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# Assessment of Palm Kernel Shell Powder Strengthened with Renolith as Partial Replacement for Cement

**Wasiu, J. and Osegbowa, E.D.**

**Abstract:** The increase in the population density of the world today requires man to find a suitable substitute to cement as a major material used in construction in order to find an economical, safe and eco-friendly structure for habitation. Palm Kernel shells contribute to the ever-growing volume of solid waste in the environment and its conversion to a viable construction material cannot be overemphasized. This research is therefore focused on the use of Palm Kernel Shell Powder (PKSP) as a partial replacement for cement. Experimental tests were carried out on the PKSP at replacement levels of 0,10, 15, 25, 50 and 75%. Renolith, a chemical polymer was added at 0, 12.5 and 25% by volume to the concrete mix. Slump and compressive strength tests were carried out in line with relevant specifications. The results revealed that PKSP can adequately replace cement at an optimum value of 15%. The addition of Renolith at 12.5% to the mix also improved the strength and workability properties of the mix. It was concluded that the use of PKSP as partial replacement for cement will provide an economy of 15% by volume for cement and an eco-friendly environment through the conversion of PKS wastes to construction material.

**Keywords:** Cement, Compressive Strength, Concrete, Palm kernel shell powder, Renolith

## I. Introduction

Concrete is a man-made material produced from a mixture of fine and coarse aggregates, cement, and water used for construction purposes [1], [2] and [3]. Other materials known as admixtures are sometimes included in the production of concrete, so as to improve one or more of its properties either at its fresh state or hardened state or both fresh/hardened states [4]. Concrete is a heterogeneous construction material widely used in the construction industry and forms the main ingredients for infrastructural development of any nation [5]. Concrete is among the earliest and most commonly used material in the world for construction purposes, mainly due to its advantages; economy, ease of usage, abundance, long-lastingness, and its potential to withstand severe weather conditions [6-7]. It is on record that concrete is the second most commonly utilized materials after water in the globe [8]. Approximately 25 billion tonnes of concrete are processed around the globe annually [9]. The advantage which concrete possesses has made it useful in the construction of buildings and structures used for different applications like; agricultural, industrial, commercial and residential purposes in many countries of the world. Concrete is good in compression and poor in tension; however, the inclusion of steel reinforcement takes care of concrete's poor tension property that it can resist different degrees of tensile loading [10-11].

The high rate of population growth and industrialization in many countries of the world has led to high demand for construction materials (concrete) due to increased need for

**Wasiu, J. and Osegbowa, E.D.** (Department of Civil Engineering, Edo State University Uzairue,Edo State, Nigeria)
Corresponding author: wasiu.john@edouniversity.edu.ng
**Phone Number**
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infrastructures. This has led to the shortage and high cost of concrete constituents – especially cement and aggregates. The release of carbon (iv) oxide ($CO_2$) and other greenhouse gases during the manufacturing of ordinary Portland cement (OPC) have adversely affected the environment [4].

This study is aimed at investigating the effects of palm kernel shell powder (PKSP) strengthened with Renolith as a partial replacement for cement in concrete production.

PKSP is obtained from the Palm kernel shell (PKS). PKS is extracted from the oil palm tree (elaeis guinensis) – a tree indigenous to West Africa and commonly found in the tropics [12]. The palm kernel shell (PKS) is the hard endocarp of palm kernel fruit that protects the palm seed, and it is obtained after taking out the palm oil from the mesocarp of the fruit [13]. PKS is one of the commonly seen agricultural wastes that are not optimally used [14]. The waste that is normally generated from the oil palm industries are enormous and often discarded in the open, causing harms of different degree to the environment [15]. In Nigeria, about 1.5 million tons of PKS are produced annually; most of which are often dumped as waste products [16]. The use of palm kernel shell (PKS) as an alternative construction material is gaining more relevance in Nigeria due to its enormous waste generated to the environs. Also, the high cost of materials (cement, fine and coarse aggregate) used in making concrete has brought about the need to find other materials that can be used as partial/complete substitutes for these conventional materials for the production of concrete [17].

Renolith is an advanced cementitious, water-soluble, non-flammable, non-toxic and environmentally friendly additive [18-19] and it is among the many chemicals found in commercial centres, formulated from the combination of locally manufactured chemical products in Germany by Renolith International [20]. It is considered a secondary binder due to the fact that it is only effective as a good stabilizer for soil in combination with cement. Renolith is easy to use in combination with other materials as it increases the modulus of elasticity and flexibility of the materials. It is commonly used to modify loose soil on site to save construction time and cost.

[4] investigated the strength of concrete produced with environmental waste glass powder (EWG) strengthened with Renolith as partial replacement for cement. Results revealed improvement in workability and compressive strength.

[21] examined the workability of fresh concrete and mechanical properties (compressive strength, flexural tensile strength and splitting tensile strength) of hardened concrete made with palm PKSA as partial replacement for cement. It was observed that the addition of PKSA in concrete production leads to the reduction of cost of concrete production, and also helps to solve environmental waste disposal problem posed by PKS.

[22] studied the effect of ground palm kernel (GPK) shells as part substitute for cement in concrete. The study revealed an optimum value of GPK shells substitution as 20% for shells without fuel and 10% for shell with fuel. It also found an improvement on the flexural strength property.

[23] examined the impact of PKS as a partial replacement for coarse aggregate in concrete. PKS was used to partially replace coarse aggregate at different levels (0% -20% at 5% intervals). The study concluded that the

optimum percentage of PKS replacement in concrete is 10% by weight of the conventional material.

[19] examined the effectiveness of cement and Renolith as stabilizers for black cotton soil suitable for subgrade pavements. The research concluded that cement and Renolith are good stabilizers for clayey soils due to their improvement on strength of the soil.

## II. Materials and Methods

### A. Materials

i. **Palm kernel shell powder (PKSP):** Palm kernel shell was obtained in Ado-Ekiti metropolis. The shells collected were plastered with dried clay and other unwanted materials. They were thoroughly washed with clean water and air dried. The PKS was turned into powder (PKSP) using a pulverising machine. The PKS and the PKSP are shown in Figures 1 and 2 respectively.

ii. **Fine and Coarse Aggregates:** The fine and coarse aggregates used for this study are shown in Figure 3 and Figure 4 respectively. These materials were sourced from Ado-Ekiti metropolis.

iii. **Water:** The water used for this study was portable water obtained from the tap in the laboratory. The water was tested to ensure that it is potable and conformed to the requirements of [24].

iv. **Cement:** Ordinary Portland Cement (OPC), of grade 42.5, Dangote Brand was used in this research and was obtained from Ado – Ekiti Metropolis, in Ekiti State as shown in Figure 5. It conforms to the standards specified by [25].

v. **Renolith:** Renolith, a white liquid chemical polymer admixture used for this study (Figure 6) was obtained from Akure-Ondo, Ondo State.

Figure 1: Palm kernel shells

Figure 2: Palm kernel shell powder

Figure 3: Fine aggregate

Figure 4: Coarse Aggregates

Figure 5: OPC, Dangote Brand

## B. Methods

**i. Specific Gravity Determination:** Specific gravity is the ratio of the weight of given volume of aggregates to the weight of equal volume of water at a specific temperature. The Specific Gravity (Gs) was determined with Standard Reference to [26-27]. The specific gravity was computed from equation 1.

$$Gs = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)} \quad (1)$$

**ii. Sieve Analysis:** The sieve analysis was carried out by shaking the fine and coarse aggregates through a stack of screen with openings of known sizesThe procedure was carried out in accordance with [28] by weighing out the sample of the sand and oven dried for twenty-four hours at 110 ºC. The coefficient of curvature (Cc) and coefficient of uniformity (Cu) were obtained using equations 2 and 3 respectively.

$$Cc = \frac{(D_{30})^2}{D_{60} D_{10}} \quad (2)$$

$$Cu = \frac{D_{60}}{D_{10}} \quad (3)$$

**iii. Mix Ratio of Constituent materials:** The mix ratio of the constituent materials used was 1:2:4. The substitution of PKSP by cement is in the order: 0%, 25%, 50% and 75% as displayed in Table 1. While the dilution of the Renolith with water were: 12.5%, 25%, 50% and 75% respectively as shown in Table 2.

**iv. Slump Test:** A Slump test was used to ascertain the workability of the different concrete mixtures. A slump cone apparatus (with a height of 300 mm, bottom diameter 200 mm, and top diameter of 100 mm), standard tamping rod, non-porous base plate, and measuring scale was used and the test was carried out following the

Figure 6: A 5-litre Renolith sample

Figure 7: Slump Measurement

Figure 8: Concrete cube test

specification of [29]. For all the different concrete mixes, the associated slump was measured and recorded. Figure 7 showed the slump type and measurement.

**Table 1: Concrete Mix Ratio**

| Replacement (%) | Cement (g) | PKSP (g) | Fine (g) | Coarse (g) |
|---|---|---|---|---|
| 0 | 1333 | 0 | 2667 | 5333 |
| 10 | 1200 | 133 | 2667 | 5333 |
| 15 | 1133 | 200 | 2667 | 5333 |
| 25 | 1000 | 333 | 2667 | 5333 |
| 50 | 667 | 667 | 2667 | 5333 |
| 75 | 333 | 1000 | 2667 | 5333 |

Table 2: Dilution of Renolith

| Dilution (%) | Renolith (g) | Water (g) | Total (g) |
|---|---|---|---|
| 12.5 | 250 | 1750 | 2000 |
| 25.0 | 500 | 1500 | 2000 |
| 50.0 | 1000 | 1000 | 2000 |
| 75.0 | 1500 | 500 | 2000 |
| 100.0 | 2000 | - | 2000 |

v. **Compressive Strength Test:** A Compressive strength test was used to ascertain the degree to which a sample can withstand compressive loads. A total of 44 concrete cube samples (150 x 150 x 150 mm) were cast and tested at 7, 14, 21 and 28 days curing days using a 2000kN Compression Testing Machine as shown in Figure 8. The compressive strength test was carried out in line with [30]. The compressive strength (C.S) for the concrete cube sample was computed with equation 4.

$$C.S = \frac{\text{Failure Load}}{\text{Area of Sample}} \tag{4}$$

## III. Results and Discussion

i. **Specific Gravity and Sieve Analysis:** The specific gravities of the fine and coarse aggregates were 2.66 and 2.77 respectively and within the specification of [27] and thus having a high strength and producing a durable concrete for the research work. The coefficient of curvature and coefficient of uniformity are 2.18 and 1.14 for the fine aggregates and 1.57 and 1.05 for the coarse aggregates respectively. All these values are within the specification of [28].

ii. **Slump Tests Result:** The slump test determines the consistency of the concrete mixes prepared in the laboratory or the construction site. The slump obtained at different percentages of replacements of PKSP with cement is presented in Figure 9. The slump of each design mix generally increases with increase in the percentage of PKSP replacement in the concrete mix. A true slump of value 28-38mm was observed between 0-15% PKSP replacement with cement while a collapse slump of values 40-90mm was recorded for 25-75% PKSP. The addition of Renolith tends to cause a reduction in the slump values by 7.1-13.3%. This reduction may be due to strong particle bonding caused by the use of Renolith in the design mix. The true slump observed here was in the range of 30-38mm while the collapse slump values recorded were in the range of 59-78mm.

iii. **Compressive Strength Results:** The compressive strength of PKSP at different percentages of replacement (0-75%) with and without the addition of Renolith are presented in Figures 10, 11 and 12 respectively. The compressive strength decreases with an increase in the percentages of PKSP. Following the grade C30 design, the compressive strengths at 28 days of curing (0%, 10% and 15% PKSP) were 42, 35 and 30.3 N/mm$^2$ respectively. These values are within specified design grade of C30.

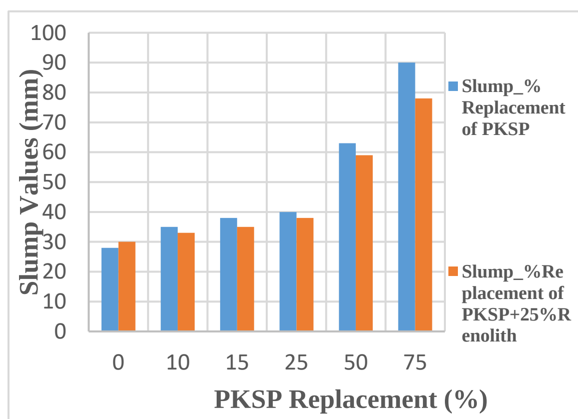


Figure 9: Slump values at different percentages of PKSP

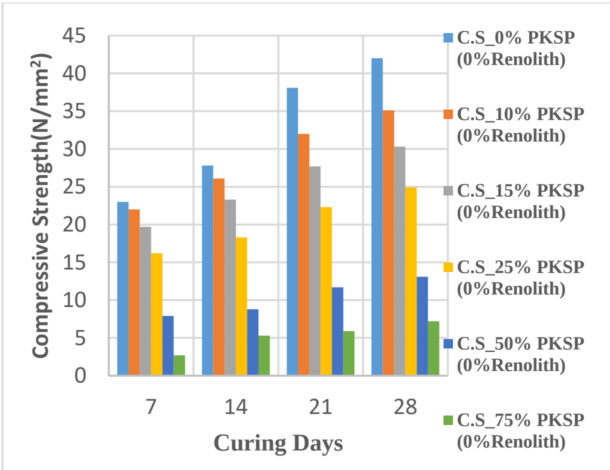


Figure 10: Compressive Strength at different percentages of PKSP (0% Renolith)

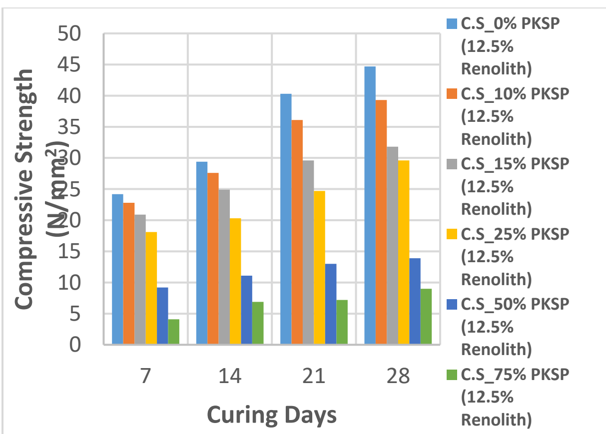


Figure 11: Compressive Strength at different percentages of PKSP (12.5% Renolith)

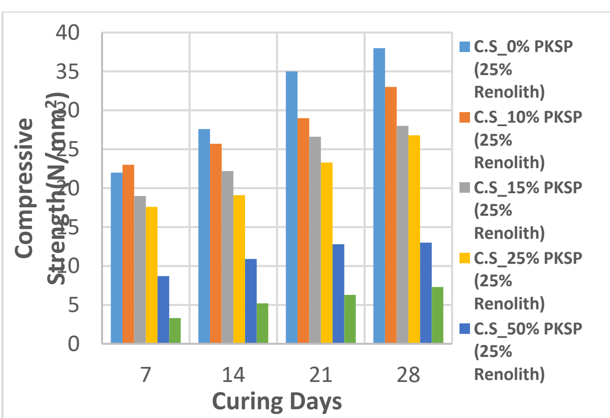


Figure 12: Compressive Strength at different percentages of PKSP (25% Renolith)

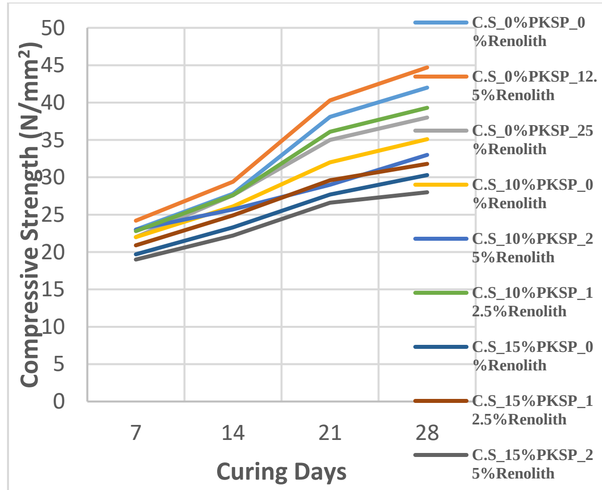


Figure 13: Compressive Strength at different (0-15%) percentages of PKSP (0-25% Renolith)

This represents an optimum replacement of PKSP with cement at 15%. On the other hand, the compressive strengths recorded upon the addition of 12.5% of Renolith revealed an improvement in strengths in the range of 6.4-12.3%. The strengths at 28 days (0%, 10% and 15% PKSP + 12.5% Renolith) was 44.7, 35.3 and 31.8N/mm$^2$ respectively. The increase in strength may be a result of the formation of "micro-rubber-bands" between the constituent materials and forming a stronger bond within the concrete mix than would have been for the mix without Renolith. These findings are in line with the research of [4], [18-19] and [23]. Furthermore, the addition of a higher dosage of Renolith (0%, 10% and 15% PKSP + 25% Renolith) causes a slight decrease in the compressive strengths and within the range of 5.7-10.5% compared to concrete without Renolith. Generally, Renolith has shown positive improvement in strength and workability when used carefully in the concrete mix. Figure 13 also shows the comparison of compressive strength with the addition of 0-25% Renolith to different percentages of PKSP in the concrete mix. The results revealed an improvement in the compressive strengths using an optimum dosage of Renolith to be 12.5% at the different PKSP replacement. However, there is a decrease in the compressive strength with higher dosage of Renolith.

## IV. Conclusion

The following conclusions were drawn from this research:

1. The specific gravity, coefficient of uniformity and coefficient of curvature of the fine and coarse aggregates are within the relevant specifications and adjudged to be good materials for the research.
2. The compressive strength for concrete produced with PKSP at different levels of replacements (0%, 10%,15%, 25%, 50% and 75%) with cement decreases with an increase in PKSP.
3. The addition of the chemical polymer, Renolith tends to improve the compressive strength of the concrete produced and also helps to improve the workability of the concrete. The improvement is within the range of 6.4-12.3%. This is also in consonance with the research of [ 4,18,20].
4. Optimum replacement of PKSP was experimentally found to be 15% for dense-weight reinforced concrete elements and greater than 15%-50% for light-weight concrete elements. Above 50% may not be feasible for either light-weight or dense-weight concrete.
5. This research will help to reduce PKS as an environmental waste and the cost aof disposal of such waste and also provides an eco-friendly environment.

The addition of Renolith to the concrete mix has in no doubt improve the strength properties of concrete. But greater care should be taken in the dosage administration. A 25% dosage was found to decrease the compressive strength by approximately 9.5% while a 12.5% dosage was found to improve strength properties. Further investigation can be carried out on lower dosages (2-10%) of Renolith on the strength properties of concrete.

## References


[1] Shahrior, A.M. and Syed, I.A. "Concrete and its Properties", 10.13140/RG.2.2.18980.50564, https://www.researchgate.net/publication/343267549_Concrete_and_It%27s_properties, 2020.

[2] Kayode, O.O., John, W. and Victor, B.A. "Effectiveness of Palm Kernel Shell Ash Concrete Reinforced with Steel Fibres", *ABUAD Journal of Engineering Research and Development (AJERD),* vol. 2, no. 2, 2019, pp. 1-9.

[3] Supriani, F., Islam, M. and Yuzuar, A. "Concrete Tensile Strength Test Using Different Sand Gradation Zones to Mitigate Earthquake Buildings", *International Journal of Engineering Technology and Sciences (IJETS),* vol. 8, no. 1, 2021, pp. 19 – 24.

[4] Wasiu, J. and Garba, Y.S. "Strength Characteristics of Concrete Using Waste Glass Powder Strengthened by Renolith as Partial Replacement for Cement", *International Journal of Multidisciplinary Sciences and Engineering,* vol. 8, no. 6, 2017, pp. 28 – 33.

[5] Orji, F.N., Egwuonwu, C.C. and Asoegwu, S.N. "The Investigation of Periwinkle Shell-Rice Husk Composite as a Replacement for Granite in Concrete", *Open Science Journal of Bioscience and Bioengineering,* vol. 4, no. 1, 2017, pp. 1 - 5.

[6] Hasan, M.Y.T. "Introduction to Concrete Technology", Department of Civil Engineering, Fahad Bin Sultan University March 2015.

[7] Ishaya, A., Oyemogum, I.M. and Arinze, A. "Properties of Concrete Produced with Bottle Caps (WBC) as Partial Replacement of Coarse Aggregate and Orange Leaves Power as Plasticizer", *Civil and Environmental Research,* vol. 8, no. 7, 2016, pp. 91 – 95.

[8] Ezekiel, S.P., Raphael, N.M. and John, N.M. "Effects of Palm Kernel Shell and Rice Husk Ash as Partial Replacements of Normal Weight Aggregate

and Ordinary Portland Cement in Concrete", *European International Journal of Science and Technology,* vol. 6, no. 8, 2017, pp. 42 – 54.

[9] Chana, P. "Low Carbon Cements: The Challenges and Opportunities", *Proc. Future Cement Conf. & exhibition*, London, vol. 8, no. 9, 2011, pp. 1-7.

[10] Adebayo, O. "Assessment of Palm Kernel Shells as Aggregate in Concrete and Laterite Blacks", *Journal of Engineering Studies and Research,* vol. 18, no. 2, 2012, pp. 88 - 93.

[11] Raju, P. and Md, M. "Performance of RCC Beams with and Without Curtailment", *International Journal of Research in Engineering and Technology,* vol. 4, no. 13, 2015, pp. 70 -70.

[12] Wasiu, J., Salami, V. and Awolusi, T.F. "Oil Palm Fiber as Partial Replacement Aggregates for Normal Concrete", *International Journal of Engineering Research,* vol. 4, no. 9, 2015, pp. 487- 491.

[13] Emiero, C. and Oyedepo, O.J. "An Investigation on The Strength and Workability of Concrete Using Palm Kernel Shell and Palm Kernel Fibre as A Coarse Aggregate", *International Journal of Scientific & Engineering Research,* vol. 3, no. 4, 2012, pp. 1 – 5.

[14] Oke, P.K. and Ayodeji, O.Z. "Development and Evaluation of the Performance of Palm Kernel Shell (PKS) Grinder", *European Journal of Mechanical Engineering Research,* vol. 7, no.1, 2020, pp. 51- 65.

[15] Auta, S.M., Arogundade, M.A. and Riminntsiwa, N.S. "Effect of Palm Kernel Shell (PKS) as Coarse Aggregate on the Compressive Strength of Revibrated Concrete", *Faculty of Engineering Ahmadu Bello University, Zaria, National Engineering conference,* 2018, pp. 1 – 6.

[16] Apeh, O. and Adejoh, S. "Assessment of Palm Kernel Shells as Partial Replacement of Coarse Aggregates in Highway Pavements", *International Journal of Advanced Academic Research Sciences, Technology and Engineering,* vol. 6, no. 3, 2020, pp. 70 – 79.

[17] Sunday, U.A. "Compressive Strength of Concrete with Palm Kernel Shell as a Partial Replacement for Coarse Aggregate, Review Paper", *SN Applied Sciences*, 2019.

[18] Quadri, A.I., Olagbaye, A.J. and Abdulhameed, M.I. "Renolith Appraisal on Lateritic Soils Along Oshogbo-Iwo Road in Southwest Nigeria", *International Journal of Science and Qualitative Analysis,* vol. 4, no. 1, 2018, pp. 1- 6.

[19] Haneefa, J.S., and Suresh, P.K.P. "An Experimental Study on Renolith Treated Black Cotton Soil for Subgrade Pavements", *International Journal of Science and Research (IJSR),* vol. 5, no. 11, 2015, pp. 1240 - 1244.

[20] Owolabi, T.A. and Aderinola, O.S. "An Assessment of Renolith on Cement-Stabilized Poor Lateritic Soil", *Sci - Afric Journal of Scientific Issues, Research and Essays,* vol. 2, no. 5, 2014, pp. 222 – 237.

[21] Olowe, K.O. and Adebayo, V.B. "Investigation on Palm Kernel Ash as Partial Cement Replacement in High Strength Concrete", *SSRG International Journal of Civil Engineering (SSRG-IJCE),* vol. 2, no. 4, 2015, pp. 48 – 56.

[22] Armah, E.A., Koffi, H.A. and Amuzu, J.K.A. "Compressive and Flexural Strengths of Concrete Containing Ground Palm Kernel Shells as Partial Replacement of Cement", *Journals of Modern Materials,* vol. 7, no. 1, 2020, pp. 7 – 16.

[23] Ogunwemimo, O., Salami, L.O. and Familusi, A.O. "Evaluation of Palm Kernel Shell as a Partial Replacement for Coarse Aggregate in Concrete", *Journal of New Trends in Civil Engineering,* vol.1, no. 2, 2019, pp. 001-004.

[24] BS EN 17075 (2018). "Water Quality". *General Requirements and performance test procedure for water monitoring equipment*. European Standard Test.

[25] British Standard 1971, "Cement Composition, Specification and Conformity Criteria for Common Cements", *British Standards Institution, London,* 2000.

[26] Nigerian Industrial Standard NIS, 444-1, "Composition Specification and Conformity Criteria for Common Cement", *Nigerian Industrial Standard*, ed. 2003.

[27] British Standard 1377, part 2, "Methods of Test for Soils for Civil Engineering Purpose - Specific Gravity", *British Standard Institution, London,* 1990.

[28] British Standard 812 – 103, "Methods for Determination of Particle Size Distribution*", British Standards Institution, London,* 1985.

[29] British Standard 1881, part 102, "Methods for Determination of Slump, *British Standards Institution, London,* 1983.

[30] British Standard EN 12390 – 3, "Testing Hardened Concrete - Compressive Strength of Test Specimens", *Standard British Standards Institution, London,* 2002.