EFFECT OF PARTIAL REPLACEMENT OF CEMENT WITH PALM KERNEL SHELL ASH ON COMPRESSIVE STRENGTH OF CONCRETE

T.E Adejumo[1*], and S.O Atuluku[2]

1, 2 - Civil Engineering Department, Federal University of Technology, Minna, Nigeria.
*Corresponding author email: adejumo.taiye@futminna.edu.ng, +2349033795541

ABSTRACT

Partial replacement of cement by agricultural biomass/waste products is one of the effective means of reducing the cost of construction materials. The study presents the effect of partial replacement of cement with palm kernel shell ash on the compressive strength of concrete. The test procedures carried out in accordance with British Standard Institution guide. The palm kernel shell was obtained by burning palm kernel shell at 900^{0}C for 3 hours. The cement was replaced by palm kernel shell ash at 5, 10 and 15%. The optimum compressive strength of concrete at 28 days curing is 26.41 N/mm^2, which is higher than that of 7, 14 and 21 days. The maximum compressive strength were obtained to be 18.60 N/mm^2, 19.42 N/mm^2, and 20.20 N/mm^2 at 7, 14 and 21 curing respectively. Therefore, the study revealed that the compressive strength of concrete increases with curing age and decreases with increasing percentage of palm kernel shell ash replacement beyond 15%.

Keywords: Cement; Concrete; Compressive Strength; Palm kernel shell ash; Replacement.

1. INTRODUCTION

There has been so much demand in construction industries on the need for construction materials in many countries around the world. Efforts have equally been made by various researchers to reduce the cost of concrete and hence total construction cost by investigating and ascertaining the usefulness of material which would be classified as agricultural and industrial wastes. The adoption of new materials in today's construction market is the result of resource constraint, advances in engineering techniques and cost saving measures. (Tangchirapat, 2009).

The world in general, has turned its focus on environmental effects associated with improper disposal of waste materials which results in excessive accumulation of dirts and pollution. Millions of tons of palm kernel shell are constantly being dumped in the environment through careless disposal and they are mostly resistant to degradability which makes it a problem to the environment (Basri, 1999).

As a result of limited usage of these wastes materials, the rate at which they are disposed as landfill materials are expected to increase consequently leading to potential failure, environmental problems, accumulation, burning and landfill of solid waste disposal which can be expensive and undesirable. When these materials are reused in workable areas such as in the construction industry it is considered as an active area over the entire world which is a current practice (Olowe and Adebayo 2015).

Due to the increase in demand for more building materials and failure of structures (buildings) in recent time across the country (Nigeria), measures has been set up to proffer solutions to this problem especially using locally sourced materials. Cement is one of the vital material in the construction industry therefore its specification must be strictly adhered to. But as a result of the increase in cost of cement which mostly deters construction activities, an alternative choice of Palm Kernel Shell Ash (PKSA) which is likely to be a waste in the environment is being explored towards reduction in construction cost (Joshua et al., 2015). Hence this work is geared towards the possibility of the use of palm kernel shell ash as partial replacement for cement in concrete production.

The word Cement is translated from the Latin word "cementum'' which means the stone and marble powder which is used as binding material for blocks at the time of the Romans. In the European language, the word "cement'' is named as any organic and inorganic binder such as gum, gels, plastics, welding and asphalt alloy and aqueous cement. Cement is an important construction material and an essential binder in the construction industry globally. Its production relies heavily on continuous exploration of non-renewable natural resources leading to depletion of such resources while it contributes about 5% to 7% of total gaseous anthropogenic emission to the atmosphere (Chen *et al.*, 2010).

The palm kernel shell (PKS) is a waste material obtained during the extraction of palm oil by crushing the palm nut in the palm oil mills. They are hard, flaky and of irregular shape. These wastes if properly pulverised has cementitious properties hence making it pozzolanic (Awal and Hussin, 2011). The recycling of these waste into value added products in construction applications will reduce demand on non-renewable natural resources which are fast depleting as well as scarce and costly coupled with the energy required in processing them. This also will further enhance local material research, development, production, utilisation and improvement which will enhance a long term economy by adequately enhancing a cleaner environment and achieving concrete performances with physical tests (Neville, 2011).

2.0 MATERIALS AND METHODS

2.1 Materials

The materials (raw) required for these research work includes: Dangote brand of Ordinary Portland cement (OPC), fine aggregate, coarse aggregate, palm kernel shell ash (PKSA) and clean water. The palm kernel shells used in these research were obtained at Umomi in Kogi State. The Ordinary Portland cement and aggregates were obtained at Albashiri quarry site along Bida – Minna road. The palm kernel shell was burnt in an incinerator using a fabricated furnace for about 3 hours to obtain the ash behind the Civil Engineering Laboratory, Federal University of Technology Minna. After which the ash was sieved using sieve 75um to obtain the required fineness as that of cement. Tap water free from contaminants was obtained from Civil Engineering Laboratory, Federal University of Technology, Minna, and was used for mixing and also curing of the concrete.

2.2 Methods

The production of concrete tests was conducted in Civil Engineering Laboratory, Federal University of Technology, Minna. The materials mentioned in 2.1 above were used, prescribed mix design proportion of 1:2:4 with water cement ratio of 0.6. A total of 48 concrete cubes specimen (150mm X 150mm X 150mm) were cast according to (BS 1881: part 108, 1983), cured according to (BS1881: part 111, 1983) and tested according to (BS 1881: part 116, 1983) at the curing ages of 7, 14, 21, and 28 days respectively.

Tests conducted include sieve analysis according to (BS 812: part 103.1, 1985), specific gravity according to (BS 812: part 107, 1995), bulk density according to (BS 812: part 108, 1995), aggregate impact value test according to (BS 812: part 2, 1995), water absorption test according to (BS 812: part 107, 1995), slump test according to (BS 1881: part 102, 1983) and finally the compressive strength test according to (BS 1881: part 116, 1983) after curing for 7, 14, 21, and 28 days.

2.2.1 Casting of concrete cubes

After concrete mixing, slump test precedes casting of concrete cubes. The concrete mould of 150mm × 150mm × 150mm dimensions was used. The moulds were rubbed with engine oil so as to allow easy removal of the sample when de-moulding. The moulds were placed on a rigid horizontal surface and filled with concrete in such a way as to remove entrapped air as possible and produce full compaction of the concrete with neither segregation nor laitance. The concrete was poured inside the mould in three layers; each layer being given 25 strokes of the 16mm tamping rod. Each layer is of approximately 50mm deep. The test cube was prepared in accordance to (BS 1881: part 108, 1983).

2.2.2 Curing of concrete cube

Curing follows immediately after de-moulding of the cubes from the mould. The cubes will be submerged immediately in the curing tank for the required curing age of 7, 14, 21, and 28 days which are the ages to be considered for the purpose of this study. The curing of the cubes was carried out in accordance to (BS 1881: part 111, 1983). **2.2.3**

Compressive strength test

After curing the concrete specimen, crushing is done. Crushing operation was performed on concrete cubes by applying compressive force on them gradually until the cubes starts cracking having attained its supposed maximum strength limit in a compressive strength testing machine. Compressive strength test was carried out on the concrete cubes at curing age 7, 14, 21, and 28 days respectively, in accordance to (BS 116: part 116, 1963).

Figure 1: Samples after de-moulding

Figure 2: Sample undergoing compressive strength test

Figure 3: Sample undergoing slump test

3.0 RESULTS AND DISCUSSION

The sieve analysis test was carried out on aggregates and the fineness modulus of fine aggregate was calculated and obtained to be 2.60 which conforms with the requirement that aggregate fineness modulus must fall within the range of 2.3-3.1.The specific gravity for the aggregates were obtained as 2.66 and 2.69 for fine and coarse aggregate respectively which falls within the standard range of specific gravity 2.5 – 3.0. The specific gravity of the palm kernel shell ash was obtained as 2.34, which is lesser compared to that of ordinary Portland cement of 3.15 as reviewed in the literature from previous researches and duly referenced. The bulk densities of the material were found to be 1534.11 kg/m^3 and 1660.82 kg/m^3 for un-compacted and compacted fine aggregates respectively, likewise 1481.48 kg/m^3 and 1656.92 kg/m^3 for un-compacted and compacted coarse aggregates which conforms with the standard range of (1500-1700) kg/m^3 and (13001800) kg/m^3 for fine and coarse aggregate respectively. Percentage porosity of fine aggregate and coarse aggregate was found to be 7.63 and 10.59 % respectively, and void ratio 0.42 and 0.44 %.

The water absorption was found to be 24.60 % for fine aggregate, 2.8 % for coarse aggregate and 73.24 % for palm kernel shell ash. The aggregate impact value was gotten as 24.40 %.

Slump test was also carried out to determine the workability/consistency of the fresh concrete**.**

The compressive strength of the cubes after 7 days of curing age with 0 % having the highest compressive strength of 18.60 N/mm^2 followed by 5, 10 and 15 % obtained as 16.02 N/mm^2, 12.21 N/mm^2, and 10.95 N/mm^2 respectively.

The compressive strength for 0, 5, 10 and 15 %, for 14 days curing age and the compressive strength increased than that of 7 days curing ages, the compressive strength obtained are 19.42 N/mm^2, 17.81 N/mm^2, 14.77 N/mm^2 and 11.69 N/mm^2 respectively.

The compressive strength for 0, 5, 10 and 15 %, for 21 days curing age and the compressive strength increased than that of 7 days curing ages and 14 days curing ages, the compressive strength obtained are 20.20 N/mm^2, 19.33 N/mm^2, 15.10 N/mm^2 and 12.29 N/mm^2 respectively.

The maximum compressive strength for 0, 5, 10 and 15 %, at 28 days of curing ages with the compressive strength which is higher than that of 7, 14 and 21 days curing ages, the compressive strength obtained are 26.41 N/mm^2, 20.07 N/mm^2, 16 N/mm^2 and 13.81 N/mm^2 respectively. Figure 5 shows the graph of compressive strength against curing age of concrete specimen.

Table 1. Sieve Analysis of Fine Aggregate (Sand)

S/ No	Sieve sizes (mm)	Weight retained (g)	Cumulative weight retained (g)	Cumulative percentage retained (%)	Cumulative Percentage passing (%)
1	5.00	0.21	0.21	0.042	99.96
2	3.35	8.86	9.07	1.814	98.19
3	2.36	27.75	36.82	7.364	92.64
4	2.00	13.72	50.54	10.108	89.89
5	1.18	62.68	113.22	22.644	77.36
6	0.85	57.75	170.97	34.194	65.81
7	0.60	74.93	245.9	49.180	50.82
8	0.43	93.33	339.23	67.846	32.15
9	0.30	79.08	418.31	83.662	16.34
10	0.15	66.76	485.07	97.014	2.99
11	0.08	12.01	497.08	99.416	0.58
12	0.00	2.92	500.00	100.000	0.00
			Total weight:500g		

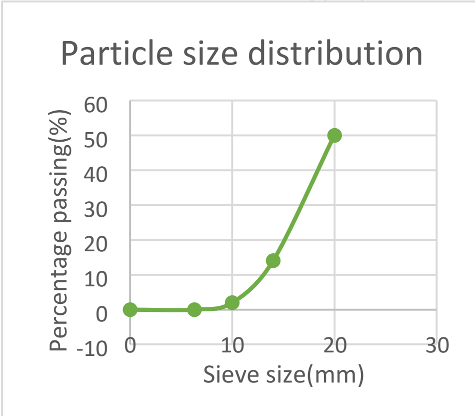

Figure 4: Particle Size Distribution of Coarse Aggregate

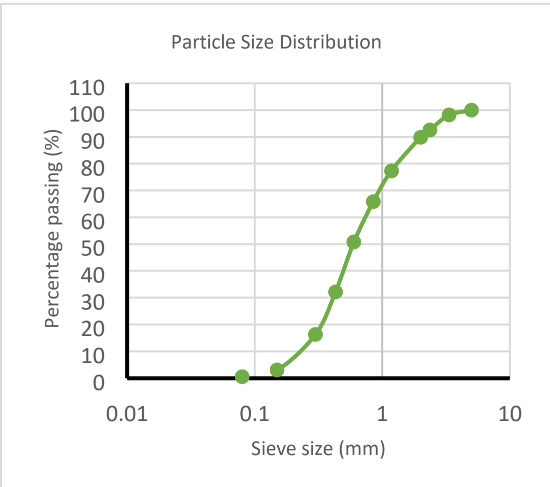

Figure 3: Particle Size Distribution of Fine Aggregate

Table 3. Specific Gravity of PKSA

Trials	1	2	3
Weight of empty vessel	100.8	100.5	100.6
Weight of sample (g)	106	105	105.4
Weight of vessel + sample + water (B)(g)	216.4	214.1	215.2
Weight of vessel + water only (C) (g)	213.2	211.6	212.6
Specific gravity Gs	2.60	2.25	2.18
Average specific gravity		**2.34**	

Table 4. Slump Test

(%) PKSA	**Slump Value (mm)**
0%	46
5%	32
10%	39
15%	56

Table 2. Sieve Analysis of Fine Aggregate (Sand)

S/No	Sieve sizes (mm)	Weight retained (g)	Cumulative weight retained (g)	Cumulative percentage retained (%)	Cumulative percentage passing (%)
1	20..0	2.50	2.50	50.00	50.00
2	14.00	1.80	4.30	86.00	14.00
3	10.00	0.60	4.90	98.00	2.00
4	6.30	0.10	5.00	100.00	0.00
5	0.00	0.00	5.00	0.00	0.00
			Total weight:5kg		

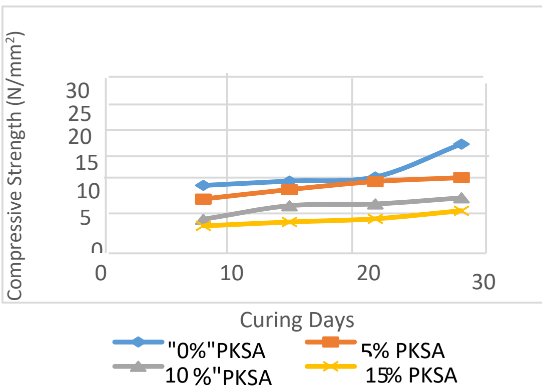

Figure 5: Graph of compressive strength against Curing Days of concrete

4.0 CONCLUSION

From the results obtained from investigation of effect of partial replacement of cement with palm kernel shell ash on compressive strength of concrete, the following conclusions were drawn:

1. Palm kernel shell ash can be used as a material for partial replacement in light weight concrete structures where structural members are not resisting extensive impact load.
2. The specific gravity of the palm kernel shell ash was obtained as 2.34 which is lesser compared to that of ordinary Portland cement of 3.15 as reviewed by previous researches and duly cited. The use of palm kernel shell ash as partial replacement of cement exhibits a lower water absorption rate and slower setting time of concrete. Its use also reduce the volume of cement used in concrete, thereby reducing the cost of concrete production and also minimize the environmental issues arising from the improper disposal of palm kernel wastes.
3. The compressive strength of concrete increase with curing age and decrease with increasing percentage of palm kernel shell ash replacement.
4. The optimum compressive strength of concrete at 28 days curing age is 26.41 N/mm^2, which is higher than that of 7, 14 and 21 days curing age with their maximum compressive strength of 18.60 N/mm^2, 19.42 N/mm^2, and 20.20 N/mm^2 respectively.

5.0 RECOMMENDATIONS

From the investigation of effect of partial replacement of cement with palm kernel shell ash on compressive strength of concrete, the following recommendations are made:

1. Curing of concrete with palm kernel shell ash (PKSA) as partial replacement of cement should reach 28 days in order to obtain maximum compressive strength.
2. Further studies should be carried out on 0 – 50% replacement of cement with palm kernel shell ash in order to reveal its possibility or otherwise.
3. Reduced cost of construction arising from the use of locally available agricultural waste materials such as palm kernel shell ash will enhance infrastructural developments.

6.0 REFERENCES

American Society for Testing and Materials ASTM C618-92a. (1994) *Chemical and Physical Specifications*, 2 Parks Street, London.

American Society for Testing and Materials ASTM C618, (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 Material*, C618-92a.

Awal, A. S. M. A., and Hussin, M. W. (2011). The Effectiveness of Palm Oil Fuel Ash in preventing expansion due to alkali. *American Journal of Engineering Research*, pp-32-36.

Basel, N. S. and Mohammed, A. R. (2003). Performance of Mortar and Concrete. Construction and Building Materials, 169, pp. 800-818, 2018.

Basri, H. B., Mannan, M. A., and Zain, M. F. M. (1999). Concrete using waste oil palm shell as ash. *Cement and Concrete Research*, 29: 619-622.

BS EN 197:1 (2000). British Standard European Norms 197: Part 1 (2000). Cementcomposition, specifications and conformity criteria for common cements. *British Standard Institution*, London.

Basri, H. B., Mannan, M. A., and Zain, M. F. M. (1999). Concrete using waste oil palm shell as ash. *Cement and Concrete Research*, 29: 619-622.

BS 1881 Part 102 (1983). *Method of determination of slump test value of concrete*, British Standard Institute (BSI), 2 Parks Street, London.

BS 1881 Part 103 (1993). *Method of determination of compacting factor test of concrete,* British Standard Institute (BSI), 2 Parks Street, London.

BS 1881 Part 111 (1983). *Method for curing of normal concrete specimens,* British Standard Institute (BSI), 2 Parks Street, London.

BS 1881 Part 114 (1983). *Method for determination of density of hardened concrete cubes*, British Standard Institute (BSI), 2 Parks Street, London.

BS 1881 Part 116 (1983). *Method for determination of compressive strength of concrete cubes*, British Standard Institute (BSI), 2 Parks Street, London.

BS 1881 Part 125 (1983). *Method of sampling fresh concrete in the laboratory*, British Standard Institute (BSI), 2 Parks Street, London.

BS 812 Part 103 (1985). *Method of determination of particle size distribution*, British Standard Institute (BSI), 2 Parks Street, London.

BS 812 Part 103 (1985). *Method of determination of particle size distribution*, British Standard Institute (BSI), 2 Parks Street, London.

BS 812 Part 107 (1995). *Method of determination of specific gravity of aggregates and absorption test*, British Standard Institute (BSI), 2 Parks Street, London.

BS 812 Part 109 (1990). *Method of determination of moisture content of aggregates*, British Standard Institute (BSI), 2 Parks Street, London.

BS 812 Part 2 (1995). *Method of determination of aggregate impact value*, Construction Standard (CS3), North Point, Hong Kong.

BS EN 197:1 (2000). British Standard European Norms 197: Part 1 (2000). Cementcomposition, specifications and conformity criteria for common cements. *British Standard Institution*, London.

Camoes, A. and Ferreira, R. M. (2010). Structures and Architecture. University of Mingho, Portugal.

Chen, C., Harbert, G., Bouzidi, Y., Jullien, A. (2010). Environmental impact of production: Details of the different processes and cement plant variability evaluation. *Journal of cleaner production* 18, 478-485

Fadele, O. A. (2016). Compressive strength of concrete containing palm kernel shell ash. *American Journal of Engineering Research.*, Vol-5, issue-12, pp-32-36.

Gworipalan, N., Cabrera, J., Cusens, A. R., and Wainwright, P. J. (1992). Effect of Curing on Durability of Concrete. *ACI Compilation 24. American Concrete Institute*, Farmington Hills, Michgan, USA, pp. 47-54.

Jackson, P. J. (1983). Building Materials and construction. Retrieved from https://books.google.com.ng>books 23/02/2020.

Kong, F. H. and Evans, R. H. (1994). Reinforced and Prestressed Concrete, Chapman and Hall, London.

Mamlouk, M. S. and Zaniewski, J. P. (2006). Materials for Civil and Construction Engineers. pp. 8-10.

Mannan, M. A. and Ganapathy, C. (2004). Concrete from an Agricultural waste-oil palm shell (OPS). *Building and Environment*, 39(4), pp. 441-448.

Neville, A. M and Brooks J. J (2011). Concrete Technology, 2nd Edition, Longman.

Neville, A. M. (1996). Properties of Concrete, *ELBS 5th Edition*. Pitman, London.

Neville, A. M., and Brooks, J. J. (2002). Concrete Technology (2nd Indian reprint). *Pearson Education Limited*, Singapore.

Nilson, A. H. (1980). Design of Concrete Structures. Published by McGraw-Hill Inc. pp. 8-9

Olowe, K. O., and Adebayo, V. B. (2015). Investigation of palm kernel ash as partial replacement for high strength concrete. *International Journal of Civil Engineering.*, Vol-2, issue-4, pp-48-50 retrieved from www.internationaljournalssrg.org 22/02/2020.

Palm Kernel Shell p.d.f retrieved from www.indiamart.com/impcat/pks 20/02/2020.

Price, H.W. (1951). Factors influencing concrete strength. *Journal of American Concrete institute.* Vol. 47, pp. 417-32.

Shetty, M. S. (2005). Concrete technology theory and practice. *First Multicolour Illustrative Revised edition.* Indian.

Tangchirapat, W., Jaturapitakkul, C. and Chindaprasirt, P. (2009). Use of palm oil fuel ash as supplementary cementitious materials for producing high strength concrete. *Construction and Building Materials*, 23(7): 2641-2646.

Tay, J. H. (1990). Ash from oil palm waste as concrete material. *Journal of Materials in Civil Engineering*, 2(2): 619-622.

Teo, D. C. L., Mannan, M. A., Kurian, V. J., Ganapathy, C. (2007). Light weight concrete made from oil palm shell: Structural bond and durability properties. *Building and Environ*ment. 42: 2614–2621.