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INFLUENCE OF SUPERPLASTICIZER ON THE COMPRESSIVE STRENGTH AND CHARACTERISTICS OF PALM KERNEL SHELL CONCRETE

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ABSTRACTS

This research investigates the impact of superplasticizer on the compressive strength and properties of concrete incorporating palm kernel shell PKS as partial replacement for granite coarse aggregate. The study aimed to develop alternative aggregates for concrete production by examining the physical and mechanical properties of PKS and evaluating the effects of curing age, percentage replacements of PKS, and superplasticizer content on the compressive strength of the concrete. Concrete specimens were batched in a 1:2:4 ratio, with PKS partially replacing granite coarse aggregate at 5, 10, 15, and 20. Superplasticizer was added at 0.5, 1, and 1.5 by weight of cement. The specimens were tested at 7, 14, 21, and 28 days of curing. Results showed that superplasticized PKS concrete exhibited slower strength development compared to plain concrete, with optimal strength at 5 PKS replacement and 1 superplasticizer at 28 days. The study concludes that PKS can serve as partial substitutes for granite aggregate in concrete, although further research is needed to optimize their usage.

KEYWORDS: Concrete, Compressive strength, Superplasticizer, Aggregate, Palm kernel shell.

1.0 INTRODUCTION

One of the building materials that is most frequently utilized worldwide is concrete. Over the last ten years, concrete technology has advanced significantly. Concrete is an engineered material that contains various new ingredients instead of being a substance made of cement, aggregates, water, and admixtures. Components used as ingredients in concrete that are added to the batch right prior to or throughout mixing are known as additives. These components are distinguished from cement, water, and aggregates.

One typical way to accomplish full compaction in concrete is to add chemical admixtures, especially in cases where there is a shortage of experienced workers and reinforcement overcrowding. Researchers in the past have emphasized that adding chemical admixtures gives concrete the desired characteristics in both its fresh and hardened states.

It has been found that concrete's characteristics can be altered by partially substituting environmentally friendly waste materials for cement, such as bagasse ash[1], rice husk ash[2], palm oil ash[3], and kaolin.[4] Additionally, other studies have discovered the utilization of waste materials as a substitute for aggregate, including the recycling of concrete aggregate[5], palm oil shell[6], even red-colored brick masonry as fines aggregates.[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.

The paste made from cement will have a high density and good pasting quality if the amount of water is reduced. High compressive strength will result from improved paste quality. An additive called a superplasticizer is introduced to concrete mixtures to lower their water content or to slow down the concrete's setting rate without affecting the mixture's flow characteristics. Both when concrete is fresh and when it has hardened, the qualities will benefit from the employment of a superplasticizer. Using a superplasticizer when the concrete is still fresh can lessen bleeding because it lowers the water-to-cement ratio or the water content of the concrete.

In order to partially replace coarse aggregate in concrete, this study used waste from palm oil shells. The main agricultural solid waste source in Nigeria and most part of the world was oil palm shell. In the past ten years, research has demonstrated that oil palm shells can be used to make lightweight concrete in place of gravel. Furthermore, the use of silica fume strengthened the concrete's original strength. The impact of silica fume addition on the initial strength of concrete has been the subject of several investigations.[7]

A byproduct of the shredding, breaking, and extracting processes in the palm oil processing mill is palm kernel shell (PKS). Large amounts of it can be found in tropical regions of the world, particularly in Asia and Africa. About 1.5 million tons of PKS are produced as trash as a consequence of Nigeria's enormous demand for palm kernel oil.[8] PKS waste is produced in large quantities, which presents disposal and environmental issues. In addition to being utilized in building, PKS is a fuel in the community. PKS particles vary in shape and have edges that are slightly rough and spiky, according to the kind of extraction technique used. The particles usually have a smooth surface and range in thickness from 1.5 mm to 4 mm on the concave or convex face.

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 seek to investigate the effects of incorporating superplasticizer and palm kernel shell PKS as partial replacements for granite coarse aggregate on the compressive strength and other properties of concrete.

2.0 MATERIALS AND METHODS

2.1 Materials

2.1.1 Ordinary Portland cement

Ordinary Portland cement (OPC) of grade 42.5R which conforms to NIS 444-1:2018 was used for the experiment. The brand of cement that was used is Dangote 3X OPC. The 3X stands for Xtra Strength, Xtra life, and Xtra yield. Consistency tests and setting time tests was conducted on the cement in accordance with BS EN 196-1:2018.

2.1.2 Coarse and Fine Aggregates

River sand was utilized as the fine aggregate in this study.

The sizes range from 150 µm to 600 µm, 1.18 mm to 2.36 mm, and 5 mm, with 2.46 and 1.5 molar specific gravities and water absorption, respectively. According to sieve analysis, 26.76% of the sample passes 600µm. Granite particles with a maximum size of 20mm, which is conforming to BS EN 12620 (2013) was utilized as coarse aggregate in this experiment. The aggregate's specific gravity is 2.66 and its water absorption rate is 0.614%. Before mixing, aggregates was also cleaned to get rid of any tiny particles that may have adhered to the surface. The coarse aggregates was partially replaced with palm kernel shell in certain percentages to achieve the aim of the study.

2.1.3 Aggregated palm kernel shells

The main ingredient used in the experiment is palm kernel shell, which was acquired from Ondo state, in the south west regions of Nigeria. For the practical, a total of 100 kg of this material was brought. The palm kernel was cleaned to get rid of fibers and unwanted objects, the palm kernel shell source was left out in the sun for three days to get rid of any remaining water and microbiological growth on the shell's surface.

2.1.4 Super-Plasticizer

In this investigation, Glenium C380 was the superplasticizer used. This is a novel superplasticizer that works well with many kinds of concrete. Its ability to increase both early and final strength is one of its advantages.

2.1.5 Mixing Water

Portable water was used in this study. The source of the water is Building Department, Federal University of Technology, Akure, Ondo State, Nigeria. Concrete was mixed and allowed to cure during the experiment. To ensure the quality of the concrete, the water tested.

Batching

Batching is the process of measuring the constituents of concrete in their correct proportion either by mass or by volume. The goal is to produce concrete of the desired quality and uniformity of the product. The proportion of constituents used was 1:2:4 mix (Table 1).

Table 1: Batching of Cement, Aggregates and Superplasticizer for 12 Numbers of 100 X100 X 100mm Concrete Cubes.

% Replacement	Cement (Kg)	Sand (Kg)	Granite (Kg)	PKS (Kg)	Water, Cement Ratio
0	3.73	7.46	14.92	0.00	0.60
5	3.73	7.46	14.17	0.75	0.60
10	3.73	7.46	13.42	1.50	0.60
15	3.73	7.46	12.26	2.25	0.55
20	3.73	7.46	11.92	3.00	0.55

3.0 RESULTS AND DISCUSSIONS

3.1 Specific Gravity of fine Aggregates

The test conducted according to BS EN 1097-3 (2010) provides the specific gravity of fine aggregate as shown in the Table 2

$$\text{Specific gravity} = \frac{W2 - W1}{(W4 - W1) + (W3 - W2)}$$

Specific gravity of the fine aggregate is 2.60.

The specific gravity of PKS, as observed by several scientists, ranges from 1.17 to 1.62 and has never exceeded 2.0.[16,17,18] Ndoke[16] recorded the highest value for the specific gravity of PKS.

Table 2: Specific Gravity of Fine Aggregate.

Mass/Specific Gravity	Sample
Empty glass, W_1	78.4g
Glass + sample, W_2	139.4g
Glass + sample + water, W_3	406.9g
Glass + water, W_4	369.4g
Specific Gravity	2.60

3.2 Natural moisture content of fine aggregate (sharp sand)

The average natural moisture content of the three (3) samples of fine aggregate (sharp sand) was ≈ **0.6%.** The moisture content of the fine aggregate is a measure of the amount of water/moisture in the sample used. The moisture natural content of fine aggregates has great effects on the physical and mechanical properties of the concrete such as workability, strength and durability, water/cement ratio, and shrinkage. The average moisture content for the 3 samples of fine aggregate tested was obtained to be 0.57% which falls within the typical expected value of moisture content for fine aggregates

Table 3: Result of Natural Moisture Content Test of Fine Aggregate.

Weights/Moisture Content	SAMPLE A	SAMPLE B	SAMPLE C
Container (g), W1	32.5	46.8	38.3
Container + Wet Sample (g), W2	103.2	121.8	105.9
Container + Dry Sample (g), W3	102.7	121.5	105.5
Wet Sample (g), W2-W1	70.7	75	67.6
Moisture (g), W2-W3	0.5	0.3	0.4
Moisture Content (%) (W2-W3)/(W2-W1)	0.71	0.40	0.59
Average, % (MC)		**0.57**	

Moisture content for sample A $=\frac{0.5}{70.7} \times 100 = 0.71\%$

Moisture content for sample B $= \frac{0.3}{75} \times 100 = 0.40\%$

Moisture content for sample C $= \frac{0.4}{67.6} \times 100 = 0.59\%$

Average Moisture Content $= \frac{0.71+0.40+0.59}{3} = \mathbf{0.57\%}$

3.3 Sieve analysis result

This gives the particle size distribution of the fine sand sample, as shown in Table 4.

The particle size distribution curve of the fine aggregate was plotted as shown in figure 1. The fineness modulus was obtained to be **4.37** which indicates that the fine aggregate used is graded as moderately fine. Reading the D10 and D60 values from figures allowed for the determination of the coefficient of uniformity for each sample type. The coefficient of uniformity CU was determined to be **0.87** which falls within the range of well-graded aggregates.

Weight of the can - 99.9g

Weight of the sample - 200g

Weight of the can + sample - 299.9g

Weight of the can + dry sample - 257.5g

Weight of the sample = 257.5g - 99.9g = 157.6g

Sample Mass = 157.6g

Table 4: Sieve analysis for fine aggregate.

Sieve Size (mm)	Weight of Sieve(g)	Weight of Sieve + Sample Retained (g)	Weight of sample retained (g)	Percentage Retained (%)	Cumulative Percentage	Percentage Passing (%)
4.75	379.00	389.60	10.60	6.73	6.73	93.27
2.36	478.50	484.00	5.50	3.49	10.22	89.73
1.70	367.50	370.20	2.70	1.71	11.93	88.07
1.18	361.40	367.80	6.40	4.06	15.99	84.01
0.212	335.20	459.00	123.80	78.55	94.54	5.46
0.150	249.50	256.50	7.00	4..44	98.98	1.02
0.072	411.40	411.40	0.00	0.00	98.98	1.02
Pan	181.80	183.40	1.60	1.02	100.00	0.00
			157.60	100.00		

Weight of sample retained = Weight of sample + sample retained - Weight of sieve

Percentage weight retained = $\frac{\text{Weight retained}}{\text{Total weight retained}} \times 100$

Percentage passing = Total weight retained (%) - Corresponding value of cumulative (%).

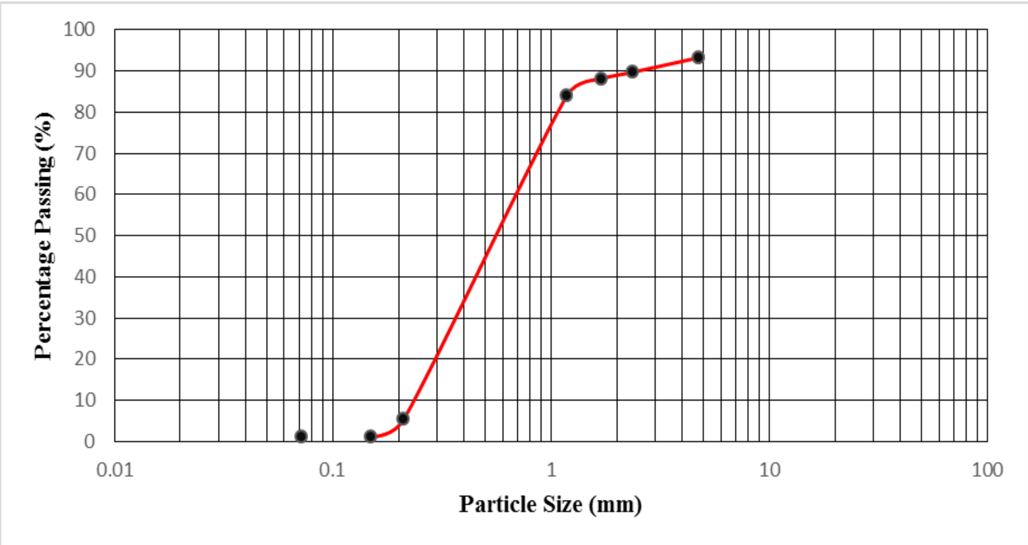

Figure 1: Grading curve for Fine Aggregate.

Fineness Modulus (FM) = $\frac{\text{cummulative percentage retained on standard seive}}{100}$

$$= \frac{6.73+10,22+11,93+11,93+15.99+94.54+98.98+98.98+100}{100} \quad = 4.37$$

The formula gives the coefficient of uniformity

For Sharp Sand, $C_U = \frac{D60}{D10} = \frac{0.88}{0.27} = \mathbf{3.26}$

$$C_c = \frac{(D30)2}{D60 \times D10} = \frac{(0.51)2}{0.88 \times 0.27} = \mathbf{0.87}$$

3.4 Sieve analysis for palm kernel shell

This gives the particle size distribution of the palm kernel shell, as shown in Table 5.

The particle size distribution curve of the substitute coarse aggregate (palm kernel shell) was plotted as shown in figure 2. The fineness modulus was obtained to be **4.65** which indicates that the palm kernel shell used is graded as moderately coarse or an intermediate between fine and coarse.

Weight of the can – 69.6g

Weight of the sample - 200g

Weight of the can + sample - 269.6g

Sample Mass = 200g

Table 5: Particle Size Distribution of Palm Kernel Shell.

Sieve Size (mm)	Weight of Sieve (g)	Weight of sieves + Sample Retained (g)	Weight of Sample Retained (g)	Percentage Retained (%)	Cumulative Percentage	Percentage Passing (%)
19.5	406.90	406.90	0.00	0.00	0.00	100
14	408.50	435.00	26.50	13.25	13.25	86.75
12.7	628.50	643.20	14.70	7.35	20.60	79.40
9.53	377.10	440.80	63.70	31.85	52.45	47.55
6.7	513.90	586.40	72.50	36.25	88.70	11.30
6.3	401.70	405.90	4.20	2.10	90.80	9.20
4.5	618.50	635.10	16.60	8.30	99.10	0.90
Pan	157.30	159.10	1.8	0.9	100.00	0.00
			200.00	100.00		

Weight of sample retained = Weight of sample + sample retained - Weight of sieve

Percentage weight retained = $\frac{\text{Weight retained}}{\text{Total weight retained}} \times 100$

Percentage passing = Total weight retained (%) - Corresponding value of cumulative (%)

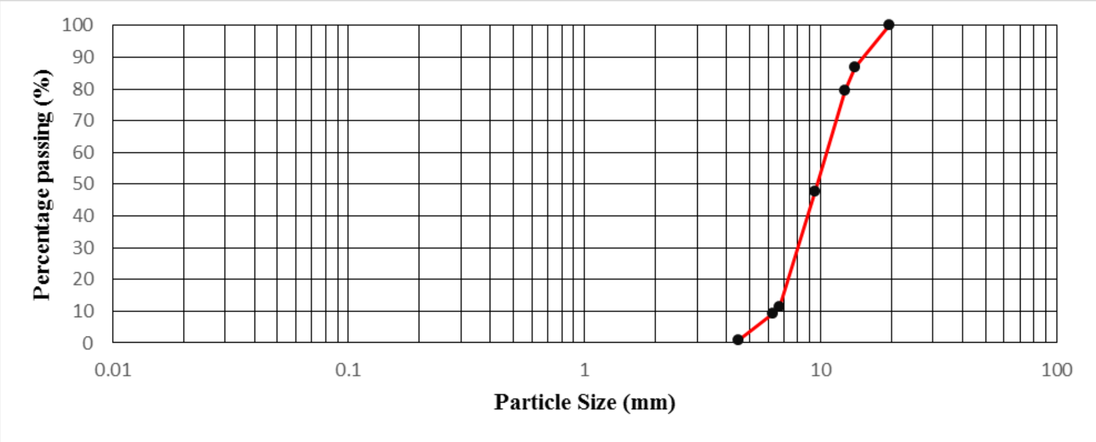

Figure 4.3: Grading Curve for palm kernel shell Coarse Aggregate.

$$\text{Fineness Modulus (FM)} = \frac{\text{cummulative percentage retaines on standard seive}}{100}$$

$$= \frac{13.25+20.60+52.45+88.70+90.80+99.10+100}{100}$$

$$= \mathbf{4.65}$$

3.5 Weights and Densities of Specimen.

The average weights and densities of concrete specimen cast for control and Palm Kernel Shell are presented in Tables 6, and 7 respectively.

Figure 4 shows the densities of control specimen cast. The highest density of 2700 kg/m^3 was observed for plain concrete specimen while the lowest density was observed to be 2450 kg/m^3 for 1% superplasticized concrete.

Figure 5 shows the densities for specimen with Palm Kernel Shell partial replacement and it was observed that the densities generally decreased with an increase in percentage preplacement as the peak value was observed to be 2500 kg/m^3 at 5% partial replacement and 2200 kg/m^3 at 20% partial replacement.

Table 6: Weights and Densities of Control Specimen.

Specimen	Weight (kg)	Density (kg/m^3)
C1	2.7	2700
CA	2.5	2500
CB	2.45	2450
CC	2.63	2630

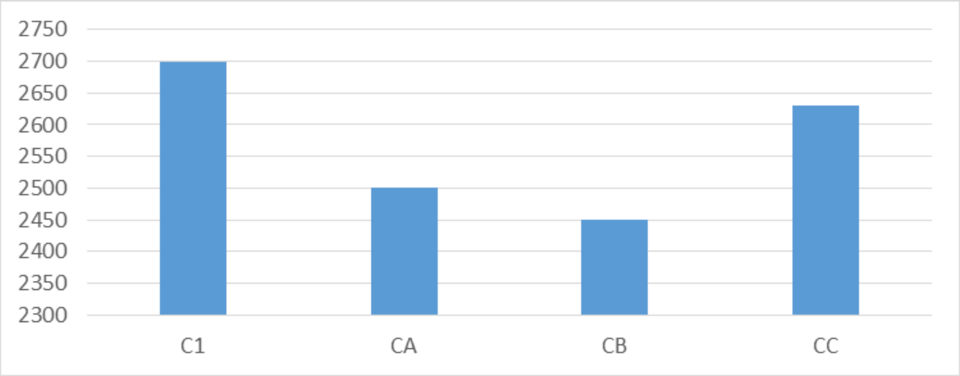

Figure 4: Densities of Control Specimens.

Table 7: Weights and Densities of Specimen with Palm Kernel Shell.

Specimen	Weight (kg)	Density (kg/m^3)
PW5	2.32	2320
PW10	2.30	2300
PW15	2.29	2290
PW20	2.26	2260

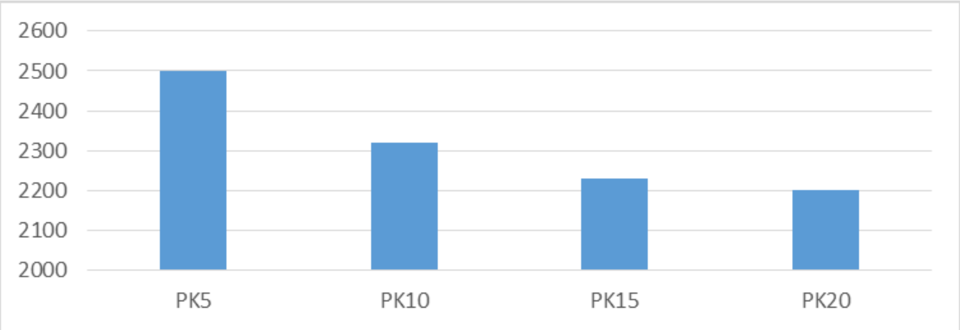

Figure 6: Densities of Specimen with Palm Kernel Shell.

3.6 Compressive Strength

The compressive strength values of the control specimens for plain concrete and superplasticized concrete at 0.55%, 1.0% and 1.5% superplasticizer content are presented in Table 8 and Tables 9 present the compressive strength values of palm kernel shell partial replacement with superplasticizer respectively.

Figure 7 shows the effect of curing age on the compressive strength characteristics of superplasticized concrete with palm kernel shell partial replacement for coarse aggregate. This depicts that the peak strength of 26.97 kN/mm^2 was achieved by the control specimen at 28 days curing age. Also, it was observed that 5% partial replacement was optimum partial replacement for coarse aggregate with a peak value of 26.44kN/mm^2 at 21 days curing age and 1% superplasticizer content.

Table 8: Compressive Strengths of Control Specimens.

Specimen/Curing Age	7 days Strength (N/mm^2)	14 days Strength (N/mm^2)	21 days Strength (N/mm^2)	28 days Strength (N/mm^2)
C1	13.73	15.18	22.51	26.97
C_A	6.76	9.70	21.78	17.12
C_B	12.31	21.25	24.75	21.25
C_C	19.06	20.28	21.89	25.13

Table 9: Compressive Strengths of Superplasticized Concrete with Palm Kernel Shell.

Specimen/curing age	7 days Strength (N/mm^2)	14 days Strength (N/mm^2)	21 days Strength (N/mm^2)	28 days Strength (N/mm^2)
PK5	18.91	19.65	20.46	13.75
$PK5_A$	21.11	15.86	17.68	20.19
$PK5_B$	20.55	20.96	26.44	19.23
$PK5_C$	19.13	17.33	17.90	23.97
PK10	10.31	8.70	11.44	14.43
$PK10_A$	14.85	11.97	17.23	16.38
$PK10_B$	10.71	14.28	16.78	16.55
$PK10_C$	10.52	10.75	14.60	13.78
PK15	11.08	8.86	9.31	12.51
$PK15_A$	9.93	9.23	15.05	11.76
$PK15_B$	11.26	11.60	11.92	14.43
$PK15_C$	7.46	12.97	11.99	12.84
PK20	8.05	12.96	8.91	8.63
$PK20_A$	11.43	9.92	11.09	11.71
$PK20_B$	6.12	9.13	7.80	13.37
$PK20_C$	6.25	5.08	8.25	11.12

The Effect of Percentage Replacement of Granite Coarse Aggregate with Palm Kernel Shell on Compressive Strength of Superplasticized Concrete.

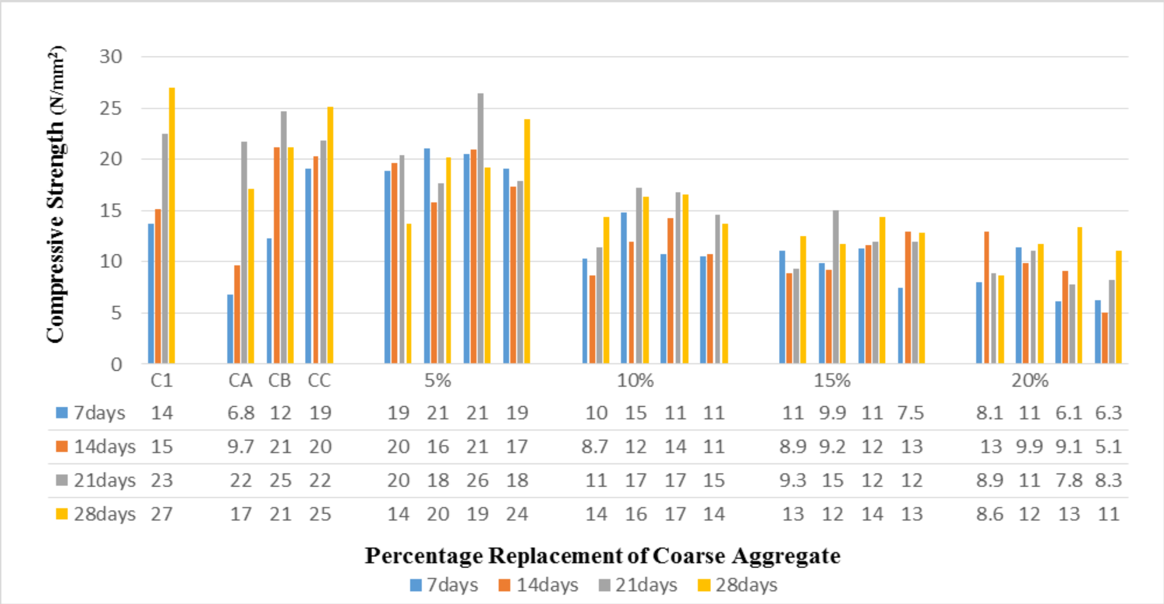

Figure 7: Effect of Percentage Replacement on the Compressive Strength Characteristics with Palm Kernel Shell.

4.0 CONCLUSION

The research investigated the impact of incorporating palm kernel shell as partial replacements for granite coarse aggregate in superplasticized concrete. Findings revealed that, palm kernel shell replacements resulted in slower strength development compared to plain concrete. Notably, superplasticized palm kernel shell concrete reached its peak strength value of 26.44 kN/mm^2 at 21 days curing age of 1% superplasticizer content at partial replacement of 5%. Palm kernel shell showing optimal strength at lower replacement percentages. Moreover, palm kernel shell replacement exhibited superior strength development with superplasticizer content. In terms of density, specimens with shell replacements experienced a decrease with higher replacement percentages, with palm kernel shell concrete demonstrating the lowest density at the highest replacement percentage tested. Overall, the study suggests that palm kernel shell can be utilized as partial replacements for granite coarse aggregate in superplasticized concrete, albeit with varying effects on strength development, workability, and density. Further research may be warranted to fine-tune their usage for specific concrete applications.

4.1 Recommendation

It is recommended that in order to fully realize the potential of PKS, concrete use must be sta ndardized. Thorough research on the tensile capability of the material is also necessary to support the usage of reinforced PKS concrete in reinforced concrete construction. Both rural farming communities with palm kernel mills and other builders can benefit from the production of lightweight concrete utilizing PKS. Further investigation is necessary on several topics concerning the optimal utilization and assimilation techniques of residual elements in concrete. Similarly, government and researchers should work together to develop and implement a sustainable solid waste management plan.

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