AMERICAN JOURNAL OF INNOVATION IN SCIENCE AND ENGINEERING (AJISE)

ISSN: 2158-7205 (ONLINE)

VOLUME 2 ISSUE 1 (2023)

PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

American Journal of Innovation in Science and Engineering (AJISE)

Volume 2 Issue 1, Year 2023
ISSN: 2158-7205 (Online)
DOI: https://doi.org/10.54536/ajise.v2i1.1228
https://journals.e-palli.com/home/index.php/ajise

Structural Behavior of Concrete Produced Using Palm Kernel Shell (PKS) as a Partial Substitute for Coarse Aggregate

Ogunjiofor Emmanuel Ifeanyi[1*], Amete Daniel Chima[1], Nwabunwanne Johnbosco Chukwudubem[1]

Article Information

Received: January 21, 2023

Accepted: February 01, 2023

Published: February 06, 2023

Keywords

Coarse Aggregates, Construction Costs, Lightweight Concrete, Palm Kernel Shell (PKS), Partial Replacement

ABSTRACT

The possibility that our available resources will soon run out completely cannot be overstated. There have been series of research into alternative materials, especially materials available locally which may be useful as a substitute alternative materials used in the production of concrete. This has become necessary due to increasing costs of construction and the need of reducing stresses in the environment in order to make construction more sustainable. The goal of this research was to assess the strength of concrete made with palm kernel shell (PKS) used in place of some of the coarse material. The experiments listed below were carried out: compressive strength test, slump test, sieve analysis, and water absorption test. The concrete was created using cement, sand, coarse stones (coarse materials), and palm kernel shell. For the compressive strength test, a total of 48 cubes with dimensions of 150 mm x 150 mm x 150 mm were cast, with the ratio of these materials being 1:1.5:3 (Cement: Sand: Aggregates), by weight batch. In place of the coarse aggregate, PKS of 0%, 10%, 20%, and 30% were used. Before the compressive strength was calculated, all of the samples were cured for 7, 14, 21, and 28 days. This experiment provides insight into how much concrete's weight could be reduced while maintaining its strength. The outcomes of these tests were compared with the control group after completion. The findings showed that adding 10% palm kernel shell(PKS) to the concrete with coarse aggregate is beneficial without significantly reducing the concrete's strength.

INTRODUCTION

Considering that concrete is still a common construction material in the world today, it has become important to explore for alternatives due to the high cost of concrete's component elements, like fine aggregate, coarse aggregate, and cement. Concrete's importance in building and civil engineering projects cannot be overstated. As a result of the enormous demand for concrete in the building sector, which uses normal weight aggregates (NWAs) like gravel and sand, there have been numerous severe environmental ills caused by the significant drop in naturally occurring aggregates (Mefteh *et al.*, 2013). As a result, sustainable and renewable materials are more important than ever. Various of these standard building materials, like maize comb, sawdust, coconut shell, rice husk, and palm kernel shell, can be swapped out for or combined with some waste agricultural products. These regional resources are typically dumped in our environments as waste, which pollutes the ecosystem. Many of these materials has a light-weight aggregate usage (LWA) in producing light-weight concrete, in which has, lower self-weight and hence, it reduces the dead load of the concrete structures when as comparison to traditional concrete, which has a heavy dead load, in addition to being used for structural stability, versatility, and economic viability (Nguyen *et al.*, 2013). Therefore, including these waste materials into concrete will increase its sustainability and aid in reducing the rate at which nonrenewable natural resources are being exploited (Pelisser *et al.*, 2011). A solution to the problems with energy conservation that are prevalent in many agro sectors can also be found in employing regional raw elements as concrete's building blocks substitute (Ismail & Ramli 2013).

This study seeks to ascertain whether palm kernel shell, a more renewable and environmentally friendly material, may successfully substitute coarse aggregate in concrete. By making lightweight concrete economically and using less expensive materials like palm kernel shell, its workability, density, water absorption, weight reduction and compressive strength performance can be greatly enhanced.

When palm kernel shell is utilized instead of using coarse aggregates, there is minimal or no environmental harm caused, which reduces waste disturbance and pollution (Emiero and Oyedepo 2012). Concrete produced with palm kernel shell (PKS) results in lower building costs when compared to substitute materials (Daniel and Emmanuel 2012).

LITERATURE REVIEW

Civil engineers are involved in building, overseeing and preserving the entire infrastructure that strengthens the modern society today, including roads, structures, tunnels, dams, bridges, and other structures. This infrastructure totally depends on concrete, which is quite expensive and whose price is increasing daily. Therefore, in this study work, we show how to fabricate lightweight concrete and concrete that is economical.

We must take the lead in protecting the environment by using waste materials in construction because the construction sector propels development while also serving as the main source of pollution and environmental

[1] Chukwuemeka Odumegwu Ojukwu University, Anambra State, Nigeria
[*] Corresponding author's e-mail: ogunjioforemmanuel@gmail.com

disruption. There is little or no environmental harm from using this. Therefore, this study work covers employing palm kernel shell as a partial replacement for coarse aggregates in the manufacture of concrete. The concrete produced is lightweight and affordable because palm kernel shell has a low specific gravity compared to other types of coarse aggregate (Williams *et al*., 2012).

PKSs, or palm kernel shells, are organic waste materials, remain in the oil plant after the crude oil and nuts have been extracted. In Nigeria, PKS has been utilized as fuel in both households and businesses. On the other hand, (Oyejobi *et al*., 2012) claim that palm kernel shells have replaced granite because of the need for lightweight concrete and the cost-effectiveness of PKS over conventional aggregates. Ndoke, (2006) and Yusuf *et al*., (2011) stated that PKS has been used as a partial substitute for concrete, asphalt, and pavement in numerous investigations. The Olanipekun *et al*., (2006) research evaluated the mechanical characteristics of palm kernel shell and coconut shell both concrete and the cost benefits of employing palm kernel shell (pks) shell as a light-weight aggregate. According to Okafor, (1988) and Okpala, (1990) the majority of palm kernel shells between 60 and 90% fall within the 5.00 mm to 12.70 mm range, with a maximum thickness of 4 mm, and a specific gravity range of 1.17 to 1.37.

Alengaram *et al*. (2008) observed that the light weight concrete's 28th day compressive strength ranges from 15 to 25 MPa and its density ranges from 1700 to 2050 kg/m^3. According to a study by Teo *et al*., 2006 palm oil shell concrete has a compressive strength of 28.1 MPa, which is above the minimal necessary compressive strength required for structural lightweight concrete. Study made by Daneshmand & Saadatian, (2011) states that palm kernel shell concrete's strength at 28 days may reach 52 MPa.

According to Mohammed *et al*., (2012) at mix proportions for concrete of 1:1.60:0.96 (cement: sand: coarse aggregate) and 1:1.53:0.99(cement: sand: coarse aggregate), respectively, the structural cement content and water-cement ratio were 450 kg/m^3 and 0.45. The examination recorded data for workability above 20 mm, strength above 15 MPa, and density between 1800 and 1900 kg/m^3. The lack of coarse aggregate content may have contributed to the mix's uneconomical character since the ratios of sand and gravel were similar in the mixture as opposed to the usual mix design. Bediako *et al*., (2016) conducted experimental work Using calcined clay a percentage partial cement with a weight replacement of 10% to 30%. The results indicated that the maximum amount of substitution for active pozzolanic reactivity should therefore not exceed more than 20% of palm kernel. Also, Khankhaje *et al*. (2017) substituted gravel to a degree ranging from 0 to 75% using palm kernel and cockle shells. According to the research, the forms of both shells increased their water permeability and void content, which reduced their compressive strength but allowed for the use of the strength in uses for permeable concrete.

Yusuf *et al*. (2016) created an equation for the strengths of oil palm kernel concrete under compression and flexure using three nominal mixes and modifying the water-cement ratio. The research showed that OPKSC's flexural and compressive strengths were linked by the logarithm model, and PKS concrete performed admirably. In proportions of 50/50 and 60/40, respectively, Huda *et al*. (2016) substituted palm oil shell and oil palm clinker for natural aggregate. The study found that concrete with a mix ratio of 1:2.57:0.76, 1 part of cement: 2.57 part of fine aggregate (i.e. Sand and Palm oil clinker in 60/40 proportion): 0.76 part of coarse aggregates (i.e. Stone and palm kernel shell in 50/50 proportion) produced concrete with compressive strengths between 46 and 47 MPa, splitting tensile values between 3.67 and 6 MPa, and elastic moduli between 10.16 and 10.18 MPa. In terms of mode of failure, their report considered various ratios of beam behavior.

However, this current study was interested in partially changing coarse aggregates with the species of Palm Kernel Shells (PKS) gotten from the study area Ihiala L.G.A, Anambra State alternative materials. This study's main objective was to assess PKSs' suitability as a light weight aggregate. Based on the properties of palm kernel shell(PKS), the study sought to increase the compressive strength of palm kernel shell(PKS) concrete. This was achieved by investigating how the interaction between the design mix's elements affected compressive strength. Because the proportions of sand as the fine aggregate and PKS as the coarse aggregate. can vary, early tests of this unique material will be carried out. Both before and after the concrete had solidified, we looked at its compressive strength, density, and workability. Not to mention, the experimental combination that had the greatest optimized compressive strength and analysis of variation results showed that it was within the allowed range.

MATERIALS AND METHODOLOGY

Palm kernel shells(PKS)

The palm kernel shells that was used was gathered from a local palm kernel grinding machine shop's abandoned stockpile in Uli, Ihiala local government area of Anambra State, Eastern part of Nigeria, West Africa. The palm kernel shells, which are organic, light, inert, and generally black in color, have micro grooves on their external convex surfaces that give them a rough texture. Cleaning and air drying of the palm kernel shells took place for 72hours at a 40 degrees' Celsius temperature. PKS was graded in sizes between 10 and 16 mm for partial replacements of coarse aggregate of 0%, 10%, 20%, and 30%.

Coarse Aggregate

The employed coarse aggregate contains no finer particles and has a nominal size of 3/8 inch, or roughly 10mm. To make sure that the water cement ratio was not impacted, the coarse aggregate was dried for 24 hours with a saturated surface state. The building material market, Afor-egbu market, Uli, Anambra State, was where the coarse aggregate for use was purchased.

Fine Aggregate

The fine aggregate(sand) used was made up of coarse, angular, firm grains that were free of silt and clay coatings. It had no organic material in it. It was free of hygroscopic salt and is a sturdy, chemically inert material. The utilized sand grains were of a size that passed through a 4.75 mm filter and were completely retained on a 75-micron sieve. The sand was bought from the neighborhood building supply store in Uli, Anambra state. The sand that was obtained is referred to be "Wall-white" sharp sand in the area.

Cement

Dangote cement, an Ordinary Portland Cement (OPC), class 42.5R according to EN 197:1, was the kind of cement utilized (2011). This cement is simple to find in the neighborhood market (Uli timber and building material market, Afor-egbu, Uli, Anambra state).

Water

This study's water source is portable water that was gathered from the Uli Campus of Chukwuemeka Odumegwu Ojukwu University's Civil Engineering Concrete/Soil Laboratory. This water is pure and suitable for concrete works.

Batching

Before mixing, the several concrete ingredients (cement, sand, coarse aggregates, and water) were measured in a process called "concrete batching." Weight batching is the term used when measurement is done based on weight. Due to the modest amount of concrete work involved, this method was chosen, because it might not be practical or effective for larger concrete projects. Therefore, a concrete with concrete grade of M20 having a relative ratio of 1:1.5:3 was adopted for the study.

Table 1: Quantity of Cement, Sand, Coarse Aggregate and PKS Required for Mix 1-4

Mix No.	% of PKS	No. of cubes	Qty. of cement req.		Qty. of sand req.		Qty. of C. A req.		Qty. of PKS	
			Vol. (m^3)	Wt. (kg)	Vol. (m^3)	Wt. (kg)	Vol. (m^3)	Wt. (kg)	Vol. (m^3)	Wt. (kg)
1	0%	12	0.0128	18.4	0.019	30.4	0.0385	60	-	-
2	10%	12	0.0128	18.4	0.019	30.4	0.0346	54	0.0038	2.85
3	20%	12	0.0128	18.4	0.019	30.4	0.0308	48	0.0077	5.7
4	30%	12	0.0128	18.4	0.019	30.4	0.0269	42	0.012	8.55

Note: while adopting weight batching in Table 1, the moisture content in the aggregate and sand agglomeration should be taken in to account.

Mixing

Mixing of the batched materials was done manually and properly. We ensured the materials were mixed uniformly before pouring of water and remixing again in order to obtain a uniform concrete paste, which is achieved through rotation or stirring. The goal of the mixing operation is to cover the surface of all aggregate particles with cement paste.

Placing and Compaction of concrete

Concrete was placed in 150x150x150mm cube modes. Rather than being piled high or in sloping layers, the concrete was laid down in uniform layers. Trapped air was released from the bottom of each layer; the layer thickness was suitable with the vibration method using a poker vibrator. To achieve monolithic construction, each layer was fully compacted before the next is laid, and each succeeding layer was put down while the layer underneath it is still plastic.

Setting of concrete, Removal of Mold and Curing of concrete

The concrete cubes were allowed to set for 24 hours in a cool dried place. The concrete mold was removed after 24hours of setting and was then taken to the curing tank for curing. The concrete was immersed in a water tank for curing. This water-curing tank contains clean portable water obtained from civil engineering concrete laboratory. The concrete cubes and cylinders were kept in the water tank for 7, 14, 21 and 28 days respectively.

RESULTS AND DISCUSSION

The findings of experiments on the workability (slump) of freshly mixed concrete, the result of the compressive strength of hardened concrete cubes at various curing ages, and the mechanical and physical characteristics of coarse particles and palm kernel shell(PKS) are described.

Sieve analysis test (Particle size distribution test)

Sieve analysis test was carried out on the fine aggregate used for producing the PKS concrete. This test was conducted to determine permeability, porosity and the viability of the fine aggregate in PKS concrete. Well graded fine aggregate is necessarily for production of a good concrete with the PKS.

We conducted sieve analysis test in order to determine if the fine aggregates used was well graded. The distribution test was carried out with fine aggregate that was obtained from Amorka, Uli, Ihiala, Anambra state. We also ensure that the test was done according to the procedures in BS EN 933-2. It was observed from Table 2 that the fine aggregates used for the experiment was well graded. The results from Table 2 was used to plot a graph of cumulative % passing to sieve sizes in Figure 1,

Table 2: Results of the Sieve Analysis Test Conducted for fine aggregate used to produce the PKS concrete.

New Sieve no.	IS Sieve size (mm)	Mass of each sieve in (g) M_1	Mass of each sieve + mass of soil retained M_2	Mass of soil retained (g) $(M_2 - M_1)$	Percentage retained on each sieve (%) $\{(M_2-M_1)/M\} \times 100$	Cumulative Percentage retained (%)	Cumulative Percentage passing (%)
10	2.314	721.65	732.72	11.07	3.69	3.69	96.31
16	1.183	675.23	713.91	38.68	12.89	16.58	83.41
30	0.601	610.54	693.85	83.31	27.77	44.35	55.64
40	0.424	569.54	656.36	56.82	18.94	63.29	36.70
50	0.305	540.98	602.70	61.72	20.57	83.86	16.13
100	0.150	528.45	560.57	32.12	10.71	94.57	5.43
200	0.075	509.58	523.73	14.15	4.72	99.29	0.71
Pan	Pan	488.65	490.78	2.13	0.71	100	0
Total				299.93(M)			

Note: M = Mass of soil sample (300g), M1 = Mass of each sieves used in (g), M2 = Mass of each sieves + mass of soil retained (g)

Slump Test

Table 3 below shows the obtained slump test results obtained. Number of trials: 1, Height of cone: 300mm. From the results obtained from Table 3, it is observed that the degree of workability decreases with an increase in the percentage of replacement of palm kernel shell(PKS) in concrete. Hence, concrete with palm kernel shell as partial replacement for coarse aggregate have a very low degree of workability.

Table 3: Table of slump test values

Specimen sample	Coarse aggregate (location)	Slump value	Type of slump
1	0%	20mm	True slump
2	10%	15mm	True slump
3	20%	10mm	True slump
4	30%	5mm	True slump

Initial setting time and final setting time of cement used for the experiment

The initial setting time and final setting time was determined for the cement used for the PKS concrete. The cement used was Dangote cement, grade 42.5R. The initial and final setting time test was used to determine the time required for the PKS concrete to set and harden respectively.

Table 4: Initial and final setting time test results for the PKS concrete

Time intervals in minutes	15 min.	30 min.	45 min.	60 min.	75 min.	90 min.
Degree of penetration in (mm) for Initial setting time	10	12	15	18	20	23
Degree of penetration in (mm) for Final setting time	25	26	28	29	30	31

The result from Table 4 shows initial setting time and final setting time of the concrete produced which conforms to the setting time of conventional concrete used commonly in the construction industry today. This test was carried out to see if the concrete produced with partial replacement of coarse aggregate with PKS varies so much with other concrete. It was observed that partial replacement of coarse aggregate does not affect the setting time of concrete.

Result of Water Absorption test

Table 5 shows the rate of water absorption by the concrete cubes. It was observed that the rate of water absorption decreased with an increase in percentage addition of palm kernel shell. This phenomenon depicts that PKS absorbs less water when compared with the conventional coarse aggregate.

Table 5: Water absorption of the concrete cube

S / No.	Percentage Of PKS	Ave. Wt. of dry concrete (W1)	Wt. of saturated concret (W2)	Water absorption (W2 – W1)
1	0%	8.15	8.40	0.25
2	10%	7.70	7.85	0.15
3	20%	7.51	7.65	0.14
4	30%	6.35	6.45	0.10

Weight Analysis of Concrete Cube

Table 6 shows that the weight of the concrete cubes decreases with an increase in the percentage addition of palm kernel shell. It was shown that as the percentage of palm kernel shell (PKS) used as a partial replacement for coarse aggregate increases, the weight of the concrete decreases. This was because of low density of PKS when compared with that of conventional coarse aggregates

Table 6: Below is a weight chart for various cubes made with various amounts of palm kernel shell

S/ No.	Percentage of PKS	Original wt. of concrete(kg)	Wt. after replacement (kg)	% Change (Decrease in weight)
1	0%	8.15	8.15	0.0
2	10%	8.15	7.70	5.52
3	20%	8.15	7.51	7.85
4	30%	8.15	6.45	20.85

Compressive Strength Test

The result of the compressive strength obtained after 7 days, 14 days, 21 days and 28 days of curing is presented in the table below;

From the Table 7, the compressive strength values recorded after 7, 14, 21 and 28 days, it was observed that the compressive strength of the concrete produce with palm kernel shell decreased with the increased of PKS% but the compressive strength was reasonable up to 20%. This implies that the percentage replacement of palm kernel shell depends on the structural requirement of the proposed structure. The higher the required strength, the lower the percentage of replacement and vice versa. Modelling of results

Table 7: Result of crushed concrete cubes after curing

% Replacement for Palm kernel shell as Coarse aggregate	Compressive Strength in MPa (N/mm2)							
	7 days		14 days		21 days		28 days	
	Load (kN)	Ave. value in MPa(N/mm2)	Load (kN)	Ave. value in MPa(N/mm2)	Load (kN)	Ave. value in MPa(N/mm2)	Load (kN)	Ave. value in MPa(N/mm2)
0%	427.7	19.0	771.3	34.2	816.75	36.3	843.75	37.5
10%	510.8	22.6	679.5	30.0	731.25	32.5	767.25	34.1
20%	417.9	18.5	338.5	15.0	402.75	17.9	438.75	19.5
30%	241.1	10.7	234.0	10.3	263.25	11.7	301.5	13.4

Modelling of Results

Sieve Analysis

Figure 1 is a graph that shows the relationship between the cumulative percentage passing of the fine aggregate used and the sizes of the sieve used. The cumulative curve in Figure 1 indicates that the particle size distribution of the fine aggregate used for the experiment is well graded.

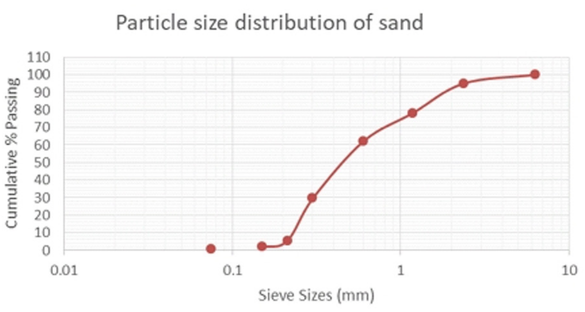

Figure 1: Graph of Sieve Analysis Results fine aggregate from Uli.

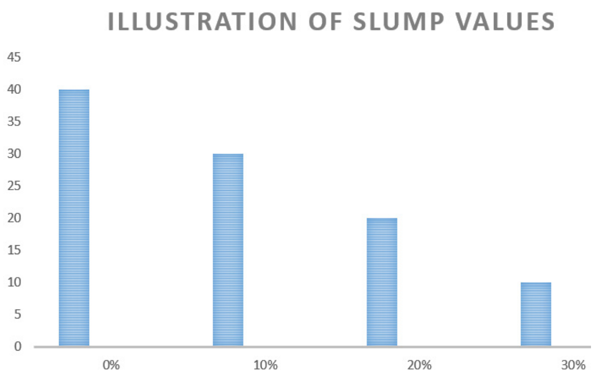

Figure 2: A bar chart of the slump test result

Slump test

From the Figure 2, it was evidence that the height of slump (degree of workability) decreases with an increase in the percentage (%) of Palm Kernel Shell (PKS). For 0% of PKS concrete, slump value was up to 20mm, for 10% of PKS concrete, slump value was 15mm, for 20% increase of PKS, slump value obtained was 10mm, while 10% PKS concrete has slump value approximately 5mm. Therefore, the degree of workability of PKS concrete decreases with increased PKS%.

Setting Time

From Figure 3 shown above, it is observed that the

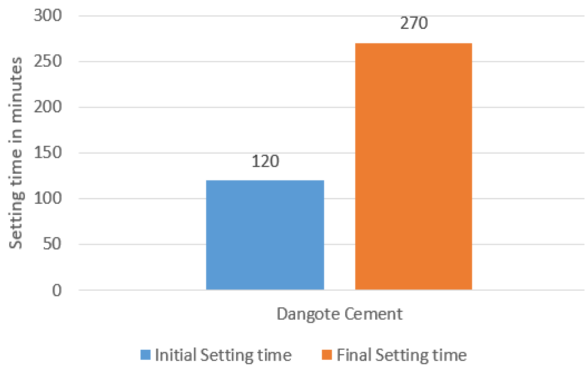

Figure 3: A bar chart showing the initial setting time and final setting time of cement used

initial setting time and final setting time for conventional cement conforms to the one used for the experiment.

CONCLUSION AND RECOMMENDATION

The findings demonstrated that the strength declines with an increase in the percentage of replacement when coarse aggregate is partially replaced with palm kernel shell (PKS) at various rates. Up to 20% of replacement, the obtained compressive strength was acceptable. Therefore, the primary factor determining the proportion to be used in actual construction is the structural desired strength of a structural part. The percentage of replacement decreases as necessary strength increases.

Concrete's compressive strength, price, and weight all drop in tandem with a percentage increase in palm kernel shell (PKS) in concrete.

This study will do a lot to promote the use of PKS as a coarse aggregate rather than throwing it away as waste. By using trash instead of construction materials, which significantly lowers the price and weight of the concrete, this will increase the sustainability policy in the construction industries in places like southeast Nigeria where palm trees are abundant and make the construction process environmentally harmless. PKS is used to make lighter, less expensive concrete.

It is recommended that 10% replacement can be used for columns, beams and foundation while 20% replacement can be used for suspended slab and over-site/ mass concrete works. The use of PKS for coarse aggregate is limited to areas where Palm trees are predominantly available, as transportation of it to other regions will increase the cost of concrete production. Further research on the durability and long term effect of use of PKS in concrete production should be investigated.

REFERENCES

Alengaram, U.J., Jumaat, M.Z., & Mahmud H., (2008). Ductility behavior of reinforced palm kernel shell concrete beams. *Eur. J. Sci. Res., 23*(3) 406-420 https:\scholar.google.com\scholar.

Alengaram, U.J., Jumaat, M.Z., & Mahmud H., (2008). Influence of Cementitious Materials and Aggregates Content on Compressive Strength of Palm Kernel Shell Concrete. *Journal of Applied Sciences 8*(18), 3207–13.

Bediako, M., Gawu, S.K., Adjaottor, A.A., Ankrah, J.S., & Atiemo, E., (2016). Analysis of co-fired clay and palm kernel shells as a cementitious material in Ghana. Case Stud. Constr. Mater., 46-52. https:\scholar.google.com\scholar

Daneshmand, S. & Saadatian, O., (2011). Influence of oil palm shell on workability and compressive strength of high strength concrete. *Ann. Faculty Eng. Hunedoara, 9*(2), 51. https://www.sciencedirect.com/science/article/pii/S1018363918304525#bb0045

Daniel Yaw Osei & Emmanuel Nana Jackson, (2012 August 8). Experimental Study on Palm Kernel Shells as Coarse Aggregate in Concrete. *International Journal of Scientific & Engineering Research, 3*.

Huda, M.N., Jumat, M.Z.B., & Islam, A.S., (2016). Flexural performance of reinforced oil palm shell & palm oil clinker concrete (PSCC) beam. *Constr. Build. Mater., 127,* 18-25. https://www.sciencedirect.com/science/article/pii/S1018363918304525#bb0060

Ismail, S., & Ramli, M., (2013). Engineering properties of treated recycled concrete aggregate (RCA) for structural applications. *Constr Build Mater 44,* 464–476. https://doi.org/10.1016%2Fj.conbuildmat.2013.03.014

Khankhaje, E., Rafieizonooz, M., Salim, M.R., Mirza, J., & Hussin, M.W., (2017). Comparing the effects of oil palm kernel shell and cockle shell on properties of pervious concrete pavement. *Int. J. Pavement Res. Technol., 10*(5), 383-392. https://www.sciencedirect.com/science/article/pii/S1018363918304525#bb0070.

Mefteh, O., Kebaïli, H., Oucief, L., & Berredjem, NA., (2013). Influence of moisture conditioning of recycled aggregates on the properties of fresh and hardened concrete. *J Clean Prod 54*, 282–288. https://doi.org/10.1016%2Fj.jclepro.2013.05.009

Mohammed, B.S., Fang, O.C., Hossain, K.M.A., & Lachemi M., (2012). Mix proportioning of concrete containing paper mill residuals using response surface methodology. *Constr. Build. Mater, 35*, 63-68. https://www.sciencedirect.com/science/article/pii/S1018363918304525#bb0075

Ndoke, P.N., (2006). Performance of palm kernel shells as a partial replacement for coarse aggregate in asphalt concrete. *Leonardo Electron. J. Prac. Technol., 5*(9), 145-152. https://www.sciencedirect.com/science/article/pii/S1018363918304525#bb0080

Nguyen, DH., Boutouil, M., Sebaibi, N., Leleyter, L., & Baraud, F., (2013). Valorization of seashell by-products in pervious concrete pavers. *Constr Build Mater 49*, 151–160. https://doi.org/10.1016%2Fj.conbuildmat.2013.08.017

Okafor, F.O., (1988). Palm kernel shell as a lightweight aggregate for concrete. *Cem. Concr. Res., 18*(6), 901-

910. https://www.sciencedirect.com/science/article/pii/S1018363918304525#bb0085

Okpala, D. (1990). Palm kernel shell as a lightweight aggregate in concrete. *Build. Environ., 25*(4), 291-296. https://www.sciencedirect.com/science/article/pii/S1018363918304525#bb0090

Olanipekun, E., Olusola, K., & Ata, O. (2006). A comparative study of concrete properties using coconut shell and palm kernel shell as coarse aggregates. *Build. Environ., 41*(3), 297-301. https://www.sciencedirect.com/science/article/pii/S1018363918304525#bb0095

Oyejobi, D.O., Abdulkadir, T.S., Yusuf, I.T., & Badiru, M.J., (2012). Effects of palm kernel shells sizes and mix ratios on lightweight concrete. *J. Res. Inf. Civ. Eng., 9*(2), 217-226. https://www.sciencedirect.com/science/article/pii/S1018363918304525#bb0100

Pelisser, F., Zavarise, N., Longo, TA., & Bernardin, AM., (2011). Concrete made with recycled tire rubber: effect of alkaline activation and silica fume addition. *J Clean Prod, 19*(6), 757–763. http://scholar.google.com/scholar_lookup?&title

Teo, D.C.L., Mannan, M.A., & Kurian, V.J., (2006). Structural concrete using oil palm shell (OPS) as lightweight aggregate. *Turk. J. Eng. Environ. Sci., 30*(4), 251-257. https://www.sciencedirect.com/science/article/pii/S1018363918304525#bb0130

Williams, F.N., Ijigah, E.A., Anum, I., & Isa, R.B., (2014). Suitability of Palm Kernel Shell as Coarse Aggregate in Lightweight Concrete Production, Civil and Environmental Research, IISTE, 6(7).

Yusuf, I.T., Jimoh, Y.A., & Salami, W.A., (2016). An appropriate relationship between flexural strength and compressive strength of palm kernel shell concrete. *Alexandria Eng. J., 55*(2), 1553-1562. https://www.sciencedirect.com/scien