EFFECT OF PARTIAL REPLACEMENT OF COARSE AGGREGATE WITH PALM KERNEL SHELL ON COMPRESSIVE STRENGTH OF CONCRETE

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CERTIFICATION

This is to ascertain that this particular project titled "The Effect of Partial Replacement of Coarse with Palm Kernel Shell on Compressive Strength of Concrete" was carried out by Okegbe Chibundu .L. with registration number (NAU/2017224042) from the Department of Civil Engineering, Faculty of Engineering, Nnamdi Azikiwe University, Awka, Anambra State.

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APPROVAL PAGE

This work of research titled "The effect of Partial Replacement of Coarse Aggregate with Palm Kernel Shell on Compressive of Concrete" has been assessed, reviewed and approved by the Department of Civil Engineering, Faculty of Engineering, Nnamdi Azikiwe University, Awka, Anambra State.

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DEDICATION

I would like to specially dedicate this report to The Almighty God, who has been my ultimate source of strength, endurance and grace during the course of this research. I would additionally want to dedicate this report to my parents who have been of great support in every aspect of my life from the beginning, and also to my late grand father, Mr John Okegbe.

ACKNOWLEDGEMENT

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ABSTRACT

This report is a comprehensive summary of the research carried out by myself on the effect of replacement of coarse aggregate with palm kernel shell, on the compressive strength of concrete. During the course of this research, the various tests carried out include: sieve analysis of the materials (particle size distribution), water absorption, specific gravity teat and compressive strength test. The sieve analysis gives results for granite, the percentage passing through 4.75mm is 0.16, for sand, the percentage passing through sieve size 0.075mm is 0.96 and for palm kernel the percentage passing sieve size 4.75mm is 2.34. The gradation of CA, SD and PKS obtained from their respective shape parameters (Cu and Cc) shows that they are poorly graded. The specific gravity tests conducted, SD and CA and PKS, the average apparent specific gravity gotten were 2.62, 2.68 and 2.28 respectively. The range of specific gravity from 2.58 to 2.62 obtained for SD and GT satisfies ASTM D854-14 requirement which states that the specific gravity of aggregates should be between 2.55 to 2.9 and therefore justifies the use of the aggregates for this work. Water absorption capacity of CA and PKS 1.48 and 17.58 respectively. The slump test result carried out shows that the slump value increases with consistent addition of the additive (PKS) from 5% to 25% at w/c ratio of 0.6 with the highest slump recorded at 25% partial replacement of CA. By comparing the normal concrete cubes with those of the palm kernel shell concrete, I was able to come to the conclusion that although palm kernel shell concrete is used to make lightweight concrete, the normal concrete is still better in terms of strength and durability. I therefore recommend that beyond a percentage of 15%, palm kernel shell should not be used to replace coarse aggregate, this is because the strength of the concrete decreases significantly after this point.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

As a country, Nigeria can still be classified as a developing nation. That is to say that irrespective of the technology being used and infrastructures, when compared to first world countries, we still have a long way to go in terms of development and innovation. Civil engineering deals with the analysis, design, construction and maintenance of infrastructures. Building such infrastructure cannot be done without the use of concrete, no matter how minute.

Concrete is an essential part of any construction project. It is the most widely used construction material in the entire world. Rather than existing as an independent material, concrete is a mix of various materials. These materials include cement, water, fine aggregate, and crushed stones or gravel. Sand and gravel or crushed stones are examples of fine aggregate and coarse aggregate, respectively. Concrete is similar to mortars in both composition and structure. This similarity means concrete works as a binder for the various masonry units in construction, just like any mortar. Unlike ordinary mortar, however, concrete has a wide range of applications. This versatility is as a result of concrete having both fine aggregates and coarse aggregates that are larger. The large size of the coarse aggregates confers strength attributes to concrete, that mortar doesn't have. This makes it suitable for application in larger and heavier structures. Most mortars have sand as the sole aggregate and are hence weaker than concrete.

Concrete is a very strong material that can withstand great tensile and compressive stresses without yielding. This strength is, of course, a function of the material components of the concrete mix. This variability explains why poorly graded concrete is weaker than a well-graded mix. The strength of concrete makes it suitable for constructing foundations, wastewater treatment facilities, super structures, and other establishments

Workability underscores the ease of use of a particular material or equipment and how it retains quality during use. Concrete companies have an easy time mixing concrete for starters. The subsequent handling, transportation, placing, and finishing process is also as seamless as the mixing. For such ease of use, concrete is an extremely workable material that is great even for large construction projects. Concrete lasts for ages, even under very adverse conditions. Concrete can resist weathering action, chemical action, abrasion, and both tensile and compressive stress for long periods without compromising its structural integrity. This attribute makes a concrete structure more stable and suitable for places with rough conditions. Concrete can last for well over a thousand years. In fact, the first instances of human-made concrete date back to 500 BC. The fact that we are still able to see this concrete shows just how durable concrete is. Commercial concrete work require little maintenance save from a few touch-ups on the finishing. The longevity of concrete makes it a great material for permanent buildings and other structures like bridges and even dams.

Due to the constant inflation in costs of materials and the desire to maintain the cost of construction at a considerable price, it is necessary to research the use of substitute materials, such as locally available ones which can be used to replace the orthodox ones used in production of concrete where possible.

Palm kernel is a material which can be easily found and have a lot of uses both commercially and industrially. In Industries it is used for the production of Palm Oil. So, this research paper discusses the use of palm kernel shell as partial replacement of coarse aggregates.

1.2 Statement of Problem

The high cost of the materials needed for concrete is a cause for concern, along with the effects of the aggregates on the environment as a whole.

1.3 Aim and Objectives

The main aim of this experiment is to produce lightweight concrete and economical concrete by using the environmentally friendly method and thus contributing to the safety of the environment. Other objectives include:

1. Classify the fine aggregate (sand), coarse aggregate (granite) and additive (palm kernel shell) used for the research.
2. Determine the feasibility and efficacy of using palm kernel shell as an additive for partial replacement of coarse aggregate (granite).
3. Study the effect of palm kernel shell on the workability, and compressive strength of concrete.

4. Make comparative analysis between the compressive strength of both conventional and non-conventional concrete.

1.4 Scope of Research

This research is restricted to the evaluation of the effect of partial replacement of coarse aggregate with palm kernel shell on the compressive strength of concrete and the laboratory test to be conducted include: Sieve analysis and Specific gravity of fine, coarse aggregate and additive (palm kernel shell), Water absorption of coarse aggregate and additive (PKS), workability test of the fresh concrete and lastly to investigate the effect of partial substitution of coarse aggregate with palm kernel shell, compressive strength test of the hardened concrete cube will be conducted.

1.5 Significance of study

This research will be carried out to assess the efficacy of using palm kernel shell as a partial substitute for coarse aggregates in concrete and the findings obtained from the research will be useful in the following ways:

1. It will guarantee massive infrastructural development through the relative economy achieved in the utilization of construction material.

2. Ensure environmental sustainability through the use of environmentally friendly materials for concrete production.

3. Reduction of environmental load posed by unauthorized dumping of agricultural waste (palm kernel shell).

4. Enhance rational use of natural resources.

5. Guarantee the availability of construction materials through the use of renewable resources (palm kernel shell).

CHAPTER TWO

LITERATURE REVIEW

2.1 Preamble

This chapter analyses the relevant literature on the topic of study. It samples the work of other researchers in the field of science and engineering as they relate to this study which focuses on palm kernel shell (PKS), cement, granite and concrete but most importantly, the effect of partial replacement of granite with palm kernel shell on flexural and compressive strength of concrete.

2.2 Concrete

Concrete is the most widely used construction material in the entire world. Rather than existing as an independent material, concrete is a mix of various materials. These materials include cement, water, fine aggregate, and crushed stones or gravel. Sand and gravel or crushed stones are examples of fine aggregate and coarse aggregate, respectively. The strength of concrete makes it suitable for constructing foundations, wastewater treatment facilities, super structures, and other establishments. The expensive cost of concrete constituents such as cement, fine and coarse aggregate has given rise to the need to search for alternative construction materials. The general importance of concrete application in construction projects and civil works cannot be overemphasized. The enormous demand for concrete in construction adopting orthodox aggregates, such as gravel and sand has led to tremendous depletion in naturally occurring aggregates causing severe harm to the environment which is irreversible.

It is a compound material which comprises essentially of a binding material such as a mixture of Portland cement and water within which are embedded particles or fragments of aggregate usually a combination of fine and coarse aggregate (Mc Graw-Hill, 2013). Concrete is a synthetic construction material made by mixing cement, fine aggregate, coarse aggregate and water in the proportions. Concrete is known for its durability and strength, making it an ideal material for building structures that need to withstand heavy loads or harsh environments. Additionally, concrete is relatively expensive and easy to produce, which makes it a popular choice in the construction industry.

2.2.1 Constituents of Concrete.

The materials or components used for concrete production include cement, fine aggregate (sand), coarse aggregate (granite) and water.

I. Water

Water is an important ingredient of concrete as it actively participates in chemical reaction with cement, since it helps to form the strength giving cement gel. The quantity of water in the mix plays a vital role on the strength of the concrete. Some water which have adverse effect on hardened concrete, sometimes may not be harmless or even beneficial during mixing, so clear distinction should be made between the effect on hardened concrete and the quality of mixing water. Thus, the quality and quantity of water is required to be given adequate consideration in the production of concrete. (Nakhil, et al. 2016), states that water plays a vital role in the strength of concrete as it helps in the following areas:

a) Water enables the cement paste wet the aggregate, promoting cohesion and allowing it to adhere effectively and efficiently to the wet surface of the aggregate.

b) During the curing period, water is required for the cementing material to undergo hydration, which allows it to set and harden.

c) To enable the preparation of mixture of the various materials and to modify the workability of concrete, thereby making it easier to use in the chosen location.

(A) Impact of Water Quality on Concrete

The hardening of cement gives strength and durability to concrete. The quality of mixing water may affect the setting, hardening and strength of the concrete. Great control on properties of cement and aggregates is exercised, but the control on the quality of water is neglected.

(Nakhil, et al. 2016), carried out a research on the impact of water quality on strength properties of concrete using portable water, ground water and sewage water and it was discovered that portable water satisfies the requirement of water to be used for construction work as there was significant resulting increase in the flexural, split tensile and compressive strength of the concrete compared to other source of water. (Tahir, et al. 2020), stated that the quality of water has a significant effect on the strength properties of concrete as treated water produces concrete with comparatively higher strength than groundwater and saline water.

[Mc Coy ,2017] reported that water with pH of 6.0 to 8.0, which does not taste saline or brackish, is suitable for use. [Steinour ,2015] described that impurities in water may interfere with the setting of the cement, adversely affect the strength of the concrete or cause staining of its surface, and also lead to corrosion of the reinforcement. [P. Ghosh et.al] reported that presence of micro-organism in mixing water increases the compressive and tensile strength of concrete.

(B) Impact of Water-Cement ratio on Concrete

In concrete mix design, the water-cement ratio is responsible for binding all constituents of concrete together. If the water-cement proportion is higher, it brings about wider spacing between the cement aggregates and thus, influences the compaction. (Shatty, 2020) stated that the water-cement ratio of concrete must lie within practical limit (0.55-0.6) as this determines the strength of concrete. According to (Shatty, 2020) lower cement–water ratio could be used when the concrete is vibrated to achieve higher strength where as higher water-cement ratio is required when the concrete is hand compacted. In other words, the effect of water-cement ratio on strength and durability properties of concrete depends on the method of compaction.

II.Cement

Cement is one of the most essential components of concrete as the compressive strength of concrete largely depends on the quality and quantity of cement since it binds the fine aggregate (sand) and coarse aggregate (gravel, crushed stone) together to form a strong compound (concrete) which has the ability to bear loads.

Cement grade or cement strength class corresponds to the minimum 28 days compressive strength of concrete. Generally, there are three cement grades: grade 33, grade 43 and grade 53 which have a compressive strength of 32.5Mpa, 42.5Mpa and 52.5Mpa respectively. (Chanadan, 2019) stated that in terms of quality of assurance of cement, any cement with a compressive strength of 32.5Mpa would be adjudged as meeting the strength requirement of cement grade 32.5Mpa. During the course of this research work, Ordinary Portland Cement (OPC) will be used for the production of concrete. Ordinary Portland Cement (OPC) is cement containing 95% - 100% clinker and gypsum and 0% - 5% minor additional constituents (Chanadan, 2019).

(A) Chemical Composition of Ordinary Portland Cement

Lime (Cao), silica (SiO_2), alumina (AlO_2) and iron oxide (Fe_2O_3) are the main raw materials used in the manufacture of Portland cement. The four compounds are usually referred to as the major constituents of cement. They are described in abbreviated form by cement chemists as follows: CaO = C; SiO_2 = S; Al_2O_3 = A; and Fe_2O_3 = F. Likewise, H2O in hydrated cement is denoted by H, and SO3 by S. In addition to the main compounds listed above, there exist minor compounds, such as MgO, TiO_2, Mn_2O_3, K_2O and Na_2O; they usually amount to not more than a few per cent of the mass of cement. Two of the minor compounds are of particular interest: the oxides of sodium and potassium, Na_2O and K_2O, known as the alkalis. They have been found to react with some aggregates, the products of the reaction causing disintegration of the concrete, and have also been observed to affect the rate of the gain of strength of cement (Neville, 2005). The relative proportions of these oxide compositions are responsible for influencing the various properties of cement; in addition to rate of cooling and fineness of grinding.

III. Fine Aggregate

Fine aggregate is a type of material that is smaller than 5mm in diameter, such as sand. It is one of the main materials used in construction as a component of concrete and mortar. Fine aggregate helps to fill the voids between larger particles, providing a smooth surface and improving the workability of the moisture. (Shatty, 2020) stated that fine aggregate are important constituents as it gives body to the concrete and also help to reduce shrinkage. (Mindness and Young, 2015), Fine aggregate aid in the hydration of cement as it react with cement in the presence of water to form paste. In other word, hydration of cement is largely controlled by the fineness of the aggregate. (Anna, 2019) stated that fine aggregate has the possibility of improving particle parking as they act as fillers both in lean and rich mixes with crushed aggregate.

IV. Coarse Aggregate

Coarse aggregate is a type of material that is larger than 5mm in diameter, such as gravel or crushed stone. It provides strength and stability to the final product of the concrete and helps to fill the voids between fine particles. Coarse aggregate occupies over 75% of the concrete volume acting as economic filler material. (Ezeldin and Actcin, 2019) compared concrete with the same mix proportion containing four different coarse aggregate types. They concluded that in high strength concrete, higher strength coarse aggregate typically yield higher compressive strength while in normal strength –concrete coarse aggregate has little effect on compressive strength. Some research (Strange and Bryant, 2019) and (Nallathambi, et al. 2014) has shown that there is an increase in fracture toughness with an increase in the sizes of coarse aggregate. Coarse aggregate improves the drainage and reduces the risk of cracking in the final product.

2.3 Palm Kernel Shell (PKS).

Palm Kernel Shell back in the early 80's and 90's was regarded as a waste, as more than 350,000 tons were available for sale. The palm kernel shell had been a little known then for its potential usage on a large scale especially in concrete work (Mohammad, 2017). Beyond 2000, research into utilization of Palm Kernel Shell as light weight aggregate and other uses had received a big boost.

In the last three decades, palm kernel shell (PKS) has been used by scientists as light weighted aggregates to substitute conventional normal weighted aggregates in building and road construction in Africa and Southeast Asia. One of the advantages of PKS is that it has better impact resistance compared to normal weighted aggregates. Innumerable articles have been published on the physical, mechanical, structural and functional properties using PKS as Lightweight aggregate. Palm kernel shells (PKS) are organic waste materials obtained from crude palm oil producing factories in Asia and Africa (Alengaram, et al, 2020).

During the crude palm oil process the fruit's flesh is melted through a steaming treatment. The residual nuts are further mechanically crushed to extract the seeds or kernels. The Palm Kernel Shells (PKS) is a virgin biomass with a high calorific value, typically about 3,800 Kcal/kg (ASTM, 1978). Oil Palm trees grow in the coastal belt in Nigeria which varies in depth from 100 to 150 miles and a riverine belt which follows the valleys of the Niger and Benue for a distance of about 450 miles from the sea. The main palm oil producing states include Ogun, Ondo, Oyo, Edo, Cross River, Anambra, Enugu, Imo, Abia, Ekiti, Akwa-Ibom, Delta and Rivers.

Palm kernel shells in the past had been used solely as fuelling material at home and for industries. The quest for alternative civil engineering construction material which is economical and light in weight has been a major drive in carrying out this work. Palm kernel shell possesses hard characteristics as coarse aggregate and there have been attempts to use it as a coarse aggregate to replace conventional coarse aggregates traditionally used for concrete production (Mohd et al., 2008). (Ata et al., 2016) compared the mechanical properties of palm kernel shell concrete with that of coconut shell concrete and reported the economy of using palm kernel shell as lightweight aggregate. Generally, palm kernel shell consists of 60 – 90% of particles in the range of 5 – 12.7mm (Okafor, 2018). The specific gravity of palm kernel shell varies between 1.17 and 1.37, while the maximum thickness of the shell was found to be about 4mm (Okpala, 2020).

2.3.1 Physical Properties of Palm Kernel Shell Concrete

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/m3. They also reported a 28days cube compressive strength in the range of 15 to 25MPa. In the same study (Okafor, 2014) 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 28 days compressive strength of palm kernel shell concrete varied depending on the mix ratio employed. Also (Ayanbadefo, 2018) 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 46 percent and 58 percent lower respectively compared to granite aggregates, which shows that palm kernel shell is a good shock absorbing material.

In addition, (Alengaram et al., 2020) investigated the physical and mechanical properties of different sizes of palm kernel shells as lightweight aggregates (LWA) and their influence 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 11 percent 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 Nigeria and reported that the density of the palm kernel shell concrete was about 22 percent lower than that of the normal weight concrete for both cement types.

2.3.2 Density of Palm Kernel Shell (PKS) Concrete.

Generally, when the density of concrete is lower than 2000kg/m3, it is categorized as light weight concrete. Thus, the palm kernel shell concrete can be produced within this target density of 2000kg/m3, hence palm kernel shell concrete is a light weight concrete. According to (Mohd et al., 2018), the 28 days cube compressive strength obtained was 15 –25MPa while the structural behavior of palm kernel shell is very limited. On density of concrete and percentage replacement of palm kernel shell in concrete, (Alengaran et al., 2020); (Olutoge et al., 2014) and (Okpala, 2020), 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., 2015), found the density of palm kernel shell concrete to be 740kg/m3 . They concluded that the materials have properties which resembled those of lightweight concrete materials. Generally, when the density of concrete is lower than 2000kg/m3, it is categorized as lightweight concrete (LWC).

Yusuf et al. carried out an experiment on the structural application of lightweight concrete incorporated with palm kernel shells adopting a mix ratio of 1:1:2 and w/c of 0.5. (Neville, 2016) 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.

2.3.3 Bond Characteristics of Palm Kernel Shell Concrete (PKSC).

Some research had been done in assessing the bond characteristics of the palm kernel shell in concrete matrix like works of (Raheem et al., 2018) and (Jumaat et al., 2019). According to (Raheem et al., 2018) and (Jumaat et al., 2019), 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, 2015). Previously, researchers like (Okafor, 2017), (Mannan and Ganapathy, 2020) and (Jumaat et al., 2019) 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., (2019) 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., 2019). The behaviour of palm kernel shell concrete in a marine environment had been previously reported by (Mannan and Ganapathy, 2020) and they revealed that the compressive strength of palm kernel shell concrete was 28.1MPa at an age of 28 days. They also observed that the bond property of palm kernel shell concrete is comparable to other types of lightweight concrete.

2.3.4 Strength of Concrete made with Palm Kernel Shells

The properties of palm kernel shell concrete affecting its durability such as creep (Ali, 2018) and shrinkage (Mannan and Ganapathy, 2020) were also compared with normal weight concrete. Creep of concrete results from the action of sustained stress which graduates into gradual increase to strain in time; it can be of the same magnitude as drying shrinkage. Creep does not include immediate elastic strains caused by loading or shrinkage or swelling caused by moisture changes. Achieving the 16 minimum concrete grade requirement as well as specifying areas where palm kernel shell concrete (PKSC) can be used, will increase the adoption of palm kernel shell in many civil works thereby eradicating the biological and environmental hazards caused as a result of improper disposal of the palm kernel shells and reduce cost of construction. Palm kernel shells could be employed for construction purposes in rural villages where they are easily accessible and places where natural occurring aggregates are expensive, to enable residents who want to build structures to be able to do so with minimum resistance.

2.4 Sustainability of Palm Kernel Shells in Building Construction

Palm Kernel shell as a reliable building material in Nigeria, in the search for providing more affordable housing system for both the rural and urban population of Nigeria and other developing countries, various suggestions highlighting the reduction of orthodox (common) building material costs have been put forward. One of the top suggestions has been the gathering, development and adoption of alternative, non-conventional local construction materials including the possibility of using some agricultural and industrial wastes and residues (e.g. palm kernel shells) as construction materials (Tukiman and Mohd, 2019). The quality and cost effectiveness of construction materials employed in housing developments are among the major factors that determines the optimal delivery of housing projects (Akutu,2018). Therefore, materials to be used for building construction must provide objective evidence of quality and cost effectiveness in terms of functional requirements and low income economy respectively. In light of this, the search for cheaper materials that are socially acceptable and economically available, at an acceptable quantity within the reach of an ordinary man becomes a subject of continuous interest. The belief that the African region is full of raw materials suitable for local uses encourages this, yet the construction sector is not making optimal use of them (chandran, 2019).

2.5 Effect of Mineral Admixture on Palm Kernel Shell Concrete (PKSC).

Various researches in the past have shown that the cube compressive strength could be enhanced with the addition of mineral admixtures such as silica fume and fly ash to mention a few. Among studies done in this area include the works of (Neville, 2013 and 2015); (Alengaram et al., 2020); (Teo et al., 2006); (Alengaran et al., 2010); (Robert et al., 2013) and (Alengaram et al., 2008).

(Neville, 2015) 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, (2013), 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., 2020) and (Teo et al., 2016) respectively investigated 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/m3 and that the performance of beams made from palm kernel shell concrete of dimension (3000mm ×250mm × 150mm) was superior with respect to ductility. (Alengaram 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/mm2 . Similarly, (Robert et al., 2013) 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., 2020), from his research paper on the influence of sand content and silica fume on mechanical properties 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/m3. It was observed that oven dry densities were about 220 to 260kg/m3 lower than water cured densities. The highest density of 1971kg/m3 was reported for mix containing sand/cement (s/c) ratio of 1.6. (Alengaram et al., 2020) also observed 18 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/m3 and hence mixes containing s/c ratio higher than 1.6 was not considered. The authors reported 10 to 15 percent 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.

2.5.1 Effect of proportion and aggregate size on palm kernel shell concrete.

(Nuhu-Koko, 2010), (Akpe , 2007), (Olusola and Babafemi, 2013) and (Abang, 2012) 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, 2010), (Akpe, 2007), (Olusola and Babafemi, 2013), the compressive strength of concrete varies between 0.3N/mm2 and 22.97N/mm2 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/mm2 and 1.89N/mm2 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/mm2 which is above the minimum value of 17MPa for lightweight concrete. (Abang, 2012) 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.

2.5.2 Effect of Palm Kernel Shell Sizes and Mix Ratio on Concrete.

(Oyejobi et al., 2012) worked on the effect of palm kernel shell sizes and mix ratio on concrete. Concrete mixes of 1:1½:3, 1:2:4, 1:3:6 and 1:4:8 were used to produce cubes, beams and cylinders which were cured for 7, 14 and 28 days before testing. PKSC had density that was less than 2000 kg/m3 for a lightweight concrete. The results showed that concrete mix of 1:1½:3 with compressive strength of 20.1N/mm2 at 28 days hydration period met the British Standard recommended minimum strength of 15N/mm2 for structural lightweight concrete while other concrete mixes did not but they can also be employed as plain concrete. Results of tests on modulus of rupture and splitting tensile strength exhibited similar trend to that of compressive strength test. The nominal mix 1:1½:3 gave the highest values of modulus of rupture and splitting tensile strength.

2.5.3 Effect of Partial Replacement Coarse aggregate with Palm Kernel Shell (PKS) on Workability of Concrete.

(Mohamed et al. 2018), investigated the proportioning of mixture for oil palm kernel shell lightweight concrete with batch of 1:1.6:0.96 and 1:1.53:0.99 for C:S:OPKS ratio with cement content of 450 kg/m3 which yielded minimum slump of 20 mm, density within the range of 1800 and 1900 kg/m3 and minimum compressive strength of 15 N/mm2. (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/mm2 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 fiber (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 fiber 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/mm2 and 10.38N/mm2 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.

2.5.4 Effect of Partial Replacement Coarse aggregate with Palm Kernel Shell (PKS) on Compressive Strength of Concrete.

(Ndoke, 2006) in his work observed the performance of palm kernel shells as partial replacement for coarse aggregate in asphalt cement. According to (Teo et al., 2006), for structural concrete using oil palm shell (OPS) as light weight aggregate, the compressive strength of OPS concrete was 28.1MPa at 28days curing which is approximately 65% higher than the minimum required strength of 17MPa for structural light weight concrete recommended by American Standard of Testing Materials (ASTM 1330). (Mohammad et al., 2016) replaced nominal concrete constituents with agricultural solid wastes of oil palm shell (OPS) and oil palm fuel ash (OPFA) at 10–15% in a bid to produce a sustainable OPS lightweight concrete of enhance mechanical properties.

Increase in percentage addition of POFA led to subsequent decrease in flexural and split tensile strengths of OPSC but gave optimum sustainability performance at 10%. (Elnaz et al., 2016) developed an economical lightweight pervious concrete by replacing gravel sized 6.3–9.5 mm with palm kernel shell (PKS) sized 4.75–6.3 mm and 6.3–9.5 mm. In the same manner PKS was used to replace limestone from 25 to 75% to reduce cost. Results showed maximum compressive of12 N/mm2 and higher permeability values ranging from 4 to 6 mm/s which can be applied in parking lots and roads of light traffic.

Oyedepo et al. (2015) evaluated the performance of both coconut and palm kernel shells ash (CSA and PKSA) as cement replacements in concrete, adopting mix proportion of 1:2:4 and w/c of 0.63. Maximum compressive strengths of 15.4 N/mm2 and 17.26 N/mm2 was achieved at 20% cement replacement with PKSA and CSA while 10% cement substitution with CSA gave a compressive strength of 20.58 N/mm2 at 28 days. (Sachin et al., 2017) conducted an experiment on partial replacement of coarse aggregate with palm kernel shell in concrete. The ratio of these materials are 1: 1.5: 3 by volume batch and the dimension of the cube is 150mm x 150mm x 150mm and the size of coarse aggregate which is used are passed by 16 mm sieve and retained on 12.5mm sieve. Then the partial replacement of coarse aggregate is done by 5%,10%, 15%, 20%, and 25% and the testing of the cube is done on 7days, 14days, and 28days. This experiment gives the idea about the possible amount of weight reduction of concrete without heavily affecting the strength of concrete.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials, Sourcing and Preservation

The materials required for this research work are fine aggregate (sharp sand) designated as SD. Coarse aggregate (granite) designated as GT, additive (palm kernel shell) designated as PKS, ordinary Portland cement and water. The mode of sourcing and preservation of these materials are discussed below:

1.Cement:

The ordinary Portland cement designated as OPC used for this experiment is BUA cement. This cement was purchased at first market, Ifite-Awka in Anambra State. After buying it, the cement was carried to the school laboratory where it was stored in a cool dry place and prepared for various laboratory testing. The cement sample satisfied the requirements for use as the major component of concrete in that, it was not caked or baked through visual inspection and quick setting time.

2.Water:

The water sample used for this experiment was collected from Bakassi well in Nnamdi Azikwe University (UNIZIK), Awka, Anambra State. The water sample passed all the necessary requirement for use as a component of concrete based on the fact that it was colourless, odourless, devoid of suspended solid particles, contained infinitesimal trace of dissolved solid particles with no trace of turbidity after being subjected to tests in the laboratory.

3.Coarse Aggregate (Granite):

The granite samples designated as CA was gotten by me at a site which had finished construction and had leftover granite. The granite sample passed all the necessary physical test in that, it has high crushing strength, it is relatively large in size (within range of 4.75mm to 20mm) and is a representative of granite (chippings) in color. The granite was collected in 3 cement bags and was transported to the school laboratory via public transport. This granite sample collected is to be partially replaced with palm kernel shell (PKS).

4.Fine Aggregate (Sand):

The sand used in mixing the concrete was sharp sand which was gotten from a site at Ifite, Awka Anambra State. The sand sample was collected in 6 cement bags with the aid of shovel. The fine aggregate sample passed the necessary requirements for use as component of concrete due to the fact that it is gritty, with particle sizes visible to the naked eye. The sand sample after collection was taken to the school laboratory for various testing

5. **Palm Kernel Shell:**

The palm kernel shell to be used to replace the coarse aggregate was gotten from Egbagu, Amansea. It was being sold in cement bags, and I bought 3 cement bags filled with palm kernel shells and then carried them to school. At the laboratory, the palm kernel shell was sieved to remove impurities, after which it was dried for 2 days to eliminate water and any microbial activity on the shell surface.

Figure 3. 1 Palm Kernel Shells

3.2.Batching:

Due to the fact that the process of measuring the quantities of each material i.e. cement, fine and coarse aggregate and water in their relative proportion before they are mixed is known as batching. There are basically two methods of batching; by weight and by volume. This research made use of batching by weight, which involves the application of mathematical concept known as ratio to find out the requirement weight.

3.2.1 Batching Calculations

The volume of cement, sand, coarse aggregate and palm kernel shell, water base on the ratio of normal 1:2:4 mix.

The method of batching used here in this research is by weight.. The cement-aggregate ratio used in this work was 1:2:4. Palm kernel shell (PKS) were used to replace granite at specific levels of 5%, 10%, 15%, 20% and 25% replacement by weight of granite. The mix proportion was calculated below:

No of cubes per batch = 9

(i.e three cubes each for ages 7, 14 and 28 days test).

Note: Batch implies control mix (0% PKS Replacement, 5% PKS Replacement, 10% PKS

Replacement, 15% PKS Replacement, 20%Replacement and 25% PKS Replacement).

Size of each cube = 150mmx150mmx150mm

Volume of cube = $150^3 = 3.375 \times 10^{-3}\ m^3$

To Get the mass of concrete

Density x volume

Where density = 2400 (constant)

Volume = $3.375 \times 10^{-3} m^3$

2400 x 0.003375 = 8.1kg

The ratio used in this research is 1:2:4 = Cement: Sand: Granite

For Cement

Weight of Cement = $^{1}/_{7}$x 8.1 = 1.157kg

Therefore, Weight of cement for 9 cubes

1.157 x 9 cubes = 10.42kg

For Fine Aggregate (Sand)

Weight of Sand = $^{2}/_{7}$ x 8.1kg = 2.31kg

Therefore, Weight of Sand for 9 cubes

2.31 x 9 cubes = 20.79kg

For Coarse Aggregate

Weight of Coarse aggregate = $^{4}/_{7}$ x 8.1kg= 4.63kg

Therefore, Weight of Coarse aggregate for 9 cubes

4.63 x 9 cubes = 41.67kg

Water Cement Ratio

The water –cement ratio adopted in the course of the research was 0.6 and this was used to calculate the amount or weight of water required per batch.

Weight of water = 0.6 x weight of binder (cement)

$^{w}/_{1.16}$ = 0.6

w = 696L x 9 cubes = 6264L

Table 3 1Mix Design of Concrete

Constituents Materials	**Control 0% PKS**	**5% PKS**	**10% PKS**	**15% PKS**	**20% PKS**	**25% PKS**
Cement (Kg)	10.42	10.42	10.42	10.42	10.42	10.42
PKS (Kg)	0	2.083	4.167	6.251	8.335	10.418
Fine Aggregate (Kg)	20.79	20.79	20.79	20.79	20.79	20.79
Coarse Aggregate (Kg)	41.67	39.59	37.53	35.42	33.34	31.25
Water Cement Ratio (Litres)	6264	6264	6264	6264	6264	6264

3.3. Methods of Study

In the course of this project, various tests were carried out on the both the individual components of the concrete (sand, gravel, water and palm kernel shell) and the concrete mixture itself. Below are explanatory deescriptions of the experiments carried out.

3.3.1. Sieve Analysis

Sieve analysis is a procedure used to determine the particle size distribution of a granular material (sand, gravel). The size distribution is often of critical importance to the behaviour of the material during use. Sieve analysis can be performed on any type of non-organic or organic granular material including sand, crushed rock, clay, granite,3 feldspar and a wide range of manufactured powders, grains and seed down to minimum size depending on the exact method. The standard grain size analysis test determines the relative proportion of different grain sizes as they are distributed among certain size ranges.

The grain size analysis is widely used in classification of soils. The data obtained from the grain distribution curve is used in the design of filters for earth dams and to determine the suitability of soil for road construction, air field etc. Information obtained from grain size analysis can be used to predict soil water movement although permeability test are more generally used. Soil gradation is very important to geotechnical engineering; it is an indication of other engineering properties such as shear strength, compressibility and hydraulic conductivity. In a design, the gradation of the in-situ- soil help in the selection of filler material for the construction of highway embankment and it also controls the design and ground water drainage of site. A poorly graded soil (one with predominantly one-sized particle) will have better drainage property than the well graded soil (soil with varieties of particle sizes) because of the relatively higher magnitude of void present. A well graded can be easily compacted more than a poorly graded soil. However, most engineering project may have gradation requirement that must be satisfied before the soil is to be used is accepted for construction work. When options for ground remediation technique are to be considered the soil gradation is a controlling factor.

Soil possesses a number of physical characteristics which can be used as aid to identify it sizes in the field. A handful of soil rubbed through the finger can yield the following:

1. Sand and other coarser particle are visible to the naked eye.

2. Silt particle becomes dusty and are easily brushed off.

3. Clay particle are greasy and sticky when wet and hard when dry and have to be scrapped or washed off hand and boot.

For a soil to be well graded the value of coefficient of uniformity (Cu) has to be greater than 4 and 6 for gravel and sand respectively, while the Coefficient of Curvature (Cv) should be in the range of 1 to 3.

Apparatus

The apparatus needed for this experiment are listed below:

1.Mechanical sieve shaker.

2. Stack of sieves including pan and cover

3. Weighing balance of 0.01g sensitivity.

4. Hand brush.

5. Mortar and pestle (Used for crushing if the sample is conglomerated or lumped)

6. Thermostatically controlled Oven (With temperature of about 80OC-110OC).

7. Masking tape for identification of sample.

8. The calculation for attaining Coefficient of uniformity and Coefficient of curvature are outlined below.

Percentage retained (%) = $\frac{\text{mass of soil retained in the sieve(g)}}{\text{total mass of soil sample}} \times 100$

Cumulative percentage retained = $\sum Percentage\ retained$ (%)

Cumulative Percentage Finer (%) = 100-Cummulative percentage retained.

Coefficient of Curvature =$D60$

$D10$

Coefficient of Uniformity = $(D30)^2$

$D10 \times D60$

Where

D10= particle size such that 10% of the soil is finer than the size

D30= particle size such that 30% of the soil is finer than the size.

D60= particle size such that 60% of the soil is finer than t

Figure 3. 2 Mechanical Sieve Shaker

TEST PROCEDURE

1. The stack of sieves to be used for the experiment should be cleaned properly, using hand brush.

2. About 500g of air-dried soil sample is weighed on a weighing balance.

3. The weighed soil sample is poured into the 75um sieve and washed under a steady supply of water

until clear water start coming out from the sieve after passing through the soil sample.

4. After washing, the washed soil sample is poured into a pre-weighed plate and dried inside the

thermostatically controlled oven at a controlled temperature of 80-110OC for 16-24hrs.

5. The sample is removed from the oven and its weight (net weight) is determined by deducting the weight of plate from the weight of plate and soil.

6. The stacks of sieve are arranged in ascending order, and placed in the mechanical sieve shaker,

After which the sample is poured and connect the shaker for about 10-15 minute.

7. The sieve shaker is disconnected and the mass retained on each of the sieve sizes is determined.

8. Determine the percentage retained, Cumulative percentage retained and Cumulative

percentage finer.

9. Plot the graph of sieve Cumulative percentage finer against sieve sizes.

10. Determine D10, D30 and D60 from the plotted graph.

11. Determine the Coefficient of Curvature and Coefficient of Uniformity and classify the

soil using the American Association of State Highway and Transportation Official

(AASHTO) and Unified Soil Classification System (USCS) respectively.

3.3.2 Specific Gravity for Fine Aggregate

Specific gravity is the ratio of mass of unit volume of soil at a stated temperature to mass of equal volume of gas-free distilled water at the same temperature (Krishna, 2002). Also as defined by (Braja, 2006), Specific gravity can be defined as the ratio of unit weight of a material to unit weight of water. The specific gravity of soil solids is often needed for various calculations in soil mechanics. It can be determined accurately in the soil laboratory.

The apparatus employed for this experiment includes:

1. Density bottle of 50ml capacity and a stopper.

2. Desiccator containing anhydrous silica gel.

3. Thermostatically controlled oven with temperature of about 80-110OC.

4. Weighing balance of 0.01g sensitivity.

5. Mantle heater.

6. Plastic wash bottle.

7. Distilled water.

8. Funnel

9. Thin glass rod for stirring.

10. 425um Sieve.

11. Dry piece of cloth for cleaning.

12. Masking tape for identification of sample.

13. Exercise book and pen for recording of result

3.3.3 Specific Gravity Test for Coarse Aggregate (Granite).

The specific gravity of aggregate is defined as the ratio of aggregate to the weight of equal volume of water. The specific gravity of an aggregate is considered to be a measure of strength or quality of the material. Aggregate having low specific gravity is generally weaker than those with high specific gravity. This property helps in general identification of aggregate.

APPARATUS USED.

1. Wire mesh Bucket or perforated container of convenient sizes with thin wire hangers for suspending it from a balance.

2. Pycnometer of 1000ml.

3. Set up consisting of container for filling water and suspending the wire basket in it and airtight container of capacity similar to that of a bucket, a shallow tray, two dry absorbent clothes.

TEST PROCEDURE

1. About 2 kg of aggregate sample is taken, washed to remove fines and then placed in the wire basket. The wire basket is then immersed in water, which is at a temperature of 22^0C to 320C.

2. Immediately after immersion the entrapped air is removed from the sample by lifting the basket 2mm above the base of the tank and allowing it to drop, 25 times at a rate of about one drop per second.

3. The basket, with aggregate are kept completely immersed in water for a period of 24 ± 0.5 hour.

4. The basket and aggregate are weighed while suspended in water, which is at a temperature of 22^0Cto 32^0C.

5. The basket and aggregates are removed from water and dried with dry absorbent cloth.

6. The surface dried aggregates are also weighed.

7. The aggregate is placed in a shallow tray and heated to about 1100C in the oven for 24 hours. Later, it is cooled in an airtight container and weighed.

3.3.4. Water Absorption on Aggregate Test.

Water absorption test gives an idea on the internal structure of aggregate. Aggregates having more absorption are more porous in nature and are generally considered unsuitable, unless found to be acceptable based on strength, impact and hardness test.

APPARATUS REQUIRED

1 Wire mesh bucket of not more than 6.3mm mesh or a perforated container of convenient sizes with thin wire hangers for suspending it from the balance.

2 Set up of water absorption which consists of container for filling water and suspending the wire basket in it and an airtight container of capacity similar to that of the basket, a shallow tray and two dry absorbent clothes.

TEST PROCEDURE

1. About 2 kg of aggregate sample is taken, washed to remove fines and then placed in the wire basket. The wire basket is then immersed in water, which is at a temperature of 220C to 320C.
2. Immediately after immersion the entrapped air is removed from the sample by lifting the basket 25mm above the base of the tank and allowing it to drop, 25 times at a rate of about one drop per second.
3. The basket, with aggregate are kept completely immersed in water for a period of 24 ± 0.5 hour.
4. The basket and aggregate are weighed while suspended in water, which is at a temperature of 220C to 320C.
5. The basket and aggregates are removed from water and dried with dry absorbent cloth.
6. The surface dried aggregates are also weighed.

7. The aggregate is placed in a shallow tray and heated to 100 to 1100C in the oven for 24 ± 0.5 hours.

Later, it is cooled in an airtight container and weighed.

Calculation for water absorption

1. Weight of saturated aggregates in air: = W1

2. Weight of oven dry aggregates in air: = W2

Water Absorption (%) = (W1 – W2)/W2 x 100

3.3.5. Compressive Strength Test of Concrete Cubes

Compressive strength test is used to determine the mechanical strength of concrete to sustain the axial force applied on the surface of concrete. Compressive strength is the major parameter which influences other properties of concrete such as flexural strength, splitting tensile strength and modulus of elasticity. To evaluate the effect of replacement of coarse aggregate with palm kernel shell on the compressive strength of concrete, plain control concrete is compared with five concrete batch mixes containing different percentages of palm kernel shell aggregates (PKSA).

The apparatus required for this test include:

1. Testing Machine - The testing machine may be of any reliable type (usually known as Universal Testing Machine), of sufficient capacity for the tests and capable of applying the load at the rate specified in 5.5. The allowable error shall be not greater than ± 2 percent of the maximum load.

2. Moulds :- The size of the mould used was 150mm x 150mm x 150 mm size conforming to IS:10086-1982.

3. Weights and weighing device

4. Tools and containers for mixing

5. Tamper (square in cross section)

TEST PROCEDURE

1.A given quantity of cement and fine aggregate were place on a tray and mixed thoroughly.

2. Another given quantity of coarse aggregate after being sieved to it selected size (19mm) was added to the already mixed fine aggregate and cement and then mixed thoroughly until the coarse aggregate was uniformly distributed throughout the batch.

3. A required water-cement ratio was added and then mixed until the concrete appears to be homogeneous and of the desired consistency.

4.The concrete cubes mould was cleaned and the internal surface and base was greased uniformly.

5.After a thorough mix, the fresh concrete was placed in the cube mould in three layers and tapped with a tamping rod for 25 strokes per layer.

6. The tamping of the strokes were done in such a way as to distribute the concrete evenly within the mould and to remove the void spaces that may have been trapped in the concrete mix.

7. After tamping was done, the top surface of the concrete was leveled and smoothened by using the trowel or knife edge.

8. The concrete was left to set for a duration of 24hours.

9. After 24hours setting, the concrete cubes were removed from the mould and placed into the curing tank at a temperature of 27°± 2°C and cured for 7, 14, 28days respectively.

10. After 7 days, three cubes each from the three different samples were removed from the curing tank and dried with sunlight.

11. After drying, the cubes were weighed with the weighing balance, then crushed with the crushing machine and the reading was obtained and recorded. The bearing surfaces of the testing machine shall be wiped clean and any loose sand or other material removed from the surfaces of the specimen which are to be in contact with the compression plates.

12. In the case of cubes, the specimen shall be placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast, that is, not to the top and bottom

13. The axis of the specimen shall be carefully aligned with the centre of thrust of the spherically seated platen. No packing shall be used between the faces of the test specimen and the steel platen of the testing machine.

14. The load shall be applied without shock and increased continuously at a rate of approximately 140 kg/sq cm/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained.

15. The maximum load applied to the specimen shall then be recorded and the appearance of the concrete and any unusual features in the type of failure shall be noted.

The compressive strength of concrete cube is computed as follows:

Compressive Strength (N/mm^2) = $Applied\ load\ (N)$ / $Area\ of\ Cube\ (mm \times mm)$

Where applied load (N) = Force

Now conversion of applied load from Ton force to KN or N.

1 Ton force = 10kN or 10,000N.

For 220kN = 220× 1000 = 220,000N

Area of cube = 150mm×150mm = 22,500mm2

Compressive Strength = 220,000N / 22,500mm^2 = 9.78N/mm

Figure 3. 3 Concrete cubes in mould

Figure 3. 4 Crushing of the concrete cubes

3.3.6. Slump Test (Workability Test)

Slump test measures the degree of concistency of fresh concrete before setting. It is very useful in calculating and checking the uniformity of batch improperly mixed. It is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work. It is not a suitable method for very wet or very dry concrete. It does not measure all factors contributing to workability. However, it is used conveniently as a control test and gives an indication of the uniformity of concrete from batch to batch.

The apparatus employed for conducting Slump test include:

1. Slump Cone: Metallic Mould in form of frustum of a cone (Internal dimension are 20cm for bottom diameter, 10cm for top diameter and 30cm for height).

2. A steel tamping rod (16mm diameter)

3. Trowel

4. Measuring Cylinder

5. Porcelain evaporating dish.

Figure 3. 5 Slump cone

Figure 3. 6 100ml Measuring Cylinder

TEST PROCEDURE

1. The internal surface of the mould is cleaned thoroughly (this is done in order to prevent moisture and adherence of old set concrete).

2. The mould is placed on the base plate or alternatively on any smooth, horizontal, rigid and non-absorbent surface.

3. The various component of the concrete are measured and mixed depending on the concrete grade and mix ratio to be used.

4. The mixed concrete is divided into 3 layers such that each layer is approximately one-third the height of the mould.

5. Each layer is placed into the mould and tamped for 25 times (given 25 blows) using the tamping rod, taking care to distribute the stroke evenly over the cross section.

6. After tamping each layer consecutively, use a trowel and tamping rod to strike off level the rodded concrete at the top layer of the mould.

7. The mould is removed from the concrete by raising it slowly and carefully in a vertical direction. Immediately the concrete will subside and the subsidence is referred to as the SLUMP of the concrete.

The difference in height between the height of the mould and the average value of the subsidence was measured and is referred to as slump value of concrete.

Figure 3. 7 Measurement of slump.

CHAPTER FOUR

RESULTS AND DISCUSSION

Table 4. 1 Physical Properties of the various materials used in the laboratory test

Properties	**CA**	**SD**	**PKS**
Specific gravity	2.68	2.62	2.28
Water absorption	1.48	–	17.58
Coefficient of uniformity	1.8	2.78	1,03
Coefficient of curvature	1.3	0.81	0.97
Gradation	GP	SP	SP
Percentage passing sieve size 4.75mm	0.16	–	2.34
Percentage passing sieve size 0.075mm	–	0.96	–
AASHTO Classification system	A-1-b	A-2-4	A-1-b
USCS classification system	GM	SC	GM

Table 4. 2 Slump Test Value for CA + PKS Concrete at 0.6w/c ratio.

Percentage Replacement of PKS (%)	**Slump Value (mm)**	**Slump Type**
0	53	Shear slump
5	66	Shear slump
10	74	Shear slump
15	85	Shear slump

20	94	Shear slump
25	104	Shear slump

Table 4. 3 Compressive Strength Test Result for Concrete Cubes grade 1:2:4 for 0%PKS

Cube No.	**Weight (kg)**	**Age (days)**	**Mix ratio**	**Load (KN)**	**Compressive Strength (N/mm^2)**	**Average Compressive Strength (N/mm^2)**
OC7 A	8.1	7	1:2:4	287.36	12.8	
OC7 B	8.1			267.84	11.9	12.0
OC7 C	8.2			257.54	11.4	
OC14A	8.1	14	1:2:4	388.64	17.2	
OC14B	8.0			411.20	18.3	17.7
OC14C	8.3			397.81	17.7	
OC28A	8.0	28	1:2:4	559.67	24.8	
OC28B	8.1			544.37	24.1	25
OC28C	8.0			587.44	26.1	

Table 4. 4 Compressive Strength Test Result for Concrete Cubes grade 1:2:4 for 5%PKS

Cube No.	**Weight (kg)**	**Age (days)**	**Mix ratio**	**Load (KN)**	**Compressive Strength (N/mm^2)**	**Average Compressive Strength (N/mm^2)**
OC7 A	8.0	7	1:2:4	234.37	10.4	
OC7 B	8.1			257.54	11.4	10.8
OC7 C	8.0			239.26	10.6	

OC14A	8.1	14	1:2:4	364.57	16.2	
OC14B	8.0			374.11	16.6	16.8
OC14C	8.0			394.34	17.5	
OC28A	8.0	28	1:2:4	498.45	22.2	
OC28B	8.1			489.68	21.8	22.1
OC28C	8.0			501.20	22.3	

Table 4. 5 Compressive Strength Test Result for Concrete Cubes grade 1:2:4 for 10%PKS

Cube No.	Weight (kg)	Age (days)	Mix ratio	Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
OC7 A	7.9	7	1:2:4	240.85	10.7	
OC7 B	7.7			248.47	11.0	10.6
OC7 C	7.9			230.19	10.2	
OC14A	7.8	14	1:2:4	345.28	15.3	
OC14B	8.0			328.56	14.6	15.2
OC14C	8.0			356.31	15.8	
OC28A	7.9	28	1:2:4	402.10	17.9	
OC28B	8.1			413.55	18.4	18
OC28C	7.8			398.14	17.7	

Table 4. 6 Compressive Strength Test Result for Concrete Cubes grade 1:2:4 for 15%PKS

Cube No.	Weight (kg)	Age (days)	Mix ratio	Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
OC7 A	7.5	7	1:2:4	241.57	10.7	
OC7 B	7.4			220.11	9.8	10.1
OC7 C	7.9			225.67	10.0	
OC14A	7.6	14	1:2:4	328.56	14.6	
OC14B	7.8			309.26	13.7	14.1
OC14C	7.9			318.34	14.1	
OC28A	7.9	28	1:2:4	365.34	16.2	
OC28B	7.8			349.13	15.5	15.6
OC28C	7.6			339.72	15.1	

Table 4. 7 Compressive Strength Test Result for Concrete Cubes grade 1:2:4 for 20%PKS

Cube No.	Weight (kg)	Age (days)	Mix ratio	Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
OC7 A	7.5	7	1:2:4	220.10	9.8	
OC7 B	7.6			209.23	9.3	9.3
OC7 C	7.8			201.31	8.9	
OC14A	7.4	14	1:2:4	294.45	13.1	
OC14B	7.3			299.86	13.3	13.5
OC14C	7.4			321.47	14.2	
OC28A	7.4	28	1:2:4	342.14	15.2	

OC28B	7.5			331.74	14.7	15
OC28C	7.4			340.77	15.1	

Table 4. 8 Compressive Strength Test Result for Concrete Cubes grade 1:2:4 for 25%PKS

Cube No.	**Weight (kg)**	**Age (days)**	**Mix ratio**	**Load (KN)**	**Compressive Strength (N/mm^2)**	**Average Compressive Strength (N/mm^2)**
OC7 A	7.3	7	1:2:4	169.21	7.5	
OC7 B	7.4			165.62	7.4	7.8
OC7 C	7.5			192.79	8.6	
OC14A	7.4	14	1:2:4	287.49	12.7	
OC14B	7.3			281.97	12.5	12.5
OC14C	7.6			278.94	12.4	
OC28A	7.5	28	1:2:4	299.86	13.3	
OC28B	7.4			292.43	13.0	13.2
OC28C	7.4			302.45	13.4	

ANALYSIS OF TEST RESULTS

4.2.1 Particle Size Distribution (Sieve Analysis)

The figure below (Figure 4.1) shows the semi logarithmic graph of the particle size distribution of the CA, SD and PKS. Results derived indicate that for CA, the percentage passing through 4.75mm is 0.16 and according to AASHTO, is classified as A-1-b and the constituent material therefore constitutes an excellent sub-grade material. According to USCS, it is classified as GM (Gravelly mixed with silt sized particles i.e Silty gravel). For SD, the percentage passing through sieve size 0.075mm is 0.91 and according to AASHTO Classification system, it is classified as A-2-4 and SC (clayey sand) according to USCS Classification system. This material constitutes a good sub-grade material for road construction. While the percentage passing sieve size 4.75mm for the additive (PKS) is 2.34 and according to AASHTO, it is categorized as A-1-b and GM (gravel mixed with silt). It can be deduced from the findings that the coarse aggregate (CA) is of larger size compared to the additive (PKS) since lower percentages is passes through sieve size 4.75mm. The gradation of CA, SD and PKS obtained from their respective shape parameters (Cu and Cc) shows that they are poorly graded.

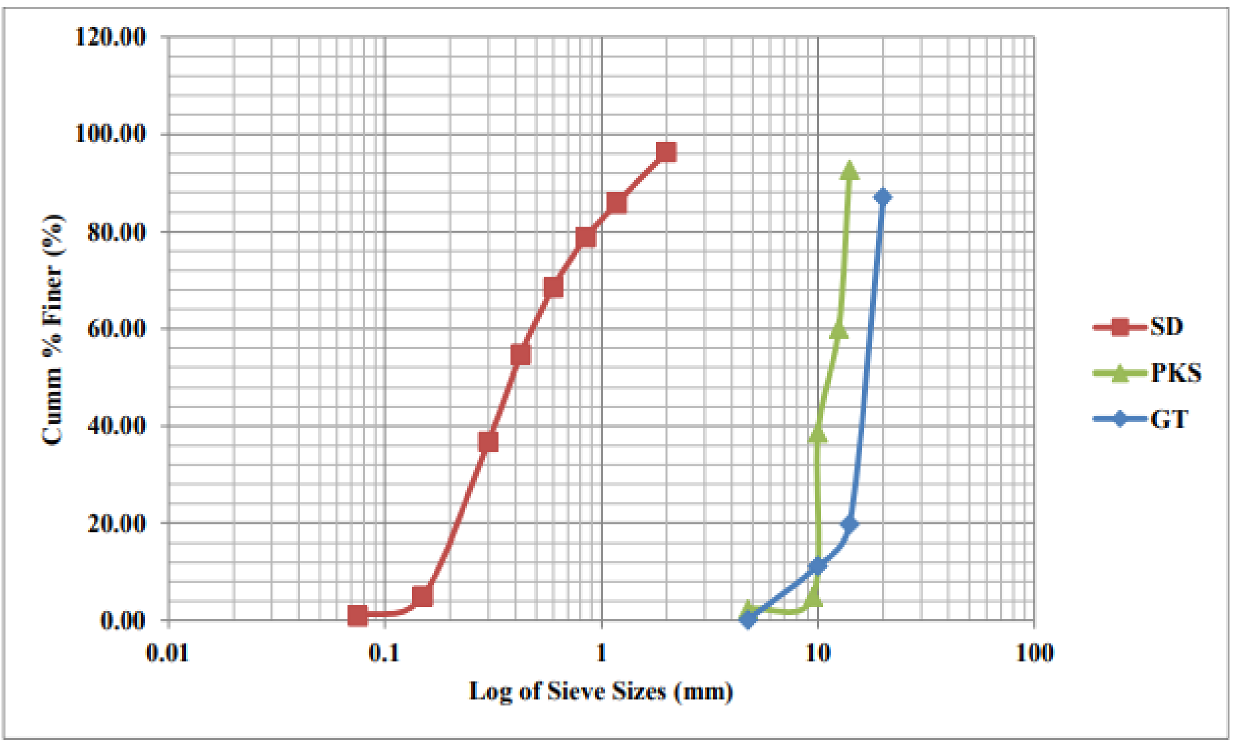

Figure 4. 1 Particle Size Distribution Curve for aggregate (SD and GT) and additive (PKS).

4.2.2 Specific Gravity Test.

Specific gravity is a measure of density relative to the density of a reference substance. The reference material could be anything, but the most common reference is pure water; it is used to obtain the unit weight of construction materials in the presence of water. Specific gravity tests were carried out in accordance to ASTM D854-14 specification. For the aggregates referred as SD and CA and the additive (palm kernel shell) designated as PKS, the average apparent specific gravity computed are 2.61, 2.69 and 2.27 respectively. The range of specific gravity from 2.58 to 2.62 obtained for SD and GT satisfies ASTM D854-14 requirement which states that the specific gravity of aggregates should be between 2.55 to 2.9 and therefore justifies the use of the aggregates for this work. The Federal Ministry of work Standard Specification for roads and bridges (1997) states that a good sub-grade material should have specific gravity value ranging from 2.5 to 2.75. The values obtained also suggest that CA and SD satisfy this requirement. From the specific gravity test result, it can also be inferred that the additive (PKS) with a lower specific gravity value (2.29) have a low unit weight in the presence of water and this can be attributed to the degree of voids present in the additive.

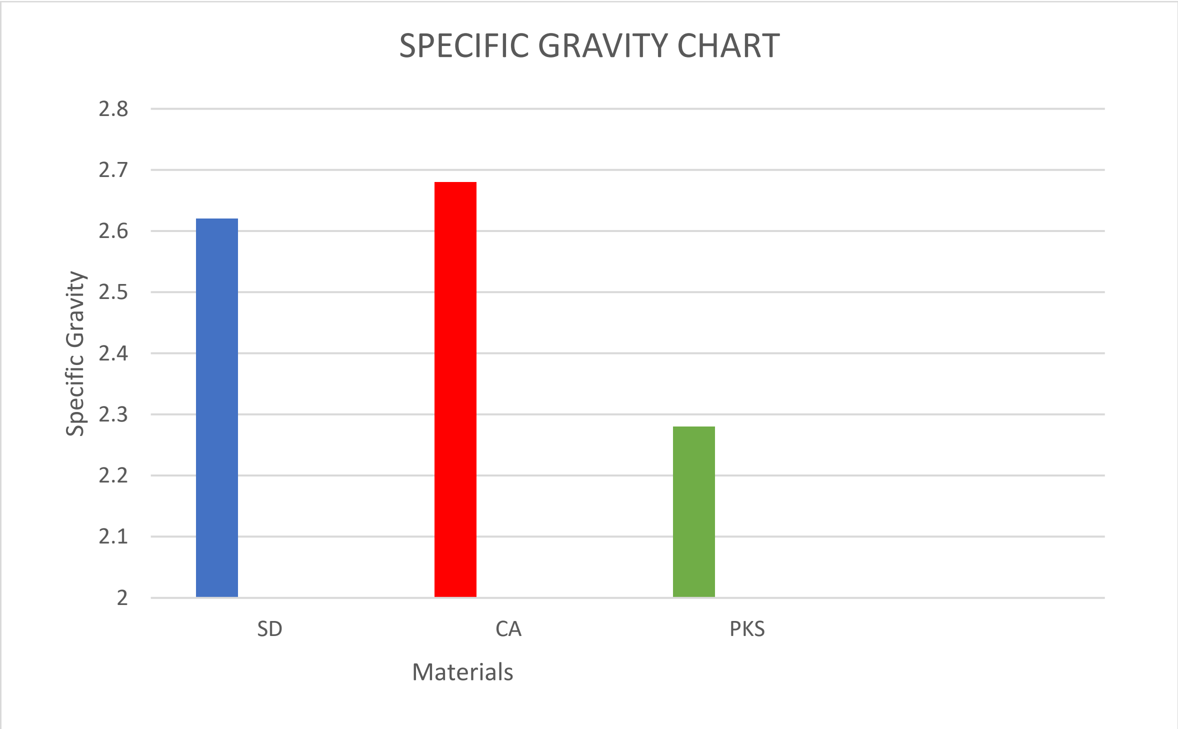

Figure 4. 2 Specific Gravity Chart for Aggregate (SD and CA) and Additive (PKS)

4.2.3 Water Absorption Test.

Water absorption is defined as the transport of liquids in porous solids caused by surface tension acting in the capillaries (Basheer, 2001). It is conducted to ascertain the amount of voids present in a material as materials with large voids have high water absorption capacity. From the findings obtained, the water absorption capacity of GT and PKS are 1.44 and 17.07 respectively. This result is evident to the internal structure of both GT and PKS as the additive (PKS) contains higher voids than GT which makes it unsuitable for constructional purposes. This result is in correlation/ association with previous researches conducted by (Azuna, 2019), (Amu, 2008) and (Ndoke, 2006) where the absorption capacity of PKS was assessed.

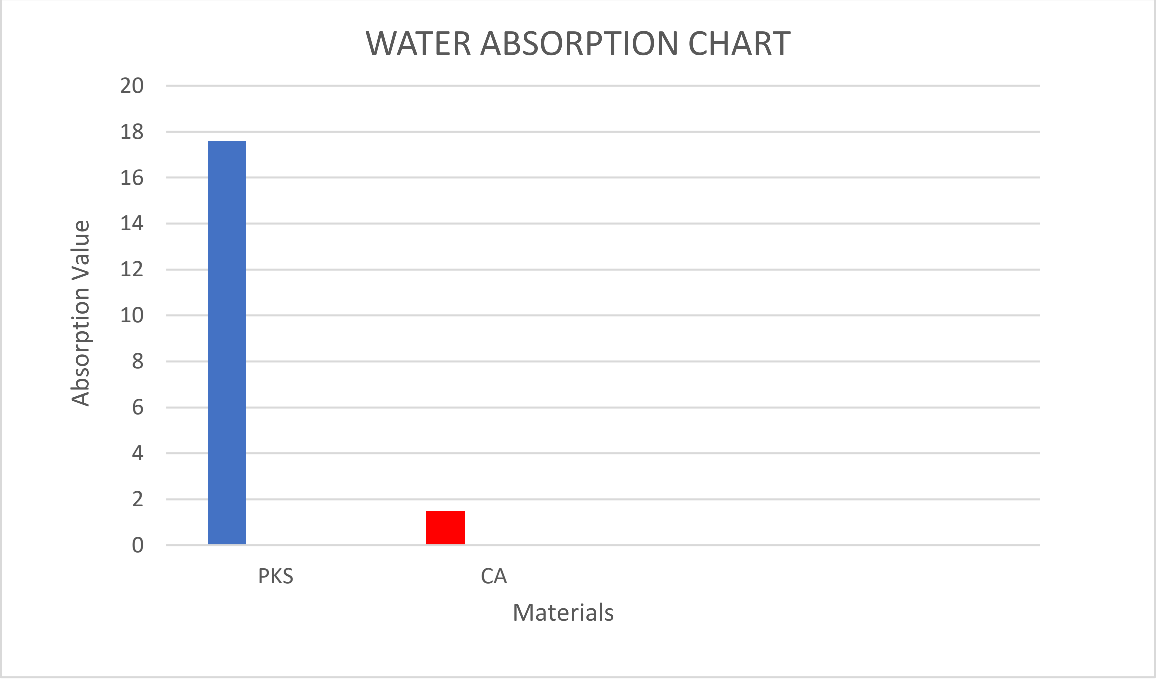

Figure 4. 3 Water absorption Chart for Coarse aggregate (GT) and Additive (PKS).

4.2.4. Slump (Workability Test)

The table below (Table 4.4) presents the slump test result of SD-PKS concrete. Slump test was carried out to check the effect of PKS on the workability of fresh concrete. The test was carried out in accordance with the requirements of BSEN, (1995). From the results gotten, it was denoted that the slump value increases with constant addition of palm kernel shell from 5% to 25%, using a water/cement ratio of 0.6, with the highest slump value gotten at 25% replacement of coarse aggregate with palm kernel shell. This result suggests that increase in PKS up to 25% increases the workability of the concrete. The type of slump formed by the freshly mixed concrete is known as shear slump, this is because one-half of the concrete slides down in an inclined plane. This finding is in agreement with previous research conducted on the effect of complete replacement of coarse agreement with PKS on concrete by (Azuna, 2019) but lack correlation with the works of Mannan and Ganapathy (2001) where relatively low slump value was recorded.

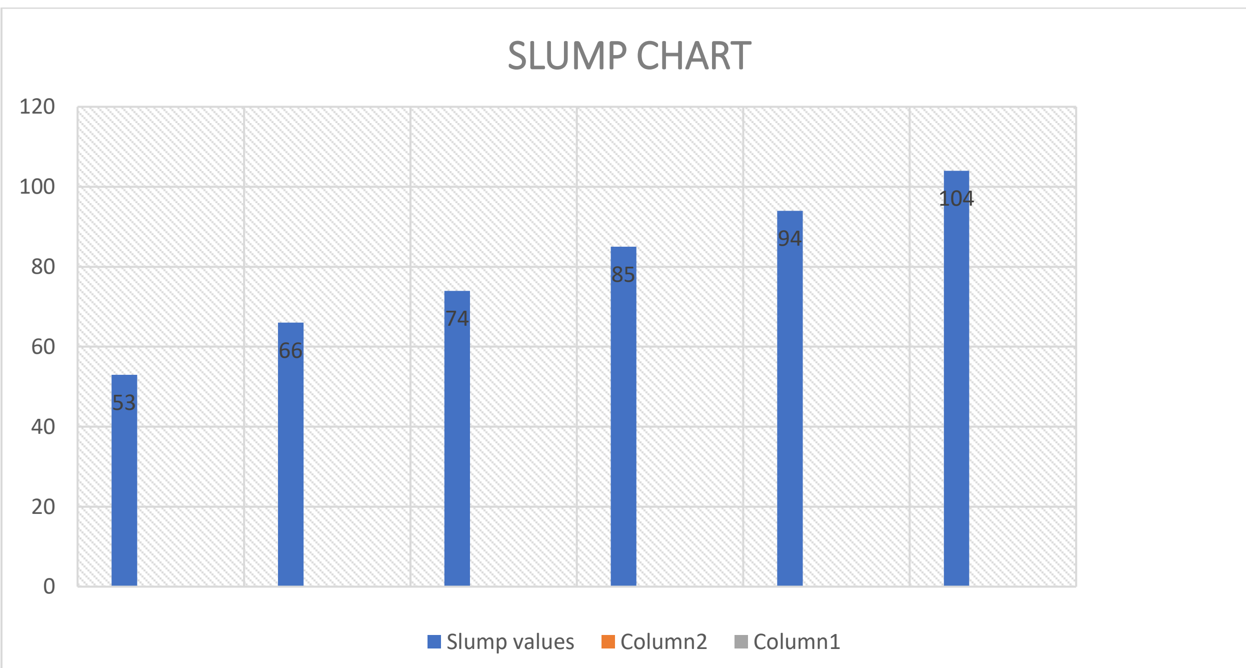

***Figure 4. 4 Slump Value Chart for GT + PKS Concrete*.**

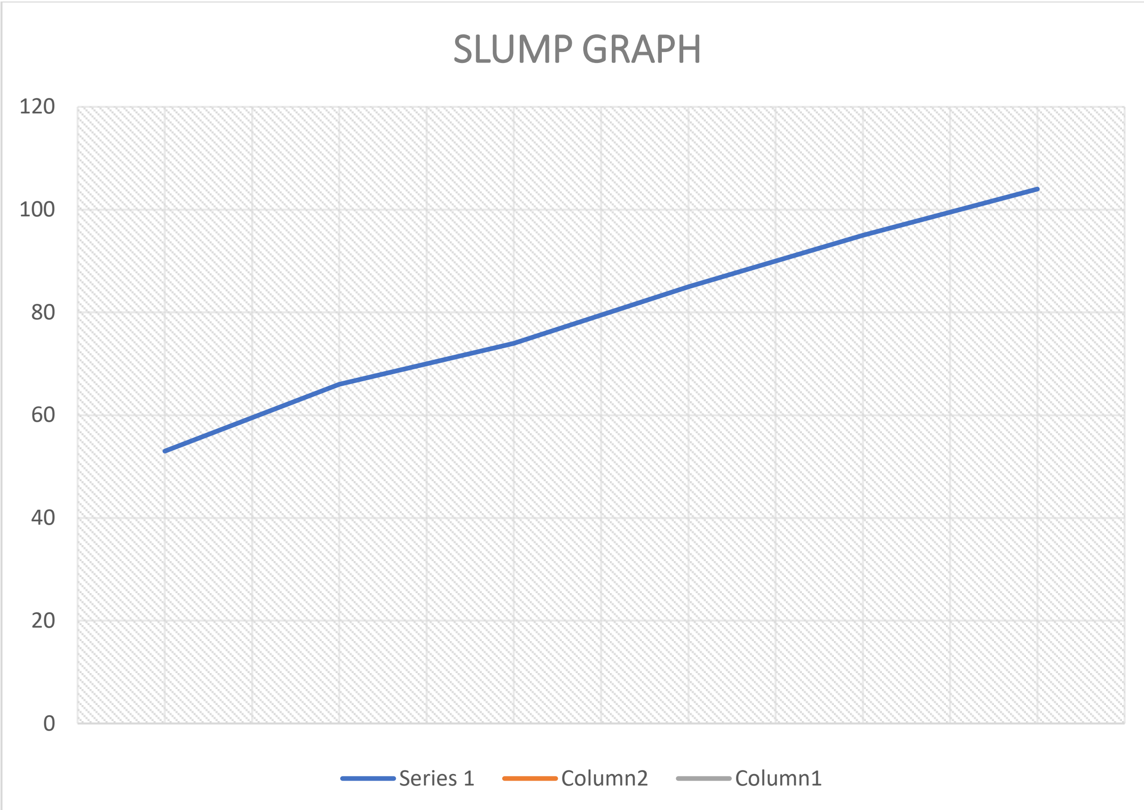

***Figure 4.4. 1 Slump Value Graph for GT + PKS Concrete*.**

4.2.5. Compressive Strength Test.

The results gotten from the compressive strength test carried out in the laboratory on the various concrete cubes are given in the chart and graph below (Figure4.5.1 & 4.5.2) Results presented in the tables show that the compressive strength of concrete increases with curing age. There is a decrease in the compressive strength of the concrete cubes with the increase in palm kernel shell as a replacement for coarse aggregate.

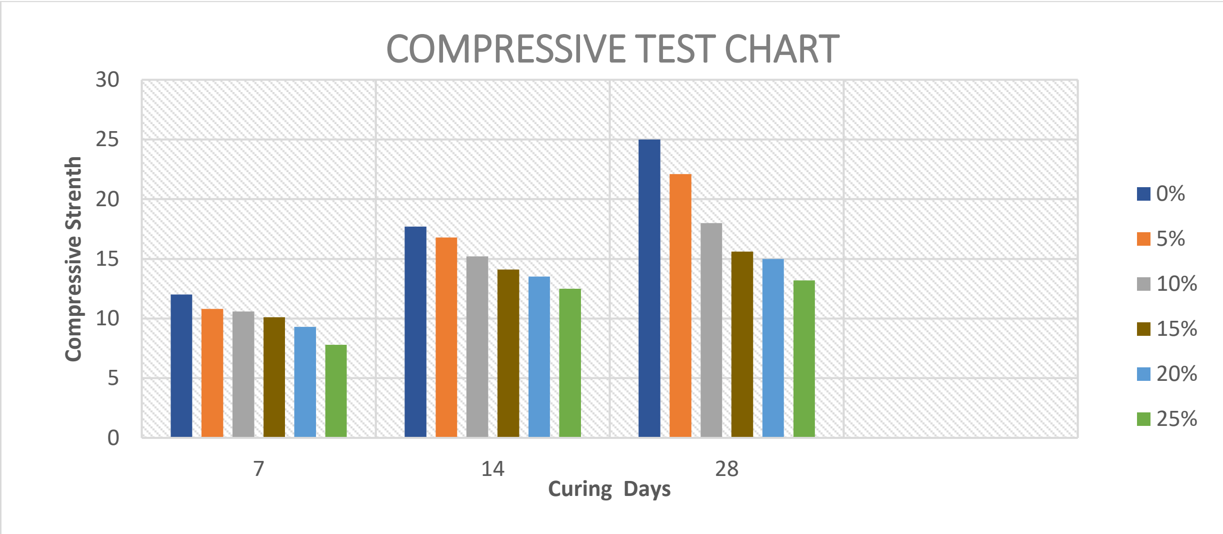

Figure 4.5, 1 Chart Showing the Compressive Strength against Curing days for GT + PKS Concrete

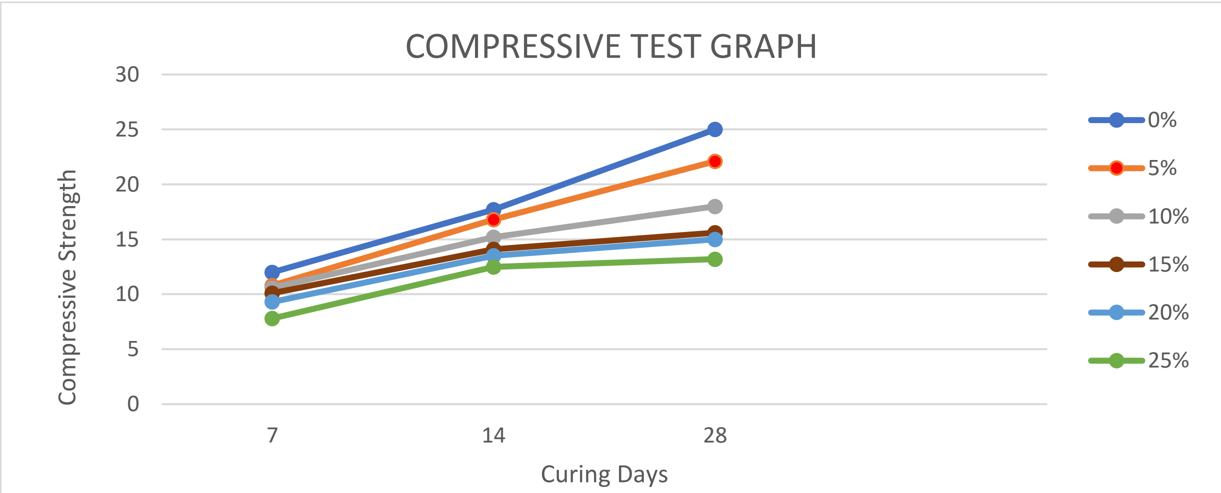

Figure 4.5, 2 Graph Showing the Compressive Strength Value against Curing days for GT + PKS Concrete

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Below, are the conclusions drawn from the research carried out on the use of palm kernel shell for partial replacement of coarse aggregate:

1). The Sieve analysis results shows that for CA, the percentage passing through 4.75mm is 0.16 and according to AASHTO, it is classified as A-1-b and the constituent material constitutes an excellent sub-grade material. According to USCS, it is classified as GM (Gravelly mixed with silt sized particles i.e Silty gravel). For SD, the percentage passing through sieve size 0.075mm is 0.96 and according to AASHTO Classification system, it is classified as A-2-4 and SC (clayey sand) according to USCS Classification system. This material constitutes a good sub-grade material for road construction. While the percentage passing sieve size 4.75mm for the additive (PKS) is 2.34 and according to AASHTO, it is categorized as A-1-b and GM (gravel mixed with silt The gradation of CA, SD and PKS obtained from their respective shape parameters (Cu and Cc) shows that they are poorly graded.

2). The specific gravity tests were conducted in accordance to ASTM D854-14 specification. For the aggregates designated as SD and CA and the additive (palm kernel shell) designated as PKS, the average apparent specific gravity computed are 2.62, 2.68 and 2.28 respectively.The range of specific gravity from 2.58 to 2.62 obtained for SD and GT satisfies ASTM D854-14 requirement which states that the specific gravity of aggregates should be between 2.55 to 2.9 and therefore justifies the use of the aggregates for this work.

3). The water absorption test conducted, indicate that the water absorption capacity of GT and PKS are 1.48 and 17.58 respectively. This result is evident to the internal structure of both GT and PKS as the additive (PKS) contains higher voids than CA which makes it unsuitable to be used individually for constructional purposes.

4). The slump test result recorded indicate that the slump value increases with consistent addition of the additive (PKS) from 5% to 25% at w/c ratio of 0.6 with the highest slump recorded at 25% partial replacement of GT. This result suggests that increase in PKS up to 25% increases the workability of the concrete. The slump type formed by the fresh CA + PKS concrete is classified as shear slump since the slump value exceed 40mm.

5). The results obtained from the compressive strength test performed on the hardened concrete cubes shows that the compressive strength of concrete increases with curing age. From the result of compressive strength against percentage replacement of PKS content, it was observed that the compressive strength of the hardened concrete decreased.

5.2 Recommendation.

1). This research advises against the use of Palm kernel shell (PKS) as partial substitute for coarse aggregate in concrete beyond 15% since the compressive strength of the concrete decreases significantly after this point.

2). The concrete replacement of 5%, 10% and 15% yields concrete which is suitable to be used for house slabs, footings and footpaths, and other non structural works.

3). The recommendation should be subject to further research in order to find out if other materials can be added to palm kernel shells in other to improve the compressive strength of concrete.

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APPENDIX A

Table A 1 Specific Gravity Result for Sand.

Determinants	**Test 1**	**Test 2**	**Test 3**
Wt of density bottle, W1 (g).	24.07	25.73	25.90
Wt of bottle + dry soil, W2 (g)	34.08	35.71	35.90
Wt of bottle + soil + water, W3 (g).	78.89	83.04	85.,79
Wt of bottle + water, W4 (g).	72.75	76.89	79.56

The Specific gravity of the sample is calculated as follows:

Test 1 $= \frac{W2-W1}{(W2-W1)-(W3-W4)} = \frac{34.08-24.07}{(34.08-24.07)-(78.89-72.75)} = 2.57$

Test 2 $= \frac{W2-W1}{(W2-W1)-(W3-W4)} = \frac{35.71-25.73}{(35.71-25.73)-(83.04-76.89)} = 2.61$

Test 3 $= \frac{W2-W1}{(W2-W1)-(W3-W4)} = \frac{35.90-25.90}{(35.90-25.90)-(85.79-79.56)} = 2.68$

Specific Gravity $= \frac{Gs1+Gs2+Gs3}{3} = \frac{2.57+2.61+2.68}{3} = 2.62$

Table A 2 Specific Gravity Result for Crushed Granite

Determinants	Test 1	Test 2	Test 3
Wt of Saturated aggregate and basket in water W1 (g)	458.61	472.1	502.12
Wt of basket in Water W2 (g).	190.48	183.74	184.55
Wt of Saturated aggregate in air W3 (g)	436.62	434.24	440.22
Wt of Oven-dried aggregate in air W4 (g).	427.24	432.42	434.86

The Specific gravity of the sample is calculated as follows

Test 1 = $\frac{W4}{W4-(W1-W2)} = \frac{427.24}{427.24-(458.61-190.48)} = 2.68$

Test 2 = $\frac{W4}{W4-(W1-W2)} = \frac{432.42}{432.42-(472.1-183.74)} = 2.65$

Test 3 = $\frac{W4}{W4-(W1-W2)} = \frac{434.86}{434.86-(502.12-184.55)} = 2.72$

Specific Gravity = $\frac{Gs1+Gs2+Gs3}{3} = \frac{2.68+2.65+2.72}{3} = 2.68$

Table A 3 Specific Gravity Result for PKS

Determinants	Test 1	Test 2	Test 3
Wt of Saturated aggregate and basket in water W1 (g)	334.8	311.60	304.17
Wt of basket in Water W2 (g).	149.12	145.61	142.47
Wt of Saturated aggregate in air W3 (g)	367.88	342.11	334.68
Wt of Oven-dried aggregate in air W4 (g).	320.77	298.24	296.42

The Specific gravity of the sample is calculated as follows:

Test 1 $=\frac{W4}{W4-(W1-W2)} = \frac{320.77}{320.77-(334.8-149.12)} = 2.37$

Test 2 $=\frac{W4}{W4-(W1-W4)} = \frac{298.24}{298.24-(311.60-145.61)} = 2.26$

Test 3 $=\frac{W4}{W4-(W1-W2)} = \frac{296.42}{296.42-(304.17-142.47)} = 2.20$

Specific Gravity $= \frac{Gs1+Gs2+Gs3}{3} = \frac{2.37+2.26+2.20}{3} = 2.28$

APPENDIX B

WATER ABSORPTION TEST

Water absorption = $\frac{\boldsymbol{W1-W2}}{\boldsymbol{W2}}\ \boldsymbol{x}\ 100$

Where W1 = Weight of Saturated aggregate in air

W2 = Weight of oven-dried aggregate in air

For Coarse Aggregate :

W1 = 19.17g

W2 = 18.89g

∴ Water absorption = $\frac{\mathbf{19.17-18.89}}{\mathbf{18.89}}\ \boldsymbol{x}\ 100$ = 1.48

For Palm Kernel Shell:

W1 = 19.4

W2 = 16.5

∴ Water absorption = $\frac{\mathbf{19.4\ -16.5}}{\mathbf{16.5}}\ \boldsymbol{x}\ 100$ = 17.58