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An Investigation of the Compressive Strength of Super Plasticized Palm Kernel Shell Concrete

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Abstract: **This study investigated the effects of full/partial replacement of crushed granite with palm kernel shells (PKS) on the compressive strength, density and workability of super plasticized concrete. Concrete samples were prepared using a nominal volume mix ratio of 1:1.5:3 at a water/cement ratio of 0.6. Coarse aggregate was partially replaced with clean Palm Kernel shells from 0% to 100% at intervals of 25% while Conplast SP 430, a high range water reducer was added to each mix at 0%, 1% and 2% of cementitious material. 100mm×100mm×100mm concrete cubes were produced and compressive strength determined in accordance with ASTM guidelines at 7days, 14days, and 28days. Also the slump and density values were also determined. The results showed that an increase in PKS yields a corresponding decrease in compressive strength, density and workability of concrete. For each mix, addition of super plasticizer resulted in considerable improvements in measured parameters except for compressive strength where improvement was marginal for the dosage administered. Optimum super plasticizer content was observed to be at 1%. Contents above this resulted in marginal improvements only. At 75% replacement, compressive strength and other parameters were observed to be adequate for lightweight concrete production with an average value of over 17kN/m^2 at 28 days and good slump and density values. There is need to standardize the use of PKS as constituent material for light weight concrete production.**

Keywords: **Concrete, Super plasticizer, Palm Kernel Shell (PKS), Compressive Strength, Workability.**

I. INTRODUCTION

Concrete is extensively utilized in the construction of various engineering structures because of its inherent qualities and flexibility. The most outstanding property of concrete which endears it to users is its compressive strength. Most other properties of concrete, like the flexural strength and bond strength, improve simultaneously with its compressive strength. The extensive use of concrete results in excessive drawdown of natural resources like aggregates which in turn negatively impacts the environment. Besides the high cost of producing concrete is a major source of concern for developers. These concerns have given rise to increasing interest in the research of new materials that could replace concrete constituents especially the aggregates which make up about 70% - 80% of the total volume [1]. Researchers have investigated the potential of various materials in concrete production including industrial wastes and by products of manufactured products [2], construction and demolition wastes, and agricultural waste [3]. In recent times there has been growing interest in the use of agricultural waste like shells of various sea foods and crops as potential aggregate materials. These wastes ordinarily pose a threat to the environment especially in developing countries where waste to wealth technology is lacking. The use of agricultural waste such as shells of various types results in practical and economic advantage especially as these shells are generally almost always free and easy to transport [2]. Researchers have shown that the use of Palm Kernel Shell (PKS) in concrete production can result in good quality light weight concrete [4], [5]. PKS can also result in concrete with properties similar to that of normal weight concrete [6], [7]. Also, PKS has similar bulk density as light weight concrete aggregates [8].

Palm Kernel Shell (PKS) is an agricultural waste obtained from the threshing, crushing and extraction activities in the palm oil processing mill. It is available in large quantities in the tropical regions of the world especially in Asia, and Africa. The high demand for palm kernel oil in Nigeria has resulted in the generation of over 1.5 million tons of PKS as waste [9]. The high volume of PKS waste results in disposal and environmental challenges. Besides construction, PKS is used as fuel in local communities. PKS particles are irregularly shaped with slightly rough and spiky edges depending on the extraction method. The particles are typically of a smooth surface on the concave or convex face with thickness ranging from 1.5 mm to 4 mm [10].

Being an organic material, PKS has high water absorption due to the skin pores of the shells. Depending on the specie, the 24hr water absorption can range between 14% - 33% [11]. This high water absorption has serious impact on the quality of concrete produced with PKS. Hence the mix design of PKS concrete does not follow that of Normal Weight Concrete [11]. Researchers have also reported a loose and compacted bulk density range of 500 – 740kg/m^3 for PKS. This makes PKS a suitable material for the production of concrete with lower densities usually ranging from 1600 – 1900kg/m^3 [12], [13]. The compressive strength of concrete depends on the water-cement ratio. The high absorption capacity of PKS can therefore negatively impact the strength of PKS concrete. To mitigate this inadequacy, water reducing admixtures like super plasticizers can be deployed. The use of admixtures to modify concrete behaviour is well researched and applied even in conventional concrete production.

II. MATERIALS AND METHODS

The research was carried using the following equipment in the soil and materials laboratory of the Department of Civil Engineering, University of Uyo, in Akwa Ibom State of Nigeria: Cast Iron concrete cube moulds, mini concrete mixer, shovel, digital weighing balance, sieve analysis set, tamping rod, measuring pans, slump apparatus, and digital crushing machine for compressive strength test. Crush rock granite; with sizes ranging from 5mm – 15mm; obtained from a quarry located at Akamkpa in Cross River state, Nigeria was used as the natural coarse aggregate. River sand sourced locally was used as fine aggregate for all concrete mixes. While the PKS obtained locally in Akwa Ibom state of Nigeria was used as partial or full replacement for coarse aggregate. The collected PKS was washed, and sun dried to remove dust, dirt, oil and other impurities that may negatively impact test results before storing in dry sacks away from water. Prior to using, PKS was sorted to eliminate particles that are less than 3.35mm. This elimination was necessary in order to reduce the overall water absorption of the concrete mixes to be produced. Dangote brand grade 32.5 Portland-Limestone cement; which conforms to BS EN 197 – 1 requirements; obtained locally in Uyo was used in producing all concrete samples. Conplast SP 430, a sulphonated naphthalene polymer that easily disperses in water was used to produce concrete samples with PKS. Ordinary water from the public supply was used throughout the experiments.

The study utilized a volume batching method with a nominal mix ratio of 1:1.5:3 and water cement ratio of 0.6 for all samples. Coarse aggregate was replaced with PKS from 0% to 100% at intervals of 25% by volume of material. Superplasticizer was dosed by weight of cement at 0% - 2% at 1% intervals. 117 concrete cubes of size 100mm x 100mm x 100mm were produced with 9 samples for each mix. The specimens were demoulded after 24hrs and cured by immersion in fresh water for 7 days, 14 days and 28 days crushing in accordance with BS 1881-part 116, 1983. The compaction factor apparatus was used to test the workability of fresh concrete while demoulded density was also measured before crushing specimens. Before crushing, samples were removed from the curing bay and left at room temperature for at least 2hrs.

Fig 1: Palm kernel shells in various sizes

III. RESULTS AND DISCUSSION

A. GRADATION: Uniformity coefficient of the coarse aggregates was 1.77 and 2.00 for Crushed granite and PKS respectively. This implies that both materials are well graded as can been seen in figure 2. Prior to gradation test, PKS particles were sorted to remove small particles below 3.5mm.

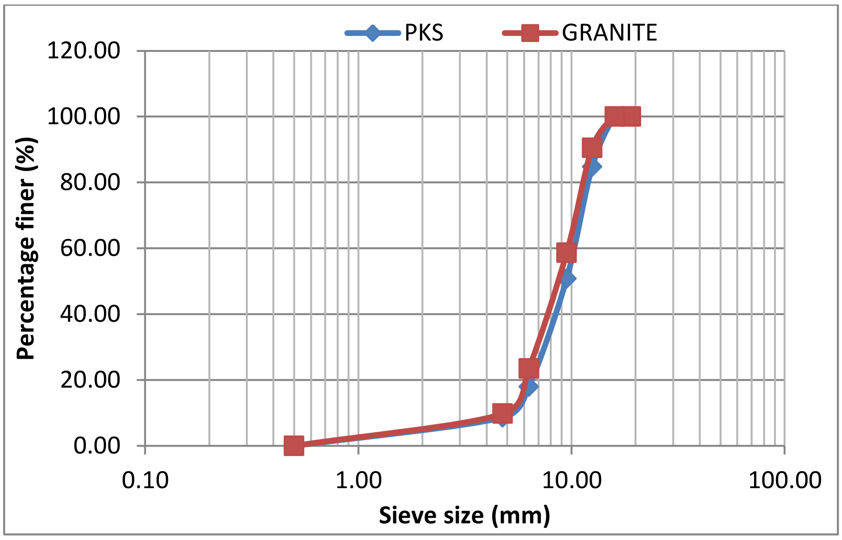

Figure 2: Particle size distribution of granite and PKS

B. WORKABILITY: The results from the workability test are presented in Table 1. It can be seen that the workability of concrete reduces as PKS content increases. As PKS percentage increases there is a corresponding increase in the specific surface hence the requirement of more water to achieve workability. It can also be seen that an increasing dosage of superplasticizer results in higher values of slump and hence better workability. At 25% replacement level, it can be deduced that benefits are optimized.

Table 1: Results of workability test

% PKS	% Super plasticizer	Slump (mm)
0	0	12
25	0	10
25	1	18
25	2	25
50	0	5
50	1	12
50	2	17
75	0	2
75	1	10
75	2	15
100	0	0
100	1	4
100	2	7

C. DENSITY: The variation of density with Palm Kernel Shell content is presented in Figure 3. It shows that density reduces with increase in percentage content of PKS. It also shows that density increased with age of cube specimen. At 50% replacement level and below, PKS concrete has density that is above 2000kg/m^3 hence may be classified as normal weight concrete material [11]. The positive benefit of super plasticizer on the density of samples was observed to be insignificant. Hence the average densities of samples with 0% - 2% super plasticizer content were used to plot the graph. This could be as a result of its direct action only on reducing the need for water.

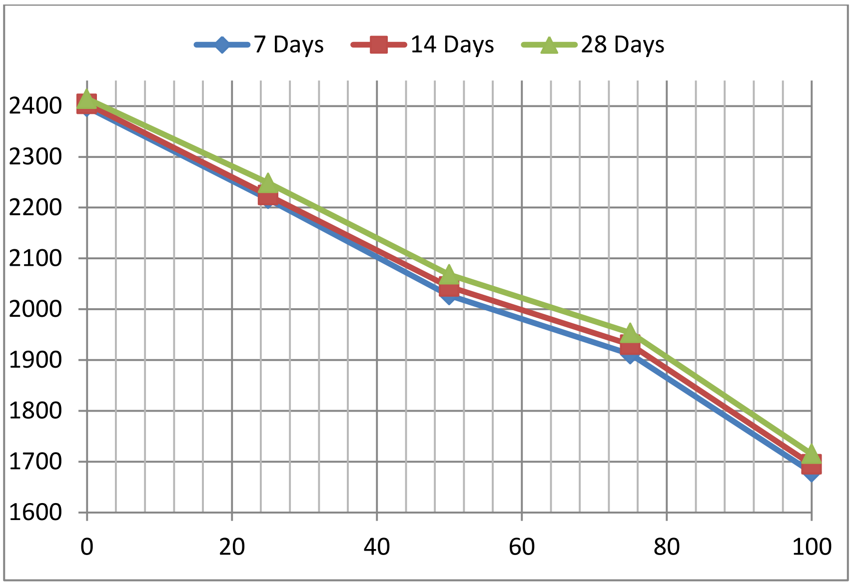

Figure 3: Density variation with PKS content

D. COMPRESSIVE STRENGTH: The variation of compressive strength with Palm Kernel Shell content was measured relative to the Super plasticizer content. The results are presented in Figures 4to 6. From the Figures, the compressive strength is seen to decreases as Palm Kernel Shell content increased. This is as a result of the need for more cement paste to coat the larger surface area arising from the increase in PKS content. Besides the smooth surface of the PKS particles can also impact the cement paste aggregate bonding. The average 28-Day compressive strength of samples with between 0% and 75% PKS content was observed to vary between 15kN/m^2 and 20kN/m^2. The values imply that the PKS concrete satisfies the criteria for lightweight concrete with light weight aggregate specified in BS 8110, 1997. It can also be seen that the difference in compressive strength is small as PKS content increases. By implication depending on the need of the user and relative availability of both coarse aggregate materials, PKS content of 25% -75% may be adopted. However, it is imperative to note that concrete properties are optimum at 25% PKS content as such for best results overall a 25% replacement level is ideal in the production of light weight concrete for structural works. The compressive strength was also observed to increase marginally by about 1.5% as super plasticizer content increased. But no difference was observed as super plasticizer content increased from 1% to 2%.

It can thus be noted that addition of super plasticizer resulted in improved workability rather than strength. This might be due largely to the utilization of cement paste to coat a larger specific surface of aggregate due to increasing content of PKS.

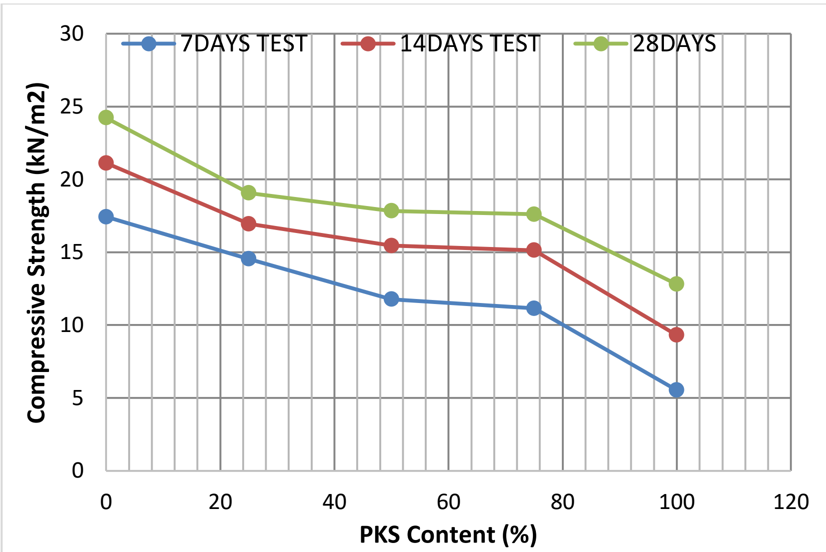

Figure 4: Compressive strength variation with PKS content at 0% Super Plasticizer content

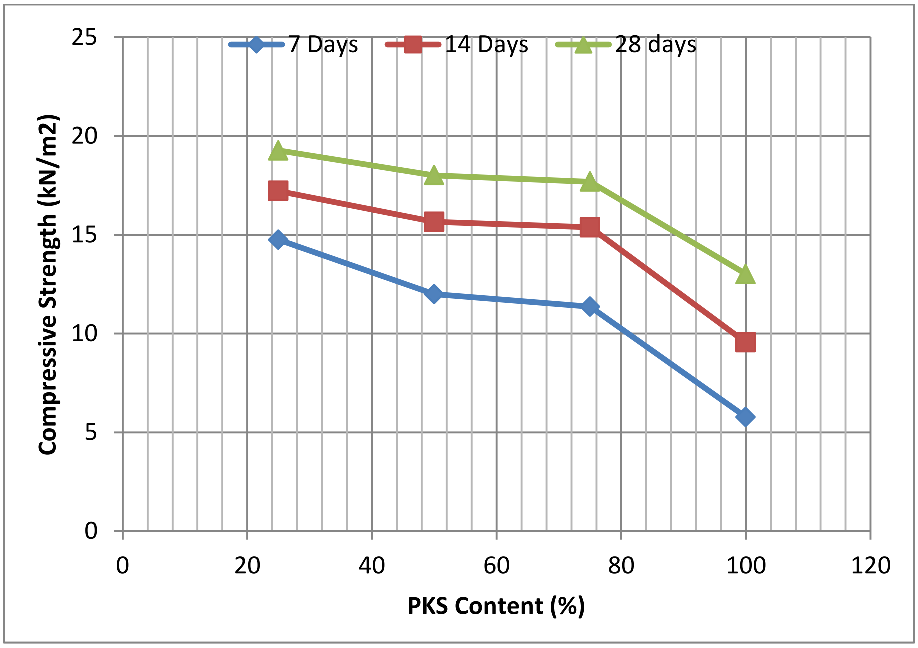

Figure 5: Compressive strength variation with PKS content at 1% Super Plasticizer content

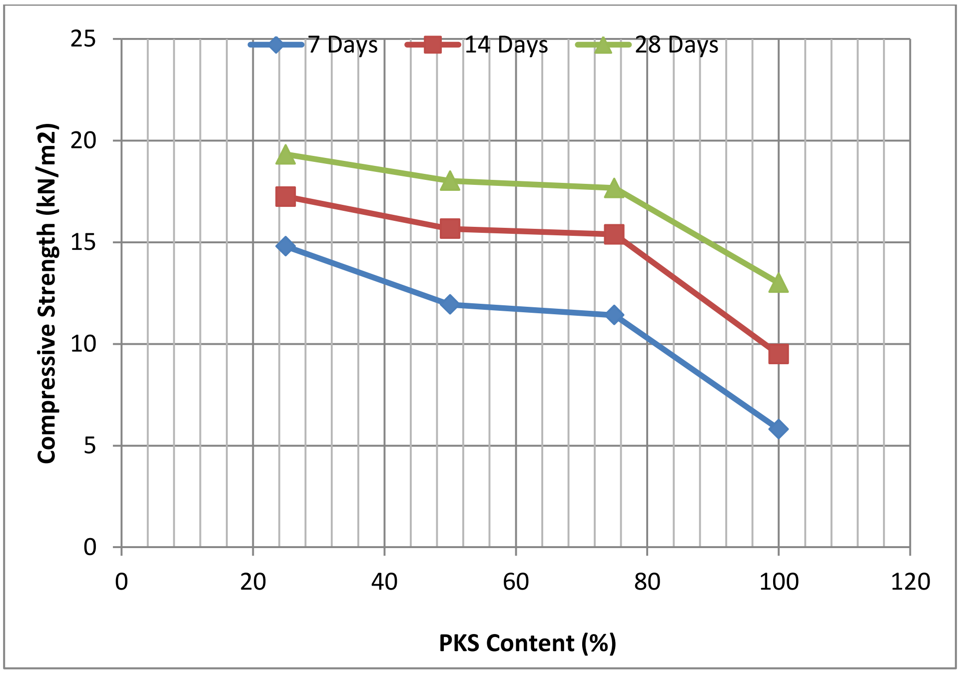

Figure 6: Compressive strength variation with PKS content at 2% Super Plasticizer content

IV. CONCLUSION

Based on the results of this research, it can be concluded that PKS concrete can safely be deployed in light weight concrete works. Increase in PKS content leads to corresponding loss of workability, lower density and lower compressive strength. To mitigate the losses the use of chemical admixtures can be employed however the nature and type of admixture may have an impact on the eventual outcome as it was observed here with significant benefit recorded for workability upon addition of Conplast SP 430. Although, at 75% replacement level compressive strength values meet the minimum requirement for lightweight concrete, the mix that results is not workable. Optimum values for workability, density and compressive strength was at 25% Palm Kernel Shell (PKS) content. The use of PKS in lightweight concrete production can benefit rural farming communities with palm kernel mills and even other builders. To maximize its use however there is need to standardize the use of PKS in concrete. There is also an urgent need to investigate the tensile capacity of reinforced PKS concrete to herald its use in reinforced concrete construction.

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