NIPES

Journal of Energy Technology and Environment

Journal homepage: www.nipesjournals.org.ng

Suitability of Periwinkle Shell Mixed with Palm Kernel Shell Wastes as Replacement for Coarse Aggregate in Concrete Production

Osamuyi Osasu, Ebuka Nwankwo* and Paul Iyoha

Department of Civil Engineering, University of Benin, Benin City, Nigeria.
E-mail: ebuka.nwankwo@uniben.edu*

Article Info

Article history:
Received 03 July 2021
Revised 16 July 2021
Accepted 31 July 2021
Available online 31 August 2021

Keywords:
Periwinkle Shell (PWS), Palm Kernel Shell (PKS), *Aggregate, Compressive Test, Concrete*

doi Crossref NIPES JOURNALS

https://doi.org/10.37933/nipes.e/3.3.2021.11
https://nipesjournals.org.ng

Abstract

This paper investigates the suitability of Palm Kernel Shell (PKS) mixed with Periwinkle Shell (PWS) as full replacement for coarse aggregate in concrete production. Since aggregates make up over 65% of the volume and mass of concrete, replacing these large quantities traditional and expensive coarse aggregates with cheap and abundant PKS and PWS would have significant impact on the environment and cost of concrete production. Aggregate impact value (AIV) test and compression test were carried for various mixtures of PWS and PKS. Compressive test and the AIV test results were compared with concrete made with 100% coarse aggregates - granite in this case. A design nominal mix of 1: 1.2: 2.6 was used in this study and a total of 72 concrete cubes were cast. Results show that replacing coarse aggregates with a mixture of 75%PWS and 25%PKS (75%PWS/25% PKS) performed better than other PKS and PWS mixtures when used as full replacement for coarse aggregates. It is observed that strengths of concrete produced with this mixture of PWS and PKS are half of those produced with concrete made of coarse aggregate. However, the use of potential waste products and the elimination of expensive granite (coarse aggregates) in concrete production offers some economic and environmental benefits. The impact of PWS and PKS on shrinkage, thermal cracking and other elastic properties of concrete were not investigated in this work but will form the basis of future studies.

1. Introduction

The compressive strength of concrete is one of the most important mechanical properties of hardened concrete. The design of reinforced concrete structures relies on the compressive strength of concrete as its fundamental input [1]. The strength of concrete is influenced by its constituents, namely, cement, aggregates, water and admixtures[2]. In the casting of concrete, coarse aggregates i.e. granite - constitute about 55% to 60% of the total mass or volume. It constitutes a major cost component in concrete production. It is rated second after cement in terms of cost [3]. As a result of cost, alternative materials to coarse aggregates in concrete production would impact the cost of concrete production in Nigeria and, thus, make building construction more cost-effective. Commonly available argon-materials have been considered as alternative by many researchers [4][5][6]. Also, in order to reduce the cost of concrete, agro-based materials such as cow bone ash, palm kernel shells, fly ash, rice husk, coconut hush ash, corn cob ash and peanut shells have also been used as pozzolanic material and cement replacement materials in concrete construction [7].

Thus, aggregate substitution presents a strategy for reducing the cost of concrete. Agro-related products such as PKS and PWS present a potential substitute for coarse aggregates in the concrete construction. Periwinkles (Nodilittorina radiata) are small greenish blue marine snails with spiral conical shell and round aperture. The average winkle grows to a shell height of 20 mm, but the largest recorded winkle grew to 52 mm [7]. They are most found in the Niger Delta regions and in other swampy regions of Nigeria. The hard shells of periwinkle (PWS), which are regarded as wastes ordinarily posed environmental nuisance in terms of its unpleasant odour and unsightly appearance in open-dump sites located at strategic places[7]. On the other hand, Palm Kernel Shells (or PKS) are the shell fractions left after the Palm Kernel nut has been removed after crushing in the palm oil mill. PKS are a fibrous material and can be easily handled in bulk directly from the product line to the end use. Large and small shell fractions are mixed with dust-like fractions and small fibres [8].

Both PWS and PKS could constitute significant waste on the environment. There have been many researches on the use of each of these potential waste product as partial replacements of coarse aggregates in concrete production. Some of these fundamental researches are found in [9] [10][11]. However, this work attempts to investigate the effect of combining PWS and PKS in the production of concrete and using these potential waste materials as full replacement of granite.

2. Methodology

The Ordinary Portland Cement (OPC) used in this investigation conforms to the requirements of BS EN 197-1:2000 [12]. The PKS and PWS were obtained from markets in the Niger Delta region of Nigeria. The PKS and PWS were washed and thoroughly cleaned before they were used in concrete production. Crushed granites used in the control experiments were obtained from quarries in Edo State. In the production of concrete, batching by volume was used in producing the concrete used. Preliminary mixes of 1:1.2:2.6 (cement: fines: coarse) using a water/cement ratio of 0.55. The fine aggregate used was well graded river sand. Moulds of size 150 x 150 x 150 mm were used producing the test cubes. Cast cubes were cured in large water tanks until the age of test required. Cubes prepared were tests at 7 days, 14 days and 28 days. In this investigation, coarse aggregates were replaced in the following proportions: 100%PWS, 100%PKS, 25%PWS/75%PKS, 50%PWS/50%PKS, 75%PWS/25%PKS. Control samples were producing using100% granite as coarse aggregates. The following tests were conducted:

2.1. Slump Tests

This was carried out using the slump apparatus. The apparatus was oiled and concrete was poured inside to fill it in 3 layers while tamping 25 times at every layer. Afterwards, the apparatus was removed gently and the difference between the top of the resultant concrete form and the apparatus was measured and recorded.

2.2. AIV Test

This was carried out to test the aggregates resistance to sudden impact loads. The samples were sieved through 14mm and 10mm sieves to remove the oversized and undersized aggregates. The amount retained on the 10mm sieve were measured and recorded. The measured samples were poured into the cylindrical steel cup and tamped 25 times in line with BS EN 1097-2:1998 - Tests for mechanical and physical properties of aggregates. Methods for the determination of resistance to fragmentation. The cup was properly levelled at the top. The aggregate was weighed in the steel cup and recorded. 15 blows were given to the aggregate using the apparatus at an interval of 2 seconds. The aggregates were then removed and sieved through the 2.36mm sieve. The aggregates that passed the sieved and were retained in the sieve were weighed and recorded.

2.3. Compression Test

In testing for the compressive strength of the concrete cube samples, the Compressive Test machine was turned on and the gauges were set to zero. Thereafter, the cube samples were taken one at a time and was set at the middle of the machine, the top screw was lowered to hold the cubes in place, (the hydraulic lever was turned until it locks the cube firmly). Once this was done, the compression machine starts exerting compressive force on the cube sample, such that the cube is crushed at a particular maximum force, the dial gauge gave the maximum force reading

3.0. Result and Discussion

3.1. Workability

Table 1 presents the workability results obtained for concrete batches made with different mixtures of PKS and PWS using a mix ratio of 1:1.2:2.6 (cement: fines: coarse) and a water/cement ratio of 0.55.

Table 1: Workability of concrete with different replacements for coarse aggregate

Coarse Aggregate	Slump test results (mm)
100% Granite	33
100% PWS	42
100% PKS	42
25%PWS/75%PKS	39
50%PWS/50%PKS	40
75%PWS/25%PKS	43

It is observed that workability increases when granite is replaced with PKS/PWS. This confirms with published works using lightweight aggregates [7]. Also, it is important to mention that slump test can be impacted by size, texture, combined grading, cleanliness and moisture content of the aggregates[13]. Thus, it can be inferred that the light weight of PKS/PWS contributes to increased flow in the fluid state of concrete – increased slump values.

3.2. AIV Test

The Aggregate Impact Value Testing Apparatus, meets with BS EN 1097-2:1998 [14], it is robustly designed to determine the Aggregate Impact Value (AIV) of aggregates which provides a relative measure of the resistance of an aggregate to sudden shock or impact. Table 2 shows the AIV obtained from this investigation.

Table 2: AIV for different combination of PWS/PKS and granite used

Coarse Aggregate	AIV (%)
100% Granite	18
100% PWS	31
100% PKS	9
25%PWS/75%PKS	13
50%PWS/50%PKS	14
75%PWS/25%PKS	16

The values obtained in table 2 can be compared with published standard values of varies materials that can be used as aggregates in Table 3.

Table 3: Standard AIV values (Source: SS31, BS882) [15]

Type of aggregate	AIV (%)
Steel Slag	10 -14
Hard Limestone	13
Granite	29
Soft Limestone	28
Sandstone	21
Gravel	14
Lightweight aggregate	38

Generally, it is accepted AIV values greater than 20% are exceptionally strong; values between 10 to 20% are strong; values between 20 to 30% are satisfactory for road construction and values greater than 35% are weak. Thus, the values obtained in Table 3 shows that 25%PWS/75%PKS mixture meets the requirement for coarse aggregate.

3.3. Density and Weight

Table 4 shows the densities of concrete produced by PWS, PKS, PWS/PKS combinations and granite. It is observed that densities of concrete produced with full replacement of granite by PWS and PKS are significantly reduced. However, the densities of concrete produced corresponds to structural lightweight concrete requirements. Structural lightweight concrete has density of 1440 kg/m^3 to 1840 kg/m^3 compared to normal weight concrete with a density in the range of 2240 kg/ m^3 to 2400 kg/ m^3 [16]. For structural application, the light weight concrete strength should have strengths greater than 17.0 MPa.

Table 4: Densities different combination of PWS/PKS and granite used

Coarse Aggregate	Density in kg/m^3 (7 days)	Density in kg/m^3 (14 days)	Density in kg/m^3 (21 days)	Density in kg/m^3 (28 days)
100% Granite	2555	2417	2533	2548
100% PWS	1913	1893	1963	2140
100% PKS	1743	1913	1957	2030
25%PWS/75%PKS	1773	1857	1897	2023
50%PWS/50%PKS	1773	1953	1857	1953
75%PWS/25%PKS	1816	1923	1930	2000

3.4. Compression Test

From Figure 1, 100% granite (i.e. when used a coarse aggregate) had the highest compressive strength of 43N/mm^2 at 28 days. However, with full replacement of granite (i.e. with 100%PWS, 100%PKS, 25%PWS/75%PKS, 50%PWS/50%PKS and 75%PWS/25%PKS), the highest compressive strength observed for full replacement with 75%PWS/25%PKS. Notice that the maximum strength of 23N/mm^2 obtained with replacing granite with 75%PWS/25%PKS can be used for structural purposes. This shows that concrete produced by using PWS and PKS as coarse aggregate can also be used in structural works. In Nigeria, periwinkle shell had been used both for construction and non-construction purposes[16]. This result show that the availability of large quantities of PKS and PWS in Nigeria and their ability to be used as coarse aggregates in concrete production would have significant impact in curbing agricultural waste generation in southern Nigeria.

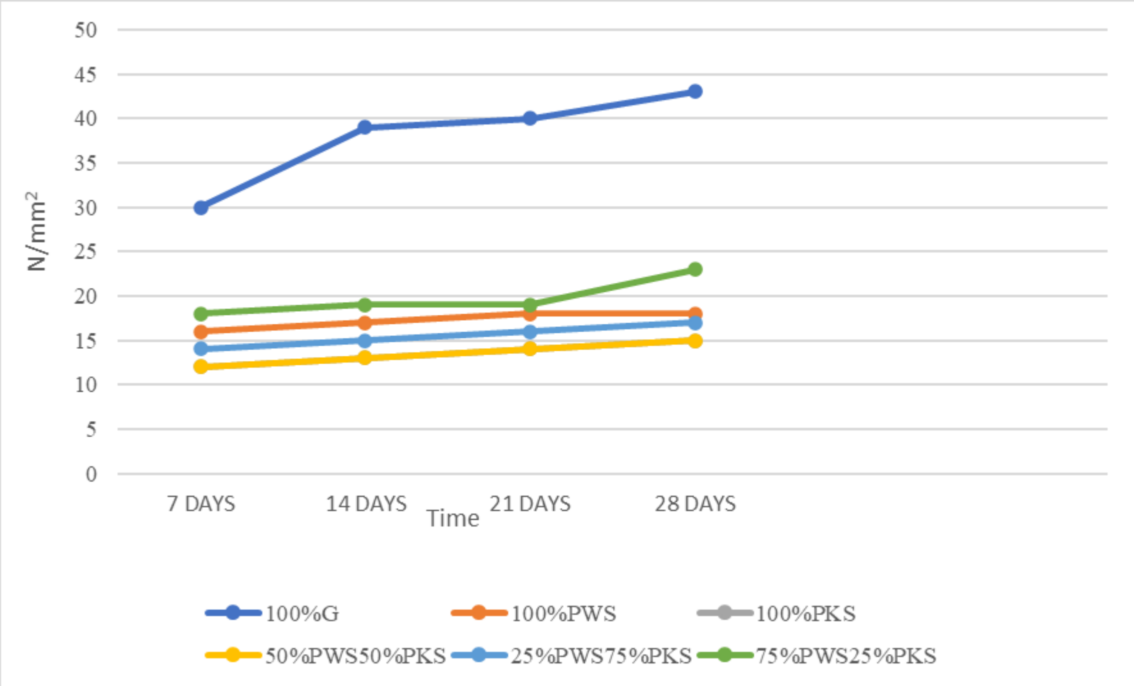

Figure 1: variation in compressive strength for concrete cube samples of various forms of coarse aggregates

4. Conclusion

This research shows that the large quantities of PKS and PWS which constitute agricultural waste in the southern part of Nigeria can be effectively used as a concrete material. Strengths of concrete above 20N/mm^2 can be produced with full replacement of coarse aggregates with these potential waste materials. Strengths above 20N/mm^2 suggests that these concretes can be used for structural application. The replacement of granite with PKS and PWS also significantly increases the workability of concrete in its fluid state. However long-term effects of durability and creep still needs to be investigated. Significant weight of construction can be obtained by partially replacing coarse aggregates with PKS and PWS and various combinations of PKS/PWS as shown in this investigation. Up to 20% of weight reduction was achieved by replacing granite with these potential waste materials. This weight saving has the potential of resulting to significant savings in foundation cost, reducing the transportation cost of cast concrete and reduction in the cost of propping and transportation.

The AIV values of PKS fall within the standard values for strong aggregates while PWS are within the range for lightweight aggregates. Thus, the combination of this waste materials produces a good replacement of coarse aggregate in concrete production.

Though significant weight reduction in the compressive strength was observed in concrete made with full replacement of granite with PKS/PWS mixture, the elimination of granite which is a relatively costly materials in concrete production offers some benefits. Besides, the high cost of granite in Nigeria has resulted in the use of natural gravels that are not free from clays coating and other fine materials that could affect hydration and bond of cement paste which can lead to building or structure collapse [17]. However, it is recommended that more work be done in access the effective cost benefit of this full replacement strategy for granite for wide range of concrete grades.

An effective combination of PKS/PWS that could lead to the production of optimum strength of produced concrete has been established as 75%PWS/25%PKS.

References

[1] A. M. Neville, *Properties of Concrete*, 5th Editon. Harlow, United Kingdom: Pearson Education Limited, 2012.
[2] M. G. Richardson, *Fundamentals of Durable Reinforced Concrete*, First Edit. London, United Kingdom: Taylor & Francis Ltd, 2019.
[3] S. Egamana and S. Sule, “Optimisation of Compressive Strength of Periwinkle Shell Aggregate Concrete,” *Niger. J. Technol.*, vol. 36, no. 1, pp. 32–38, Dec. 2016, doi: 10.4314/njt.v36i1.5.
[4] A. A. Umoh and Olusola, “Performance of Periwinkle Shell Ash Blended Cement Concrete Exposed to Magnesium Sulphate,” *Civ. Eng. Dimens.*, vol. 15, no. 2, 2013, doi: 10.9744/CED.15.2.96-101.
[5] J. O. Osarenmwinda and A. O. Awaro, “The potential use of periwinkle shell as coarse aggregate for concrete,” in *Advanced Materials Research*, 2009, vol. 62–64, pp. 39–43, doi: 10.4028/www.scientific.net/amr.62-64.39.
[6] A. W. Otunyo and B. N. Okechukwu, “Performance of concrete with partial replacement of fine aggregates with crushed waste glass,” *Niger. J. Technol.*, vol. 36, no. 2, p. 403, Apr. 2017, doi: 10.4314/njt.v36i2.12.
[7] A. P. Adewuyi, A. P. Adewuyi, and T. Adegoke, “Exploratory study of Periwinkle shell as Coarse Aggregate in Concrete works,” *ARPN J. Eng. Appl. Sci.*, pp. 1--5, 2008, Accessed: Jun. 19, 2021. [Online]. Available: http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.525.3421.
[8] S. Zafar, “Palm Kernel Shells as Biomass Resource,” *BioEnergy Consult*, 2021.
[9] F. Falade, “An investigation of periwinkle shells as coarse aggregate in concrete,” *Build. Environ.*, vol. 30, no. 4, pp. 573–577, Oct. 1995, doi: 10.1016/0360-1323(94)00057-Y.
[10] F. O. Okafor, “Palm kernel shell as a lightweight aggregate for concrete,” *Cem. Concr. Res.*, vol. 18, no. 6, pp. 901–910, Nov. 1988, doi: 10.1016/0008-8846(88)90026-9.
[11] R. I. Umasabor, “Evaluation of curing methods and periwinkle shell concrete using response surface methodology,” in *Sustainable Construction Materials and Technologies*, Jun. 2019, vol. 1, no. 7, p. 771, doi: 10.1007/s42452-019-0794-8.
[12] BSI, *BS EN 197-1:2000 - Cement. Composition, specifications and conformity criteria for common cements*. London, 2000, p. 52.
[13] N. P. Mailvaganam, “Factors Influencing Slump Loss in Flowing Concrete,” *Spec. Publ.*, vol. 62, pp. 389–404, Jan. 1979, doi: 10.14359/17734.
[14] BSI, *BS EN 1097-2:2000 - Tests for mechanical and physical properties of aggregates. Methods for the determination of resistance to fragmentation*. London, 2020, p. 46.
[15] H. Yi, G. Xu, H. Cheng, J. Wang, Y. Wan, and H. Chen, “An Overview of Utilization of Steel Slag,” *Procedia Environ. Sci.*, vol. 16, pp. 791–801, 2012, doi: 10.1016/j.proenv.2012.10.108.
[16] O. J. Oyedepo, “Evaluation of the Properties of Lightweight Concrete Using Periwinkle Shells as a Partial Replacement for Coarse Aggregate,” *J. Appl. Sci. Environ. Manag. Sept*, vol. 20, no. 3, pp. 498–505, 2016, doi: 10.4314/jasem.v20i3.2.
[17] A. T. Busuyi, “Cost Evaluation of Producing Different Aggregate Sizes in Selected Quaries in Ondo State Nigeria,” 2016. Accessed: Jun. 20, 2021. [Online]. Available: www.eajournals.org.