UNIVERSITY OF EDUCATION, WINNEBA.

INVESTIGATIONS INTO THE PROPERTIES OF SANDCRETE BLOCKS MANUFACTURED WITH PULVERIZED PALM KERNEL SHELLS AS A PARTIAL REPLACEMENT FOR SAND

ADAMU WAHAB

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OCTOBER, 2021

DECLARATION

CANDIDATE'S DECLARATION

I, **ADAMU WAHAB** hereby declare that this dissertation is my original research, except for quotations and references contained in published works (which have all been identified and acknowledged). The entire dissertation is my 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 dissertation were supervised following guidelines and supervision of dissertation laid down by the University of Education, Winneba.

NAME OF SUPERVISOR: **DR. EMMANUEL APPIAH - KUBI**

SIGNATURE………………………………..

DATE ………………………………………

DEDICATION

I dedicate this research work to the Almighty Allah through whose protection and grace, I have been able to reach this far in my education. Also, I cannot conclude this work without mentioning the people who gave meaning to my life, my family, and especially my dear father Alhaji Wahab Ibrahim.

LIST OF ABBREVIATIONS

PKS	Palm Kernel Shells
PS	Pit Sand
PPKS	Pulverized Palm Kernel Shells
FM	Fineness Modulus
ASTM	American Society For Testing and Materials
SEM	Standard Error of the Mean;
Std Dev	Standard Deviation.
CBT	Competency-Based Training
CS	Coconut Shell
GPK	Ground Palm Kernel Shells
OPC	Ordinary Portland Cement
BS	British Standard

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ABSTRACT

The use of palm kernel shells as aggregate material is attracting research interest. Increasing demand for sandcrete blocks makes it vital to consider the potential of sandcrete blocks manufactured with pulverized palm kernel shells. This study aimed at investigating the properties of sandcrete blocks manufactured with pulverized palm kernel shells as a partial replacement for sand. Materials used for the study were pulverized palm kernel shells, pit sand, ordinary portland cement and tap water. Experiments were conducted on specimens of 2%, 4%, 6%, 8%, 10%, 20% and 30% pulverized palm kernel shells content. Mixing of the materials was done mechanically and moulding of specimens was also done mechanically. Seventy-two (72) specimens were produced for the experiment. The specimens were cured under wet jute sacks for 28 days. The density of the specimens was determined using ASTM C138/C138M as a guide. Water absorption and compressive strength of the specimens were also determined following ASTM C140. Data collected were analysed using Sigma Plot and Microsoft Excel Software. The results were presented using descriptive and inferential statistics. The study recorded an increase in water absorption but a decrease in density and compressive strength of pulverized palm kernel shells specimens compared to the control specimen. One-way ANOVA test results show that there is a statistically significant difference between the control group and the construct at $p \leq 0.001$ and $p \leq 0.039$ respectively. The density of specimens of 2% up to 4% of pulverized palm kernel shell content found in the study places the specimens as lightweight masonry units according to ASTM C 129. The compressive strength for specimens of 2% up to 20% obtained in this study is good for non-load bearing walls application.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

There is a growth in the population of human settlement globally and building infrastructure to meet the needs of the society is also increasing. However, the rapid growth in the country's economy and human population requires additional infrastructure to accommodate additional people and components (Anosike & Oyebade, 2012). This has led to increased demand for building materials such as sandcrete blocks to put up structures. According to Baiden and Tuuli (2004), sandcrete blocks are walling units made from natural sand or crushed stone dust mixed with cement and water in the right proportion and pressed in a mould to form a shape. Over 90% of infrastructure in Nigeria is being constructed using sandcrete blocks, making it a very vital unit in the construction industry (Baiden & Tuuli, 2004). Sandcrete blocks are extensively used in Nigeria, Ghana, and other countries as load-bearing and non-load bearing walling units (Anosike & Oyebade, 2012).

There are two main types of fine aggregates used in Ghana for sandcrete block production, they are natural sand and crushed sand (Baiden & Tuuli, 2004). According to Millers (2020), sandcrete blocks are popularly used for the building of infrastructure because of the following potentials; Sandcrete blocks can be manufactured off-site, sandcrete blocks provide a natural level of fire resistance, sandcrete blocks can resist strong winds, and are practically soundproof. However, despite the significance of sandcrete blocks as a potential building material, it has some drawbacks such as; The cost of building structures with sandcrete blocks is significantly higher as compared to other lightweight building materials such as shell create blocks.

Research has proven that agricultural by-products such as; sugarcane bagasse, rice husk, coconut fronds, husk and shells, millet husk and straws, peanut shells, cassava bagasse, palm fronds and palm kernel shells regarded as waste have potential that can be utilized to enhance the properties of soil block, sandcrete blocks, mortar and concrete. This has made scientists, engineers and technologists to conduct more research into agricultural by-products as a potential building material to build sustainable infrastructure, examples can be found in several research works; Influence of plantain pseudostem fibres and lime on the properties of cement mortar (Danso, 2020); Durability of lightweight concrete using oil palm shell as aggregates(Traore et al., 2021); Prediction of optimum compressive strength of light-weight concrete containing Nigerian palm kernel shells (Oyejobi et al., 2020); Piassava fibers as reinforcement of concrete (Abu et al., 2016); Properties of coconut, oil palm and bagasse fibres as potential building materials (Danso, 2017); Using palm kernel shall as partial replacement for sand in sandcrete block production (Dadzie & Yankah, 2015); Lightweight masonry block from oil palm kernel shell (Muntohar & Rahman, 2014); Palm kernel shells as partial replacement for fine aggregate in asphalt (Rasheed et al., 2019); The performance with lime treated palm kernel shells and sugarcane bagasse ash as partial replacements of coarse aggregate and cement (Samson et al., 2019); The compressive strength of concrete with palm kernel shells as partial replacement for coarse aggregate (Azunna, 2019); Bond and flexural strength characteristics of partially replaced self-compacting palm kernel shells concrete (Samson et al., 2019); Mechanical properties of green concrete with palm nut shell as low cost aggregate (Agbenyeku &

Okonta, 2014); Suitability of agricultural waste product (palm kernel shell) as coarse aggregate in concrete: a review (Nwachukwud et al., 2017).

The attention of researchers is towards the optimization of conventional building materials by using indigenous materials, local industrial materials and agricultural by-products such as palm kernel shells abundant in certain localities (Joshua et al., 2014). The production of palm oil has increased over the past years in the world. The total production of palm oil was estimated at 45.1 million tons for the year 2009–2010 (Muntohar & Rahman, 2014). Palm kernel shells are an agro by-product that has found their way into the construction industry. Palm kernel shells are a by-product of palm oil production which is mostly used as a source of fuel for domestic and industrial purposes in the areas where they occur. The disposal of the shells from palm oil production is an environmental problem of concern (Dadzie & Yankah, 2015).

According to Danso (2018), resource depletion and environmental pollution caused by construction activities can be minimised, if the construction industry incorporates sustainable construction materials for building development. This can be achieved by modifying and incorporating agro-waste materials such as palm kernel shells for building development. Previous studies have explored and compared the properties of sandcrete blocks and concrete manufactured with palm kernel shells (PKS) as aggregating substitute material to meet the accepTable performance and standards. However, there is limited knowledge in using pulverized palm kernel shells as a partial replacement for sand in sandcrete blocks production in the construction industry. This obliged the researcher and made it very necessary to conduct the research into using pulverized palm kernel shells as a partial replacement for sand in sandcrete block production.

1.2 Statement of the Problem

Agricultural based industries produce a vast amount of waste every year (Sadh, 2018). Examples of such waste are; palm kernel shells (PKS) and palm fronds. Today, organic wastes from agro-industries are one of the main sources of environmental pollution (Yusuf, 2017). According to Sadh (2018), If agro-waste is released into the environment without proper disposal and utilization procedure, it may lead to environmental pollution which is harmful to human and animal health. Research has shown that the utilization of industrial waste for infrastructure development in the construction industry is proven economically viable when environmental factors are considered (Kinuthia & Nidzam, 2011).

However, it is found that PKS are noTable agricultural waste indiscriminately stockpiled and disposed on the environment by the palm oil processing firms normally to be thrown away or burned. A large amount of by-products produced in the processing of palm oil is one of the main contributors to the environmental problem (Muntohar & Rahman, 2014). Muntohar and Rahman (2014) further stated that after palm oil processing and extraction, the solid and liquid residues generated from the fresh fruit bunches resulted in varying by-products including empty fruit bunches fibre, shell, and effluent. As a result of this, air, river, sea, groundwater and land pollution have increased due to the large amount of palm waste produced. Therefore, countermeasures should be taken to manage the agriculture by-products for sustainable development which will help protect the environment (Muntohar & Rahman, 2014).

Furthermore, when the PKS waste is disposed on the environment without proper measures, it's may lead to landfills and when it rains, runoff from landfills may carry them from the waste source and channeled them into water bodies which are not healthy for humans and aquatic lives. Again, when the palm kernel shell wastes are burnt, they also emit pollutants such as carbons into the atmosphere. The carbon emissions get into our clean air and cause an invisible layer around the earth. This layer keeps the heat inside the earth leading to global warming which threatens living organisms. In the present situation, there is an increasing number of palm plantations and because of that the PKS wastes are also constantly increasing which strongly influences the environment and ultimately human health.

As a way of improving the situation, an alternative used of PKS has been identified by pulverizing and using it as a partial replacement for sand in sandcrete blocks production because of its potential such as plastic-like property and lightweight. It is believed that when fine PKS particles are mixed with water, a plastic-like membrane is formed making the material impermeable, thereby making it an ideal material for construction in dampness areas which will limit the amount of moisture penetration into the intended structure. Sandcrete blocks made with pulverized PKS can also be used for making lightweight building materials which can be utilized when building partition walls, parapet wells and multi-story structures to help decrease the weight of the structure which may be significantly better when compared to traditional sandcrete blocks. Furthermore, because of the impermeable property of PKS, it is believed that PKS has some level of soundproofing properties. Hence, palm kernel shell blocks can be used in putting up church buildings and auditoriums to help control noise emissions, however, no report is yet written on such performance.

Furthermore, the intensity of carbon emission into the atmosphere resulting from burning the palm kernel shells as a way of disposing of it may reduce significantly when fine palm kernel shells are utilized for sandcrete block production. Scientifically plants help to control carbons in the environment by absorbing the carbons from the atmosphere. The carbons remain in the plants forever when the plants die. Burning the palm kernel shells as a way of disposing them to reactivate and released back the carbons into the atmosphere is not pleasant for both human and animal health. The carbons within the palm kernel shells may be trapped when the palm kernel shells are utilized for sandcrete block production to put up buildings. This will significantly contribute to the reduction of carbon emissions into the atmosphere because there wouldn't be any room for burning the palm kernel shells as a way of disposing of them.

The study by Muntohar and Rahman (2014) study revealed that substituting large quantity aggregate with PKS leads to a reduction of 20-25% in the quantity of carbon emission per ton compared to normal sandcrete block. This is good news because carbon reduction is one of the focuses of suiTable construction. The use of palm kernel shells in the construction industry still requires more research work for the full determination of standards. This made the researcher conduct research into the utilization of pulverized palm kernel shells as a partial replacement for sand in sandcrete block production. Hence, the need to investigate the properties of sandcrete blocks manufactured with pulverized palm kernel shells (PPKS) as a partial replacement for sand.

1.2.1 Research Gap

Every year agricultural industry produces a large amount of waste such as sugarcane bagasse, rice husk, coconut fronds, husk and shells, millet husk and straws, peanut shells, cassava bagasse, palm fronds and palm kernel shells (Sadh, 2018). However, agricultural by-products have potentials such as low carbon emission, lightweight, impermeability, soundproofing, thermal insulation, environmentally friendly, low cost and readily available. Few research works have been done on using PKS as a partial replacement for sand in sandcrete block production. Examples can be found in research works; Lightweight masonry block from oil palm kernel shells by Muntohar & Rahman (2014) in Malaysia and using palm kernel shells as a partial replacement for sand in sandcrete block production by Dadzie and Yankah (2015) in Ghana.

In sandcrete block production, grading of the fine aggregate significantly affects the properties and performance of the sandcrete blocks. Poorly graded materials will eventually yield low performance. The study by Dadzie and Yankah (2015), revealed that the PKS from the local palm oil producers used were poorly graded since the grading test results on the aggregate did not satisfy the fine aggregate grading test requirement recommended by ASTM standard. This might have resulted in the low density and low compressive strength of the sandcrete block by Dadzie and Yankah (2015).

The study by Muntohar and Rahman (2014), also revealed that the larger particle size PKS shell creates blocks had higher water absorption than the smaller PKS particle size. The possible reason for the increase in water absorption is the existence of large micropores in specimens argued by Alengaram et al. (2011). Muntohar and Rahman

(2014) further made a strong finding that the sandcrete specimens had more pores than the shell create specimen. In a few of that, sandcrete blocks could absorb more water than shell create blocks. Furthermore, the PKS particle sizes used by Muntohar and Rahman (2014) had a fineness modulus of 5.780. While the PKS particle sizes used by Dadzie and Yankah (2015) had a fineness modulus of 3.568 respectively. According to ASTM C136. (2006), the PKS particle sizes used by Muntohar and Rahman (2014); Dadzie and Yankah (2015); Muntohar and Rahman (2014) did not meet the fine aggregate grading requirement and therefore cannot be considered as fine aggregate. Hence, it can be argued clearly from previous studies that the PKS particle sizes used for the experiment negatively affected the outcome of the experiment, because of that, Dadzie and Yankah, (2015) made a suggestion that the PKS used for sandcrete block production should be pulverized to more fine particles to meet the fine aggregate grading requirement in other to determine whether the high percentage substitution of PPKS aggregates in sandcrete blocks production would have an influence on the sandcrete blocks concerning density, water absorption and compressive strength. This will help established possible variations from those obtained in Dadzie and Yankah, (2015); Muntohar and Rahman, (2014) studies.

Further research has to be done by using well-graded PKS particle sizes, it is believed that the properties and performance of the sandcrete blocks manufactured with PPKS as a partial replacement for sand will significantly improve, which this report is yet to confirm. This obliged the researcher and made it very necessary to conduct the research associated with using pulverized palm kernel shells as a partial replacement for sand in block production.

1.3 Aim of the Study

The study aims at investigating the properties of sandcrete blocks manufactured with pulverized palm kernel shells as a partial replacement for sand.

1.4 Objectives to the Study

The specific objectives of the study were to;

- determine the particle size distribution of PS and PPKS for sandcrete block production.
- determine the density of sandcrete blocks manufactured with PPKS as a partial replacement for sand.
- determine the water absorption of sandcrete blocks manufactured with PPKS as a partial replacement for sand.
- examine the compressive strength of sandcrete blocks manufactured with PPKS as a partial replacement for sand.

1.5 Research Hypothesis

1. The water absorption of sandcrete blocks manufactured with pulverized palm kernel shells as a partial replacement for sand will be lower than the traditional sandcrete blocks.

2. The density of sandcrete blocks manufactured with PPKS as a partial replacement for sand will be higher than the traditional sandcrete blocks.

3. The compressive strength of sandcrete blocks manufactured with pulverized palm kernel shells as a partial replacement for sand will be higher than the traditional sandcrete blocks.

1.6 Significance of the Study

- The finding of the study will contribute to the body of knowledge by revealing the potential properties of sandcrete blocks manufactured with PPKS as a partial replacement for sand, that may meet the accepTable performance and standard in the construction industry.
- The study outcome will serve as a valuable guide to construction industry practitioners to develop practice, policy and standards for sandcrete blocks manufactured with PPKS as a partial replacement for sand, which may serve as a guide for future studies.
- The finding of the study will promote the use of palm kernel shell waste for sandcrete block production in the construction industry, which will reduce the environmental impact of palm oil processing waste.

1.7 Organization of the Thesis

This thesis is organized into five (5) chapters. Chapter one (1) comprises the background of the study, statement of the problem, the scope of the study, the significance of the study, the aim of the study, objectives of the study, research hypothesis and research gap. Chapter two (2) comprises a comprehensive literature review. Chapter three (3) describes the experimental materials and procedures used in the study. Chapter four (4) comprises the results of the study, whiles chapter five (5) comprises discussions of the results. Finally, chapter six (6) the final chapter summarizes the findings, conclusions, recommendations of the study and suggestions for further studies.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter covers a related literature review of the topic under study.

2.2 Sources of Sand Used in Construction

Sand is one of the most available natural resources that has been used for making concrete, mortar and sandcrete blocks since the earliest days of civilization (Verma, 2015). According to Verma (2015) sand is defined as continuously graded unconsolidated material present on the earth's surface as a result of the natural disintegration of rocks. Sand is used for many aspects of the construction industry depending on its quality. Due to the increasing demand for construction projects, there is also increasing demand for natural sand which is usually available from local river beds pits and sea sources (Paspula, 2021). The sand that is eroded from sandstone rocks, was deposited as a beach, dune or desert. After millions of years, sandstone rocks turned into sandstone cliffs and eventually eroded for the second time(Koirala & Joshi, 2017). There is a different types of sand used in the construction industry. The various type of sand depends on where it is in mind. Sand is usually minded on beaches, rivers, dunes, mountains, deserts, sandpits and quarries. These sands have different properties. According to Koirala and Joshi (2017), sand can be classified into three categories from different prospect. Example; sand's origin point of view, Composition Point of view and Grain size point of view.

2.3 Sand Under Origin Point of View

Sand from the origin point of view can be divided into four subcategories such as river sand, Pit sand, sea sand and crushed stone sand.

2.3.1 Pit Sand (PS)

Sand found on land deposits is known as PSsuch grains are generally irregular, shape and angular (Thomas & Jordan, 1987). PP is a natural and coarse type of sand which is normally obtained from pits or gutters by digging 2-3m underneath the ground. It's red-orange due to the presence of iron oxide around the grains. These sand grains are free from salt, hence it doesn't react with the moisture content present in the atmosphere. Due to its superior binding properties, PP is used in construction. As mentioned above, PP is a coarse type of sand and this is not recommended if the sand is coarser than the accepTable limits (Krishna, 2021).

2.3.2 River Sand

Sand carried by water, such as found along banks of rivers or lakes is also known as "river sand" such grains are generally rounded and smooth, due to the action of water. Such type of sand is suitable for cement work, so long as they are well-graded and clean" (Thomas & Jordan, 1987).

River sand is used in the construction industry mainly for concrete production and cement-sand mortar production. River sand is obtained by dredging from river beds. It has the major characteristics that since it has been subjected to years of abrasion, its particle shape is more or less rounded and smooth, and since it has been subjected to years of washing, it has very low silt and clay contents (Verma, 2015).

2.3.3 Sea Sand

Sea sand can become a potential resource capable of supplying fine aggregate material for domestic civil engineering and construction usage (Verma, 2015). In addition, using sea sand is more economic than using river sand because river sand is more expensive. Sea sand mainly contains much salinity as sodium chloride. If the salt is not treated and sea sand is directly utilized for civil engineering and construction concrete projects, the durability of the structure may be affected and as a result, the concrete might be swelling, precipitating, sulphating and other adverse consequences (Verma, 2015). Therefore, the salt content must be eliminated before it is utilized to avoid potential hazards. The dunes are formed by sand particles blown by the wind from the sea shore. The topmost layers of dunes contain higher chloride content due to continuous exposure to the sea breeze. However, when sea sand is utilized, the first problem encountered is the salt contained in the sea sand. A distinction must also be made between sea sand and sand deposits in dry coastal areas. The latter would tend to have very high chloride contents resulting from salt spray and evaporation over long periods.

2.3.4 Crushed Stone Sand

Crushed stone sand is a common by-product of mining and quarrying. Rather than being discarded as a waste material, it can be utilized in various construction processes (Aziz et al., 2018). The crusher dust is also known as the manufactured sand. The cost of crushed stone sand is relatively low compared to other conventional materials. Crushed stone sand uses less water than other alternatives and has excellent load-bearing capabilities and durability.

2.3.5 Sources of Palm Kernel Shells

Palm Kernel Shell (PKS) is the second inner layer of the palm fruit (Quaye & Tachie-mensah, 2016). Palm kernel shells are the hard shell of the oil palm fruit seed which is broken to take out the kernel used for extracting palm kernel oil (Putra, 2001). Palm kernel shells are produced from the processing of palm oil fruit. Carbonaceous solids contain a high volume percentage of carbon elements and may be converted as heat energy sources by thermal reaction of the carbon content. Palm kernel shells are generated after processing palm fruit into palm oil. Newman (1990), states that a shell is the outer hard covering of certain molluscs which is used for various purposes such as the making of jewellery. It is estimated that the palm kernel shells constitute about 34.5% of a single ripe, fresh fruit (Aragbaiye, 2007).

The palm kernel shell is believed to be the second inner layer of the palm fruit. (Najmi 2002); this statement has been confirmed by researchers in the process of experimentation with the shell. Palm kernel shells can be considered pellets because of their nature in form, high calorific value, low ash and low sulphur content (Quaye & Tachie-mensah, 2016). Moisture content in kernel shells is low compared to other biomass residues with different sources suggesting values between 11% and 13%. The palm kernel shell is made up of 33% charcoal, 45%pyro ligneous liquor and 21% combustible gas (Dagwa et al., 2008). Palm kernel shells contain residues of palm oil, which accounts for its slightly higher heating value than average lignocelluloses Biomass. The kernel shell also has a high calorific value. This is the amount of heat released by a unit weight or unit volume of the palm kernel shell during complete combustion. A higher level of coalification translates to higher calorific value and lower moisture content (Wiktionary, 2012). Coalification can be defined as the formation of coal by the gradual heating and compression of organic matter. Due to its high calorific value, burning garbage to produce energy is highly efficient. The kernel shell also possesses low sulphur content. The "beauty mineral, Sulphur, is necessary for healthy skin, hair and nails. Sulphur content (typical about 0.09% weight) is present in palm kernel shells. Sulphur is an essential mineral that plays an important role in the health of connective tissues, as well as skin, bones, teeth, hair and muscles, says the University of Michigan Health System (Barry, 1999).

2.4 Types of blocks for walling

British standard 6073 part I [1] defines a block as a masonry unit of large size in all dimensions than specified for bricks but no dimensions should exceed 650mm nor should the height exceed either its length or six times its thickness(Alejo, 2020).

2.4.1 Sandcrete blocks

Sandcrete blocks are composite materials produced from cement, sand and water, moulded into different sizes (Barry, 1999). British Standard (BS6073: 1981 Part 1) defines a block as a heterogeneous building material with a unit of larger size in all dimensions than specified for bricks but no dimension should be more than 650 mm nor should the height be greater than its length or six times its thickness (Ajao et al., 2018). Sandcrete blocks are walling units that when laid in their normal aspect surpass the dimensions stipulated for bricks (NIS 87; 2007). Baiden and Tuuli, (2004) opined that sandcrete hollow blocks were used to construct over 90% of building structures in Nigeria. Therefore, sandcrete blocks remained an essential component in housing production. Sandcrete block is generally used in Ghana, Nigeria, Togo, and other developing countries as walling units which may be walls, partitioning walls and foundations.

2.4.2 Concrete block

Concrete block construction has gained importance and has become a valid alternative to fired clay bricks(Data & Description, n.d.). The essential ingredients of concrete are cement, aggregate (sand, gravel) and water. Concrete blocks are produced in a large variety of shapes and sizes. They can be produced manually or with the help of machines. Cement concrete blocks can be solid (dense) or hollow. Besides different sizes and designs can be given to the blocks(Chaure et al., 2018). The blocks are made in the sizes of 12x8x4"; 12x8x3"; 12x8x6", etc. Firstly cement, stone chips and sand are mixed in a ratio of 1:6 or 1:12. This mixture is put in a vibrator machine. This is then poured into the desired size mould. After 24 hours of drying, the blocks are put in a water tank for curing. The process of curing continues for two to three weeks to give the blocks compression strength. The blocks are used in the construction process after drying. It is easy to make a concrete block. The successful block yard must however make blocks of uniform quality and sell them at a price high enough to cover costs and make a reasonable profit (Chaure et al., 2018).

2.5 Review on The Use of Palm Kernel Shells (PKS) in The Construction Industry

The use of palm kernel shells (PKS) as an aggregating substitute material to enhance the properties of sandcrete blocks, concrete and mortar have attracted much research interest in the past decade. Examples can be found in several research works; Palm kernel shells as partial replacement for fine aggregate in asphalt (Rasheed et al., 2019); The performance with lime treated palm kernel shells and sugarcane bagasse ash as partial replacements of coarse aggregate and cement (Samson et al., 2019); The compressive strength of concrete with palm kernel shells as partial replacement for coarse aggregate (Azunna, 2019) and Bond and flexural strength characteristics of partially replaced self-compacting palm kernel shells concrete (Samson et al., 2019); using palm kernel shall as partial replacement for sand in sandcrete block production (Dadzie & Yankah, 2015); Lightweight masonry block from oil palm kernel shell (Muntohar & Rahman, 2014); Palm kernel shells as partial replacement for fine aggregate in asphalt (Rasheed et al., 2019); The performance with lime treated palm kernel shells and sugarcane bagasse ash as partial replacements of coarse aggregate and cement (Samson et al., 2019); The compressive strength of concrete with palm kernel shells as partial replacement for coarse aggregate (Azunna, 2019) and Bond and flexural strength characteristics of partially replaced self-compacting palm kernel shells concrete (Samson et al., 2019).

2.6 Palm Kernel Shells (PKS) As a Potential Building Material

The relationship between the PKS aggregates content and the densities of blocks produced by Dadzie and Yankah (2015) revealed that the higher the PKS aggregates content, the lower the density. Block of 10% PKS aggregate replacement is found to be denser as compared to the control sample of 0% PKS aggregate replacement. It could also be noticed that, from 20% downward PKS replacement, the value for density decreases. Dadzie and Yankah (2015), further argued that for a better partial replacement of PKS percentage for sand in block production, 10% substitution is the ultimate if the emphasis is solely on the weight or density.

A study on palm kernel shells as a partial replacement for sand in sandcrete block production by Dadzie and Yankah (2015), also revealed the relationship between the PKS aggregates content and the resulting densities of water absorption of the block produced. It can be deduced from Dadzie and Yankah, (2015) results that the amount of water absorbed by the block reduces as the percentage replacement of the PKS increases. Dadzie and Yankah (2015), further argued that from 10% to 40% PKS aggregate replacement, the resulting water absorption densities are more than 130kg/m^3 being the minimum standard water absorption density of block made of lightweight aggregates in the ASTM C55 2011. Dadzie and Yankah (2015), made a strong argument that the resulting decrease in water absorption of the samples as the PKS content increases can therefore be a result of the coarse nature of the PKS aggregates which tend to make the block porous the more its contents increase. In terms of water absorption capacity, Dadzie and Yankah, (2015) study revealed that sandcrete blocks produced with more than 40% PKS aggregate replacement for sand content tend to be more porous since its water absorption decreases below the 130kg/m3 recommended by the ASTM C55 2011.

The relationship between the compressive strength and the PKS aggregates content by Dadzie and Yankah (2015) also revealed that aside from the 50% PKS aggregates replacements which have its compressive strength (1.605N/mm2) lower than the compressive strength (3.6N/mm2) of the control sample (0% PKS aggregates replacement), the compressive strength of the 10% to 40% PKS aggregates replacements was higher than that of the control sample. Furthermore, the compressive strength results of the 10% to 40% of the PKS aggregates replacements exceed the minimum compressive strength (2.8N/mm2) requirement by the BS 6073 (Dadzie & Yankah, 2015). The examination of the Dadzie and Yankah (2015) results indicates that between 0% to 10% PKS aggregate replacement, not only are the particles closely packed; rather aggregates mix design becomes composed of well-graded aggregates (sand and PCS). Hence the resultant effect of both higher densities and higher compressive strength.

Muntohar and Rahman (2014), also investigated the effect of mixed design and different PKS particle sizes on the properties of shell creation. The size of the shell create made was 200 mm x 100 mm x 80 mm. The ratio of cement, sand and PKS was designed as 1:1:1, 1:1:2, and 1:1:3 by the volume ratio. According to Muntohar and Rahman (2014), the PKS particle size was retained on a 2.36 mm sieve (Size A), (b) retained on a 4.75 sieve (Size B), and (c) retained on a 9.5 mm sieve (Size C) respectively was used to carry out the study. The sandcrete made from 1:4 of cement and sand ratio was prepared as control specimens and three specimens were prepared for each mixture proportions. Muntohar and Rahman (2014), the study revealed that the density of a size A of PKS is higher than that of sizes B and C. Muntohar and Rahman (2014) argued that the results indicated that a large PKS size forms a more packed void in the matrix, therefore, results in a less dense larger PKS size of the shellcrete.

The study shows the water absorption of the shell created with different mixture proportions Muntohar and Rahman (2014). The study revealed that a mix proportion of 1:1:1 had the lowest water absorption. The water absorption of the shell creates increases with increasing in the PKS proportion. According to Muntohar and Rahman (2014), larger PKS size also had higher water absorption than the smaller PKS size. The possible reason for the increase in water absorption is the existence of micropores on the shell surface argued by Muntohar and Rahman (2014).

The variation of compressive strength of the shell Crete and the control specimens by Muntohar and Rahman (2014) also revealed that the compressive strength is affected by the mix proportion, the PKS sizes, and water immersion. The highest compressive strength of the shellcrete was about 23 MPa which was obtained by mixing a proportion of 1:1:1 under dry conditions (Muntohar & Rahman, 2014). In general, it was again revealed that the compressive strength of shell create mixtures was higher than the control specimen. The maximum strength was obtained by mixing a proportion of 1:1:1 for both dry and wet treatment, while the lowest strength was obtained by mixing a proportion of 1:1:3. Muntohar and Rahman (2014), argued that the addition of a large amount of PKS tends to decrease the compressive strength.

There is a globally increasing in the population of human settlement and infrastructure development. This large urbanization will lead to a growing demand for concrete, mortar and sandcrete blocks which remains everywhere in the world the material most consumed in the construction industry. According to Keerthinarayana and Srinivasan (2010), Concrete which is made from cement has been the ultimate construction material. It is, therefore, an indisputable fact that concrete is the most indispensable material that is used in infrastructure development throughout the world. According to Armah et al. (2019), the extraction of raw materials causes serious environmental problems by damaging the landscape and most of these raw materials become scarce. Armah et al. (2019), stressed that recent events in major urban centres in Africa have shown that, the problem of waste management has become a monster, which has bedevilled most efforts by professionals of city, state and federal authorities. These wastes are due to industrial, agricultural, municipal, and other activities (Armah et al., 2019).

A study on the use of palm kernel shells as aggregate in the manufacture of concrete was done by Serge et al. (2020). Several (0, 25, 50, 75 and 100%) substitutions of the palm kernel shells as aggregate were used in the volume fraction of the coarse aggregates. The effect of the substitution was examined at 7 and 28 days (Serge et al., 2020). The study by Serge et al. (2020), revealed the difference in density as a function of the volume content of the palm nutshell. The results show a linear decrease in the density with the increase in the palm nut content.

The study by Serge et al. (2020), revealed the evolution of the compressive strength on cylindrical specimens of 160 mm in diameter and 320 mm in height depending on the palm nutshell content at 7 and 28 days. The study revealed that between 7 and 28 days there was a decrease in the compressive strength with the increase in the palm nut content.

According to Jackson et al. (2019), the use of waste materials such as coconut shells (CS) and palm kernel shells (PKS) may contribute to the deduction of the negative environmental impact of non-decaying waste materials. Jackson et al. (2019), the paper examined coconut shell (CS) and palm kernel shell (PKS) wastes for concrete production in the construction industry. Jackson et al. (2019), conducted experiments on concrete produced with CS and PKS wastes to determine their workability, compressive strength and density. Silt test, grading of aggregates, slump, compacting factor and compressive strength of concrete were carried out at the laboratory to determine the silt content, particle size distribution, workability and consistency of the mix, compressive strength and density for concrete production. Jackson et al. (2019), used three types of concrete mixes were prepared (a control mix, others consist of 20%, 40%, 60%, 80% and 100% replacement of crushed PKS and 20%, 40%, 60%, 80% and 100% replacement of crushed CS.

The compressive strength of concrete produced with proportions of coconut and palm kernel shells by Jackson et al. (2019) the relationship between average compressive strengths of concrete and age was studied. It was observed that the compressive strengths of concrete increase faster with age until 28 days. It was observed that the control (100%) was 74.20% higher than CS (100%) concrete and 77.58% higher than that of PKS (100%) at 28days. The compressive strengths of concrete achieved on the 28th day for CS (100%) and PKS (100%) concrete were 7.88 Mpa to 6.85 Mpa respectively with a percentage deviation of 13.07 for a mix ratio of 1:2:4 and a water/cement ratio of 0.55. CS (20%) had an average compressive strength of 19.29 MPa, and PKS (20%) also had an average compressive strength of 13.29 MPa with a percentage deviation of 31.10 at 28 days. CS (40%) and PKS (40%) had average compressive strength at 28 days of 13.15 MPa and 10.09 MPa respectively with a percentage deviation of 23.27. at 28 days, CS (60%) had an average compressive strength of 10.77 MPa and PKS (60%) also had an 8.49 MPa average compressive strength with a percentage deviation of 21.17.

According to Jackson et al. (2019), the average compressive strengths of CS (80%) and PKS (80%) were found to be 10.09 MPa and 7.66 MPa respectively with a percentage deviation of 24.08. It was seen that the compressive strength of concrete for all the specimens increases as the age of concrete increases and this confirms the outcome of research conducted on the compressive strengths of concrete. It was also revealed by Jackson et al. (2019), that for CS and PKS concrete, as the percentage of replacement increases, the compressive strength of the concrete decreases. The highest compressive strength of both CS and PKS concrete was achieved when the replacement percentage is 20%. However, CS (20%) had higher average compressive strength than PKS (20%) Jackson et al. (2019), further made a comparison of average compressive strengths of the 100% control, 100% CS and 100% PKS concrete at 7 days, 14 days, 21 days and 28 days. It was observed that the control (100%) had an average compressive strength of 24.60 MPa at 7days whilst CS (100%) and PKS (100%) at 7 days had 4.58 MPa and 2.81 MPa respectively. At 14days, the control (100%), CS (100%) and PKS (100%) had average compressive strengths of 27.87 MPa, 5.31 MPa and 3.01 MPa respectively. In terms of the 21 days' average compressive strengths, the control (100%) had 29.60 MPa, the CS (100%) had 5.56 MPa and the PKS (100%) had 3.15 MPa. The average compressive strengths recorded at 28 days for the control (100%), CS (100%) and PKS (100%) were 30.55 MPa, 7.88 MPa and 6.85 MPa respectively.

Armah et al. (2019), study the utilization of palm kernel shells in ground form (GPK) for partial replacement of Ordinary Portland cement (OPC) in concrete by investigating its optimal strength using nondestructive ultrasonic pulse velocity method for both cubic and cylindrical concrete test specimen. According to Armah et al. (2019), In a total of 135 cubes and 66 cylinders of concrete were prepared. The dimension of the cubic concrete specimens was 150 × 150 × 150 mm and that of the cylindrical specimens were 110 mm and 500 mm in diameter and length respectively. The mix design of the GPK shells used as a partial replacement for OPC ranged between 0% and 50% by weight of cement using a mix ratio of 1:2:4 with a water to cement ratio of 0.8. The concrete specimens were tested at curing periods of 7 days, 28 days and 60 days for the cubes and 7 days and 28 days for the cylinders (Armah et al., 2019).

The effect of replacement of GPK shells on the density of the study of the specimens by Armah et al. (2019). The results revealed that the density of concrete samples decreased with an increasing percentage of GPK shells and increased with curing age (i.e. the more the ash contents in the concrete, the lower the density) for all replacement mix ratios investigated.

According to Armah et al. (2019) for cured at 7 curing days, the test results of the density of concrete ranges from 2140.25 - 2281.48 kg/m3 as against 2354.57 kg/m3 for the control. The density of the 20%, 30%, 40%, 50% and 60% replacement are 96.90%, 94.76%, 93.37%, 91.74% and 90.90% that of the control at 7 days curing respectively. The effect of GPK ordinary shells on density was slightly less compared with the control samples.

According to Armah et al. (2019), the 28-days curing density obtained was higher than the 7-days density. The results range from 2157.04 - 2342.72 kg/m3 as against 2443.46 kg/m3 for the control. The density of the respective replacement ratios is 95.877%, 92.32%, 90.76%, 89.18% and 88.28% that of the control. Similarly, the 60-days curing density obtained was higher than the 28-days density. The results range from 2164.44

- 2358.02 kg/m3 as against 2454.32 kg/m3 for the control and the density of the replacement ratios of 20%, 30%, 40%, 50% and 60% are 96.08%, 92.37%, 90.76%, 89.20% and 88.19% that of the control. The density for the highest replacement GPK ordinary shells of 60% was reduced by less than 10%, 11.7% and 11.8% for the 7 days, 28-days and 60-days respectively when compared with the value of the control concrete.

The representative results of the modulus of elasticity of the samples study by Armah et al. (2019). The effect of replacement of GPK shells on the modulus of elasticity of the study of the specimens by Armah et al. (2019), further revealed that the modulus of elasticity of concrete samples decreased with an increasing percentage of GPK shells and increased with curing age.

According to Armah et al. (2019), the modulus of elasticity for the GPK ordinary shells at a 7-day curing period was found to be 31.30 MPa for the control and vary from 6.85 MPa to 20.0 MPa by varying the replacement ratio of the GPK ordinary shells. The modulus of elasticity of these concretes was found to decrease to 63.9%, 60.93%, 44.63%, 30.13% and 21.89% at various replacement percentages regarding the control mix. At the 28-day curing period, the modulus of elasticity for the control increased to 41.35 MPa. This shows an increment of approximately 32.11%. At this curing age, the modulus of elasticity varies from 11.10 MPa to 30.72 MPa when the GPK ordinary shell replacement percentages were varied.

According to Armah et al. (2019), the decrease corresponds to 74.29%, 62.73%, 47.93%, 34.9% and 26.6% of the control for the various replacement percentages. As the curing periods increased from 28-day to 60 days, the modulus of elasticity for the control increased to 44.63 MPa with a difference of 3.28 MPa which corresponds to 7.9%. The test results for the various replacement percentages range from 13.91 MPa to 33.56 MPa. The percentage decrease in the modulus of elasticity concerning the control for the various replacement percentages was 75.2%, 62.9%, 50.15%, 42.55% and 31.17% respectively (Armah et al., 2019).

From the results and the analysis done, Armah et al. (2019), made a strong conclusion that as the mix ratio is increased, the density and modulus of elasticity decreased and as the curing period increased, these values increased across all the mix ratios. The density and modulus of elasticity of the "fuel" shells specimen are higher than that of the ordinary shells. According to Armah et al. (2019), Based on the findings, 30% of the GPK "fuel" shells and 20% of GPK ordinary shells could be used for partial replacement of OPC in concrete for pavements, buildings, and other lightweight structural concrete. Armah et al. (2019), further argued that the use of GPK shells for partial replacement of OPC by 20% can decrease the cost of the concrete produced by the reduction of cement. It will also reduce environmental pollution due to the dumping of such agro-based waste thereby conserving materials, labour and energy.

The study on the compressive and flexural strengths of concrete containing ground palm kernel shells as a partial replacement for cement by Armah et al. (2020) explores the possibility of using waste ground palm kernel (GPK) shells as a partial replacement for cement in concrete. According to Armah et al. (2020), the palm kernel shells used in the study were in two forms: the GPK ordinary shells and shells subjected to incomplete combustion (i.e. the GPK "fuel" shells). In the preparation of the concrete specimens the mix ratio was 1: 2: 4 (cement: sand: stone) by weight and the replacement percentage was 0%, 20%, 30%, 40%, 50% and 60% respectively. The concrete specimen was moulded in both cubic and cylindrical form and its impact on the mechanical properties such as workability, compressive strength and flexural strength using the destructive test method were studied. The cubic specimen were tested at 7, 28 and 60 days whiles the cylindrical specimen was tested at 7 and 28 days (Armah et al., 2020).

The physical properties tests were determined for the cement and the GPK shells by Armah et al. (2020). For the fineness test using the sieving method, the amount of cement (being the control) retained by the sieve was far less than that retained by the GPK shells. This gives the control superior percentage fineness over the GPK shells. However, the GPK "fuel" shells are finer than the GPK ordinary shells (Armah et al., 2020). It was found that GPK "fuel" shells are finer than cement, and this may be a result of the fact that the shape of the particles in the GPK "fuel" shells was observed to be elongated. However, the fineness value of the GPK ordinary shells fell far below the typical ordinary Portland cement specific surface (Armah et al., 2020).

According to Armah et al. (2020), the porosity test results show that the control conforms to the standard porosity of OPC which is 0.5. The GPK "fuel" shells were less porous whiles the GPK ordinary shells were the most porous. Thus, the GPK ordinary shells absorbed more water than cement and the GPK "fuel" shells. The permeability results also reveal a similar trend where the GPK ordinary shells are more permeable than the control and the GPK "fuel" shells (Armah et al., 2020).

The compressive strengths and flexural strength at various GPK shell replacement percentages including the control (0% replacement) being the normal concrete examined by Armah et al. (2020). According to Armah et al. (2020), the 28 days results were used for the analyses because, it is known that, between 80% and 95% of the final and maximum strength of cement concrete is achieved in 28 days. The compressive strength and flexural strength examined by Armah et al. (2020), were found to decrease with increasing percentage replacement for a given curing period.

The results of chemical analysis by Armah et al. (2020), revealed that the Ordinary Portland Cement is composed of four major oxides which are lime (CaO), silica (SiO_2), alumina (Al_2O_3), and iron (Fe_2O_3) sum up to almost 95% and small amount of magnesia (MgO), alkalis (Na_2O and K_2O), and sulfuric anhydrite (SO_3). However, the standard minimum specification required for pozzolan to be used as a mineral admixture in Portland cement concrete is 50% according to standard ASTM C618 as cited in cited Armah et al. (2020).

According to Armah et al. (2020), from the results, the total amount of the major oxides in the control sample was 93.32% (close to the standard of 95%), whiles the GPK "fuel" shells and ordinary shells is 66.33% and 41.29% respectively. This means that the GPK "fuel" shells contain more than 50% of the four major oxides and have demonstrated their ability to be used as cementitious materials by meeting the chemical requirements of pozzolan with the ordinary shells slightly below (Armah et al., 2020).

A comparative study of the properties of concrete containing GPK ordinary shells and GPK "fuel shells" as a partial replacement for cement has been carried out by Armah et al. (2020). Armah et al. (2020), further made a strong conclusion that the results from the physical and chemical analyses imply that GPK "fuel shells" have accepTable cementitious properties by meeting the requirements as pozzolan while GKP ordinary shells do not. According to Armah et al. (2020), the mechanical results show that the compressive strength and flexural strength of the concrete specimens produced decrease, as replacement percentages are increased but increase as curing periods, are increased.

Armah et al. (2020), further stressed the optimum level of GPK shell replacement is 20% for the ordinary shells and 30% for the "fuel" shells considering compressive strength at 28 days. For the flexural strength, concrete containing up to 60% replacement of cement by GPK shells has accepTable flexural strength. Despite the finding that the GPK ordinary shells do not have cementitious properties, the mechanical properties of concrete containing these shells are such that it can be used in such low-strength construction as pavements, walkways, and non-structural domestic work. This may help reduce cement usage in concretes thereby reducing the cost of concrete production, alleviating the increasing challenges of scarcity and also minimising the negative environmental effects of disposal of such wastes (Armah et al., 2020).

2.7 The Trend of Sandcrete Blocks in The Construction Industry

The rapid growth in the nation's infrastructure development to accommodate additional people and components has been a concern. This has made sandcrete block the number one widely used building material in the construction industry to put up structures. Sandcrete blocks are extensively used in Nigeria, Ghana, and other countries as load-bearing and non-load bearing walling units (Anosike & Oyebade, 2012a). Sandcrete blocks are composite building materials manufactured from cement, sand and water, moulded into different sizes and used for construction purposes.

According to Millers (2020), sandcrete blocks are popularly used for the building of infrastructure because of the following potentials; Sandcrete blocks can be manufactured off-site, higher density, higher compressive strength, provides a natural level of fire resistance, resist strong winds, and are practically soundproof. This has made scientists, engineers and technologists constantly conduct more research into sandcrete blocks as a potential building material infrastructure development. Examples can be found in research works: Properties of Sandcrete Block Produced with Coconut Husk as Partial Replacement of Sand (Robert et al., 2020); Impact of Different Fine Aggregates on the Compressive Strength of Hollow Sandcrete Blocks (Odeyemi et al., 2019); Assessment of Sandcrete Blocks Manufacturers 'Compliance to Minimum Standard Requirements by Standard Organisation of Nigeria in Southwest, Nigeria (Ajao et al., 2018); Sandcrete Blocks and Quality Management in Nigeria Building Industry (Anosike & Oyebade, 2012); Impact of Quality Control Practices in Sandcrete Blocks Production (Baiden & Tuuli, 2004); Effects of orientation and compaction methods of manufacture on strength properties of sandcrete blocks (Baiden & Asante, 2004).

Nigeria's industrial standard reported that sandcrete blocks are formed either in a solid or hollow rectangular shape. They are commonly found in 450 mm by 225 mm by 225 mm size for load-bearing walls and 450 mm by 150 mm by 225 mm size for non-load bearing walls. Material constituents, mix proportion, admixtures presence, method of compaction and age of curing are significant factors that determine the mechanical properties of sandcrete blocks (Oyetola and Abdullahi, 2006; Anosike and Oyebade,2012). According to Odeyemi et al. (2019), The high cost of materials such as sand used in the production of sandcrete blocks has contributed to an increase in the cost of building construction.

According to Robert et al. (2020), sandcrete blocks are the most common building material in the construction industry. However, with the high and increasing cost of building materials experienced nowadays, it has been difficult to achieve affordable housing, especially in developing countries. Also, Robert et al. (2020), further argued that significant searching of sand for block production and a large amount of coconut husk thrown away as waste have increased the level of concern due to their adverse effect on the environment. This study by Robert et al. (2020), therefore sought to produce solid core sandcrete blocks in which sand component is partially replaced with coconut husk and investigate the suitability of using such blocks for building designs. The research was conducted in Nigeria by Ajao et al. (2018) to assess sandcrete blocks manufacturers 'compliance with minimum standard requirements by the standard organization. Ajao et al. (2018), further stated that the intensive use of sandcrete hollow blocks in building construction has made them essential building materials in construction industries. This necessary need has made Sandcrete hollow blocks 'Manufacturers play pranks in the Minimum Standard Requirement'. The paper by Ajao et al. (2018), assesses the compliance level of Sandcrete Block Manufacturers to Minimum Standard requirements in Southwest, Nigeria. 54 sandcrete blocks comprising 225 mm and 150 mm were gotten from block production sites within three states; Oyo, Ondo, and Lagos State. Samples of their fine aggregates were gotten for proper examination. According to Ajao et al. (2018), to compare the outcome of the test results with standards, 18 numbers of controlled experimental units which comprised 225 mm and 150 mm were produced.

The compressive strength results of sandcrete blocks by Ajao et al. (2018), revealed that the compressive strength of sandcrete block manufacturers within three States; Lagos, Ondo, and Oyo ranged between 0.95 N/mm to 1.33 N/mm, 0.79 N/mm to 1.02 N/mm, and 0.77 N/mm to 1.14 N/mm. while the average compressive strength of experimental controlled units ranged between 2.77 N/mm to 4.12 N/mm. According to Ajao et al. (2018), these compressive strength values gotten from blocks suppliers within South West were far behind the stipulated minimum standard for sandcrete blocks specified by Nigerian Industrial Standard (NIS 87: 2000) minimum of 2.5 N/mm2 for individual blocks and 3.45 N/mm2 for an average of five blocks. Ajao et al. (2018), further argued that the compressive strength results obtained indicated improper quality management practice and non-adherence to stipulated mix-design (1;8) observed among the manufacturers because the strength results were far behind stipulated standards. Hence it can be concluded from Ajao et al. (2018) study that, quality management practice and adherence to stipulated mix-design among the manufacturers greatly effluence the properties of sandcrete block.

The effects of orientation and compaction methods of manufacture on the strength properties of sandcrete blocks were also investigated in Ghana (Baiden & Asante, 2004). According to Baiden and Asante (2004), there are mostly three modes of compaction in sandcrete block manufacture in Ghana. The mould incorporated in each method comes in either vertical or horizontal orientations. The majority of local sandcrete block producers however do not make use of both orientations for any compaction method. This made it very necessary to examine the three methods of production and assesses their effect on strength properties which were investigated by Baiden and Asante (2004).

The study by Baiden and Asante (2004), revealed that the water absorption capacities for all the samples from the hand ramming compaction method (HR) mode in either orientation were lower than ASTM C140 maximum allowable. Mean values from horizontally oriented samples fell below the limit by 17.19% and those from the vertically oriented ones by 34.81%. The samples, therefore, exhibited a high degree of durability and resistance to moisture movement especially, the vertically oriented ones argued by (Baiden & Asante, 2004). Mean water absorption capacities from both horizontal and vertical orientations for vertical orientations of the manual tamping machine (MT) method of compaction were also accepTable. The horizontal position fell below the limit by 7.27% and therefore, was less durable than that of the vertical mould, which fell by 14.18%. According to Baiden and Asante (2004), the mean water absorption value for the horizontally placed block samples fell below the limit by 22.81%. Those from the vertical orientation gave a mean water absorption capacity percentage of 44.65% below the limit. More durable blocks are therefore produced in the vertical orientation. The study by Baiden and Asante (2004), further revealed that the mean compressive strength values obtained for the horizontal orientation of the MV were less than 2.75N/mm2 the minimum required by the Ghana Building Code 1989. It was, however, higher than the minimum required for a non-load bearing block. The vertically oriented samples however exceeded the minimum limit by a percentage of 1.09%. This is therefore the best for strength achievement (Baiden & Asante, 2004).

The impact of different fine aggregates on the compressive strength of hollow sandcrete blocks in conducted in Nigeria by Odeyemi et al. (2019). Sandcrete blocks are walling materials that are made of fine aggregates and cement. Sandcrete blocks are being used as building materials in many parts of Nigeria. Odeyemi et al. (2019), stated that it has been discovered that many of the blocks produced do not conform to the minimum compressive strength requirement in the construction industry. The study by Odeyemi et al. (2019), therefore, examined the effect of using four (4) different fine aggregates (quarry dust, river sand, shocking sand and plastering sand) with a binder to aggregate mix ratios of 1:6 and 1:4 on the water absorption and compressive strength of sandcrete blocks.

According to Odeyemi et al. (2019), the water absorption capacity results revealed that shocking sand has the highest capacity to absorb water with a value of 8.69 %. River sand, with a value of 6.67 % has the lowest water absorption capacity. Odeyemi et al. (2019), further argued that the 28th-day compressive strength test results of 1.31 N/mm2, 1.10 N/mm2, 0.78 N/mm2 and 0.50 N/mm2 for the sandcrete blocks produced from quarry dust, river sand, shocking sand and plastering sand respectively, with mix ratio 1:6, did not meet the minimum requirement of 2.5 N/mm2 specified by NIS 87:2007 for non-load bearing walls. However, with a mix ratio of 1:4, the compressive strength of 2.52 N/mm2 and 2.50 N/mm2 for sandcrete blocks made with quarry dust and river sand respectively met this minimum requirement. Odeyemi et al. (2019), further concluded that only quarry dust and sharp sand at a mix ratio of 1:4 are suiTable in the production of sandcrete blocks.

Impact of Quality Control Practices in Sandcrete Blocks Production conducted in by Baiden and Tuuli, (2004), revealed that sandcrete blocks are widely used in Ghana as walling units. The quality of blocks produced, however, differs from each manufacturer due to the different methods employed in the production and the properties of the constituent materials (Baiden & Tuuli, 2004).

Baiden and Tuuli, (2004) study further confirmed that mix ratio, quality, and mixing of the constituent materials affected the quality of sandcrete blocks. According to Odeyemi et al. (2018). The durability of a building is determined to a great extent by the quality of materials used in its construction. According to Odeyemi et al. (2018), self-supporting walls and building structures with load-bearing and non-load bearing sandcrete blocks are common in Nigeria because of their ease of construction and their affordability. Sandcrete skin panels and blocks are sometimes used to provide aesthetics to buildings and serve as a control to moisture infiltration and wind action (Odeyemi et al., 2018). According to Anosike and Oyebade (2012), over 90% of physical infrastructure in Nigeria is being constructed using sandcrete blocks making it a very vital material for construction purposes. Sandcrete blocks are widely used in Nigeria, Ghana, and other African countries as load-bearing and non-load bearing walling units (Anosike & Oyebade, 2012).

2.8 Agricultural By-Product As Potential Building Material

Agricultural industries produce a massive amount of waste every year (Sadh, 2018). Examples of such waste are; palm kernel shells (PKS) and palm fronds. Today, organic wastes from agro-industries are one of the main sources of environmental pollution (Yusuf, 2017). According to Sadh (2018), If agro-waste are released into the environment without proper disposal and utilization procedure that may lead to environmental pollution and harmful effect on human and animal health. Research has shown that the utilization of industrial waste for infrastructure development in the construction industry is proven economically viable when environmental factors are considered (Kinuthia & Nidzam, 2011).

Danso (2018), argued that resource depletion and environmental pollution caused by construction activities can be minimized if the construction industry incorporates sustainable construction materials for building development. This can be achieved by modifying and incorporating agro-waste materials such as palm kernel shells for building development. This has made researchers in the engineering industry constantly conduct more research into agricultural by-products as a potential building material that may meet accepTable performance and standards. Examples can be found in several research works; Influence of Plantain Pseudostem Fibres and Lime on The Properties of cement mortar (Danso, 2020); Properties of Sandcrete Block Produced with Coconut Husk as Partial Replacement of Sand (Robert et al., 2020); Palm kernel shells as a partial replacement for fine aggregate in asphalt (Rasheed et al., 2019); The performance with lime treated palm kernel shells and sugarcane bagasse ash as partial replacements of coarse aggregate and cement (Samson et al., 2019); Properties of coconut, oil palm and bagasse fibres as potential building materials (Danso, 2017); Piassava fibres as reinforcement of concrete (Abu, Yalley, & Adogla, 2016); Using palm kernel shell as a partial replacement for sand in sandcrete block production (Dadzie & Yankah, 2015); Lightweight masonry block from oil palm kernel shell (Muntohar & Rahman, 2014).

Research has proven significantly that, the utilization of agricultural waste in the construction could enhance the properties of sandcrete block, earth block, mortar and concrete. According to Danso (2020), studies have significantly demanded that research study should be carried out to investigate the suitability of some plant residue used in concrete and mortar. The use of natural fibres such as plantain pseudostem, coconut, oil palm and bagasse fibres in composite materials is attracting research interest worldwide due to the fibres' ability to increase strength, reduce environmental impact and reduce the cost of the material (Danso, 2017).

A study on the influence of plantain pseudostem fibres and lime on the properties of cement mortar by Danso (2020), revealed that the average dry densities of the 0% (control) specimens (2167–2190 kg/m3) were higher than the fibre replacement of sand by 0.25, 0.5, 0.75, and 1%, the 0.25 and 0.5% fibre replacement of sand recorded slightly better average densities (2051–2063 kg/m3) and (2044–2066 kg/m3), respectively. Danso (2020), further argued that as the fibre content increases, the density of the specimen is likely to reduce. According to Danso (2020), the fibre replacement of sand by 0.25, 0.5, and 0.75% obtained better compressive strength of 14.33, 13.89, and 12.85 MPa, respectively, over the control specimens of 11.61 MPa on the 28-day curing. Danso (2020), further argued that the compressive strength of all the mix designs increased by age from 7 days to 28 days of curing respectively.

A study on the influence of coconut fibres and lime on the properties of soil-cement mortar by Danso and Manu (2020), revealed that the average densities recorded for all the specimens were between 1597 and 1717 kg/m3. Danso and Manu (2020), observed that specimens with lime content from 0 to 10 % and fibre content from 0.2 to 0.6 %

recorded a marginal increase in density, with 5 % lime and 0.2 % fibres emerging the highest. However, the specimen with 15 % lime for all the different fibre contents recorded decreased density. Danso and Manu (2020) further argued that the addition of lime up to 10 % and fibre content of 0.2 % provides comparably, a very good density.

Danso and Manu (2020), revealed again that the 0 % fibre content specimens recorded the lowest water absorption coefficient. As the lime content increased without fibres, the absorption coefficient decreased. However, Danso and Manu (2020), further argued that all the specimens with fibres recorded a high absorption coefficient as the fibre content increased. Conversely, there was decreased water absorption with increased lime content in the specimens with fibre addition. Danso and Manu (2020), suggest that the influence of the stabilisers on the water absorption coefficient can largely be associated with the addition of lime in the specimens.

The compressive strength results by Danso and Manu (2020), show that all the lime addition specimens gained better strength than the 0 % lime content. 0 to 5 % lime addition specimens had an increase in strength and then declined with the further addition of 10 and 15 %. For fibres addition of 0.2, 0.4, 0.6 and 0.8 %, the compressive strength of the soil-cement mortar with 5 % lime increased by 22.22, 1.93, 1.45 and 14.49 % respectively, as compared with that of the soil-cement without fibres (Danso & Manu, 2020). Conversely, with the addition of 15 % lime, the compressive strength decreased by 7.11, 22.84, 22.84 and 15.74 % respectively, for 0.2, 0.4, 0.6 and 0.8 % fibre addition as compared with that of the soil-cement without fibres. (Danso & Manu, 2020). Danso and Manu (2020) argued that with the addition of 15 % lime, the compressive strength decreased by 7.11, 22.84, 22.84 and 15.74 % respectively, for 0.2, 0.4, 0.6 and 0.8 % fibre addition as compared with that of the soil-cement without fibres.

Danso and Manu (2020) further observed that the 0.2 % fibre contents obtained the highest strength. This, therefore, implies that the general optimum strength is at 0.2 % fibre and 5 % lime contents which recorded 2.53 MPa strength (Danso & Manu, 2020).

A study on the effect of sugarcane bagasse fibre on the strength properties of soil blocks by Danso et al. (2015), revealed that the average dry density of the reinforced soil blocks decreased with increased sugarcane bagasse fibre content. It was again revealed that the water absorption of the soil blocks increased with the increase in fibre content. The high-water absorption of reinforced soil blocks may be attributed to the amount of water absorbed by the cellulose of the fibres argued to Danso et al. (2015).

The compressive strength test results by Danso et al. (2015), revealed that the compressive strength of the blocks increased with increased fibre content until it reached 0.5%, and then decreased with further increase in fibre. This indicates that the reinforced soil blocks obtained an optimum compressive strength with about 26% and 19% increase over the unreinforced blocks respectively (Danso et al., 2015).

The study by Robert et al. (2020), revealed that when untreated and treated coconut husks are separately utilized at the same proportions to partially replace sand in the solid core sandcrete block samples produced and tested at curing periods of 7 days and 28 days in this work. At both ages of the block samples, the experimental verdicts showed an increase in percentage water absorption but a decrease in bulk density and compressive strength with increasing proportions of either the untreated or treated coconut husks used (Robert et al., 2020).

According to Oyebisi (2018), the high cost of conventional walling materials, increase in emission of CO_2 due to cement production and improper disposal lead to persistent holdups in low-cost and sustainable housing delivery, environmental pollution, and agricultural wastage respectively. According to Adedeji (2007), Nigeria's price increases of conventional building materials such as cement, reinforcement bars and concrete blocks and failure to adopt truly indigenous building materials production systems have not solved the persistent challenges created by the building materials sector in low-cost housing delivery.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This section describes the materials and procedures used for the study. The research work focused on investigating the properties of sandcrete blocks manufactured with pulverized palm kernel shells (PPKS) as a partial replacement for sand. The main parameters studied were particle size distribution, density, water absorption and compressive strength of the specimens.

3.2 Materials

The materials used in this study were pulverized palm kernel shell (PPKS), Pit sand (PS), Ordinary Portland Cement (OPC) and water.

3.2.1 Palm Kernel Shells (PKS)

The PKS in Figures 3.1 (A) and (B) were obtained from a palm kernel oil producing firm at Agona Gyamase in the Ashanti Region of Ghana.

The PKS shown in figure 3.1 (A) and (B) were collected, washed and sun-dried for seven days and finally pulverized to fine particles shown in figure 3.1(C). The pulverized PKS shown in figure 3.1 (C) was used for the experiment.

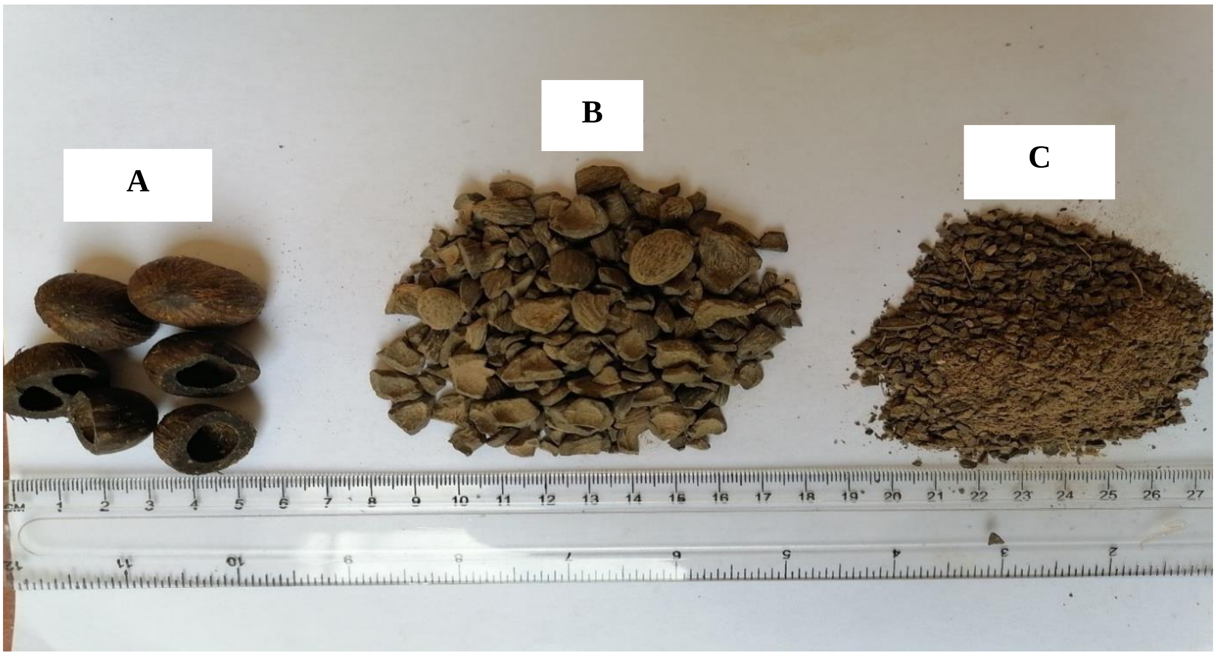

Figure 3.1 Palm Kernel Shells (PKS)

3.2.2 Pit Sand (PS)

The PS shown in figure 3.2 was used for the study, it was obtained from the local sandpit at Agona Gyamase in the Ashanti Region of Ghana. The sand was fine, sharp and conformed with ASTM C33/C33M (2016).

Figure 3.2 Pit Sand (PS)

3.2.3 Cement

Ordinary Portland Cement (OPC) grade 42.5 R produced by GHACEM was used for all mixes. According to GHACEM products specification, grade 42.5 R cement is recommended for sandcrete blocks manufacturing, which conformed with ASTM C150 (2004).

3.2.4 Water

The water used for the entire mix was obtained from Ghana Water Company Limited. The water was colourless, odourless, tasteless and free from salt which conforms with ASTM C1602/C1602M (2012).

3.3 Experimental Procedures

This section discusses the particle size distribution of PS and PPKS used for the study, mixing proportions/batching, sampling details, mixing process, moulding, curing, testing procedures, data analysis and presentation.

3.3.1 Particle Size Distribution of PS and PPKS

ASTM D3282 (2009) was used as a guide to determine the particle size distribution of the PS and PPKS. The fineness modulus (FM) for the PS and PPKS which is the index number representing the average particle size in the aggregate was also done to know whether the aggregate used for the study conforms with the fine aggregate grading requirement recommended by ASTM standard. The FM was determined and was used to show the position of the average particle sizes of PS and PPKS, ASTM C136 (2006) was used as a guide to determine the FM using the formula;

$$FM = \frac{F\sum}{100}$$

Where:

FM = Fineness modulus

$F\sum$ = Cumulative weight retained

3.3.2 Mixing Proportions/Batching

Weight batching was used for measuring materials used for the study. For the study, a block size of 100mm x 100mm x 130mm with an average mass of 3.0kg was used to determine the quantity of material (see Tables 3.2 and 3.3). A mix ratio of 1: 6 (cement: sand) at a constant water-cement ratio of 0.5 was used for the entire mixes as used by Dadzie & Yankah (2015); Ohemeng et al. (2014).

The sand content was partially replaced with 2%, 4%, 6%, 8%, 10%, 20% up to 30% PPKS replacement content. The 0% PPKS content serves as a control specimen for the study. The properties of specimens of 2%, 4%, 6%, 8%, 10%, 20% and 30% PPKS replacement content were further compared to the specimen without PPKS replacement content (control).

3.3.3 Sampling Details

The total specimens required for the study are summarised in Table 3.1. ASTM C140 (2003) was used as a guide for the sampling. For each test three (3) samples were moulding. In all, seventy-two (72) samples were moulded for the experiment.

Table 3.1 Specimens Required for Density, Water Absorption and Compressive Strength Test for Each PPKS Replacement Content

PPKS Replacement	Density	Water Absorption	Compressive Strength	Sub Total
0% PPKS	3	3	3	9
2% PPKS	3	3	3	9
4% PPKS	3	3	3	9
6% PPKS	3	3	3	9
8% PPKS	3	3	3	9
10% PPKS	3	3	3	9
20% PPKS	3	3	3	9
30% PPKS	3	3	3	9
Total				**72**

Quantity of water, cement, sand and pulverized PKS required per mould under each pulverized PKS replacement is summarised in Table 3.2.

Table 3.2 Quantity of Cement, Sand, PPKS and Water Required Per Mould

PPKS Replacement	Cement (kg)	Sand (kg)	PKS (kg)	Water (kg)	Cement/Sand Ratio	Water/Cement Ratio
0% PPKS	0.429	2.571	0.000	0.214	1 : 6	0.5
2% PPKS	0.429	2.520	0.051	0.214	1 : 6	0.5
4% PPKS	0.429	2.468	0.103	0.214	1 : 6	0.5
6% PPKS	0.429	2.028	0.543	0.214	1 : 6	0.5
8% PPKS	0.429	2.365	0.206	0.214	1: 6	0.5
10% PPKS	0.429	2.314	0.257	0.214	1 : 6	0.5
20% PPKS	0.429	2.057	0.514	0.214	1 : 6	0.5
30% PPKS	0.429	1.800	0.771	0.214	1 : 6	0.5

The quantity of water, cement, sand and pulverized PKS required for moulding seventy-two (72) block samples under each pulverized PKS replacement and the total quantities of materials required for the study are summarised in Table 3.3.

Table 3.3 Total Materials Required for The Study.

PPKS Replacement	Cement (kg)	Sand (kg)	PKS (kg)	Water (kg)	Cement/Sand Ratio	Cement /Water Ratio
0% PPKS	3.861	23.139	0.000	1.926	1 : 6	0.5
2% PPKS	3.861	22.680	0.459	1.926	1 : 6	0.5
4% PPKS	3.861	22.212	0.927	1.926	1 : 6	0.5
6% PPKS	3.861	18.252	4.887	1.926	1 : 6	0.5
8% PPKS	3.861	21.285	1.854	1.926	1 : 6	0.5
10% PPKS	3.861	20.826	2.313	1.926	1 : 6	0.5
20% PPKS	3.861	18.513	4.626	1.926	1 : 6	0.5
30% PPKS	3.861	16.200	6.939	1.926	1 : 6	0.5
TOTAL	**30.888**	**163.107**	**22.005**	**13.482**		

3.3.4 Mixing Process

The mixing of the materials was done mechanically by an electric pun mixer shown in figure 3.3(A) because of the semi-dry nature of the mixture. The measured cement was first poured into the pun, followed by the measured sand, and then the measured PPKS was finally poured into the pun as shown in figure 3.3(B). The electric pan mixer was then turned on and allowed to rotate for five minutes to achieve a homogeneous mix. Finally, measured water was then added to the mixture in the pun and allowed to rotate for three minutes to achieve a homogeneous mixture.

Figure 3.3 Pouring of the Measured Materials into the Pun Mixer

3.3.5 Moulding

For casting purposes, a hydraulic compress block moulding machine of mould size 100mm x 100mm x 130mm shown in figure 3.4 was used for all mouldings. The interior of the mould was first lubricated with mould oil to prevent the specimens from sticking to the sides of the mould and enable easy removal of the specimens, which gave the specimens smooth finishing surfaces.

The measured mixture was then poured into the mould in three-layer. Each layer was then given three gentle tamped blows seven times using a wooden tamping rod as shown in figure 3.5 B. The surface of the mould was then levelled with metal float to remove the excess materials. The top plate of the mould was placed in position and tightened firmly, finally, a pressure of 140 bar was applied from the hydraulic jack of the mould until the materials were fully compressed in the mould. The compressed specimens were gently removed from the mould and further stored on wooden pallets shown in figure 3.6.

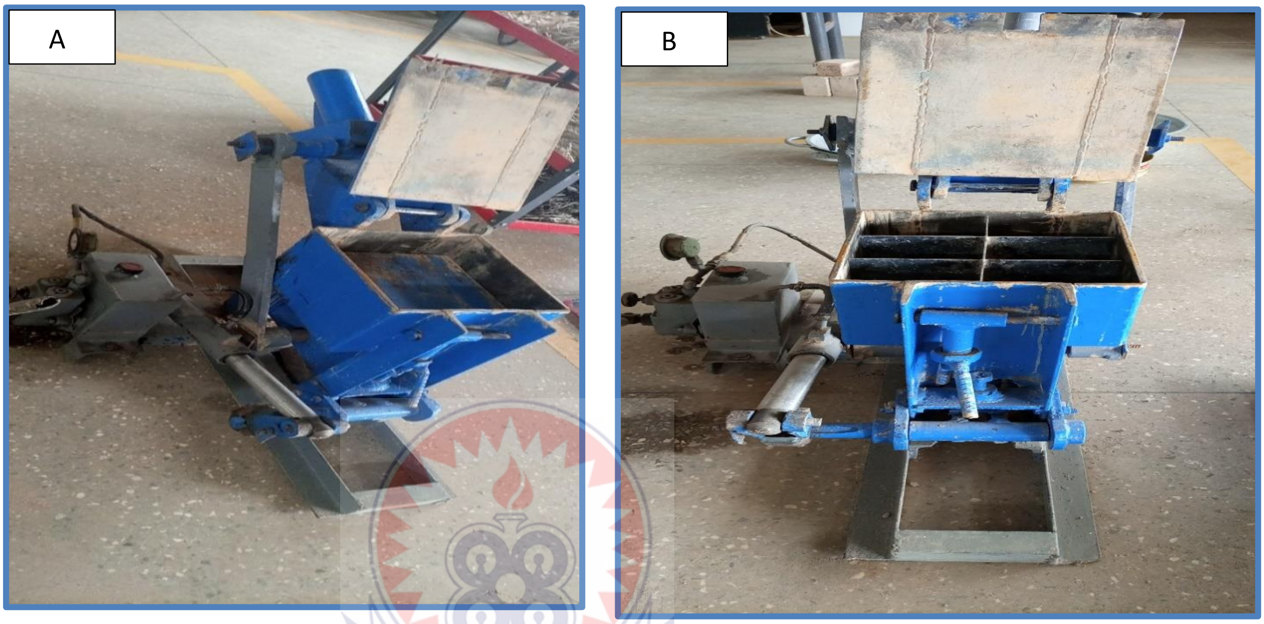

Figure 3.4: Hydraulic Compressed Block Moulding Machine.

Figure 3.5 Pouring of the Mixture onto the Mould and Tamping the Mixture in Three Layers Using Wooden Tamping Rod.

Figure 3.6 Storing of the Specimens on Wooden Pallets

3.3.6 Curing

To ensure sufficient hydration of the specimens and achieve the desired properties, curing of the specimens was done under wet jute sacks at the laboratory at an average temperature of 27 °C for 28 days shown in figure 3.7. The 28 days of cured specimens were used for the analyses of the density, water absorption and compressive strength because, it is known that, between 80% and 95% of the final and maximum strength of the cement specimens will be achieved in 28 days (Armah et al., 2020).

Figure 3.7 Soaking of the jute sacks and placing on the specimens.

3.4 Testing Procedures

After 28 curing days of the specimens of 0% up to 30% PPKS replacement content, the specimens were tested to determine the density, water absorption and compressive strength respectively.

3.4.1 Density

After 28 curing days, the specimen meant for the density test were first conditioned in ventilated oven shown in figure 3.8B at a constant temperature of 105°C for 24 hours in other to achieve a uniform mass of the specimens. The oven-dry weight and the volume of the specimens were then determined using electronic balance shown in figure 3.9 (B)

ASTM C138/C138M (2001) was used as a guide to determine the dry density of the specimens using the formula;

$$\text{Density}(D) = \frac{m}{v}\ (\text{kg/m}^3)$$

Where:

m = Mass of specimen in (kg).

v = Volume of specimen in (m^3).

Finally, the average dry density of the three replicates was recorded and the values were used for plotting a graph using Microsoft Office Professional Plus Excel (V 13).

3.4.2 Water absorption

After 28 curing days, the water absorption in percentage (%) of the specimens was determined using ASTM C140, (2003) as a guide. The specimen meant for the absorption test were first conditioned in ventilated oven shown in figure 3.8B at a constant temperature of 105°C for 24 hours in other to achieve a uniform mass of the specimens. The oven-dry weight of the specimens was then determined using the electronic balance shown in figure 3.9 and recorded as *Wd* (oven-dry weight).

The specimens were then immersed in water as shown in figure 3.10 at an average temperature of 23.5°C for 30 minutes. The specimens were then removed from the water and allowed to drain for 5 minutes by placing them on a 9.5 mm wire mesh, the visible surface water was also removed with a damp cloth. The specimens were then weighed again to determine the masses of the specimens after saturation and recorded as *Ws* (saturated weight).

ASTM C140, (2003) was used as a guide to determine the water absorption in (%) of the specimens using the formula;

Water Absorption (%) = $\frac{(Ws - Wd)}{(Wd)} \times 100.$

Where:

Ws = Saturated weight of specimen in (kg).

Wd = Oven-dry weight of specimen in (kg).

Finally, the average percentage of the three replicates for the water absorption test was recorded and the values were used for plotting a graph using Microsoft Office Professional Plus Excel (V 13).

Figure 3.8 Conditioning of the Specimens in a Ventilated Oven

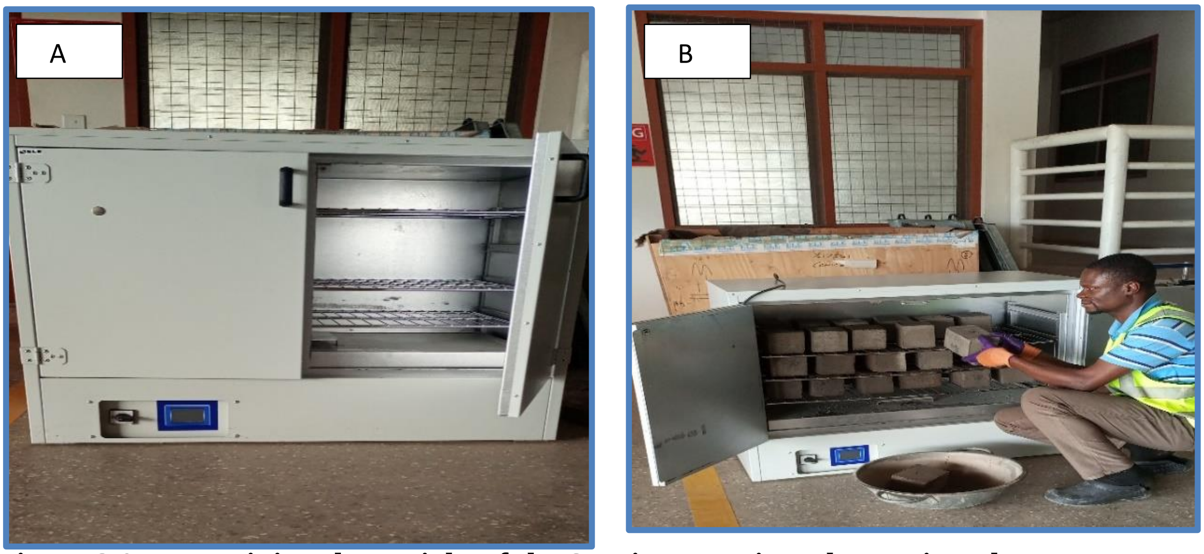

Figure 3.9 Determining the Weight of the Specimens Using Electronic Balance

Figure 3.10 Specimens immersed in the water tank.

3.4.3 Compressive Strength Test

After 28 curing days, a computerized servo-hydraulic universal testing machine, model tye-2000 shown in figure 3.11 (A) was used to crush the specimens following ASTM C140 (2003).

Before testing, the bearing surface of the testing machine was first wiped and the bed face of the specimens was cleaned to remove any loose grit. The specimen was carefully aligned with the centre of the ball seated platen of the testing machine to ensure uniform seating of the specimen. A metal plate of size 105mm by 105mm and a thickness of 2mm was then placed at the top of the specimen to ensure uniform distribution of applied load as shown. 0.05 $\text{N/mm}^2/s$ loading rate was then applied till the fracture of the specimen as shown in figure 3.11 (B). The compressive strength of the specimens was further determined using the formula;

Compressive Strength (MPa) = $\frac{Pmax}{A\,n}$

where:

Pmax = Maximum compressive load in (N).

An = Net area of specimen in (mm^2).

Finally, the average of the three replicate test values was recorded and a smooth graph was plotted using Microsoft Office Professional Plus Excel (V 13).

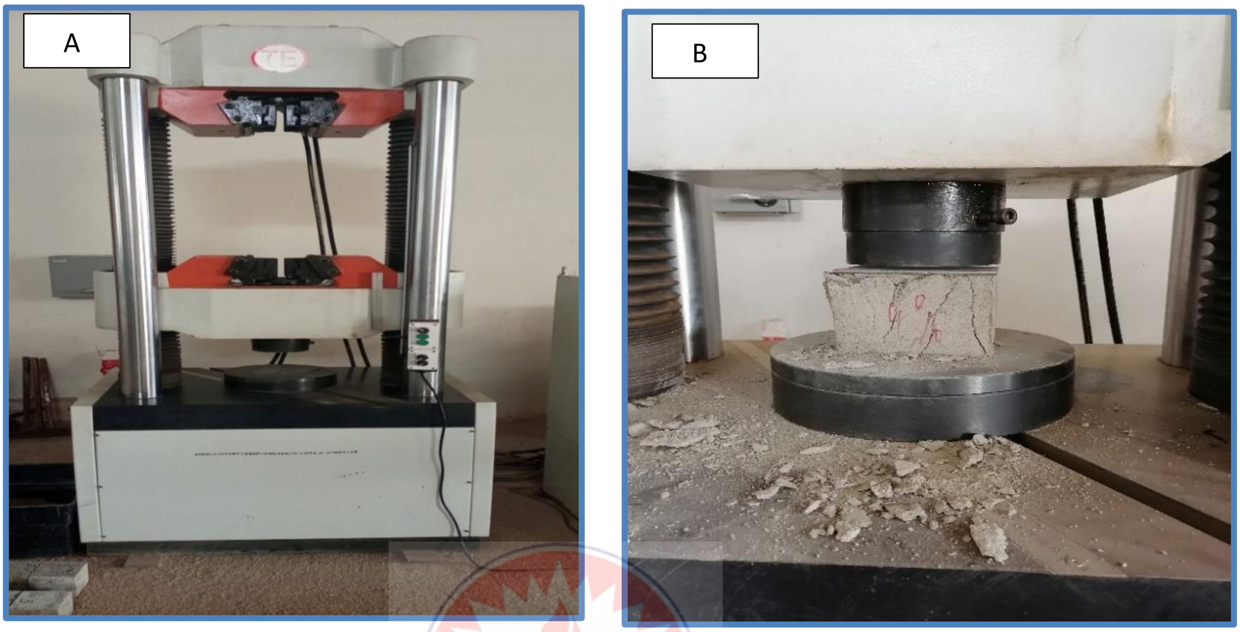

Figure 3.11 Crushing of the Specimens.

3.5 Data Analysis and Presentation

The data collected were analysed using SigmaPlot and Microsoft Excel. One-Way-ANOVA and all Pairwise Multiple Comparison Analyses between the specimens were done to determine whether there was any significant difference between the mean of the specimens. The data were presented using descriptive and inferential statistics.

CHAPTER FOUR

RESULTS

4.1 Introduction

This chapter presents the results of the particle size distribution of the PS and PPKS, results of the density test, results of the water absorption test, results of the compressive strength test and results of the One-Way-ANOVA analysis of the compressive strength.

4.2 Particle Size Distribution of PS and PPKS

The section presents the results obtained from the particle size distribution analysis of PP and pulverized PKS. Table 4.1 shows the results of particle size distribution and figure 4.1 also shows the particle size distribution curve for the PS.

Table 4.1 Particle Size Distribution Table of PS

Sieve Sizes (mm)	Weight Retained (kg)	Weight Retained (%)	Cumulative Weight Retained (%)	Weight Passing (kg)	Weight Passing (%)
5.00	0	0	0	0.815	100
2.36	0.063	7.730	7.730	0.752	92.270
1.18	0.042	5.153	12.883	0.710	82.117
0.60	0.374	45.890	58.773	0.336	41.227
0.30	0.262	32.147	90.920	0.074	9.080
0.15	0.053	6.503	97.423	0.021	2.577
Pan	0.021	2.577	100	0	0
Total	**0.815**	**100**	**∑F = 267.729**		

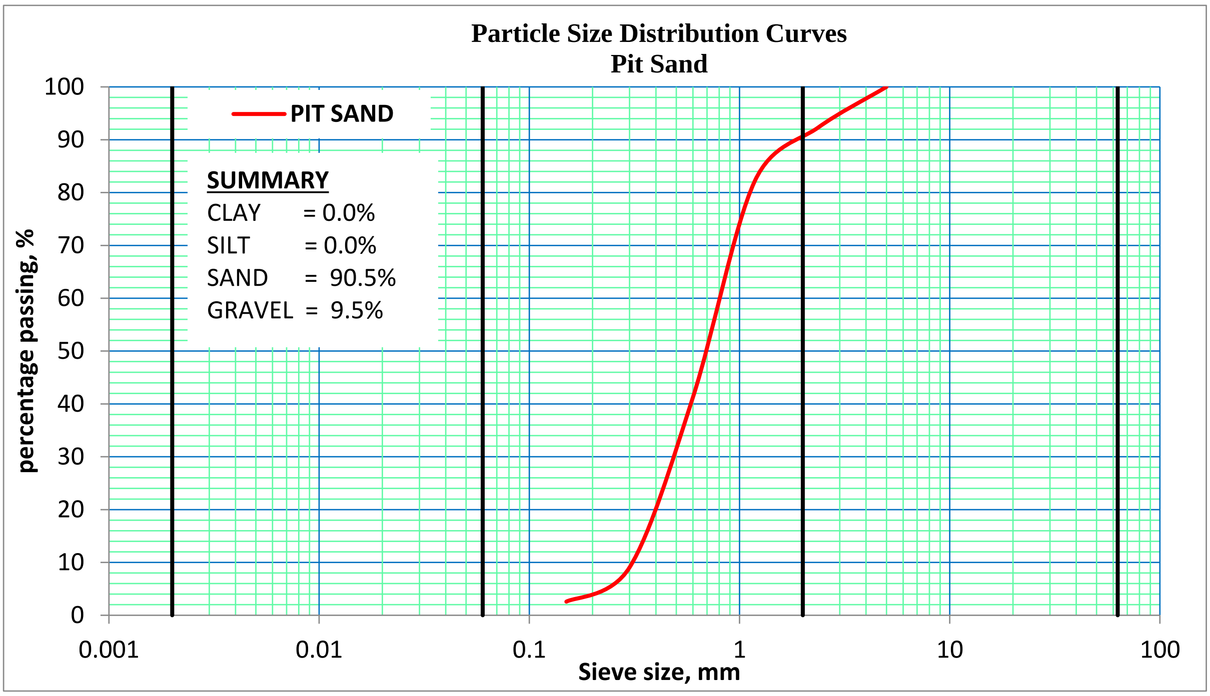

Figure 4.1 Particle Size Distribution Curve of PS

Table 4.2 shows the results of the particle size distribution Table and figure 4.2 shows the particle size distribution curve for the PPKS.

Table 4.2 Particle Size Distribution Table of PPKS

Sieve Sizes (mm)	Weight Retained (kg)	Weight Retained (%)	Cumulative Weight Retained (%)	Weight Passing (kg)	Weight Passing (%)
5.00	0	0	0	1.00	100
2.36	0.142	14.200	14.200	0.858	85.800
1.18	0.132	13.200	27.400	0.726	72.600
0.60	0.395	39.500	66.900	0.331	33.100
0.30	0.256	25.600	92.500	0.075	7.500
0.15	0.067	6.700	99.200	0.008	0.800
Pan	0.008	0.800	100	0	0
Total	**1.00**	**100**	**∑F = 300.2**		

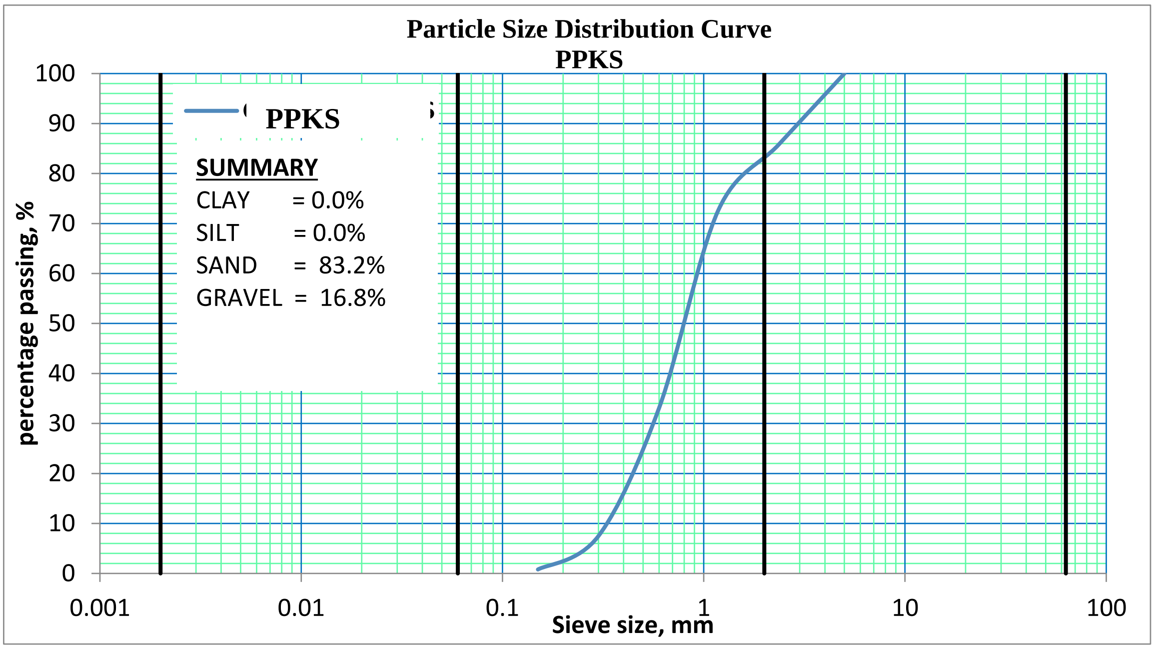

Figure 4.2 Particle Size Distribution Curve of PPKS

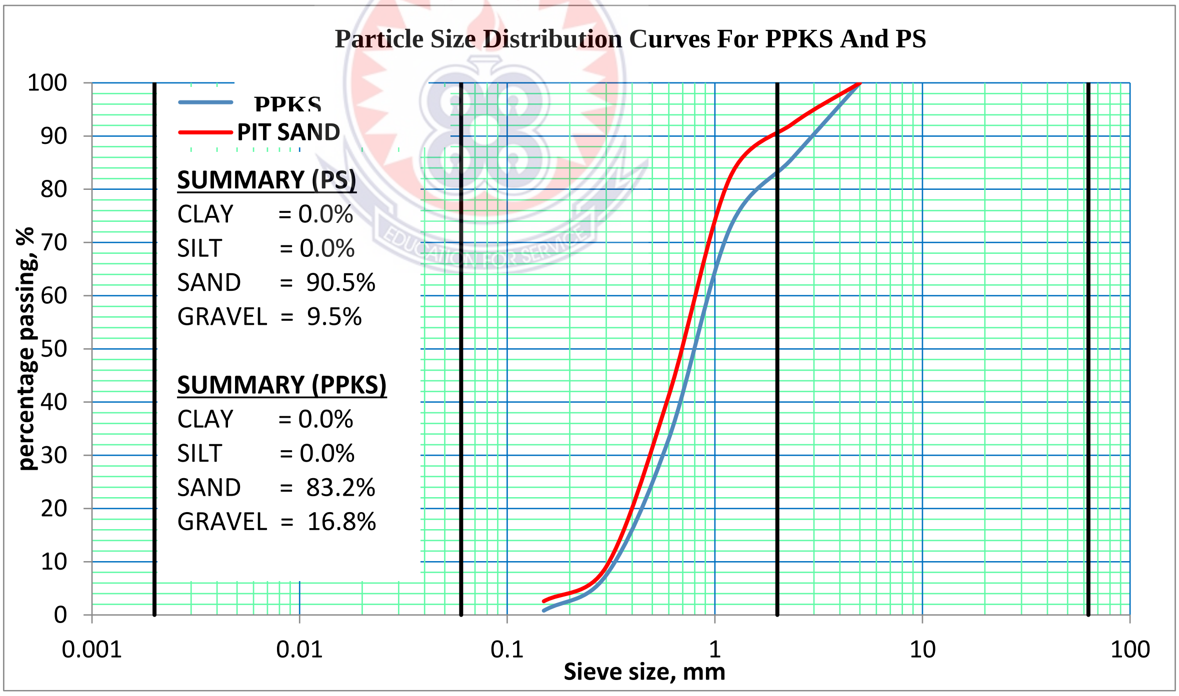

Figure 4.3 Particle Size Distribution Curve of PS and PPK

Table 4.3 Position of the Average Particle Size of PS and PPKS

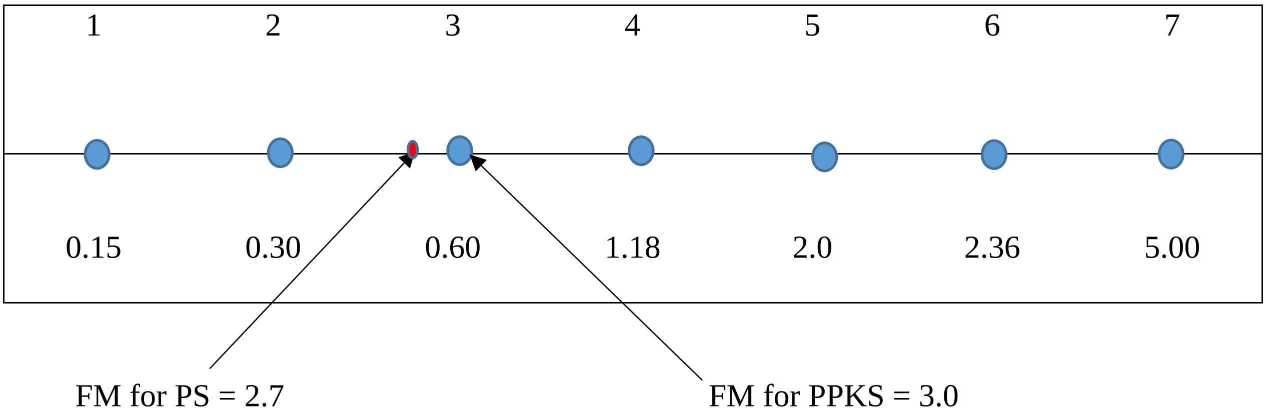

Table 4.4 Values for Fineness Modulus (FM) of Various Aggregate (ASTM C136, 2006)

	Aggregate Type	Fineness Modulus (FM)	
		Minimum	**Maximum**
1	Fine Aggregate	2.0	3.5
2	Coarse Aggregate 20mm	6.0	6.9
3	Coarse Aggregate 40mm	6.9	7.5
4	Coarse Aggregate 75mm	7.5	8.0

4.3 Results of Density Test

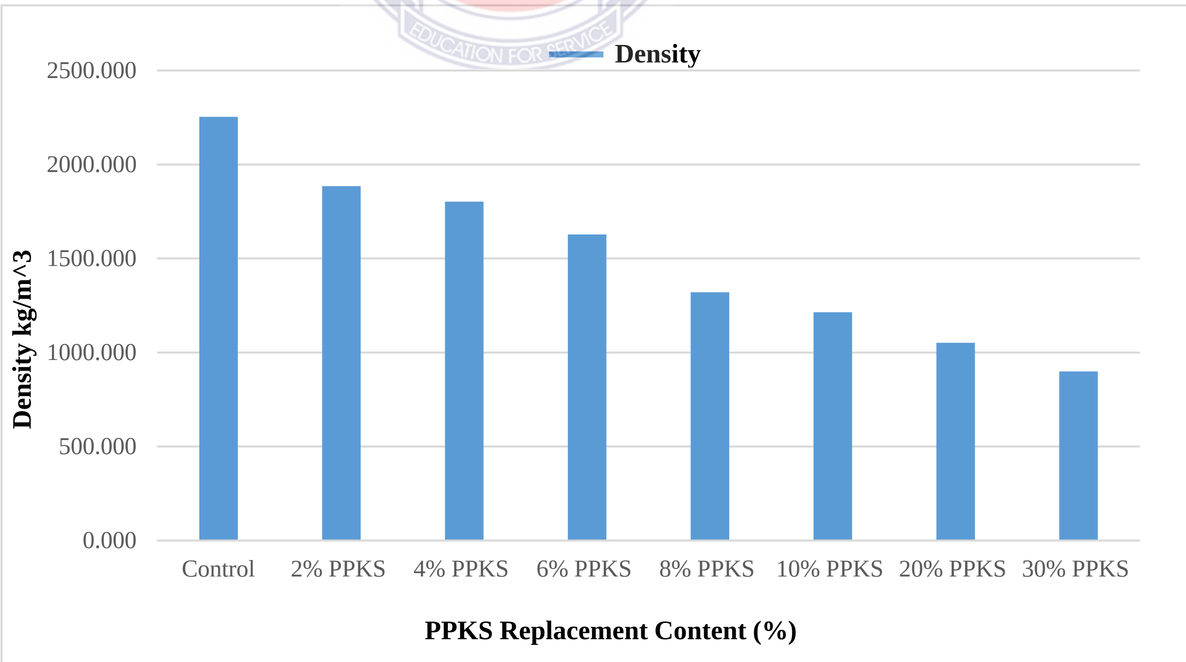

Figure 4.4 Dry Density of Specimens

4.4 Results of Water Absorption Test

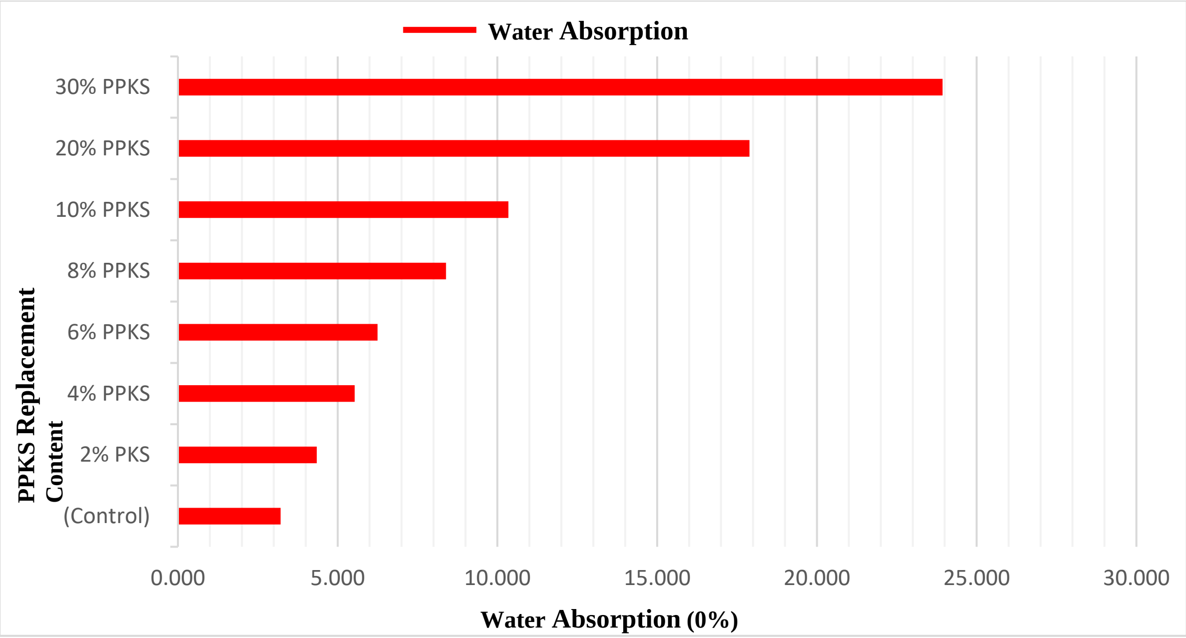

Figure 4.5 Water Absorption of Specimens

4.5 Results of Compressive Strength Test

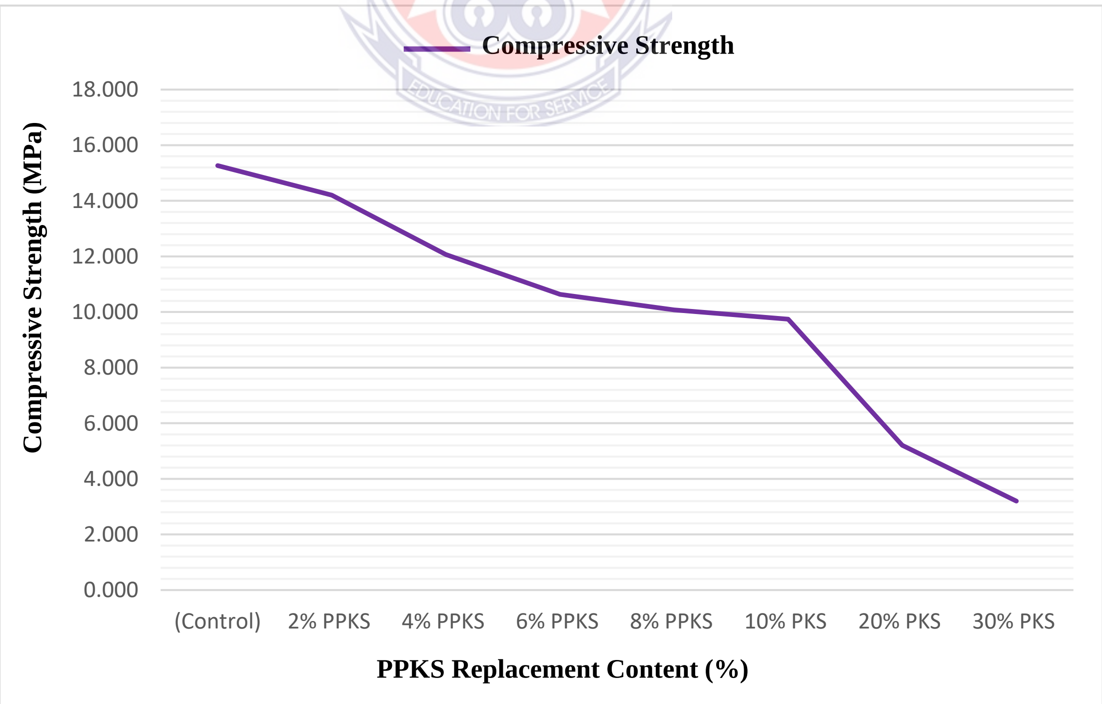

Figure 4.6 Compressive Strength of Specimens

4.6 Differences Between Compressive Strength and Water Absorption

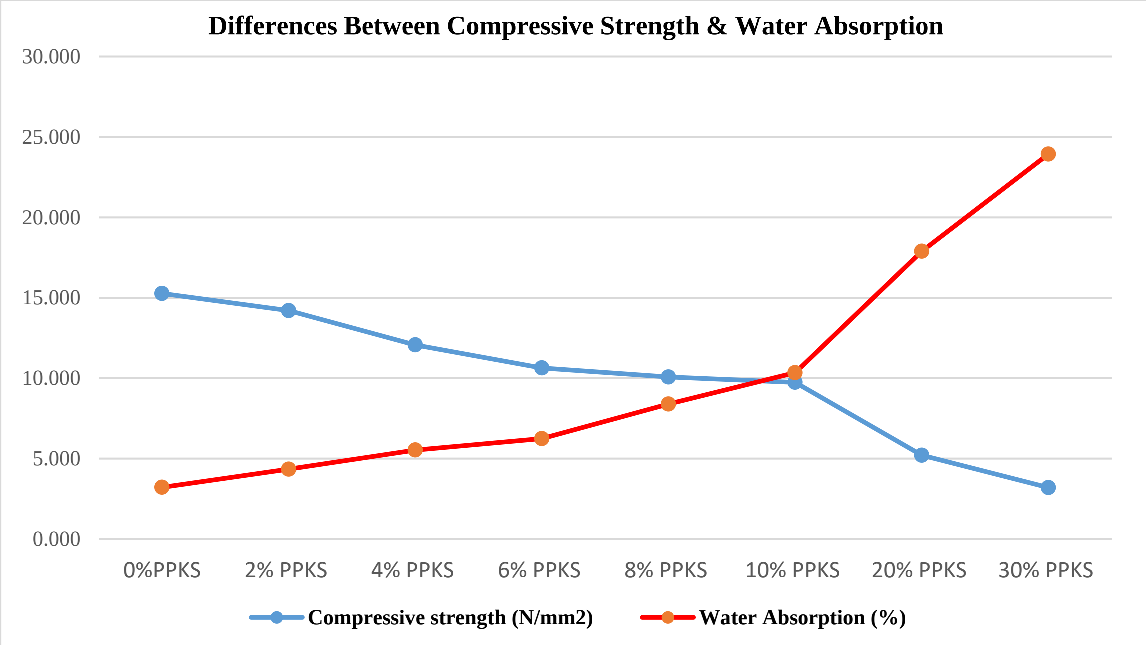

Figure 4.7 Compressive Strength vs Water Absorption

4.7 Differences Between Compressive Strength and Density

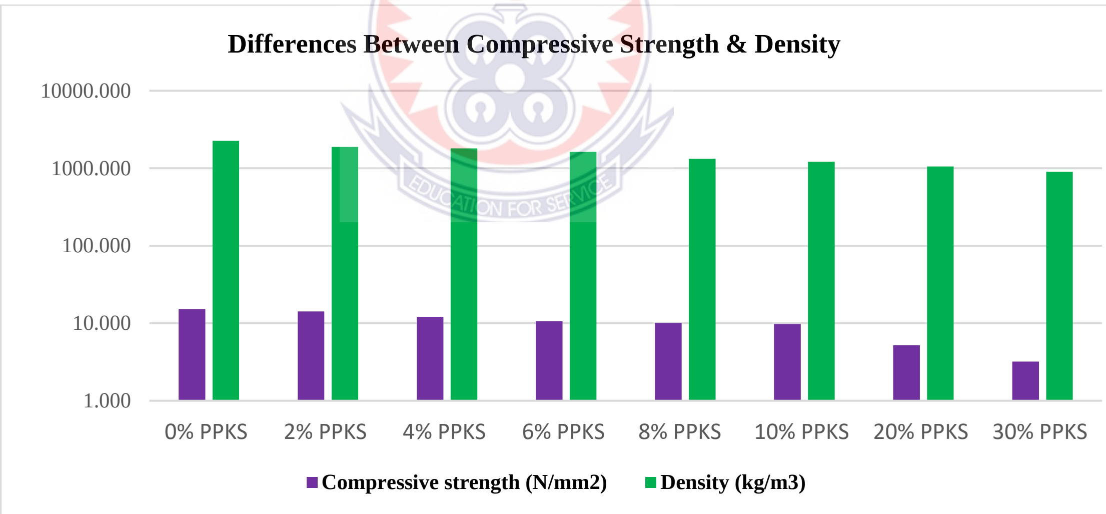

Figure 4.8 Compressive Strength vs Density

4.8 Differences Between Density and Water Absorption

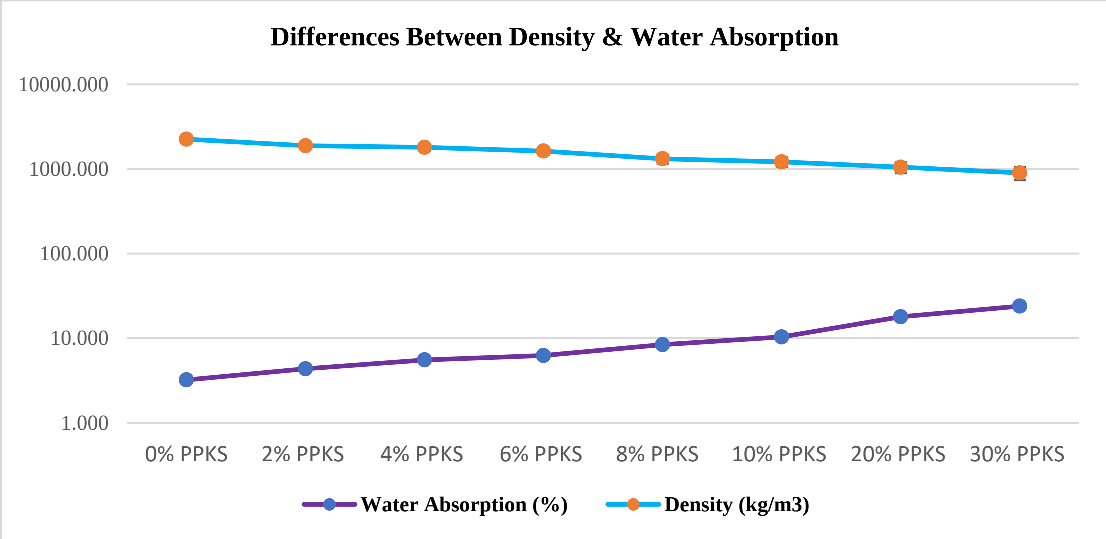

Figure 4.9 Density vs Water Absorption

4.9 Results of One-Way-ANOVA Analysis

Table 4.5 shows the results of the One-Way-ANOVA analysis of the compressive strength of the specimens at a significance level of 0.05.

Table 4.5 One-Way-ANOVA Analysis of the Compressive Strength.

Comparison	Diff of Means	T	P	P<0.05
Control vs. 30%	12.067	25.258	<0.001	Yes
2% vs. 30%	11.003	23.030	<0.001	Yes
Control vs. 20%	10.056	21.050	<0.001	Yes
2% vs. 20%	8.992	18.822	<0.001	Yes
4% vs. 30%	8.870	18.567	<0.001	Yes
6% vs. 30%	7.437	15.567	<0.001	Yes
8% vs. 30%	6.875	14.391	<0.001	Yes
4% vs. 20%	6.860	14.359	<0.001	Yes
10% vs. 30%	6.542	13.693	<0.001	Yes
Control vs. 10%	5.525	11.565	<0.001	Yes
6% vs. 20%	5.427	11.359	<0.001	Yes
Control vs. 8%	5.191	10.866	<0.001	Yes
8% vs. 20%	4.865	10.183	<0.001	Yes
Control vs. 6%	4.630	9.691	<0.001	Yes
10% vs. 20%	4.531	9.485	<0.001	Yes
2% vs. 10%	4.461	9.338	<0.001	Yes
2% vs. 8%	4.127	8.639	<0.001	Yes
2% vs. 6%	3.566	7.464	<0.001	Yes
Control vs. 4%	3.196	6.690	<0.001	Yes
4% vs. 10%	2.329	4.874	0.002	Yes
2% vs. 4%	2.132	4.463	0.004	Yes
20% vs. 30%	2.010	4.208	0.006	Yes
4% vs. 8%	1.995	4.176	0.006	Yes
4% vs. 6%	1.433	3.000	0.058	No
Control vs. 2%	1.064	2.227	0.220	No
6% vs. 10%	0.895	1.874	0.281	No
6% vs. 8%	0.562	1.176	0.590	No
8% vs. 10%	0.334	0.698	0.745	No

CHAPTER FIVE

DISCUSSION

5.1 Introduction

This chapter presents the discussions of the particle size distribution of the PS and PPKS, results of the density test, results of the water absorption test, results of the compressive strength test and results of the One-Way-ANOVA analysis of the compressive strength.

5.2 Discussions of Particles Size Distribution Test Results of PS and PPKS

The particle size distribution analysis results for PS shown in figure 4.1 revealed that the PS contain 0%, 0%, 90.05% and 9.5% respectively for clay, silt, sand and gravels. Whereas, figure 4.2 also revealed that the PPKS has 0%, 0 %, 83.2% and 16.8%% particle sizes similar to the sizes of clay, silt, sand and gravel respectively. Table 4.3 also revealed that the FM for PS was 2.7, whereas the FM for PPKS was 3.0 respectively. The results revealed that both materials used in the study met the fine aggregate grading requirement recommended by ASTM C136 (2006) shown in Table 4.4.

5.3 Discussions of Density Test Results

Figure 4.4 shows the results obtained from density test conducted on specimens of 0%, 2%, 4%, 6%, 8%, 10%, 20% and 30% PPKS replacement content after 28 curing days. It was revealed that the average density of the control specimen was 2253.167 kg/m^3. The figure shows that, replacing the sand content with 2%, 4%, 6%, 8%, 10%, 20% and

30% PPKS decreased the density of the specimens from 84%, 80%, 72%, 59%, 53%, 47% up to 40% respectively lower than the control specimen.

A decrease in density of the PPKS specimens could have been influenced by the density of the PPKS as aggregate. The density of material measures how many particles of material are squeezed into a given space. However, the more closely packed the particles, the higher the density of the material (Muntohar and Rahman, 2014). The PPKS was found to have smooth surfaces when compared to that of the pit sand. This caused the PPKS particles to have a low bond with the cement. This caused the particles of the PPKS specimens to disintegrate leaving micropores in the specimens, therefore resulting in low density for specimens of 2%, up to 30% PPKS specimens. The result of this study is consistent with Dadzie and Yankah's (2015) study which obtained similar results for palm kernel shells as a partial replacement for sand in sandcrete block production. It was revealed again that the density for specimens of 2% and 4% PPKS replacement content was 1885.095 kg/m^3 and 1802.619 kg/m^3 respectively, which met the minimum density of 1680 kg/m^3 for lightweight non-load bearing masonry units recommended by ASTM C 90-b (2011); ASTM C 129 (2003).

5.4 Discussions of Water Absorption Test Results

Figure 4.5 shows the results obtained from water absorption test conducted on specimens of 0%, 2%, 4%, 6%, 8%, 10%, 20% and 30% PPKS replacement content after 28 curing days. The study revealed that the average water absorption of the control specimen was 3.212%. Figure 4.5 shows that, replacing the sand content with 2%, 4%, 6%, 8%, 10%, 20% and 30% PPKS content increased the water absorption from 1.133%, 2.318%, 3.034%, 5.179%, 7.132%, 14.672% up to 20.722% respectively higher than the control specimen. However, increasing in water absorption of the specimens of 2%, up to 30% PPKS specimens could be a possible indication of the presence of micropores in the specimens. Studies have shown that the presence of more micropores in a material results in higher water absorption. The result of this study is consistent with the Dadzie and Yankah (2015) study, which obtained a similar result for palm kernel shells as a partial replacement for sand in sandcrete block production. The study revealed again that the water absorption for specimens of 2%, 4%, 6%, 8% and 10% was 4.345%, 5.530%, 6.246%, 8.391% and 10.344% respectively lower than the maximum water absorption of 12% for masonry units recommended by ASTM C55 (2011).

5.5 Discussions of Compressive Strength Test Results

Figure 4.6 shows the results obtained from the compressive strength test conducted on specimens of 0%, 2%, 4%, 6%, 8%, 10%, 20% and 30% PPKS replacement content after 28 curing days. The study revealed that the average compressive strength of the control specimen was 15.267MPa. The figure shows that the compressive strength of specimens of 2%, 4%, 6%, 8%, 10%, 20% and 30% PPKS replacement content decreased from 93.019%, 80%, 70%, 65.983%, 63.802%, 34.121% up to 20.957% respectively lower than the control specimen. It was revealed from the study that increasing the PPKS content in the mixes led to a reduction in the workability of the mixes. This influenced the compacting of the mixes and resulted in a decrease in the compressive strength of the PPKS specimens when compared to the control spacemen. The result of this study is consistent with the study of Dadzie and Yankah (2015), which obtained similar results for palm kernel shells as a partial replacement for sand in sandcrete. The study revealed again that the compressive strength for specimens of 2%, 4%, 6%, 8%, 10% and 20% was 14.203MPa, 12.070MPa, 10.637MPa, 10.075MPa, 9.742MPa and 5.210MPa respectively, which met the minimum compressive strength 4.14MPa for non-load bearing masonry units recommended by ASTM C129 (2003).

5.6 Discussions of The Differences Between Compressive Strength, Water Absorption and Density Test Results

Figures 4.7, 4.8 and 4.9 respectively show the differences between compressive strength and water absorption, the differences between compressive strength and density, and the differences between density and water absorption. Figure 4.7 revealed that the compressive strength of the specimens decreased as water absorption increased. Figure 4.8 also revealed that the compressive strength of the specimens decreased as density decreased and figure 4.9 revealed that the water absorption of the specimens increased as density also decreased.

5.7 Discussions of One-Way-ANOVA Analysis Test Results

Table 4.5 show a One-Way-ANOVA analysis of the compressive strength at a significant level of $p < 0.05$. it was revealed that there is a statistically significant difference between the control group and specimens of 2%, 4%, 6%, 8%, 10%, 20% and 30% PPKS specimens at $p < 0.001$. The PPKS content significantly and negatively influenced the compressive strength of the specimens from 4% up to 30%. Because of that, there is enough evidence that the comparisons between 4% up to 30% specimens and the control specimen revealed that where the control specimen can be used for construction applications, specimens of 4% up to 30% can equally not be used. The comparisons between specimens of control vs. 2%, 6% vs. 10%, 6% vs. 8% and 8% vs. 10% respectively show no statistically significant difference between the groups, which indicates both groups can equally be used for the same construction application.

CHAPTER SIX

SUMMARY AND CONCLUSION

6.1 Introduction

This chapter of the study comprises a summary of findings, conclusions, recommendations and suggestions for further studies.

6.2 Summary of Findings

The summary of findings is presented under the following objectives:

- To determine the particle size distribution of pit sand and pulverized palm kernel shells for sandcrete blocks production.
- To determine the density of sandcrete blocks manufactured with pulverized palm kernel shells as a partial replacement for sand.
- To determine the water absorption of sandcrete blocks manufactured with pulverized palm kernel shells as a partial replacement for sand.
- To examine the compressive strength of sandcrete blocks manufactured with pulverized palm kernel shells as a partial replacement for sand.

6.2.1 Particle Size Distribution of PS and PPKS

The main findings were as follows:

- The FM for Pit sand was 2.7 which lies very close to the 0.60mm sieve whereas the FM for PPKS was 3.0 which also lies exactly on the 0.60mm sieve.

- The FM for Pit sand and PPKS indicated that both materials used in the study met the fine aggregate grading requirement recommended by ASTM C136 (2006).

6.2.2 Density of Sandcrete Blocks Manufactured with Pulverized Palm Kernel Shells as a Partial Replacement for Sand.

The main findings were as follows:

- The average density for the control specimen was 2253.167 kg/m^3, replacing the sand content with 2%, 4%, 6%, 8%, 10%, 20% and 30% PPKS decreased the density of the PPKS specimens from 84%, 80%, 72%, 59%, 53%, 47% and 40% respectively below the control specimen.

- In general, the density of material measures how many particles of material are squeezed into a given space, the more closely packed the particles, the higher the density of the material. It was observed after 28 curing days that, specimens with high PPKS replacement content particles disintegrate, which shows that the higher the PPKS replacement content in the mixes the lower the bond between the cement, sand and the PPKS which create micropores in the PPKS specimens, therefore resulted in low density for specimens of 2%, up to 30% PPKS replacement content.

- The density of specimens of 2% and 4% PPKS replacement content was 1885.095 kg/m^3 and 1802.619 kg/m^3 respectively, which met the minimum density of 1680 kg/m^3 for lightweight non-load bearing masonry units recommended by ASTM C 90-b (2011); ASTM C 129 (2003).

6.2.3 Water Absorption of Sandcrete Blocks Manufactured with Pulverized Palm Kernel Shells as a Partial Replacement for Sand.

The main findings were as follows:

- The average water absorption of the control specimen was 3.212%. Replacing the sand content with 2%, 4%, 6%, 8%, 10%, 20% and 30% PPKS content increased the water absorption of the PPKS specimens from 1.133%, 2.318%, 3.034%, 5.179%, 7.132%, 14.672% and 20.722% respectively above the control specimen.

- The PPKS were found to have a smooth surface, however, increasing in water absorption of the specimens of 2%, 4%, 6%, 8%, 10%, 20% and 30% PPKS specimens could be a possible indication of the presence of micropore in the PPKS specimens.

- The water absorption for specimens of 2%, 4%, 6%, 8% and 10% was 4.345%, 5.530%, 6.246%, 8.391% and 10.344% respectively lower than the maximum water absorption 12% for masonry units recommended by ASTM C55 (2011).

6.2.3 Compressive Strength of Sandcrete Blocks Manufactured with Pulverized Palm Kernel Shells as Partial Replacement for Sand.

The main findings were as follows:

- The average compressive strength of the control specimen was 15.267Mpa, the compressive strength for specimens of 2%, 4%, 6%, 8%, 10%, 20% and 30% PPKS replacement content decreased from 93.019%, 80%, 70%, 65.983%, 63.802%, 34.121% and 20.957% respectively below the control specimen.

- The compressive strength of specimens of 2%, 4%, 6%, 8%, 10% and 20% PPKS replacement content was 14.203MPa, 12.070MPa, 10.637MPa, 10.075MPa, 9.742MPa and 5.210MPa respectively, which met the minimum compressive strength of 4.14MPa for non-load bearing masonry units recommended by ASTM C129 (2003).

- It was revealed from the study that increasing the PPKS content in the mixes led to reducing in the workability of the mixes. This influenced the compacting of the mixes and resulted in a decrease in the compressive strength of the PPKS specimens when compared to the control spacemen.

6.3 Conclusions

1. The density of specimens of 2% up to 4% PPKS content found in the study places the specimens as lightweight masonry units according to ASTM C 129 (2003).
2. The specimens with 2% up to 30% PPKS content were found to absorb more water than the control specimen.
3. The compressive strength of specimens of 2% up to 20% PPKS content found in the study places the specimens in non-load-bearing masonry units according to ASTM C 129 (2003).

6.4 Recommendation

1. For PPKS replacement in sandcrete blocks production for ideal situations, the PPKS content should be between 2% to 4%. Because the 2% up to 4% PPKS specimens met the minimum requirement for lightweight masonry units recommended by ASTM C 129 (2003).
2. PPKS blocks are strongly recommended not to be used in areas where high moisture penetration is expected.

3. Furthermore, PPKS blocks are strongly recommended for non-load bearing walls such as partition wall construction.

6.5 Suggestions for Further Studies

4. Pit sand from different geographical locations should be used to conduct a similar study to determine its possible use in the construction industry.

5. Factors that affect durability such as abrasion resistance should be investigated to determine the rate of influence on the PPKS blocks.

6. Water from different sources should be used to conduct a similar study to determine its possible use in the construction industry.

7. The water absorption capacity of the PKS should be investigated as raw aggregate.

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