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

BY

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CERTIFICATION

I, therefore, attest to the fact that the following report, titled "EXPERIMENTAL STUDY ON THE EFFECT OF THE PARTIAL REPLACEMENT OF COARSE AGGREGATE WITH PALM KERNEL SHELL ON THE COMPRESSIVE STRENGTH OF CONCRETE," was written and assembled by MICHAEL EGHOSA (Matric Number: ENG1804872), a student at the University of Benin's Ugbowo Campus in Edo State. This is in partial fulfillment of the requirements for the awarding of the Bachelor of Engineering (B.Eng.) degree in Civil Engineering at the University of Benin; Edo State, Nigeria.

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DEDICATION

I dedicate this project to Jehovah God most importantly, for everything He has done for me, especially for His guidance, sustenance and protection through not just this project but also, through my stay in this prestigious institution. Also, to my Parents **MR and MRS MICHAEL and FAITH** for their support towards my education.

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ABSTRACT

The construction industry is increasingly looking for sustainable alternatives to traditional construction materials. PKS is an agricultural waste product and its incorporation into concrete not only reduces waste but also offers potential economic and environmental benefits. This study addresses this concern by investigating the viability of using palm kernel shell (PKS) as a partial replacement for coarse aggregate in concrete.

To evaluate its effect, we conducted a series of experiments in which we replaced conventional coarse aggregate with PKS at varying percentages (0%, 5%, 10%, 15% and 20%). To ascertain how PKS presence affected this crucial attribute, tests were conducted on the compressive strength of the resultant concrete specimens. Cement, sand, coarse aggregate, and palm kernel shell are the materials used. Concrete cubes of 100 mm by 100 mm by 100 mm were formed using a 1:1.5:4 (C30) concrete mix ratio, which was batched by weight. The cubes were crushed after 3, 7, 14, and 28 days to compare the strength at (0%, 5%, 10%, 15% and 20%) PKS replacement

According to this research, the results showed that as the percentage of palm kernel shell in concrete increases, the compressive strength decreases alongside its cost and the weight of concrete. At around 10% partial replacement of coarse aggregate with palm kernel shell in concrete gives a significant decrease in cost and weight of the concrete without much affecting the compressive strength of concrete.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

According to Naik (2008), concrete is the most widely used artificial material in the world. Because of its strength and ability to support weight, concrete is a common and adaptable building material (Oti, 2015). When evaluating concrete's performance in structural applications, one of its most crucial attributes is its strength of compression. Although crushed stone and gravel have historically been the most popular aggregates used in the making of concrete, their negative effects on the environment make more sustainable alternatives necessary.

With a growing focus on sustainability and the development of eco-friendly building materials, the worldwide construction sector is currently experiencing a substantial transition (Ahmed et al., 2021). The most common building material utilized worldwide is concrete. One area of particular interest is using industrial and agricultural by-products to improve its sustainability (Neville, 2011). One such by-product is palm kernel shells (PKS), a waste material from the palm oil industry.

Palm kernel shells (PKS) have drawn interest as a partial substitute for coarse aggregates in concrete due to its potential for cost reductions, sustainable resource utilization, and a few special qualities such as promoting environmental sustainability by recycling this waste material and lowering the carbon footprint of building projects when used in concrete.

This study aims to accomplish two primary goals. Initially, we want to determine whether it is feasible to use PKS in place of some of the coarse aggregate in concrete. Secondly, our goal is to comprehend how different replacement percentages of PKS affect the compressive strength of the resulting concrete mixtures without neglecting the relevance of using PKS in concrete based on factors such as local availability, cost, and project requirements. In regions where palm oil production is common, PKS may be a readily available and cost-effective alternative to traditional coarse aggregates. However, its limitations, such as lower mechanical properties and susceptibility to environmental degradation, need to be addressed to ensure the long-term performance and structural integrity of the concrete. As with any construction material, a well-informed and carefully executed approach is crucial to harness the benefits of PKS while meeting the necessary construction standards.

1.2 STATEMENT OF THE PROBLEM

The statement of the problem revolves around the need to balance sustainability and structural performance in the construction industry. Key problems include low adoption and awareness, problems with PKS's consistency and quality, a lack of standards and laws, worries about the palm oil industry's effects on society and the environment, complicated supply chains, the need for specialized handling, and doubts about the long-term performance and durability of PKS-based building materials. To overcome these obstacles and promote the use of PKS, the Nigerian construction industry must invest in research, quality control, and industry collaboration while addressing the wider sustainability and ethical considerations associated with the palm oil industry. The study aims to address these problems by investigating how replacing traditional aggregates with PKS affects the compressive strength of concrete. The central problem is finding a sustainable solution that minimizes environmental impact while ensuring concrete maintains structural integrity for various construction applications.

1.3 AIM AND OBJECTIVE OF THE STUDY

This main aim of this study is to examine the impact of partially replacing traditional coarse aggregates with palm kernel shell (PKS) on the compressive strength of concrete.

To achieve this aim, this research is guided by the following specific objectives:

1. To determine the feasibility of partially substituting PKS for traditional coarse aggregates in manufacturing of concrete.
2. To determine how varying percentages of PKS substitution, (which might range from 0% - 20%) influence the compressive strength of concrete.
3. To understand how the curing process's effects on the environment and the functionality of concrete containing PKS may be affected.
4. To analyze the data collected and identify areas for optimization in the concrete mixtures.

1.4 SCOPE OF STUDY

Firstly, it focuses on the use of PKS as a partial substitute for traditional coarse aggregates in concrete. This study examines varying percentages of PKS replacement (ranging from 0% to 20%) This range is chosen to comprehend how PKS percentage affects concrete strength and its implications for structural applications. These mixtures were subjected to an array of mechanical tests, including compressive strength allowing for a comprehensive examination of the engineering properties and load-bearing capacity of the concrete.

The main outcome measure that is used to evaluate load-bearing capability and structural appropriateness is the concrete specimens' strength of compression. Similarly, environmental effects of the study are also taken into account, such as decreased energy use and waste reduction in the manufacturing of concrete. The text provides actionable advice for academics and engineers who wish to integrate PKS into concrete mix designs. It highlights the significance of striking a balance between structural performance and sustainability objectives.

In conclusion, the scope of this study is comprehensive, aiming to bridge the gap between sustainability and structural performance in the construction industry. It investigates PKS's viability as a renewable substitute. to conventional coarse aggregates in concrete and its impact on compressive strength. The study examines varying percentages of PKS replacement, maintaining consistent water-cement ratio and workability across all mixtures.

1.5 JUSTIFICATION OF STUDY

The significance of this study holds immense significance as it explores the eco-friendly use of palm kernel shell (PKS) to lessen construction's negative effects on the environment and align with global sustainability objectives. By repurposing PKS, it addresses waste management issues in the palm oil industry, contributing to waste reduction. Additionally, it promotes the conservation of natural resources by considering PKS as a substitute for traditional aggregates, thereby mitigating the environmental consequences of resource extraction.

Moreover, the study offers insights into optimizing PKS content in concrete, enabling a balance between sustainability and structural performance by conducting a comprehensive environmental impact assessment and fostering innovation and research, it promotes the use of viable building techniques, potentially transforming the entire building sector towards greater environmental responsibility.

CHAPTER TWO

LITERATURE REVIEW

The building sector has faced increasing scrutiny due to its substantial environmental impact, particularly with the widespread use of concrete, a fundamental construction material. Reducing the ecological effect of conventional building materials, especially concrete, is becoming more and more important as the demand for building materials rises internationally. A key focus area in this transition is the exploration of alternative materials and methods that enhance sustainability. One such substitute is to use palm kernel shell in place of some of the traditional coarse aggregates (PKS).

The literature review is an essential component of this study, as it offers a comprehensive overview of existing research and knowledge in the field partial substitution of traditional coarse particles with palm kernel shell (PKS) in concrete. It encompasses various themes and aspects, shedding light on the environmental benefits, mechanical properties, workability, durability, and economic considerations.

2.1 CONCRETE: A HISTORICAL PERSPECTIVE

2.1.1 ANCIENT ORIGINS

Concrete's origins trace back to ancient civilizations, with evidence of its use in Egyptian and Mesopotamian construction. However, the Romans revolutionized concrete technology, employing a blend of lime, volcanic ash, and aggregate, leading to durable structures like the Colosseum and the Pantheon (Bodart, 2017).

2.1.2 EVOLUTION OF TECHNIQUES

Concrete's evolution continued through the Renaissance and experienced a resurgence during the Industrial Revolution. The 19th century witnessed a pivotal moment with the invention of Portland cement, a key component in modern concrete (Mindess et al., 2003).

2.1.3 VERSATILITY OF CONCRETE

2.1.3.1 STRUCTURAL APPLICATIONS

Concrete's versatility is evident in its widespread use as a foundational material for buildings and bridges. Its exceptional compressive strength is crucial in supporting structural loads (Nawy, 2008).

2.1.3.2 ARCHITECTURAL EXPRESSION

The moldability of concrete allows for diverse architectural designs, enabling the construction of both sleek modern structures and intricate historical monuments (Kosmatka et al., 2002).

2.1.4 BENEFITS OF CONCRETE

2.1.4.1 DURABILITY

Concrete is renowned for its durability, with structures exhibiting longevity and resilience. Proper design and curing practices contribute to its ability to withstand weather conditions and structural stresses (Neville, 2011).

2.1.4.2 ENERGY EFFICIENCY

Concrete's thermal mass properties enhance energy efficiency by absorbing, storing, and releasing heat. This feature aids in regulating indoor temperatures and reducing energy consumption (Mehta and Monteiro, 2006).

2.1.4.3 SUSTAINABLE PRACTICES

Efforts to enhance the sustainability of concrete include the use of alternative cementitious materials and recycled aggregates. Innovations in production methods aim to reduce environmental impact (Scrivener et al., 2018).

2.1.5 ISSUES ASSOCIATED WITH CONCRETE USE

2.1.5.1 ENVIRONMENTAL IMPACT

Environmental issues are raised by the fact that conventional concrete manufacture increases carbon dioxide emissions. Research focuses on eco-friendly alternatives and sustainable practices to mitigate these impacts (Sanjayan and Manalo, 2018).

2.1.5.2 MAINTENANCE CHALLENGES

While concrete is durable, challenges such as cracking, spalling, and corrosion may arise. Regular maintenance and inspections are essential to address these issues and ensure the longevity of concrete structures (Richardson and Taylor, 2007).

2.2 COMPOSITION OF CONCRETE

2.2.1 CEMENT

Cement is a fundamental ingredient in concrete, responsible for binding the mixture into a solid mass. The most commonly used type is Portland cement, which consists of limestone, clay, and other minerals (Mindess et al., 2003). During hydration, cement particles react with water to form a gel, known as the cement paste, providing the binding matrix in concrete (Neville, 2011).

2.2.2 AGGREGATE

Concrete's total amount and strength are influenced by aggregate, which are made up of both fine and coarse materials. Coarse aggregates, such as gravel or crushed stone, provide bulk and stability, while fine aggregates, like sand, fill the spaces between particles, enhancing workability (Kosmatka et al., 2002). The quality and gradation of aggregates significantly impact the properties of the concrete mix (Neville, 2011).

2.2.3 ADMIXTURE

Admixtures are additional ingredients incorporated into the qualities of the cement mortar. They improve durability, flowability, setting time, and other characteristics. Common types include plasticizers, accelerators, and water reducers (Mindess et al., 2003). Admixtures allow for the optimization of concrete performance under various conditions, offering greater versatility in construction applications.

2.2.4 WATER

An essential element in the cement hydration process is water. The potential and workability of the concrete mix are influenced by the water quality. Proper water-cement ratio control is essential to ensure optimal hydration without compromising the structural integrity of the concrete (Neville, 2011).

2.3 ALTERNATIVE MATERIALS FOR AGGREGATES

Over the past few years, the building sector has explored alternative materials for aggregates in concrete to address environmental concerns and reduce the demand for traditional resources. These alternatives offer unique benefits, contributing to sustainable construction practices.

2.3.1 RECYCLED CONCRETE AGGREGATES (RCA)

Recycled concrete aggregates, derived from demolished structures, serve as a sustainable alternative to conventional aggregates. Studies have shown that incorporating RCA in concrete can achieve comparable mechanical properties while reducing the environmental impact of construction waste (Parekh and Modhera, 2011). For example, Parekh and Modhera (2011) demonstrated that recycled fine and coarse aggregates exhibit better resistance to carbonation compared to natural aggregates.

2.3.2 WASTE MATERIALS

Various waste products, like demolished concrete, ceramics, and glass, can be processed and used as aggregates in concrete production. Monish et al. (2013) investigated the utilization of demolished waste as coarse aggregate and found positive results regarding its feasibility in concrete production.

2.3.3 LIGHTWEIGHT AGGREGATES

Materials like expanded clay, shale, or slate May become expanded as well as lightweight aggregates in concrete. These aggregates reduce the overall weight of the concrete, making it suitable for specific applications where weight is a critical factor, such as in precast components (Neville, 2011).

2.3.4 NATURAL POZZOLANS

In addition to cementitious elements, organic pozzolanic components like calcined clay or volcanic ash could be utilized in concrete. These materials enhance the performance of concrete by improving workability and reducing the heat of hydration (Mindess et al., 2003). For instance, the addition of natural pozzolans in concrete has been explored in several studies (Animesh Awasthi et al., 2018).

2.3.5 BENEFITS AND CONSIDERATIONS

The use of alternative aggregates offers benefits such as resource conservation, waste reduction, and energy savings. However, challenges related to quality control, variability, and standardization need to be addressed for widespread adoption (Kosmatka et al., 2002).

2.4 EFFECT ON STRENGTH

2.4.1 STRENGTH PERFORMANCE OF RECYCLED AGGREGATES

Numerous research has looked at the impact of alternative aggregates, especially recyclable aggregates, on concrete's strength characteristics. Parekh and Modhera (2011) observed that recycled aggregate concrete can exhibit comparable compressive strength to conventional concrete. However, it was noted that the strength of recycled aggregate concrete may slightly decrease compared to natural aggregate concrete, depending on factors like the blending ratio of recycled aggregate and the water-to-cement (w/c) ratio (Jitendra Kumar Tanaji Mohite et al., 2015).

2.4.2 OTHER INFLUENCING FACTORS

The replacement of conventional coarse aggregates with alternative materials, such as waste rubber and demolished waste, has also been explored. (B. Govinda Rajulu et al., 2017) found that incorporating elastomeric aggregate waste results in the formation of lightweight concrete with improved elasticity and energy absorption properties. However, it's crucial to note that the mechanical properties, including compressive strength, may be influenced by the optimal utilization of these alternative materials (B. Govinda Rajulu et al., 2017).

2.5 EFFECT ON DURABILITY

2.5.1 DURABILITY ASPECTS OF RECYCLED AGGREGATES

The durability of concrete is a critical aspect, and the use of alternative aggregates has implications for long-term performance. In a study by (Katrina Mc Nei and Thomas H.K. Kang, 2013), the impact of recycled concrete aggregate (RCA) on material properties was investigated. The study highlighted that the properties of recycled aggregates are significantly affected by the residual glued concrete mix, maybe influence the durability aspects of the concrete. Additionally, (Shivakumar et al., 2014) explored the utilization of building demolished waste in porous concrete and found that the porous concrete exhibited encouraging results in terms of drainability, making it a potential alternative with low density and high porosity.

2.6 REVIEW OF PREVIOUS STUDIES

2.6.1 INSIGHTS FROM PAST RESEARCH

Previous research, including studies by Limbachiya et al. (2000), Exteberria et al. (2007), and Yang et al. (2008), has provided valuable insights into the use of recycled aggregates in concrete. Limbachiya et al. (2000) observed that concrete specimens with up to 30% recycled concrete aggregates (RCA) exhibited compressive strengths comparable to conventional concrete. However, Yang et al. (2008) noted that the compressive strength of RCA concrete could be influenced by factors such as water absorption and the source concrete's strength.

2.6.2 CONSIDERATIONS FOR STRUCTURAL APPLICATIONS

Tavakoli and Soroushian (1996) emphasized the importance of strength tests when using recycled concrete aggregates for building uses. The foundational concrete's durability and the acceptable RCA fraction need careful consideration to ensure the desired concrete strength is achieved. Additionally, the impact of RCA on flexural strength needs further research for a more representative relationship (Tavakoli and Soroushian, 1996; Yang et al., 2008).

2.7 LITERATURE FINDINGS

Numerous studies have explored the potential of palm kernel shell (PKS) as a sustainable alternative in concrete production.

Notable among these studies is the work which explored the engineering and durability qualities of very volumetric concrete crude oil ash from palm oil and palm kernel shell (PKS). PKS is an agricultural waste product generated during palm oil processing, and its use in concrete reduces waste and environmental impact (Nazari et al., 2019).

Similarly, researchers studied the performance of PKS used as a coarse particulate in thin concrete. They found that the lightweight nature of PKS can lower transportation costs in the construction industry and reduce energy consumption (Yusuf et al., 2019).

Additionally, researchers conducted a sustainability assessment of concrete that comprises waste fuel ash and palm oil as well as PKS. They highlighted that using PKS in concrete can be an eco-friendly solution for waste reduction and support sustainability (Gupta et al., 2021).

Researchers such as Gong, Y., and Hu, Y. (2018) reviewed sustainable construction materials and their integration in structural engineering. They emphasized that incorporating PKS in concrete enhances resource efficiency, aligning with sustainability principles (Gong and Hu, 2018).

Major researchers looked into the influence of PKS and coconut shells on the mechanical and durability properties of normal weight concrete. They emphasized that compressive strength is a crucial property in assessing concrete performance (Raji et al., 2021).

Most researchers explored the utilization of PKS as a lightweight aggregate in concrete. They noted that the effect of PKS on Strength of concrete fluctuates according on replacement %. (Olutoge et al., 2015).

Also, Awoyera et al. (2019) researched sustainable construction using PKS in place of some of the coarse aggregate. They found that lower water-cement ratios in PKS concrete may lead to improved compressive strength (Awoyera et al., 2019).

Yusuf et al. (2019) highlighted that PKS can act as internal curing in concrete, contributing to enhanced strength. Furthermore, Jaturapitakkul, C., and Kiattikomol, K. (2003) emphasized that PKS concrete mix designs must be carefully optimized to balance strength and workability.

Similarly, Awoyera et al. (2019) mentioned that as porosity of PKS can impact the workability of concrete mixes. In the same note, Raji et al. (2021) mentioned that superplasticizers are often used to enhance the workability of PKS concrete.

Olutoge et al. (2015) also highlighted that PKS concrete is lighter, making it suitable for applications with reduced structural load.

2.8 KEY OBSERVATIONS

This literature review examines the key findings and trends throughout the study related to the utilization of palm kernel shell (PKS) in concrete.

Environmental Sustainability: The building sector is a major a cause of the deterioration of the environment. Traditional aggregate production involves significant energy consumption, environmental disturbances, and transportation emissions. The utilization of palm kernel shell (PKS) as a sustainable alternative in concrete can significantly reduce the environmental footprint of construction materials by repurposing agricultural waste (Ahmed, Jameel, and Ahsan, 2021).

Waste Reduction: The palm oil industry generates substantial quantities of PKS as a waste product. Inefficient disposal of PKS can lead to environmental issues and increased waste management costs. By incorporating PKS into concrete, this waste can be repurposed effectively, reducing disposal problems and contributing to waste reduction goals (Ganiron et al., 2018).

Resource Conservation: Conventional coarse aggregates are limited resources that must be extracted. has notable environmental impacts. The use of PKS as a substitute for these aggregates can conserve natural resources and mitigate the negative consequences associated with aggregate mining (Neville, 2011).

Sustainable Construction Practices: The study aligns with the global shift towards sustainable construction practices. The construction industry's commitment to environmental responsibility and sustainable development is driving the exploration of alternative materials like PKS that offer an eco-friendly choice without compromising structural integrity (Oti, 2015).

Optimization Potential: Understanding how varying percentages of PKS replacement affect compressive strength provides valuable insights for optimizing PKS usage. This knowledge can lead to the development of guidelines for engineers and construction professionals to strike the right balance between sustainability and structural performance (Lim et al., 2019).

Environmental Impact Assessment: The study's inclusion of an environmental impact assessment provides a comprehensive view of the potential sustainability benefits. This holistic approach evaluates not only the immediate structural implications but also the broader environmental advantages of utilizing PKS in concrete production (Ahmed, Jameel, and Ahsan, 2021).

Innovation and Research Opportunities: Investigating the use of PKS in concrete opens doors for innovation and further research. It encourages the exploration of alternative, sustainable materials and practices in construction, fostering a culture of continuous improvement in the industry (Ganiron et al., 2018).

Wider Adoption of Sustainable Practices: This study can inspire the wider adoption of sustainable practices in the construction sector. By showcasing a real-world application of a sustainable alternative like PKS, it can motivate industry stakeholders to consider environmentally responsible choices in their construction projects.

Palm Kernel Shell (PKS) as a Sustainable Aggregate: Palm kernel shell (PKS), a byproduct of palm oil processing, has recently gained attention as a potential sustainable aggregate for concrete (Nazari et al., 2019). PKS is lightweight, abundant in palm oil-producing regions, and offers a solution to the disposal challenges posed by PKS waste. Its porous structure and low density make it an attractive candidate for partial replacement of traditional coarse aggregate (Raji et al., 2021).

2.8.1 PHYSICAL AND MECHANICAL PROPERTIES OF PKS

Research on PKS highlights unique properties that influence its suitability as a concrete aggregate:

a. **Density**: PKS is notably lighter than conventional aggregates, which results in reduced overall concrete density (Nuruddin et al., 2018).

b. **Porosity**: The porous nature of PKS can enhance the workability of concrete mixtures and lead to improved bonding with the cement paste (Awoyera et al., 2019).

c. **Strength**: While PKS is inherently weaker than traditional coarse aggregates, its mechanical properties can be improved through proper processing and mix design (Jaturapitakkul and Kiattikomol, 2003).

Impact on Compressive Strength: Strength in compression, a basic parameter for evaluating structural performance, has been a focus in studies investigating the influence Using PKS here as partial coarse aggregate substitute:

a. **Enhancements**: Some studies indicate that the introduction of PKS can improve workability and enhance compressive strength due to its porous structure, which acts as internal curing and reduces the water-cement ratio (Yusuf et al., 2019).

b. **Challenges**: However, others have noted that the weaker mechanical properties of PKS may lead to reduced compressive strength. This effect could be influenced by factors such as the percentage of PKS replacement and curing conditions (Olutoge et al., 2015).

2.8.2 SUSTAINABLE BENEFITS OF PKS IN CONCRETE

The utilization of PKS in concrete offers several sustainable benefits:

a. **Waste Utilization**: By incorporating PKS, a waste product, into concrete production, it reduces the environmental burden associated with waste disposal (Gupta et al., 2021).

b. **Energy Savings**: The lightweight nature of PKS contributes to energy savings during transportation and handling (Yusuf et al., 2019).

c. **Carbon Emissions Reduction**: A lower-density concrete mix with PKS could lead to reduced carbon emissions associated with transportation and production (Raji et al., 2021).

2.8.3 CHALLENGES AND MITIGATIONS

1. Variability in PKS Properties: PKS variability affects concrete mix consistency; researchers should source and process PKS carefully, standardize, and implement quality control measures to minimize variations.

2. Mix Design and Proportioning: The challenge lies in determining the optimal PKS content for concrete mix design, which can be mitigated through preliminary tests and fine-tuning based on compressive strength and workability requirements.

3. Workability and Segregation: PKS's lightweight nature can cause segregation in concrete mixes. Mitigation involves using superplasticizers and adjusting water-cement ratios to improve workability and maintain consistency.

4. Curing Conditions: Uniform curing conditions for PKS concrete can be challenging, but consistent methods like water curing can mitigate this issue by maintaining adequate moisture levels.

5. Long-Term Durability: PKS in concrete may cause long-term durability issues like cracking, carbonation, and chloride penetration. Mitigation involves durability tests and exploring additives or coatings.

6. Standardization and Code Compliance: The research suggests that the use of PKS in concrete could potentially disrupt existing building codes and standards, necessitating collaboration with authorities and standardization bodies.

7. Economic Feasibility: Cost-effectiveness of PKS in concrete can be a concern, but mitigation involves conducting a cost-benefit analysis, evaluating potential savings and environmental benefits.

8. Environmental Impact: PKS, a sustainable alternative, raises environmental concerns due to land use and palm oil industry emissions. Mitigation measures include sourcing sustainable and certified suppliers.

9. Communication and Knowledge Transfer: The study highlights the need for effective knowledge transfer and dissemination of research findings in the construction industry, through collaboration with professionals and publication in reputable journals.

Addressing these challenges and implementing appropriate mitigations is essential for conducting a successful exploratory study of the coarse aggregate is partially substituted with PKS in concrete. Thorough planning, rigorous testing, and collaboration with industry partners can help overcome these challenges and pave the way for the adoption of sustainable construction practices.

2.9 HOW DOES PALM KERNEL SHELL (PKS) AS PARTIAL REPLACEMENT OF COARSE AGGREGATE IMPACT ON CONCRETE BASED ON LITERATURE REVIEWS?

Introduction: Sustainability and ecologically conscious methods are causing a radical change in the building sector. As a component of this evolution, researchers and engineers are exploring innovative materials and techniques that reduce the environmental footprint of concrete production. one such material that has gained attention is palm kernel shell (PKS), often considered an agricultural waste product. this essay delves into the multifaceted impact of incorporating palm kernel shell (PKS) into concrete, encompassing aspects of compressive strength, workability, durability, cost-efficiency, sustainability, and environmental impact.

Compressive Strength: Research indicates that the substitution of certain coarse aggregate with PKS in concrete can have varying effects on compressive strength. Some studies have reported an increase in compressive strength, particularly at lower replacement percentages (Awoyera et al., 2019). This improvement is attributed to the porous nature of PKS, which can act as internal curing and reduce the water-cement ratio, resulting in enhanced strength (Yusuf et al., 2019).

However, other studies have shown that high percentages of PKS replacement may lead to a reduction in compressive strength (Olutoge et al., 2015). The lower mechanical properties of PKS compared to traditional coarse aggregate can be a contributing factor to this decrease. The key here is to strike a balance in the percentage of replacement to maintain desired strength levels (Nuruddin and Shafiq, 2018).

Workability: The lightweight and porous nature of PKS can affect the workability of concrete mixes. Research suggests that PKS may require additional water to maintain workability, which can affect the water-cement ratio (Awoyera et al., 2019). To address this, researchers have proposed the use of superplasticizers and adjustments to mix proportions (Nuruddin and Shafiq, 2018).

Durability: Long-term durability is a critical consideration when using PKS in concrete. Concerns include resistance to cracking, carbonation, and chloride penetration. Some studies have indicated that the incorporation of PKS may impact the durability of concrete, particularly in aggressive environments (Nazari et al., 2019). Further research is needed to assess and enhance the long-term durability properties of PKS concrete (Yusuf et al., 2019).

Economically and Environmentally Gains: Despite the challenges, the use of PKS in concrete offers several sustainable advantages. It reduces the environmental burden associated with waste disposal as PKS is an agricultural waste product (Gupta et al., 2021). Furthermore, the lightweight nature of PKS can lead to energy savings during transportation and handling (Yusuf et al., 2019).

Standardization and Code Compliance: Incorporating PKS into concrete may not always align with existing building codes and standards, which can pose regulatory challenges. However, researchers and industry professionals are working towards the development of guidelines and standards for using PKS in concrete applications (Gupta et al., 2021).

Cost Efficiency: PKS is lightweight compared to traditional coarse aggregate. This lightweight property can lead to cost savings in terms of transportation, as less energy is required to transport the material to construction sites. Additionally, reduced transportation costs can contribute to lower carbon emissions, aligning with sustainability goals (Yusuf et al., 2019).

Waste Utilization: PKS is an agricultural waste product generated during palm oil processing. Using PKS as a construction material can be cost-efficient by repurposing a waste product that would otherwise need to be disposed of. This reduces the environmental and economic burden associated with waste disposal (Gupta et al., 2021).

Potential for Local Sourcing: In regions where palm oil production is prevalent, PKS is readily available. This local sourcing can further reduce transportation costs and contribute to cost efficiency.

Sustainability: Waste minimization is among the main sustainability benefits of utilizing PKS in concrete. PKS is an agricultural byproduct, and its use prevents the need for disposal, thus decreasing waste generation (Gupta et al., 2021).

Lower Carbon Emissions: The reduced density of concrete when PKS is used can lead to lower carbon emissions associated with transportation and production. This is in line with sustainability goals that aim to reduce the environmental impact of construction materials (Raji et al., 2021).

Renewable and Sustainable Resource: Palm trees, the source of PKS, are renewable and can be cultivated sustainably. This contrasts with the finite nature of traditional coarse aggregates like crushed stone. The use of PKS aligns with sustainable resource management practices (Nazari et al., 2019).

Energy Savings: The lightweight nature of PKS results in energy savings during transportation, handling, and construction. Reduced energy consumption is a significant factor in sustainable construction practices (Yusuf et al., 2019).

Enhanced Resource Efficiency: Using PKS in concrete in place of some of the conventional coarse aggregate can help reduce resource use, as it reduces the demand for natural coarse aggregates. This aligns with the principles of circular economy and sustainable resource management (Gong and Hu, 2018).

Conclusion: In conclusion, the application of PKS in concrete represents a long-lasting and cost-effective approach in construction. It not only reduces the environmental burden associated with waste but also offers potential cost savings in terms of transportation and waste disposal. While challenges exist, researchers and industry professionals are actively working to optimize PKS concrete mix designs, address durability concerns, and establish standardized practices for the use of PKS. This promising alternative accords mostly with concepts of sustainable construction, circular sector, as well as resource efficiency, providing an opportunity to balance cost-efficiency with sustainability in the construction industry.

2.10 PHYSICAL AND CHEMICAL PROPERTIES OF MATERIALS USED

Table 2.1: Physical properties of Cement

PHYSICAL PROPERTIES OF CEMENT	
PROPERTIES OF MATERIALS	**VALUE**
CONSISTENCY	25-35%
SETTING TIME	INITIAL SETTING: 30-45 MINUTES; FINAL SETTING: 300-400 MINUTES
COMPRESSIVE STRENGTH	3 DAY STRENGTH: ≥20 MPA; 7 DAY STRENGTH: ≥28 MPA; 28 DAY STRENGTH: ≥42.5 MPA
DENSITY	TYPICALLY, AROUND 3.15 G/CM^3
COLOR	GRAY OR WHITE
CHEMICAL COMPOSITION	PRIMARILY COMPOSED OF CLINKER, GYPSUM, AND MINOR ADDITIVES
PARTICLE SIZE DISTRIBUTION	TYPICALLY, WITH SOME PARTICLES BELOW 45 MICRONS

(SOURCE: WWW.GOOGLE.COM)

Table 2.2: Chemical Properties of Cement

CHEMICAL PROPERTIES OF CEMENT	
PROPERTY	**VALUES**
LIME	60.87
ALUMINA	5.36
SOLUBLE SILICA	20.55
IRON OXIDE	4.00
CHLORIDE	0.0173
MAGNESIA	0.74
SULFURIC ANHYDRIDE	1.83
INSOLUBLE RESIDUE	2.93
AL_2O_3/FE_2O_3	1.34

(SOURCE: WWW.DANGOTECEMENT.COM)

Table 2.3: Physical properties of Palm Kernel Shell

PHYSICAL PROPERTIES OF PALM KERNEL SHELL (PKS)	
PROPERTIES OF MATERIALS	**VALUE**
PARTICLE SIZE AND SHAPE	Typically irregular in shape, with varying sizes, but generally smaller than 20 mm in diameter
DENSITY	Lightweight with a density typically around 1.1 to 1.4 grams per cubic centimeter (g/cm^3)
MAGNETIC PROPERTIES	strongly magnetic due to their iron content, making them suitable for magnetic applications in construction.
COLOR	Usually brown or gray
THERMAL CONDUCTIVITY	Low thermal conductivity due to its insulating properties
ASH CONTENT	Contains some mineral ash, typically around 1% to 5%

(SOURCE: WWW.GOOGLE.COM)

Table 2.4: Physical properties of Coarse Aggregate

PHYSICAL PROPERTIES OF COARSE AGGREGATE	
PROPERTIES OF MATERIALS	**VALUE**
SPECIFIC GRAVITY	usually falls between 2.5 and 2.9, depending on the mineral composition of the aggregate.
BULK DENSITY	The mass densityof coarse aggregate can vary, but it is generally around 1,200 to 1,800 kilograms per cubic meter (kg/m³).
PARTICLE SIZE DISTRIBUTION	Coarse aggregate consists of particles ranging from approximately 4.75 mm (No. 4 sieve) to 50 mm (2 inches) or larger.
GEOMETRY	The configuration ofc coarse aggregate particles varies and can be angular, curved or unregular, depending on the source and processing.
COLOR	Typically ranges from gray to brown, depending on the source and composition.

(SOURCE: WWW.GOOGLE.COM)

Table 2.5: Coarse Aggregate Vs Palm Kernel Shell

CHARACTERISTICS	PALM KERNEL SHELL (PKS)	COARSE AGGREGATE (GRANITE)
Nature and Origin	Agricultural waste product from palm oil processing	Natural materials from quarries or mines
Use	Fundamental component of concrete, road construction, base material	Lightweight concrete, insulating blocks, non-structural applications
Particle Size	Typically ranges from 4.75 mm (No. 4 sieve) to 50 mm or larger	Irregular shape, smaller than 20 mm in diameter
Density	Lower density (around 1.1 to 1.4 g/cm³)	Higher density (around 2.4 to 2.9 g/cm³)
Specific Gravity	Typically, 1.1 to 1.4	Typically, 2.5 to 2.9
Durability	Durable, can withstand harsh conditions	May have lower durability and susceptibility to decay
Environmental Impact	Repurposes waste, reduces traditional coarse aggregate demand	Extraction can have environmental impact, energy consumption
Cost and Availability	Cost-effective in palm oil-producing regions, limited availability elsewhere	Availability varies, cost dependent on source and transportation

(SOURCE: WWW.GOOGLE.COM)

CHAPTER THREE

METHODOLOGY

The methodology and steps for examining the effects of partially substituting palm kernel shells (PKS) for coarse aggregate in concrete are described. This study primarily focuses on determining the characteristic properties of concrete containing different percentages of PKS as a replacement for traditional coarse aggregate. The experiment was performed in the structural laboratory of the civil engineering department of university of Benin.

The subsequent assessments should be carried out in compliance with pertinent guidelines. (BS1881) and guidelines to assess the properties of the concrete:

(i) Sieve Analysis Test

(ii) Slump Test

(iii) Water Absorption Test

(iv) ACV Test

(v) AIV Test

(vi) Compressive Test

For all tests, the coarse aggregate was replaced with palm kernel shell at 0%, 5%, 10%, 15% and 20% respectively.

Table3.1 Showing the Ratios of Replacement

RATIOS OF THE MIX PROPORTIONS FOR THE REPLACEMENT		
MIX TYPE	**TRADITIONAL COARSE AGGREGATE**	**PKS REPLACEMENT**
Control Mix	100% coarse aggregate	0% PKS
Mix A	95 % coarse aggregate	5% PKS
Mix B	90% coarse aggregate	10 % PKS
Mix C	85% coarse aggregate	15 % PKS
Mix D	80% coarse aggregate	20 % PKS

3.1 MATERIALS

The following materials were utilized in producing the concrete cubes in the laboratory.

1) Coarse Aggregate
2) Fine Aggregate
3) Cement
4) Palm Kernel Shells (PKS)
5) Water
6) Oil

3.1.1 CEMENT

Ordinary Portland cement was utilized in this investigation of grade 42.5 (Dangote cement) following through on relevant standards. This was gotten from a cement depot located by the Uselu market in Benin city. The cement was carefully handled and stored by keeping it air tight and was only opened when a sample of it was needed. To stop moisture from soaking into the cement, it was kept dry.

3.1.2 PALM KERNEL SHELLS (PKS)

Shells from palm trees were gathered from nearby Delta State factories that processed palm oil. These shells were cleaned to remove dirt, dust, and other foreign particles. They were then left to dry in a thermal chamber at a controlled temperature to eliminate any residual moisture, ensuring that the PKS were in their most stable and dry state for the experiments. The PKS were later sieved to separate them into various particle size fractions, which would be used for different levels of replacement in the concrete mixes.

3.1.3 FINE AGGREGATE

The fine aggregate, a standard river sand complying with ASTM C33 specifications, was obtained locally from Uselu market, Benin city. A sieve study of the fine aggregate revealed that it belongs to zone II since it passed through a sieve of 4.75mm and was retained on a 600microns sieve. Through careful handpicking and filtering, the fine aggregate was purified of all contaminants. In order to ensure that the fine aggregate's inherent moisture is decreased to a level that it cannot affect the test findings, it was air dried for 72 hours prior to casting.

3.1.4 COARSE AGGREGATE

Conventional coarse aggregate typically consists of crushed stone, gravel, or a combination of both. In this study, we used a locally sourced, well-graded crushed stone aggregate with a particle size ranging from 10 mm to 20 mm. The coarse aggregate was thoroughly cleaned to remove any contaminants or impurities.

It is purchased from a local supplier at Uselu market, Benin city.

3.1.5 WATER

The water utilized in the investigation was pure devoid of any pollutants or impurities. To ensure uniformity in the mix design, the quantity of water used per mix has been determined by calculating the appropriate water-to-cement ratio.

3.1.6 OIL/GREASE

Grease was used in lubricating the concrete moulds (concrete cube cavities) for the concrete to be easily separated from it after it has solidified. It was also used in lubricating the cone during slump test for easy removal to prevent any damage to the fresh concrete specimen.

3.2 SAMPLE PREPARATION

Cubic molds measuring 100 mm by 100 mm by 100 mm dimensions were applied during casting concrete specimens for various tests. To stop the concrete from adhering to the mould surfaces, the moulds were thoroughly cleaned then lubricated. Nine cube specimens were made for each blend to guarantee consistency and dependability of the outcomes. The cubes were labeled according to the mix type and curing age to maintain proper identification.

3.2.1 MACHINES AND EQUIPMENT USED DURING THE TESTS

The tools, equipment and machines used during this study include

1) Concrete mixing machine
2) Compression testing machine
3) Vibrating machine
4) Weighing machine
5) Oven
6) Shovel
7) A set of sieves
8) Head pans
9) Buckets
10) Tamping rod
11) Measuring tape
12) Slump Cone
13) Measuring cylinder
14) Hand trowel.
15) Concrete moulds
16) Head pan

3.2.2 MIX DESIGN

Identifying the ratios of different materials to produce the required qualities and performance of concrete is a critical step in the process of mix design in building construction. It aims to create a concrete mix that meets strength, durability, workability, and other specified requirements for a given construction project.

The control mix was not made with Palm Kernel Shells. additionally, 5 %, 10 %, and 15 % of the coarse aggregate was replaced with PKS.

Table 3.2: Mix Design Showing Different Percentage Replacement of Coarse Aggregate with Palm Kernel Shell

MIX DESIGN SHOWING DIFFERENT PERCENTAGE REPLACEMENT OF COARSE AGGREGATE WITH PALM KERNEL SHELL						
Percentage Replacement by weight	**No. of cubes**	**Cement (kg)**	**Fine Aggregate (kg)**	**Coarse Aggregate (kg)**	**Water/Cement ratio**	**PKS (kg)**
For 0%	**9**	**3.800**	**5.700**	**15.200**	**0.47**	**0**
For 5%	**9**	**3.800**	**5.700**	**14.440**	**0.47**	**0.760**
For 10%	**9**	**3.800**	**5.700**	**13.680**	**0.47**	**1.520**
For 15%	**9**	**3.800**	**5.700**	**12.920**	**0.47**	**2.280**
For 20%	**9**	**3.800**	**5.700**	**12.160**	**0.47**	**3.040**

3.2.3 MIX PROPORTIONS

A total of five different concrete mixes were prepared:

1. control mix (0% PKS replacement)
2. 5% PKS replacement
3. 10% PKS replacement
4. 15% PKS replacement
5. 20% PKS replacement

the mix proportions were designed to maintain a constant water-cement ratio of (0.47) for all mixes to ensure a fair comparison. The specific mix design was based on the absolute volume method, conforming to ASTM C192.

3.2.4 CURING

Proper curing is a critical aspect of concrete specimen development. The concrete samples were put through standard curing conditions to ensure consistent curing for all samples. This involved placing the specimens in a moist environment, where wet burlap and plastic sheeting were used to maintain a high level of humidity, preventing moisture loss and promoting optimal hydration of the cement. The curing duration was consistent for all specimens to eliminate curing as a variable affecting the results.

Concrete samples will be cured at specified conditions (e.g., room temperature) for different curing durations to assess strength development. Cubes cured for 3, 7, 21, and 28 days at room temp.

3.2.5 MIXING PROCEDURE

1. the needed amount of cement and sand were dry-mixed for 2 minutes.
2. palm kernel shells were then added into the mixture and given one more dry mixing for 2 minutes.
3. water was added gradually, and the mixture was wet-mixed for 5 minutes to achieve a homogeneous consistency.

3.3 PARTICLE SIZE DISTRIBUTION

3.3.1 SIEVE ANALYSIS

To determine the distribution of PKS particle sizes and traditional coarse aggregate.

The apparatus used include:

i. A set of British Standard sieve

ii. Weighing balance

iii. cleaning brush

iv. Scoop

v. Pan

3.3.1.2 PROCEDURE

1. The samples are air dried
2. Each of the sieves were weighed and recorded as W1.
3. The Sieves were arranged according to specification decreasing order of size

4. The Sample (fine aggregate), about 3000g was Sieved through a stack of Sieves by handshaking in horizontal rotation for some minutes

5. Each of the sieve and its content was weighed and recorded as W_2

6. Each sieve's weight retention was measured and recorded. by subtracting W1 from W_2

7. For the percentage retained in each sieve, weight on each sieve was divided by the original mass

3.3.2 SPECIFIC GRAVITY

Specific gravity is used to calculate the volume of voids in aggregates, aiding in the proper proportioning of concrete mixes

3.3.2.1 APPARATUS

1. Weighing Balance
2. Wire Basket
3. Container
4. Wire Hanger
5. Brush
6. Oven

3.3.2.2 PROCEDURES

1. Obtain a representative sample of the aggregate, ensuring it is free from dust, clay, or any other contaminants.
2. Dry the sample in the oven to a constant weight. This ensures that the sample is completely devoid of moisture.

3. Weigh the dry aggregate using the precise balance. Record the weight as W1.
4. Fill the container with water to a level sufficient to completely immerse the aggregates.
5. Suspend the wire basket in the water using the wire hanger, ensuring the aggregates are fully submerged.
6. Allow the aggregates to soak until all air bubbles have risen and there is no further reduction in volume.
7. Remove the basket, allowing excess water to drain off, and weigh the saturated surface-dry (SSD) aggregate. Record the weight as W2.
8. Calculate the specific gravity (G) using the formula:

$$G = \frac{\mathbf{W1}}{\dfrac{(\mathbf{W1-W2})}{(\textbf{Weight of Water Displaced})}}$$

9. The difference between the weight of the water-filled basket and the weight of the basket by itself is the weight of water displaced.
10. Clean the aggregates and apparatus thoroughly for subsequent tests.
11. It is advisable to repeat the test three times and take the average for accurate results.

3.3.2.3 PRECAUTIONS

1. Ensure that aggregates are fully saturated by allowing sufficient time for immersion.
2. Eliminate air bubbles by brushing the surface of aggregates during immersion.
3. Handle aggregates carefully to prevent damage during the testing process.

3.3.3 AGGREGATE IMPACT VALUE (AIV) TEST

AIV assesses aggregates' ability to withstand unexpected impacts or shocks and provides information on the toughness and impact resistance of aggregates.

3.3.3.1 APPARATUS

1. Impact Testing Machine

2. Cylindrical Steel Cup (diameter of at least 102 mm and a depth of at least 50 mm)
3. Metal Measure (diameter: 75 mm, depth: 50 mm)
4. Tamping Rod

3.3.3.2 PROCEDURES

1. Prepare a sample of aggregate passing the 14 mm and retained on the 10 mm sieve.
2. Place the aggregate sample in the cylindrical cup, ensuring a uniform layer.
3. Compact the aggregate using the tamping rod with 25 strokes.
4. Fix the cup firmly in the machine and apply a total of 15 blows at a uniform rate.
5. After the test, remove the crushed aggregate from the cup.
6. Calculate the aggregate impact value (AIV) using the formula:

$$\text{AIV}=\frac{\text{Weight of Aggregates Passing 2.36 mm Sieve after Test}}{\text{Original Weight of Aggregates}}\times 100$$

Lower AIV indicates stronger aggregates.

3.3.4 AGGREGATE CRUSHING VALUE (ACV) TEST

ACV assesses the ability of aggregates to withstand crushing under compressive loads and also helps in quality assurance throughout the concrete production process to ensure the aggregates have sufficient strength.

3.3.4.1 APPARATUS

1. A 150mm BS Sieve
2. Cylindrical Metal Measure (115 mm diameter and 180 mm height)
3. Tamping Rod
4. Weighing Balance

3.3.4.2 PROCEDURES

1. Prepare a aggregate sample that passed the 12.5 mm sieve and was kept on the 10 mm sieve.
2. Place the aggregate in the cylindrical measure three layers, with each layer subjected to 25 strokes using the tamping rod.
3. After tamping, weigh the cylindrical measure with the aggregate.
4. Sieve the crushed aggregate through a 2.36 mm IS sieve.
5. Calculate the aggregate crushing value (ACV) using the formula:

$$ACV=\frac{\text{Weight of Fines}}{\text{Weight of Aggregates}}\times 100$$

Lower ACV indicates higher crushing strength of aggregates.

3.3.5 SLUMP TEST

The purpose of the concrete slump test is to evaluate the homogeneity or flowability of the laboratory-prepared fresh concrete.

The apparatus used include:

a. Slump cone

b. Base plate

c. Measuring tape

d. Tamping rod

3.3.5.1 PROCEDURES

1) The inside surface of the slump cone was cleaned and then coated with oil.

2) Next, the cone was set on a non-porous, smooth, horizontal base plate.

3) The cone was then filled with already mixed fresh concrete in 3 approximately equal layers.

4) Tamping was done at each layer with 25 strokes.

5) The excess concrete was removed with trowel. The cone was raised immediately with the base supported.

6) A measuring tape was used to determine the slump, which is the difference between the cone's height and the height of the concrete specimen.

3.3.6 COMPRESSIVE STRENGTH TEST

Compressive strength testing is an essential test. in evaluating the concrete's ability to withstand loads. It was carried out using a compression testing machine. Cube samples were examined after 3, 7, 21, and 28 days of cure for every mixture. This allowed for an assessment of the growth of strength with time and a comparison of PKS-replaced concrete with the control mix.

3.3.6.1 PROCEDURE

(i) The cubes were removed from the curing tank at different curing age.

(ii) The cubes were then placed on a platform and allowed to dry for about an hour.

(iii) Weight of the concrete cubes are obtained using a weighing balance.

(iv) The cubes were centrally aligned on the base plate of the Universal testing machine (UTM). The machine is started and readings is taken immediately the specimen fails

$$\textbf{Compressive Strength (N/}mm^2\textbf{)} = \frac{\textbf{Maximum Load (KN)}}{\textbf{Cross Sectional Area (mm}^2\textbf{)}}$$

3.3.7 WATER ABSORPTION TEST

The water absorption test for aggregates is conducted to measure the amount of water absorbed by the aggregate particles under specific conditions.

3.3.7.1 APPARATUS

1. Sensitive weighing Balance
2. Drying Oven
3. Container
4. Brush
5. Measuring Cylinder

3.3.7.2 PROCEDURES

1. Obtain a representative sample of the aggregate, ensuring it is free from dust and foreign particles.
2. Determine the initial mass of the dry sample.
3. Place the sample in the drying oven at a temperature of 105 ± 5°C until a constant mass is achieved.
4. Cool the sample to room temperature in a desiccator.
5. Immerse the dried sample in water at a temperature of 22 ± 2°C for a specified duration, typically 24 hours.
6. After immersion, remove the excess water from the surface of the aggregate using a damp cloth.
7. Weigh the aggregate after immersion and removal of excess surface water.
8. Dry the aggregate again in the oven at 105 ± 5°C until a constant mass is achieved.

9. Weigh the aggregate after drying from immersion.

10. Calculate the water absorption using the formula:

$$\text{Water Absorption (\%)} = \frac{(\text{Weight after Immersion} - \text{Dry Weight})}{\text{Dry Weight}} \times 100$$

3.3.7.3 PRECAUTION

1. Ensure accurate weighing at each stage to maintain precision.

2. Use caution when handling hot samples and equipment.

3. Conduct tests in accordance with relevant standards or specifications.

CHAPTER FOUR

RESULTS AND DISCUSSION

In this chapter, we present a comprehensive analysis of the results obtained from the experiments conducted in Chapter 3. The data and findings are meticulously examined to explore the impact of partial replacement of traditional coarse aggregate with Palm Kernel Shells (PKS) on various properties of concrete. The chapter is organized into sections, each focusing on specific properties and aspects of concrete performance.

The tests carried out include:

(i) Sieve Analysis Test

(ii) Slump Test

(iii) Water Absorption Test

(iv) ACV Test

(v) AIV Test

(vi) Compressive Test

For all tests, the coarse aggregate was replaced with palm kernel shell at 0%, 5%, 10%, 15% and 20% respectively.

4.1 SIEVE ANALYSIS

4.1.1 PARTICLE SIZE DISTRIBUTION OF PALM KERNEL SHELLS

The sieve analysis revealed the particle size distribution of PKS. This information is essential for understanding how PKS compares to conventional coarse aggregate. Figure 4.1 illustrates the particle size distribution of PKS in comparison to traditional coarse aggregate.

Table 4.1: Result from Sieve Analysis for Coarse aggregate

Sieve Sizes	Mass Retained (g)	Percentage Retained (%)	Cumulative Percentage Retained (%)	Percentage Passing (%)
19.00mm	80.00	0.89	0.89	99.11
13.26mm	600.00	6.67	7.56	92.44
10.00mm	3910.00	43.44	51.00	49.00
8mm	3780.00	42.00	93.00	7.00
5mm	630.00	7.00	100.00	0.00
Pan	0.00	0.00	100.00	0.00

Total Mass of granite tested = 9000g **(9kg)**

Table 4.2: Result from Sieve Analysis for PKS

Sieve Sizes	Mass Retained (kg)	Percentage Retained (%)	Cumulative Percentage Retained (%)	Percentage Passing (%)
19.00mm	0.00	0.00	0.00	100.00
13.26mm	0.90	18.00	18.00	82.00
10.00mm	2.70	54.00	72.00	28.00
8mm	0.75	15.00	87.00	13.00
5mm	0.55	11.00	98.00	2.00
Pan	0.11	2.00	100	0.00

Total Mass of sand tested = 5000.00g (5kg)

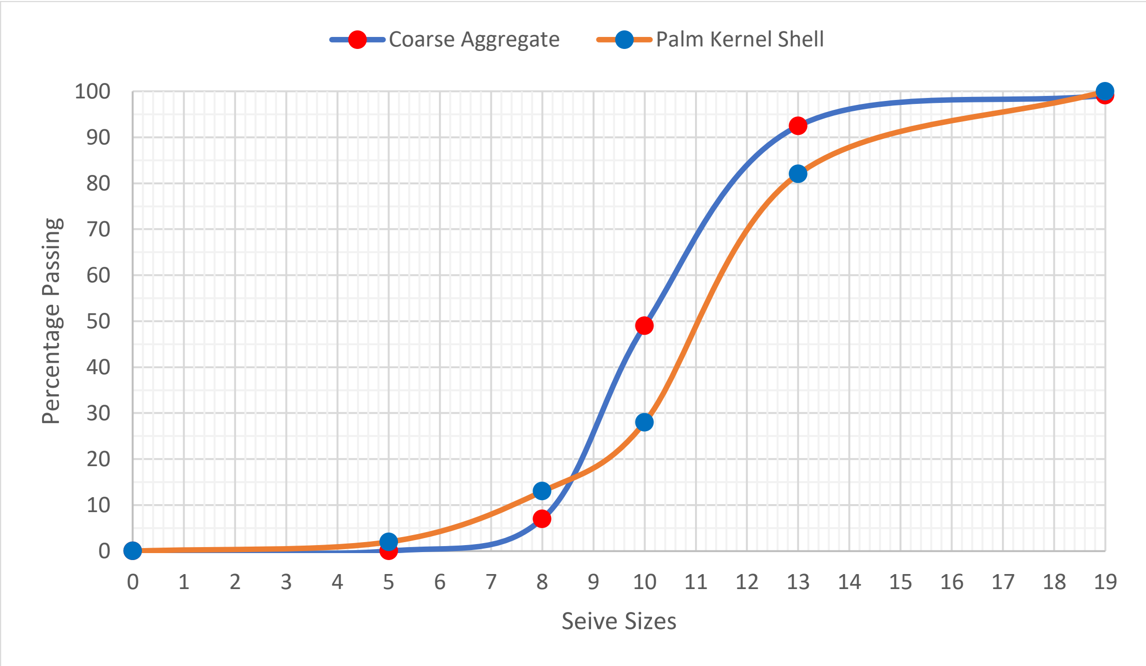

Figure 4.1: Graph Showing Particle Distribution for the Coarse Aggregate and PKS

The figure shows that PKS exhibits a particle size distribution that varies from traditional coarse aggregate. While PKS contains a significant proportion of fine particles, it is also notable that PKS particles are generally lighter in weight than conventional aggregate, which is expected given the low density of PKS.

Table 4.3: Result from Sieve Analysis for fine aggregate

Sieve Sizes	Mass Retained (g)	Percentage Retained (%)	Cumulative percentage Retained (%)	Percentage Passing (%)
4.75mm	0.00	0.00	0.00	100.00
2.36mm	2.30	2.30	2.30	97.70
2.00mm	2.85	2.85	5.15	94.85
1.18mm	10.88	10.88	16.03	83.97
600µm	33.03	33.03	49.06	50.94
425 µm	13.00	13.00	62.06	37.94
300 µm	7.94	7.94	70.00	30.00
212 µm	20.10	20.10	90.10	9.90
150 µm	3.69	3.69	93.79	6.21
75 µm	3.45	3.45	97.24	2.76
Pan	2.63	2.63	99.87	0.13
Total	99.87		∑F=231.18	

Total Mass of sand tested = 100.00g

$$\textbf{\% Retained} = \frac{\textit{Mass retained}}{\textit{Total Mass tested}} \times 100$$

Cumulative % Retained = % retained + the succeeding % retained

% passing = 100-Cummulative % Retained

$$\text{Fineness Modulus} = \frac{\sum F}{100} = \frac{213.18}{100} = 2.1318$$

Since it ranges from 2.2-2.6 it is fine sand.

% loss < 0.5

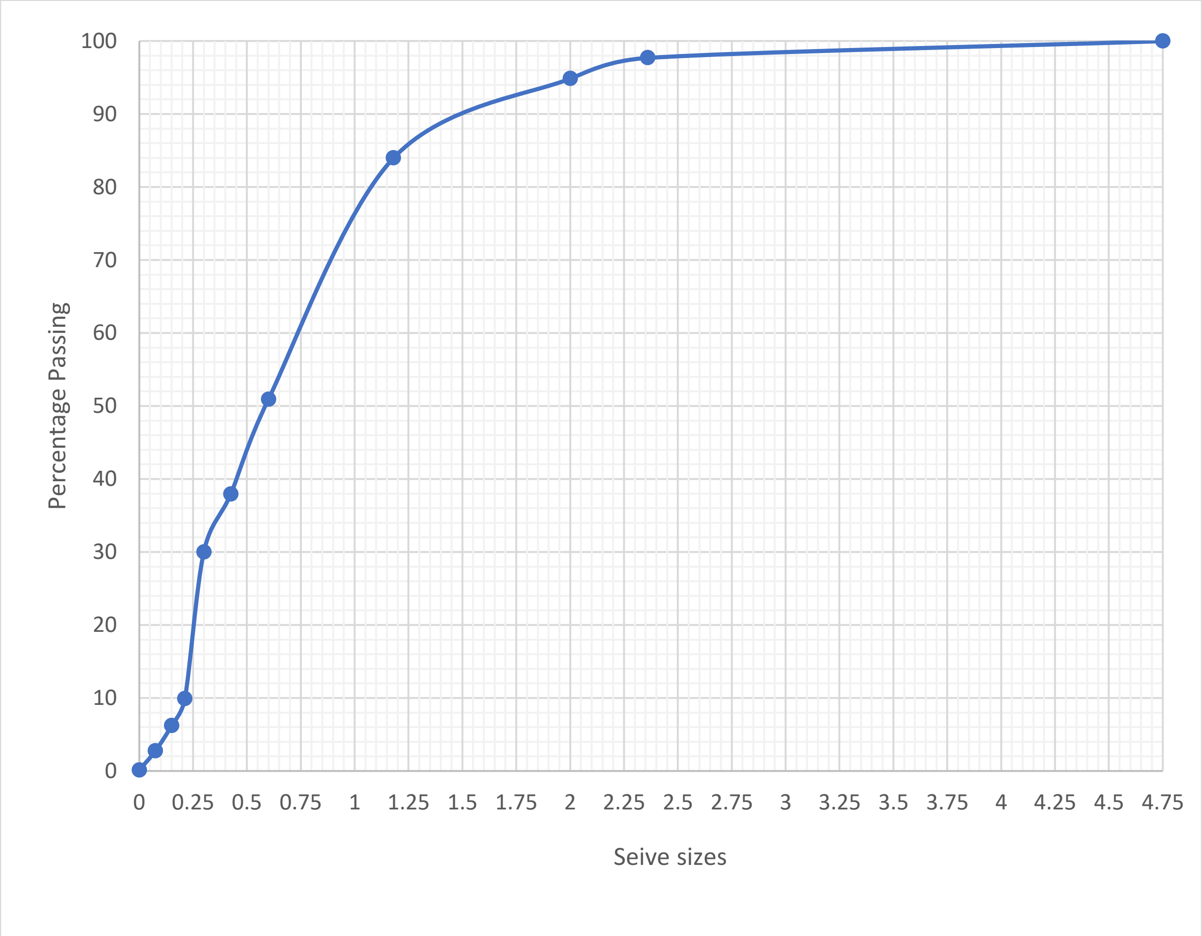

Fig 4.2 Showing Particle Distribution of the Natural Fine aggregate

4.2 AIV AND ACV TEST

4.2.1 AIV TEST RESULTS

<u>TEST A</u>

Mass of aggregate used= 327.5g

Mass of aggregate passing 2.36mm sieve = 113.5g

Mass of aggregate retained in 2.36mm sieve = 213.15g

$$\text{AIV} = \frac{\textbf{Mass of aggregate passing 2.36mm sieve}}{\textbf{Mass of aggregate retained in 2.36mm sieve}} \times \mathbf{100}$$

$$= \frac{\mathbf{113.5}}{\mathbf{327.5}} \times \mathbf{100}$$

$$= \mathbf{34.66}$$

<u>TEST B</u>

Mass of aggregate used= 331.30g

Mass of aggregate passing 2.36mm sieve = 101.3g

Mass of aggregate retained in 2.36mm sieve = 229.85g

$$\text{AIV} = \frac{\textbf{Mass of aggregate passing 2.36mm sieve}}{\textbf{Mass of aggregate retained in 2.36mm sieve}} \times \mathbf{100}$$

$$= \frac{\mathbf{101.3}}{\mathbf{331.3}} \times \mathbf{100}$$

$$= \mathbf{30.58}$$

$$\textbf{Average AIV} = \frac{\textbf{TEST A+TEST B}}{\mathbf{2}}$$

$$= \frac{\mathbf{34.66+30.58}}{\mathbf{2}}$$

$$= \mathbf{32.62}$$

INTERPRETATION OF RESULTS

Table 4.4: AIV result interpretation

AIV	CLASSIFICATION
< 10%	Exceptionally Strong
10 – 20%	Strong
20- 30%	Satisfactory for road surfacing
>35%	Weak for road surfacing

CHECK

Average Mass of aggregate used = $\frac{\mathbf{327.5+331.3}}{\mathbf{2}}$

=329.4

10% of 329.4 = 32.94

Since **32.94 < 32.62** (Average AIV value)

Hence AIV is <10% (EXCEPTIONALLY STRONG)

4.2.2 ACV TEST RESULTS

TEST A

Mass of aggregate used= 2784g

Mass of aggregate passing 2.36mm sieve = 806.9g

Mass of aggregate retained in 2.36mm sieve = 1976.3g

AIV = $\frac{\textbf{Mass of aggregate passing 2.36mm sieve}}{\textbf{Mass of aggregate retained in 2.36mm sieve}} \times \mathbf{100}$

= $\frac{\mathbf{806.9}}{\mathbf{2784}} \times \mathbf{100}$

$=$ **28.983**

TEST B

Mass of aggregate used= 2735g

Mass of aggregate passing 2.36mm sieve = 805.5g

Mass of aggregate retained in 2.36mm sieve = 1929g

AIV = $\frac{\textbf{Mass of aggregate passing 2.36mm sieve}}{\textbf{Mass of aggregate retained in 2.36mm sieve}} \times \mathbf{100}$

= $\frac{\mathbf{805.5}}{\mathbf{2735}} \times \mathbf{100}$

$=$ **29.452**

Average AIV = $\frac{\textbf{TEST A+TEST B}}{\mathbf{2}}$

$= \frac{\mathbf{28.983+29.452}}{\mathbf{2}}$

$=$**29.22**

4.3 RESULTS FROM SLUMP TEST

The slump test is used to evaluate the workability or consistency of the concrete mixes. The results of the slump tests conducted on each mix, including the control and PKS-replaced mixes, are presented in Table 4.5.

Table 4.5: Results from Slump test

SAMPLE NO	SLUMP (MM)
0% PKS REPLACEMENT	10
5% PKS REPLACEMENT	13
10% PKS REPLACEMENT	19
15% PKS REPLACEMENT	21
20% PKS REPLACEMENT	24

The table shows the slump values for each mix. It can be observed that as the percentage of PKS replacement increases, there is a general increase in the slump value. This indicates that the workability of the concrete increases with higher levels of PKS replacement. The discussion in this section will explore the implications of this increased workability on construction practices and concrete placement.

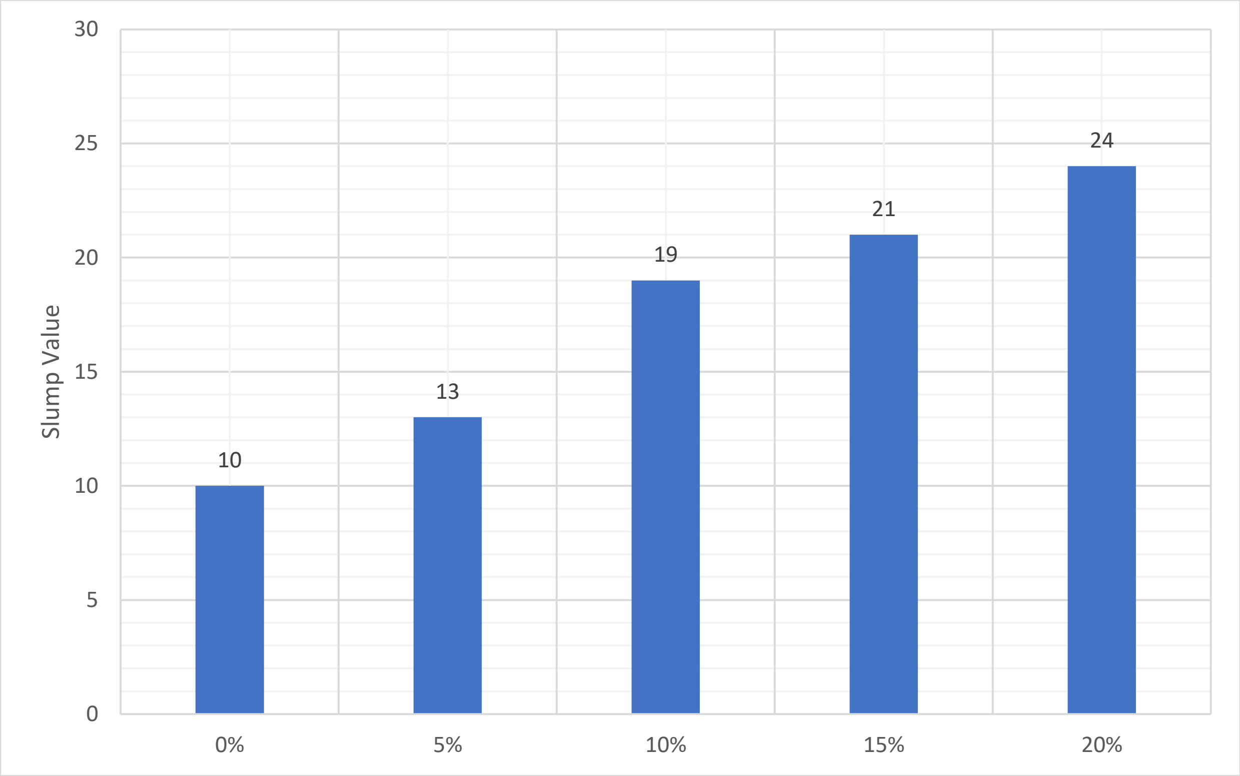

Fig 4.3 Showing the Variation of The Slump With % Increase in Replacement

4.4 COMPRESSIVE STRENGTH TEST

The primary focus of this study was the assessment of compressive strength. Once the curing period was completed, the concrete specimens were subjected to compressive strength testing. This testing was conducted using a hydraulic compression testing machine. Each specimen was carefully placed between the platens of the compression testing machine. Care was taken to ensure that the load was evenly distributed across the specimen. A gradual and continuous load was applied to the specimen until it failed. The load at failure, along with the dimensions of the specimen, was recorded.

Following the test, the recorded data serves as the basis for calculating the compressive strength of the concrete specimen.

This calculation is performed by dividing the maximum applied load by the specimen's cross-sectional area. The formula is straightforward:

Compressive Strength (KN/ mm^2)= $\frac{\textbf{Maximum Load (KN)}}{\textbf{Cross Sectional Area (mm}^2\textbf{)}}$

Water-Cement ratio used: $\frac{\textbf{Water}}{\textbf{Cement}}$ **= 0.47**

Table 4.6: Table Showing Compressive strength of 0% Percentage Replacement of Coarse Aggregate with PKS for 3days

CUBE TEST					
COMPRESSIVE STRENGTH OF 0% PERCENTAGE REPLACEMENT OF COARSE AGGREGATE WITH PALM KERNEL SHELL FOR 3DAYS					
SPECIMEN	**WEIGHT (Kg)**	**AREA (mm^2)**	**FAILURE LOAD (KN)**	**COMPRESSIVE STRENGTH (N/ mm^2)**	**AVERAGE COMPRESSIVE STRENGTH (N/ mm^2)**
TEST A	**2.681**	**100 x100**	**134.25**	**13.425**	**15.176**
TEST B	**2.650**	**100 x100**	**162.24**	**16.24**	
TEST C	**2.690**	**100 x100**	**158.79**	**15.879**	

Table 4.7: Table Showing Compressive strength of 0% Percentage Replacement of Coarse Aggregate with PKS for 7days

CUBE TEST					
COMPRESSIVE STRENGTH OF 0% PERCENTAGE REPLACEMENT OF COARSE AGGREGATE WITH PALM KERNEL SHELL FOR 7DAYS					
SPECIMEN	**WEIGHT (Kg)**	**AREA (mm^2)**	**FAILURE LOAD (KN)**	**COMPRESSIVE STRENGTH (N/ mm^2)**	**AVERAGE COMPRESSIVE STRENGTH (N/ mm^2)**
TEST A	**2.403**	**100 x100**	**221.21**	**22.121**	**22.435**
TEST B	**2.416**	**100 x100**	**225.72**	**22.572**	
TEST C	**2.422**	**100 x100**	**226.12**	**22.612**	

Table 4.8: Table Showing Compressive strength of 0% Percentage Replacement of Coarse Aggregate with PKS for 14days

CUBE TEST					
COMPRESSIVE STRENGTH OF 0% PERCENTAGE REPLACEMENT OF COARSE AGGREGATE WITH PKS FOR 14DAYS					
SPECIMEN	WEIGHT (Kg)	AREA (mm^2)	FAILURE LOAD (KN)	COMPRESSIVE STRENGTH (N/ mm^2)	AVERAGE COMPRESSIVE STRENGTH (N/ mm^2)
TEST A	2.445	100 x100	292.15	29.215	29.285
TEST B	2.464	100 x100	297.57	29.757	
TEST C	2.408	100 x100	288.83	28.883	

Table 4.9: Table Showing Compressive strength of 0% Percentage Replacement of Coarse Aggregate with PKS for 28days.

CUBE TEST					
COMPRESSIVE STRENGTH OF 0% PERCENTAGE REPLACEMENT OF COARSE AGGREGATE WITH PKS FOR 28DAYS					
SPECIMEN	WEIGHT (Kg)	AREA (mm^2)	FAILURE LOAD (KN)	COMPRESSIVE STRENGTH (N/ mm^2)	AVERAGE COMPRESSIVE STRENGTH (N/ mm^2)
TEST A	2.553	100 x100	310.55	31.055	30.8673
TEST B	2.53	100 x100	315.32	31.532	
TEST C	2.545	100 x100	300.15	30.015	

Table 4.10: Table Showing Compressive strength of 5% Percentage Replacement of Coarse Aggregate with PKS for 3days

CUBE TEST					
COMPRESSIVE STRENGTH OF 5% PERCENTAGE REPLACEMENT OF COARSE AGGREGATE WITH PKS FOR 3DAYS					
SPECIMEN	WEIGHT (Kg)	AREA (mm^2)	FAILURE LOAD (KN)	COMPRESSIVE STRENGTH (N/ mm^2)	AVERAGE COMPRESSIVE STRENGTH (N/ mm^2)
TEST A	2.203	100 x100	122.03	12.203	10.845
TEST B	2.256	100 x100	102.43	10.243	
TEST C	2.215	100 x100	100.89	10.089	

Table 4.11: Table Showing Compressive strength of 5% Percentage Replacement of Coarse Aggregate with PKS for 7days

CUBE TEST					
COMPRESSIVE STRENGTH OF 5% PERCENTAGE REPLACEMENT OF COARSE AGGREGATE WITH PKS FOR 7DAYS					
SPECIMEN	WEIGHT (Kg)	AREA (mm^2)	FAILURE LOAD (KN)	COMPRESSIVE STRENGTH (N/ mm^2)	AVERAGE COMPRESSIVE STRENGTH (N/ mm^2)
TEST A	2.434	100 x100	219.02	21.902	20.5077
TEST B	2.404	100 x100	213.49	21.349	
TEST C	2.438	100 x100	182.72	18.272	

Table 4.12: Table Showing Compressive strength of 5% Percentage Replacement of Coarse Aggregate with PKS for 14days

CUBE TEST					
COMPRESSIVE STRENGTH OF 5% PERCENTAGE REPLACEMENT OF COARSE AGGREGATE WITH PKS FOR 14DAYS					
SPECIMEN	WEIGHT (Kg)	AREA (mm^2)	FAILURE LOAD (KN)	COMPRESSIVE STRENGTH (N/ mm^2)	AVERAGE COMPRESSIVE STRENGTH (N/ mm^2)
TEST A	2.425	100 x100	286.09	28.609	26.1433
TEST B	2.419	100 x100	297.36	29.736	
TEST C	2.414	100 x100	200.85	20.085	

Table 4.13: Table Showing Compressive strength of 5% Percentage Replacement of Coarse Aggregate with PKS for 28days

CUBE TEST					
COMPRESSIVE STRENGTH OF 5% PERCENTAGE REPLACEMENT OF COARSE AGGREGATE WITH PKS FOR 28DAYS					
SPECIMEN	WEIGHT (Kg)	AREA (mm^2)	FAILURE LOAD (KN)	COMPRESSIVE STRENGTH (N/ mm^2)	AVERAGE COMPRESSIVE STRENGTH (N/ mm^2)
TEST A	2.442	100 x100	292.95	29.295	29.372
TEST B	2.459	100 x100	291.09	29.109	
TEST C	2.445	100 x100	297.12	29.712	

Table 4.14: Table Showing Compressive strength of 10% Percentage Replacement of Coarse Aggregate with PKS for 3days

CUBE TEST					
COMPRESSIVE STRENGTH OF 10% PERCENTAGE REPLACEMENT OF COARSE AGGREGATE WITH PKS FOR 3DAYS					
SPECIMEN	WEIGHT (Kg)	AREA (mm^2)	FAILURE LOAD (KN)	COMPRESSIVE STRENGTH (N/ mm^2)	AVERAGE COMPRESSIVE STRENGTH (N/ mm^2)
TEST A	2.256	100 x100	82.54	8.254	9.343
TEST B	2.054	100 x100	92.84	9.284	
TEST C	2.209	100 x100	104.91	10.491	

Table 4.15: Table Showing Compressive strength of 10% Percentage Replacement of Coarse Aggregate with PKS for 7days

CUBE TEST					
COMPRESSIVE STRENGTH OF 10% PERCENTAGE REPLACEMENT OF COARSE AGGREGATE WITH PKS FOR 7DAYS					
SPECIMEN	WEIGHT (Kg)	AREA (mm^2)	FAILURE LOAD (KN)	COMPRESSIVE STRENGTH (N/ mm^2)	AVERAGE COMPRESSIVE STRENGTH (N/ mm^2)
TEST A	2.256	100 x100	183.36	18.336	18.38
TEST B	2.2	100 x100	185.11	18.511	
TEST C	2.33	100 x100	182.93	18.293	

Table 4.16: Table Showing Compressive strength of 10% Percentage Replacement of Coarse Aggregate with PKS for 14days

CUBE TEST					
COMPRESSIVE STRENGTH OF 10% PERCENTAGE REPLACEMENT OF COARSE AGGREGATE WITH PKS FOR 14DAYS					
SPECIMEN	WEIGHT (Kg)	AREA (mm^2)	FAILURE LOAD (KN)	COMPRESSIVE STRENGTH (N/ mm^2)	AVERAGE COMPRESSIVE STRENGTH (N/ mm^2)
TEST A	2.286	100 x100	208.17	20.817	20.5227
TEST B	2.246	100 x100	217.94	21.794	
TEST C	2.078	100 x100	189.57	18.957	

Table 4.17: Table Showing Compressive strength of 10% Percentage Replacement of Coarse Aggregate with PKS for 28days

CUBE TEST					
COMPRESSIVE STRENGTH OF 10% PERCENTAGE REPLACEMENT OF COARSE AGGREGATE WITH PKS FOR 28DAYS					
SPECIMEN	WEIGHT (Kg)	AREA (mm^2)	FAILURE LOAD (KN)	COMPRESSIVE STRENGTH (N/ mm^2)	AVERAGE COMPRESSIVE STRENGTH (N/ mm^2)
TEST A	2.374	100 x100	200.16	20.016	21.12
TEST B	2.400	100 x100	218.01	21.801	
TEST C	2.287	100 x100	215.43	21.543	

Table 4.18: Table Showing Compressive strength of 15% Percentage Replacement of Coarse Aggregate with PKS for 3days

CUBE TEST					
COMPRESSIVE STRENGTH OF 15% PERCENTAGE REPLACEMENT OF COARSE AGGREGATE WITH PKS FOR 3DAYS					
SPECIMEN	WEIGHT (Kg)	AREA (mm^2)	FAILURE LOAD (KN)	COMPRESSIVE STRENGTH (N/ mm^2)	AVERAGE COMPRESSIVE STRENGTH (N/ mm^2)
TEST A	2.193	100 x100	80.65	8.065	8.448
TEST B	2.104	100 x100	82.93	8.293	
TEST C	2.055	100 x100	89.86	8.986	

Table 4.19: Table Showing Compressive strength of 15% Percentage Replacement of Coarse Aggregate with PKS for 7days

CUBE TEST					
COMPRESSIVE STRENGTH OF 15% PERCENTAGE REPLACEMENT OF COARSE AGGREGATE WITH PKS FOR 7DAYS					
SPECIMEN	WEIGHT (Kg)	AREA (mm^2)	FAILURE LOAD (KN)	COMPRESSIVE STRENGTH (N/ mm^2)	AVERAGE COMPRESSIVE STRENGTH (N/ mm^2)
TEST A	2.588	100 x100	167.88	16.788	15.741
TEST B	2.528	100 x100	149.58	14.958	
TEST C	2.550	100 x100	154.77	15.477	

Table 4.20: Table Showing Compressive strength of 15% Percentage Replacement of Coarse Aggregate with PKS for 14days

CUBE TEST					
COMPRESSIVE STRENGTH OF 15% PERCENTAGE REPLACEMENT OF COARSE AGGREGATE WITH PKS FOR 14DAYS					
SPECIMEN	WEIGHT (Kg)	AREA (mm^2)	FAILURE LOAD (KN)	COMPRESSIVE STRENGTH (N/ mm^2)	AVERAGE COMPRESSIVE STRENGTH (N/ mm^2)
TEST A	2.351	100 x100	150.82	15.082	14.865
TEST B	2.355	100 x100	149.88	14.988	
TEST C	2.454	100 x100	145.25	14.525	

Table 4.21: Table Showing Compressive strength of 15% Percentage Replacement of Coarse Aggregate with PKS for 28days

CUBE TEST					
COMPRESSIVE STRENGTH OF 15% PERCENTAGE REPLACEMENT OF COARSE AGGREGATE WITH PKS FOR 28DAYS					
SPECIMEN	WEIGHT (Kg)	AREA (mm^2)	FAILURE LOAD (KN)	COMPRESSIVE STRENGTH (N/ mm^2)	AVERAGE COMPRESSIVE STRENGTH (N/ mm^2)
TEST A	2.351	100 x100	194.22	19.422	18.7633
TEST B	2.407	100 x100	181.43	18.143	
TEST C	2.455	100 x100	187.25	18.725	

Table 4.22: Table Showing Compressive strength of 20% Percentage Replacement of Coarse Aggregate with PKS for 3days

CUBE TEST					
COMPRESSIVE STRENGTH OF 20% PERCENTAGE REPLACEMENT OF COARSE AGGREGATE WITH PKS FOR 3DAYS					
SPECIMEN	WEIGHT (Kg)	AREA (mm^2)	FAILURE LOAD (KN)	COMPRESSIVE STRENGTH (N/ mm^2)	AVERAGE COMPRESSIVE STRENGTH (N/ mm^2)
TEST A	2.033	100 x100	76.47	7.647	8.011
TEST B	2.101	100 x100	84.14	8.414	
TEST C	2.015	100 x100	79.72	7.972	

Table 4.23: Table Showing Compressive strength of 20% Percentage Replacement of Coarse Aggregate with PKS for 7days

CUBE TEST					
COMPRESSIVE STRENGTH OF 20% PERCENTAGE REPLACEMENT OF COARSE AGGREGATE WITH PKS FOR 7DAYS					
SPECIMEN	WEIGHT (Kg)	AREA (mm^2)	FAILURE LOAD (KN)	COMPRESSIVE STRENGTH (N/ mm^2)	AVERAGE COMPRESSIVE STRENGTH (N/ mm^2)
TEST A	2.239	100 x100	99.47	9.947	10.8227
TEST B	2.198	100 x100	114.41	11.441	
TEST C	2.178	100 x100	110.8	11.08	

Table 4.24: Table Showing Compressive strength of 20% Percentage Replacement of Coarse Aggregate with PKS for 14days

CUBE TEST					
COMPRESSIVE STRENGTH OF 20% PERCENTAGE REPLACEMENT OF COARSE AGGREGATE WITH PKS FOR 14DAYS					
SPECIMEN	WEIGHT (Kg)	AREA (mm^2)	FAILURE LOAD (KN)	COMPRESSIVE STRENGTH (N/ mm^2)	AVERAGE COMPRESSIVE STRENGTH (N/ mm^2)
TEST A	2.330	100 x100	121.14	12.114	12.6153
TEST B	2.396	100 x100	137.28	13.728	
TEST C	2.398	100 x100	120.04	12.004	

Table 4.25: Table Showing Compressive strength of 20% Percentage Replacement of Coarse Aggregate with PKS for 28days

CUBE TEST					
COMPRESSIVE STRENGTH OF 20% PERCENTAGE REPLACEMENT OF COARSE AGGREGATE WITH PKS FOR 28DAYS					
SPECIMEN	WEIGHT (Kg)	AREA (mm^2)	FAILURE LOAD (KN)	COMPRESSIVE STRENGTH (N/ mm^2)	AVERAGE COMPRESSIVE STRENGTH (N/ mm^2)
TEST A	2.336	100 x100	141.33	14.133	14.4653
TEST B	2.358	100 x100	140.99	14.099	
TEST C	2.511	100 x100	151.64	15.164	

Table 4.26: Table Showing Average Compressive strength at 28days for different PKS replacement

SPECIMEN	PKS Percentage (%)	Compressive Strength (MPa)
Control Mix	0%	30.8673
TEST A	5%	29.372
TEST B	10%	21.12
TEST C	15%	18.7633
TEST D	20%	14.4653

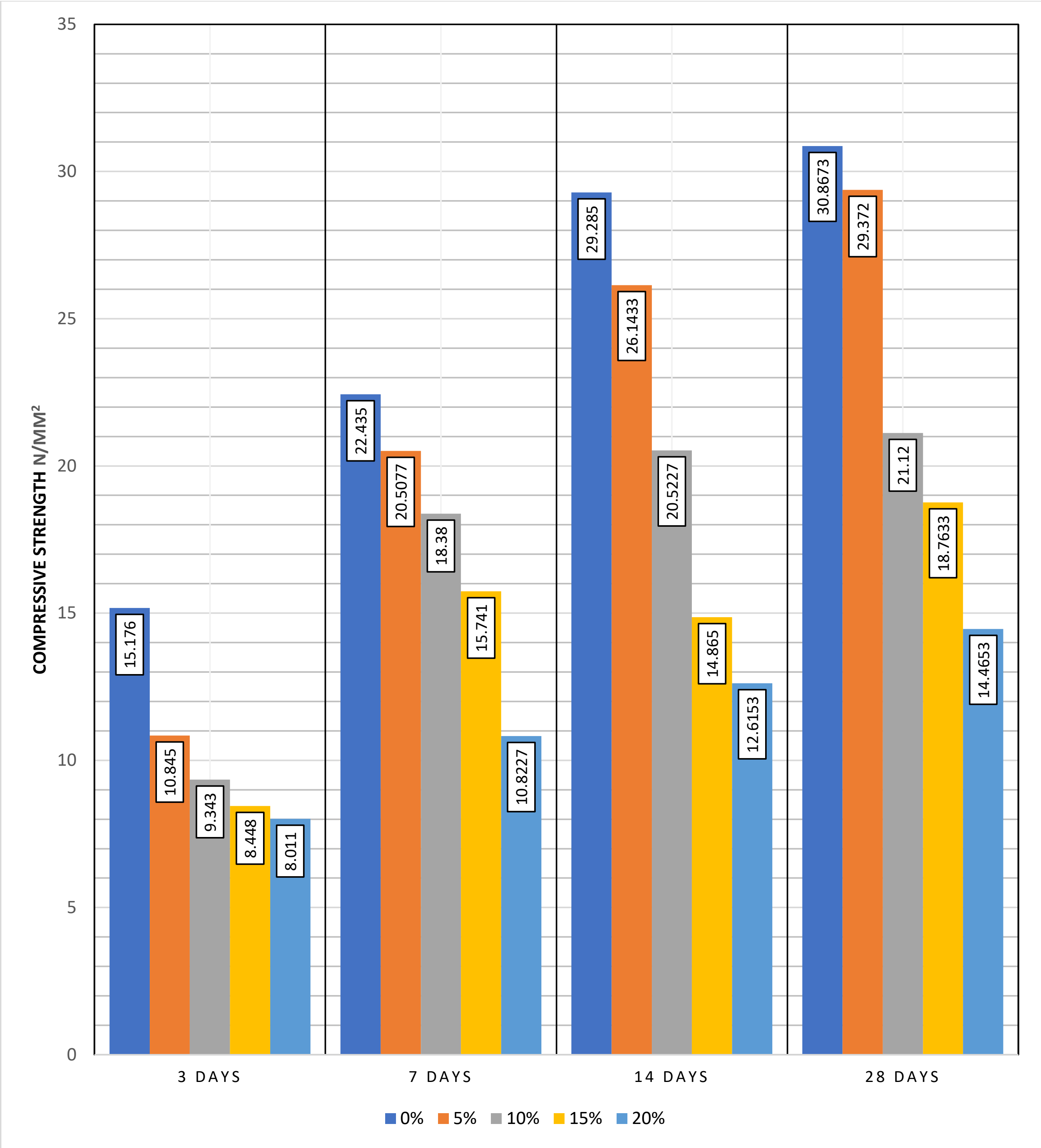

Figure 4.4: Chart Showing Average Compressive Strength for Various Proportion of Palm Kernel Shell

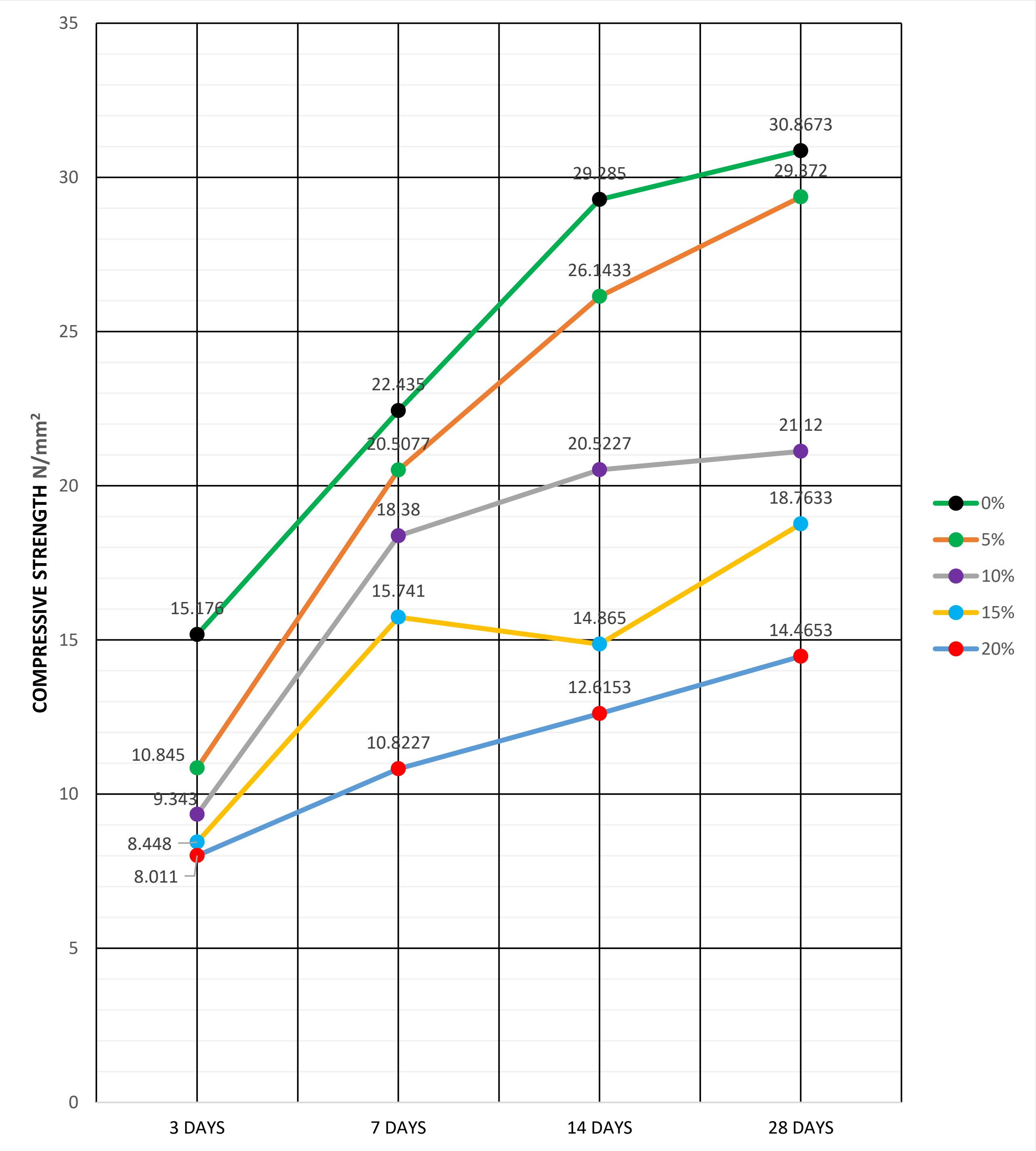

Figure 4.5: Graph Showing Average Compressive Strength for Various Proportion of Palm Kernel Shell

4.4 WATER ABSORPTION RESULTS

The movement of liquids through porous materials brought on by surface tension in the capillaries is known as water absorption. The highest amount of water absorbed by the palm kennel shell, as determined by the given result, indicates that the material has a higher absorption capacity than a typical coarse aggregate.

Table 4.25: Water absorption capacity of control concrete with 0% replacement

SAMPLE	WEIGHT OF CONCRETE BEFORE IMMERSION (KG)	WEIGHT OF CONCRETE AFTER IMMERSION (KG)	ABSORPTION GAIN (KG)	% GAIN OF WATER
TEST A	2.513	2.618	0.105	4.18
TEST B	2.511	2.886	0.375	14.93
TEST C	2.619	2.738	0.119	4.54
Average	2.548	2.614	0.066	2.59

Table 4.26: Water absorption capacity at of the casted concrete at varying replacement percentage

Cube no.	% Replacement of coarse aggregate	Weight before immersion (kg)	Weight after immersion (kg)	Absorption gain (kg)	% Gain in moisture	Average % gain in moisture
A_{11}	5%	2.722	2.715	0.007	2.57	**4.52333**
A_{12}		2.712	2.734	0.022	8.11	
A_{13}		2.694	2.702	0.008	2.89	
B_{11}		2.605	2.671	0.066	2.54	

B_{21}	10%	2.626	2.683	0.057	2.22	**2.04667**
B_{22}		2.611	2.647	0.036	1.38	
C_{11}	15%	2.547	2.599	0.052	2.04	**1.47667**
C_{21}		2.508	2.550	0.042	1.67	
C_{22}		2.515	2.533	0.018	0.72	
E_{11}	20%	2.522	2.548	0.026	1.03	**2.50667**
E_{21}		2.417	2.493	0.073	3.02	
E_{22}		2.451	2.536	0.085	3.47	

4.4 DISCUSSION OF RESULTS

Fig 4.5 shows that the slump of the fresh concrete decreased with increase in the replacement of the fine aggregate. This implies that the presence of PKS in the concrete decreased its workability. however, the average slump values shows that all the replacement percentages passed the slump test which is expected to range between 10mm to 30mm for the designed concrete grade (C30).

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.0 CONCLUSION

Palm kernel shell can be utilized for applications requiring low to moderate strength and generally has good potential as a coarse aggregate in the construction of lightweight buildings. The results of the study demonstrate a clear trend - as the percentage of PKS replacement increased, the compressive strength of the concrete decreased. The control group, with no PKS content, exhibited the highest compressive strength, while the mixture with the highest PKS content (20%) exhibited the lowest.

The reduction in compressive strength with increased PKS content can be attributed to the lightweight and porous nature of PKS. This characteristic leads to a decrease in the overall density of the concrete and increased porosity, which negatively impacts the load-bearing capacity of the material.

Differences in properties between PKS and conventional aggregates can weaken the interfacial bonding between the aggregates and the cement matrix. This may have further contributed to the observed reduction in compressive strength.

Overall, it is important to balance sustainability and structural performance when incorporating PKS into concrete mix designs. The results suggest that while high PKS content may lead to a reduction in compressive strength, PKS may find optimal applications in areas where lower structural weight is desirable, such as in non-load-bearing elements or lightweight concrete construction.

5.1 RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made to improve the effect of partial replacement of coarse aggregate with PKS in concrete production:

1. Research and Development: Further research and development efforts are needed to explore and refine the use of PKS in concrete. This includes investigating optimal mix designs, admixtures, and curing techniques to maximize the material's potential and address its limitations.

2. Standards and Guidelines: Standardization bodies should consider developing guidelines and standards for the use of PKS in concrete. This will provide a framework for quality control and ensure the safe and effective incorporation of this sustainable material in construction projects.

3. Awareness and Education: Industry professionals, including architects, engineers, and builders, should be educated about the benefits and challenges of using PKS in concrete. Awareness campaigns and training programs can promote the adoption of sustainable building practices.

4. Policy Support: Policymakers and government agencies should provide incentives and support for sustainable construction practices, including the use of alternative materials like PKS. This may include tax benefits, grants, and regulatory adjustments to encourage the adoption of eco-friendly construction materials.

5. Collaboration and Knowledge Sharing: Collaboration among researchers, industry stakeholders, and policymakers is essential to advance the use of PKS in concrete. Sharing knowledge and experiences can accelerate the adoption of this sustainable practice.

6. Case Studies and Demonstration Projects: The construction industry should invest in case studies and demonstration projects that showcase the successful use of PKS in real-world applications. These projects can serve as models for future sustainable construction endeavors.

7. Quality Assurance: Rigorous quality control measures should be implemented to ensure the consistency and reliability of PKS-incorporated concrete. This includes material testing, mix design optimization, and construction practices that adhere to established standards.

5.2 LIMITATIONS

This project work is not without its limitations. Some of the limitations include:

1. Incorporating PKS into concrete can result in reduced workability due to the irregular shape and lightweight nature of PKS particles.
2. Replacing traditional coarse aggregate with PKS can lead to reduced compressive strength in concrete.
3. There may be gaps in research and development, limiting the full potential of PKS in concrete.
4. Encourage further research to explore optimal mix designs, curing methods, and construction techniques that maximize the benefits of PKS.
5. Many industry professionals may lack awareness and knowledge about the benefits and challenges of PKS-replaced concrete.

5.3 POSSIBLE SOLUTIONS TO LIMITATIONS

To address these limitations, the following solutions can be considered:

1. The use of Superplasticizers enhances PKS-replaced concrete's workability by reducing water demand. Careful mix design balances workability and strength, adjusting proportions and using additional materials all these are essential to overcome workability issues.

2. Rigorous quality control and mix design optimization are crucial to maintain consistent strength. Through thorough mix design optimization, the percentage of PKS replacement can be adjusted to minimize strength loss while maximizing sustainability.

3. Encourage further research to explore optimal mix designs, curing methods, and construction techniques that maximize the benefits of PKS.

4. Organize training programs, workshops, and seminars to educate architects, engineers, and builders about the use of PKS in concrete.

APPENDICES

Plate1: oiling the mould

Plate 2: Mixing process for the concrete

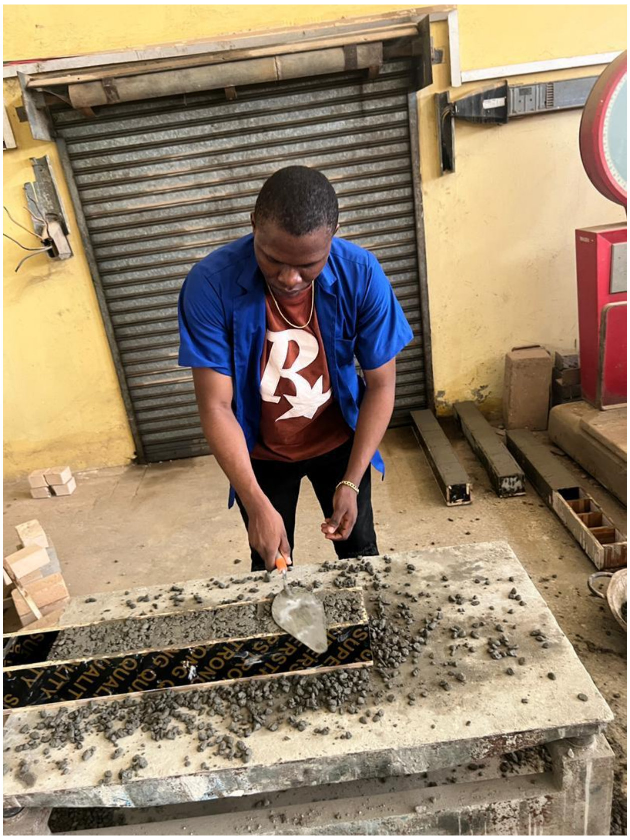

Plate3: concrete slump

Plate 4: universal compressive and tensile machine

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