



Effect of Varying the Proportions of Palm Kernel Shells on the Properties of Concrete Interlocks Cured in Air

Uduavwodia Ejomafuvwe^{*1}, Mathias Ekpu¹, Samuel O. Sada¹, Friday E. Ukorakor¹, Sunday C. Ikpeseni¹

¹Department of Mechanical Engineering, Delta State University, Abraka, Nigeria

*Corresponding author: ejosdmachine@gmail.com (Ejomafuvwe U.)

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Abstract

This study investigates the effect of palm kernel shells (PKS) on the properties of concrete interlocks cured in air. The palm kernel shells were used as partial replacement for conventional building materials, such as granite chips (GNC), to determine the optimal PKS content that meets acceptable standards. Samples of materials required were collected, sieved, measured in weight and batched in a mix ratio of 1:2:3. The palm kernel shells replacement varies with granite chips from 0% PKS with 100% GNC to 100% PKS with 0% GNC at intervals of 10-unit using water to cement value of 0.5. A total of eleven (11) samples of concrete interlocks were molded, cured for 28 days in the air, measured and subjected to various tests such as weight test, density test, water absorption test and compressive strength test. The weight and density of the samples followed similar trend as both quantities increased from 0% to 30% of PKS replacements and then began to decrease as the PKS replacement continued to increase from 30% to 100%. The highest percentage by weight of water absorbed by the samples was at the 100% PKS having a percentage weight value of 6.20% while the lowest percentage by weight of water absorbed by the samples was at the 0% PKS having a percentage weight value of 2.46%. The highest compressive strength of the samples with PKS replacements was achieved at 10% PKS with 90% GNC combination, with a compressive strength value of 12.58 MPa. The sample produced at 10% PKS replacement fell short of the minimum strength requirement of 15.00 MPa specified in BS 8110 (1997) but outperformed the compressive strengths of samples from factory X (12.00 MPa) and factory Y (10.00 MPa). Moreover, the sand mixing ratio in this study was 25% higher than the BS 8110 (1997) recommendation but 50% lower than that used in factory Y. Moreso, BS 8110 (1997) suggests curing methods that retain moisture, rather than specifying air curing. Future studies should focus on roughening the smooth surfaces of the shell particles to enhance bonding with other concrete aggregates.

Keywords: Palm kernel shells; granite chips; compressive strength; concrete aggregates; concrete interlocks; mix ratio; PKS replacement.

1. Introduction

Nigeria is a country rich in natural resources such as petroleum, minerals, agricultural commodities among others. Palm oil fruits, one of the agricultural products, were extensively cultivated and exported, contributing over 60% to the nation's Gross Domestic Product (GDP) before the discovery of crude oil in 1956 (Obuka et al., 2019). Today, Nigeria cultivates more than 4 tons of palm oil fruit per hectare whose shells lack a proper disposal method (Udom, 2002). A large percentage of these shells are either dumped into water bodies, causing pollution, or openly burned without recovering energy from the heat. These disposal methods contribute to environmental concerns (Momoh et al., 2022) as the shells poses a significant environmental challenge (Samotu et al., 2015), highlighting the need for proper waste management. Economically converting these shells into high-value products can promote their use in various applications, such as the production of blocks, bricks and interlocks for building and construction work (Ibearugbulem et al., 2018).

Palm kernel shells are solid residues generated from the cracking of palm kernel nuts which are in turn obtained from the milling of palm oil fruits (*Elaeis guineensis*). Palm oil fruits are contained in a bunch on a palm oil tree and are grown largely on plantations in southern Nigeria. However, the crops originated from the tropical rainforest region of West Africa (Goh et al., 2017). Palm kernel shells are hard (Ikubanni et al., 2020), porous (Ndoke, 2006), and often spherical in shape (Dagwa et al., 2012), making them suitable for use as road-building materials, aggregates in masonry and concrete works, and other engineering applications (Uchegbulam et al., 2022). Although palm kernel shells contribute to environmental pollution, they have practical applications in concrete interlock production, which justifies their consideration for this purpose. Concrete interlocks are masonry units used in landscaping many residential and commercial areas (Atoyebi et al., 2022). They have beautiful surface appearances, easy maintenance methods, and reduced cracking tendencies (Koganti et al., 2020). A good concrete interlock consists of a proper ratio of sand, cement, and granite chips as aggregates (Wasiu et al., 2015).

The mining of conventional building materials such as granite chips is associated with the emissions of carbon dioxide (CO₂) into the atmosphere (Suthirat et al., 2016). Approximately 3kg of these greenhouse gases are released for every 1 ton of granite rocks crushed at quarry sites. These gases often trap heat in the air, leading to the warming of the earth thereby causing climate change (Suthirat et al., 2016). Sand, on the other hand, is mined by dredging it from rivers or pits. However, the recent increase in the demand for sand in building and construction works has led to indiscriminate dredging of near-shores thereby threatening the livelihood of the local communities where the dredging activities are carried out (Adekunbi et al., 2018). The ever-rising cost of these building materials is another problem hindering the infrastructural development of the nation (Gana and Asebiomo, 2019).

The use of palm kernel shells as aggregates in the production of concrete interlocks is believed to bring about a direct decline in the depletion of natural resources such as the granite rocks which will in turn lead to a reduction in the emission of carbon dioxide into the atmosphere from the quarries and granite mining sites. This study aims to utilize palm kernel shells in concrete interlock production to assess their effect on the final product and determine the optimal quantity needed to achieve acceptable strength. By addressing disposal challenges and reducing carbon dioxide emissions from rock crushing at quarries, the study contributes to sustainable practices. Additionally, it provides valuable insights for concrete interlock producers, building engineers, and other stakeholders in tackling the high cost of building materials, environmental pollution, and global warming.

2. Materials and Methods

2.1 Materials Used

The materials used in this experimental work were cement, sand, granite chips, palm kernel shells, diesel oil and water. The palm kernel shells used in this study were waste collected from a home in Ughelli, Nigeria. The shells were crushed, washed, sun dried and sieved to obtain particle sizes ranging from 5mm to 12mm. The granite chips used in this study were procured from a vendor in Ughelli, Nigeria. The chips were washed, sun dried and sieved to obtain particle sizes ranging from 5mm to 12mm. The cement used in this study was Portland limestone cement produced by Dangote Industries with a strength grade of 42.5N. The sand used in this study was sharp sand dredged from a river with particle sizes passing through the 3mm openings. The water used in this study was a potable fresh water.

2.2 Sieve Analysis

The palm kernel shell aggregates as well as the granite chip aggregates were separately crushed, washed, sun dried and sieved using five different hand sieve shakers with hole sizes of 5.0mm, 6.3mm, 8.0mm, 10.0mm and 12.0mm respectively. The aggregates retained in each of the sieve shakers were measured using the Zhengya weighing apparatus. The percentage by weight retained, the cumulative percentage by weight retained and cumulative percentage by weight passing through the sieve shakers were calculated using Equations 1, 2 and 3, and recorded in Tables 1 and 2 respectively. Also, the fineness modulus of both aggregates was calculated using Equation 4, and recorded in Tables 1 and 2 respectively.

$$\%WdR = \frac{WdR}{WdRT} \times 100\% \quad (1)$$

$$\%CWdR = \sum \%WdR \quad (2)$$

$$\%CWdP = 100 - \%CWdR \quad (3)$$

$$FMA = \frac{\%CWdRT}{100} \quad (4)$$

where WdR refers to the dry weight retained, while WdRT refers to the total dry weight retained. %WdR represents the percentage by dry weight retained, and %CWdR represents the cumulative percentage by dry weight retained. %CWdP represents the cumulative percentage by dry weight passing. Σ %WdR refers to the summed percentage by dry weight retained, and %CWdRT refers to the total cumulative percentage by dry weight retained. FMA refers to the fineness modulus of the aggregates.

Table 1: Sieve analysis of palm kernel shells

| Sieve Size (mm) | Dry weight retained (g) | Percentage by dry weight retained (%) | Cum. percentage by dry weight retained (%) | Cum. percentage by dry weight passing (%) |
|-----------------|-------------------------|---------------------------------------|--|---|
| 12.0 | 0.00 | 0.00 | 0.00 | 100 |
| 10.0 | 98.4 | 2.98 | 2.98 | 97.02 |
| 8.0 | 106.1 | 3.22 | 6.22 | 93.78 |
| 6.3 | 1535.2 | 46.52 | 52.72 | 47.28 |
| 5.0 | 1560.3 | 47.28 | 100 | 0.00 |
| Total | 3300 | 100 | 161.92 | 338.08 |
| Finesse Modulus | - | - | 1.62 | - |

Table 2: Sieve analysis of granite chips

| Sieve Size (mm) | Dry weight retained (g) | Percentage by dry weight retained (%) | Cum. percentage by dry weight retained (%) | Cum. percentage by dry weight passing (%) |
|-----------------|-------------------------|---------------------------------------|--|---|
| 12.0 | 0.00 | 0.00 | 0.00 | 100.00 |
| 10.0 | 102.0 | 3.09 | 3.09 | 96.91 |
| 8.0 | 294.0 | 8.91 | 12.00 | 88.00 |
| 6.3 | 1351.0 | 40.94 | 52.94 | 47.06 |
| 5.0 | 1553.0 | 47.06 | 100 | 0.00 |
| Total | 3300 | 100 | 168.03 | 331.97 |
| Finesse Modulus | - | - | 1.68 | - |

2.3 Sample Preparations

A total of eleven (11) samples of concrete interlocks were produced in a small scale in the laboratory. Prior to production, all aggregates (i.e. cement, sand, GNC and PKS) were measured in mass and batched in the ratio 1:2:3 with a water to cement value of 0.5 as shown in Table 3.

Table 3: Weight ratio of aggregates for the varying samples of concrete interlocks

| Sample Mix | Weight ratio in grams | | | Water volume (cm ³) | Water volume to Cement mass ratio |
|----------------------|-----------------------|----------|-------------|---------------------------------|-----------------------------------|
| | 1 | 2 | 3 | | |
| | Cement (g) | Sand (g) | PKS/GNC (g) | | |
| 0% PKS with 100% GNC | 200 | 400 | 00/600 | 100 | 0.50 |
| 10% PKS with 90% GNC | 200 | 400 | 60/540 | 100 | 0.50 |
| 20% PKS with 80% GNC | 200 | 400 | 120/480 | 100 | 0.50 |
| 30% PKS with 70% GNC | 200 | 400 | 180/420 | 100 | 0.50 |
| 40% PKS with 60% GNC | 200 | 400 | 240/360 | 100 | 0.50 |
| 50% PKS with 50% GNC | 200 | 400 | 300/300 | 100 | 0.50 |
| 60% PKS with 30% GNC | 200 | 400 | 360/240 | 100 | 0.50 |
| 70% PKS with 30% GNC | 200 | 400 | 420/180 | 100 | 0.50 |
| 80% PKS with 20% GNC | 200 | 400 | 480/120 | 100 | 0.50 |
| 90% PKS with 10% GNC | 200 | 400 | 540/60 | 100 | 0.50 |
| 100% PKS with 0% GNC | 200 | 400 | 600/00 | 100 | 0.50 |

The first sample of concrete interlocks was prepared by mixing cement, sand, and 0 percent PKS with 100 percent GNC uniformly with the gradual application of water to form the control sample. The second to eleventh samples of concrete interlocks were prepared by replacing granites chips with 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100 percent PKS. Each prepared mix sample was then poured into diesel-lubricated wooden molds measuring 150mm × 80mm × 50mm. All eleven molds were left to cure in the air for 28 days before the samples were removed for measurement and compressive testing.

2.4 Measurements

The eleven samples of concrete interlocks produced were taken to the laboratory for measurements and testing. Prior to testing, the dimensions of each sample were measured using a steel rule as shown in Table 4, and their masses were measured using the Zhengya weighing apparatus. The volume and density of each sample were calculated using Equations 5 and 6 respectively.

$$V = l \times b \times h \quad (5)$$

$$e = \frac{m}{V} \quad (6)$$

where v represents the volume of each sample, l represents the length of each sample, b represents the breadth of each sample, h represents the height of each sample, e represents the density of each sample, and m represents the mass or weight of each sample.

Table 4: Dimensions of all the concrete interlocks samples produced

| Sample Mix | Length (cm) | Breadth (cm) | Height (cm) | Volume (cm ³) |
|----------------------|-------------|--------------|-------------|---------------------------|
| 0% PKS with 100% GNC | 15.00 | 8.00 | 5.00 | 600.00 |
| 10% PKS with 90% GNC | 15.00 | 8.00 | 5.00 | 600.00 |
| 20% PKS with 80% GNC | 15.00 | 8.00 | 5.00 | 600.00 |
| 30% PKS with 70% GNC | 15.00 | 8.00 | 5.00 | 600.00 |
| 40% PKS with 60% GNC | 15.00 | 8.00 | 5.00 | 600.00 |
| 50% PKS with 50% GNC | 15.00 | 8.00 | 5.00 | 600.00 |
| 60% PKS with 40% GNC | 15.00 | 8.00 | 5.00 | 600.00 |
| 70% PKS with 30% GNC | 15.00 | 8.00 | 5.00 | 600.00 |
| 80% PKS with 20% GNC | 15.00 | 8.00 | 5.00 | 600.00 |
| 90% PKS with 10% GNC | 15.00 | 8.00 | 5.00 | 600.00 |
| 100% PKS with 0% GNC | 15.00 | 8.00 | 5.00 | 600.00 |

2.5 Water Absorption Testing

The samples to be tested were first immersed in a curing tank containing distilled water at room temperature. The samples, after 24 hours of immersion, were taken out of the water and allowed to drain before they were re-measured using the Zhengya weighing apparatus. The weight of water absorbed and the percentage by weight of water absorbed by each sample were calculated using Equations 7 and 8 respectively and were recorded in Table 5.

$$W_{ab} = W_{wR} - W_{dR} \quad (7)$$

$$\%W_{ab} = \frac{W_{wR} - W_{dR}}{W_{dR}} \times 100\% \quad (8)$$

Where W_{wR} = wet weight retained, W_{dR} = dry weight retained, W_{ab} = weight of water absorbed, $\%W_{ab}$ = percentage by weight of water absorbed.

2.6 Compressive Strength Testing

During testing, each of the samples was subjected to the Universal compressive testing machine. Both ends of each sample were crushed in each test session for even distribution of load or force by the machine. The compressive area of each sample was calculated using Equation 9 and the compressive forces were recorded from the testing machine as shown in Table 6. After testing, the compressive strength of each sample tested was calculated using Equation 10.

$$A = l_c \times b_c \quad (9)$$

$$E = \frac{F}{A} \quad (10)$$

Where A = compressive area of each sample, l_c = compressive length of each sample, b_c = compressive breadth of each sample, E = compressive strength of each sample, F = compressive force or load applied on each sample, A = compressive area of each sample.

Table 5: Percentage by weight of water absorbed by the samples

| Sample Mix | Weight of sample (g) | Weight after 24hrs in water (g) | Weight of water absorbed (g) | Percentage by weight of water absorbed (g) |
|----------------------|----------------------|---------------------------------|------------------------------|--|
| 0% PKS with 100% GNC | 1220 | 1250 | 30 | 2.46 |
| 10% PKS with 90% GNC | 1246 | 1277 | 31 | 2.49 |
| 20% PKS with 80% GNC | 1250 | 1283 | 33 | 2.64 |
| 30% PKS with 70% GNC | 1300 | 1336 | 36 | 2.77 |
| 40% PKS with 60% GNC | 1170 | 1207 | 37 | 3.16 |
| 50% PKS with 50% GNC | 1130 | 1169 | 39 | 3.45 |
| 60% PKS with 40% GNC | 1050 | 1092 | 42 | 4.00 |
| 70% PKS with 30% GNC | 980 | 1023 | 43 | 4.39 |
| 80% PKS with 20% GNC | 860 | 905 | 45 | 5.23 |
| 90% PKS with 10% GNC | 840 | 888 | 48 | 5.71 |
| 100% PKS with 0% GNC | 790 | 839 | 49 | 6.20 |

Table 6: Compressive forces or loads of all the samples of the concrete interlocks

| Sample Mix | Compressive Length (mm) | Compressive Breadth (mm) | Compressive Area (mm ²) | Compressive Force (KN) |
|----------------------|-------------------------|--------------------------|-------------------------------------|------------------------|
| 0% PKS with 100% GNC | 120.00 | 50.00 | 6000 | 78.50 |
| 10% PKS with 90% GNC | 120.00 | 50.00 | 6000 | 75.50 |
| 20% PKS with 80% GNC | 120.00 | 50.00 | 6000 | 68.20 |
| 30% PKS with 70% GNC | 120.00 | 50.00 | 6000 | 60.10 |
| 40% PKS with 60% GNC | 120.00 | 50.00 | 6000 | 57.90 |
| 50% PKS with 50% GNC | 120.00 | 50.00 | 6000 | 53.60 |
| 60% PKS with 40% GNC | 120.00 | 50.00 | 6000 | 41.20 |
| 70% PKS with 30% GNC | 120.00 | 50.00 | 6000 | 34.70 |
| 80% PKS with 20% GNC | 120.00 | 50.00 | 6000 | 27.40 |
| 90% PKS with 10% GNC | 120.00 | 50.00 | 6000 | 25.60 |
| 100% PKS with 0% GNC | 120.00 | 50.00 | 6000 | 17.60 |

3. Results and Discussion

3.1 Sieve Analysis Test Result

The frequency polygon in Figure 1 shows the relationship between the cumulative percentages by weight of aggregates passing and the sieve sizes. From Figure 1, it can be seen that the cumulative percentage passing through sieves of palm kernel shells and granite chips respectively increases as the sieve sizes increases from 5.0mm to 12.0mm. In accordance with BS EN 933-1 (1997) for the determination of the particle size distribution of aggregates, the fineness modulus of palm kernel shells was calculated as 1.62 while that of granite chips was calculated as 1.68. This shows that the palm kernel shell aggregates were less coarse than those of granite chips. The coefficient of uniformity of palm kernel shells was 1.28 indicating that the palm kernel shell aggregates were well graded with fine, medium and coarse particles since the coefficient of uniformity

was less than 4. Also, the coefficient of uniformity of granite chips was 1.30 indicating that the granite chip aggregates were also well graded with fine, medium and coarse particles since the coefficient of uniformity was less than 4. It can be deduced from the experiment that the particles of the granite chips were about the same sizes as those of palm kernel shells since larger percentages of both aggregates were retained in the 6.3mm and the 5.0mm sieve shakers.

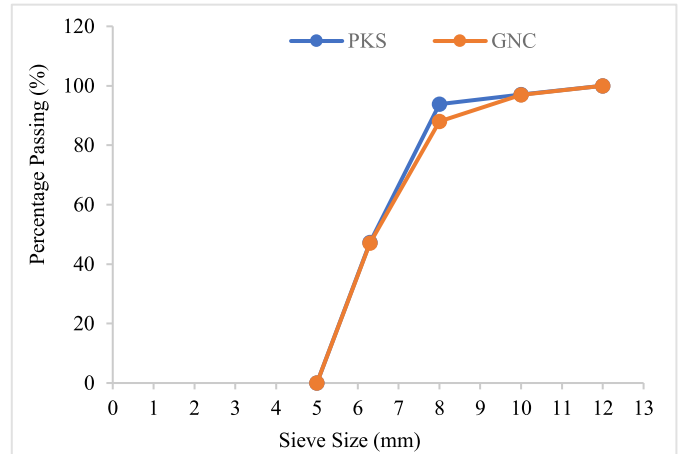


Figure 1: Percentage passing versus sieve sizes

3.2 Samples of Concrete Interlocks

Figure 2 shows the eleven samples of concrete interlocks produced in this study with varying percentage replacement ratio of palm kernel shells with granite chips. From Figure 2, it can be seen that the surfaces of the samples produced become rougher as the percentage replacement ratio of the palm kernel shells increases from 0% to 100%. This observation is in agreement with the work reported by Azunna, (2019) where he stated that the surfaces of the samples become roughened due to the inability of palm kernel shells to form proper bonding with other aggregates. This is because palm kernel shells possess smooth spherical shape which makes it difficult for cement paste and other aggregates to hold onto it.



Figure 2: Eleven (11) samples of concrete interlocks with varying percentage ratio of PKS.

3.3 Water Absorption Test Result

The frequency polygon in Figure 3 shows the relationship between the percentage by weight of water absorbed in each of the samples produced and percentage replacement ratio of the palm kernel shells with granite chips. From Figure 3, it can be seen that the percentage by weight of water absorbed by each sample increases as the percentage replacement ratio of the palm kernel shells increases from 0% to 100%. This finding is in accordance with the work done by Nurazuwa et al., (2017) where they postulated that palm kernel shells have better water absorption ability than granite chips due to their porous organic nature. The highest percentage by weight of water absorbed by the samples was at the 100% PKS having a percentage weight value of 6.20% while the lowest percentage by weight of water absorbed by the samples was at the 0% PKS having a percentage weight value of 2.46%. The 6.20% highest value by weight of water absorbed by the 100% PKS with 0% GNC sample fall within the range of 5% to 25% for light weight aggregates specified by the Concrete Society (1987). Although BS 8007 and BS 6349 recommend a maximum water absorption limit of 3% for

aggregates in concrete structures, palm kernel shell samples can still perform adequately despite their higher absorption rates because their pores would help to enhance internal curing. Higher absorption rates by palm kernel shell samples have also been reported in the works of earlier researchers such as Padavala et al., 2024 at 18.33%; Ndoke, 2006 at 23.40%; Ekong, 2013 at 26.25% among others.

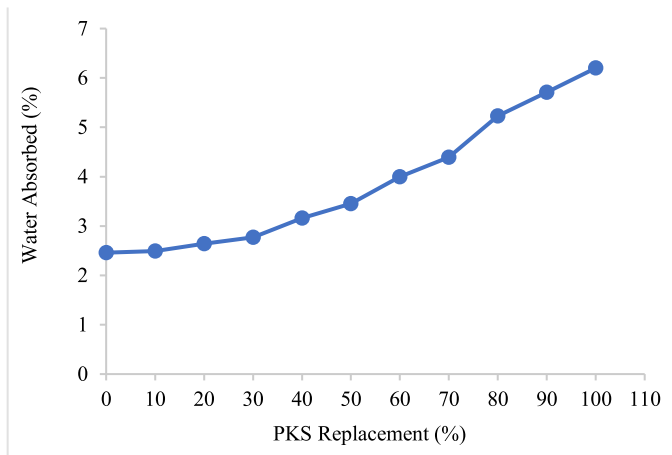


Figure 3: Water absorbed versus varying ratio of PKS with GNC

3.4 Experimental Results

Table 7 shows the results of the weight, density and compressive strength tests of the eleven samples of concrete interlocks produced. The weights of the samples were obtained using Zhengya weighing apparatus while the density of each sample was calculated using Equation 8. The compressive strength of each sample tested was then calculated using Equation 10.

Table 7: Weight, Density and Compressive strength test results

| Sample Mix | Weight (g) | Density (kg/m ³) | Compressive Strength (MPa) |
|----------------------|------------|------------------------------|----------------------------|
| 0% PKS with 100% GNC | 1220 | 2033 | 13.08 |
| 10% PKS with 90% GNC | 1246 | 2077 | 12.58 |
| 20% PKS with 80% GNC | 1250 | 2083 | 11.37 |
| 30% PKS with 70% GNC | 1300 | 2167 | 10.02 |
| 40% PKS with 60% GNC | 1170 | 1950 | 9.65 |
| 50% PKS with 50% GNC | 1130 | 1883 | 8.92 |
| 60% PKS with 40% GNC | 1050 | 1750 | 6.87 |
| 70% PKS with 30% GNC | 980 | 1633 | 5.78 |
| 80% PKS with 20% GNC | 860 | 1433 | 4.57 |
| 90% PKS with 10% GNC | 840 | 1400 | 4.27 |
| 100% PKS with 0% GNC | 790 | 1317 | 2.93 |

3.4.1 Effect of Weight and Density on the Samples

The frequency polygon in Figure 4 shows similar relationship between the quantities (weight and density) of the samples produced and percentage replacement ratio of the palm kernel shells with granite chips. From Figure 4, it can be seen that the weight and density of the samples increase as the percentage replacement ratio of the palm kernel shells increase from 0% to 30% and then began to decrease as the percentage replacement ratio of the palm kernel shells kept on increasing from 30% to 100%. This phenomenon is in line with the work done by Dadzie and Yankah, (2015) where the weight and density of their samples increased as the palm kernel shell replacement increases from 0% to 10% before decreasing as the palm kernel shell replacement kept on increasing from 10% upwards. The highest weight and density of the samples was at the 30% PKS having a weight value of 1300g and density value of 2167kg/m³ while the lowest weight and density of the samples was at the 100% PKS having a weight value of 790g and density value of 1317kg/m³. Also, the control sample was at 0% PKS having a weight value of 1220g and density value of 2033kg/m³ which were lower than the weights and densities of the samples ranging from 10% PKS to 30% PKS but higher than those ranging from 40% PKS to 100% PKS. These figures suggest that the aggregates of the samples ranging from 10% to 30% contain certain substances influencing the weight and density increment of the samples. The analysis of these results has shown that samples of concrete interlocks produced with palm kernel shell aggregates are heavier and denser than the conventional concrete interlocks when the percentage replacement ratio of the palm kernel shells do not exceed 30%.

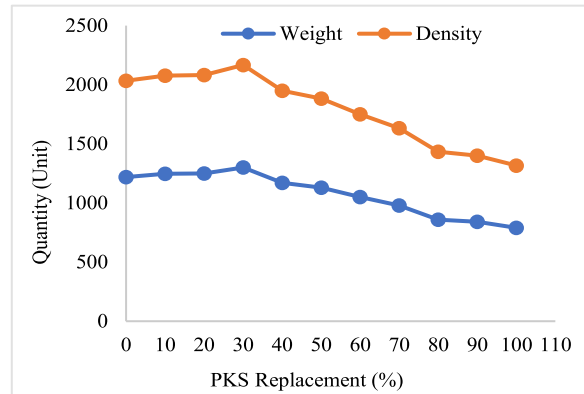


Figure 4: Weight and density of concrete interlocks versus varying ratio of PKS with GNC

3.4.2 Effect of Compressive Strength on the Samples

The frequency polygon in Figure 5 shows the relationship between the compressive strength of the samples produced and percentage replacement ratio of the palm kernel shells with granite chips. From Figure 5, it can be seen that the compressive strength of the samples decreases as the percentage replacement ratio of the palm kernel shells increase from 0% to 100%. This finding is in accordance with the work done by Olanrewaju et al., (2023); Yusra and Opirina (2019); and many other researchers around the globe. The highest compressive strength of the samples with PKS replacements was at the 10% PKS, having a compressive strength value of 12.58MPa, while the lowest compressive strength of the samples with PKS replacements was at the 100% PKS, having a compressive strength value of 2.93MPa. Also, the control sample at 0% PKS has a compressive strength value of 13.08MPa, which was higher than the compressive strength of the samples ranging from 10% PKS to 100% PKS. The analysis of these results has shown that samples of concrete interlocks produced with palm kernel shell aggregates are relatively stronger when the percentage replacement ratio of the palm kernel shells do not exceed 10%.

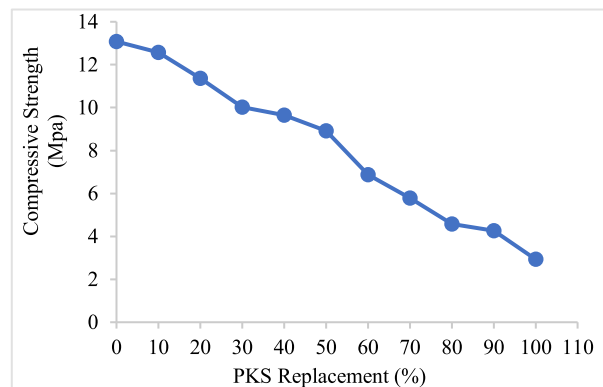


Figure 5: Compressive strength of concrete interlocks versus varying ratios of PKS

3.5 Comparison of Compressive Strengths

BS 8110 (1997) recommends a minimum compressive strength value of 15.00MPa for structural low-weight concretes at 28 curing days having a mixing ratio of 1:1.5:3 (BS 8110-01 1997; Okorafor et al., 2019). Factory X produces samples with an average compressive strength value of 12.00MPa at 28 curing days having a mixing ratio of 1:2:3 (located in Patani Road, Ughelli, Delta State of Nigeria). Factory Y produces samples with an average compressive strength value of 10.00MPa at 28 curing days having a mixing ratio of 1:3:3 (located in Afiesere Road, Ughelli, Delta State of Nigeria).

This study produces samples with optimal compressive strength values of 12.58MPa with PKS (10%) and 13.08MPa without PKS (control sample) at 28 curing days having a mixing ratio of 1:2:3 (study conducted in the mechanical laboratory of the Delta State University, Abraka, Nigeria).

The histogram in Figure 6 compares the compressive strengths as recommended by BS 8110 (1997), factory X and factory Y, as well as the samples produced with 10% PKS in this study. From Figure 6, it is revealed that the compressive strength of the samples produced at the 10% PKS lagged the minimum strength recommended by the BS 8110 (1997) but surpassed the strengths of the samples produced at factories X and Y respectively. However, the sand mixing ratio of this study was 25% higher than that recommended by the BS 8110 (1997) but 50% lower than that of factory Y. Moreso, BS 8110 (1997) suggests curing methods that retain moisture, rather than clearly specifying air curing as a standard practice.

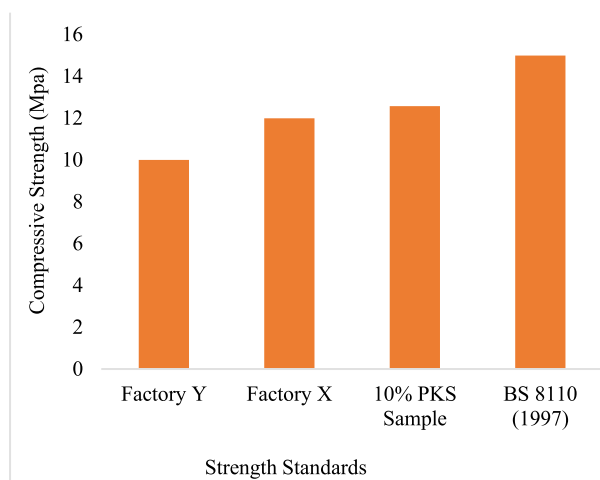


Figure 6: Comparing different compressive strengths

4. Conclusion

The study analyzes the effect of varying the proportions of PKS on the properties of concrete interlocks cured in air. The results obtained so far have shown that the 10% PKS with 90% GNC combination has the highest compressive strength value of 12.58MPa, aside from the control sample with compressive strength value of 13.08MPa. The analysis of the results has shown that producing concrete interlocks at 10% PKS with 90% GNC combination by factory X and factory Y could reduce palm kernel shell wastes in their immediate environments as well as lowering the cost of producing their interlocking concretes. It should be noted that the palm kernel shell surfaces were not roughened before using them for the study due to the unavailability of palm kernel shell roughening devices or machines. Future work in this field of study should focus on roughening the surfaces of the shells so as to enhance the bonding of the shells with other aggregates of the samples. Concrete interlocks produced with palm kernel shell aggregates in the mixing ratio 1:2:3 at 10% PKS with 90% GNC combination therefore have good commercial potential as a result of their high compressive strength value, which surpasses the strength values at factory X (12.00MPa) and factory Y (10.00MPa) respectively.

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