UNIVERSITY OF EDUCATION, WINNEBA

THE USE OF PALM KERNEL SHELL ASH AS CEMENT EXTENDER IN CONCRETE

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DECLARATION

STUDENT'S DECLARATION

I, Kenneth Kwaku Yeboah, declare that this thesis with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE: ……

DATE: ……

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of Thesis as laid down by the University of Education, Winneba.

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DEDICATION

This thesis is dedicated to my wife Miss. Theresah Akyaa, and my little kids Kwaku Asokwa-Korankye Yeboah and Kwame Afrim Mensah Yeboah. May God richly bless you.

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GLOSSARY

ASTM	American Society for Testing and Materials
BS	British Standard
BRRI	Building and Road Research Institute
CSA	Coconut Shell Ash
CSF	Condensed Silica Fume
Cs	Compressive Strength
FA	Fly ash
GGBS	Ground Granulated Blastfurnance Slag
ISO	International Organisation for Standardization
OPC	Ordinary Portland Cement
PKSA	Palm Kernel Shell
PC	Portland Cement
RHA	Rice Husk Ash

ABSTRACT

The national housing policy of Ghana which was approved by cabinet in 2010, advocates the use of local building materials for the construction of buildings. It is against this background, that in recent years many studies have been conducted to find cheap but useful local building materials to replace the conventional ones which are to some extent expensive. Cement is one of the most important elements in building construction works which is relatively expensive. This research seeks to study the possibility of utilizing palm kernel shell ash (PKSA) as cement extender in concrete production. The study aimed at finding the chemical composition of PKSA, strength and durability properties of concrete produced from OPC with partial replacement of PKSA. The palm kernel shell was burnt, sieved and was tested at a chemistry laboratory and then compared with the chemical composition of OPC. The PKSA was used to prepare concrete cubes at replacement levels of 0%, 5%, 10%, 15% and 20%, cured for 28 days. From the study, it was evident that PKSA contains chemicals such as Si02 (silicon), Al203 (aluminium), Fe203 (iron oxide), CaO (calcium oxide), MgO (magnesium oxide) and K2O (potassium oxide) which are active ingredient in OPC but are not at the required levels. The PKSA replacement percentage in concrete mix improved workability but water absorption rate was comparatively high. Compressive strength declined as PKSA increased in the mix as well as density. The study showed an inverse correlation between compressive strength and PKSA percentage replacement levels. Following the high water absorption rate of PKSA concrete, it was not recommended for concrete works in water-logged areas. Despite the reduction in strength of PKSA concrete, 5% replacement is recommended for normal concrete works.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

The construction industry can be seen as a vital industry for the economic progress of many countries. The industry embraces different construction methods for the infrastructural needs of the country, and therefore makes it a multifaceted industry for economic growth which no country can live without. The industry makes use of deferent materials for its day to day activities and eternity of these materials is as vital as the industry itself. One major and most widely used material in the construction industry is concrete. It is a composite building material made from the combination of aggregate and a binder such as cement. The use of concrete as a material in construction is very old and till date the most plastic material for construction purposes (Neville, 2010; Spencen *et al.,* 2011). The most common form of concrete is Portland cement concrete, which consists of aggregates (mostly gravel and sand), Portland cement and water.

With the advancement of technology and the need for sustainable construction practices, cement been one of the major materials (matrices) for most concrete production needs to be given the needed attention to ensure its availability for this and the generation to come. Due to the high cost of producing cement with its adverse effect on the over-all cost of construction projects, there is the need to find an alternative cementitious material to supplement the quantity of cement required for the infrastructural needs of the country, and to minimize the increasingly cost and scarcity of this important commodity. Hence

many attempts have been made in recent years to find different pozzolanic materials for this purpose.

By-products, both industrial and agricultural which were regarded as waste in years past have been explored. Elinwa and Awari (2001) found that groundnut husk ash could be suitably used as partial replacement of OPC in concrete making. Cisse and Laquerbe (2000) reported that sandcrete blocks obtained with unground Senegalese RHA as partial replacement of OPC had greater mechanical resistance than 100% OPC sandcrete blocks. Malhotra and Mehta (2004) reported that ground RHA with finer particle size than OPC improves concrete properties as higher substitution amounts result in lower water absorption values and the addition of RHA causes an increment in the compressive strength.

Mehta and Pirtz (2000) investigated the use of rice husk ash to reduce temperature in high strength mass concrete and concluded that RHA is very effective in reducing the temperature of mass concrete compared to OPC concrete. All these works show that by-products, both industrial and agricultural if properly investigated, could be used for constructional purposes. Many researchers have confirmed that cementing quality is enhanced if a pozzolan is blended in suitable quantity with Portland cement.

In the light of these, it has become essential to develop beneficial uses of these by-products to solve the problems associated with total reliance on cement coupled with its high cost. It is believed that the successful utilization of these as a supplement to cement (OPC) for construction would add value to these agricultural by-products as well as

reduce the cost of building works and other construction projects that make much use of cement.

1.2 Statement of the Problem

According to Maslow's, theory of needs, one can progress in life when the basic needs like air, food, shelter etc. are satisfied. As a developing country, many people are unable to provide for themselves and their families these basic needs. Available data shows that the housing deficit in the country is in excess of one million seven hundred thousand. The Minister of Water Resources, Works and Housing, on the 15th of October, 2013, with an encounter with Meet- the- Press series in Accra, stated that, a minimum of 85 thousand housing units is needed annually to address the housing deficit in the country over the next 20 years.

Meanwhile, the cost of cement is on the increase and unaffordable, yet the need for housing and other construction projects that require the use of it keeps growing with increasing population. Data from building and road research institute (BRRI) shows that cement utilisation in Ghana had increased from 1.8 million tonnes in 2000 to about 3.2 million tonnes in 2011 (http://www.brri.org/2-uncategorised/162-the-pozzolana-cement-technology). More than $300 million is spent annually on clinker and cement importation in Ghana, thus the need to find alternative binding materials that can be used solely or in partial replacement of cement (http://www.brri.org/2-uncategorised/162-the-pozzolana-cement-technology).

It is for this reason that the national housing policy which was approved by cabinet in 2010, advocates the use of local building materials for the construction of buildings. It is against this background, that in recent years many studies have been conducted to find cheap but useful local building materials to replace the conventional ones which are to some extent expensive. One of such inquiries is the use of waste materials and agricultural by-products. Presently, millions of tons of agricultural and plant wastes such as rice husk, groundnut husk, corncob, coconut shell, etc. are generated in many communities in our country Ghana due to the intensified food production and local economic ventures. For lack of technological ways of using these wastes, they are usually burnt off or left on farm lands to deteriorate.

With the growing emphasis on the utilization of waste materials and by-products in other forms where possible, there is the need to find other technological means of utilizing them in other fields. Since cement is one of the most important elements in building construction works, this research seeks to study the possibility of utilizing palm kernel shell ash (PKSA) as cement extender in concrete production. It is believed that successful outcome would be an essential contribution toward solving the housing problem which has saddled most individuals and the government for a number of decades.

1.3 Aim and Objectives of the Study

The main aim of this study is to investigate into the strength and durability properties of concrete produced from OPC with palm kernel shell ash (PKSA) as cement extender.

1.4 Specific Objectives

- To find the chemical properties of palm kernel shell ash.
- To determine the compressive strength, workability and water absorption properties of concrete produced from blended OPC and palm kernel shell ash (PKSA).
- To design a model to predict the compressive strength of PKSA concrete.

1.5 Significance of the Study

The study would contribute to literature on partial replacement of OPC with palm kernel shell ash. It would provide essential information about partial replacement of OPC with palm kernel shell ash to estate developers, contractors and the building industry as a whole. Again, successful outcome will give an alternative material to augment the higher amount of cement required for the infrastructural needs of the country. More so, global utilization of the palm kernel ash with cement would reduce energy use and CO2 emissions during cement production extensively. The findings would add to the existing block of knowledge on the utilization of agricultural by-products in construction industry, to serve as reference for researchers who may undertake similar projects.

1.6 Limitations of the Study

Studies have proven that the strength of pozzolana materials increases with increases in age, but the specimen used in this study was cured for only twenty eight days due to time constraints. Again the specimen should have been tested in the national laboratory

(Ghana Standard Board), but due to financial constraints, they were tested in a building laboratory in a renowned tertiary institution in the country. Also, the burning of the palm kernel shell should have been done with a control temperature in an oven, but due to unavailability of the oven, it was burnt in the open air.

1.7 Organization of the Dissertation

The structure of this dissertation contains six chapters. Chapter one deals with the introduction, which forms the beginning of the main body of the study (background), including the problem statement, the purpose and objectives of the study, hypothesis, significance of the study, limitation, and the organization of the study.

Chapter two focuses on the review of related literature, while the methodology is the subject of chapter three. It describes the material, preparation of concrete cubes and cylinders, and testing of specimen. Chapter four presents the analysis of the outcome and discussion of findings with tables, figures and graphs. Chapter five presents the discussion of results. The discussion highlights the major findings of the study and inferences made from them in view of the findings from related previous studies. The final chapter, which is chapter six, brings to bear the summary of findings, conclusions and recommendations. The major research findings are itemized to show how they contribute to body of knowledge.

CHAPTER TWO

LITERATURE REVIEW

This chapter seeks to elucidate all available relevant works relating to the topic under research. Concrete is the world's most consumed man made material (Naik, 2008). Its great versatility and relative economy in filling wide range of needs has made it a competitive building material (Sashidar and Rao, 2010). In terms of volume it is the most widely used manufactured material, with nearly two tonnes produced annually for each living person (Mack, Oliveira and John, 2016). Production of concrete depends on the availability of cement, fine aggregates (sand) and coarse aggregates (stones), the costs of which have risen astronomically over the past few years due to the high cost of the main matrix (cement), to the displeasure of both clients and contractors.

As a result, many researches have been conducted to find an alternative but equally good material (pozzolanic materials), to supplement cement in the production of concrete to enhance the reduction of cement usage in concretes, thereby reducing the production cost.

2.1 Concrete as a Construction Material

The use of concrete as a material in construction is very old and till date the most plastic material for constructional purposes (Neville, 1996). Beside water, concrete is the most consumed substance with three tonnes used per person per year (Borger and Carraquillo, 1994). It is estimated that, the concrete industry produces about 12 billion tonnes of concrete each year and uses about 2.86 billion tonnes of Portland cement worldwide (Global Cement Report, 2010).

Concrete is a construction material which consists of the mixture of fine, coarse aggregate, cement which are proportionally mixed with a certain percentage of water. The importance of concrete as construction material is increasing every day. Green concrete is a plastic mass, which can be molded into any desired shape (Gupta and Amit, 2004). Its versatility and ready availability have ensured that it has been and will continue to be of great and increasing importance for all types of construction throughout the world (Domone and Illston, 2010).

The properties of concrete are essential factors which cannot be looked down upon. The properties determine to a great extent the strength and serviceability of structures. Concrete is plastic and malleable in green state but strong and durable when hardened. These qualities explain why concrete can be used for constructing skyscrapers, bridges, overhead road systems etc. (Portland Cement Association, 2005). There are many factors that determine the quality of concrete and its strength properties. These include the type of cement used, aggregate quality and grading, the degree of compaction, quality and quantity of water used in concreting, curing method, type of reinforcement embedded including its sizes, arrangement and spacing etc. (Portland Cement Association, 2005)

2.2 Cement

Cement is defined as a powdered material that chemically reacts with water and therefore attains the property of setting and hardening (Neville, 1996). It is an essential component of concrete which after hydration process, binds the aggregates together to form hard, strong and monolithic whole possessing unique properties. It is by no means a simple

material, and its complexities have an impact on the properties and behavior of concrete from mixing right through to the end of its life (Domone *et al*, 2010).

Cement defined as an inorganic material that exhibit characteristic properties of setting and hardening when mixed to a paste with water. (https://en.wikipedia.org/wiki/Cement) Inorganic cements containing reactive chemicals can be divided into two according to the way they set and harden into:

- Non hydraulic cements (e.g. lime) which harden only in air and will not harden under water;
- Hydraulic cements (e.g. Portland cement), which when mixed with water, form a paste which sets and hardens by means of hydration reactions and processes and which, after hardening, retains its strength and stability even under water.

2.2.1 Basic Chemistry of Portland Cement

Limestone and a 'cement rock' such as clay or shale are quarried and brought to the cement factory. These rocks contain Lime ($CaCO_3$), Silica (SiO_2), Alumina (Al_2O_3), and Ferrous Oxide (Fe_2O_3).

The cement is made by heating the aforementioned raw materials rich in oxides of Silicon, Calcium, Aluminium and Iron to temperature of around 1,200-1,400ºC.The chemical reactions that occur within the partially molten mass result from the formation of four main cement materials. Table 2.1 shows the major mineral constituents of Portland cement clinker. In addition to the main chemical constituents listed in Table 2.1,

there exist minor compounds such as TiO2, MnO2, K2O and Na2O (Jayamanna *et al.,* 2013).

Table 2.1: Major mineral Constituents of Ordinary Portland Cement

Name of Compound	Oxide Composition	Abbreviation
Tricalcium Silicate	3 Cao.SiO2	C3S
Dicalcium Silicate	2CaO.SiO2	C2S
Tricalcium Aluminate	3CaO.Al2O3	C3A
Tetracalcium Aluminoferrite	4CaO.Al2O3.Fe2O3	C4AF

Source: Jayamanna *et al.,* (2013)

2.2.2 The Hydration of Portland Cement

When cement is mixed with water, an almost instantaneous exothermic reaction begins upon contact, producing a large amount of heat. Initially the mixture, or paste, is in a plastic state and over time it sets to become rigid and hardens. This hardening is associated with an increase in the strength of the paste. In general terms, hydration is the chemical combining of a compound with water, causing the water involved to be absorbed during the reaction (Bye, 1999). In cement chemistry terms, hydration is the term collectively used for the chemical reactions that take place between the different cement phases present and water. The heat liberated during this process is known as the heat of hydration.

Hydration, however, is a very complex process due to the heterogeneous nature of Portland cement. A series of individual reactions between the water present and the different components of the cement take place both simultaneously and successively and can affect one another directly or indirectly. Chemical and physio-mechanical changes occur in the cement paste due to the combination of the various reactions, particularly during hardening and setting of the paste or concrete (Massazza and Daimon, 1992).

The progress and kinetics of hydration of PC are influenced by a number of internal and external factors such as (Odler, 1998):

- The phase composition of the cement, not only in terms of the quantities of the four major crystallographic phases, but also with respect to the presence of foreign ions within the crystal lattice of the individual phases.
- The fineness of the cement – particle size distribution and specific surface area affect the rate of reaction.
- The water/cement or water/binder ratio, w/c.
- The temperature at which the sample is cured.
- The addition of any chemical admixtures that modify the rate of hydration and the physical properties of the cement paste, such as workability and flowability
- The presence of any cement extenders such as fly ash, blastfurnace slag or silica fume.

Massazza and Daimon (1992) also noted how parameters such as non-evaporable water, chemical shrinkage and heat of hydration affect the degree of hydration.

The four major crystallographic compounds that participate in the hydration reactions are shown in Table 2.2. Each of these compounds reacts differently with water, contributing to the heat of hydration at different times, in different amounts and at different rates. Other participants in the hydration reaction include free CaO ions, alkali sulphates and gypsum (calcium sulphate) (Odler, 1998). Cements therefore differ quite significantly in their heat evolution characteristics because of the varying amounts of the major crystallographic phases present and different ways in which they affect the heat of hydration.

The assumption generally adopted however, is that the heat of hydration of cement is equal to the sum of the individual heats of hydration of the cement phases. The C2S present contributes the least to the heat of hydration and the C_3A contributes the most to the heat evolved, followed by the C_3S (Copeland and Kanto, 1972). This supports the observation that cement with high C_3S and C_3A contents will have a large amount of heat evolved relative to cement with a large amount of C_2S. The alluminate and alite phases also hydrate far more rapidly than the other mineral components and this suggests that cements that hydrate quickly also produce a large amount of heat in the early stages of hydration.

2.2.3 The Mechanisms of Hydration

With the hydration of cement, there are at least two, and possibly up to four cycles of increasing and decreasing rates of reaction. Four distinct stages of hydration can be identified from the heat rate versus time curve shown in Figure 2.1. During the early

stages, there are significant interactions between the main phases since most particles are smaller than 5 µm and there is a wide distribution of interstitial phases. During the later stages of hydration however, the phases can be considered to be hydrating independently of one another because of the barriers created by the hydration products formed and the limited amount of free water available (Bye, 1999)

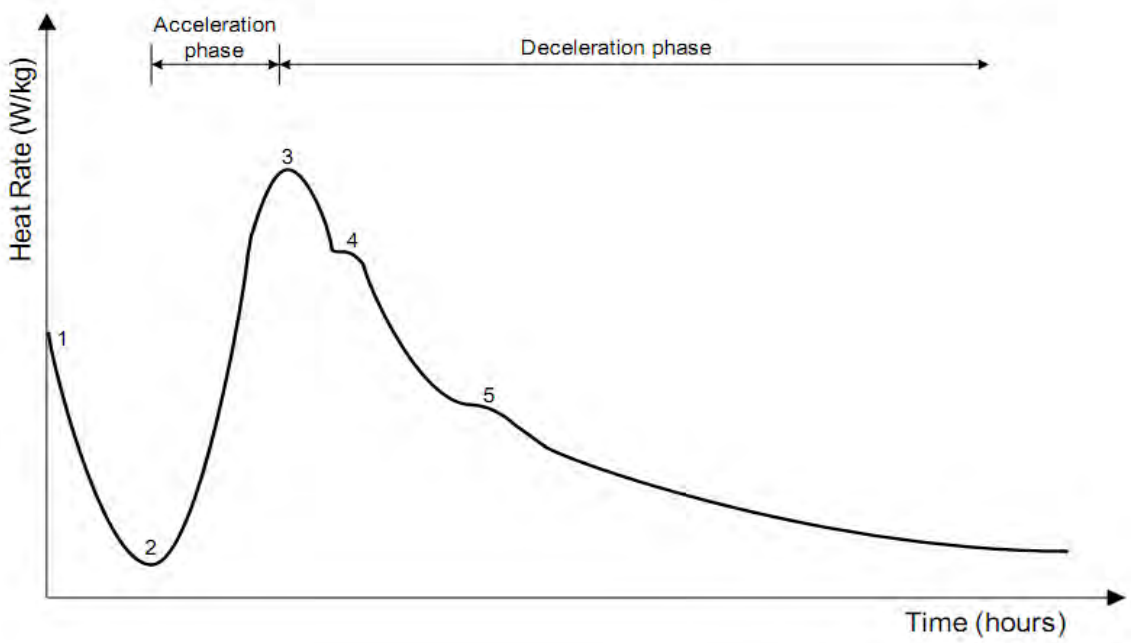

Figure 2.1. A typical heat rate versus time curve for the hydration of cement (Bye, 1999, Mindess and Yong, 1981**)**

Stage 1: Pre-induction Stage. Almost immediately on adding water, some of the clinker esulphates and gypsum dissolve, producing an alkaline, sulfate-rich solution. Soon after mixing, the most reactive of the clinker minerals - reacts with the water to form an aluminate-rich gel. The gel reacts with sulfate in solution to form small rod-like crystals of ettringite .Hydration of free lime and the wetting of the cement also occur at this stage

(Lee, 1983). C3A hydration is a strongly exothermic reaction but it does not last long, typically only a few minutes. The fast heat evolution at the pre-induction period is attributed to the hydration of C3A, the hydration of free lime and the wetting of the cement. C3A is the most active at this stage and reacts with gypsum to produce ettringite. The main products are ettringite and calcium hydroxide (Zhou, 2006). The duration of this stage is less than 60 minutes. This reaction leads to the initial setting time of cement.

Stage 2: Induction or Dormant Stage. The early rate of hydration and heat evolution soon slows down quite rapidly as the layer of hydration products formed around the cement grains begins to act as a barrier between the cement particles and the water. The gypsum in the cement also begins to retard the hydration of C_3A in order to prevent false set from occurring. This dormant period occurs during the first few hours after mixing (Odler, 1998).

Stage 3: Acceleration Stage. The end of the dormant period is signified by a sudden rapid increase in the rate of hydration and heat evolution of the paste roughly three to twelve hours after mixing. Initial set of the cement usually occurs on the lower side of trough 2, where the rate of heat evolution is still increasing. Final set generally occurs soon after the maximum exothermic peak is reached (Copeland and Kanto, 1972).

Although all four of the major phases are involved in hydration during the acceleration stage, it is mainly the reaction of the alite, and to a lesser extent the alluminate phase, that result in peak 3 in figure 2.1. The reaction between C_3A and $CaSO_4$ produces ettringite.

The increased rate of C_3S hydration leads to the formation of secondary CSH gel around the cement particles (Odler, 1998).

The hydration of alite governs the time and shape of peak 3 (Copeland and Kanto, 1972). At roughly the same time as initial set begins, the alite has hydrated sufficiently for CSH particles to start interlocking. This leads to final set of the cement and contributes to the strength development of the paste. The decrease in the rate of heat evolution after peak 3 is due to two main reasons; the surface area of unhydrated cement particles has decreased, and the layer of CSH gel coating the cement grains limits the ingress of water.

The rate of the C_3A reaction also increases as gypsum is consumed and more ettringite (AFt) crystals or rods are formed (Bye, 1999). The precipitation of a form of calcium hydroxide, known as Portlandite, from the liquid phase also plays a major role in the increased rate of heat evolution associated with peak 3. The hydration of C_2S also increases, but at a much slower rate than that of the C_3S, and makes a greater contribution to the later stages of hydration.

Stage 4: Post-Acceleration Stage. The rate of hydration gradually slows down after the main peak in the rate of heat evolution, which, as mentioned, is due mainly to CSH and Portlandite formation. The progression of hydration is now largely controlled by the rate of diffusion of free ions in the liquid phase through the layer of hydration product surrounding each cement grain. CSH formation continues steadily and the contribution of C_2S to its production increases with time (Odler, 1998).

An additional peak or shoulder (peak 4) is often seen as the gypsum content is depleted and a short renewal of ettringite formation is seen coupled with the conversion of ettringite to monosulphate (AFm). The ettringite crystals usually stop forming about one day after initial mixing of the concrete. Occasionally a second shoulder (peak 5) occurs when C_3A reacts with some C_4AF causing some of the AFt crystals to be replaced by AFm plates, which are deposited on the surface of the cement grains (Bye, 1999).

2.2.4 The Kinetics of Hydration

The kinetics of cement hydration is affected by the relationship between the degree of hydration and the age of the paste, and any other factors that affect the two (Taylor, 1997). The kinetics also differs for the various constituent phases found in cement (Massazza and Daimon, 1992).

Hydration of Alite. The hydration of C_3S begins almost immediately when the cement and water come into contact. This initial reaction is rapid, but only lasts a few minutes before the dormant period begins. At this point, the reaction slows down quite dramatically, but does not cease. The reaction then speeds up again and continues to do so until a large portion of the available alite has been used up (Barret and Bertrandie, 1991). As the surface area or fineness of the alite crystals increases, so too does the rate of hydration of the alite. This leads to an increase in the amount of heat evolved from the cement with respect to time and contributes to the size and shape of peak 3 in figure 2.1 (Bye, 1999). The rate of C_3S hydration also depends on its reactivity, which is governed to an extent by the following factors (Odler, 1998):

- The amount and quality of foreign ions present in the crystal lattice.

- Hydration of alite is accelerated in cements when greater amounts of SO_3 are present.
- Alite hydration decelerates with an increasing C_2S/C_3S ratio in the clinker.

According to Bye (1999), there are two distinct ways in which alite hydrates. The first is a through-solution mechanism where the rate of growth of CSH gel is dependent on the surface area of hydration product already formed. As hydration progresses, the CSH gel formed acts as a protective barrier around the cement grain, creating a situation where the rate of reaction is dependent on the rate of dissolution of water through this layer. For the second mechanism, alite hydration takes place at the surface of the CSH layer where ions are diffused from the cement particles into solution around the particles. The first mechanism is more dominant than the second mechanism during the early stages of hydration, and vice versa.

The formation of CH or portlandite, is also associated with the hydration of C_3S. Crystalline CH begins to form at the end of the dormant stage and the amount produced increases as alite hydration progresses (Odler, 1998).

Hydration of Belite. Belite exists in the form of four main polymorphs in cement, namely α-, α'-, β- and γC_2S. Although all four polymorphs are involved in the hydration of belite, only the β polymorph is of any real concern in the hydration of cement. βC_2S reacts in a very similar way to C_3S, producing similar hydration products (Bye, 1999). The difference between the alite and β-belite reactions is that the βC_2S reacts at a much

slower rate and produces less CSH or CH hydration products than the C_3S. βC_2S also shows a period of secondary hydration, unlike alite.

According to Bye (1999), this suggests that spalling of the layer of hydration product takes place at the surface of the unhydrated belite. C_2S therefore contributes very little to peak 3 in figure 2.1, but does increase concrete strength during the later stages if hydration is allowed to continue. Since belite reacts very similarly to alite, the hydration products are the same, namely CSH gel and CH crystals.

Hydration of Tricalcium Alluminate. The C3A in cement reacts extremely quickly when in contact with water, producing almost all the heat associated with peak 1 in figure 2.1. The gypsum present in cement however, acts as a retardant to the hydration of the alluminate phase. If gypsum were not present, the C_3A hydration would cause premature flash set of the concrete. Bye (1999) suggests that the retardation of C_3A in the presence of free calcium and sulphate ions in the aqueous phase is mostly due to the formation and deposition of ettringite crystals on the surface of the particles. Bye (1999) adds that retardation is further increased in the presence of calcium hydroxide, which causes the precipitation of a more compact layer of supersaturated crystals.

Between five and twenty five percent of the alluminate present reacts within the first five minutes of hydration according to Odler (1998). The reactivity depends on the quality and quantity of the alkalis presents in the crystal lattice of the cement, and is increased in the presence of K^+ ions and decreased in the presence of Na^+ ions.

Hydration of Calcium Aluminoferrite. C_4AF hydration is similar to that of C_3A, only much slower and less volatile. The rate of hydration varies according to the A/F ratio in the cement (Odler, 1998).

2.3. Thermal Analysis of Portland cement

Cement undergoes phase changes when it is subjected to heat treatment between 20oC and 1100^{o}C. The reactions that occur with an increase of temperature in cement paste and concrete according to Lea (1970) and Sharma and Pandey (1999) are summarized as follows:

- From 30°C to 105 °C; surface water begins to evaporate and a part of the bound water escapes. It is generally considered that the evaporable water is completely eliminated at 120 °C.
- Between 110°C and 170°C: the decomposition of gypsum (with a double endothermal reaction) and ettringite occurs and the loss of water from part of the carboaluminate hydrates takes place.
- Between 180°C and 500 °C: the loss of bound water from the decomposition of the C-S-H and carboaluminate hydrates occurs and
- From 450°C to 550°C: dehydroxylation of the portlandite (calcium hydroxide) takes place.
- 700–900 °C: decomposition of calcium carbonate.

2.4. Cement Utilization in Ghana

A study conducted by Mott McDonald Consulting Limited in 1996, on usage of cement in Ghana showed that the building sector accounted for more than 90% of cement consumption whilst the road sector consumed the remaining 10% mainly for the construction of bridges, culverts, drains, pedestrian pavements, among others.

Cement consumed in Ghana is produced from imported clinker and gypsum from Togo, Middle East and Europe. Since the year 2008 more than $280 million is spent annually on clinker and cement importation in Ghana. Cement consumption will continue to increase because of increasing population growth and increased infrastructure developmental activities by the Government, estate developers, institutions and private individuals (Atiemo, 2004).

According to Atiemo (2004), utilisation of local limestone, clam shells, pozzolana, and slag, among others in production of cement will expectedly decrease the cost of production by at least 10% as a result of energy reduction and reduced cost of materials. It will also result in capital retention and increased technical capacity. As reported by Atiemo (2004), Table 2.2 presents the trend of cement consumption in Ghana from the year 2000 to 2009. It shows that cement usage has increased from 1.8 million tonnes to about 3.3 million tonnes. This demand has also affected the price of cement greatly and is certainly beyond the reach of the vast majority of people in this country, where income levels are low and about half of the population lives in poverty. Meanwhile, several materials exist in Ghana which can be blended with ordinary Portland cement for

building and construction without affecting the strength, quality and durability of the cement products. In most cases the quality of the cement is improved and the cost of production greatly reduced.

As a result of the afore-mentioned problems of high cost and unavailability of cement, the use of durable local cementitious materials would help to reduce the price of cement in these countries. Several materials exist in Ghana which can be blended with ordinary Portland cement.

Table 2.2. Estimated consumption of Portland cement in Ghana

Year	Cement in Million Tonnes
2000	1.81
2001	2.05
2002	2.15
2003	2.33
2004	2.50
2005	2.65
2006	2.80
2007	3.02
2008	3.31
2009	3.29

Source: GHACEM and Diamond Cement Ltd (2010)

Ghana utilizes about 3.3 million tons of cement annually. Consumption in West Africa exceeds 150 million tons, with more than 70% being imported. A reduction of clinker imports by at least 15% substitution with local admixtures will greatly reduce the cost of locally produced cement and environmental pollution. Utilisation of local limestone, clam shells, pozzolana, and slag, among others in the production of cement

2.5 Cement Extenders

Cement extenders are routine additive used for reducing slurry density and increasing the yield of cement slurry. Extenders reduce the amount of cement required to produce a given volume of set product which results in a greater economy (Shadizadeh et al, 2010).

Different types of cement extenders or additives, such as fly ash, blastfurnace slag or silica fume are added to a concrete mixture as a replacement material for a portion of the cement present. Such replacement materials are commonly referred to as cement extenders. Most of these additional materials react with some of the components of the cement paste yielding desirable characteristics such as improved strength, workability and better durability (Greensmith, 2005).

2.5.1 Fly Ash

Fly ash (FA) is obtained from the ash produced from coal-burning power stations removed by electrostatic precipitators (Addis, 1986). A major part of the dust carried out from the burning of the coal contains a glassy material that is derived from the clay present in the pulverised coal (Bye, 1999). Fly Ash is a fine powder consisting of round,

hollow spherical particles that constitute mainly glass and quartz, mullite and calcium oxide.

The fineness of the Fly Ash plays an important role with respect to the reactivity of the material and the workability of the concrete in which it is used. As a general rule, the finer the fly ash the greater the pozzolanic activity and the better the workability of the concrete mixture. However, too fine FA is used in a concrete mixture that already contains a significant proportion of fines, the concrete could lose workability and become sticky.

Advantages of using Fly Ash

Addis (1986) and Langan et al. (2002) note some of the advantages and disadvantages of using FA as a replacement material in the binder:

- A reduction in the cost of materials and a saving on energy, as less cement is used resulting in a reduction in CO2 emissions
- Better workability and concrete cohesiveness
- A reduction in construction costs as workability is improved
- Reduced water penetration
- Reduced shrinkage
- Reduced heat of hydration
- Reduced cracking tendency
- Slower strength development due to the accompanying pozzolanic activity.

The Effects Fly Ash on Concrete Properties

The most notable effect of adding FA to a concrete mixture is the reduced water demand and great improvement in workability and flow. This is often the main reason for adding FA to a concrete mixture. According to Bye (1999), this is the result of the absorption of negatively charged particles of silica-alumina glass on the cement grain surfaces. Flow and workability are improved by the mutual repulsion of these negative charges in the paste. The extent of this improvement depends on the fineness and carbon content of the FA and, as mentioned, the finer the material, the greater the effect (Addis, 1986). The carbon content however, has the reverse effect and the more carbon present, the more detrimental the effect on the workability of the concrete.

The hydration of FA cements differs from that of Portland cement with respect to the rate of hydration of the different cement phases, the amount of portlandite formed, the composition of the hydration products and the additional compounds formed as a result of the reactions involving the fly ash itself (Ramachandran et al., 2003). Lower amounts of portlandite are formed in the presence of FA because of the pozzolanic nature of FA and the reaction that occurs between the FA present in the binder and in the lime produced during the PC hydration reactions (Lilkov et al., 1997). Many FA materials however, are unsuitable for use in concrete because of their low pozzolanic activity (Ramachandran et al., 2003).

According to Lilkov et al. (1997), FA has the effect of generally retarding the early stages of hydration and then accelerating the hydration process during the middle and later

stages, particularly the hydration of alite present (Langan et al., 2002). This early retardation is because of the slowing of the calcium hydroxide saturation rate in the liquid phase due to the presence of FA. C_3A and C_4AF also experience the same trend of decelerated hydration in the early stages and accelerated reactions towards the later stages. This has the overall effect of reducing the rate and amount of heat evolved in the concrete during hardening in the presence of FA. According to Addis (1986), the percentage of heat reduction in fly ash cement at twenty-eight days is approximately equal to percentage of FA replacement of PC with respect to the total mass of the binder material.

The composition of the alite and belite hydrates in the paste of a three-day-old FA/PC concrete is very similar to that of a plain PC concrete. The main difference is that the proportions of the hydration products differ (Ramachandran et al., 2003). During the later stages of hydration, the FA reduces the C/S ratio in the CSH gel produced and increases the A/C ratio. The greater the FA content, the greater these effects become.

The condensation of silicate anions with respect to the C_3S present is also more rapid when FA is introduced into the concrete mixture.

The presence of FA reduces the amount of CH in the hydration product because of the dilution effect it has during the consumption of calcium hydroxide in the pozzolanic reactions. Initially however, the formation of solid calcium hydroxide from the hydration of C_3S is greater than the consumption of CH in the pozzolanic reaction, but eventually the amount of CH present in the hardening paste peaks and then begins to decline (Bye,

1999). The replacement of solid CH with CSH gel in the hardened paste also creates the potential to reduce the permeability of the concrete by modifying the distribution of pore sizes. This can have positive effects on the durability of the concrete since the possible ingress of deleterious foreign materials is reduced due to a reduction in permeability.

The presence of fly ash consequently reduces the magnitude of the main exothermic heat rate peak (peak 3, in figure 2.1) and delays the time at which it occurs (Langan et al., 2002). This delay is greater in the presence of FA with greater calcium content.

Bye (1999) states that with a thirty percent cement replacement with fly ash, the principle peak in heat rate is delayed between three and four hours and the presence of FA depresses the maximum value. The rate of hydration however, is also dependent on the fineness of the FA used and generally, as particle size is decreased the exothermic heat rate peaks as seen in figure 2.1 become sharper and occur sooner in the hydration process (Ramachandran et al., 2003).

If FA is to be used with a view to reducing the heat of hydration, Ramachandran et al. (2003) recommend that high volume (greater than fifty percent binder content) FA cement be used with a low calcium FA because low calcium FA has shown to have the following benefits:

- Low temperature rise
- Adequate early age strength (depending on the w/c ratio)
- Higher later age strengths.

2.5.2 Blast Furnace Slag

Blastfurnace slag is a non-metallic molten by-product formed during the smelting of iron ore. This liquid generally contains siliceous and alluminosilicate impurities from the iron ore and coke involved. The principal oxides found in slag include lime, silica and alumina and hence it is made up of similar chemical compounds to those found in Portland cement, but in different proportions (Bye, 1999). If cooled slowly, slag crystallises and the material possesses little or no cementing properties. If however, it is cooled rapidly to below 800°C the slag forms a granular, glassy material with the hydraulic properties of a cementitious material. This is the type of slag used as a cement replacement material in concrete. The slag is usually ground down into a fine powder, hence the common industry name ground granulated blastfurnace slag (GGBS).

The Effect of GGBS on Concrete Properties

The addition of GGBS to a concrete mixture can influence certain properties of the concrete such as compressive strength development, heat of hydration characteristics, flexural strength and construction cost. According to Addis (1986), some of the effects of using GGBS as a cement replacement material in a mixture include:

- Lower cost of binder material.
- When comparing concretes with equivalent mixture parameters and w/c ratio, the compressive strength of slag cement is generally lower than that of PC before 28 days. The long-term strength development is also slower. The difference in strength however, tends to disappear by about 90 days of curing.

- GGBS concretes exhibit lower heats of hydration than plain PC concretes. It is for this reason that many mass concrete elements have slag in the cement binder in order to reduce the potential for thermal cracking. The extent to which slag reduces the heat evolved is difficult to predict because the effect of the slag varies depending on the composition of the GGBS and the ratio of PC to GGBS in the binder. The reduction in heat rate in the GGBS/PC cements is also more pronounced during the first three days of curing than over the first seven days. Early flexural strength of GGBS concretes is generally lower than that of equivalent PC concretes during the first three days. The opposite is true however, at seven and twenty eight days of curing. This observation indicates a slower, yet improved flexural strength development in concretes containing GGBS.

Strength development and heat of hydration effects of blastfurnace slag on the properties of concrete depend on the ability of the slag to react in the cement paste system (Coole, 1988).Concrete containing GGBFS cement has a higher ultimate strength than concrete made with Portland cement. It has a higher proportion of the strength-enhancing calcium silicate hydrates (CSH) than concrete made with Portland cement only, and a reduced content of free lime, which does not contribute to concrete strength. Concrete made with GGBFS continues to gain strength over time, and has been shown to double its 28 day strength over periods of 10 to 12 years (http://www.aboutcivil.org).

The reactivity of GGBS depends on a number of factors such as the glass content, the bulk composition and the fineness of the powder (Ramachandran et al., 2003). These

factors are all affected by the rate of cooling to below 800°C. It must be noted however, that a slag is only noticeably reactive in a concrete mixture if it has been activated. This is usually achieved if and when GGBS is in the presence of calcium sulphate (gypsum) or substances such as NaOH, Ca $(OH)_2$ or water glass. Portland cement itself acts as an effective GGBS activator (Bye, 1999), but this is only once an adequate amount of alkalis and portlandite has been produced from the cement hydration reactions (De Schutter, 1998)

2.5.3 Silica Fume

Silica Fume is a by-product from the manufacture of silicon or ferrosilicon alloys by the reduction of silica with carbon in an electric furnace. The gases produced are condensed into an extremely fine powder with a high silica content, hence the term condensed silica fume or CSF. It is a highly active pozzolan and this high reactivity is due to the fineness, high silica content and amorphous nature of the silica (Addis, 1986). Coatings of carbon on the surface of the silica particles however, can greatly reduce the pozzolanic activity of silica fume.

The Effect of CSF on Concrete Properties

When w/c ratio and binder content are kept constant, the most notable effect of CSF on concrete is the dramatic increase in compressive strength over the first 28 days of curing (Lagan et al., 2002). This of course depends on the amount and nature of silica fume present. The increase in strength is also accompanied by a decrease in the permeability of the concrete, aiding in improving the durability characteristics (Addis, 1986).

Other important points to note regarding the effect of CSF on concrete include (Ramachandran et al., 2003):

- The total heat of reaction per unit mass of binder is greater in concretes containing silica fume.
- At all stages during hydration, the $Ca(OH)_2$ content of the concrete is lower in the CSF concretes compared to PC concretes. This is due to the pozzolanic nature of silica fume.
- In the presence of CSF, the heat rate curves indicate that there is no secondary ettringite or monosulphate produced during hydration.

2.5.4 Blended cement

Blended cements are currently used in many parts of the world (Bakar, Putrajaya, and Abdulaziz, 2010). Calcium hydroxide [$Ca(OH)_2$] is one of the hydration products of Portland cement and it greatly contributes toward the deterioration of cement composites. When a pozzolan is blended with Portland cement it reacts with the lime to produce additional calcium-silicate-hydrate (C-S-H), which is the main cementing compound. Thus the pozzolanic material reduces the quantity of lime and increases the quantity of C-S-H. Therefore, the cementing quality is enhanced if a pozzolan is blended in suitable quantity with Portland cement (Padney *et al.*, 2003).

Agricultural by-product pozzolans have been used in the manufacture and application of blended cements (Malhotra and Mehta, 2004). Nimityongskul and Daladar (1995) highlighted the potentialities of coconut husk ash, corn cob ash, and peanut shell ash as

good pozzolans. Elinwa and Awari (2001) successfully investigated the potentials of groundnut husk ash concrete by partially replacing Ordinary Portland Cement with groundnut husk ash. Adesanya (1996) investigated the properties of blended cement mortar, concrete, and stabilized earth made from OPC and corn cob ash and recommended that corn cob ash can serve as replacement for OPC in the production of cement composites. Dwivedia et al. (2006) successfully investigated the pozzolanicity of bamboo leaf ash. Martirena, Middendorf, and Budelman (1998) found that sugar industry solid wastes such as sugar cane straw ash has pozzolanic activity derived from its high content of amorphous silica. Many other researchers have confirmed rice husk ash a pozzolanic material that can be used to partially replace OPC in making cement composites (Cordeiro, Filho, and Fairbairn, 2009; Habeeb and Fayyadh, 2009; Rukzon, Chindaprasirt, and Mahachai, 2009). A number of researchers have also found good prospects in using blended cements made with sawdust ash (Mehta, 1997; Elinwa, Ejeh, and Mamuda, 2008; and Elinwa and Abdulkadir, 2011). Studies by Chandrasekar et al. (2003) suggest that soil, climatic, and geographical conditions could affect the physical and chemical properties and consequently the pozzolanicity of agricultural by-products.

A study carried out by Fernanda et al. (2008) also showed that, addition of rice husk as cement replacement materials provides additional improvements in compressive and splitting tensile strength and resistance to chloride ion penetration. Thus, rice husk may be utilized as effective mineral addition for designing durable concrete structures. The best content of silica recommended to be added in a volumetric substitution to the Portland cement is 10%. They further observed that the specimens with silica extracted

from rice husk showed higher compressive strength values when compared with their equivalent mixture without addition, already at the early ages. The reasons for early compressive strength development of concretes with rice husk are due to fineness, amorphous phase, specific area and degree of reactivity of rice husk.

2.6 Pozzolana

The American society of testing materials (ASTM) defines Pozzolans as siliceous or aluminous materials which possess little or no cementitious properties but will, in the presence of moisture, react with lime [Ca(OH)2] at ordinary temperature to form a compound with pozzolanic properties. A pozzolan is a material which, when combined with calcium hydroxide (lime), exhibits cementitious properties. Pozzolans are commonly used as an addition (the technical term is "cement extender") to Portland cement concrete mixtures to increase the long-term strength and other material properties of Portland cement concrete and in some cases reduce the material cost of concrete (http://www.aboutcivil.org).

Pozzolanas can be classified as natural and artificial. The basic classification into natural and artificial has no real or engineering purpose (Appiah Boakye, 2012). With respect of economy and performance, it does not matter whether the source is natural or not. Natural pozzolanas are of two types: the true natural pozzolanas and the pseudo natural pozzolanas.

The true natural pozzolanas are ashes and lavas originating from alkalitrachytic, leucitic, leucotephritic and hauynophric types of magma. These ashes result from explosive eruptive volcanoes and are forced to solidify as a pyroclastic glass (glass fragments formed by rapid quenching of magma produced by volcanic explosions) (Malquori, 1960). In the pseudo natural pozzolanas, the pyroclastic glassy minerals in the original lava have undergone hydrothermal alteration (auto-metamorphism) leading to zeolitization and sometimes argillization (Malquori, 1960, Steopoe, 1964, Kemser, 1964). Artificial pozzolanas are those materials in which the pozzolanic property is not well developed and hence usually have to undergo pyro-processing before they become pozzolanic (Hammond, 1983). Artificial pozzolanas include materials such as flyash, blast furnace slag, surkhi (burnt clay), siliceous and opaline shales, spent oil shale (used in Sweden to make gas concrete), rice husk ash, burnt sugar cane stalks and bauxite waste (Grane, 1980).

The general term pozzolana is used to designate natural as well as industrial co-products that contain a percentage of vitreous silica. This vitreous (amorphous) silica reacts at ambient temperature with the lime produced by the clinker minerals to form hydrated calcium silicates (C-S-H) (Venuat, 1984, Malhotra, 1987, Malhotra and Mehta, 1996).

2.6.1 The Action of Pozzolana

The additive (pozzolana) act in three ways as a:

1. Filler

2. Nucleating
3. Pozzolanic

1. Filler: These additives/admixtures are finer than cement, so when added to concrete they occupy the small pores previously left vacant.

2. Nucleating: These fine particles accelerate the rate of hydration and precipitation starts.

3. Pozzolanic: When cementing material reacts with water the following products result:

C_2S + H CSH + CH

C_3S + H CSH + CH

CSH is responsible for strength while CH is a soluble material reacts and dissolves in water leaving behind pores. So when admixture is added

SiO_3 or Al_2O_3+ CH CSH

Thus, it reduces the amount of CH and increases CSH

Conditions to Declare a Material Pozzolan:

- Having silica + Alumina oxide+ ferrous oxide more than 70%.
- Surface area on normal admixture is more than 300m^2/kg.
- Surface area should be more than cement used. (http://www.aboutcivil.org).

2.7 Palm Kernel Shell

Palm kernel shell PKS is the hard endocarp of palm kernel fruit that surrounds the palm seed. It is obtained as crushed pieces after threshing or crushing to remove the seed which is used in the production of palm kernel oil (Olutoge, 1995). PKS is light and therefore ideal for substitution as aggregate in the production of light weight concrete. Olutoge (1995) in his investigations into the physical properties of palm kernel shell found it density to be 740kg/m3. He concluded that this material has properties which resembled those of light weight concrete materials.

Palm kernel shell is an industrial waste and it is available in large quantities especially in palm oil producing areas. Palm kernel shells have very low ash (about 3% weight - ASTM D3174-02, 2002) and sulphur (about 0,09% weight – ASTM D4239-02, 2002) contents. Palm kernel shells (PKSA) are hard, carbonaceous, organic by- products of the processing of the palm oil fruit. It 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.

In Ghana, utilization of PKS is minimal and unmanageable while its quantity increases annually and most of the PKS are disposed as waste in landfills causing environmental problems. To solve the energy problems, solid wastes from palm oil residue are used as fuel to produce steam for electricity in advance countries. After burning, an ash by-product is produced. As a solution to the disposal problem of the ash derived from palm

oil, research studies have been carried out to examine the feasibility of using the ash as cement replacement materials (Tay et al, 1995).

As a result of the aforementioned reasons, this paper aims at studying the potential of PKSA as cement extender in concrete, the effects of increasing the volume of PKSA on the compressive strength of concrete.

2.7.1 Usage of Palm Kernel Shell in Construction

Palm kernel shells are generally not used in construction. They are used as fuel by local blacksmiths and as fill material or as palliatives (Osei and Jackson, 2012). They reported that palm kernel shells could be used as coarse aggregates in concrete. Palm kernel shells can be used as partial replacement for coarse aggregates up to 10% for heavily trafficked roads and 50% for light trafficked road.

Ndoke (2006) investigated the suitability of palm kernel shells as partial replacement for coarse aggregates in asphaltic concrete. Olutoge (2010) investigated the suitability of sawdust and palm kernel shells as replacement for fine and coarse aggregate in the production of reinforced concrete slabs. He concluded that 25% sawdust and palm kernel substitution reduced the cost of concrete production by 7.45%. He also indicated the possibility of partially replacing sand and granite with sawdust and palm kernel shell in the production of lightweight concrete slabs.

According to Olutoge, Quadri and Olafusi (2012), Palm kernel shells ash can be used in concrete .This ash has pozzolanic properties that enable it as a partial replacement for cement but also plays an important role in the strength and durability of concrete.

Olanipekun (2006) compared concrete made with coconut shells and palm kernel shells as replacement for coarse aggregates and concluded that coconut shells performed better than palm kernel shells as replacement for conventional aggregates in the of concrete.

2.7.2 Chemical Composition of PKSA

The chemical composition of PKSA depends on number of factors including; species of the tree, growing conditions and the combustion methods that include combustion temperature, efficiency of the boiler, and supplementary fuels used. The ash produced sometimes varies in tone of color from whitish grey to darker shade based on the carbon content in it. In other words, the physical characteristic of PKSA is very much influenced by the operating system in the palm oil factory (Olutoge et al, 2012). Like the coal fly ash, PKSA can be classified as either class F (pozzolana) that contains less than 10% lime (CaO) or class C with more than 10% lime (CaO) content.

Generally, after combustion, the main constituents of the PKSA as determined by Olutoge et al (2012) in their research: Investigation of the Strength Properties of Palm Kernel Shell Ash Concrete and other researchers are Silicon (SiO_2), Aluminum (Al_2O_3), and Iron Oxide (Fe_2O_3).

The total amount of SiO_2, Al_2O_2 and Fe_2O_3 present in PKSA is 66.572% which is more than the minimum required (50% Min.) specified by ASTM, for Type C Ash; while its Calcium oxide (CaO) content is about 8.786%; as shown in Table 2.3.

Table 2.3: Chemical Properties of PKSA/OPC

Chemical composition (%)	OPC	PKSA
SiO2	22.13	54.810
Al2O3	3.74	11.4
Fe2O3	2.97	0.362
CaO	63.36	8.786
MgO	2.58	6.108
K2O	0.52	6.254
True Density (g/cm^3)	2.97	2.60

Source: Olutoge *et al.,* (2012)

Table 2.4: Oxide Composition of Palm Kernel Shell Ash

Oxide	Concentration (%)
SiO_2	15.1
SO_3	0.9
K_2O	6.62
CaO	10.8
MnO	0.39
Fe_2O_3	3.98
ZnO	0.48
CuO	0.091
P_2O_5	3.5
BaO	0.44
LOl	2.42

Source: Edeh *et al.,* (2012)

In their research, it was revealed that, water absorption, initial and final setting time of the PKSA concrete took longer time than OPC concrete, which implies that the presence of PKSA increases the water absorption and setting time of concrete. Therefore the higher the PKSA content in concrete, the longer the water absorption and setting time. This is so because, the factors that influence setting time of concretes are the volume of Portland cement, water requirement, temperature of the concrete and the reactivity of the pozzolan. However, PKSA concretes do not absorb water as fast as OPC concretes; thereby retarding hydration processes in the PKSA concrete (PKSA concretes retain water for a longer period before it starts to dry up slowly).

Based on the findings from their research Olutoge et al (2012), made the following conclusions;

- PKSA contains all the main chemical constituents of cement though in varying quantities compared to that of OPC; this means it will be a good replacement if the right percentage is used.
- The use of PKSA as a partial replacement for cement exhibits a lower water absorption rate and slower setting time of concrete.
- Concrete strength increases with curing age and decreases with increasing percentage of PKSA replacement in concrete.
- The use of PKSA will reduce the volume of cement used in concrete, thereby reducing the cost of concrete production.
- The use of PKSA will minimize the environmental issues arising from the disposal of Palm kernel wastes.

CHAPTER THREE

MATERIALS AND METHODS

This chapter provides information on the method that was employed for this research work. It provides vivid description of the procedure used to find answers to the research hypothesis. Primarily, it focused on three major headings, that is: materials, preparation of concrete cubes and cylinders, and the method employed for the data analysis.

Materials section outlines and describes the various ingredients used in the preparation of the concrete. Preparation of concrete cubes and cylinders also describes the procedure through which the concrete was mixed, cast, cured and tested to obtain the raw data. The latter part describes how the raw data was organized for easily presentation and understanding.

3.1 Materials

The following materials were used in the preparation of the concrete cubes and cylinders for this research:

- Palm kernel shell ash
- Cement(ordinary Portland cement)
- Fine Aggregate
- Coarse Aggregate
- Water

3.1.1 Processing of Palm Kernel Shell

The palm kernel shell was obtained from Asamang in the Sekyere South district of the Ashanti region. It was thoroughly washed with clean water to remove the sand particles which were mixed up with it as a result of how the palm kernels are extracted by the local folks. The washed shells were then sun dried for three days to keep them dried for easy combustion. They were burnt in an uncontrolled combustion for 36hours and ground into fine ash particles. The PKSA was sieved through a 45um sieve in order to remove any foreign material and bigger size ash particles. Only the fine ashes which passed through 45um sieve were collected. The chemical analysis of the PKSA samples was further carried out at the KNUST chemistry laboratory to determine its chemical composition. Appendix C1 shows the laboratory result.

3.1.2 Chemical Composition of Palm Kernel Shell Ash.

One gram of boichar sample was weighed into a clean ceramic crucible. An empty crucible was included for a blank in each batch of 24 samples. The samples were arranged in a cool muffle furnace and temperature ramped to 500^{o}C over a period of 2 hours. This temperature was allowed to remain for an additional 2 hours. The samples were allowed to cool down in the oven.

Samples were then removed from the oven ensuring that the environment was free from breeze.

Ash samples were transferred first into already numbered 50 ml centrifuge tubes.

Crucibles were rinsed with 10 ml of distilled water into the centrifuge tubes. More rinsing of the crucible with 10 ml of aqua regia was done. The samples were shaken for 5 minutes for proper mixing on a mechanical reciprocating shaker. Samples were centrifuged for 10 minutes at 3000 rpm and then transferred into 100 ml volumetric flask and again made up to the 100 ml mark with deionised water. The clear supernatant digest were decanted into clean reagent bottles for macro- and micro-nutrients determination.

3.1.2.1 Method of determination of calcium (Ca) and magnesium (Mg)

Calcium and magnesium determination by EDTA titration involves addition of several reagents. These reagents were prepared as;

Buffer solution – 60 g of ammonium chloride was dissolved in about 200 ml of distilled water. 570 ml of concentrated ammonium hydroxide was added and diluted to 1000 ml in a volumetric flask.

Potassium cyanide: 10 % KCN (W/V) was prepared by dissolving 50 g of KCN in 500 ml of distilled water in a volumetric flask. This solution complex off all cations that react with EDTA.

Potassium hydroxide: 10 % KOH (W/V) was prepared by dissolving 100 g of KOH in a litre of distilled water. Necessary when determining Ca^{2+} since it enables it to react with EDTA.

Calcon – red (cal – red) indicator: This indicator gives red coloration when Ca^{2+} is absent but gives bluish color when Ca^{2+} is present.

Triethanolamine (TEA): 30 % (V/V) was prepared by diluting 300 ml TEA in a litre of distilled water. This is a viscous solution which is included to maintain p H.

Erichrome Black T (EBT): 0.2 g of EBT was weighed and dissolved in a mixture of 50 ml methanol (85 %) and 2 g hydroxylamine hydrochloride. Indicator for determining Ca^{2+} + Mg^{2+}. Gives red coloration in the absence of Ca^{2+} + Mg^{2+} and bluish coloration in the presence of Ca^{2+} + Mg^{2+}.

0.02N EDTA Solution (Versenate): 3.723g of reagent grade disodium ethylenediamine tetra acetate dehydrate was dissolved in distilled water. It was diluted to 1000 ml and standardized against magnesium solution with EBT indicator (one ml of 0.02 N EDTA = 0.4 mg Ca = 0.24 mg Mg). EDTA complexes with Ca^{2+} and removes it from solution giving a blue end point in the presence of Ca^{2+}.

Calcium standard (0.02 N): 1.0 g of reagent grade calcium carbonate ($CaCO_3$) was dissolved in 1 ml of conc.HCl and diluted to 1000 ml with distilled water.

Magnesium standard (0.02 N): 2.465 g of reagent grade magnesium sulfate heptahydrate was dissolved in 1000 ml distilled water.

3.1.2.2 Determination of Calcium

5.0 ml of sample solution was transferred into a 100 ml Erlenmeyer flask. 10 ml of 10 % KOH solution was added followed by 1 ml of 30 % TEA, five drops of 2 % KCN and one drop of EBT indicator solution. The mixture was shaken to ensure homogeneity. The mixture was titrated with 0.02 N EDTA solution from a red to blue end point.

Calcium in mg = Titre value of EDTA x 0.40

$$\% \text{ Calcium} = \frac{mg\ Calcium}{Sample\ wt} \times 100$$

Calculation for CaO = % Ca *1.399

3.1.2.3 Determination of Magnesium

5.0 ml sample solution was emptied into a 100 ml Erlenmeyer flask. 5 ml of ammonium chloride – ammonium hydroxide buffer solution was added followed by 1 ml 30% TEA. Three drops of 10 % KCN and a few drops of EBT indicator solution. The mixture was shaken to ensure homogeneity. The mixture was titrated with 0.02 N EDTA solution from a red to blue endpoint.

Magnesium in mg = Titre value of EDTA x 0.24

$$\% \text{ Mg} = \frac{mg\ Magnesium}{Sample\ wt} x\ 100$$

Calculation for MgO = % Mg *1.6581

3.1.2.4 Method of Determination of Potassium (K) and Sodium (Na)

1.908 g and 2.542 g of analytical grade KCl and NaCl respectively previously dried in an oven for 4 hours at 105°C were each dissolved in 200 ml of deionised water. The two solutions were mixed together and volume made up to 1000 ml. This gave a combined standard of 1000 ppm. For K, a calibration curve (standard curve) of 200, 400, 600 and 800 ppm was prepared. Similarly, a standard curve of 20, 40, 60 and 80 ppm was prepared for sodium. All the absorbance reading was taken using the flame photometer.

The potassium in the supernatant digest was determined using Jenway PFP 7 Flame photometer. Standard solutions of KH_2PO_4 with concentrations of 0, 200, 400, 600, 800 and 1000 mg/l were prepared and emissions read from the photometer. The K emissions of the plant samples were also read from the photometer. A graph of emissions versus concentrations of the standards were plotted from which the K concentrations of the plant samples were calculated.

Calculation:

K content (µg) in 1.0 g of plant sample = C x df

$$\text{K content (g) in 100 g plant sample, (\% K)} = \frac{C \times df \times 100}{1000\,000} = \frac{C \times 100 \times 100}{1000\,000} = \frac{C}{100}$$

Where

C = concentration of K (µg / ml) as read from the standard curve

df = dilution factor, which is 100 x1 = 100, calculated as :

- 1.0 g of sample made up to 100 ml (100 times)
- 1000 000 = factor for converting µg to g.

Calculation for K_2O = % K *1.2046

1. Measure 5.0 ml of digest in the Erlenmeyer flask.
2. Gently add 10 ml of 1.0 *N* KCl solution into the Erlenmeyer flask
3. Add 5 drops of phenolphthalein indicator into the mixture in the Erlenmeyer flask
4. Titrate the mixture with 0.05 *N* NaOH to pink end point.
5. Record the volume (ml) of NaOH used (V)

For exchangeable aluminium in digest

1. Add 4 ml of 3 *N* NaF to the titrated extract.
2. Titrate the mixture with 0.05 *N* HCl to colourless end point.
3. Record the volume (ml) of HCl used (V)

Calculations

Exchangeable Hydrogen (meg/100 g)

$$= \frac{V*0.05*100}{W} = V*1.67$$

where

V = Titre volume of NaOH used (ml)

Normality of NaOH = 0.05 *N*

W = volume of digest used (5.0 ml)

Exchangeable aluminum (meg/100 g)

$$= \frac{V*0.05*100}{W} = V*1.67$$

where

V = Titre volume of HCl used (ml)

Normality of HCl = 0.05 *N*

W = volume of digest used (5 ml)

Calculation for Al_2O_3 = mg/100g Al *1.8895

3.1.2.5 Method of Determination of Iron (Fe

The basic setup (air pressure = 50 – 60 psi, acetylene pressure = 10 -15 psi and voltage = 208 – 240V) of the AAS was ensured. The file for the type of analysis and hollow cathode lamps were selected with appropriate wavelengths - Fe at 248.3 nm. A calibration curve was plotted for the element to be analyzed from the stock standards (Buck Scientific,). The prepared sample solution digest were analyzed for the element. The Y in the calibration equation is absorbance of the element and X is the concentration of the element in the sample. X was calculated after substituting the absorbance reading of the sample into the calibration equation. This gave X in terms of mg/L. The total concentration of the element in the sample solution (100 ml) was calculated by multiplying the concentration in mg/L by 0.1L. This gave the total mass of the element in solution. The percentage amount of the element was found by dividing the mass of the

element in solution by initial amount of sample taken followed by a multiplication by 100.

Calculation:

$$\text{Conc. (Fe) (mg/100g)} = \frac{\text{Concentration recorded from AAS X Nominal volume}}{\text{Sample weight (g)}}$$

Where,

Nominal volume =100 ml

Sample weight = 1.00g

Calculation of Fe_2O_3 = mg/100g Fe *1.4297

3.1.2 Cement

The cement used for this work is ordinary Portland cement produced by GHACEM Company at Takoradi in the Western Region of Ghana, and conforming to BS 12(1996). Its chemical composition was obtained from literature. Table 3 in appendix A1 shows a picture of the cement that was used. The strength class was 32.5R.

3.1.3 Coarse Aggregates

Granite was used as coarse aggregates for this research work. The sizes of the coarse aggregates were in the range of 5-10mm. They were obtained from Buoku in Sunyani

municipality, by Vision Quarry Limited. The amount of coarse aggregates used was 178.05kg. Appendix A2 shows a picture of the crushed granite.

3.1.4 Fine Aggregates (sand)

Sand is naturally occurring granular material composed of finely divided rock and mineral particles (Vignesh e tal, 2014). The most common constituent of sand is silicon dioxide, usually in the form of Quartz. Normally sand is used as fine aggregate for the preparation of most concretes. Natural pit sand was used for this research work. In order not to influence the calculated amount of water required for the mix, the sand was fairly dried to reduce its bulk density. To check the suitability of the sand, an amount of it was rubbed between the fingers, no stains shown, indicating that there were no undesirable impurities presences. In all a total of 89kg of sand was used in preparing the test specimens. Appendix A3 shows the sand been weighed on the scale.

3.1.5 Water

Potable water from the Department of Civil Engineering, Sunyani Polytechnic was used for both the mixing of concrete as well as for curing of the cubes. The water had no physical colour and was free from any visible impurities. It conformed to the requirements of BS 1348 (1980).

3.2 Preparation of Concrete Cubes and Cylinders

There are many factors which account for the strength of a particular mix of concrete. These include: type of aggregates, water cement ratio, aggregates cement ratio, placing, compacting and curing method. In order to ensure that the cubes are well prepared, all the enumerated factors were taken into account and the procedure is discussed below.

3.2.1 Silt and Clay Test

This test was in accordance to BS 882:1992. Sample of sand to be used for the concrete was taken to the laboratory for silt and clay test. The materials and tools used for the test include: sand, salt, water, measuring cylinder-250ml and 500ml, and stirring rod. A saline solution was prepared by taking 2.5g of fine salt and dissolves it into 250ml of water in the 500ml measuring cylinder. The purpose of the saline solution was to accelerate the rate of settling of the various particles of the sand. 50ml of saline solution was poured into the 250ml cylinder (glass). The sand was then added into the same cylinder with the 50ml saline solution till the water level in the same cylinder reached the 100ml reading level. An additional saline solution was added till the water reads 150ml. The additional water was to facilitate the ease of stirring. The stirring rod was used to stir the mixture thoroughly. The cylinder was then placed on a flat surface for three hours for sedimentation. The height of sand and silt were measured and expressed in percentage as:

$$\text{Silt and clay content (\%)} = \frac{\text{Height of silt and clay}}{\text{Height of sand}} \times 100$$

3.2.2 Sieve Analysis Test on Crushed Granite

The test was in accordance with BS 812: Part 103.1: 1985. These apparatus were used for the test: Quartering Machine, Automatic sieve shaker, Trays, Set of BS Sieves and Beam balance. The samples were air dried and quartered to get a statistically convenient sample for the test. The quartered sample was weighed and recorded. The weighed sand was poured into the arranged BS sieves and covered. The sieves containing the material were subjected to five minutes shaking using the automatic shaker. The remained sample on each sieve were weighed and recorded. The results of the experiment performed were recorded and tabulated. Aggregate sizes from12.5mm and below was used.

3.2.3 Batching and Mixing

The materials were batched using weight proportioning method. The cement aggregates ratio used was 1: 2: 4 (cement: fine aggregates: coarse aggregates). A water cement ratio of 0.5 was used to determine the amount of water required for mixing each batch of mix. Due to the smaller volume of concrete mixed for each batched of mix, a hand mixing method was adopted. The amount of fine aggregates (sand) required was first measured and placed on the cemented floor of the material laboratory room of the Sunyani polytechnic. The cement was then measured and spread on the already measured sand. These two materials were mixed thoroughly until no distinction could be made between them using shovel. The coarse aggregate was later measured and added to the unified mix of cement and sand. Afterwards, the three materials were mixed together to obtain a uniform mix. Per the calculation made, half the batched water was then poured into the

mix and turned several times to obtain a uniform paste before adding the remaining water. Appendix A5 shows mixing of the concrete.

3.2.4 Workability Test

Workability is the ease at which concrete can be used without much difficulty. It can also be explained as the amount of work required to place concrete and to compact it thoroughly. It is conducted to ensure that concretes are of the correct water cement ratio. After each mix of concrete, a workability test was conducted using slump test.

A truncated cone, 300 mm height and 100 mm diameter at the top and 200 mm diameter at the bottom slump cone was filled in three layers. Each layer was given 25 number of blows with tamping rod of length 600mm long and 16mm diameter with a hemispherical tip. The top of the concrete was levelled with a trowel by a screeding motion. Immediately, after screeding off, the cone was slowly lifted up straight.

The slump cone was then set next to the concrete and the difference in height between the slump cone and the specimen was measured using steel tape measure. The test was performed for all samples. The slump test was performed in accordance with BS 1881: Part 102:1983.

3.2.5 Casting of Concrete Spacemen

A total of thirty (30) Concrete cubes of size 150mm x150mm x 150mm and thirty (30) cylinders of size 150mm x 300mm were cast using varying OPC-PKSA ratio of 100:0,

95:5, 90:10, 85:15, and 80:20, respectively. For each percentage replacement, three (3) cubes and three (3) cylinders were cast.

Metallic moulds having an internal measurement of 150 × 150 × 150mm and 150 × 300mm which was in accordance with BS 1881: Part 108: 1983 were used. Before casting, the metallic moulds were oiled to restrain blow holes and other surface defects. The moulds were filled in three layers, with each layer being tamped 35 times with a tamping rod. The cast specimens were left in the moulds for 24 hours before being de-moulded and then cured in water basin until it was time to be tested. Appendix A5 shows a picture of the metallic mould boxes and the cylinders.

3.2.6 Curing of Specimen

The importance of curing concrete during the early stages of hardening cannot be under estimated. Curing reduces the rate at which the initial drying shrinkage occurs, thereby minimizing cracking and increasing the durability of the concrete. For this research, after twenty four hours (24hrs) of casting the specimens were de-moulded and cured by immersing them in a water basin containing sample water that was used for the mixing. The specimen was tested at age 7days and 28days of curing for compressive and tensile strength. All the cubes and cylinders were cured in the material laboratory of Sunyani polytechnic. Appendices A6 shows pictures of specimen being cured in the water basin at the laboratory.

3.3 Density of Spacemen

To be able to calculate the density of the spacemen, the specimens were weighed prior to crushing using digital electronic weighing machine and the weight obtained were recorded according to the various replacement levels. The densities of the various blocks were calculated using:

Density = Mass/Volume.

Appendix A7 shows the cubes being weighed on the digital weighing scale.

3.4 Testing of Specimen

The main objective of this research is to study the potentials of palm kernel shell ash (PKSA) concretes in terms of strength and to compare it to the properties of normal ordinary Portland cement concrete. The performance of the concretes was assessed through: compressive strength and split tensile strength. Other properties like density and water absorption were also assessed.

3.4.1 Test for Compressive Strength

This test was carried out at the age of 7 days and 28 days of curing. Prior to crushing, the weights of the concrete cubes were recorded to determine their densities. The test was conducted at the Sunyani Polytechnic building construction laboratory. A digital compressive strength testing machine produced by Controls Milano, Italy was used. The compressive strength was determined by crushing the concrete cube specimens in the compression machine as shown in appendix A9. The crushing was done with an increasing compressive load which was applied to the specimen until failure occurred.

The maximum compressive load was recorded at the point where the cube started to deform. The pictures in appendix A9 show samples of the machine's screen at the end of the test.

3.4.2 Test for Split Tensile Strength

This test was conducted by loading an unreinforced concrete cylinder of 150mm diameter by 300mm high. It was determined to test the ability of the concrete to resist failure due to bending. The test was conducted at the Sunyani Polytechnic building construction laboratory. The same digital compressing strength testing machine produced by Controls Milano, Italy was used, but a different attachment was inserted to enable tensile test to be conducted as illustrated in appendix A11. The cylinders were position centrally in the machine and a load was then subjected to it. The load was gradually increased until the specimen was split. The maximum load which caused the splitting of the specimen was recorded as well as the strength. The pictures in appendix A11a show samples of the machine's screen at the end of the test.

3.5 Data Analysis

For easy understanding of the research findings, the raw data obtained in the various tests were analyzed using different statistical tools.

3.5.1 Silt and Clay Test Analysis

Silt is granular material of size somewhere between sand and clay, whose mineral origin is quartz and feldspar (http://www.dictionary.com/browse/silt). Too much silt in given

sand affects the quality of the sand for constructional purposes. As a result, silt and clay test was conducted to see whether the sand used for the study was within the acceptable level of silt and clay for constructional purposes. The study used descriptive data analysis technique to analyze data obtained from this test. The result was compared to standards and conclusions were drawn.

3.5.2 Sieve Analysis of Crushed Granite

Grading of aggregates is very essential in preparation of concrete since the aggregates sizes have greater influence on some properties and the strength of the concrete at large. A graph was plotted for percentage passing against sieve size to show the particles distribution of the aggregates. Conclusions were drawn as it was compared to standards from literature.

3.5.3 Particles Distribution of PKSA

The ability of most matrix (binding agents) is affected by the fineness of its particle sizes. The test was conducted to ascertain the fineness of the PKSA that was used for this research work. Table was used to show the raw data obtained and a graph was plotted for percentage passing against sieve size to show the particles distribution of the PKSA.

3.5.4 Slump Test Analysis

Slump test was done on the fresh concrete to confirm consistency for the various design mixes, to assess the workability of concrete and also to determine whether there were variations in workability among different percentage levels of replacement.

The results obtained were tabulated and represented on a bar graph using Microsoft Excel, they were then compared to various forms of slump such as shear, collapse and true and conclusions were drawn descriptively.

3.5.5 Compressive Strength Analysis of PKSA Concrete

The mean strength of concrete specimens were computed and presented on a bar graph using Microsoft excel. A graph of PKSA against Compressive strength was created to check the correlation between them. The correlation between compressive strength and PKSA replacement was drawn using the Pearson co-efficient of correlation.

3.5.6 Water Absorption Analysis

This was done to ascertain the water absorption properties of the concrete at the various replacement levels. The data obtained was analysed using excel, mean and standard deviation were obtained. Table 4.5 shows the result of the water absorption analysis.

3.5.7 Analysis of Concrete Density

The average densities of the various replacement levels of PKSA were computed and presented on a bar graph. A correlation test was also performed using the Pearson co-efficient of correlation and presented on a graph.

CHAPTER FOUR

RESULTS PRESENTATION

This chapter outlines the results obtained from the study. It was presented based on the objectives of the study.

4.1 Silt and Clay Test Analysis

This test was conducted to ascertain the fineness of the fine aggregate for concrete production. The allowable percentage of silt and clay for concrete should not exceed 16% by standard. The experiment recorded these measurements:

Height of sand = 116ml

Height of clay and silt = 9.2ml

The clay and silt content was calculated as: $S_c = \frac{HSC}{HS} \chi 100\%$

Where S_c = clay and silt content per cent

Hsc = height of clay and silt (fines)

HS = height of sand

$$S_C = \frac{9.2}{116} x100\%$$
$$= 7.93\%$$

The experiment recorded 7.93% of silt and clay which is within the limits, therefore, the sand is fit for concrete.

4.2 Sieve Analysis of Crushed Granite

The sizes of the crushed granite ranged from 0.075mm to 19.05mm. The study used particles between 0.075mm to 12.7mm. Figure 4.1 shows the particles distribution of granite used for cubes and beams. Particles of size 12.7mm was approximately 90% in the distribution. However, there were substantial amount of various particles in the distribution ranging from 0.075mm to 12.7mm.

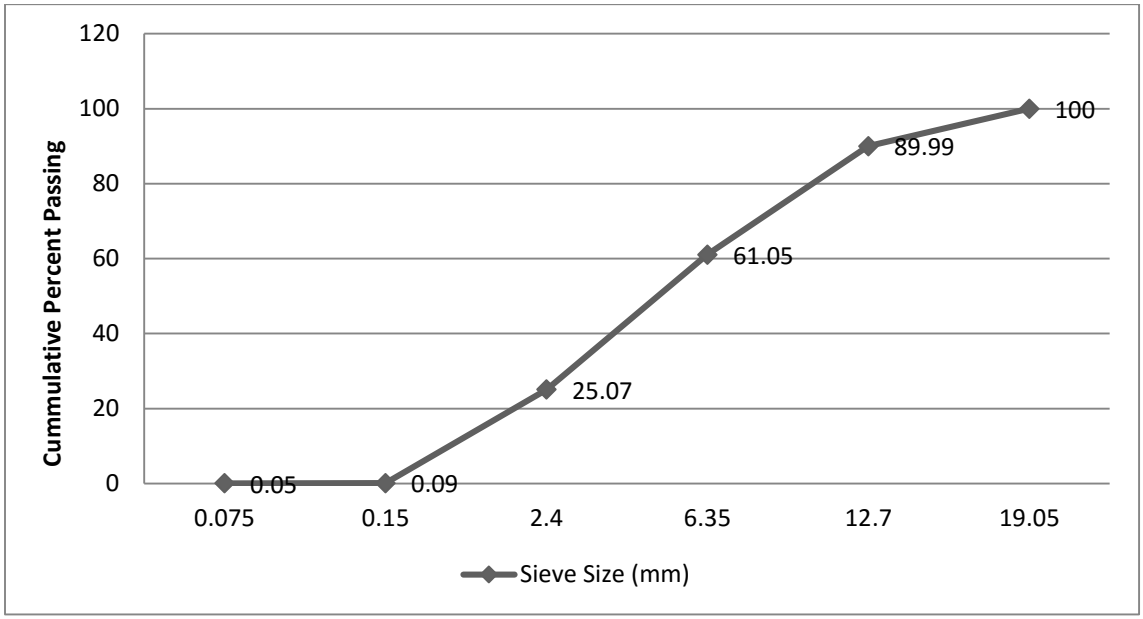

Figure: 4.1: Particles distribution of crushed granite.

4.3 Particles Distribution of PKSA

The PKSA was sieved through 45um sieve in order to remove any foreign material and bigger size ash particles; and only the fine ashes which pass through 45um sieve were collected and used for the preparation of the concrete. Figure 4.2 shows the particle distribution of PKSA. 100% of PKSA passed through the 0.6mm while 99% passed

through 0.4mm sieve. The PKSA which passed through the 0.045 was 31.3% being the least.

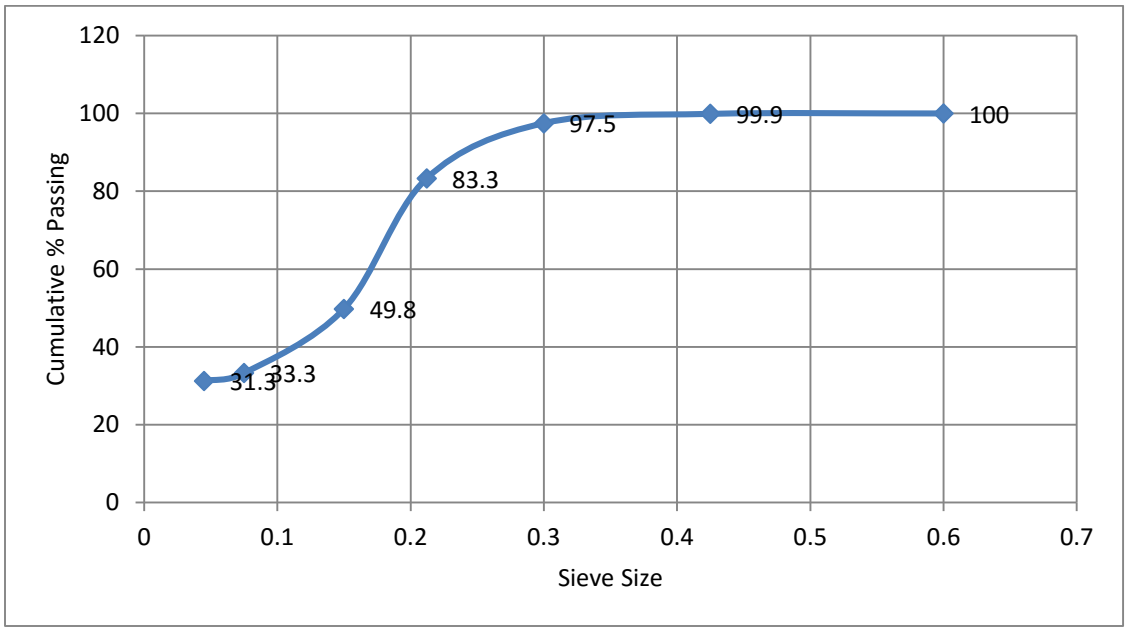

Figure 4.2 Sieve Analysis of PKSA

4.4 Chemical Composition of PKSA sieve

Table 4.1 shows the oxide composition of the OPC and PKSA respectively. From the results PKSA contains 54.20% SiO_2, 13.65% Al_2O_3 and 3.87% Fe_2O_3. This gives 71.72% of SiO_2+ Al_2O_3 +Fe_2O_3 which is in line with ASTM C 618-78 requirement of 70% minimum for pozzolanas. This implies that, PKSA meets the requirement for a pozzolana. The colour of the PKSA was dark grey.

Table 4.1 Chemical Composition of PKSA

Chemical Composition	OPC	PKSA
$Si0_2$ (silicon)	22.13	54.2
Al_20_3 (aluminium)	3.74	13.65
Fe_2O_3 (iron oxide)	2.97	3.87
CaO (calcium oxide)	63.36	4.40
MgO (magnesium oxide)	2.58	26.8
K_2O (potassium oxide)	0.52	42.3

4.5 Workability of the Various Mixes

Workability test was conducted for the various design mixes (control, 5%, 10%, etc.) using the slump method. It was carried out in line with BS 1881: Part 102: 1983. It was observed that in all the mixes there were true slump. From the results it can be seen that as the percentage replacement of OPC with PKSA increases, the workability of concrete increases. Replacing cement by an equal mass of PKSA causes a decrease in volume since the density of cement is higher than that of PKSA. This therefore decreases the water demand, but since the quantity of water remains the same for all mixes, yet the increase in workability.

The result is illustrated in Figure 4.2 for the various replacement levels. The control yielded the lowest slump and 20% replacement also attained the highest slump. From the slump result of the various mixes the concrete made is of medium degree workability.

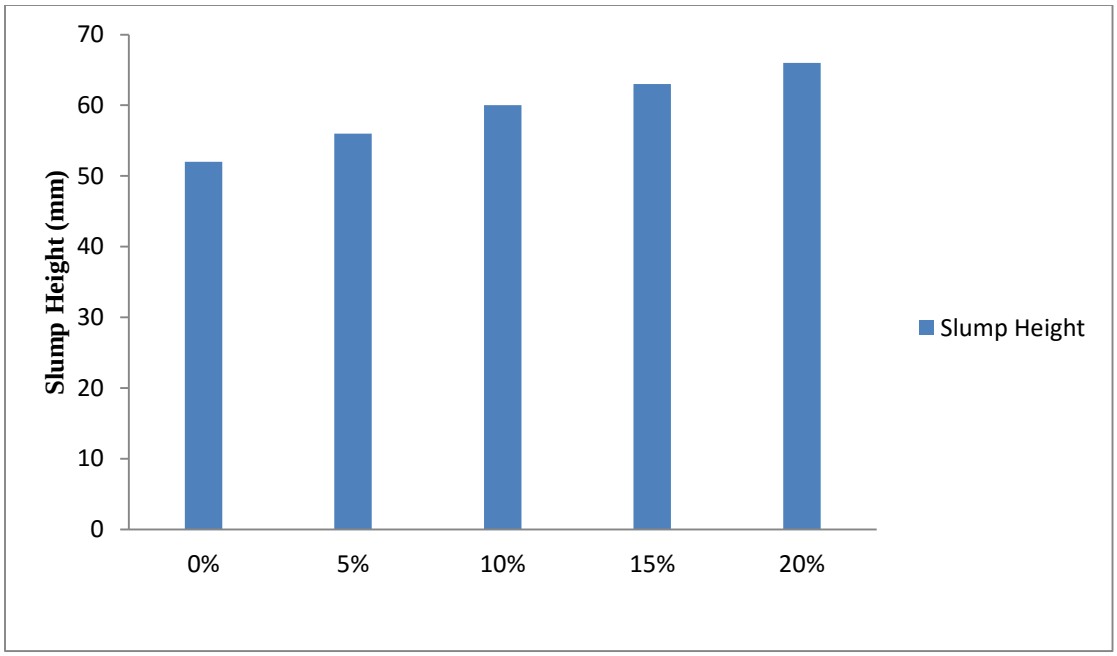

Figure 4.3: Summary of Workability Test on the Various Mix Ratios

4.6 Compressive Strength of PKSA Concrete

Compressive strength test result is shown in Table 4.3. From the table, the control (0%) yielded the highest average compressive strength of 30.08N/mm^2. It was observed that there was reduction in strength as the percentage of PKSA increased**.** At 5% replacement of PKSA the strength was 17.29N/mm^2 which was reduced to 15.72 (±0.58) at 10% replacement. With 15% replacement of PKSA, the strength was 14.63N/mm^2 (±0.49) which reduced to 12.26N/mm^2 (±0.05) at 20% replacement of PKSA.

Table 4.2 Compressive Strength of PKSA Ratio in Concrete

Sample	N	Mean (N/mm^2)	Std. Dev.
0%	3	30.08	0.42
5%	3	17.29	0.34
10%	3	15.72	0.58
15%	3	14.63	0.49
20%	3	12.26	0.05

Source: Field Data 2014

4.7 Strength versus PKSA Proportion in a Mix

Figure 4.4 shows the relationship between compressive strength and PKSA percentage in concrete mix. It can be observed that there is a negative correlation between the two variables. The $R^2 = 0.7487$ indicates that 74.87% of the variation in compressive strength can be explained by the percentage of PKSA in the concrete. It can also be noticed that the compressive strength of the PKSA $y = -76.6\chi + 25.656$, the value 25.656 is the constant for determining the compressive strength of PKSA. The value -76.6 is the co-efficient of PKSA percentage in a mix which means that if the PKSA (χ) is increased by one unit, the strength will on average decrease by 76.6 N/mm^2.

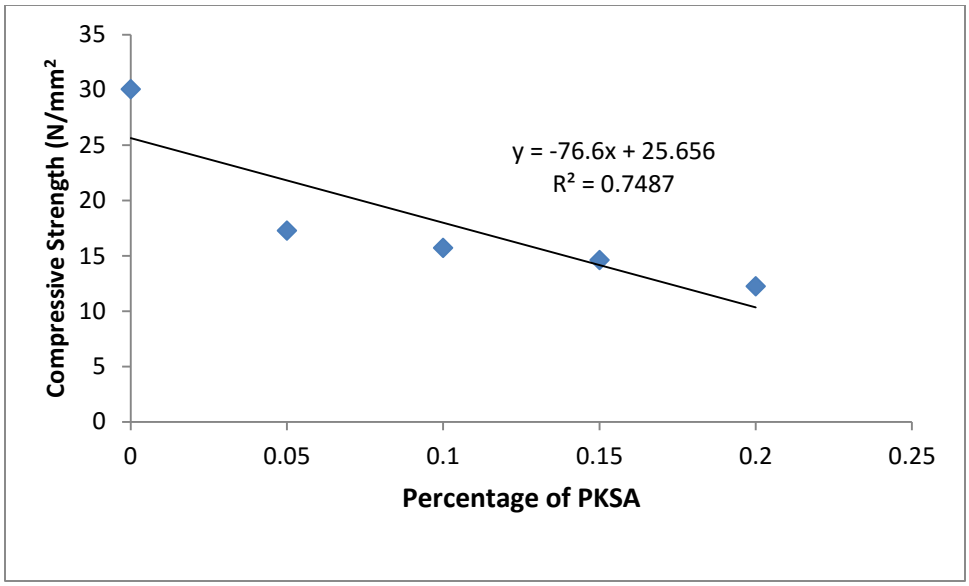

Figure 4.4: **Strength versus PKSA Proportion in a Mix**

4.8 Water Absorption of PKSA Concrete

Table 4.3 shows the water absorption rate of PKSA concrete. At 0% replacement of PKSA, the water absorption rate was 0.047%**;** at 5% replacement, the absorption percentage was 0.049%. It was observed that as the replacement levels of PKSA increased, there was a corresponding increase in water absorption rate. Therefore the higher the PKSA content in concrete, the higher the water absorption. However, PKSA concretes do not absorb water as fast as OPC concretes; thereby retarding hydration processes in the PKSA concrete (PKSA concretes retain water for a longer period before it starts to dry up slowly).

Table 4.3 Water Absorption of PKSA

Sample	N	Mean (%)	Std. Dev.
0% (Control)	3	0.047	0.005
5%	3	0.049	0.004
10%	3	0.056	0.001
15%	3	0.058	0.001
20%	3	0.090	0.001

Source: Field Data 2014

4.9 Density of PKSA Concrete

Figure 4.5 shows the average densities of the various replacement levels of PKSA. The control (0%) recorded the highest density of 361.33kg/m^3 while 20% replacement yielded the least density of 348.00kg/m^3. The densities follow the pattern of the compressive strength where the control which yielded the highest compressive strength also yielded the highest density.

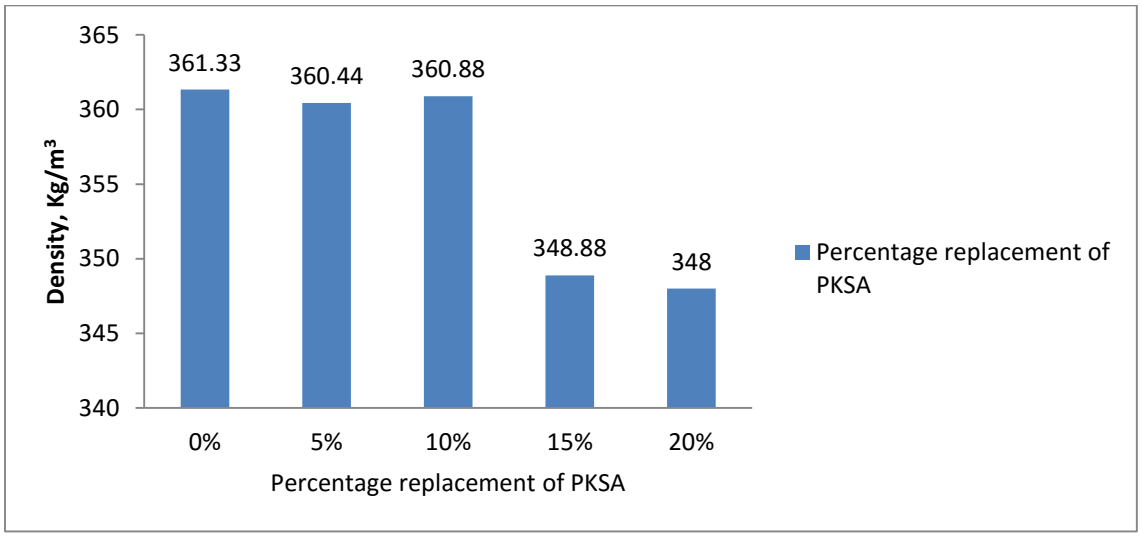

Figure 4.5: Density of PKSA Concrete

4.10 Relationship between Density and Compressive Strength of PKSA Concrete

The densities of the various replacement levels of PKSA with their corresponding compressive strength were compared to test if there is a correlation between them using the Pearson correlation coefficient. From Table 4.4, Pearson correlation coefficient was computed to be 0.63 using Excel.

Table 4.4: Relationship between Density and Compressive Strength of PKSA Concrete

Sample	Compressive Strength (N/mm^2)	Density (Kg/m^3)
0%	30.08	361.33
5%	17.29	360.44
10%	15.72	360.88
15%	14.63	348.88
20%	12.26	348.00

Source: Field Data 2014

CHAPTER FIVE

DISCUSSION OF RESULTS

This chapter gives explanation to the results obtained in the study, and then compares them to existing literature and standards so that conclusions can be drawn.

5.1 Silt and Clay Test Analysis

This test was conducted to ascertain the fitness of the fine aggregate for concrete production. The allowable percentage of silt and clay for concrete should not exceed 16% by standard. The study recorded 7.93% of silt and clay which is within the limits, therefore, the sand is fit for concrete (IS 2386-Part II).

5.2 Sieve Analysis of Crushed Granite

Coarse aggregates used in concrete contain aggregates of various sizes. Proper gradation of coarse aggregates is one of the most import factors in producing workable concrete (Neville *et al*, 2010). Proper gradation ensures that a sample of aggregates contains all standard fractions of aggregate in required proportion such that the sample contains minimum voids so as to influence concrete strength and density. A well-graded aggregate has a gradation of particles size that fairly evenly spans the size from the finest to the coarsest and it is characterized by the S-shaped in gradation curve. From Figure 4.1 in chapter four, the gradation curve is S-shaped indicating the crushed granite for the study was well graded (Building Research Institute, 2016).

5.3 Particles Distribution of PKSA

Figure 4.2 in chapter 4 shows the particle distribution of PKSA. 100% of PKSA passed through the 0.6mm while 99% passed through 0.4mm sieve. The PKSA which passed through the 0.045 was 31.3% being the least.

5.4 Chemical Composition of Palm Kernel Shell Ash (PKSA)

The result of the chemical analysis carried out on the palm kernel shell ash is presented in Table 4.2 of the previous chapter. According to Neville (2002), the raw materials used in the manufacture of Portland cement, consists mainly of lime, silica, alumina and iron oxide. The chemical analysis of the palm kernel shell ash reveals that it contains some quantities of these elements. The chemical constituents of the PKSA are Silicon (SiO_2), Aluminium (Al_2O_3), and Iron Oxide (Fe_2O_3). The total amount of SiO_2, Al_2O_3 and Fe_2O_3 present in the PKSA used for this research is 80.49% which is more than the minimum required 50% specified by the American Society for Testing and Materials (ASTM D5370-14) for type C ashes. Furthermore, this is also in line with ASTM C 618-78 which specifies a minimum requirement of (SiO_2+ Al_2O_3 +Fe_2O_3 = 70%) for pozzolanas materials. It was seen that PKSA contains all the essential oxides present in OPC and these oxides are important for the properties of concrete. Igarashi *et al*., (2005) are of the view that when pozzolanic materials are incorporated in concrete, the silica present in these materials reacts with the Ca $(OH)_2$ released during the hydration of cement and forms additional calcium silicate hydrate (C-S-H), which improves durability and the mechanical properties of concrete.

The ash produced sometimes varies in tone of colour from whitish grey to darker shade based on the combustion method and the carbon content in it. In other words, the physical characteristic of PKSA is very much influenced by the operating system in the palm oil factory (Utsev and Taku, 2012). The colour of the PKSA used for this study was dark grey and this was due to the environment the combustion took place.

5.5 Workability

Workability is one of the physical parameters of concrete which affect the strength and durability as well as the cost of labour and appearance of the finished product. Concrete is said to be workable when it is easily placed and compacted homogeneously i.e. without bleeding or segregation. Unworkable concrete needs more work or effort to be compacted in place, also honeycombs and or pockets may also be visible in finished concrete (http://www.aboutcivil.org/concrete-workability-factors.htm; Neville *et al.,* 2010). According to Neville *et al., (2010*), workability is influenced by a number of factors which include:

- Water content in the concrete mix
- Amount of cement & its Properties
- Aggregate Grading (Size Distribution)
- Nature of Aggregate Particles (Shape, Surface Texture, Porosity etc.)
- Temperature of the concrete mix
- Humidity of the environment
- Mode of compaction

- Method of placement of concrete
- Method of transmission of concrete

The degree of workability ranges from very low to high: 0-25 very low, 25-50 low, 25-100 medium, and 100-172 high (Neville *et al.,* 2010). The slump results from the study were within the range of 50 to 64 which fall within the medium range of 25 to 100. The slumps of the samples were seen to be increasing with increase in PKSA percentage. The slump of the concrete increased as the percentage of PKSA increased and decreased in comparison with the conventional concrete (Amu et al., 2011). Neville *et al*. (2010) reported that grading affects workability of concrete. The differences in the slump of samples were ± 1, the differences may be due to operational error such as measuring of the water etc. There were no significant effects of PKSA replacement level on workability (slump).

5.6 Compressive Strength

Compressive strength test result is shown in Table 4.3 in the previous chapter. From the Table, the control (0%) yielded the highest compressive strength of 30.08N/mm^2 (± 0.42). At 5% replacement of PKSA the strength was 17.29N/mm^2 (± 0.34) which was reduced to 15.72 (±0.58) at 10% replacement. With 15% replacement of PKSA, the strength was 14.63N/mm^2 (±0.49) which reduced to 12.26N/mm^2 (±0.05) at 20% replacement of PKSA.

The targeted strength for the concrete mix design for the study was 30MPa. With the exception of the control, none of the four treated samples exactly hit the targeted strength. It was observed that there was reduction in strength as the percentage of PKSA increases. The reduction in strength was expected because the quantity of the chief compounds in the OPC was not the same with the PKSA. The strength pattern of PKSA concrete in this study was in line with other researchers such as Vignesh *et al*., (2013) who obtained decrease in compressive strength with increase in the percentage replacement of OPC with CSA. Malhotra and Mehta, (2004). They investigated agricultural by-product pozzolans have been used in the manufacture and application of blended cements. Nimityongskul and Daladar (1995) highlighted the potentialities of coconut husk ash, corn cob ash, and peanut shell ash as good pozzolans. Elinwa and Awari (2001) successfully investigated the potentials of groundnut husk ash concrete by partially replacing Ordinary Portland Cement with groundnut husk ash.

Adesanya (1996) investigated the properties of blended cement mortar, concrete, and stabilized earth made from OPC and corn cob ash and recommended that corn cob ash can serve as replacement for OPC in the production of cement composites. Dwivedia *et al*. (2006) successfully investigated the pozzolanicity of bamboo leaf ash. Martirena *et al.*, (1998) found that sugar industry solid wastes such as sugar cane straw ash has pozzolanic activity derived from its high content of amorphous silica. Many other researchers have confirmed rice husk ash as pozzolanic material that can be used to partially replace OPC in making cement composites (Cordeiro *et al*., 2009; Habeeb and Fayyadh, 2009; Rukzo *et al*., 2009).

One common characteristic about these studies stated above which is in line with this current study is about the strength development in these agro by-product for partial replacement of OPC, all these studies recorded a reduction in strength with increase in the percentage of agro ash. Even though there was a reduction in strength of PKSA concrete, it was evident that 5% PKSA Concrete at 28 days curing age was 17.29N/mm^2 that meets the minimum required strength of concrete (10 to 40 MPa) at 28 days; it is therefore recommended for normal concrete works.

5.7 Strength versus PKSA Proportion in a Mix

Figure 4.2 in the previous chapter shows the relationship between compressive strength and PKSA percentage replacement in concrete mix. It can be observed that there is a negative correlation between the two variables. The $R^2 = 0.7487$ indicates that 74.87% of the variation in compressive strength can be explained by the percentage of PKSA in the concrete. It can also be noticed that the compressive strength of the PKSA $y = -76.6\chi + 25.656$, the value 25.656 is the constant for determining the compressive strength of PKSA concrete. The value -76.6 is the co-efficient of PKSA percentage in a mix which means that if the PKSA (χ) is increased by one unit, the strength will on average decrease by 76.6.

Furthermore, correlation coefficient was computed from the sample data using the Pearson Correlation Coefficient, it was found out to be -0.87 which indicate a strong negative correlation between the variable that is the association between strength and PKSA replacement is inverse proportion as PKSA replacement percentage increases strength reduces (Bluman, 2004). The result was in line with Vignesh *et al.,* (2014). They

utilize coconut ash for partial replacement of OPC. Their study concluded a reduction in strength as the coconut ash in is increased in the mix proportion.

5.8 Water Absorption of PKSA Concrete

From Table 4.5 in the previous chapter, it was observed that as the replacement levels of PKSA increased, there was a corresponding increase in water absorption rate. This is because; PKSA concretes retain water for a longer period before it starts to dry up slowly. PKSA concretes do absorb water faster than OPC concretes; thereby retarding hydration processes in the PKSA concrete. Considering the water absorption property of PKSA concrete, it is not recommended for substructure construction which is more likely to be susceptible to moisture.

According to ASTM C1585, water absorption is influenced by a number of factors which include concrete mixture proportions, the presence of chemical admixtures and supplementary cementitious materials, the composition and physical characteristics of the cementitious component and of the aggregate, the entrained air content, the type and duration of curing, the degree of hydration or age, the presence of micro-cracks, the presence of surface treatment such as sealers or form oil and placement method such as consolidation and finishing. This study was in line with Nagalakshmi (2013) who obtained higher water absorption as the percentage of fly ash increased.

5.9 Density of PKSA Concrete

The density of concrete is determined largely by the type of aggregate and the cement used in the mixture. Enrique (1966) reported that since aggregates, cement, water and air have different specific weights, the overall density of any concrete mix depends largely on the relative amount of these materials present. It was observed from the research that, the control obtained the highest. The density kept reducing as the percentage of PKSA increased**.** This was expected, since the density of cement is higher than that of the PKSA. This is in line with Vignesh *et al.,* (2014), who had average density decrease with percentage replacement from 2525.5Kg /m3 for OPC to 2314Kg / m3, at 30% replacement.

5.10 Relationship between Density and Compressive Strength of PKSA Concrete

Concrete must has to ensure satisfactory compressive strength and durability. The mechanical properties of concrete are highly influenced by its density. A denser concrete generally provides higher strength and fewer amount of voids and porosity (Iffat, 2015).

The densities of the various replacement levels of PKSA with their corresponding compressive strength were compared to test if there is a correlation between them using the Pearson correlation coefficient. From Table 4.6 in the precious chapter, Pearson correlation coefficient was computed to be 0.63 using Excel indicating a correlation between the variables.

From table 4.6 in the previous chapter, it was observed that as the PKSA percentages are increase in the mix, it showed a reduction in strength as well as density. The result was in line Iffat (2015) that there is a relation between concrete strength and density.

CHAPTER SIX

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This chapter brings to the end of the study. It outlined the summary of the findings, drawn conclusions and recommendations based on the findings.

6.1 Summary of Findings

From the research, the following findings were revealed.

The PKSA has most of the chemical constituents present in OPC but in varying quantity. The constituents include: silicon, aluminium, iron oxide, calcium oxide, magnesium oxide and potassium oxide. The colour of the PKSA was dark grey.

The replacement of PKSA in the mix design made concrete workable relatively to the control concrete. The introduction of PKSA in the concrete mix saw a decline in the 28 days compressive strength. The reduction in strength was expected because the quantity of chief components in OPC was not the same with the PKSA. Though there was a reduction in strength,

The relationship between strength and PKSA proportioning in the mix was inversely proportional, that is as PKSA percentage in the mix increased, there was an average reduction of strength by 47.08%. The PKSA concrete absorbed more water than the control (plain concrete). There was also a reduction in density with the addition of PKSA relative to the control.

6.2 Conclusions

Following the findings that were unearthed from the study, these conclusions were drawn;

- The chemical composition of PKSA varied in quantity as compared with OPC.
- The colour of PKSA was dark grey and it is influenced by the combustion procedure employed.
- PKSA concrete has high water absorption rate.
- PKSA concrete showed a reduction in strength and density
- It is concluded that a model $y = -76\,\chi + 25.66$, where y = strength of concrete and χ = PKSA present in mix, can be used to predict the compressive strength of PKSA concrete.

6.3 Recommendations

These recommendations have been made following the results from the study:

- Since PKSA concrete has high water absorption rate, it is not recommended for moisture prone areas.
- With the addition of the PKSA**,** concrete was made relatively workable, and PKSA can therefore serve as plasticizer.
- The replacement of PKSA in concrete saw a decline in strength, however, it is recommended that replacement rate of 5% is good for normal concrete works.

- There are various varieties of palm oil fruits; it is recommended that a further study should be conducted to see the chemical composition of these fruits and in relation to OPC.

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APPENDICES

Appendix A

Materials and Apparatus for Experiment

A1 Ordinary Portland cement

A2 Crushed Aggregate

A3 Digital Weighing Scale Being used to Measure Material.

A4 Sieving of PKSA

A 5 Mixing of Concrete by Hand

A6 Metallic Mould for Cubes

A7 Cubes and Cylinders Being Cured in Water

A8 Weighing of Cubes

A9 Drying of Cubes and Cylinders in an Oven

A10 Compressive Strength Testing Machine

A11 Split Tensile Strength Testing Machine

A11a Screen at the end of tes

Appendix B

Summary of Experiment Materials

B1 Quantity of cubes and cylinders used for the experiment

% Replacement	Cubes Qty 7days	Cylinders Qty 7 days	Cubes Qty 28 days	Cylinders Qty 28days
0% (Control)	3	3	3	3
5%	3	3	3	3
10%	3	3	3	3
15%	3	3	3	3
20%	3	3	3	3
TOTAL	15	15	15	15

B2 Measurement of Materials for Preparation of Specimen

Parameters:

Mix ratio 1:2:4

Where:

1 represents one part of cement in weight

2 represent two parts of sand in weight

4 represent three parts of stone in weight

Cube size 150 × 150 × 150, all in millimeters

Volume of one cube of concrete = L×B×H

= 150 × 150 × 150

= 3375000mm^3 = 0.003375m^3

Total volume of concrete for cubes = 0.003375m^3 × 30

= 0.10125m^3

Size of cylinders 150 × 300, all in millimeters

Volume of one cylinder of concrete = Surface area × height

= (3.142 × 0.075^2) × 0.3

= 0.005302m^3

Total volume of concrete for cylinders = 0.005302 × 30

= 0.15906m^2

Total volume of concrete for experiment = Total volume of concrete for cubes + Total volume of concrete for cylinders

= 0.10125m^3 + 0.15906m^2 = 0.26031m^3

Allowing 10% wastage, volume of concrete for experiment = 110/100 × 0.26031m^3

= 0.286m^3

Since the concrete materials were batched by weight; the measurements in volumes were converted to weight by using ratio and proportion.

Converting volume to weight;

If 1 bag of cement weighs 50kg and has a volume of 0.033m^3

Therefore, Total weight of concrete = 0.286m^3/ 0.033 × 50 kg

= 433 kg

B3 Water/Cement Ratio

The water cement ratio (W/C) chosen for the research was 0.5. It was calculated as:

W/C = Weight of Water/Weight of Cement

Therefore, Weight of Water =W/C × Weight of Cement

In all, the total weight of water for the preparation of the concrete was 30.929 kg

B4 Weight and Volume of Concrete Materials

Constituent	Volume (m^3)	Weight (kg)
Cement	1/7 × 0.286 = 0.0409	1/7 × 433 = 61.857
Sand	2/7× 0.286 = 0.0817	2/7× 433 = 123.714
Stone	4/7× 0.286 = 0.1634	4/7× 433 = 247.428
Water		0.5 × 61.857 = 30.929

Appendix C

Test Result

C1 Chemical Composition of Palm Kernel Shell Ash

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
FACULTY OF RENEWABLE NATURAL RESOURCES.
LABORATORY ANALYSIS REPORT

CLIENT: MR. KENNETH KWAKU YEBOAH FRNR, KNUST							LABORATORY ANALYST: NAPOLEON MENSAH TEL: +233 (0) 243126881				
SAMPLE DATE	July 8, 2016						REPORT DATE	July 1, 2016			
SAMPLE NAME	<----------% TOTAL ---------->						<----------mg/100g---------->				
(BIOCHAR)	N	pH	CaO	K_2O	MgO	Na	Cu	Fe_2O_3	Mn	Al_2O_3	SiO_2
BIOCHAR 1	-	-	0.042	0.428	0.262	-	-	0.039	-	0.1360	0.534
BIOCHAR 2	-	-	0.046	0.417	0.274	-	-	0.038	-	0.1365	0.550
BIOCHAR 3			0.044	0.423	0.268			0.039		0.137	0.542

C2 Compressive Test Result

Curing Age	% Replacement	Concrete Mix	Compressive Strength (N/mm^2)			
			1	2	3	Mean
7 days	0% (control)	1:2:4	21.75	22.68	21.67	22.03
	5%	1:2:4	12.55	12.82	12.68	12.68
	10%	1:2:4	11.52	12.92	11.55	11.99
	15%	1:2:4	10.91	11.32	11.12	11.12
	20%	1:2:4	8.55	8.51	9.12	8.73

Curing Age	% Replacement	Concrete Mix	Compressive Strength (N/mm^2)			
			1	2	3	Mean
28 days	0% (control)	1:2:4	29.00	30.24	31.00	30.08
	5%	1:2:4	18.10	17.09	16.68	17.29
	10%	1:2:4	15.16	17.00	15.00	15.72
	15%	1:2:4	14.90	14.36	14.63	14.63
	20%	1:2:4	12.10	11.50	13.18	12.26

C3 Grading Test Results on Crushed Granite Sample

NAME: CRUSHED GRANITE Lab. Ref. No:_____DATE: 12 /06/2014

STATION: SUNYANI POLYTECHNIC CAMPUS

B. S. Sieve	Wt. Retained	% Retained	% Passing	Riffled Wt.
76.20mm (3 in)				
63.50mm (2 ½ in)				
50.80mm (2 in)				
38.10mm (1 ½ in)				
25.40mm (1 in)				
19.05mm(3/4 in)	-	-	100	-
12.70mm (1/2 in)	2994	10.01	89.99	90
9.52mm (3/8 in)	-	-	-	-
6.35mm (1/1 in)	324	28.94	61.05	61
4.76mm (3/16 in)	-	-	-	-
3.18mm (1/8 in)	-	-	-	-
2.40mm (7 mesh)	3	35.98	25.07	25
1.80mm (14 mesh)	-	-	-	-
600um (25 mesh)	-	-	-	-
400um (36 mesh)	-	-	-	-
3000um (52 mesh)	-	-	-	-
210um (72 mesh)	-	-	-	-
150um (100 mesh)	3	24.17	0.09	01
75um (200 mesh)	3	0.85	0.05	
.75um (...200 mesh)	3	0.09	0	0
TOTAL…….	3324			