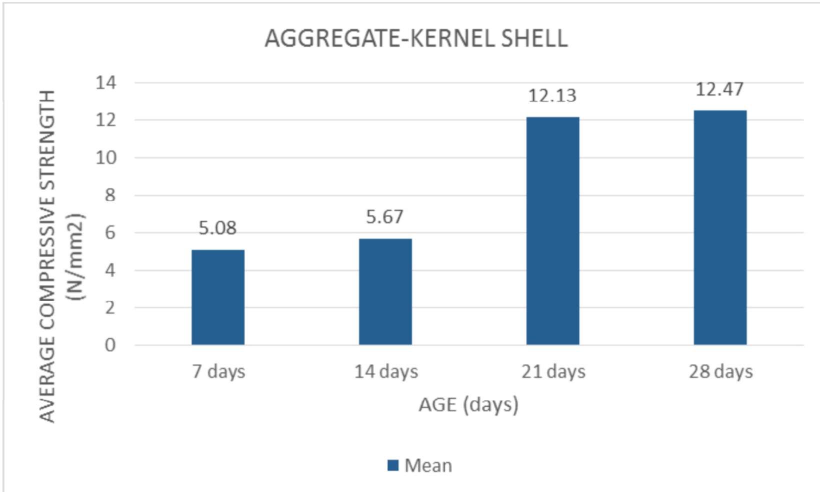
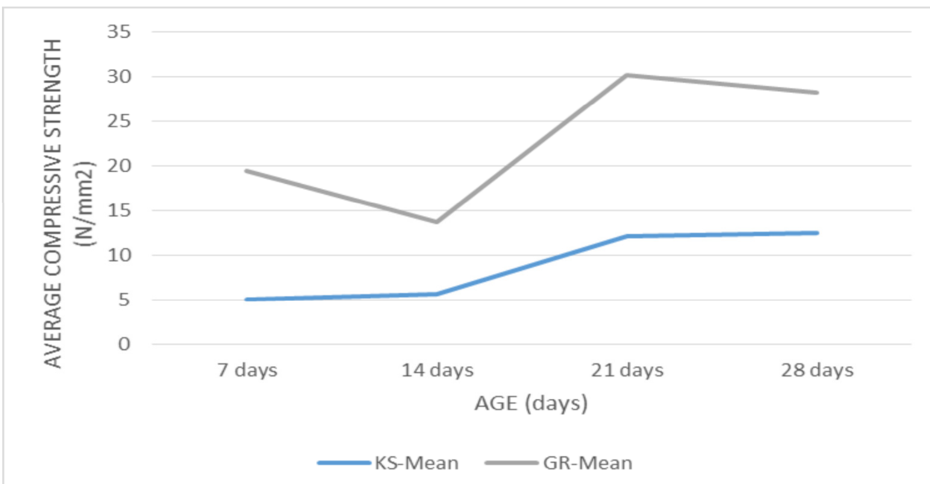


Table 4.3 Compressive strength result for Kernel shell as coarse aggregate

KERNEL SHELL	7 days	14 days	21 days	28 days
KS1	5.91	5	10.2	12.5
KS2	5.2	6.2	13.1	
KS3	4.13	5.8	13.1	10.7
Mean	5.08	5.67	12.13	12.47

Figure 4.3 Graph comparing the compressive strength of gravel and kernel shell as coarse aggregate





From the graph above, it can be seen that as the curing days increases so also the compressive strength of the concrete increases.

SCHMIDT REBOUND HAMMER

Rebound hammer test was carried out to determine the compressive strength of concrete without destroying the sample. The following result were complied

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Table 4.4 Values of rebound hammer of concrete with gravel as coarse aggregate

GRANITE	7 DAYS			14 DAYS			21 DAYS			28 DAYS		
1	12	14	14	12	13	13	13	18	15	18	20	17
2	11	11	13	14	12	13	15	12	15	16	14	20
3	14	12	11	14	14	15	15	13	15	16	18	17
4	20	11	12.5	12	13	14	14	14	13	15	21	14
5	17	12	13	17	16	18	16	16	20	16	18	19
6	15	14	13	17	18	14	15	19	17	16	19	22
AVERAGE	14.8	12.3	13.6	14.3	14.3	14.5	14.7	15.3	15.8	16.2	18.3	18.2
MEAN AVERAGE	13.56666667			14.36666667			15.26666667			17.56666667		

Table 4.5 Values of rebound hammer of concrete with kernel shell as coarse aggregate

KERNEL SHELL	7 DAYS			14 DAYS			21 DAYS			28 DAYS		
1	11	14	12	13	11	10	14	11	13	13	23	17
2	15	16	14	11	16	10	15	16	12	14	16	14
3	18	12	13	16	15	12	10	14	12	16	17	12
4	16	15	12.5	12	13	10.5	18	17	13	14	15	15
5	12	11.9	16	16.5	14	13	16	15	17	18	20	17
6	13	14	13	16	16	13	17	13	17	17	16	17
AVERAGE	14.2	13.8	13.4	14.1	14.2	11.4	15	14.3	14	15.3	17.8	15.3
MEAN AVERAGE	13.8			13.23333333			14.43333333		16.13333333			

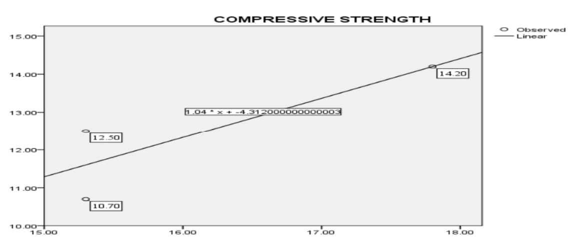

Figure 4.4 Rebound hammer graph for kernel shell as coarse aggregate at 28days

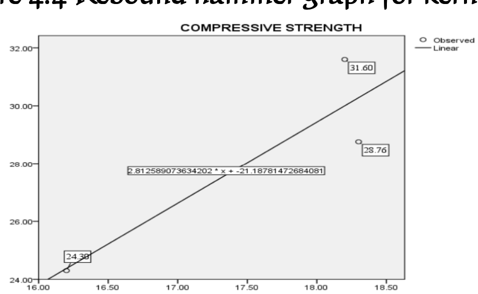

Figure 4.4 Rebound hammer graph for gravel as coarse aggregate at 28days

RECOMMENDATION

With the study carried out, it is indicated that there is a possible use of palm kernel shell as a structural material; it is recommended that its long-term behavior should be looked into in order to evaluate its possibility. Volume batching should be used in palm kernel shell concrete construction; further research should be conducted to organize the use of Palm kernel shell as structural material. There should also be collaboration between the government and the construction companies to aid the use of locally available materials which have been found suitable to reduce the cost of construction.

CONCLUSION

The aim of this project was to evaluate kernel shell as construction material for low cost houses, and find out the compressive strength, durability, availability of kernel shell. Based on the results obtained kernel shell was found to be suitable for minor construction works like bungalow houses, shops, light weight concrete, and other small construction work. Proper mix should be ensured during mixing to achieve adequate bonding of the material.

The advantages of lightweight concrete are listed below;

1. It is governed primarily by economic consideration
2. Reduces the dead load of a structure
3. Improved hydration due to internal curing
4. Ease of renovation and repair
5. It offers easy workability
6. Industrial waste if found suitable can be utilized economically
7. They have a lower thermal expansion than ordinary concrete. Because of this thermal efficiency, it reduces the heating and cooling load in buildings.

This study was conducted in order to find the effective way of applying kernel shell as coarse aggregate. Analysis of the strength characteristics of concrete containing kernel shell have the following result.

- It is identified that kernel shell waste can be used as a construction material
- There exists to be a high potential for the use of palm kernel shells as aggregates in the manufacture of lightly reinforced concrete.
- There are possible cost reductions in concrete production using palm kernel shells as full replacement for granite.
- The economic power of the rural residents will be improved if they are encouraged to plant palm trees from which these shells could be gotten.
- The goal by governments in developing countries could use of locally available materials in infrastructure development which will be met with the use of palm kernel shells as construction materials for low cost houses.
- Water absorption for concrete containing kernel shell increases but is still within standard range.

• The inclusion of kernel shell reduces the concrete strength, but due to research higher percentage of kernel shell should be used so that it could fall in the range of light weight concrete component.

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