COMPARATIVE STUDY ON THE COMPRESSIVE STRENGTH OF CONCRETE USING

PALM KERNEL SHELL AND COCONUT SHELL AS COARSE AGGREGATE

BY

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CERTIFICATION

This is to certify that this work was carried out by Ifebunso, Osborn Chidera, Mat. No. ENG2009628, of the Department of Civil Engineering, Faculty of Engineering, University of Benin, Edo State, Nigeria.

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DEDICATION

This work is dedicated to the Almighty God the giver of Life for his guidance throughout my sojourn in school and also to my lovely parent Mr. and Mrs. Tony Ifebunso Esq for serving as a source of inspiration towards my academic pursuit.

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My profound gratitude goes to the Almighty God for his mercy and faithfullness in making this study a success.

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ABSTRACT

The high cost of concrete materials in building projects has been a concern in Nigeria. This project was carried out to investigate and compare the use of Palm kernel shell and Coconut shell in replacement of coarse aggregate in 1:1:2 concrete mix design and 0.5 water/cement ratio. It aimed at determining the maximum partial replacement of by Palm kernel shell and Coconut shell in concrete and comparing their compressive strength and other relavant mechanical properties.

A total of 143 cubes of size 100mm × 100mm × 100mm were casted, the test conducted include: Sieve analysis test, Workability (Slump) test, Density test, Compressive strength test and Water absorbion test.

From Sieve analysis result obtained, the values obtained shows that the PKS is poorly graded and will contain lot of voids while the CS contain smaller void. From the slump test results, true slump was obtained for both PKS and CS as coarse aggregate replacement as the slump values were within 7-42mm which is medium workability range, although the CS concrete had higher slump compared to PKS. Both Palm kernel shell and Coconut shell concrete had density greater than 2000kg/m^3 for light weight concrete, the results shows that PKS concrete has lesser density compared to CS concrete, meaning it offers better sound insulation and fire resistance. The results shows that for PKS concrete the maximum compressive strength obtained and is useful was 21.93N/mm^2 (25% replacement) but with poor workability , moreover the useful maximum compressive strength for CS concrete was 20N/mm^2 (40% replacement) but with poor workability. The results also showed that the useful maximum compressive strength of PKS concrete and CS concrete with good workability was 28.63N/mm^2 (5% replacement) and 29.48N/mm^2 (5% replacement) respectively. CS as coarse aggregate had an appreciable strength compared to PKS as a coarse aggregate in concrete, considering strength/economic ratio, Coconut shell is recommended to be used as a partial replacement of coarse aggregate in making light weight concrete. The cost benefit analysis showed that 40% replacement with Coconut ahell in 1m^3 of concrete there is a savings of #3,120 and at 35 replacement with In 1m^3 of concrete there is a savings of #4,452.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

PKS - Palm Kernel Shell.

CS - Coconut Shell.

LWC - Lightweight Concrete.

LWAC - Lightweight Aggregate Concrete.

ACV - Aggregate Crushing Value.

AIV - Aggregate Impact Value.

PKSC - Palm Kernel Shell Concrete

PKSA - Palm Kernel Shell Aggregate.

CSA - Coconut Shell Aggregate.

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Concrete is a composite material mainly made up of cement, aggregates, and water. It is one of the most commonly used construction materials in civil engineering works around the world because of its excellent resistance to water and overall stability. Concrete production is not only an essential part of societal growth but also a major source of employment opportunities (Naik, 2008).

The production of concrete depends on the availability of cement, sand, and coarse aggregates such as granite, the prices of which have risen significantly over the years. The high cost of these materials has encouraged the search for cheaper alternatives for building construction. Lightweight concrete (LWC) has proven beneficial in this regard, as it helps to reduce costs and is easily accessible in Nigeria. In addition, it offers several advantages over normal concrete, including better fire resistance, improved heat insulation, sound absorption, and higher damping capacity.

Lightweight aggregate concrete (LWAC) is not a recent development in concrete technology; it has been in use since ancient times. The continued good condition of some of these old structures serves as evidence of the durability and long-term performance of this material (Chandra & Bentsson, 2002).Palm Kernel Shells (PKS) and Coconut Shells (CS) are examples of agricultural materials that can be used as lightweight aggregates for the production of structural lightweight concrete, and they are commonly found in tropical regions, especially in Africa. Research has shown that PKS and CS-based lightweight concrete possesses good thermal properties suitable for low-cost housing (Harimi et al., 2007). The use of these agricultural wastes as lightweight aggregates in construction not only reduces material costs but also helps to minimize waste disposal problems in areas where such by-products are abundant yet underutilized.

1.2 Statement of the Problem

The rising cost of construction materials, largely due to the extensive use of aggregates in civil engineering works, has led to the search for alternative materials particularly locally sourced ones that are inexpensive or readily available to replace conventional materials currently used in concrete production. The incorporation of agricultural and industrial wastes as supplementary construction materials not only offers practical and economic benefits but also helps conserve natural resources and protect the environment.

The generation of Palm Kernel Shells (PKS) and Coconut Shells (CS) often results in environmental pollution and disposal challenges. Recent studies by Alengaram et al. (2011) and Mahmud (2008) have explored the potential use of Palm Kernel Shells as aggregate replacements in concrete. Typically, PKS are discarded as waste or used for minor applications such as filling potholes. Hence, there is a growing need to identify suitable alternative materials that can effectively replace coarse aggregates in the production of lightweight concrete.

1.3 Aim and Objectives

The aim of this project is to compare the compressive strength of concrete using Palm kernel shell and Coconut shell as coarse aggregate.

The objectives of this study are to;

1. Determine the compressive strength of concrete at different replacement level; 5%,10%, 15% ,20%., 25% and 30%.

2. Determine the optimum proportion of coarse aggregate that can be substituted for palm kernel shell and coconut shell while maintaining the strength.

3. Compare the compressive strength and other relevant mechanical properties of concrete with replaced palm kernel shell and coconut shell.

1.4 Scope of the Study

In this research, a series of tests will be conducted to evaluate the properties of concrete in which Palm Kernel Shells (PKS) and Coconut Shells (CS) are used as partial replacements for coarse aggregates. These tests will include determining their crushing resistance, maximum replacement level, density, water absorption capacity, and optimum workability at varying replacement percentages. The compressive strength of the modified concrete will also be assessed using 100 × 100 × 100 mm cube specimens with a mix ratio of 1:1:2.

1.5 Justification of the Study

The outcome of this research will provide valuable insights into the comparative strength of concrete produced with different proportions of Palm Kernel Shell and Coconut Shell as aggregate replacements. The use of low-cost construction materials that maintain acceptable performance levels is essential for developing nations (Zemke & Woods, 2009).

The adoption of these alternative materials will:

1. Significantly reduce construction costs in Nigeria.
2. Contribute to national poverty reduction efforts.
3. Ensure the use of affordable and locally available resources.

CHAPTER TWO

LITERATURE REVIEW

Concrete is the most widely used construction material globally. However, the increasing cost of its key constituents, particularly coarse aggregates, has encouraged the search for alternative materials. The growing demand for concrete that relies on natural aggregates such as gravel and sand has led to the depletion of these natural resources, resulting in significant environmental degradation (Vishwa & Sanjay, 2015). Consequently, there is an urgent need to explore sustainable and renewable material options.

The agricultural and industrial sectors have contributed to the generation of large quantities of by-products and waste materials of various types. Some agricultural residues, including palm kernel shells, coconut shells, rice husks, and periwinkle shells, have shown potential as substitutes for conventional construction materials.

In many cases, these local materials are discarded and left to accumulate in the environment, leading to pollution. However, they can be utilized as lightweight aggregates (LWA) in the production of lightweight concrete. This type of concrete offers the advantage of reducing the self-weight of structures compared to conventional concrete, which is heavier. The use of such waste materials also helps to minimize the depletion of non-renewable resources (Milutiene et al., 2012).

Among agricultural wastes that have demonstrated potential in concrete production are Palm Kernel Shells (PKS) and Coconut Shells (CS). Research over the past four decades has shown that PKS and CS can serve effectively as lightweight aggregates (LWA) to replace traditional coarse aggregates in building construction.

2.1 Concrete

Concrete is a composite material composed primarily of cement, aggregates, and water (Naik, 2008). The aggregates typically consist of crushed stones or granite as coarse aggregates, and sand as the fine aggregate. The properties of concrete depend largely on the types and proportions of aggregates and cement used, as well as the production method.

Ordinary Portland cement, which serves as the primary binder, holds the aggregates together. Mortar, another binding material, is used to join masonry units such as bricks and blocks. Alternative binders like fly ash and slag cement are also used in various concrete formulations. Additionally, non-cementitious types of concrete, such as asphalt concrete (using bitumen as a binder) and polymer concrete (using polymers as a binder), are applied in specialized construction works, such as road pavements and industrial floors.

Concrete is known for its relatively high compressive strength but comparatively low tensile strength. To overcome this limitation, it is often reinforced with materials possessing high tensile strength, such as steel (Sinha & Roy, 2007). The failure of concrete under low tensile stress is often due to the propagation of microcracks that develop during cement hydration as a result of heat generation (Hashem et al., 2002). Today, concrete remains indispensable in the construction of architectural structures, foundations, dams, pavements, and reservoirs.

2.2 Portland Cement

Portland cement is a material with both adhesive and cohesive properties, enabling it to bind separate fragments into a compact mass. It is a carefully formulated and chemically processed mixture of lime, silica, alumina, and iron oxide. The ability of cement to hold aggregates together is activated by water or other low-viscosity fluids (Sinha & Ray, 2007).

Cement possesses the unique characteristic of setting and hardening under water as a result of a chemical reaction with it. Historically, the Egyptians and early Romans utilized various cementing materials in their constructions. The Egyptians employed burnt gypsum as a cementing substance, while the early Romans used materials obtained by burning limestone. The notable durability of ancient Roman mortars is strong evidence of their advanced knowledge in preparing cementitious materials.

Later, the Greeks and Romans produced cementing materials by combining volcanic ash or tuff with limestone, sand, and water. This mixture was termed *Pozzolana*, derived from the region near Pozzuoli in Italy, where the volcanic ash was found. Eventually, any material, whether natural or artificial, exhibiting similar properties to that volcanic ash was referred to as *Pozzolana*.

In 1756, John Smeaton conducted extensive experiments to identify a material capable of withstanding the effects of seawater. Based on his findings, he concluded that limestone containing a significant proportion of clay yielded lime with superior hydraulic properties. This hydraulic cement later became known as *Portland cement* because its hardened form resembled the color and quality of Portland stone. The various classifications, properties, and standards governing Portland cement are specified in ASTM C150-2005 and BS EN 197-1:2011.

2.3 Aggregate

Aggregates are granular materials such as sand, gravel, or crushed stones that resist compressive forces in concrete. They typically constitute between 60% and 80% of the total concrete volume and can be classified as either coarse or fine. Aggregates are essential components of concrete, and their size, shape, and grading significantly affect the water requirement and workability of the mix.

For an ideal concrete mix, aggregates must be clean, strong, and durable, free from impurities, chemicals, or clay coatings that may hinder hydration or weaken the concrete. In most cases, aggregates are washed to remove unwanted materials that can negatively impact quality. The surface texture of the aggregate also affects the bond between the aggregate and the cement paste.

The type and source of aggregates play a crucial role in determining the compressive strength of concrete. The elastic characteristics of the aggregates influence the overall elasticity and shrinkage resistance of the hardened concrete (Sinha & Roy, 2007). Additionally, factors such as the maximum aggregate size, grading, particle shape, and surface roughness have indirect effects on the concrete's compressive strength.

2.4 Water

Water (chemical formula: H_2O) is a clear liquid that forms the basis of Earth's streams, lakes, and oceans, and it is a major component of all living organisms. It exists naturally in three states: liquid (water), solid (ice), and gas (steam or vapor). The water used for concrete mixing and curing must be clean and free from harmful substances such as oils, acids, alkalis, salts, sugars, and organic matter, as these can affect the quality and durability of the concrete.

The strength and overall quality of concrete are determined by the properties of its ingredients and the proportion of the mix (Sinha & Roy, 2007). The water-to-cement ratio is especially critical—lower water content typically leads to higher concrete strength, provided that the mixture remains workable. Excessive water dilutes the cement paste, creating a porous and weaker structure.

2.5 Palm Kernel Shell (PKS)

Palm Kernel Shell (PKS) is a by-product of the palm oil extraction process. It is produced in large quantities in regions where oil palm is processed. The oil palm tree (*Elaeis guineensis*), native to West Africa, is one of the most economically valuable tropical trees.

The palm oil industry generates waste products such as palm kernel shells and palm fibers, which are often discarded, contributing to environmental pollution without any economic benefit. PKS is a hard, organic, and carbonaceous material obtained after extracting the palm kernel. It consists of particles of varying sizes—small (0–5 mm), medium (5–10 mm), and large (10–15 mm) (Alengaram et al., 2010).

In Nigeria, oil palm cultivation is prevalent in rainforest regions, particularly near the coastal areas. Palm kernel shells are sometimes used as fuel for local cooking or as filler materials in construction works. However, they have limited commercial use and often pose disposal and waste management challenges. In some areas, PKS is used by local blacksmiths as fuel and for filling potholes, but in most cases, it is simply discarded as industrial waste. This improper disposal poses environmental hazards, underscoring the importance of finding alternative and sustainable ways to utilize palm kernel shells (Ndoka, 2006).

2.6 Palm Kernel Shell As An Alternative Coarse Aggregate

The high cost of conventional aggregates used in concrete has driven efforts to identify more sustainable and affordable alternatives in the construction industry. It is widely believed that Africa is rich in natural resources that can serve as substitutes for industrial materials; however, these resources remain underutilized in construction (Ramachandran, 1983). Palm Kernel Shell (PKS), a by-product of palm oil production, has been explored as a potential replacement for traditional coarse aggregates. Its application in concrete production can help reduce environmental waste, minimize construction costs, and support sustainable building practices.

PKS is a hard, woody by-product derived after palm oil extraction, with a bulk density of about 500–700 kg/m^3—significantly lower than that of conventional aggregates such as granite (1,500–1,700 kg/m^3) (Olanipekun et al., 2006). Its irregular surface texture and high crushing resistance improve bonding with cement paste, although they may slightly reduce workability. PKS can either partially or completely replace natural coarse aggregates such as gravel or granite to produce lightweight concrete with adequate compressive strength for non-load-bearing structures (Mannan & Ganapathy, 2004).

This substitution not only aids in managing agricultural waste and promoting recycling but also improves thermal and acoustic insulation properties, reduces the dead load of structures—especially advantageous for high-rise buildings—and remains cost-effective. Nevertheless, further studies are still required to assess its durability in harsh environmental conditions. PKS represents an eco-friendly and sustainable alternative in modern concrete production. The development of oil palm shell lightweight concrete introduces new possibilities for producing strong yet lighter structures. Continued research is necessary to refine mix proportions and enhance its potential for wider structural applications.

2.7 Coconut Shell (CS)

Coconut shells (CS) are hard, fibrous, and brown materials obtained as agricultural waste after the extraction of coconut meat. They represent one of the most common agricultural residues in tropical regions. The leading producers—Indonesia, the Philippines, and India—account for approximately 87.14% of global coconut production (World Atlas, 2016). Although coconut is cultivated in over 93 countries, India ranks third, with about 1.78 million hectares devoted to coconut farming. The country's coconut industry contributes over one-quarter of global coconut oil output and continues to expand with rising global demand.

However, the disposal of coconut shells poses a major solid waste challenge. In many regions, shells are discarded after the fruit is processed, contributing to environmental pollution. Although they have limited traditional uses, a large proportion still remains unutilized. Given their strength and hardness, coconut shells possess characteristics suitable for replacing coarse aggregates in concrete. Utilizing coconut shells in the construction industry, particularly for producing masonry blocks, provides a dual benefit—reducing construction costs and promoting waste recycling.

There is also a growing interest in developing lightweight and cost-effective materials for construction applications. Lightweight concrete has become popular because of its reduced density and ease of handling. By using crushed coconut shells, lightweight concrete can be produced due to the lower density of the shells compared to traditional coarse aggregates.

2.8 Coconut Shell as an Alternative Coarse Aggregate

Concrete production consumes large quantities of natural resources. To ensure resource availability for future generations, the construction industry must adopt sustainable engineering practices that emphasize the conservation of non-renewable resources and energy efficiency. Modern technologies are increasingly focused on integrating recycled industrial, domestic, and agricultural wastes as substitutes for cement or aggregates in concrete production.

One sustainable approach involves the use of solid waste by-products as construction materials. This method is especially useful for producing lightweight concrete suitable for non-load-bearing structures. Coconut shell (CS) is one such material—it is compatible with cement and requires no special treatment before use as coarse aggregate. The smoother inner surface of the shell improves the workability of concrete, while its natural toughness provides good impact resistance and high sound insulation. Compared to conventional aggregates, CS has a higher water absorption and moisture retention capacity. Moreover, the sugar content within the shell does not interfere with the cement hydration process or the strength development of concrete.

Concrete made with coconut shell aggregates meets the basic strength and performance requirements for structural applications. Such concrete demonstrates adequate compressive strength and other desirable properties, making CS a viable alternative coarse aggregate. Its utilization also provides an effective solution to agricultural and environmental waste management issues, contributing to sustainable construction practices.

2.9 Review of Similar Previous Studies

Ibrahim et al. (2024) examined the use of Palm Kernel Shell (PKS) as a partial substitute for coarse aggregates in the production of pedestrian interlocking bricks. The study evaluated key properties of PKS concrete, including compressive strength, moisture resistance, and slump behavior. Results indicated that the average compressive strength of conventional aggregate concrete for samples A, B, and C was 14.7 N/mm² at 7 days, 16.5 N/mm² at 14 days, and 13.6 N/mm² at 28 days. In comparison, concrete incorporating PKS recorded compressive strengths of 9.8 N/mm², 10.3 N/mm², and 9.6 N/mm² at 7, 14, and 28 days respectively. Additionally, the average moisture resistance for PKS-based concrete samples was found to be 14.8%.

Krishkumar et al. (2019) explored the application of coconut shells as a replacement for granite in M20 grade concrete. Concrete cubes of 150 × 150 × 150 mm were cast with varying replacement levels of 25%, 50%, 75%, and 100%, and tested for workability and compressive strength at 7, 14, and 28 days. The 28-day compressive strength results were 19.71, 19.53, 19.08, and 18.91 N/mm² respectively for the four replacement levels. Their findings confirmed that the use of coconut shells is both eco-friendly and cost-effective.

Danso (2021) studied the impact of varying Palm Kernel Shell sizes as replacements for coarse aggregates in lightweight concrete. PKS sizes of 6 mm, 8 mm, 10 mm, and 12 mm, along with a mix containing 25% of each size, were used to replace conventional aggregates, and the specimens were cured for 7, 14, 21, and 28 days. All samples exhibited densities below 2000 kg/m³, meeting the classification for lightweight concrete suitable for structural purposes. The 12 mm PKS mix achieved the highest compressive strength of 10.2 MPa after 28 days, which was 4–15.9% higher than the other sizes. Similarly, its flexural strength reached 2.85 MPa, surpassing other mixes by 3.2–57.07%.

Olamilekan et al. (2024) assessed the suitability of crushed coconut shells as coarse aggregates in concrete. Replacement levels of 0%, 50%, and 100% were tested with samples cured for 3, 7, and 28 days. Parameters evaluated included workability, compressive strength, split tensile strength, sieve analysis, specific gravity, and water absorption in comparison with control mixes. The outcomes indicated that coconut shells can serve effectively as lightweight aggregate substitutes, providing an environmentally sustainable option for concrete production.

Ogunjiofor et al. (2023) investigated the structural performance of concrete in which Palm Kernel Shells were used as partial replacements for coarse aggregates. Experimental tests—including compressive strength, slump, sieve analysis, and water absorption—were conducted on 48 cubes of 150 mm × 150 mm × 150 mm prepared in a 1:1:1.5 mix ratio. PKS replacements were applied at 0%, 10%, 20%, and 30%, and samples were cured for 7, 14, 21, and 28 days. Results revealed that a 10% PKS substitution yielded favorable strength characteristics without significantly compromising overall compressive performance.

Odeyemi et al. (2021) evaluated the effect of different curing methods on the compressive strength of PKS concrete. Concrete cubes with a mix ratio of 1:1:2 and a water-cement ratio of 0.55 were tested at curing ages of 7, 14, 21, and 28 days. The immersion curing method achieved the highest compressive strength (17.07 N/mm² at 28 days), followed by sprinkling (15.78 N/mm²), wet-curing (14.48 N/mm²), and open-air curing (13.11 N/mm²). The study concluded that immersion and sprinkling are the most effective methods for enhancing the strength of PKS concrete.

Janani et al. (2022) conducted a study on the use of coconut shells as coarse aggregates in lightweight concrete. The investigation revealed that coconut shells can effectively serve as an alternative to conventional natural aggregates. The substitution of coconut shell aggregate not only reduced the overall cost of construction but also conserved natural aggregate resources. Due to its lightweight property, the use of coconut shell aggregates helps decrease the dead load of buildings.

Owolabi and Faisal (2023) examined the influence of Palm Kernel Shells (PKS) on the mechanical properties of “Kernelrazzo” concrete floor finishes. Using a water-cement ratio of 0.5 and 19 mm granite, compressive strength values obtained at 28 days were 30.50 N/mm^2, 22.32 N/mm^2, 26.46 N/mm^2, 19.72 N/mm^2, 16.47 N/mm^2, and 12.96 N/mm^2 respectively. The flexural strength values for the concrete grades were 5.44 N/mm^2, 3.85 N/mm^2, 4.56 N/mm^2, 3.01 N/mm^2, and 2.46 N/mm^2.

Gaston et al. (2020) investigated the physico-mechanical properties of concrete incorporating palm kernel shells sourced from Haut Nkam, Cameroon. Replacement levels of 0%, 25%, 50%, 75%, and 100% of coarse aggregates were used to assess mechanical performance after 7 and 28 days. The study found that at 25% replacement, the compressive strength at 28 days matched that of the control mix (approximately 41 MPa). However, at 100% replacement, the strength dropped significantly to around 5.37 MPa. At 50% replacement, the concrete achieved a reduced density of approximately 2000 kg/m^3, qualifying it as lightweight concrete.

Foysal Ahmed (2024) studied the strength properties of concrete using coconut shell as a partial replacement for coarse aggregates. A total of 144 cubes (100 × 100 × 100 mm) were cast with a mix ratio of 1:2:4 and a water-cement ratio of 0.5. Replacement levels of 2%, 5%, 8%, 10%, 12%, 15%, and 20% of coarse aggregates were tested. The findings indicated a slight decrease in compressive strength with increasing replacement, with up to 8% substitution maintaining about 75% of the strength of conventional concrete.

Kumar et al. (2022) examined the performance of fiber-reinforced concrete using coconut shell aggregates. Their findings showed a high water absorption capacity of approximately 24%, though the crushing and impact values were comparable to other lightweight aggregates. The average density of fresh concrete was 1975 kg/m³, with a 28-day compressive strength of 19.1 N/mm². The study concluded that crushed coconut shells are suitable for replacing traditional aggregates in lightweight concrete production.

Kuman et al. (2017) explored the use of coconut shell ash as an aggregate replacement in M25 grade concrete with a mix ratio of 1:2:4 and water-cement ratio of 0.48. Coarse aggregates were replaced by 10%, 15%, and 20% coconut shells, while cement was partially replaced with 5% coconut shell ash. After 28 days, an optimum compressive strength of 21.7 MPa was achieved. The research suggested that coconut shell aggregates are more appropriate for producing low-strength lightweight concrete while also helping reduce material costs.

Apeksha and Sarvesh (2017) investigated the performance of concrete made with coconut shell as a coarse aggregate. A total of 138 M20-grade concrete cubes with a water-cement ratio of 0.55 were tested at replacement levels of 10%, 20%, 30%, and 40%. The results indicated a gradual decrease in compressive strength as the replacement percentage increased. At 40% replacement, the 7-day compressive strength reduced by 62.6%, and the 28-day strength decreased by 21.5% compared to conventional concrete. However, the replacement reduced the overall weight of the concrete by about 7.47%.

E.N. Jaskson et al. (2019) evaluated the compressive strength of concrete produced with varying proportions of coconut shell (CS) and palm kernel shell (PKS). Mixes included replacement levels of 20%, 40%, 60%, 80%, and 100% for each material, alongside a control mix. The results revealed that as replacement levels increased, workability decreased for both PKS and CS concretes. The compressive strength for CS concrete ranged from 7.88 MPa to 19.29 MPa, while PKS concrete ranged from 6.85 MPa to 13.29 MPa, indicating that CS concrete exhibited superior strength.

Azunna (2019) examined the compressive strength of concrete incorporating PKS as a partial replacement for coarse aggregates using a 1:2:4 mix ratio. Tests included sieve analysis, specific gravity, slump, water absorption, and compressive strength at curing ages of 7, 14, 21, and 28 days. The results showed normal water absorption compared to plain concrete, but compressive strengths of 4.78 N/mm^2 and 4.44 N/mm^2 at 10% and 25% replacement, respectively, were insufficient for lightweight structural use.

Oyedekpo et al. (2015) assessed the performance of coconut shell ash (CSA) and palm kernel shell ash (PKSA) as partial cement replacements in concrete. Using a 1:2:4 mix and water-cement ratio of 0.63, concrete cubes were cast at replacement levels of 10–50%. The 20% PKSA and CSA replacements achieved compressive strengths of 15.4 N/mm^2 and 17.26 N/mm^2, respectively, at 28 days, while 10% CSA replacement yielded the optimum value of 20.58 N/mm^2.

Kamil and Purnomo (2024) investigated the compressive strength of concrete with simultaneous replacement of conventional aggregates using palm kernel shells and coconut husks. Four mix variations were tested: A (1% coconut fiber, 5% PKS), B (2% coconut fiber, 5% PKS), C (1% coconut fiber, 10% PKS), and D (2% coconut fiber, 10% PKS).

Compressive strength tests at 7, 14, and 28 days revealed that mix A (1% coir and 5% PKS) produced the compressive strength most comparable to conventional concrete.

Yusuf et al. (2018) studied the flexural strength of PKS concrete for structural applications. Concrete cubes (150 × 150 × 150 mm) and prisms (100 × 100 × 500 mm) were cast using a 1:1:2 mix ratio and water-cement ratio of 0.5, and tested at 7, 14, 21, and 28 days. After 28 days, the PKS beam supported a load of 3981 N, with a deflection of 0.947 mm and flexural strength of 2.883 N/mm^2. Theoretical and experimental flexural values were found to be closely correlated.

Dhoble et al. (2021) examined the behavior of concrete containing coconut shells as partial coarse aggregate replacements at 0%, 5%, 10%, and 15%. Compressive strengths recorded were 25.48, 23.12, 24.66, and 20.7 N/mm^2 respectively. Replacements up to 10% were found to be effective in maintaining satisfactory strength and cost balance, though higher percentages reduced both strength and density. The use of coconut shell aggregates also contributed to approximately 15% reduction in environmental pollution.

Ezeanokwasa (2022) evaluated the partial replacement of coarse aggregates with PKS in concrete with a 1:2:4 mix and 0.5 water-cement ratio. Granite was replaced with PKS at 4%, 8%, 12%, 16%, and 20% levels. Tests carried out included sieve analysis, specific gravity, slump, water absorption, density, and compressive and flexural strength. The specific gravity values for granite, sand, and PKS were 2.69, 2.61, and 2.29 respectively, while water absorption values were 1.44% for granite and 17.07% for PKS. The density results showed that concrete made with granite had the highest density, while PKS-based mixes produced the lowest.

2.10 Research Gap

Despite numerous studies on concrete incorporating Palm Kernel Shell (PKS) and Coconut Shell (CS) as coarse aggregates, there remains a need for more comprehensive analysis of such materials. Most existing research has primarily emphasized the strength and long-term performance of PKS and CS concrete, overlooking other critical properties that influence their suitability for specialized applications.

This study, therefore, seeks to bridge these research gaps by:

1. Assessing the Fire Resistance of concrete made with Palm Kernel Shell and Coconut Shell to determine their ability to withstand elevated temperatures while maintaining structural stability.
2. Investigating the Sound Insulation Properties of Palm Kernel Shell and Coconut Shell concrete for potential use in acoustic-sensitive structures such as schools, hospitals, and offices.
3. Evaluating the Cost Efficiency and Environmental Impact of utilizing Palm Kernel Shell and Coconut Shell as coarse aggregate substitutes in concrete production.

CHAPTER THREE

METHODOLOGY

3.1 Flow Chart of Methodology

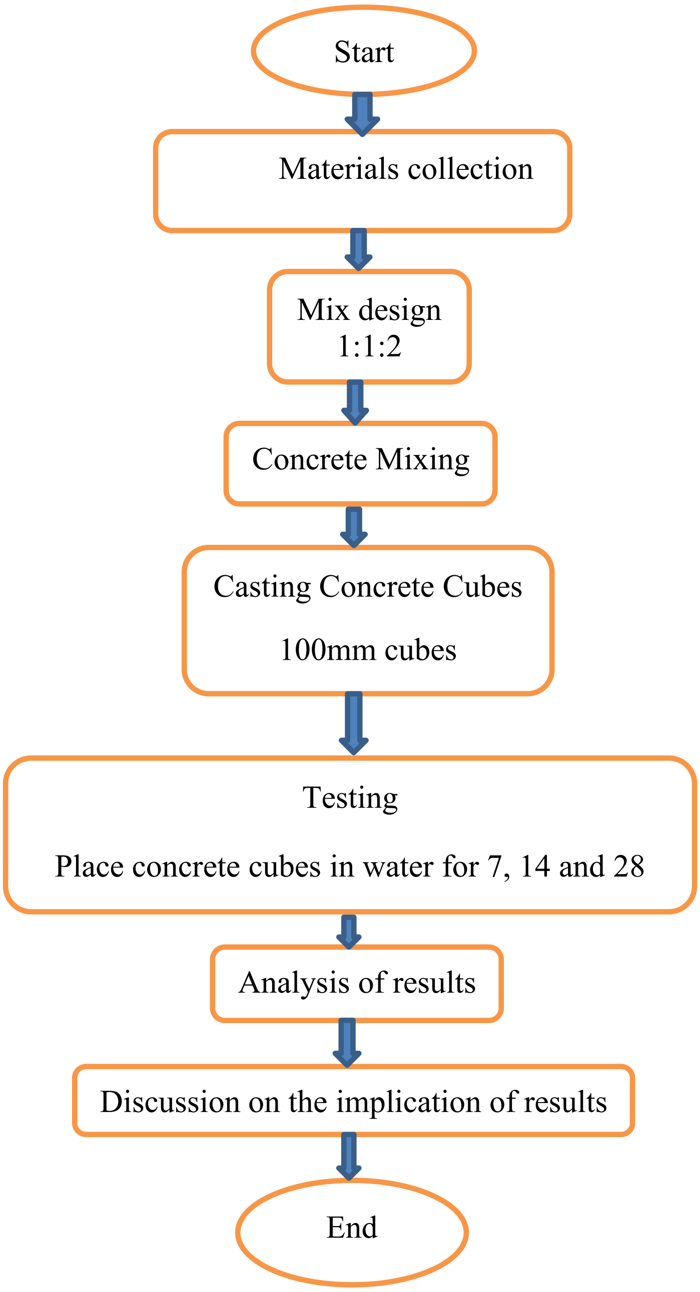


Figure 3.1 Flow chart on the methodology for compressive strength of concrete using Palm kernel shell and coconut Shell

3.2 Selection of Materials

The palm kernel shells used in this study were obtained from a palm kernel oil processing site located in Ikpoba Hill, Benin City, while the coconut shells were sourced from the New Benin Market, Edo State. The coconut shells were air-dried for 14 days before being manually crushed to the required size. Similarly, the palm kernel shells were allowed to dry for 14 days prior to use. River sand served as the fine aggregate in the concrete mix. Ordinary Portland Cement (OPC) produced by the Dangote Group at Ikpoba Hill, Benin City, was utilized as the binding material. Crushed granite, with a nominal size of 10 mm to ensure effective compressive strength, was procured from a quarry site at Ikpoba Hill. Water obtained from the Department of Civil Engineering, University of Benin, was used for both mixing and curing of the concrete cubes.

3.3 Equiments and Materials Used

Equipment used includes:

1. Tamping rod
2. Measuring cylinder
3. Shovel
4. Hand trowel
5. Mold of 100mm x 100mm x 100mm
6. Sensitive weighing balance
7. Sieve of various sizes
8. Head Pans
9. Trays

10.Grease and iron brush

11. Oven

3.4 Practical Tests

3.4.1 Sieve Analysis

Sieve analysis is a procedure used to determine the particle size distribution of granular materials. It can be performed on both organic and inorganic materials such as sand, crushed rock, stones, or clays. The objective is to classify soil or aggregate particles into specific size ranges and to determine the relative proportions by dry weight of each fraction. This test helps identify whether a material predominantly consists of sand, silt, or clay, which in turn influences its engineering properties.

In this study, sieve analysis was conducted on the fine aggregate (river sand), coarse aggregate (granite), and the replacement materials (coconut shell and palm kernel shell). A measured sample of each material was sieved using standard sieves of decreasing mesh sizes. The mass retained on each sieve, the cumulative mass passing, and the percentage passing were recorded. A particle size distribution graph was subsequently plotted for each material to evaluate their gradation characteristics.

3.4.2 Workability Test (Slump Test)

The slump test is an empirical method used to assess the consistency and workability of fresh concrete. The apparatus used consisted of a slump cone with a base diameter of 200 mm, a top diameter of 100 mm, and a height of 300 mm. The cone was oiled and placed on a smooth, non-absorbent horizontal surface.

Fresh concrete was filled into the cone in three equal layers, each layer being tamped 25 times with a standard 16 mm tamping rod. After the top surface was leveled with a trowel, the cone was carefully lifted vertically within 5–10 seconds. The slump value, which represents the concrete's consistency, was measured as the vertical difference between the top of the cone and the highest point of the concrete specimen.

3.4.3 Density Test

The density test was conducted to determine the mass per unit volume of the concrete, which serves as an indicator of its quality and strength. The density of concrete depends on factors such as the density and quantity of aggregates, air void content, cement concentration, and the maximum size of aggregates.

The procedure involved weighing a sample brick to determine its mass and calculating its density by dividing the mass by the total volume. Generally, the acceptable density range for conventional concrete bricks lies between 1,900 kg/m³ and 2,400 kg/m³, while lightweight concrete bricks typically have densities around 1,400 kg/m³.

3.4.4 Compressive Strength Test

The compressive strength test measures the ability of a concrete specimen to withstand axial loads without failure. It is determined as the ratio of the applied load to the cross-sectional area of the specimen.

In this study, compressive strength tests were conducted on hardened concrete cubes produced with coconut shell and palm kernel shell as partial replacements for coarse aggregate. The concrete cubes were cured and tested at **7, 14, and 28 days**, and the compressive strength values were recorded accordingly.

$$compressive\ strength = \frac{compressive\ load}{100}$$

3.4.5 Water Absorbion Test

The water absorption test was conducted to evaluate the porosity and moisture absorption capacity of Palm Kernel Shell (PKS) and Coconut Shell (CS) when used as partial replacements for conventional coarse aggregates in concrete. This test provides insight into the materials' durability and long-term performance when exposed to moisture in concrete applications.

The procedure involved removing the samples from water and allowing excess water to drain for 1–2 minutes. The surfaces were then gently wiped with a dry cloth to eliminate surface moisture, after which the saturated surface-dry weight (W_2) of each sample was recorded. Subsequently, the samples (PKS, CS, and conventional aggregates) were placed in an oven at 100°C for 24 hours to remove all moisture. After oven drying, the specimens were allowed to cool in a desiccator to room temperature, and their dry weights (W_1) were measured using an electronic weighing balance.

Water Absoption (W) = $\frac{(W_2-W_1)}{W_1 \times 100}$

W = Water Absorption

W_1 = Oven-dry weight (g)

W_2 = Saturated dry weight (g).

3.5 Mix Proportions and Casting of Concrete Cubes

A control mix ratio of **1:1:2** by weight was adopted for this study, with a water–cement ratio of 0.5. The replacement levels of coarse aggregate with coconut shell and palm kernel shell were 5%, 10%, 15%, 20%, 25%, and 30%.

Concrete casting was carried out using wooden moulds with internal dimensions of 100 mm × 100 mm × 100 mm. All specimens were prepared in accordance with BS 1881 (1996). After casting, the cubes were demoulded after 24 hours and transferred into a curing tank for water curing to promote hydration and strength development. The specimens were later tested for compressive strength at curing ages of 7, 14, and 28 days.

Workability of the fresh concrete at each replacement level was assessed using the **slump test**. After curing, the concrete cubes were removed from the water tank and left in open air for approximately five hours before testing, to account for the moisture absorption characteristics of the replacement aggregates. Compressive strength tests were performed using a manual compression testing machine at the Civil Engineering Laboratory, University of Benin.

3.6 Cost Benefit Analysis

A cost–benefit analysis was conducted to assess the economic viability of using palm kernel shell (PKS) and coconut shell (CS) as partial replacements for granite in concrete production. Current market prices of granite, PKS, and CS were obtained from local building material suppliers and recorded on a unit volume basis. Based on the selected mix proportion, the quantity of coarse aggregate required for 1 m^3 of concrete was determined, and the corresponding amounts of granite, PKS, and CS were calculated.

The resulting material costs were compared with those of the control mix containing 100% granite to determine the cost differences. Cost savings achieved at each replacement level were then evaluated and expressed in monetary terms.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Introduction

In this chapter, various laboratory tests which were conducted The study aims to compare the particle size distribution of the aggregate used, slump values of PKS and CS as coarse aggregate replacement, the compressive strength of PKS and CS as coarse aggregate replacement and the densities of PKS and CS when used as coarse aggregate. This chapter show the results of particle size distribution, slump test and the compressive strength test performed on concrete cube specimens. The specimen was cured, weighed and results were collected for 7 days, 14 days and 28 days with 3 specimens crushed and the average of the three values taken. The mix ratio of the concrete is 1:1:2. The size of granite used is 10m with a water-cement ratio of 0.5 .

4.2 Sieve Analysis

The particle size distribution of fine aggregate, palm kernel shells and Coconut shells are shown in Figure 4.2a - Figure 4.2c. The fine aggregate shows thai it is well graded.

Sieve analysis is used to characterize the size distribution of particles in a given sample. From figure 4.1 below, it is shown that the fine aggregate (Sand) is said to be well graded. Figure 4.2. shows the particle size distribution of PKS, the values obtained show that the PKS is poorly graded and will contain lot of voids. Hence, it will require more amount of cement paste to fill the voids. Also from Figure 4.3, the values from the particle size distribution of CS shows that the CS is also poorly gradet and will contain voids but not as much as the PKS.

Table 4.2a Sieve Analysis for Fine aggregate

Sieve Size (mm)	Weight Retained (g)	% Retained	% Passing
2.360	22.99	7.99	92.01
2.000	3.40	1.13	90.18
1.180	14.05	4.68	86.12
0.600	195.57	65.19	21.01
0.425	52.08	17.35	3.66
0.3000	6.11	2.04	1.62
0.212	1.18	0.39	1.23
0.150	0.66	0.22	1.01
0.075	0.81	0.27	0.74
Receiver	1.2		

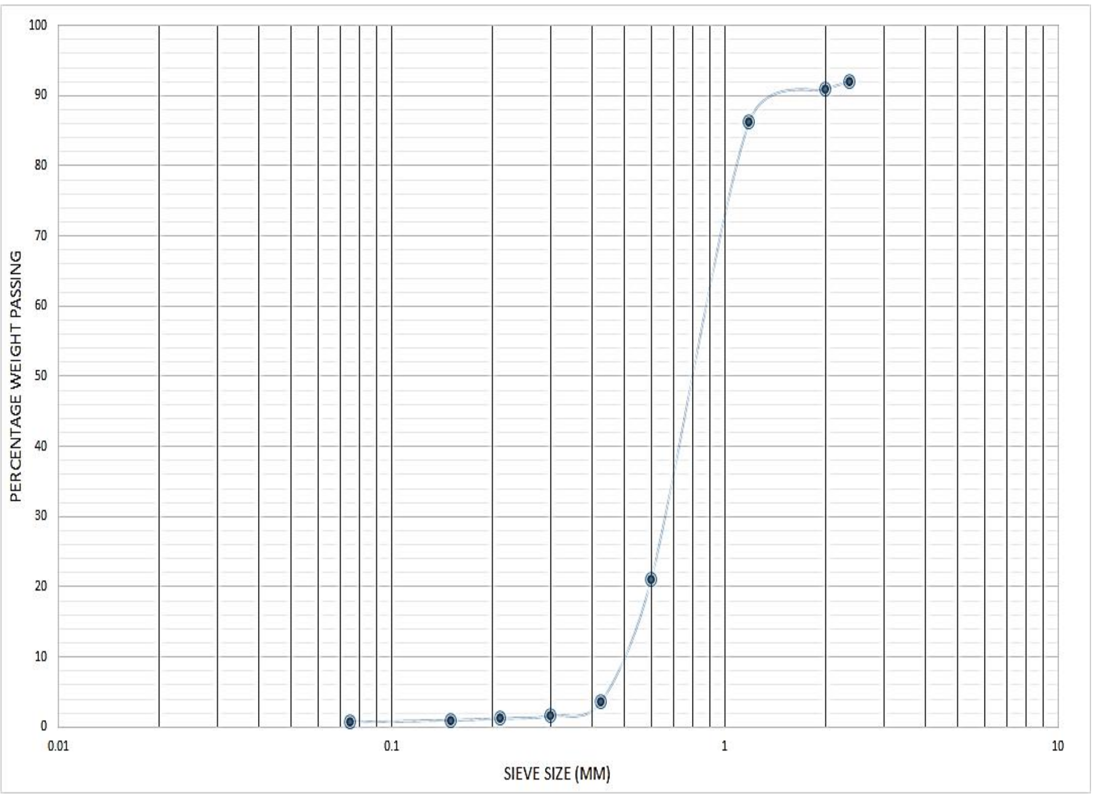


Figure 4.2a Sieve Analysis graph of fine Aggregate

Table 4.2b Sieve Analysis for PKS aggregate

Sieve Size (mm)	Weight Retained (g)	Weight Passing (g)	% Weight Passing
19	0	1000	100
13.26	58.6	941.4	94.14
10	324.8	616.6	61.66
8	394.5	222.1	22.21
5	189.6	32.5	3.25
3.3	150	17.5	1.75
Base pan	6.1		

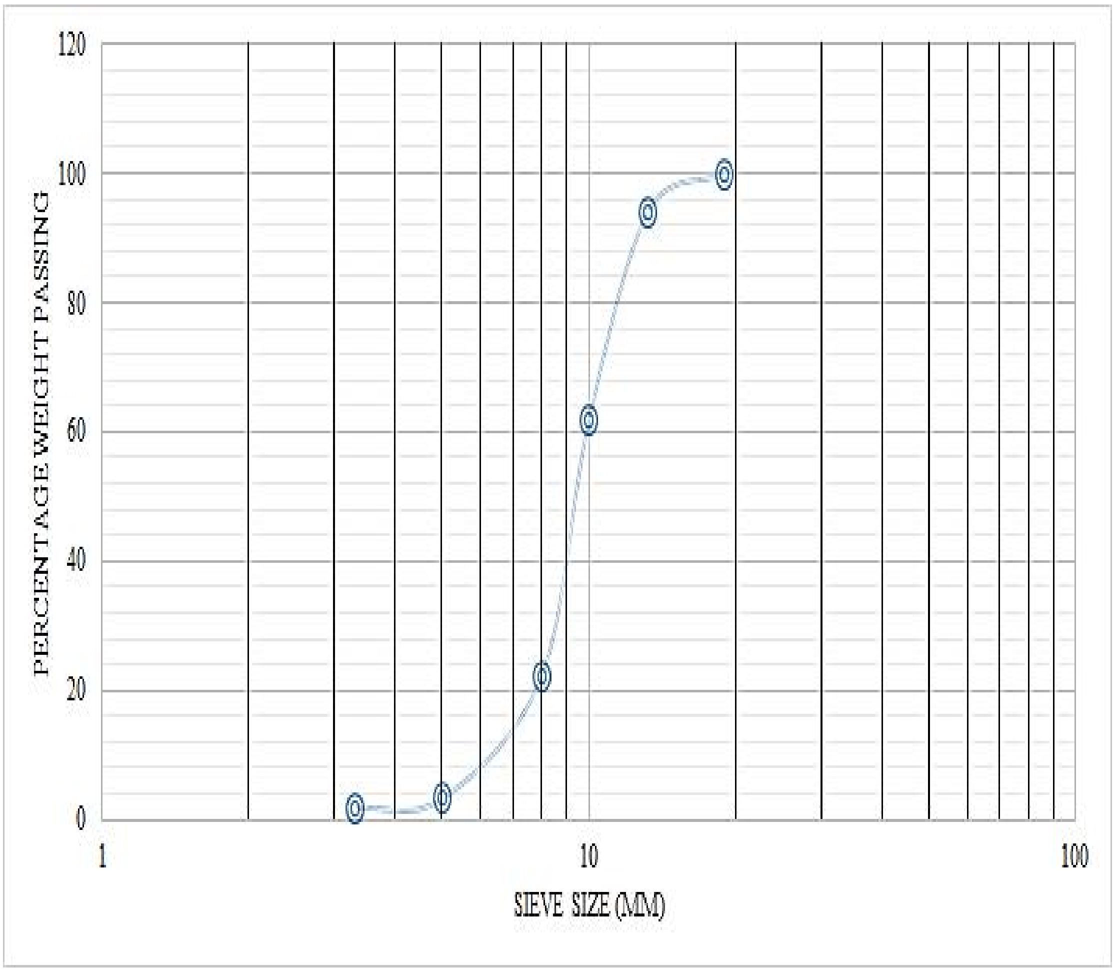


Figure 4.2b Sieve Analysis graph of PKS aggregate

Table 4.2c Sieve Analysis for CS aggregate

Sieve Analysis (mm)	Weight retained (g)	Weight passing (g)	% Weight Passing
19	8.0	492	98.2
13.26	157.3	334.7	66.94
10	207.5	127.2	25.44
8	78.6	48.6	9.72
5	40.4	8.2	1.64
3.3	2.3	5.9	1.18
Base pan	3.4		

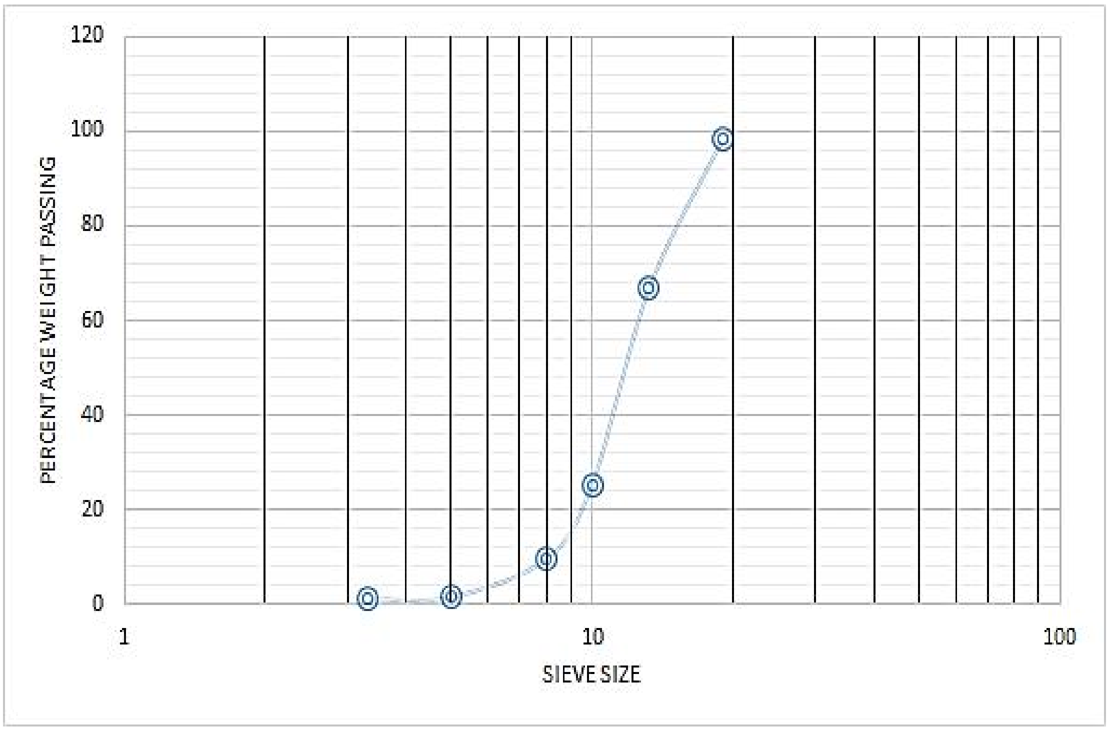


Figure 4.2c Sieve Analysis graph for CS aggregate

4.3 Workability Test

Slump teat was used to determine the workability of the concrete , the results obtained are shown in Table 4.3a and Table 4.3b. It was observed that the Slump of the fresh concrete reduces as the replacement of the coarse aggregate , the reduction was as a result of the increase in the quantity of PKS aggregate and CS aggregate.

The workability of the concrete where the granite was replaced with Coconut shell had higher slump compared to that of Palm kernel shell. The Concrete with Coconut Shell was more workable and it also had smoother surface texture.

Table 4.3a Slump result for PKS concrete

% PKS	Slump (mm)
0	42
5	39
10	32
15	28
20	22
25	16
30	7

Table 4.3b Slump result for CS concrete

%CS	Slump (mm)
0	42
5	39
10	36
15	31
20	28
25	21
30	15

4.4 Density Test

The density of concrete decreases as the replacement of coarse aggregate increased in both Palm kernel shell and Coconut shell as shown in Table 4.4a and Table 4.4b.

The PKS concrete had a lesser density compared to CS concrete. At 0% of Palm kernel and Coconut shells, the density of the concrete at 28 days was 2568 kg/m³, the minimum density of Palm kernel shell and Coconut shell at 28 days were 2159 kg/m³ (30% replacement) and 2265 kg/m³ (30% replacement).

Table 4.4a Average Density of Palm kernel shell concrete

% PKS	Average Density (kg/m³)		
	7 days	14 days	28 days
0	2539	2646	2569
5	2582	2627	2523
10	2497	2356	2463
15	2372	2400	2365
20	2268	2263	2347
25	2166	2247	2332
30	2167	2186	2159

Table 4.4b Average Density of Coconut shell concrete

% CS	Average Density (kg/m³)		
	7 days	14 days	28 days
0	2539	2646	2569
5	2441	2493	2649
10	2345	2451	2541
15	2308	2405	2472
20	2218	2394	2414
25	2147	2334	2357
30	2256	2313	2265

Figure 4.4a Comparison on Average Density of concrete made with Palm Kernel shell and Coconut shell.

With the above densities , both PKS and CS concrete are classified as lightweight concrete, having better fire resistance and thermal insulating property compared to conventional concrete with high density. It was observed that concrete made with Palm Kernel shell offers better fire resistance and sound insulation compare to CS as a result of it lesser density and porosity, heat travel slower in PKS concrete hence taking longer time for heat to reach to the reinforcements.

PKS concrete is very suitable in the decking of kitchen which is prone to fire outbreak in homes, also it is suitable for ascoutic structures such as schools, hospitals, offices etc due to its noise reverberation and echo reduction.

4.5 Compressive Strength Test

Compression Strength test is used to determine the strength of concrete to sustain or bear load or axial force applied on the concrete. The purpose of this test was to determine and compare the effect of replacement of palm kernel shell and Coconut shell as coarse aggregate on the compressive strength of 1:1:2 concrete. The average compression strength is summarized in Table 4.5a and Table 4.5b below.

The compressive strength of the concrete cubes increased with increase in curing days. As the percentage of replacement increased the compressive strength reduced, it was observed that concrete with coconut shell had more compressive strength compared to concrete with Palm kernel shell.

The maximum compressive strength of 1:1:2 mix ratio of Palm Kernel shell and Coconut shell as coarse aggregate were 28.64 N/mm² and 29.48 N/mm² respectively (both at 5% replacements). The minimum compressive strength of Palm Kernel shell and Coconut shell were 21.93 N/mm² (at 25% replacement) and 22.62 N/mm² (at 30% replacement). In addition, higher reduction in the compressive strength of concrete using Palm kernel shell compared to Coconut shell is due to its mechanical properties, since Palm kernel shells are weaker and has more void.

Table 4.5a Average compressive Strength of PKS Concrete

% PKS	Average Compressive strength (N/mm²)		
	7 days	14 days	28 days
0	23.28	27.84	31.97
5	22.07	26.27	28.63
10	21.44	24.42	26.86
15	19.45	23.52	26.23
20	18.08	21.69	24.25
25	17.24	20.93	21.93
30	15.43	19.13	19.67

Table 4.5b Average compressive Strength of CS Concrete

% CS	Average Compressive strength (N/mm²)		
	7 days	14 days	28 days
0	23.28	27.84	31.97
5	23.17	25.81	29.48
10	22.48	25.26	28.63
15	20.53	24.47	27.26
20	20.11	23.26	25.14
25	17.21	21.32	24.82
30	16.96	20.94	22.62

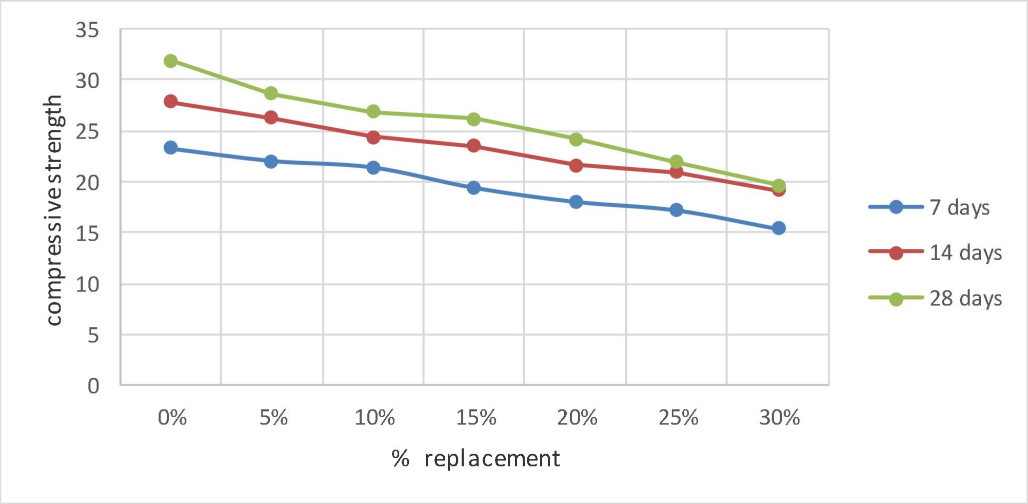


Figure 4.5a Average Compressive strength of PKS concrete

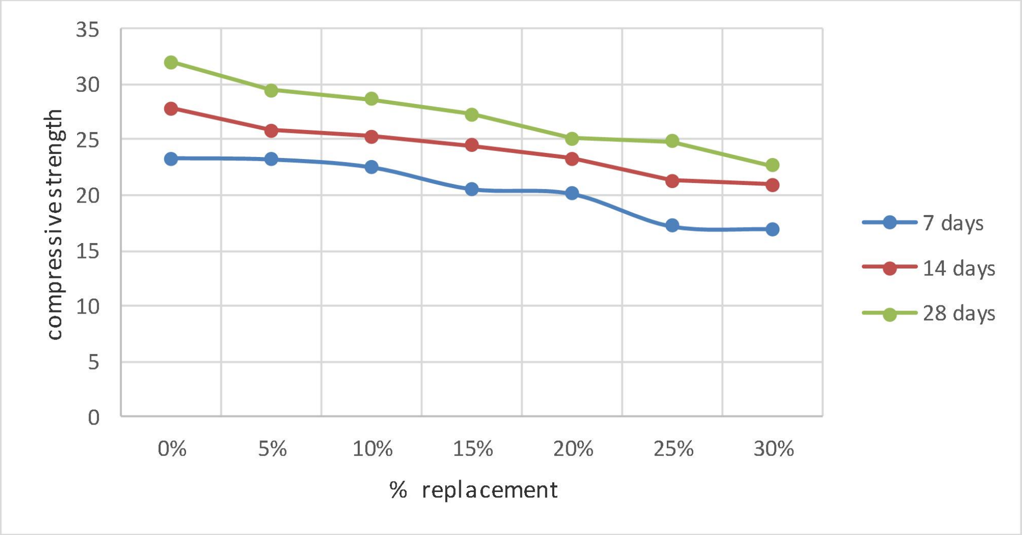


Figure 4.5b Average Compressive strength of CS concrete

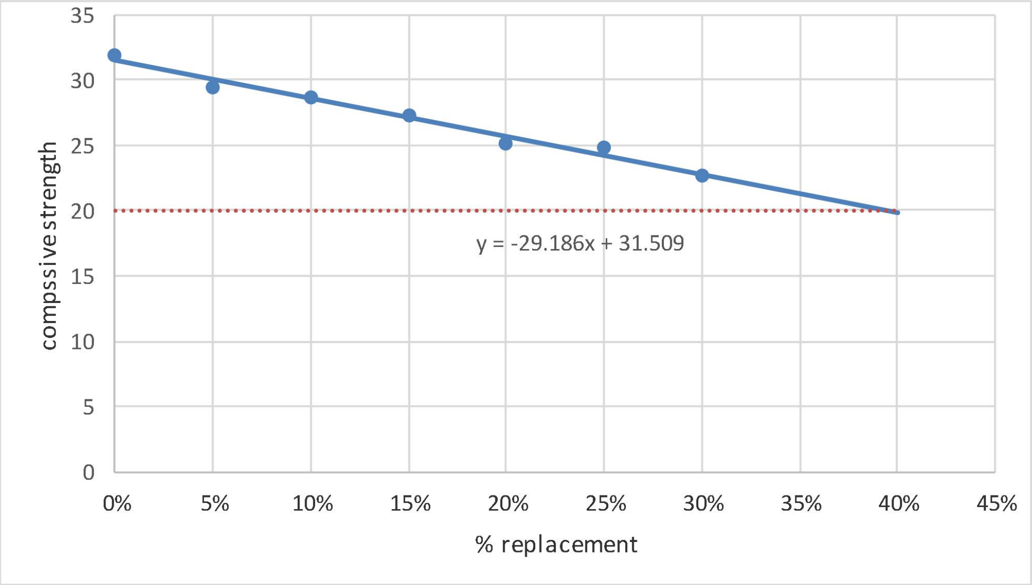
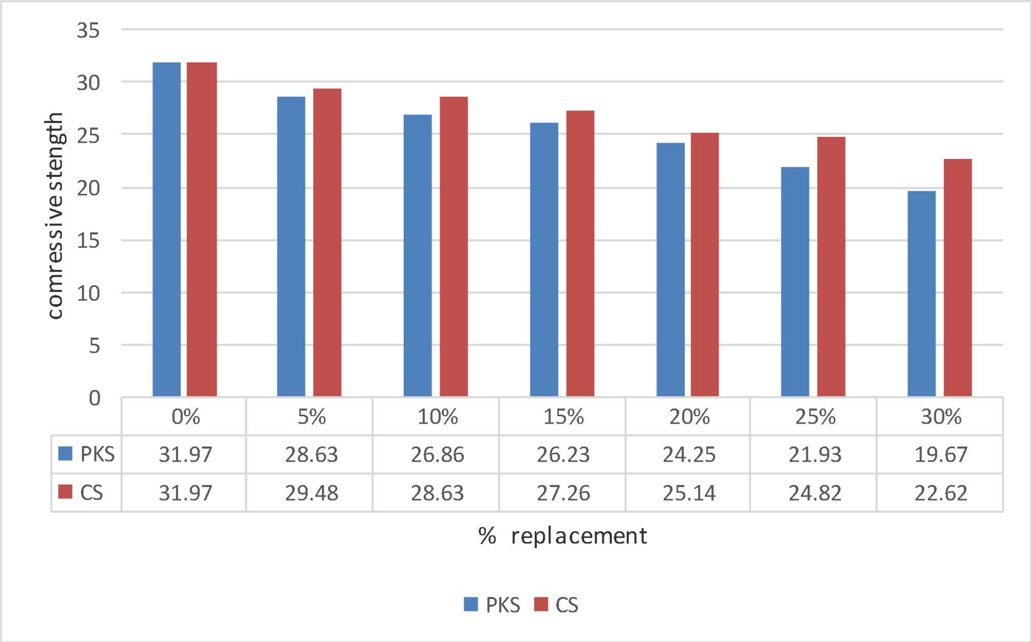


Figure 4.5c 28 days comoressive strength of CS concrete



	0%	5%	10%	15%	20%	25%	30%
■ PKS	31.97	28.63	26.86	26.23	24.25	21.93	19.67
■ CS	31.97	29.48	28.63	27.26	25.14	24.82	22.62

Figure 4.5d Comparison of Compressive strength of concrete made with Palm Kernel shell and Coconut shell

4.6. Water Absorbion Test

The results obtained from water absorption tests showed that the percentage water absorption increases with increase in the percentage replacement of the coarse aggregate by Palm kernel shells and Coconut shell. The value ranges from 0.46% - 6.69% and 0.46% - 4.96% for Palm kernel shell and Coconut shell respectively.

Higher values of water absorption were obtained from Palm kernel shell compared to Coconut shell as a result of the higher water absorption capacity of Palm kernel shells, however, PKS concrete performs better with respect to its water absorbion capacity. The lower values of CS concrete shows it is denser, more durable and higher quality concrete and performs better in marine structures and water-retaining structures.

4.7. Cost Benefit Analysis

The cost of 10 tonnes of granite (1 tipper load or 10,000kg) is #200,000. The cost of 1 tipper load of Palm Kernel Shell is #98,000. The cost of 1 tipper load of Coconut Shell is #110,000. The density of concrete is 2400 kg/m^3. In mix ratio 1:1:2 , the proportion of coarse aggregate in concrete is 1200kg/m^3.

For 35% PKS replacement in 1 cubic metre (1 m^3), the mass of 35% PKS of concrete is 420kg, therefore;

10,000 kg of PKS = #94,000. 4.1

420 kg of PKS = (420/10,000)94,000 = #3,948. 4.2

then the remaining 65% of granite which is 780kg, therefore;

10,000 kg of granite = #200,000. 4.3

780 kg of granite = (780/10,000)200,000 = #15,600. 4.4

Summing equations 4.2 and 4.4 : #3,948 + # 15,600 = #19,548.

For 40% CS replacement in 1 cubic metre (1 m^3), the mass of 40% CS of concrete is 480kg, therefore;

10,000 kg of CS= #110,000. 4.5

480 kg of CS = (480/10,000)110,000 = #5,280. 4.6

then the remaining 60% of granite which is 720 kg, therefore;

10,000 kg of granite = #200,000. 4.7

780 kg of granite = (780/10,000)200,000 = #14,400. 4.8

Summing equations 4.6 and 4.8 : #5,280 + #14,400) = #20,880.

Actual cost of granite in concrete without any replacement;

10,000kg of granite = #200,000. 4.9

1200 kg of granite = (1200/10,000)200,000 = #24,000. 4.10

Actual savings for using 35% PKS;

Actual cost of granite without replacement - Cost of 35% PKS

#24,000 - #19,548 = #4,452. 4.11

At 35% PKS replacement in $1m^3$ #4,452 is saved.

Actual saving for using 40% CS;

Actual cost of granite without replacement - Cost of 40% CS

#24,000 - #20,880 = #3,120 4.12

At 40% CS replacement in $1m^3$ #3,120 is saved.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study investigated the compressive strength of concrete produced using Palm kernel shell (PKS) and Coconut Shell (CS) as partial replacement for conventional aggregate in 1:1:2 mix ratio. The compressive strength of the concrete decreased as the percentage replacement increased for both PKSC and CSC. Using PKS and CS as coarse aggregates in making light weight structures, it was found that the CSC has higher compressive strength compared to PKSC, moreover PKSC offers better sound insulation and fire resistance compared to CSC as a result of it lesser density.

On the bases of Cost benefits, the PKSC appears to be cheaper. However, considering both concrete based on cost/strength ratio, the CS is more suitable than PKS when use d to replace conventional aggregate in concrete production.

Base on this investigation, the following conclusions were being drawn:

1. Compressive strength of the concrete decreased as the percentage of replacement increased in both PKS concrete and CS concrete, the compressive strength of PKS concrete were 28.63 N/mm² (at 5% replacement), 26.86 N/mm² (at 10% replacement), 26.23 N/mm² (at 15% replacement), 24.25 N/mm² (at 20% replacement), 21.93 N/mm² (at 25% replacement), 19.67 N/mm² (at 30% replacement). Then CS concrete the compressive strength were 29.48 N/mm² (at 5% replacement), 28.63 N/mm² (at 10% replacement), 27.26 N/mm² (at 15% replacement), 25.14 N/mm² (at 20% replacement), 24.82 N/mm² (at 25% replacement), 22.62 N/mm² (at 30% replacement) making it have better durability and strength.

2. The optimum proportion replacement of PKS concrete in concrete mix ratio of 1:1:2 is 25% replacement (21.93 N/mm²) while for the CS concrete was 40% replacement (20 N/mm²). Replacement above 25% and 40% generally compromised strutural integrity in PKS and CS concrete respectively.

3. Coconut shell concrete exhibited better mechanical performance than Palm kernel shell concrete at equivalent replacement in terms of compressive strength, density and water absorbion. PKS concrete offer better sound insulation and fire resistance compared to CS concrete.

4.The cost benefit analysis showed that 40% replacement with Coconut ahell in 1m³ of concrete there is a savings of #3,120 and at 35 replacement with In 1m³ of concrete there is a savings of #4,452.

5.2 Recommendations

From the result obtained, Palm kernel shell and Coconut shell are suitable to be used as a partial replacement of coarse aggregate in making light weight concrete and ascoutic structures. Future research should be done to investigate the durability and long-term performance of PKS and CS concrete under different environmental conditions. Also, more studies should be done when water-reducing admixtures are introduced to determine the strength and other relevant properties of Palm kernel shell and Coconut shell in concrete.

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APPENDIX

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Figure A1: Measuring of materials

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Figure A2: Moulding of concrete cubes

Figure A3: Slump of fresh concrete

Figure A4: Crushing of concrete