Effect of Water Cement Ratios on Compressive Strength of Palm Kernel Shell Concrete

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Abstract

This study examined the effect of varying water cement ratio on the compressive strength of concrete produced using palm kernel shell (PKS) as coarse aggregate at different replacement levels. The replacement levels of coarse aggregate with palm kernel shells (PKS) were 0%, 25%, 50%, and 100% respectively. PKS concrete cubes (144 specimens) of sizes 150mm x 150mm x 150mm were cast and cured in water for 7, 14, 21 and 28 days respectively. A mix ratio of 1:2:4 was adopted with water-cement ratio of 0.45, 0.5, and 0.6 respectively while the batching was done by weight. Slump test was conducted on fresh concrete while compressive strength test was carried out on the hardened concrete cubes using a compression testing machine of 2000kN capacity. The result of tests on fresh concrete shows that the slump height of 0.45 water cement ratio (w/c) increases with an increase in PKS%. This trend was similar to 0.50 and 0.60 w/c. However, the compressive strength of concrete cube decreases with an increase in w/c (from 0.45 to 0.60) but increases with respect to curing age and also decreases with increase in PKS%. Concrete with 0.45 water-cement ratio possess the highest compressive strength. It was observed that PKS is not a good substitute for coarse aggregate in mix ratio 1:2:4 for concrete productions. Hence, the study suggest the use of chemical admixture such as superplasticizer or calcium chloride in order to improve the strength of palm kernel shells-concrete.

Keywords: Palm kernel shell, water-cement ratio, concrete, compressive strength.

Introduction

Concrete is the most widely used construction material. It consists of cement, aggregates, water, and sometimes admixture (Saravananand Suganya, 2015). The aggregates account for 75% of the concrete volume and play a major role in concrete properties such as workability, strength, dimensional stability and durability. There is a growing interest in using waste materials as alternative aggregate materials and significant research is made on the use of many different materials as aggregate substitutes (Ravikumar *et al.,* 2015). Industrial waste materials such as coal ash, blast furnace slag and steel slag and agricultural waste materials such as coconut shell, palm kernel shells and so on have been used by many researchers as replacement of aggregate in concrete for the purpose of recycling industrial and agricultural waste materials. In recent time, several researchers have used palm kernel shells (agricultural waste) for production of light-weight concrete. However, this study focused on utilization ofpalm kernel shells with varying water cement ratio for production of normal-weight concrete in a quest for reducing environmental pollution.

Palm kernel shells (PKS) are organic waste materials obtained from crude palm oil producing factories mostly in Asia and Africa (Alengaram *et al.,* 2010). The oil palm industry is important in many countries such as Malaysia, Indonesia and Nigeria. However, Malaysia is the world leader in the production and exportation of palm oil that contributes about 57.6% of the total supply of palm oil in the world. Oil palm shells are produced in large quantities by the oil mills. In Malaysia and Nigeria, it was estimated that over 4 and 1.5 million tonnes respectively of palm kernel shell (PKS) waste is produced annually and only a fraction is used for fuel (for steam boilers at palm oil mills) and other applications (Shafigh *et al.,* 2010). The main palm oil producing states in Nigeria includes, Ogun, Osun, Ondo, Oyo, Edo, Cross River, Anambra, Enugu, Imo, Abia, Ekiti, Akwa-Ibom, Delta and Rivers (Adeyemi *et al.,* 2017).

Alengaram *et al.,* (2010) examine the effect of aggregate size and proportion on strength properties of palm kernel shell concrete. The research presents information on the physical and mechanical properties of different sizes of palm kernel shells (PKS) used as lightweight aggregates (LWA) and their influence on mechanical properties of palm kernel shell concrete (PKSC). Silica fume and fly ash were used as cementitious materials and all mixes had 1% superplasticizer on cement weight. The study reported that PKS consists of about 65 to 70% of medium size particles in the range of 5 to 10 mm. The other two sizes, namely, small (0-5 mm) and large (10-15 mm) sizes were found to influence the mechanical properties of PKSC. The 28-day compressive strengths were found in the range of 21 to 26 MPa. The concrete mix that was made with medium size PKS only produced lower compressive strength of about 11% compared to the mix that contained all sizes of PKS. However, the exclusion of medium size particles didn’t cause any segregation in the gap-graded aggregate concrete. The strength of PKS and bond governed the failure of PKSC. It was concluded that PKSC with about 70% of PKS of large size produced the highest modulus of elasticity of about 11 GPa.

Daneshmand and Saadatian (2011), investigated the influence of oil palm shell on workability and compressive strength of high strength concrete. In the experiment, concrete was produced by different percentage of OPS i.e. 10%, 20%, 30%, 40% and 50% by weight of coarse aggregate. The results demonstrated that the workability for OPS samples shows a relatively medium to high workability with slump values ranging from 28 to 50mm and compaction factor from 0.93 to 0.95. It was concluded that the study can bea valuable contribution to the production of high strength concrete as well as lightweight concrete particularly in construction of high rise buildings.

Shafigh *et al.,* (2010) carried out a study on mix design and mechanical properties of oil palm shell lightweight aggregate concrete. It was reported that research over the last two decades shows that OPS can be used as a lightweight aggregate for producing structural lightweight aggregate concrete. However, the study concluded that significant achievements can be attained in OPS concrete and comparing it with other lightweight aggregate concrete.

Observation from previous studies indicated that PKS was used for light-weight concrete. Whereas, this study focused on utilization of PKS with varying water cement ratio for production of normal-weight concrete.

Materials and Methods

Materials

The materials consist of Ordinary Portland cement (OPC) – Dangote cement brands 42.5R which conformed to NIS 444 – 1:2003, water, fine aggregate (natural sand) which passes through sieve 4.75mm and conformed to BS 882 (1992), coarse aggregate (crushed stone) of maximum size 19.0mm and conformed to BS 882 (1992) and palm kernel shells (obtained from a local palm oil producing factory in Konta-Ijabe, Osun State Nigeria).

Preparation of palm kernel shells (PKS)

The palm kernel shells were washed and properly rinsed to remove dirt and residue which can doubtlessly affect the performance of the concrete produced. After rinsing, the palm kernel shells were air dried and sieved mechanically with sieve shaker. The palm kernel shells passed through the sieve of 19mm diameter.

Methods

Palm Kernel Shell cubes of 144 numbers (150 x 150 x150 mm) were cast for different water cement ratios of 0.45, 0.5 and 0.6 with different percentage replacement levels with PKS of control, 25%, 50% and

100%. The cubes were cured for 7, 14, 21 and 28 days. Slump test was conducted on fresh concrete while compressive strength tests were carried out on the hardened concrete cubes using a compression testing machine at the end of each curing ages.

Results and Discussion

Specific gravity

The result obtained from specific gravity of fine aggregate, coarse aggregate and palm kernel shell (PKS)are shown in Table 1.

Table 1: Specific gravity of fine, coarse aggregate and palm kernel shell

Test Samples	Specific Gravity
Fine Aggregate	2.53
Palm Kernel Shell	1.36
Coarse Aggregate	2.64

Specific gravity of aggregates as specified by ACI Education Bulletin E1 (2007) ranges from 2.30 to 2.90. The results of specific gravity of fine and coarse aggregate shown in Table 1 are within the acceptable limits while that of Palm Kernel Shell is below the limit and it implies that PKS is a lightweight aggregate.

Concrete slump test

This test was conducted to determine the workability of concrete. The slump test is the most well-known and widely used test method to characterize the workability of fresh concrete. The test was conducted in accordance with ASTM C192/C192M (2006) and the results are shown in Figure 1.

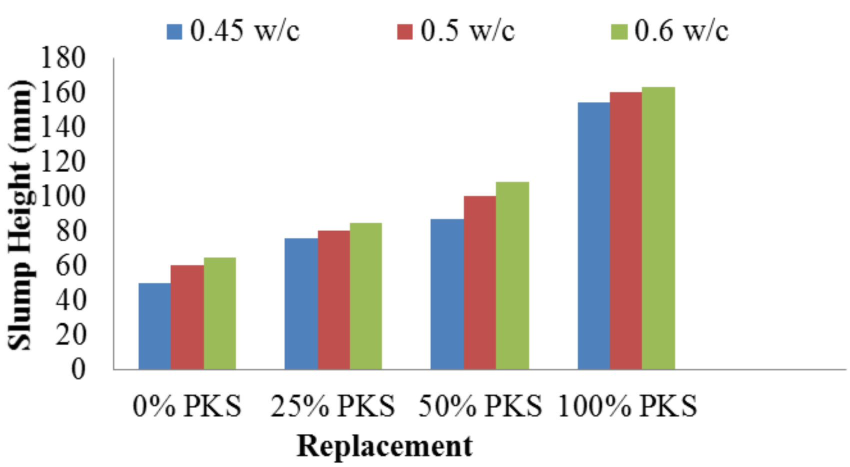

Fig. 1: Percentage replacement with various water-cement ratios against slump height

The slump height increases with an increase in water-cement ratio and PKS% i.e. the more the water-cement ratio, the more the slump height increases.

Compressive strength

The compressive strength test conforms to BS 1881:116 (1983) and the average compressive strength results are shown in Figure 2 to Figure 4.

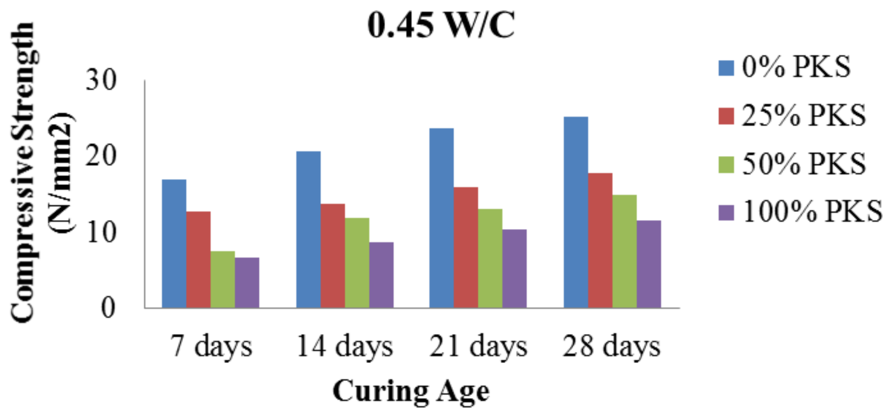

Fig. 2: Effect of percentage (%) replacement of PKS with water-cement ratio of 0.45

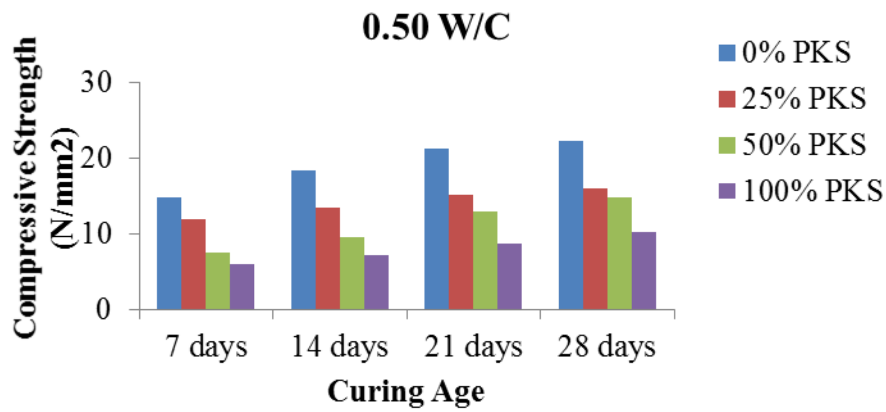

Fig. 3: Effect of percentage (%) replacement of PKS with water-cement ratio of 0.50

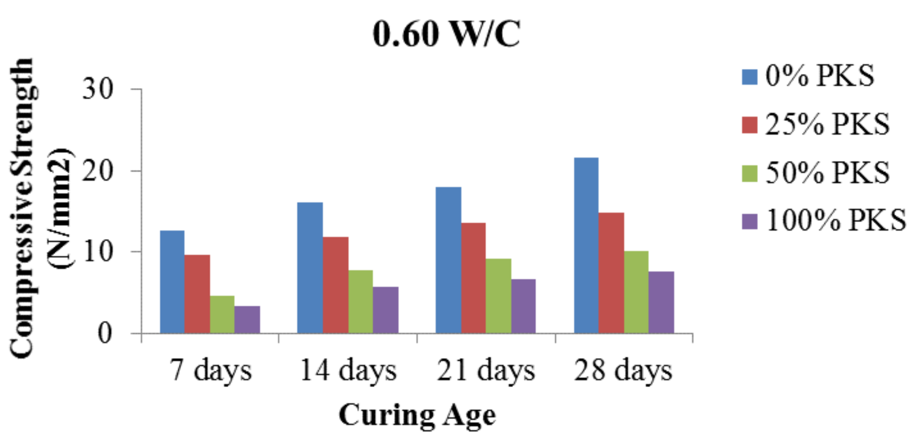

Fig. 4: Effect of percentage (%) replacement of PKS with water-cement ratio of 0.60

The compressive strength result shows that the concrete cube gain strength with an increase in the curing age but the strength decreases with an increase in the water cement ratio. However, the strength of concrete cubes decreases with an increase in PKS percentage.

At 7 days, the compressive strength results of 0% PKS with water-cement ratio of 0.6, 25% PKS (with water-cement ratio of 0.45, 0.5 and 0.6), 50% PKS (with water-cement ratio of 0.45, 0.5 and 0.6) and 100% PKS (with water-cement ratio of 0.45, 0.5 and 0.6) is lower than the minimum required compressive strength of 13.5 N/mm^2 for concrete grade 20 as specified by BS 8110 Part 2 (1985) while the strength of 0%PKS with water-cement ratio of 0.45 and 0.5 met the minimum required compressive strength of 13.5 N/mm^2 for grade 20 concrete specified by BS 8110 Part 2 (1985).

At 28 days, the strength of 0% PKS (with water-cement ratio of 0.45, 0.5 and 0.6) was above the specified value of 20 N/mm^{2}for grade 20 concrete (BS 8110:1985) while the strength of 25% PKS (with water-cement ratio of 0.45, 0.5 and 0.6), 50% PKS (with water-cement ratio of 0.45, 0.5 and 0.6) and 100% PKS (with water-cement ratio of 0.45, 0.5 and 0.6) were lower than the specified value of 20 N/mm^{2}for grade 20 concrete (BS 8110: Part 2, 1985) as shown in Table 2.

Table 2: Required/recommended strength of concrete (BS 8110 Part 2, 1985)

Grade	**Characteristic Strength, f_{cu} (N/mm^2)**	**Cube strength at an age of:**				
		7 days	2 months	3 months	6 months	1 year
20	20.0	13.5	22	23	24	25
25	25.0	16.5	27.5	29	30	31
30	30.0	20	33	35	36	37
40	40.0	28	44	45.5	47.5	50
50	50.0	36	54	55.5	57.5	60

Conclusion

The following conclusion can be drawn from the study:

i. Palm kernel shell is a lightweight aggregate and can be used to produce lightweight concrete.
ii. The specific gravity of PKS aggregate is relatively low compared to specific gravity of coarse aggregate as a result of the high amount of voids within the particles.
iii. The slump value increases with an increase in water-cement ratio and PKS% i.e. the more the water-cement ratio and PKS%, the more the slump height increases.
iv. The compressive strength of concrete cube increases with increase in curing age and decreases with increase in water-cement ratio and PKS%.
v. Concrete with 0.45 water-cement ratio possess the highest compressive strength.
vi. Palm kernel shells (PKS) is not a good substitute for coarse aggregate in mix ratio 1:2:4 concrete production. Hence, chemical admixture such as superplasticizer or calcium chloride should be used to improve the strength of palm kernel shells-concrete.

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