Pakistan Journal of Engineering and Technology, PakJET
Multidisciplinary & Peer Reviewed
Volume: 4, Number: 2, Pages: 5- 12, Year: 2021

Mechanical Properties of Concrete with Agricultural Waste as a Partial Substitute for Granite as Coarse Aggregate

Joshua Chukwuemeka Emeghai, Ogheneale Umukoro Orie

Civil/Structural Engineering, University of Benin, Nigeria
Corresponding author: Joshua Chukwuemeka Emeghai (joshua.emeghai@eng.uniben.edu).

***Abstract*- The paper investigated the effect of Palm Kernel Shell (PKS) as a partial substitute for granite as coarse aggregate in concrete production, aimed at developing an alternative form of construction material without compromising structural integrity. Randomly sourced dried and undried palm kernel shells were used to replace coarse aggregate by weight to a standard mix ratio of 1:2:4:0.5. The dried shells were obtained by heating in an improvised oven at 80^{0}C. The physical and geotechnical properties of the aggregates were determined. Results showed that the aggregate impact value of granite and PKS used were 0.228 and 0.104 respectively. The substitution of the coarse aggregate was varied from 0% to 20%. A slump test was used to determine the workability of the fresh concrete. A total of 108 concrete cubes measuring 100mm×100mm×100mm were investigated at 7days, 14days, 21days, and 28days. The control mix gave compressive strengths of 25.67 N/mm^2, 29.83 N/mm^2, 31.33 N/mm^2 and 35.67 N/mm^2 at 7, 14, 21 and 28days respectively. The compressive strengths of undried PKS cement blended concrete and dried PKS substitute at 5% were 23.17 N/mm^2, 27.00 N/mm^2, 28.00 N/mm^2, 26.00 N/mm^2 and 17.50 N/mm^2, 16.17 N/mm^2, 18.16 N/mm^2, 20.00 N/mm^2 respectively for 7, 14, 21 and 28days curing periods. The highest compressive strength of 28.00 N/mm^2 decreased by 21.50% from the control of 35.67 N/mm^2. This compressive strength is adequate for lightweight construction works as specified by BS EN 206:2013.**

***Index Terms*—Agricultural Waste, Blended Concrete, Compressive Strength, Construction, Substitute**

I. INTRODUCTION

Mitigation of the continuously increasing demand for low cost and environmentally friendly construction materials, while strengthening economic growth and competitiveness has been achieved using agricultural wastes and other recycled materials in the construction industry [1-3]. The production of palm oil results in various waste products such as empty fruit bunches, palm kernel ash, and palm kernel shells [4-6]. In most countries, these waste products are being stockpiled in open land fields and this has a negative impact on the environment [7]. The applications of agricultural wastes as aggregate or cement substitution material in concrete have engineering potentials and economic advantage especially in low-cost non-load bearing lightweight concrete [8-10]. Although the compressive strength of PKS cement blended concrete fulfills the requirement for lightweight concrete, especially for low-cost housing construction and also in earthquake-prone areas, higher strength is preferred for medium-strength structural members [4]. Palm kernel shell cement blended concrete (PKS blended concrete) has a low modulus of elasticity when compared to conventional concrete [11]. Some investigations have shown that palm kernel shells can be used as a substitution for coarse aggregates to produce structural lightweight concrete up to 30% before a drastic reduction in compressive strength occurs [4] [11-12].

Investigations have shown that the workability of coconut shell concrete increases with the addition of fly ash and compressive strength decreases with an increase in coconut shell substitution [13-14]. Other than that, researchers found that coconut shell can reduce the material cost in construction because of low cost and abundant agricultural waste due to its potential as lightweight aggregate in concrete [15-16]. However, full substitutes of coarse aggregate with coconut shells also have decreased the compressive strength of concrete [17].

The effects of ground periwinkle shell on the compressive strength of concrete have also been investigated. The work revealed that periwinkle shell concrete had a drop in compressive strength with optimum strength occurring at 5% partial substitution. The addition of silicon compound in crushed periwinkle shell composition was recommended because the crushed periwinkle shell has a negative effect on concrete [18-19]. Further studies on the suitability of periwinkle shell sand-crete blocks as a walling material for building construction were carried out by Job and Achuenu

[20]. It was discovered that at 1:6 mix with 0.6 water/cement ratio and up to 30% substitution, gave an optimum strength at 28 days of 2.45 N/mm^2.

The applications of agricultural wastes in concrete were reported by *Jing He et. al* [21]. They investigated the applications in two categories: agricultural waste without chemical process, and agricultural waste through combustion. Further investigation revealed the following as applications of agricultural wastes on concrete.

- Reduced cost of material in concrete production.
- Production of lightweight concrete
- Thermal property – agricultural wastes help concrete to have a reasonable thermal property that can result in sustainability.
- Improved mechanical properties of concrete

However, there are probable drawbacks of using agricultural wastes as coarse aggregate in concrete such as in shrinkage and creep, fatigue, and durability, etc. Adetukasi A. O. and Ikponmwosa E. E. [22] recommended less than 25% PKS content in avoidance of large shrinkage and creep. Further research done by Amarnath Yerramala and Ramachandrudu C. reported that the shape of the agricultural waste (Coconut shell) is responsible for low workability, honeycombs, and low split tensile strength. It was also stated that both the compressive strength and split tensile strength are directly related. [23]

The present paper focuses on the mechanical properties of concrete made with palm kernel shell as a partial substitute for natural granite in concrete.

II. EXPERIMENTAL DETAILS

1. Material

All materials (coarse aggregate, fine aggregate, palm kernel shell, water, and cement) used for the production of concrete were randomly sourced. The aggregates were air-dried in the laboratory to remove moisture. The Palm Kernel Shell was gotten from the Nigerian Institute for Oil Palm Research (NIFOR) Benin City, Edo State. It belongs to the Elaeis guineensis species and it was about 10 years of age.

Plate1:Fineaggregate

Plate 2: Coarse aggregate

Plate 3: PKS in a locally assembled oven (Due to: Okovido and Ahmedu, 2018)

Plate 4: Concrete Mixer

2. Methodology

The PKS was divided into two portions, a portion was dried at 80^{0}C using an oven locally assembled by Okovido and Ahmedu [24]. While the other portion was left at 20-25^{0}C room temperature. The coarse aggregate used is crushed granite of igneous rock, which was gotten from quarry Ifon, Ondo

State. Its particle size range was 5-10mm. The fine aggregate was gotten from Okhuaihe River Sand (ORS) in Edo State and was passed through a 5mm sieve. Plate 1 and 2 show fine and coarse (granite and PKS) aggregate respectively. Analysis was carried out on the aggregates and their representative grain size distribution was determined following BS 812-103.1:1985 [25]. Their specific gravity was done conforming to BS 1377-2:1990 [26]. Slump test was used to ascertain the workability of the concrete conforming to BS 1881-102:1983 [27] specifications and the cube samples compressive strength were tested at 7days, 14days, 21days, and 28days with procedures conforming to BS1881-116:1983 [28]. Limestone Ordinary Portland Cement (OPC) of N18 411-122014-CEM II AL 42.5R CB-4209 type with properties conforming to those specified in BS 12:1996 [29] was used. The material proportion is given in **Table 1.**

Table 1: Material Proportion

Percentage replacement (%)	Cement (kg)	Fine aggregate (kg)	Coarse aggregate (kg)	PKS (kg)	Water (kg)
0	5.67	9.469	22.094	0.00	3.06
5	5.67	9.469	20.989	1.105	3.06
10	5.67	9.469	19.884	2.210	3.06
15	5.67	9.469	18.780	3.314	3.06
20	5.67	9.469	17.675	4.419	3.06

The sample cube preparations conformed to BS1881-108:1983 [30] specifications. The samples were identified as, A, U, and D. Samples A were the control samples, samples U contained undried palm kernel shell at 5%, 10%, 15%, and 20% substitutions, while samples D had dried palm kernel shell respectively. Three cube samples were cast for each percentage making a total of 108 samples.

III. RESULTS AND DISCUSSION

The sieve analysis chart showed that the PKS was uniformly graded, having uniformly coefficient C_u and coefficient of gradation C_c of 1.63 and 0.94 respectively. The granite and ORS were poorly graded due to their uniformly coefficient C_u and coefficient of gradation C_c of (1.38 and 1.14) and (3.07 and 0.902) respectively. The result further showed that ORS belonged to zone 5 in the AASHTO classification. (See **Fig. 1, 2, and 3**)

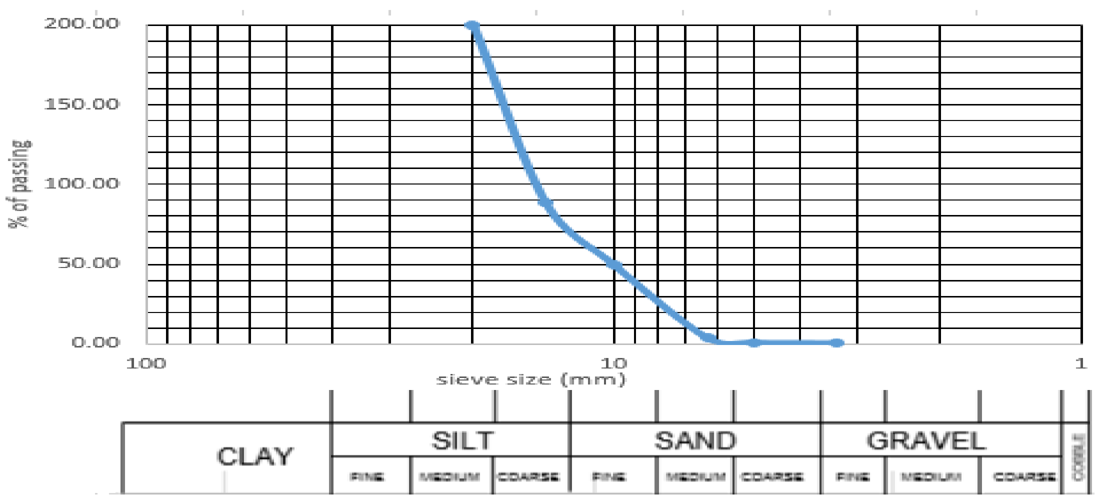

FIGURE 1: Particle size distribution of palm kernel shell

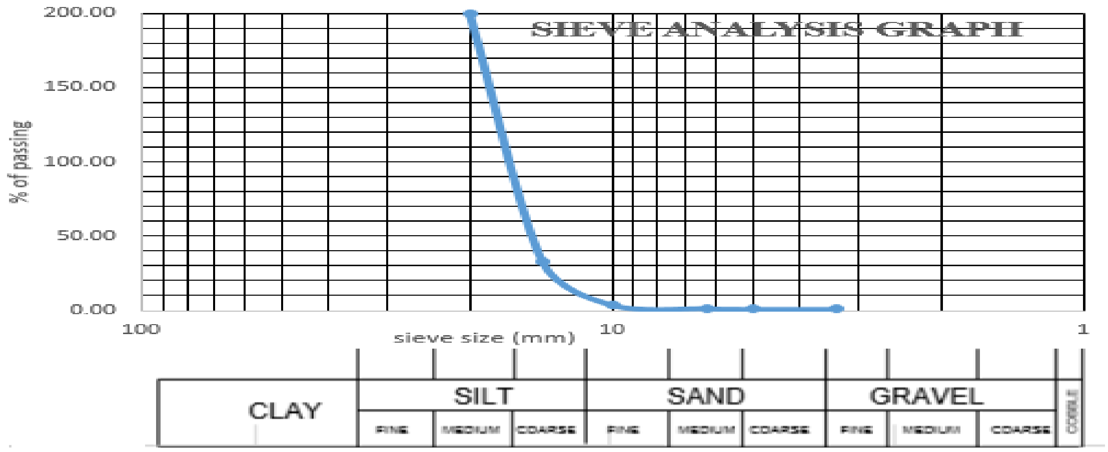

FIGURE 2: Particle size distribution of granite

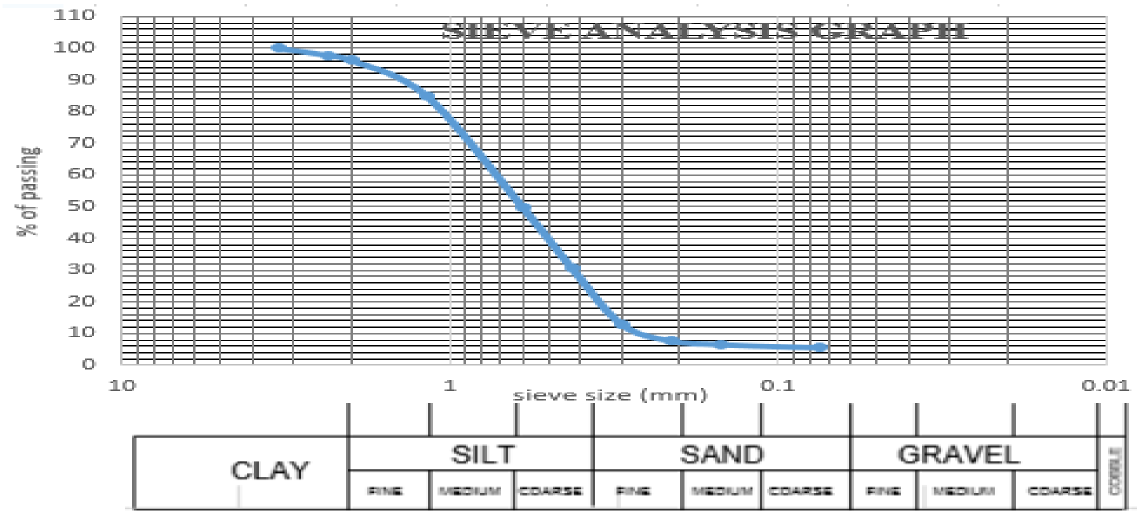

FIGURE 3: Particle size distribution of ORS

The specific gravity of the palm kernel shell was 1.13 as shown in **table 2** below which was lower than 2.45 and 2.74 of ORS and granite respectively. This implied that the specific gravity of PKS, ORS, and granite was all denser than water. It also implied that granite was denser than its counterparts i.e., ORS and PKS.

Table 2: Specific gravity of aggregates

Material	Specific gravity
Fine aggregate	2.45
Granite	2.74
Palm Kernel Shell	1.13

Table 3 showed that the AIV of granite and PKS were 22.84% and 10.44% respectively. According to BS 812-112:1990 [31] classification of aggregates, PKS is considered strong while granite is satisfactory for road construction.

Table 3: Aggregate impact value (AIV) for materials

Material	Aggregate impact value
Granite	22.84%
PKS	10.44%

The slumps of the dried PKS cement blended concrete were higher than its counterpart. However, all the slumps were true and the control sample had the highest of 20mm. No slump was observed at 15% substitution for the undried PKS cement blended concrete and 20% substitution for both. It was also observed that the higher the substitution the lower the workability i.e., slump. (See **Fig. 4**)

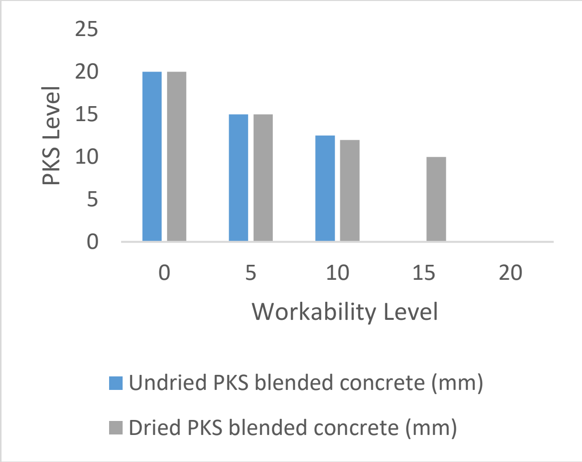

FIGURE 4: Workability of undried and dried PKS cement blended concrete

Figures 5, and 6 presented the effect of partial substitute of the granite in concrete with undried and dried PKS respectively on compressive strength. The figures revealed that the compressive strength of the control samples was 25.67 N/mm^2, 29.83 N/mm^2, 31.33 N/mm^{2,} and 35.67 N/mm^2 at 7, 14, 21, and 28 days respectively. However, this showed a 38.95% increase in compressive strength. It also revealed that the maximum compressive strength of 20.00 N/mm^2 and 28.00 N/mm^2 for the dried and undried PKS cement blended concrete was attained at a 5% replacement level at 28 days and 21 days respectively. This showed a decrease of 28.57% in compressive strength of dried PKS cement blended concrete.

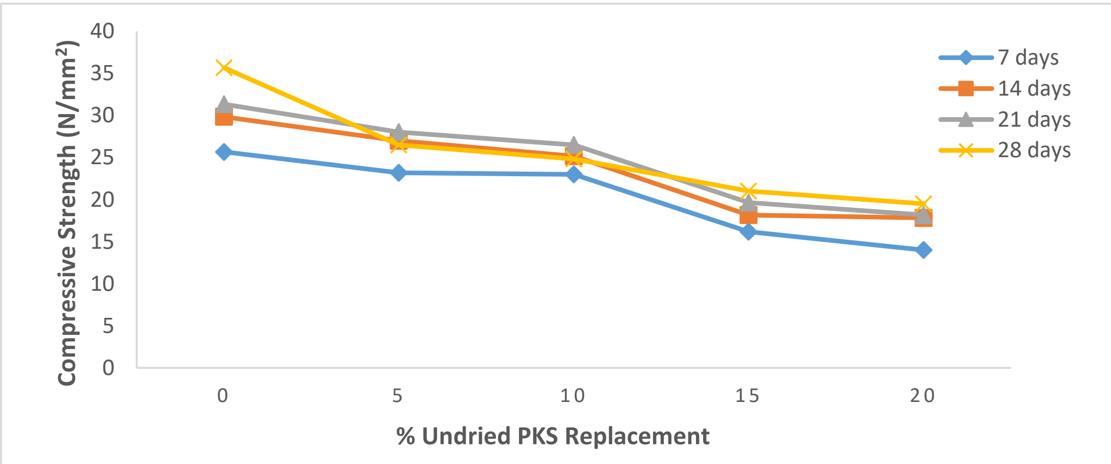

FIGURE 5: Effect of undried PKS replacement on compressive strength.

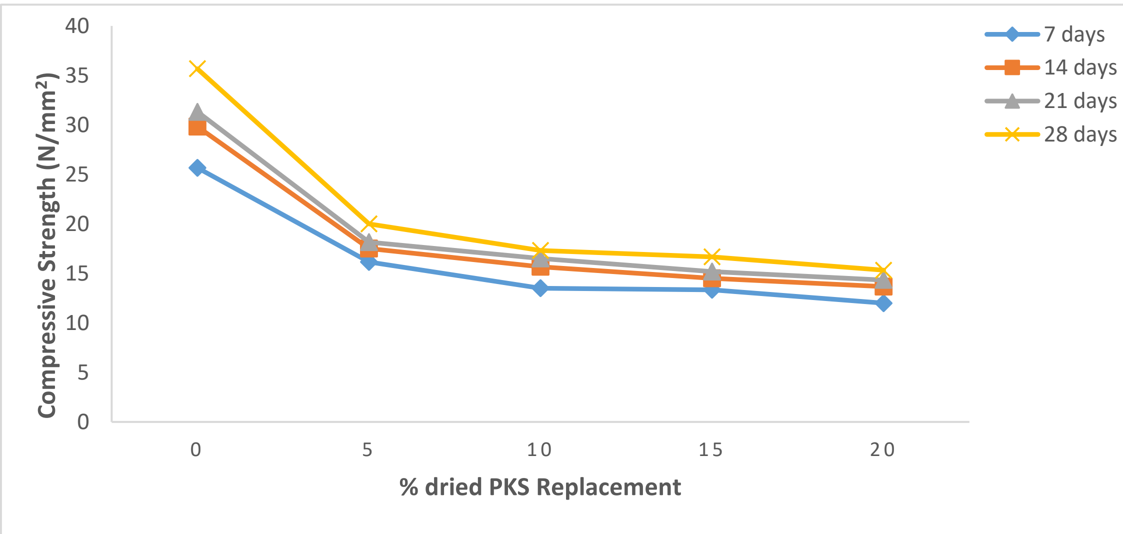

FIGURE 6: Effect of dried PKS replacement on compressive strength.

Figure 5 reported that 10% undried PKS granite substitute gave compressive strengths of 23.00 N/mm^2, 25.17 N/mm^2, 26.50 $N/mm^{2,}$ and 24.83 N/mm^2 at 7, 14, 21, and 28 days respectively. Hence at 21 days, the compressive strength was 15.42% lower than the control. **Fig. 6** revealed that the percentage substitution level is inversely proportional to the compressive strength. Hence at 28 days, 20% substitute of dried PKS cement blended concrete produced compressive strength of 15.33 N/mm^2 which was 57% less than the control.
It can be seen from **Fig. 7, and 8** that the compressive strength of 16.17 N/mm^2 and 13.33 N/mm^2 at 15% replacement for undried and dried PKS cement blended concrete respectively were attained at 7 days. This showed there was an increase of 29.87% and 25.05% compressive strength with a difference of 4.82% at 28 days curing period. It was also seen that the minimum and maximum compressive strength of 12.00 N/mm^2, 14.00 N/mm^2 and 20.00 N/mm^2, 28.00 N/mm^2 were attained at 20% and 5% for 7, 21 days, and 7, 28 days respectively for both dried and undried PKS cement blended concrete. However, we observed that the compressive strength is directly proportional to the curing period.

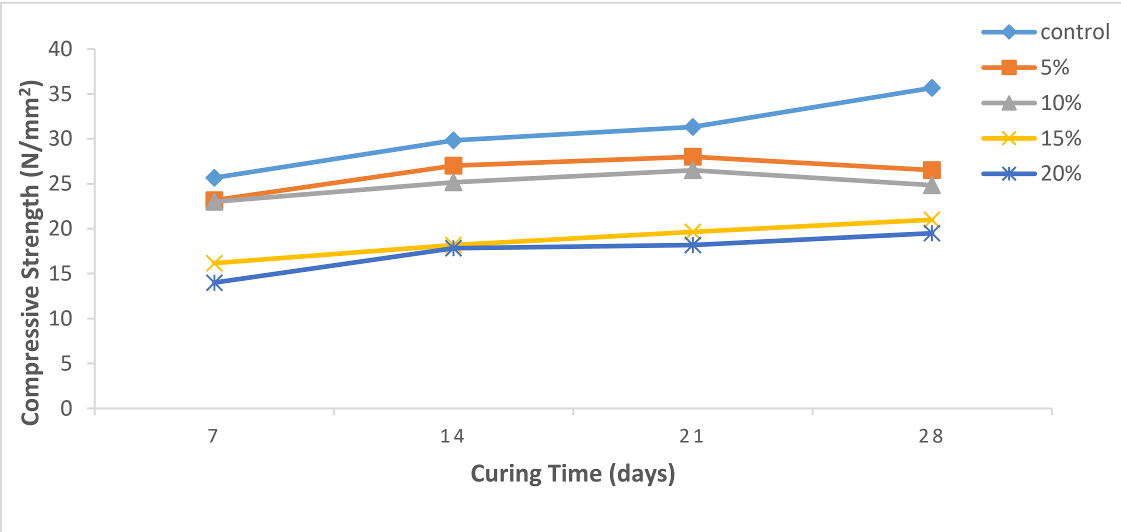

FIGURE 7: Effect of curing on compressive strength of undried PKS concrete.

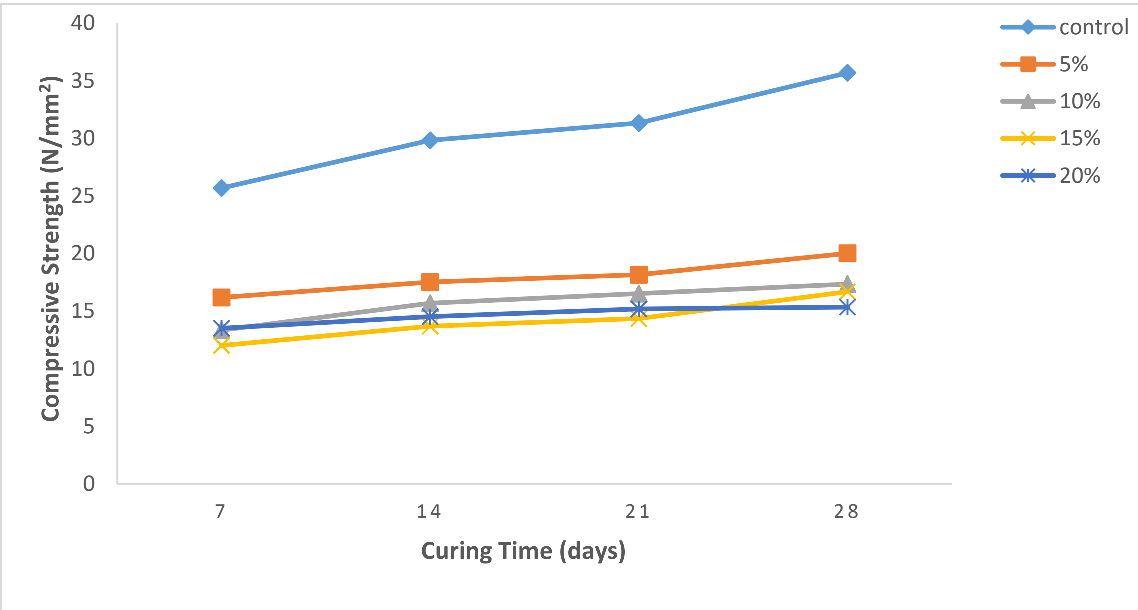

FIGURE 8: Effect of curing on compressive strength of dried PKS concrete

IV. COSTS ANALYSIS

The cost analysis reported that the cost of producing a conventional concrete cube with a mix ratio of 1:2:4 was $65.58 per m^3 while the cost of producing 5% PKS blended concrete is $65.35 per m^3. This gives a production cost reduction of 3.42%. However, *Jalam, U. A. et. al* [32-41] investigated the cost benefits of using agricultural wastes as partial coarse aggregate in concrete. The result reported the highest cost saving of 41% cost reduction in mass concrete and the possibility of an overall cost saving of about 24% in the total cost of concrete material if the materials are gotten from the production site.

V. CONCLUSION

The following conclusions could be drawn from this research:

- Though the Palm Kernel Shell used showed an impressive strength characteristic. However, there was a decline as the granite was partially replaced with dried PKS at various percentages.
- It has been observed that the maximum compressive strength of the undried palm kernel shell concrete was attained at 5% substitution at 21 days but with further addition, it was decreased. However, the maximum compressive strength of the dried palm kernel shell concrete was attained at 5% substitution at 28 days.
- Palm Kernel Shell can be adopted as a partial substitute material for coarse aggregate in concrete production but should not exceed *5% by weight* of the aggregate.
- Undried palm kernel shell should be considered over dried palm kernel shell whenever there is a need for palm kernel shell substitute in concrete production.
- Finally, this research validated the use of palm kernel shells as an option in recycling abundantly available agricultural waste into a useful end product in the construction industry.

REFERENCES

[1] A. Agabe, "Effect of Crushed Waste Aggregate on the Compressive Strength of Concrete," B. Eng. Thesis, Civil Eng. Dept., University of Benin, Benin City, 2005.

[2] D. Cenqiz, "The Strength Properties of High-Volume Fly Ash Roller Compacted and Workable Concrete and Influence of Curing Conditions," Cement and Concrete Research, vol. 35, pp. 1112-1121, Nigeria, 2005.

[3] O.U. Orie and O.J. Omokhiboria, "Mechanical Properties of Eggshell and Palm Oil Fuel Ashes Cement Blended Concrete" Research Journal in Engineering and Applied Sciences, vol. 3, no. 6, pp. 401-405, 2014.

[4] P.N. Ndoke, "Performance of Palm Kernel Shells as Partial Replacement for Coarse Aggregate in Asphalt Concrete," M.S thesis, Civil Eng. Dept., Federal University of Technology, Minna, Nigeria, 2006.

[5] E.A. Olanipekun, K.O. Olusola, and O. Ata, "Comparative Study Between Palm Kernel Shell and Coconut Shell as Coarse Aggregate," Journal of Engineer and Applied Science, vol. 1, pp. 23-28, 2005.

[6] K.P. Jnyanendra, and S.S. Basarkar, "Concrete Using Agro-waste as Fine Aggregate for Sustainable Built Environment," International Journal of Sustainable Built Environment, vol. 5, pp. 312-333, 2016.

[7] J. Manasseh, "A Review of Partial Replacement of Cement with Some Agro-waste. Nigerian Journal of Technology," vol. 29, no. 2, pp. 12-20, 2010.

[8] E. Uffuah, and O.E. Alutu, "The Effects of Agricultural Waste Ashes on Concrete Strength. Built Environment Journal," vol. 2, pp. 21-32, 2005.

[9] T. Nwanfor, and S. Sule, "Stability of Groundnut Shell Ash/Ordinary Portland Cement Concrete in Nigeria," Advances in Applied Science Research, vol. 3, no. 4, pp. 2283-2287, 2012.

[10] S.A. Kakade, and A.W. Dhawale, "Light Weight Aggregate Concrete by Using Coconut Shell. International Journal of Technical Research and Application," vol. 3, pp. 127-129, 2015.

[11] D.C.L. Teo, M.A. Mannan, and V.J. Kurian, "Structural Concrete Using Oil Palm Shell (OPS) as Light Weight Aggregate," M.S thesis, Civil Eng. Prog., University of Malaysia, Sabah-Malaysia, 2006.

[12] H. Mohammed, K.O. Afolabi, and L.E. Umoru, "Crushed Palm Kernel Shell as a Partial Replacement of Fine Aggregate in Asphaltic Concrete," International Journal of Material Methods in Technology, vol. 2, pp. 1-5, 2014.

[13] A. Yerramala, "Properties of Concrete with Coconut Shells as Aggregate Replacement," International Journal of Engineering Inventions, vol. 1, pp. 21-31, 2012.

[14] K.V. Rao, A.H.L. Swaroop, P.K.R. Rao, and C.N. Bharath, "Study on Strength Properties of Coconut Shell Aggregate," International Journal of Civil Engineering Technology, vol. 6, pp. 42-61, 2015.

[15] P.S. Kambli, and S.R. Mathapati, "Compressive Strength of Concrete by Using Coconut Shell," IOSR Journal of Engineering, vol. 4, 1-7, 2014.

[16] A. Kanojia, and S.K. Jain, "Performance of Coconut Shell as Coarse Aggregate in Concrete," Construction and Building Materials, vol. 140, pp. 150-156, 2017.

[17] H. Dahiya, and N. Dharni, "Concrete with Crushed Coconut Shell as Coarse Aggregate," Journal of Mechanical and Civil Engineering, vol. 1, pp. 15-19, 2015.

[18] A. Shagari, "Effect of Crushed Periwinkle Shells as Fine Aggregate on Compressive Strength of Concrete," B. Eng. Thesis, Civil Eng. Dept., University of Benin, Benin City, Nigeria, 2005.

[19] M.O. Olutu, "Effect of Ground Periwinkle Shell on the Strength Properties of Concrete," M. Eng. Thesis, Civil Eng. Dept., University of Benin, Benin City, Nigeria, 2016.

[20] F.O. Job, and E. Achuenu, "The Suitability of Periwinkle Sand-Crete Blocks as a Walling Material," Journal of Environment Review, vol. 3, no. 2, pp. 293-300, 2000.

[21] H. Jing, K. Satoru, and A. Varenyam, "The Utilization of Agricultural Waste as Agro-Cement in Concrete: A Review," Sustainability, vol. 12, pp. 1-16, 2020.

[22] A. O. Adetukasi, and E. E. Ikponmwosa, "Shrinkage and Creep Characteristics of Palm Kernel Shell Concrete," Journal of Engineering Studies and Research, vol. 26, no. 1, pp. 47-56, 2020.

[23] A. Yerramala, and C. Ramachandrudu, "Properties of Coconut Shells as Aggregate Replacement," International Journal of Engineering Inventions, vol. 1, Issue 6, pp. 21-31, 2012.

[24] J.O. Okovido, and A.R. Ahmedu, "Strength Characteristics of Geopolymer Concrete Utilizing Blends of Silicate Bearing Materials," Structural Engineering, vol. 1, no. 1, pp. 21-34, 2018.

[25] Method for Determination of Particle Size Distribution, BS 812-103 (Part 1), British Standard Institution, London, 1985.

[26] Muhammad Nasir Khan, Syed K. Hasnain, Mohsin Jamil, Sameeh Ullah, "Electronic Signals and Systems Analysis, Design and Applications International Edition," in

Electronic Signals and Systems Analysis, Design and Applications: International Edition , River Publishers, 2020
[27] Khan, Muhammad Nasir, Hasnain Kashif, and Abdul Rafay. "Performance and optimization of hybrid FSO/RF communication system in varying weather." Photonic Network Communications vol. 41, no. 1, pp. 47- 56, 2021.
[28] Khan, Muhammad Nasir, Mohsin Jamil, Syed Omer Gilani, Ishtiaq Ahmad, Muhammad Uzair, and H. Omer. "Photo detector-based indoor positioning systems variants: A new look." Computers & Electrical Engineering, vol. 83, pp. 106607, 2020.
[29] Kashif, Hasnain, Muhammad Nasir Khan, and Ali Altalbe. "Hybrid optical-radio transmission system link quality: link budget analysis." IEEE Access, vol. 8, pp. 65983-65992, 2020.
[30] Khan, Muhammad Nasir, and Fawad Naseer. "IoT based university garbage monitoring system for healthy environment for students." In 2020 IEEE 14th International Conference on Semantic Computing (ICSC), pp. 354-358. IEEE, 2020.
[31] Uzair, Muhammad, R. O. B. E. R. T. D DONY, Mohsin Jamil, KHAWAJA BILAL AHMAD MAHMOOD, and Muhammad Nasir Khan. "A no-reference framework for evaluating video quality streamed through wireless network." Turkish Journal of Electrical Engineering & Computer Sciences, vol. 27, no. 5, pp. 3383-3399, 2019.
[32] Khan, Muhammad Nasir, Syed Omer Gilani, Mohsin Jamil, Abdul Rafay, Qasim Awais, Bilal A. Khawaja, Muhammad Uzair, and Abdul Waheed Malik. "Maximizing throughput of hybrid FSO-RF communication system: An algorithm." IEEE Access, vol. 6, pp. 30039-30048, 2018.
[33] Khan, Muhammad Nasir, Syed K. Hasnain, and Mohsin Jamil. Digital Signal Processing: A Breadth-first Approach. Stylus Publishing, LLC, 2016.
[34] Khan, Muhammad N. "Importance of noise models in FSO communications." EURASIP Journal on Wireless Communications and Networking vol. 2014, no. 1, pp. 1-10, 2014.
[35] Method of Test for Soils for Civil Engineering Purposes, BS 1377 (Part 2), British Standard Institution, London, 1990.
[36] Method for Determination of Slump, BS 1881-102, British Standard Institution, London, 1983.
[37] Method for Determination of Compressive Strength of Concrete Cubes, BS 1881-116, British Standard Institution, London, 1983.
[38] Specification for Portland Cement, BS 12, British Standard Institution, London, 1996.
[39] Method for Making Test Cubes from Fresh Concrete, BS 1881-108, British Standard Institution, London, 1983.
[40] Method for Determination of Aggregate Impact Value, BS 812-112, British Standard Institution, London, 1990.
[41] U. A. Jalam, A. A. Jalam, I. M. Sale, and O. F. Job, “Cost Evaluation of Utilizing Building Materials Derived from Agricultural Waste as Sustainable Materials for Lightweight Construction,” Economic and Environmental Studies, vol. 16, no 4, pp. 673-685, 2016.