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

BY

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CERTIFICATION

This is to certify that this project topic titled “The Effect of Partial Replacement of Coarse with Palm Kernel Shell on Compressive Strength of Concrete was carried out by Ezeobi Linus Uchenna with registration number (NAU2017224020) in the Department of Civil Engineering, Nnamdi Azikiwe University, Awka, Anambra State.

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APPROVAL PAGE

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

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DEDICATION

I would specially dedicate this to The Almighty God.

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I wish to express my profound gratitude and thanks to God Almighty for his grace and mercy throughout my life and my stay in the university

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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.

This study was carried out to investigate the effect of partial replacement of coarse aggregate (granite) with Palm Kernel Shell on compressive strength of concrete. Concrete specimens were prepared with a mix ratio of 1:2:4 (Cement: Sand: Granite and Palm Kernel shell). Water/cement ratio of 0.55 was adopted for all relevant laboratories testing. The granite was partially replaced with PKS at different percentages of 5, 10, 15, 20 and 25% by weight of the dry sample. The test conducted include: Sieve analysis of Granite (CA), Sand (FA) and Palm Kernel Shell (PKS), Specific gravity of PKS, SD and GT, Slump (Workability) test of fresh concrete, Water absorption test of Granite (GT) and Palm Kernel Shell (PKS), Density test of Granite (GT), Sand (SD) and Palm Kernel Shell (PKS) and Compressive Strength test of hardened concrete cubes.

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CHAPTER ONE

INTRODUCTION

1.1 Background of study

Nigeria is a developing country desirous of growth, and for continuous growth, we need continuous development and one of leading factor for development is infrastructure. Civil engineering entails the analysis, design, construction and maintenance of infrastructure that supports modern society including buildings, bridges, roads, tunnels, dams, etc. The entire infrastructure involves a large amount of concrete.

Concrete is the world's most consumed man made-material (Naik, 2008). Its great versatility and relative economy in filling wide range of needs have made it a competitive building material (Sashidar and Rao, 2010). Concrete production is not only a valuable source of societal development, but it is also a significant source of employment (Naik, 2008). Production of concrete relies to a large extent on the availability of cement, sand and coarse aggregates such as granite, the costs of which have risen significantly over the past few years. Despite the rising cost of production, the demand for concrete is increasing. The negative consequences of the increasing demand for concrete include depletion of aggregate deposits; environmental degradation and ecological imbalance (Short & Kinniburg, 1978). The possibility of complete depletion of aggregates resources in the near future can therefore not be over emphasized.

Rising construction costs and the need to reduce environmental stresses to make construction sustainable, have necessitated research into the use of alternative materials, especially locally available ones which can replace conventional ones used in concrete production. The use of such re-placement materials should not only contribute to construction cost reduction and drive infrastructural development but also contribute to reduce stress on the environment and make engineering construction sustainable to help transform the building and construction sectors of national economies and contribute towards the realization of national and global poverty reduction strategies. Such materials should be cheap and readily available. The use of cheaper building materials without loss of performance is very crucial to the growth of developing countries (Zemke & Woods, 2009).

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 economical advantages. The wastes generally have no commercial value and being locally available, transportation cost is minimal (Chandra & Berntsson, 2002). Agricultural wastes have advantages over conventional materials in low cost construction (Abdullah, 1997).The use of waste materials in construction contribute to conservation of natural resources and the protection of the environment. (Ramezanianpour, Mahdikhani & Ahmadibeni, 2009). Nimityongskul and Daladar (1995) investigated the use of coconut husk ash, corn cob ash and peanut shell ash as cement replacement in concrete production. Slim and Wakefield (1991) investigated the use of water works sludge in the manufacture of clay bricks.

The palm oil industry produces wastes such as palm kernel shells, palm oil fibres which are usually dumped in the open thereby impacting the environment negatively without any economic benefits. Palm kernel shells (PKS) are hard, carbonaceous, and organic by- products of the processing of the palm oil fruit. PKS consists of small size particles, medium size particles and large size particles in the range 0-5mm, 5-10mm and 10-15mm (Alengaram, Mahmud, Jumaat & Shiraz, 2010). The shells have no commercial value, but create disposal and waste management problems.

From the foregoing explanation, this research will therefore explore into ways of improving the compressive and flexural strength of concrete produced with partial replacement of coarse aggregate with palm kernel shell.

1.2 Statement of problem

The increasing cost of construction materials and the environmental degradation caused by the high utilization of aggregates for concrete is a challenge in civil engineering construction. The high demand and continuous use of crushed granite for concrete in construction will overtime deplete the natural stone deposits and this will affect the environment thereby causing ecological imbalance. The palm oil industry produces wastes such as palm kernel shells, palm oil fibres which are usually dumped in the open thereby impacting the environment negatively without any economic benefits. There is need to explore and find suitable replacement material to substitute for the coarse aggregate in the production of light weight concrete. This research will therefore explore into ways of improving the compressive strength of concrete produced with partial replacement of coarse aggregate with palm kernel shell.

1.3 Aim and Objectives

The aim of the study is to evaluate the effect of partial replacement of coarse aggregate with palm kernel shell on compressive strength of concrete. The objectives include:

1. Characterize (classify) the fine aggregate (sand), coarse aggregate (granite) and additive (palm kernel shell) used for the research.

2. Study the effect of palm kernel shell on the workability and compressive strength of concrete.

3. Determine the maximum amount of palm kernel shell required for optimum improvement of compressive strength of the concrete.

4. Make relevant recommendation based on the findings obtained.

1.4 Significance of study

The study is restricted to the evaluating 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), Bulk density test of fine, coarse aggregate and additive (palm kernel shell), 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 Scope 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. Ensure 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 Concrete

Concrete is the most commonly used material employed for construction purpose in the world today (Meftah, et al 2013), the expensive cost of concrete constituents such as cement, fine and coarse aggregate has necessitated the need to search for alternative construction material (Meftah, et al 2013: Nguyen, et al 2013). The general importance of concrete application in construction projects and civil works cannot be overemphasized. The overwhelming demand for concrete in construction adopting normal weight aggregates (NWA), such as gravel and sand has led to tremendous depletion in naturally occurring aggregates causing numerous damage to the environment which are irreparable (Nguyen, et al 2013).

It is a composite material that consist 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, 2003).

Concrete is a synthetic construction material made by mixing cement, fine aggregate, coarse aggregate and water in the proportions. Each of these components contributes to the strength of concrete. Concrete is by far the most versatile and most widely used construction material (Aderinola, et al. 2020). It can be engineered to satisfy a wide range of performance specification, unlike other building material such as natural stone or steel which generally have to be used as they are.

2.2.1 Constituents of Concrete.

Mc Graw-Hill, (2003) stated that the ingredient used for concrete production include cement, fine aggregate (sand), coarse aggregate (granite).

2.2.1.i. Water

Shatty,(2000) states that water is an important ingredient of concrete as it actively participate in chemical reaction with cement. Since it help to form the strength giving cement gel. Nakhil, et al. (2011) stated that water is an essential ingredient as part of mixing water is utilized in the hydration of cement and the balanced water is required for impacting workability to concrete. Thus the quality and quantity of water is required to be given adequate consideration in the production of concrete, Also that water plays a vital role in the strength of concrete as it helps in the following areas:

(i) It wets the surface of aggregate as it helps to develop cohesion thereby enabling the cement paste to adhere quickly and satisfactorily to the wet surface of aggregate than to the dry surface.

(ii) To prepare a plastic mixture of the various ingredient and to impact workability to concrete so as to facilitate placing in the desired position.

(iii) Water is also needed for hydration of the cementing material to set and harden during the period of curing.

2.2.I.(a) Influence of Water Quality on Concrete

A research was conducted on the impact of water quality on strength properties of concrete using portable water, ground water and sewage water and it was deduced that portable water satisfy 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.

2.2.I.(b) Influence of Water-Cement ratio on Concrete

Shatty, (2000) stated that the water-cement ratio of concrete must lie within practical limit (0.55-0.6) as this determine the strength of concrete. According to Shatty, (2000) lower cement –water ratio could be used when the concrete is vibrated to achieve higher strength where higher water-cement ratio is required when the concrete is hand compacted. In other word, the effect of water-cement ratio on strength and durability properties of concrete depends on the type of compaction. But however, regardless of the type of compaction employed during the production of concrete the water-cement ratio falls within the practical limit (0.55-0.6) as any deviation could result to fall in the strength of concrete due to introduction of air voids.

2.2.II Cement

Cement is one of the essential ingredient of concrete as the compressive strength of concrete largely depends on the quality and quantity of cement as cement is the strength giver that binds the fine aggregate (usually sand or other substitute) and coarse aggregate (gravel, crushed stone) together to form a rigid mass that is capable of sustaining loads Chanadan, (2019). Cement grade or cement strength class correspond 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).

2.2.II.i Chemical Composition of Ordinary Portland Cement (OPC)

The raw materials used in the manufacture of Portland cement consist mainly of lime (Cao), silica (SiO_2), alumina (Al2O_3) and iron oxide (Fe_2O_3). The four compounds are usually regarded 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, H_2O in hydrated cement is denoted by H, and SO_3 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. Table 2.0 shows the approximate oxide composition limits of ordinary Portland cement.

Table 2.0 Oxide Composition Limit of Ordinary Portland Cement (OPC) (Shetty, 2005)

Oxides	**Approximate Percentages**
CaO	60-67
SiO_2	17-25
AL_2O_3	3.0-8.0
Fe_2O_3	0.5-6.0
MgO	0.1-4.0
Alkalis(K_2O, N_2O)	0.4-1.3
SO_3	1.3-3.0

The oxides present in the raw materials when subjected to high clinkering temperature combine with each other to form complex compounds. The identification of the major compounds is largely based on R.H. Bogue's work and hence it is called ―Bogue's Compounds. The four compounds usually regarded as major compounds are tricalcium silicate (C3S), dicalcium silicate (C2S), tricalcium aluminate (C3A) and tetracalciumalumino ferrite (C4AF). Shetty, (2005).The Bogue's formula used in calculating the percentage of the various compounds is given as follows: C3S = 4.07 (CaO) – 7.60 (SiO_2) – 6.72 (Al_2O_3) – 1.43 (Fe_2O_3) – 2.85 (SO_3) C2S = 2.87 (SiO_2) – 0.754 (3CaO.SiO_2)C3A = 2.65 (Al_2O_3) – 1.69 (Fe_2O_3) C4AF= 3.04 (Fe_2O_3).

2.2.II Properties of Ordinary Portland Cement

2.2.II. (i) Fineness of cement

As hydration take place at the surface of the cement, it is the surface area of the cement particles which provide the material available for hydration. The rate of hydration is controlled by fineness of the cement. For a rapid rate of hydration, a higher fineness is necessary. Anna,(1994) investigated the effect of fineness of cement and eventually came up with the following observation:

(i) Higher fineness require higher grinding (High cost implication)

(ii) Finer cement deteriorate faster upon exposure to atmosphere

(iii) Finer cement are very sensitive to alkali-aggregate reaction

(iv) Finer cement require more gypsum for proper hydration

(v) Finer cement requires more water.

The fineness of cement has an important bearing on the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat. Finer cement offers a greater surface area for hydration and hence fastens the development of strength. Fineness of cement is determined by permeability. For example in the blaine air permeability method, a known volume of air is passed through cement. The time is recorded and the specific surface is calculated by a formula. Fineness is expressed in terms of specific surface of the cement (Cm2/gr). For OPC specific surface area is 2600-3000 Cm2/gr. This test is conducted as per BS EN196-6:1995.

2.2.II.(ii) Setting Time of Cement

Setting time refers to a change from liquid state to solid state. During setting time, cement paste acquire some strength (Gartener, et al. 1989). The water content has a marked effect on time of setting. In acceptance test for cement, the water content is regulated by bringing the paste to a standard condition of wetness and this is referred to as “normal consistency”. Normal consistency of OPC ranges from 20-30% by weight of concrete. Vicat apparatus is used to determine normal consistency. Normal consistency is that condition for which the penetration of a standard weighed plunger into the paste is 10mm in 30sec. In practice, the terms initial set and final set are used to describe arbitrary chosen time of setting. Initial set indicates the beginning of a noticeable stiffening and final set may be regarded as the start of hardening (or complete loss of plasticity). It is the also the period between the time water is added to cement and time at which 1 mm square section needle fails to penetrate the cement paste, placed in the Vicat's mould 5 mm to 7 mm from the bottom of the mould. Final setting time is that time period between the time water is added to cement and the time at which 1 mm needle makes an impression on the paste in the mould but 5 mm attachment does not make any impression. The setting time test is carried out using the Vicat apparatus as per BS-EN 196 part3 (1995). The results of the test should comply with the requirements of BS-EN 197 part1 (2000), which recommend a minimum of 60 minutes and a maximum of 10 hours as the initial and final setting times of ordinary Portland cement respectively. (Gartener, et al 1989) summarized the factors affecting setting time as:

(i.) Temperature and Humidity.

(ii.) Amount of water

(iii.) Chemical composition of cement

(iv.) Fineness of cement (the finer the cement, the faster the setting)

Marthong, (2012), Investigated that the addition of saw dust ash in OPC grade 42.5 had increased the initial and final setting times. This was attributed to the low rate of hydration in the paste containing the saw dust ash.

c. Soundness of Cement.

Soundness is referred to as the volume stability of cement paste. The cement paste should not undergo large changes in volume after it has set. Free CaO and MgO may result in unsound cement (Chanadan, G. 2019). Upon hydration, C and M (calcium and magnesium) will form CH and MH with volume increase thus cracking. (Gartener, et al. 1983), Since unsoundness is not apparent until several months or years, it is necessary to provide an accelerated method for its determination which include:

(i.) Lechatelier Method where only free CaO can be determined.

(ii.) Autoclave Method where both free CaO and MgO can be determined.

In the soundness test a specimen of hardened cement paste is boiled for a fixed time so that any tendency to expand is sped up and can be detected. Soundness means the ability to resist volume expansion. For ordinary Portland cement, BS-EN 197 part1 (2000) has specified a maximum expansion of 10mm. The work of Chowdhury et al, (2015) indicated that the soundness of cement was improved with the addition of saw dust ash as partial replacement. In the research, cement was replaced by the ash within the range of 5% to 30% and the soundness was found to increase with an increase in the ash content.

2.2.II.(iii) Strength of Cement and it's effect on Concrete.

Strength test are not carried out on neat cement paste because it is very difficult to form this paste due to cohesive property of cement. Strength test are carried out on cement mortar prepared by standard gradation (1 part cement + 3 part sand + ½ part water). The strength of cement is tested through compression, direct tension or flexure tests. According to BS-EN 196 part1 (1995), prisms of size 40mmx40mmx160mm are cast of a cement sand mortar produced using 1:3 mix ratio. The test prisms are tested for compressive strength at 2days and 28 days.

According to BS 5826, cement mortar is classified into M4, M6, and M12 with compressive strengths of 4N/mm2, 6N/mm2, and 12N/mm2 respectively at 28 days. BS EN 998 part 2 (2003) had also provided similar compressive strength.

Chandan, G.(2019) Investigated on the effect of grade of cement on compressive strength of concrete where it was reported that the compressive strength is largely dependent on the grade of cement as cement grade 52.5 produces comparatively higher compressive strength than cement grade 42.5 and 32.5 respectively. Similar observation was also confirmed by (Gideon, et al. 2015).

2.2.II.(iv) Hydration of Ordinary Portland Cement (OPC).

It is the chemical reaction of cement with water. As the water comes into contact with cement particles, hydration reactions start immediately at the surface of the particles. (Gartener, et al. 1989). Although hydrate such as C-H are formed, process of hydration is a complex one and results in reorganization of the constituents of original compound to form new hydrated compounds. (Gartener, et al. 1989) state that at any stage of hydration, the hardened cement paste (HCP) consist of:

(i.) Hydrate of various compounds referred to collectively as Gel.

(ii.) Crystals of calcium hydroxide (CH)

(iii.) Some minor hydrate compound

(iv.) Unhydrated cement

(v.) Residue of water filled spaces-pores.

Jenings, et al.(1983) opined that upon hydration, C3S, C2S and CH are formed which become an integral part of the hydration products. CH does not contribute very much to the strength of Portland cement. According to (Jenning, et al. 1983) C3S having a faster rate of reaction accompanied by greater heat of hydration develops early strength of the paste. On the other hand, C2S hydrates and hardens slowly so results in less heat generation and develops most of the ultimate strength. (Gartener, et al. 1989) summarized hydration process as:

i. Immediately after mixing with water

ii. Reaction occurs around particles referred to as early stiffening.

iii. Accompanied by formation of skeletal structure referred to as first hardening

iv. Gel infilling known as later hardening.

III. Fine Aggregate

Fine aggregate plays an important role as it combines with cement in the presence of water increasing the workability and uniformity of concrete (Balamuwgan and Perumal, 2013). Shatty, (2000). Stated that fine aggregate are important constituents as it gives body to the concrete and also help to reduce shrinkage. Mindness and Young, (1987), 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, 1994) stated that fine aggregate have 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 occupies over 75% of the concrete volume acting as economic filler material. (Ezeldin and Actcin, 1991) 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, 1979) and (Nallathambi, et al. 1984) has shown that there is an increase in fracture toughness with an increase in the sizes of coarse aggregate.

2.3 Palm Kernel Shell (PKS).

Palm Kernel Shell was partially a waste in the 1990s and early 2000 as more than 350,000 tons were available for sale. The PKS had been a little known then for its potential usage on a large scale especially in concrete work (Mohammad, 2007). Beyond 2000, research into utilization of Palm Kernel Shell as light weight concrete and other uses had received a big boost. Palm kernel shells (PKS) are organic waste materials obtained from crude palm oil producing factories in Asia and Africa (Alengaram, et al, 2010).

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 fueling 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 (2006) 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, 1988). 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, 1990).

2.3.1 Physical Properties of Palm Kernel Shell Concrete.

Okafor, (1988) and Okpala, (1990), reported that palm kernel shell consists of 60 to 90percent particles in the range of 5 to 12.7mm, specific gravity between 1.17 and 1.37, maximum thickness of the shell was found to be 4mm and density to vary in the range of 1,700 to 2,050kg/m^3 . They also reported a 28day cube compressive strength in the range of 15 to 25MPa. In the same study Okafor, (1988) conducted a study using palm kernel shell as aggregate replacement in concrete and discovered that similar to normal weight concrete (NWC), water to cement (w/c) ratio affects the mechanical properties of palm kernel shell concrete. He reported that the 28 day compressive strength of palm kernel shell concrete varied depending on the mix ratio employed. Also Ayanbadefo, (1990) in his research on the investigation into the use of palm kernel shell as light weight aggregate for concrete reported that the Aggregate Impact Value (AIV) and the Aggregate Crushing Value (ACV), were approximately 46percent and 58percent lower respectively compared to granite aggregates, which shows that palm kernel shell is a good shock absorbing material.

Also Alengaram et al., (2010) investigated the physical and mechanical properties of different sizes of palm kernel shells as lightweight aggregates (LWA) and their influence on mechanical properties of palm kernel shell concrete reported that the 28day compressivestrengths 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.

The density of palm kernel shell ranges from 1700 to 2050kg/m3 and it depends on factors such as type of sand and palm kernel shell contents (Mohd et al., 2008). 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., 2008), 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., 2010; Olutoge et al., 2010, 1995 and Okpala, (1990), investigated among other things the density of palm kernel shell aggregate as well as its concrete and discovered that when palm kernel shell is completely used as coarse aggregate, the density of the palm kernel shell concrete is less by over 20percent with reference to normal weight concrete. Olutoge et al., (1995), found the density of palm kernel shell concrete to be 740kg/m3. They concluded that the materials have properties which resembled those of light weight concrete materials. Generally, when the density of concrete is lower than 2000kg/m3, it is categorized as lightweight concrete (LWC).

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

2.3.3 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., (2008) and Jumaat et al., (2009). According to Raheem et al., (2008) and Jumaat et al., (2009), the poor bond between palm kernel shell aggregate and the concrete matrix produced a poorly compacted concrete because of the smooth and convex nature of the shell.

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

2.3.4 Durability of Palm Kernel Shell Concrete (PKSC).

Durability properties of PKSC such as creep (Ali, 1984) and shrinkage (Mannan and Ganapathy, 2002) were also compared with normal weight concrete (NWC). Achieving the minimum concrete grade requirement as well as specify areas where palm kernel shell concrete (PKSC) can be used will promote the application 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.

2.4 Palm Kernel Shell (PKS) as a sustainable building material in Nigeria

PKS as a Sustainable Building Material in Nigeria as a quest for implementing affordable housing system for both the rural and urban population of Nigeria and other developing countries, various proposals focusing on cutting down conventional building material costs have been put forward. One of the suggestions in the forefront has been the sourcing, development and use 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, 2009). 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, 1983). 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 view of this, the search for low-cost material that is 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).

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

Neville, (1995) had reported that Silica fume (SF) has the ability to localize at the surface of the aggregates to enhance the bond between an aggregate and the cement matrix. This addition of silica fume strengthens the zone of weakness being the zone between the aggregate and the cement paste interface. The weaker bond between aggregate-matrix contributes to the lower tensile strength in palm kernel shell concrete. In Normal weight concrete (NWC), the rough surface of aggregates increases the bond and thereby increasing tensile strength. According to Neville, (1996), Silica fume (SF) is always employed in the production of palm kernel shell concrete of grade 30 and above mainly to improve the bond between the smooth convex surfaces of palm kernel shell and cement matrix. He further reported that Silica fume (SF) particles are 100 times smaller than cement particles and the extremely very fine Silica fume (SF) particles have the ability to be located in the very close proximity of the aggregate particles. Alengaram et al., (2008) and Teo et al., (2006) 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. Alengaran et al., (2010) also observed that when mineral admixtures of silica fume (SF) and fly ash (FA) were added to a concrete mix with palm kernel shell aggregate, the compressive strength at 28days was improved to 37N/mm2

. Similarly, Robert et al., (2003) reported that the extremely fine Silica fume (SF) particles would produce calcium silicate and aluminate hydrates in Concrete on reacting with liberated calcium hydroxide.

This chemical reaction increases strength and reduces permeability by increasing the density of the concrete matrix. Also Alengaram et al., (2008), from his research paper on the influence of sand content and silica fume on 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/m^3. It was observed that oven dry densities were about 220 to 260kg/m^3 lower than water cured densities.

The highest density of 1971kg/m^3 was reported for mix containing sand/cement (s/c) ratio of 1.6. Alengaram et al., (2008) also observed that an increase in sand content beyond s/c ratio of 1.6 might have resulted in higher density than the limit for lightweight concrete (LWC) of 2000kg/m3 and hence mixes containing s/c ratio higher than 1.6 was not considered. The authors reported 10 to 15percent increase in strength for mixes containing silica fume. It was further reported that the silica fume plays a major role in early strength development of palm kernel shell concrete.

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

Nuhu-Koko (1990), Akpe (1997), Olusola and Babafemi, (2013) and Abang, (1982) have studied the effects of proportion and aggregate sizes on palm kernel shell concrete. Aggregates have an overwhelming influence on the properties of concrete considering the percentage occupied in the mix. According to Nuhu-Koko (1990), Akpe (1997), Olusola and Babafemi (2013), the compressive strength of concrete varies between 0.3N/mm2 and22.97N/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/mm^2 and 1.89N/mm^2 respectively at maximum coarse aggregate size of 20mm. However, at 50percent palm kernel shell content, which results in lightweight concrete, compressive strength, was 18.13N/mm^{2}which is above the minimum value of 17MPa for lightweight concrete. Abang (1982) reported that a higher proportion of Palm kernel shell in a mix lowers the workability and compressive strength of palm kernel shell concrete. He also observed that the strength of the shell also plays a significant role in the strength of the concrete.

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

Yusuf and Jimoh (2011) worked on the appropriateness of the various nominal mixes of the palm kernel shell concrete' as rigid pavement. They evaluated the mixes accordingly at both fresh and matured ages with corresponding costs. They reported that the Nigerian PKS satisfies the density criterion for normal concrete and lightweight concrete in all respects while the palm kernel shell concrete at nominal mixes of 1:1.5:3 and 1:1:2 satisfied the specifications for rigid pavement.

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 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.

Okechukwu et al. (2017), conducted a study on assessment of palm kernel shell as a composite aggregate in concrete. Mix design of 1:2:4 and a water-cement ratio of 0.6 were used to produce concrete specimen cubes of size 150 mm3. A total of 60 cubes were made and wholly submerged in water to cure for 28 days at intervals of seven days i.e. seven, 14, 21 and 28 days after which their densities and compressive strengths were determined. Granite was replaced by palm kernel shell in the mix at 25% interval resulting in three replicates of specimen cubes at each curing age. Compressive strength and density decreased continuously as palm kernel shell was added to the mix for all the Curing ages tested. The 28 day compressive strength of the palm kernel shell concrete ranged from 12.71 to 16.63 N mm2, whereas the density ranged from 1562 to 2042 kgm3

Festus et al (2012), conducted an investigation of the strength properties of palm kernel shell concrete. The chemical properties of the ash are examined whereas physical and mechanical properties of varying percentage of PKSA cement concrete and 100% cement concrete of mix 1:2:4 and 0.5 water-cement ratios are examined and compared. A total of 72 concrete cubes of size

150 × 150 × 150 mm^3 with different volume percentages of PKSA to Portland cement in the order 0:100, 10:90 and 30:70 and mix ratio of 1:2:4 were cast and their physical and mechanical properties were tested at 7, 14, 21 and 28 days time. Although the compressive strength of PKSA concrete did not exceed that of OPC, compressive strength tests showed that 10% of the PKSA in replacement for cement was 22.8 N/mm2 at 28 days; which was quite satisfactory with no compromise in compressive strength requirements for concrete mix ratios 1:2:4.

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 10%, 13%, 15%, 20%, and 25% and the testing of the cube is done on 7day, 14day, and 28day. This experiment gives the idea about the possible amount of weight reduction of concrete without heavily affecting the strength of concrete.

Based on the backdrop of previous researches conducted, this study will evaluate the effect of partial replacement of coarse aggregate with palm kernel shell on compressive and flexural strength of concrete and the granite will be admixed with the additive (palm kernel shell) from 4%PKS starting from 0%PKS to 20%PKS thereby establishing six different specimens.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials, Sourcing and Preservation.

The materials required for this research work are fine aggregate (river sand) designated as SD. Coarse aggregate (granite) designated as GT, (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 which refers to the hydraulic binding material ground was used for this experiment and the particular one which was used is the Bua cement. The cement sample satisfy the requirement for use as one of the major component of concrete in that, it was not caked or baked through visual inspection and quick setting time.

2 Water

A portable water which is suitable as mixing water for cement concrete, plain cement concrete for construction works. The water sample passed all the necessary requirement for use as ingredient of concrete based on the fact that it is colorless, devoid of suspended solid particles, contains infinitesimal trace of dissolved solid particles with no trace of turbidity after being subjected to laboratory testing.

3 Palm Kernel Shell Ash (PKS).

The palm kernel shell designated as PKS is a hard fibrous material that encloses the nut or seed of the palm kernel fruit .It is obtained as a residual waste from the cracking of the palm kernels, and the extraction of the nuts in the mill. The palm kernel shell sizes ranges between 5mm to 16mm. The coarse aggregate (crushed granite) will be completely admixed with palm kernel shell in a stepped increase starting from 0%-5%-10%-15%-20% and 25% by dry weight of palm kernel shell so as to establish six different specimens.

Plate 3.1 Palm Kernel Shell Sample to be used for research

4. Coarse Aggregate (Crushed Granite).

The granite samples designated as GT 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. This granite sample will be partly replaced with palm kernel shell (PKS).

5.Fine Aggregate (Sand).

The sand sample was collected with the aid of shovel. The sample passed the necessary requirement for use as ingredient of concrete based on the fact that it is gritty with particle sizes visible to the naked eyes .Fine sand used must not have a modulus less than 1.2 to 1.5, and the slit preferred is generally 4 percent. The sand sample after collection was conveyed to the school laboratory for the sieve analysis tests.

3.2 Batching

Being 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. And there are two methods of this batching; ‘By weight and By volume’. This research adopted batching by weight, which involves the application of mathematical concept known as ratio to find out the requirement weight. Weight was used for the measurement.

3.2.1 Mix Proportion of Concrete Specimens

The proportioning by weight was used in this research. The cement-aggregate ratio used in this work was 1:2:4. Palm kernel shell (PKS) were used to replace granite at dosage 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 = $150^3 = 3.375x10^{-3}$ m^3

To Get the mass of concrete

Density x volume

Where density = 2400 (constant)

Volume = $3.375x10^{-3}m^3$

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)

Weight of cement = 1.6

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

w = 696L x 9 cubes = 6264L

Table 3.0 Mix 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 this project, different test were carried out, test was carried out on different percentages of replacement of palm kernel shell with Sand. Below are the detailed descriptions of the experiments.

3.3.1 Sieve Analysis

Sieve analysis is a procedure used to assess 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 performed on any type of non-organic or organic granular material including sand, crushed rock, clay, granite, 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.

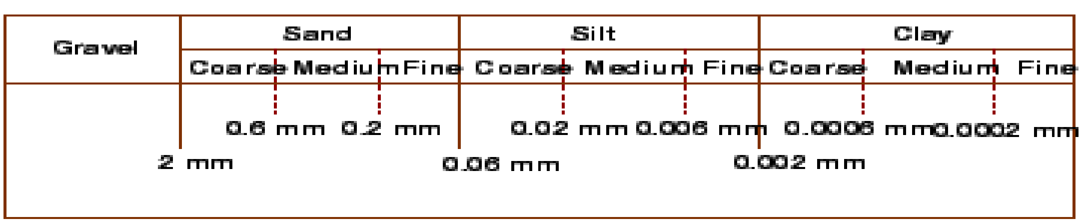


Plate 3.1 Ranges for grain Sizes of different Soil type

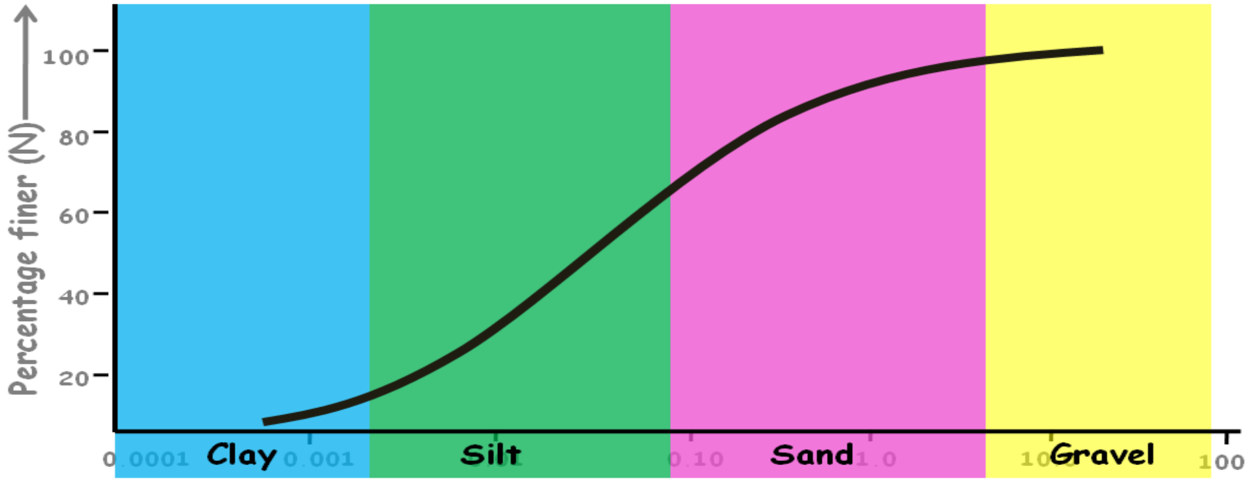


Plate 3.2 Grading Curve Ranges for Different Soil Types

Soil posses 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.

The apparatus needed for this experiment is listed below:

1. Stack of sieves including pan and cover.

2. Mechanical sieve shaker.

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. Exercise book and pen for recording of result.

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

Percentage retained (%) = mass of soil retained in the sieve(g) x 100

total mass of soil sample

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 the size

Plate 3.3 Mechanical Sieve Shaker

TEST PROCEDURE

1. Clean properly the stack of sieves to be used for the experiment using hand brush.

2. Weigh about 500g of air-dried soil sample on a weighing balance.

3. Pour the weighed soil sample into 75um sieve and wash under a steady supply of water until clear water start coming out from the sieve after passing through the soil sample.

4. After washing pour the washed soil sample into a pre-weighed plate and dry it inside the thermostatically controlled oven at a controlled temperature of 80-110OC for 16-24hrs.

5. Remove the sample from the oven and determine it weight (net weight) by deducting the weight of plate from the weight of plate and soil.

6. Arrange the stacks of sieve in the ascending order, place in a mechanical sieve shaker, and thereafter pour the sample and connect the shaker for about 10-15 minute.

7. Disconnect the sieve shaker and determine the mass retained on each of the sieve sizes.

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 gels

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 220C 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 220Cto 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 about 1100C in the oven for 24 hours. Later, it is cooled in an airtight container and weighed.

3.3.4 Compression Test of Concrete Cubes

The test method covers determination of compressive strength of cubic concrete specimens. It consists of applying a compressive axial load to molded cubes at a rate which is within a prescribed range until failure occurs.The Apparatus Used includes:

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

2. Cube Moulds - The mould shall be of 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. **Sampling of Materials -** Samples of aggregates for each batch of concrete shall be of the desired grading and shall be in an air-dried condition. The cement samples, on arrival at the laboratory, shall be thoroughly mixed dry either by hand or in a suitable mixer in such a manner as to ensure the greatest possible blending and uniformity in the material.

2. **Proportioning -** The proportions of the materials, including water, in concrete mixes used for determining the suitability of the materials available, shall be similar in all respects to those to be employed in the work.

3. **Weighing -** The quantities of cement, each size of aggregate, and water for each batch shall be determined by weight, to an accuracy of 0.1 percent of the total weight of the batch.

4. **Mixing Concrete -** The concrete shall be mixed by hand, or preferably, in a laboratory batch mixer, in such a manner as to avoid loss of water or other materials. Each batch of concrete shall be of such a size as to leave about 10 percent excess after moulding the desired number of test specimens.

5. **Mould -** Test specimens cubical in shape shall be 15 × 15 × 15 cm. If the largest nominal size of the aggregate does not exceed 2 cm, 10 cm cubes may be used as an alternative. Cylindrical test specimens shall have a length equal to twice the diameter.

6. **Compacting -** The test specimens shall be made as soon as practicable after mixing, and insuch a way as to produce full compaction of the concrete with neither segregation nor excessive laitance.

7. **Curing -** The test specimens shall be stored in a place, free from vibration, in moist air of atleast 90 percent relative humidity and at a temperature of 27°± 2°C for 24 hours ± ½ hour from the time of addition of water to the dry ingredients.

8. **Placing the Specimen in the Testing Machine -** 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.

9. 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

10. 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.

11. 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.

12. 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. Crushing of Concrete Cubes

3.3.5 Slump Test (Workability Test)

Slump test 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. 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. Porcelin evaporating dish.

Plate 3.8 Apparatus used for Slump Test

TEST PROCEDURE

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

2. Place the mould on the evaporating dish or alternatively on any smooth, horizontal, rigid and non-absorbent surface.

3. Measure and mix properly the various component of the concrete depending on the concrete grade.

4. In a vertical direction. Divide the concrete into four layers such that each layer is onequarter the height of the mould.

5. Place each layer into the mould and tamp for 25 times 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 struck off levelthe rodded concrete at the top layer of the mould.

7. Remove the mould from the concrete by raising it slowly and carefully in a vertical direction. Immediately the concrete will subside and the subsidence is referred as SLUMP of the concrete. Measure the difference in height between the height of the mould and the average value of the subsidence this is referred to as slump value of concrete

CHAPTER 4

RESULTS AND DISCUSSION

Table 4.1. Physical Properties of the various materials used in the laboratory test

Properties	**FA**	**CA**	**PKS**
Specific gravity	2.40	2.63	2.25
Water absorption	_	1.27	19.62
Coefficient of uniformity	2.5	**1.9**	**1.5**
Coefficient of curvature		**1.4**	**0.67**
Gradation	**SP**	**GP**	**SP**
Percentage passing sieve size 4.75mm	**-**	**0.16**	**2.34**
Percentage passing sieve size 0.075mm	**0.96**	**-**	**-**
AASHTO Classification system	**A-2-4**	**A-1-b**	**A-1-b**
USCS classification system	**SC**	**GM**	**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	56	Shear slump
5	68	Shear slump
10	76	Shear slump
15	85	Shear slump
20	95	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)**
EL7 A	8.1	7	1:2:4	290.14	12.9	
EL7 B	8.1			272.85	12.1	12.1
EL7 C	8.2			257.53	11.4	
EL14A	8.1	14	1:2:4	390.72	17.4	
EL14B	8.0			415.60	18.5	17.8
EL14C	8.3			390.81	17.4	
EL28A	8.0	28	1:2:4	560.65	24.8	

EL28B	8.1			544.37	24.1	25.0
EL28C	8.0			587.44	26.1	

Table 4.3.1 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)**
EL7 A	8.0	7	1:2:4	237.37	10.6	
EL7 B	8.1			258.45	11.5	10.9
EL7 C	8.0			241.26	10.7	
EL14A	8.1	14	1:2:4	366.57	16.3	
EL14B	8.0			376.11	16.7	16.9
EL14C	8.0			395.20	17.6	
EL28A	8.0	28	1:2:4	499.45	22.2	
EL28B	8.1			490.61	21.8	22.1
EL28C	8.0			502.10	22.3	

Table 4.3.1 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)**
EL7 A	7.9	7	1:2:4	242.92	10.8	
EL7 B	7.7			250.14	11.1	10.7
EL7 C	7.9			232.19	10.3	
EL14A	7.8	14	1:2:4	350.29	15.6	
EL14B	8.0			330.41	14.7	15.4
EL14C	8.0			357.41	15.9	
EL28A	7.9	28	1:2:4	404.81	18.0	
EL28B	8.1			415.56	18.5	18.1
EL28C	7.8			399.24	17.8	

Table 4.3.1 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)**
EL7 A	7.5	7	1:2:4	245.61	10.9	
EL7 B	7.4			221.22	9.8	10.3
EL7 C	7.9			230.71	10.3	

EL14A	7.6	14	1:2:4	331.61	14.7	
EL14B	7.8			310.26	13.8	14.2
EL14C	7.9			320.34	14.2	
EL28A	7.9	28	1:2:4	366.21	16.2	
EL28B	7.8			349.31	15.5	15.6
EL28C	7.6			340.72	15.1	

Table 4.3.1 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)**
EL7 A	7.5	7	1:2:4	221.11	9.8	
EL7 B	7.6			210.32	9.4	9.4
EL7 C	7.8			202.31	9.0	
EL14A	7.4	14	1:2:4	296.54	13.2	
EL14B	7.3			298.87	13.3	13.6
EL14C	7.4			323.41	14.4	

EL28A	7.4	28	1:2:4	345.16	15.3	
EL28B	7.5			332.76	14.8	15.1
EL28C	7.4			341.76	15.2	

Table 4.3.1 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)
EL7 A	7.3	7	1:2:4	201.81	9.0	
EL7 B	7.4			187.64	8.4	8.7
EL7 C	7.5			194.81	8.7	
EL14A	7.4	14	1:2:4	291.46	13.0	
EL14B	7.3			283.94	12.6	12.7
EL14C	7.6			279.98	12.5	
EL28A	7.5	28	1:2:4	299.61	13.3	
EL28B	7.4			295.51	13.1	13.3
EL28C	7.4			304.31	13.5	

ANALYSIS OF TEST RESULTS

4.2.1 Particle Size Distribution (Sieve Analysis)

Figure 4.1 is the semi logarithmic plot of the particle size distribution of the CA, SD and PKS. Result recorded 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 0.91 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 (GT) is of larger size compared to the additive (PKS) since lower percentages is passes through sieve size 4.75mm. The gradation of GT, SD and PKS obtained from their respective shape parameters (Cu and Cc) shows that they are poorly graded.

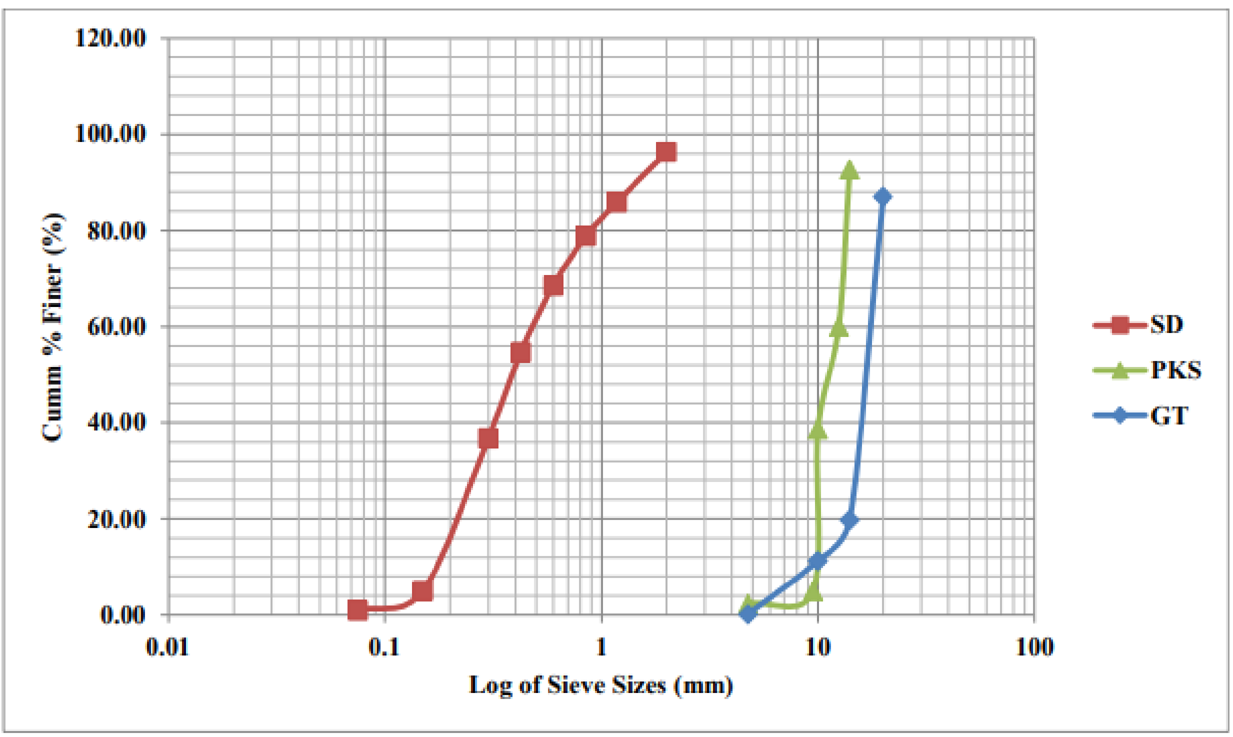
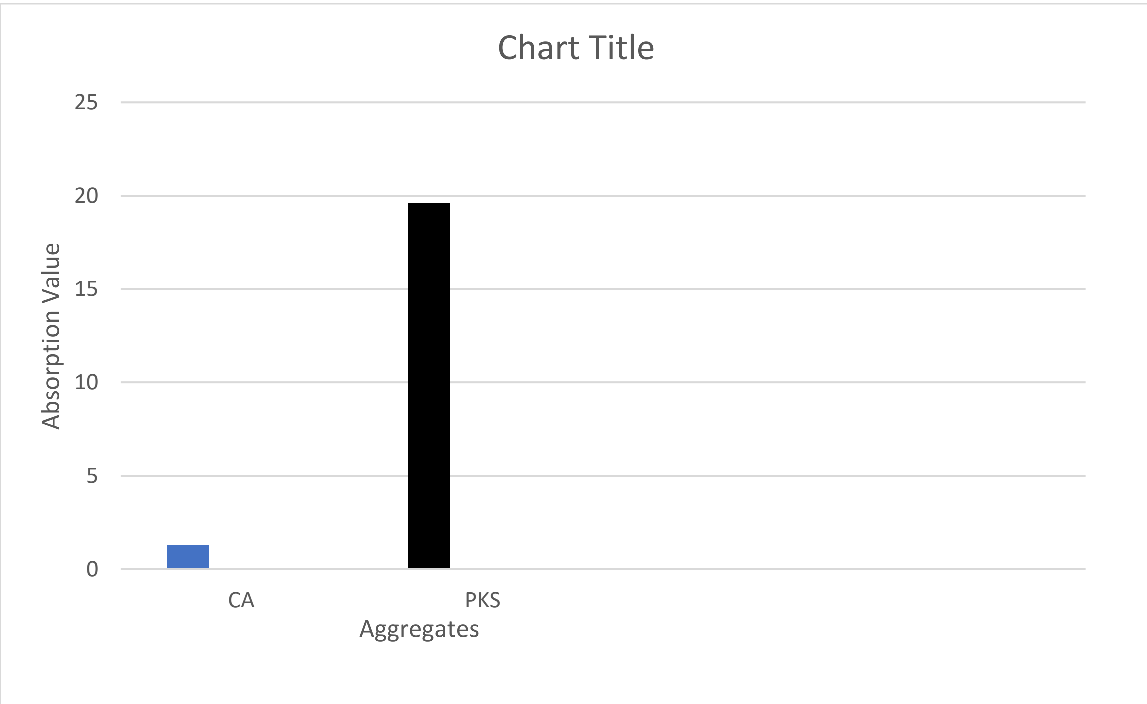


Figure 4.1 Particle Size Distribution Curve for aggregate (SD and GT) and additive (PKS).

4.2.2 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 1.27 and 19.62 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.



4.2.3 Specific Gravity Test.

The specific gravity of the soil is defined as the ratio of weight of the soil to the rate of equal volume of water; it is used to obtain the unit weight of construction materials in the presence of water. Specific gravity tests were conducted in accordance to ASTM D854-14 specification. For the aggregate designated 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 GT 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.

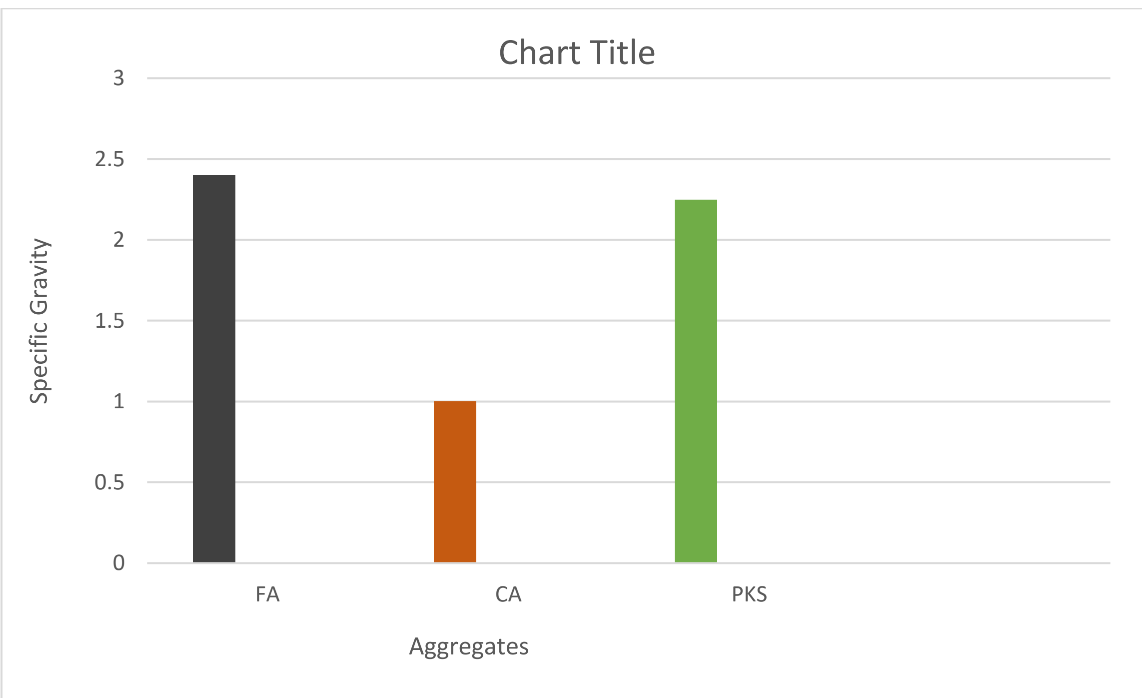


Figure 4.2 Specific Gravity Chart for Aggregate (FA and CA) and Additive (PKS).

4.2.4. Slump (Workability Test)

The table below (Table 4.5) 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.

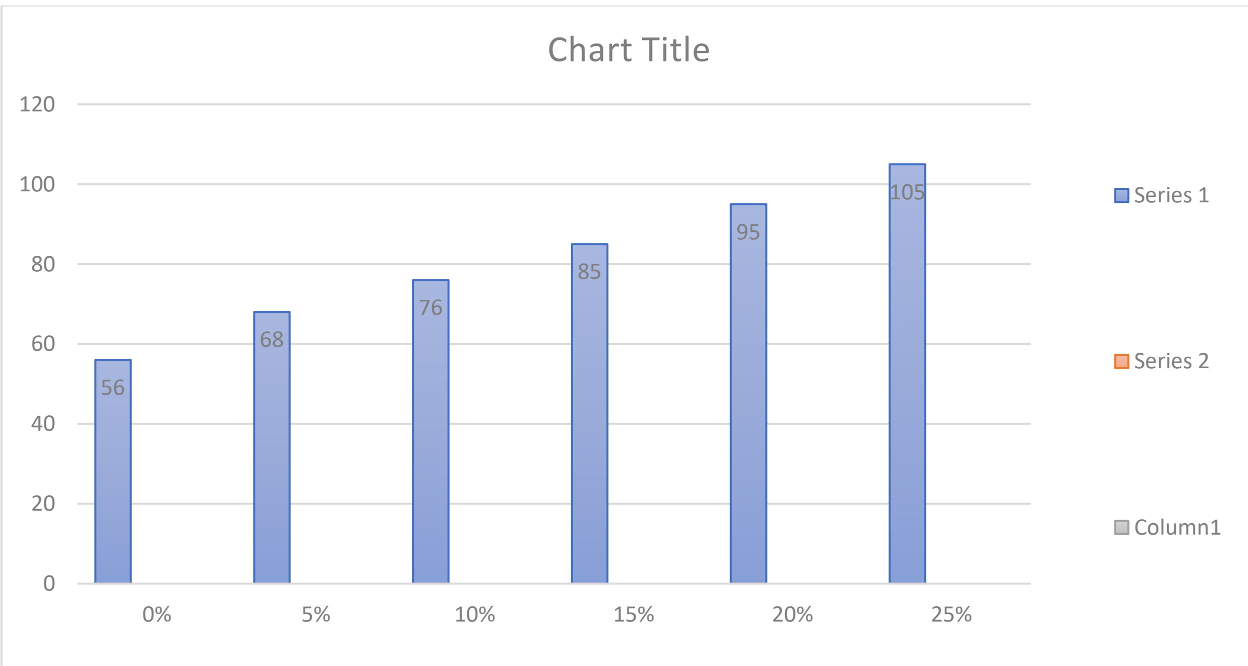


Figure 4.5 Slump Value Chart for GT + PKS Concrete.

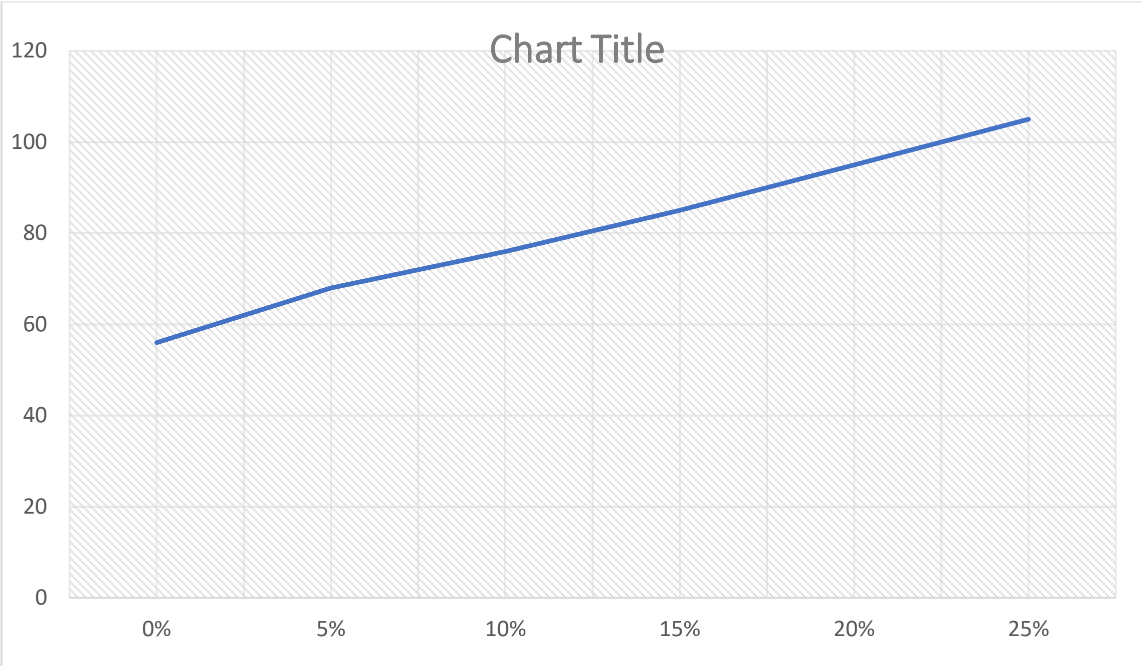


Figure 4.5.1 Slump Value Graph for GT + PKS Concrete.

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 tables below (Table 4.5.1 & 4.5) 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.

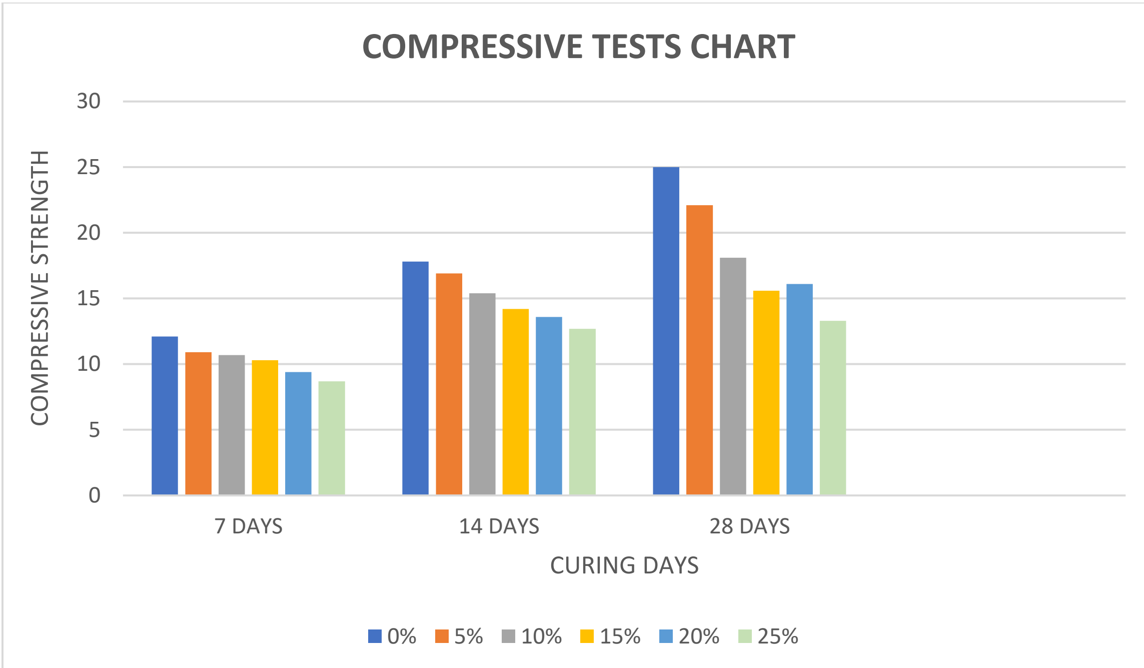


Figure 4.5. 1 Chart Showing the Compressive Strength against Curing days for GT + PKS Concrete

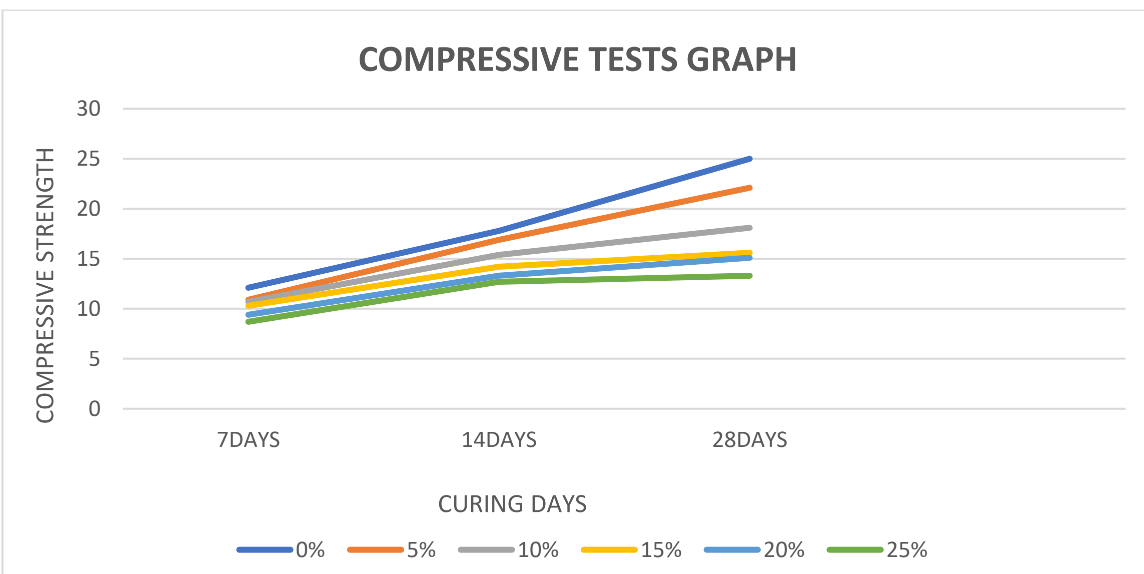


Figure 4.5. 2 Graph Showing the Compressive Strength Value against Curing days for GT PKS Concrete

` CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

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 (clay 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 FA and CA and the additive (palm kernel shell) designated as PKS, the average apparent specific gravity computed are 2.40, 2.68 and 2.25 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 1.24 and 19.62 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 indicates that the slump value increases with consistent addition of the additive (PKS) from 5% to 25% at a w/c ratio of 0.6 with the highest slump recorded at 25% partial replacement of CA. This result shows 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 carried out 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 marginally.

6. The additive (PKS) is therefore deemed as feasible but ineffective as no improvement in the compressive strength of the concrete was observed.

7. Based on the finding obtained from compressive strength test from 0% to 25% addition of PKS at w/c of 0.6, study therefore advises against the use of this material as partial replacement for coarse aggregate in concrete beyond 10% as the compressive strength of the concrete decreases significantly after this point.

5.2 Recommendation.

1 This study discourages the use of Palm kernel shell (PKS) as partial substitute for coarse aggregate in concrete beyond 10% since the compressive strength of the concrete decreases significantly after this point and no obvious improvement in the compressive strength was observed.

2 The recommendation should be subject to further research so as to ascertain whether 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 A1. Specific Gravity Result for Sand.

Determinants	**Test 1**	**Test 2**	**Test 3**
Wt of density bottle, W1 (g).	25.08	26.45	26.94
Wt of bottle + dry soil, W2 (g)	35.09	36.81	36.99
Wt of bottle + soil + water, W3 (g).	76.72	82.12	84.,79
Wt of bottle + water, W4 (g).	71.45	75.89	78.61

The Specific gravity of the sample is calculated as follows:

Test 1 $= \frac{W2-W1}{(W2-W1)-(W3-W4)} = \frac{35.09-25.08}{(35.09-25.08)-(76.72-71.45)} = 2.11$

Test 2 $= \frac{W2-W1}{(W2-W1)-(W3-W4)} = \frac{36.81-26.45}{(36.81-26.45)-(82.12-75.89)} = 2.51$

Test 3 $= \frac{W2-W1}{(W2-W1)-(W3-W4)} = \frac{36.99-26.94}{(36.99-26.94)-(84.79-78.61)} = 2.60$

Specific Gravity $= \frac{Gs1+Gs2+Gs3}{3} = \frac{2.11+2.51+2.60}{3} = 2.40$

Table A2. 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 A3. Specific Gravity Result for PKS

Determinants	Test 1	Test 2	Test 3
Wt of Saturated aggregate and basket in water W1 (g)	336.7	313.50	306.07
Wt of basket in Water W2 (g).	151.02	147.51	144.31
Wt of Saturated aggregate in air W3 (g)	369.78	344.01	318.24
Wt of Oven-dried aggregate in air W4 (g).	322.67	300.14	298.32

The Specific gravity of the sample is calculated as follows:

Test 1 $=\frac{W4}{W4-(W1-W2)} = \frac{322.67}{322.67-(336.7-151.02)} = 2.36$

Test 2 $=\frac{W4}{W4-(W1-W4)} = \frac{300.14}{300.14-(313.50-147.51)} = 2.24$

Test 3 $=\frac{W4}{W4-(W1-W2)} = \frac{298.32}{298.32-(313.7-147.51)} = 2.14$

Specific Gravity $= \frac{Gs1+Gs2+Gs3}{3} = \frac{2.36+2.24+2.14}{3} = 2.25$

APPENDIX B

WATER ABSORPTION TEST

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

Where W1 = Weight of Saturated aggregate in air

W2 = Weight of oven-dried aggregate in air

For Coarse Aggregate :

W1 = 20.01g

W2 = 19.76g

∴ Water absorption = $\frac{20.01-19.76}{19.76}\ x\ 100$ = 1.27

For Palm Kernel Shell:

W1 = 18.9

W2 = 15.8

∴ Water absorption = $\frac{18.9-15.8}{15.8}\ x\ 100$ = 19.62