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Enhancing the Compressive Strength of Palm Kernel Shell Concrete as a Partial Replacement for Coarse Aggregate Using Super plasticizer

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ABSTRACTS

This study investigated the effects on the density, workability, and compressive strength of super plasticized concrete of adding palm kernel shells (PKS) either totally or partially in place of crushed granite. Concrete samples were made with a water/cement ratio of 0.6 and a notional volume mix ratio of 1:1.5:3. Clean palm kernel shells were added to partially replace coarse aggregate at intervals of 25%. High range water reducer Glenium C380 SP was added at 0%, 1%, and 2% cementitious material to each mix. Following ASTM guidelines, concrete cubes measuring 100 mm by 100 mm by 100 mm were formed, and after seven, fourteen, and twenty-eight days, their compressive strength was evaluated. The values for slump and density were also determined. The results showed that as PKS increases, the density, workability, and compressive strength of concrete all decrease. Every combination that received super plasticizer had a significant improvement in the measured parameters, with the exception of compressive strength, where the dosage applied produced only very minor increases. The optimal level of superplasticizer concentration was determined to be 1%. The contents that followed only marginally eased the situation. The average value of more than 17 kN/m^2 at 28 days, along with good slump and density values, were found to be sufficient for the building of lightweight concrete at 75% replacement in terms of compressive strength and other features. PKS needs to be a regular component material for creating lightweight concrete.

Keywords: Superplasticizer, Palm kernel shell,Concrete, Compressive Strength, Fresh properties.

I. INTRODUCTION

Concrete is one of the most widely used building materials globally. Over the past decade, significant advancements have been made in concrete technology. Today, concrete is an engineered material that incorporates various new ingredients, moving beyond the traditional mix of cement, aggregates, water, and admixtures. These additional ingredients, known as additives, are introduced into the mix just before or during the mixing process. Unlike cement, water, and aggregates, additives are specifically used to modify and enhance the properties of the concrete.

A common method for achieving full compaction in concrete is by incorporating chemical admixtures, particularly in situations where there is a lack of skilled labor or when there is dense reinforcement. Previous research has highlighted that the use of chemical admixtures imparts desirable properties to concrete in both its fresh and hardened states.

Research has shown that the properties of concrete can be modified by partially replacing cement with environmentally friendly waste materials such as bagasse ash [1], rice husk ash [2], palm oil ash [3], and kaolin [4]. Furthermore, other studies have explored the use of waste materials as substitutes for aggregates, including recycled concrete aggregate [5], palm oil shell [6], and red-colored brick masonry as fine aggregate [7].

Chemical and mineral admixtures are the two categories into which admixtures are divided. Chemical admixtures known as water reducing admixtures offer concrete several benefits both when it's new and when it's hardened. There are many water reducing admixtures on the market;

high-range admixtures are also referred to as superplasticizers. The combination of cementitious ingredients and water (w/cm) in the E-ISSN: 2732-9984 has an impact on a number of concrete properties.

Superplasticizers can prolong the setting time of concrete by providing additional water to lubricate the mix, provided that the water-to-cement ratio is maintained. The addition of a superplasticizer to harden the concrete will boost its compressive strength by improving the density of the concrete through improved compaction. Furthermore, if a superplasticizer is present and the water-to-cement ratio is lowered, the rate of carbonation slows down [1]. Adding reactive Liboment-163 will allow for optimal control of the fresh concrete's slump test in all mix configurations.

Reducing the water content in a cement paste results in higher density and better bonding quality, leading to increased compressive strength. A superplasticizer, an additive introduced into concrete mixtures, helps reduce the water content or delay the setting time without compromising the mixture's flowability. The use of a superplasticizer enhances the properties of concrete in both its fresh and hardened states. In fresh concrete, the addition of a superplasticizer reduces the water-to-cement ratio or overall water content, which in turn minimizes bleeding.

This study utilized palm oil shell waste as a partial replacement for coarse aggregate in concrete. Palm oil shell is a major source of agricultural solid waste in Nigeria and many other parts of the world. Over the past decade, research has shown that palm oil shells can be used to produce lightweight concrete as an alternative to gravel. Additionally, the incorporation of silica fume has been found to enhance the concrete's initial strength. Several studies have examined the effect of silica fume on the early strength development of concrete [7].

Palm kernel shell (PKS) is a byproduct generated during the shredding, cracking, and extraction processes in palm oil mills. It is abundantly available in tropical regions, especially in Asia and Africa. In Nigeria alone, the high demand for palm kernel oil results in the production of approximately 1.5 million tons of PKS waste annually [8]. The large quantities of PKS waste pose significant disposal and environmental challenges. Besides its use in construction, PKS also serves as a fuel source in local communities. Depending on the extraction method, PKS particles vary in shape, with slightly rough and spiky edges. The particles typically have a smooth surface and range in thickness from 1.5 mm to 4 mm on their concave or convex faces.

Because PKS is an organic material, its epidermal pores allow for a significant absorption of water. The 24 hour water absorption might range from 14% to 33%, based on the species [9]. The high absorption of water has a detrimental effect on the concrete quality made using PKS. As a result, PKS concrete's mix design differs from Normal Weight Concrete's [10]. Researchers have also observed an unconsolidated and compacted bulk density range of 500 – 740kg/m3 for PKS. Because of this, PKS can be used to produce concrete with lesser densities, typically between 1600 and 1900 kg/m^3[11], [12].

Hence, this study aims to analyze the effect of superplasticizer on the compressive strength of concrete enhanced with palm kernel shell.

II. MATERIALS AND METHODS

2.1 Materials

2.1.1 Ordinary Portland Cement

Ordinary Portland Cement (OPC) of grade 42.5R, conforming to NIS 444-1:2018, was used for the experiment. The cement brand used was Dangote 3X OPC, where "3X" signifies Xtra Strength, Xtra Life, and Xtra Yield. Consistency and setting time tests were conducted on the cement in accordance with BS EN 196-1:2018.

2.1.2 Fine and Coarse Aggregates

River sand was used as the fine aggregate in this study, with particle sizes ranging from 150 µm to 600 µm, 1.18 mm to 2.36 mm, and up to 5 mm. The sand has specific gravities of 2.46 and 1.5, with respective water absorption rates. Sieve analysis showed that 26.76% of the sample passed through the 600 µm sieve. Granite particles with a maximum size of 20 mm, conforming to BS EN 12620 (2013), were used as the coarse aggregate. The granite has a specific gravity of 2.66 and a water absorption rate of 0.614%. Before mixing, the aggregates were cleaned to remove any fine particles adhering to their surfaces. In certain percentages, the coarse aggregate was partially replaced with palm kernel shell to achieve the study's objectives.

2.1.3 Palm kernels shell Aggregate

The primary material used in the experiment was palm kernel shell, sourced from Ondo State in the southwest region of Nigeria. A total of 100 kg of this material was obtained for the study. The palm kernel shells were cleaned to

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remove fibers and any unwanted debris. To eliminate any residual moisture and prevent microbiological growth, the shells were sun-dried for three days.

2.1.4 Superplasticizer

The superplasticizer used in this experiment was Glenium C380, a new-generation additive known for its excellent performance across various concrete types. One of its key advantages is its ability to enhance both the initial and final strength of the concrete.

2.1.5 Blending Water

Portable water was used in this investigation, sourced from the Building Department of the Federal University of Technology in Akure, Ondo State, Nigeria. The water was tested to ensure its purity before being used in the experiment. It was used both in the preparation and curing of the concrete.

III. METHODS

3.1 Testing of materials and aggregates

The materials underwent a number of tests to determine their compatibility for the trials. Tests on palm kernel shell and coarse aggregates were performed, including the sand equivalent test, clay lump test, sieve analysis, specific gravity test, aggregate impact value test, and aggregate crushed value test. Tests were done on the cement paste for consistency and curing time.

3.2 Concrete Mix Proportion

Concrete mix proportions refer to the exact ratios of cement, aggregates (both coarse and fine), water, and sometimes admixtures used to produce concrete with specific properties. These proportions are carefully determined through mix design to ensure the concrete meets the required durability, strength, and performance criteria for a particular construction application. The details of these proportions are presented in Table 1 and Table 2.

Tables 1 show the proportions of the concrete mixture utilized in this study.

MIX PROPORTION					
Mix proportion of cement, Aggregates of 100 x 100 x 100 mm concrete cubes					
Replacement (%)	Cement (kg)	Sand (Kg)	Granite (Kg)	PKS (Kg)	Water (kg)
0	3.802	8.22	15.9	0.00	2.28
5	3.802	8.22	15.1	0.80	2.28
10	3.802	8.22	14.31	1.59	2.28
15	3.802	8.22	13.51	2.39	2.28
20	3.802	8.22	12.72	3.18	1.90

Table 2 show the weights of Superplasticizer Used in the Concrete Mixes

Weight of Superplasticizer used in the concrete mixes			
Replacement (%)	Cement (kg)	SP (Kg)	Water (kg)
0	3.802	0.00	2.28
0.5	3.802	0.019	2.28
1	3.802	0.038	2.28
1.5	3.802	0.057	1.90

3.3 Production of Concrete

A concrete mix consists of components combined to create concrete, including cement, aggregates (such as crushed stone, sand, and gravel), water, and often additional ingredients like admixtures or additives. In this study, palm kernel shell (PKS) was used to partially replace coarse aggregate at replacement levels of 0%, 5%, 10%,

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15%, and 20% by weight, with concrete cubes containing 0% PKS serving as the control. Superplasticizer was added at 0.5%, 1%, and 1.5% of the cement mass to the mixes with different PKS replacement percentages. A total of 240 concrete cubes, each measuring 100 mm on each side, were cast using cube molds across 20 different batches.

3.4 Test of compressive strength

After assembling the cube molds, the compressive strength test was performed following BS EN 12390-4:2002. The interior surfaces of the molds were lubricated with engine oil to facilitate the removal of the hardened concrete cubes. Concrete was placed in the 100 mm x 100 mm x 100 mm molds in three layers, each layer receiving 25 blows to ensure proper compaction. The mix used 100% granite for coarse aggregate, with palm kernel shell substituted at 0%, 5%, 10%, 15%, and 20% by weight, and the mix ratio was 1:2:4. Superplasticizer was added at 0.5%, 1%, and 1.5% of the cement mass.

The concrete cubes were demolded after 24 hours and cured in a water tank maintained at 20 °C. They were left in the tank until the specified curing periods of 7, 14, 21, and 28 days were completed. After curing, the cubes were weighed and tested for compressive strength, with the cast faces placed in contact with the compression machine's plate. The load was applied at a constant stress rate of 0.02–0.4 N/mm², and the crushing strength was recorded to the nearest 0.05 N/mm². The test setup is illustrated in Figure 1.

Figure 1: Testing Machine Compressive Strength Set up

The sand equivalent is 71, and the presence of friable particles and clay lumps in the fine aggregates is 0.267%. The consistency of the cement is presented in Table 3.

Table 3. Result of Cement Consistency and Setting Time Test (Cement source is Dangote Cem I 42.5)

SAMPLE NO.	CONSISTENCY	INITIAL SETTING TIME (mins)	FINAL SETTING TIME (mins)
A	32	27	425
B	30	25	450
AVERAGE	31	26	438

IV. RESULTS AND DISCUSSION

4.1 Results of all Particles Size Distribution

Figures 2, 3, and 4 show the particle size distribution of aggregates, including sharp sand, coarse aggregates, and palm kernel shell (PKS). The variation in particle sizes of the coarse aggregates and fine sand follows typical particle gradients. The size and distribution of particles in concrete significantly influence its strength and water demand, as well as the compressive strength and damage development process. The homogeneity coefficients for PKS and the coarse aggregates were 1.77 and 2.00, respectively, indicating that both materials are well-graded, as

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illustrated in the figures. Before the grading test, PKS particles were sieved to remove any particles smaller than 3.5 mm.

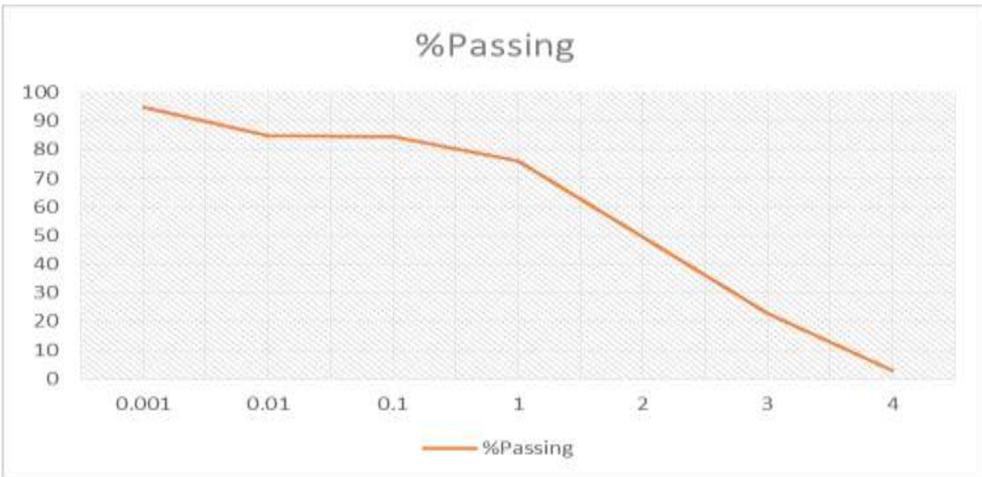

Figure 2 Particle size distribution of sharp sand.

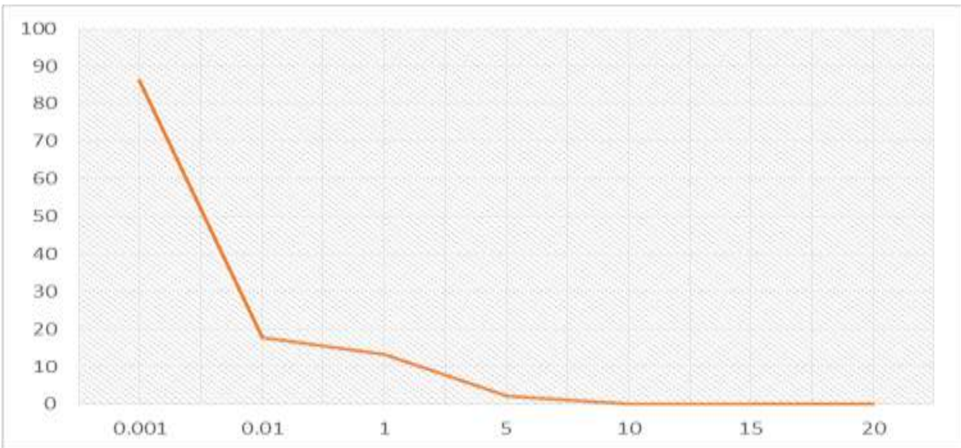

Figure 3 Particle size distribution of Coarse Aggregates

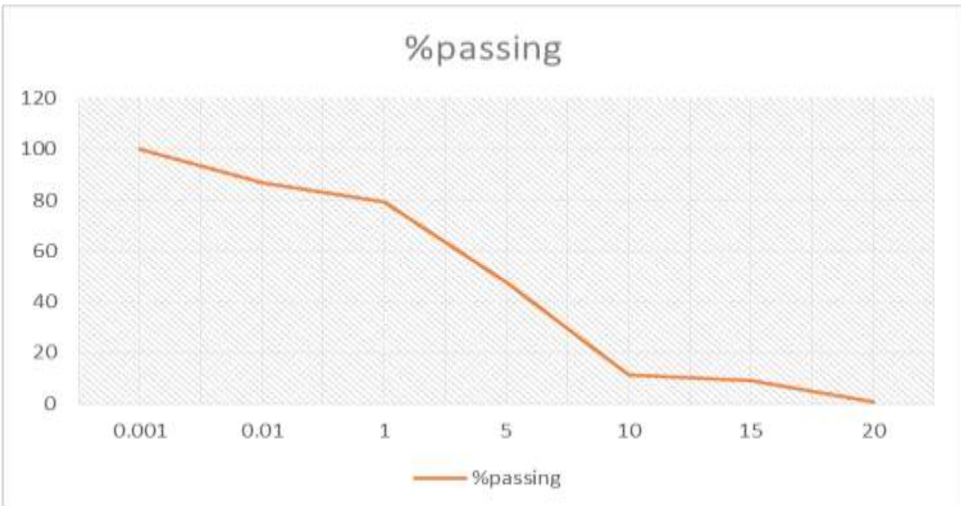

Figure 4 Particle size distribution for Palm kernel

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4.2 Compressive Strength of Control samples with Superplasticizer

The results for samples containing superplasticizer without palm kernel shell are presented in Figure 5. It can be observed that sample CC shows a consistent increase in compressive strength from 7 days up to 28 days. These samples achieved a higher compressive strength compared to the control sample. At 28 days, sample CC recorded a compressive strength of 27.86 N/mm², compared to 22.89 N/mm² for sample CB, 20.28 N/mm² for sample CA, and 19.06 N/mm² for sample C1. This represents an increase of approximately 31.59% over the control samples. These results demonstrate that superplasticizer significantly contributes to the development of compressive strength in concrete, whether or not the aggregates are partially replaced.

Figure 5 Compressive strength of Control Samples

4.3 Compressive strength of Samples with 5% replacement of Superplasticizer

The compressive strength results for all samples containing a 5% replacement of superplasticizer are shown in Figure 6. The results indicate that sample PK5C achieved the highest compressive strength of 25.91 N/mm², while sample PK5B recorded 24.64 N/mm², representing a 9.5% increase in compressive strength. Compared to the control experiment, PK5C demonstrated a 13.66% higher compressive strength at 28 days. Across all testing ages, PK5C consistently showed higher compressive strength values than both the other samples and the control samples. These findings align with previous studies [10, 11], which established that lower replacement percentages of palm kernel shell and superplasticizer result in higher compressive strength in concrete.

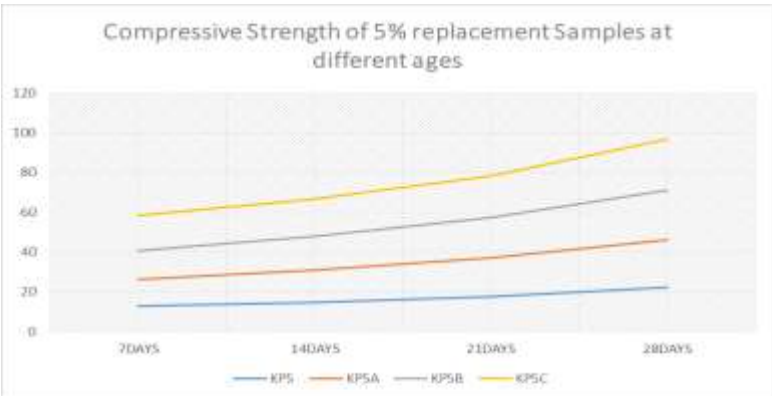

Figure 6 Compressive strength of PK5 samples

4.4 Compressive strength of samples with 10% Superplasticizer

The results displayed in Figure 7 show the compressive strength of all samples containing 10% superplasticizer. The data indicates that PK10C achieved the highest compressive strength at 28 days.

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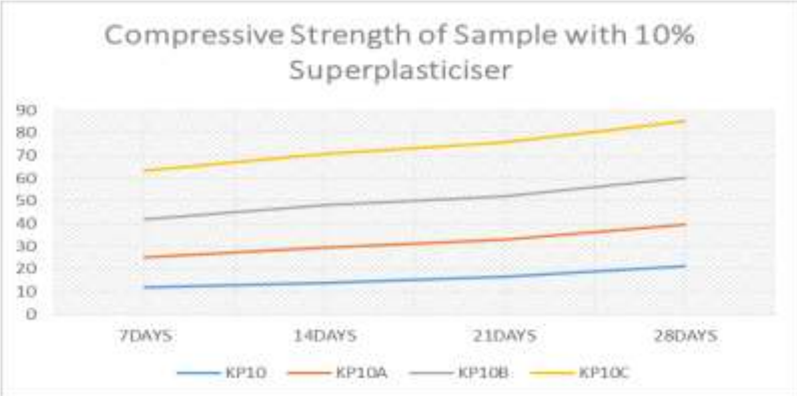

Figure 7 Compressive strength of sample with 10% superplasticizer

4.5 Compressive strength of samples with 15% Superplasticizer

The result of samples that contain 15% of superplasticizer is shown in Figure 8 and it reveal that samples PK15C recorded higher compressive strength all through the ages tested. Particularly, at age 28 days, it recorded 22.02N/mm2 compared to what was recorded by other samples, which are 15.25N/mm2, 16.03N/mm2 and 18.09N/mm2 respectively. This goes to show that the samples is better than other samples in spite of the percentage replacement. This corroborate the findings of other researchers [7, 8, 10]

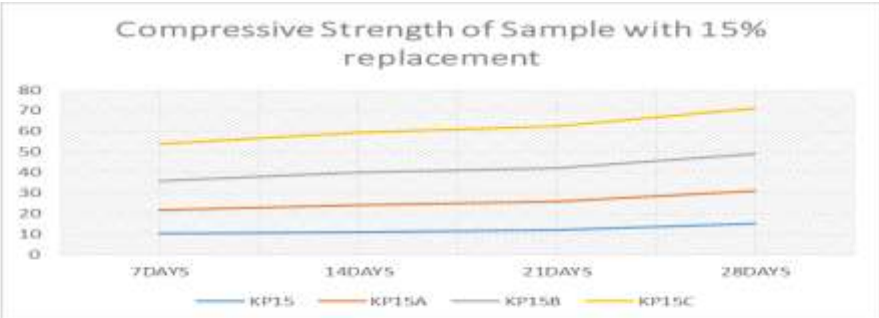

Figure 8Compressive strength of PK15 Samples

4.6 Compressive strength of samples with 20% Superplasticizer

The result of samples that contain 20% replacement is shown in Figure 9. The result clearly shows that PK20C specimen has the highest compressive value at all ages and particularly at the age of 28days. The value at the age of 28 days is 22.02 N/mm2 and higher than all other samples including the controlPK20.

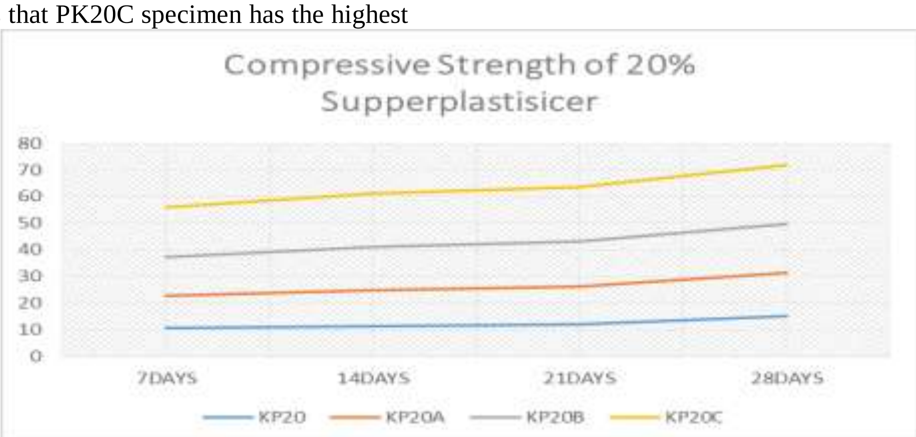

Figure 9 Compressive Strength of PK20 Samples

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V. CONCLUSION

The highlights of the conclusion are as follows:
The sand equivalent test yielded a mean score of 71, indicating that the sand quality is good and meets the required standards.
The clay lumps test showed an average value of less than 1.0, confirming that the fine aggregates are friable and free of clay lumps.

At 28 days, PKS5C exhibited the highest compressive strength among all samples, indicating that reducing the palm kernel shell (PKS) content leads to an increase in compressive strength. The study's findings support the idea that PKS concrete is suitable for use in lightweight concrete applications. However, increasing the PKS concentration results in decreased workability, reduced density, and lower compressive strength. While chemical admixtures can mitigate these losses, the type and nature of the admixtures play a crucial role in the outcome. This was demonstrated in the study, where the use of a superplasticizer significantly improved workability.

Although the compressive strength at the 20% PKS replacement level meets the minimum standards for lightweight concrete, the mix is not workable. Optimal workability, density, and compressive strength were achieved at a 20% PKS content.

5.1 Recommendation

To fully harness the potential of PKS in concrete, it is recommended that its use be standardized. Additionally, comprehensive research on the tensile strength of PKS concrete is essential to support its application in reinforced concrete structures. The production of lightweight concrete using PKS can benefit both rural farming communities with palm kernel mills and other builders. Further research is needed on the best methods for utilizing and integrating residual elements into concrete. Collaboration between government and researchers is also necessary to develop and implement a sustainable solid waste management plan.

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