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Compressive Strength of Concrete Containing Palm Kernel Shell Ash

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ABSTRACT: *This study examined the influence of varying palm kernel shell ash content, as supplementary cementitious material (SCM) at specified water/cement ratios and curing ages on the compressive strength of concrete cubes samples. Palm kernel shell ash was used as a partial replacement for ordinary Portland cement (OPC) up to 30% at 5% intervals using mix ratio 1:2:4. River sand with particles passing 4.75mmBS sieve and crushed aggregate of 20mm maximum size were used while the palm kernel shell ash used was ofparticles passing through 212µm BS sieve. The compressive strength of the test cubes (100mm) were tested at 5 different curing ages of 3, 7, 14, 28 and 56 days. The result showed that test cube containing Palm kernel shell ash gained strength over a longer curing period compared with ordinary Portlandcement concrete samples and the strength varies with percentagePKSAcontent in the cube samples. The results showed that at 28 days test cubes containing 5%, 10%, 15%, 20%, 25% and 30% PKSA content achieved compressive strength of 26.1 MPa, 22.53MPa, 19.43 MPa, 20.43 MPa, 16.97 MPa and 16.5MPa compared to 29MPa of Ordinary Portland cement concrete cubes. It was concluded that for structural concrete works requiring a characteristic strength of 25Mpa,5% palm kernel shell ash can effectively replace ordinary Portland cement while up to 15% PKSA content can be used for concrete works requiring 20Mpa strength at 28 days.*

***Keywords*:** *Supplementary cementitiousmaterials, Palm kernel shell ash,ordinary Portland cement, compressive strength.*

I. INTRODUCTION

Cement is an important construction material and an essential binder in the construction industry globally. The production of cement relies heavily on continuous exploitation of non-renewable natural resources leading to a depletion of such resources while it contributes about 5% to 7% of the total gaseous antropogenic emission to the atmosphere (Chen *et al*., 2010). This remains a challenge to environmental health and sustainability since the demand for and consumption of cement will continue to increase with the increasing need for infrastructure and housing development which are essential need of man to enhance his productivity and comfortability. In view of these challenges, studies in the past few decades have focused on the investigation of the behaviour and performance of some industrial and agricultural waste as supplementary cementing materials (SCMs). These materials were found to possess binding properties when in finely divided and amorphous form in the presence of water and are commonly referred to as pozzolans. These SCMs are either obtained in finely divided form, most often in form of ash from industrial waste stream or processed into ash prior to use.

In developed countries, most of the pozzolanic materials that are being utilised in concrete production are waste from industrial processes such as pulverised fuel ash commonly termed fly ash, ground granulated blast furnace slag, silica fume and palm oil fuel ash. In most developing countries especially Nigeria, due to low industrial activities, investigations on the utilisation of SCMs have focused on recycling of waste from the agricultural and forestry sector. Agricultural and forestry materials and by-waste products abounds in the country and are often massively burnt in heaps or left in the open field with a little fraction utilised as fuel or animal feed. As Kinuthia, Mofor, Melo and Djialli (2006) rightly observed that waste from these sources is a potential source of building materials beside natural non -renewable resources which is currently being exploited given their renewable nature when properly managed. The recycling of these waste serve as a better and efficient means of disposing the waste thereby enhancing a cleaner and healthier environment while providing the building materials industry with a raw material thereby ensuring conversion of waste to wealth and improving local materials production.

ASTM C 618-93 describes Pozzolanic materials as siliceous and aluminous amorphous materials with little or no cemetitious properties which can form cementitious compounds in the presence of water by reacting with lime. Concrete is an essential building material which offers the advantage of strength and durability which makes it a material of structural importance. Cement plays a significant role in the strength and durability properties of concrete as itsgain in strength and durability can be linked to the products formed duringthe chemical hydration process of the cement paste in the presence of water (Neville and Brooks, 2002). The hydration of cement in the presence of water results in the production of calcium silicates hydrates (C-S-H) and calcium hydroxide (Neville, 2011). The calcium silicates are said to be the most essential products responsible for the strength development of the hardened concrete while calcium hydroxide produced remains in a free state in the hardened mass. This calcium hydroxide helps to protect the reinforcement bars in concrete but also creates a weak link in concrete thereby increasing its susceptibility to chemical attack especially sulphates which may lead to deterioration of the concrete over time (Shetty, 2012). The use of pozzolanic materials in concrete production have been found to be beneficial as these materials reacts with the excess calcium hydroxide (lime) to form more cementitious compound thereby enhancing the strength of concrete.

Several studies have been conducted on the use and suitability of some agricultural waste as SCMs in concrete production. Ogunbodeand Akanmu (2012)studied the use of cassava peels ash as SCMs in laterised concrete and found out that concrete cubes containing up to 30% ash content achieved the 28 days strength of OPC concrete at 90 days. This further reinforced the fact that pozzolans contribute to later strength gain of concrete beyond 28 days required for OPC concrete. Joshua et al. (2015), studied palm kernel nut ash as partial replacement for OPC in concrete, the findings of the study showed that 10% ash content performed better that OPC concrete in terms of the compressive strength gained at 28 days. Ettu et al.(2013) studied the compressive strength gained in concrete containing rice husk ash (RHA).The concrete samples containing RSA up to 15% had a compressive strength comparable to that of OPC concrete at 28 days while it showed a higher strength gained at 90 days above that of OPC concrete thereby further reinforcing it as a pozzolan. Elinwa and Awari(2001) studied groundnut husk ash. Some studies on the use of palm oil fuel ash (POFA)an industrial waste as a SCM, have identified it as a pozzolanic material, POFAbeing obtained from the combustion of the combination of the palm fibre, shell and empty fruit bunch between 800 ˚C and 1000˚C (Wunchock et al., 2011).

Palm kernel shell ash (PKSA) a variant of POFAis obtained from the open air burning of palm kernel shell a waste material obtained from local palm oil mills.A comparison of the oxide composition of PKSA and POFAshowed that POFA has about 44% silicon dioxide, 11% aluminium oxide and 8% calcium oxide (Abdullawal and Hussin, 2011) while PKSA has about 55% silicon oxide, 11% aluminium oxide and 9% calcium oxide(Olutoge et al., 2012). This implies that the asheshave higher silica and alumina and lower lime content compared to ordinary Portland cement. The use of PKSA and its investigation as SCM is to take advantage of its high silica content which in finely divided form can react with excess lime release during the hydration of OPC to form more calcium silicates hydrates responsible for further strength gain in concrete.

The purpose of this study is to investigate the pozzolanic potentials of palm kernel shell ash by assessing its influence on the compressive strength development of concrete. Compressive strength is often used as a measure of concrete strength performance in the hardened state as well as structural ability with respect to stresses.This material going by its chemical properties may be pozzolanic in nature which may enhance its utilisation subject to satisfactory performance. Although, the technology for large scale calcining at higher temperatures are not readily available in a developing nation like Nigeria, the potential of ash obtained using alternative method was examined. The recycling of this waste into value added products in construction application using simple techniques will reduce demand on non-renewable natural resources which are fast depleting as well as on the scarce and costly energy required in processing them. This also, will further enhance local materials research, development, production, utilisation and improvement.A long term benefit may be economy, enhancing a cleaner environment and achieving concrete with better performance.

II. MATERIALS AND METHODOLOGY

The palm kernel shells used were obtained from a local palm oil processing mill in Osun State Nigeria. The palm kernel shells were air dried and burnt in open air while the burnt residue was then pulverised at a local mill to obtain PKSA. The ash obtained was then sieved through the 212mm BS sieve, the sieved ash has a specific gravity of 2.25. The fine aggregate (river sand) was also locally sourced and sieved through the 5mm BS sieve, the sieved sample was then air dried at the laboratory to obtain a saturated surface dry sample. Likewise the coarse aggregate used was sourced from a local quarry through a building site and also air dried to saturated surface dry condition. The specific gravity of the fine aggregate was 3.33 while the coarse aggregate (granite) used had a maximum size of 20mm and specific gravity of 3.33. Potable water from the laboratory tap was used. Ordinary Portland cement made by Lafarge conforming to BS EN 197-1:2000 was obtained from the local market.

The materials were batched by weight using nominal mix ratio of 1:2:4 and hand-mixed to represent the local site practice using suitable water/binder ratio based on workability requirement. A summary of the batching of the materials, mix proportioning and slump of each mixed proportion are presented in Table 1. The concrete cube samples were prepared to simulate local construction conditions but cured under laboratory conditions at room temperature to facilitate its hydration and strength development process in a controlled environment.

The specimen concrete cubes were cast of 100mm size mould and the cubes demoulded 24hrs after casting and then cured in water under laboratory conditions until the testing date.The following test were carried out on the sample materials in accordance with the requirement of the appropriate British standards bulk density test, sieve analysis test, moisture content test and specific gravity test while slump test was carried out on the fresh concrete and compressive test done on the cured hardened concrete.

Table 1: Material proportioning and slump values of mix

Ingredient	Mix Proportion					
Materials	0%	5%	10%	15%	20%	25%	30%
OPC (Kg)	5.40	5.1	4.86	4.59	4.32	4.05	3.78
PKA (Kg)	0	0.3	0.54	0.81	1.08	1.35	1.62
C. A (Kg)	21.4	21.4	21.4	21.4	21.4	21.4	21.4
F.A (Kg)	10.7	10.7	10.7	10.7	10.7	10.7	10.7
Water (Kg)	2.43	2.43	3.3	3.4	3.4	3.5	3.5
W/B ratio	0.45	0.45	0.61	0.63	0.63	0.65	0.65
SLUMP (mm)	0	0	75	75	75	76	77

*W/B- water/binder ratio

III. DISCUSSION OF RESULTS

The specified gravity of the palm kernel shell ash was obtained to be 2.25 which is lesser compared to that of OPC of 3.15as specified by Neville and Brooks. The difference in these weights is not more than 30% batching by weight can still be adopted, though it is envisaged that a little more PKSAmight berequired.From the experimental results computed in the tables above, the ratio of the loose bulk density to the compacted bulk density for coarse aggregates was 0.903 while for fine aggregate it was 0.797which is within the limits specified by Neville and Brooks (2002) i.e. between 0.87 and 0.96. Also, sieve analysis test was carried out on the fine aggregate used for this experiment from which the grading curve was obtained to observe the distribution of the particles sizes and the fineness modulus. The particle size distribution of the fine aggregate and palm kernel shell ash (PKSA) are presented in Figures1 and 2.

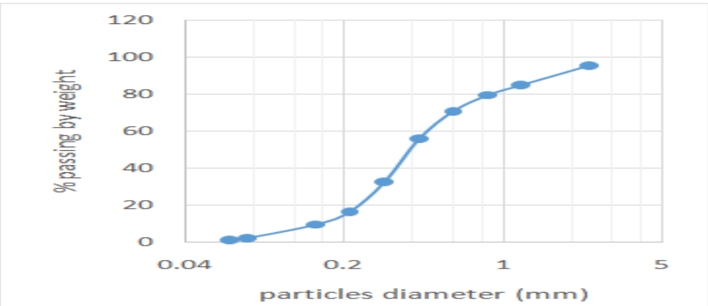

Figure 1: Particles size distribution for fine aggregate

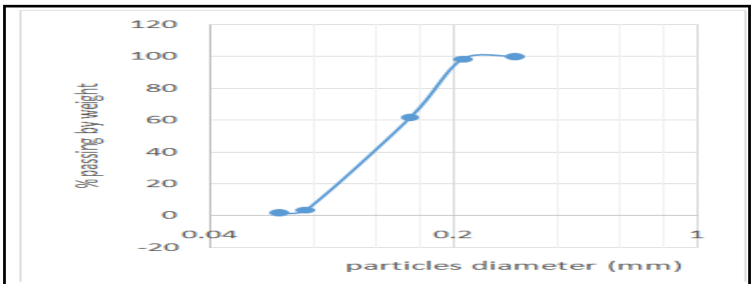

Figure 2: Particle size distribution for PKSA

IV. WORKABILITY

The workability of the fresh concrete was measured with the slump cone. Workability affects the ease of placement or degree of compaction of concrete hence to achieve desired compaction the water content was adjusted as the PKSA content in the mix increases. The water/cement ratio which produced workable concrete at each replacement level was used and a slump of between 0-76mm was adequate to enhance the compaction of the concrete. Beyond 5% PKSA content, water/cement ratio increased thereby making 0.45unworkable for hand mixed concrete as the addition of the ash increases the water required to produce workable concrete. It is believed that at 5% SCM content the binder is actually refer to as OPC which has a significance effect on the properties of the resulting concrete (Neville, 2011). This further implies the need to enhance the workability without reducing the strength since water/cement ratio has an implication on strength development of concrete.

V. EFFECTS OF CURING AGE AND PKSA CONTENT ON COMPRESSIVE STRENGTH

The result obtained showed that the compressive strength of concrete samples containing palm kernel ash increases with increasing curing age just as it is with normal ordinary Portland cement concretefor all replacement levels investigated. At 5% replacement level it could be seen that inspite of the slow rate of strength gain until 28 days, the strength is almost the same as that of the normal concrete at 56 days while other replacements levels showed improvement with time except 30% which witnessed a slight drop in strength at 56 days. Generally up to 15% replacement levels it could be seen that the concrete strength performance improved with time attaining about 25 MPa at 56 days.This aligns with the fact that strength of pozzolanic materials increases with increasing hydration of the cementitious materials due to the reaction between the free lime released during the hydration of OPC and the silica content of SCM. Another factor that could be responsible for the strength pattern is the difference in water/cement ratio required to achieve good compaction of the concrete cubes samples. In concrete technology, it is believed that water/cement ratio influences the strength of concrete as higher water cement ratios resulted in low strength. Aside this, other factors that could possibly influence the pattern of strength gain may be the fineness of the PKSA used and burning temperature. The fineness of SCMs influences their behaviour with lime and its hydration and thus affect strength gain in time, since it is generally believed that the finer the particles sizes the better the strength gain resulting from increasing surface area and hydration reaction.Although when the results obtained in this study were compared with that obtained by Olutoge et al.(2012) which used a finer PKSA content (45 µm), it was noted that fineness had little or no effect on the behaviour of the PKSA with OPC in concrete since the ashes were obtained using the same method of burning.It is therefore necessary to further look into the amorphousness of the PKSA, going by the discussions on strength gain of SCMs that the fineness and phase characteristics (amorphous or crystalline) of the materials influences its behaviour in concrete. Also, going by the chemical composition of POFA it could be seen that the loss on ignition of finer particles is high, there is the need to ascertain this for PKSA as this too may be a contributory factor to the trend of strength gained at higher replacement levels. Also, considering the mixing method it may be necessary to incorporate plasticizers to reduce the water/cement ratio thereby achieving a better result. From the foregoing, there is the need to further investigate the properties of PKSAand the influence on concretebehaviourto facilitate its proper classification, ascertain a more effective burning method in order to enhance its utilisation, since up to 15% it showed a good potential for use in concrete works requiring later strength.

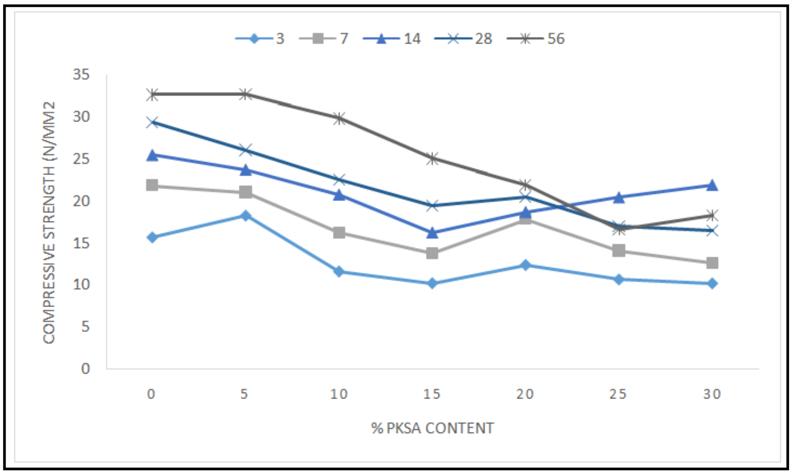

Figure 3: Effect of % PKSA and curing age on compressive strength

VI. CONCLUSION

The study investigated the effects of PKSA on the compressive strength development of ordinary Portland cement concrete.The study has added to the body of knowledge the potentials of an agricultural waste as a supplementary cementitious materials which can be improved to enhance its performance and utilisation in a developing country like Nigeria. The following conclusions were drawn from the results obtained

1. The use of PKSA increases the water required to achieve a workable concrete mix thereby influencing the workability of concrete and resulting in a high water/cement ratio.

2. Also, the processing method used to obtain the PKSA had an effect on therate of gain of compressive strength by concrete when compared to that of OPC concrete (control for the study) and POFA concrete from previous researchers.

3. At 56 days curing, concrete containing 5%, 10% and 15% PKSA showed a greater strength gain of about 25%, 33% and 23% of their 28 days compressive strength compared to 11% gained by OPC concrete, hence PKSA concrete requires a longer curing period to achieve strength comparable to OPC concrete, implying likely pozzolanic effect.

4. At 5% PKSA content, a characteristic compressive strength of 25MPAwas attained while at 10% and 15% PKSA content, 20 MPA was attained at 28 days, hence given the strength values, the use of PKSA is subject to further investigation into the properties and conditions that can enhance its behaviour in concrete and subsequently utilisation.

5. The pozzolanic effects of PKSA concrete may not be ascertained yet, hence may require other parameters to ascertain it as a pozzolan.

REFERENCES

[1] Chen, C., Habert, G., Bouzidi, Y., Jullien, A. (2010). Environmental impact of cement production: details of the different processes and cement plant variability evaluation. Journal of Cleaner Production 18, 478 – 485.

[2] Kinuthia, J. M., Mofor, L.A., Melo, U. C. and Djialli, D. (2006). From ashes to beauty: Utilisation of waste materials for sustainable development in Africa. (Obtained from Author).

[3] ASTM C 618, (2005). Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolana for Use as a Mineral Admixture in Portland cement Concrete. American Society for Testing and Materials.

[4] Neville, A.M., & Brooks, J. J. (2002). Concrete Technology (2nd Indian reprint). Singapore: Pearson Education Limited.

[5] Neville, A.M. (2011). Properties of concrete (5th edition). England: Pearson Educational Limited.

[6] Shetty, M.S. (2005). Concrete technology theory and practice (Revised Edition). New Delhi: S. Chand and company Limited.

[7] Ogunbode, E.B. and Akanmu, W.P. (2012). Turning waste to wealth: Potential of Laterized Concrete using Cassava Peels Ash (CPA) Blended Cement. International Journal of Engineering Research & Technology, 1(3), 1-12.

[8] Joshua, O., Ogunde, A.O., Omuh, I.O., Ayegba, C. and Olusola, K.O. (2015). Exploring the Pozzolanic Potential of Blend of Palm Kernel Nut Ash (PKNA) With Cement towards a Sustainable Construction Paper presented at International Conference on African Development Issues, Covenant University, 2015. www.covenantuniversity.edu.ng/eprint.

[9] Ettu, L.O., Onyeyili, I.O., Anya, U.C, Awodiji, C.T.G, and Amanze, A.P.C (2013). Strength of Binary Blended Cement Composites Containing Afikpo Rice Husk Ash. International Journal of Computational Engineering Research, 3(4), 71-76.

[10] Elinwa, A. U., &Awari, A. (2001). Groundnut husk ash concrete. Nigerian Journal of Engineering Management, 2 (1), 8 - 15.

[11] Wunchock, K., Theerawat, S., Chai, J. (2011). Effect of Palm Oil Fuel Ash Fineness on Packing Effect and Pozzolanic Reaction of Blended Cement Paste: The Twelfth East Asia-Pacific Conference on Structural Engineering and Construction. Procedia Engineering 14, 361–369.

[12] AbdulAwal, A.S.M. and WaridHussin, M. (2011). Effects of palm oil fuel ash in controlling heat of hydration of concrete. Procedia Engineering 14, 2050-2057.

[13] Olutoge, F.A Quadri, H.A., and Olafusi, O.S. (2012). Investigation of the strength properties of palm kernel shell ash concrete. Engineering, Technology & Applied Science Research 2(6), 315-319.

[14] BS EN 197: Part 1, (2000).Cement- Composition, Specifications and Conformity Criteria for Common Cements. British Standard Institution, London.