Nigerian Journal of Technology (NIJOTECH)
Vol. 41, No. 5, September, 2022, pp.827 - 833
www.nijotech.com

Print ISSN: 0331-8443
Electronic ISSN: 2467-8821
http://dx.doi.org/10.4314/njt.v41i5.2

PERFORMANCE OF OLIVE SEED ASH AS PARTIAL REPLACEMENT OF CEMENT IN CONCRETE

T. S. Ketkukah[1,*], S. I. Anowai[2] and F. G. Mije[1]

[1]Department of Civil Engineering, University of Jos, Nigeria
[2]Department of Building, University of Jos, Nigeria

*corresponding author (Phone number: +234-808-839-1573, Email: ketkukaht@unijos.edu.ng)

Article history: Received 06 June, 2022. Revised 24 October, 2022. Accepted 24 October, 2022

Abstract

The need for partial replacement of cement in concrete production has become inevitable because of adverse environmental impact of cement production, increasing cost of cement and financial benefits of utilization of waste products. This paper presents laboratory investigation of the properties of Olive Seed Ash (OSA) as partial replacement of cement in concrete. Concrete mix of 1:2:4 (Binder: Fine aggregate: Coarse Aggregate) and water-cement ratio of 0.44 were adopted in this study. Olive seed ash was used to replace cement at various levels of 0%, 5%, 10% and 15% by mass. Partial replacement of cement with OSA resulted in decrease in initial and final setting times of concrete but the values are still within acceptable limits. The results show that compressive strength, flexural strength and split tensile strength of the concrete decreased as the percentage of OSA increases. However, at 10% replacement level, the 28 days compressive strength achieved was 28N/mm^2 and this value surpasses the minimum compressive strength of 25N/mm^2 recognized by BS EN 1992-1-1 (2004) for reinforced concrete design. The results also showed that the water absorption decreased with increase in percentage replacement of cement with OSA portraying that replacement with olive seed ash has higher durability potentials. It is recommended that cement can be replaced with at least 10% OSA in concrete. This will reduce the cost of construction in addition to environmental advantage.

Keywords: Olive Seed Ash, Composition, Concrete, Strength, Water absorption.

1.0 INTRODUCTION

The construction industry relies heavily on Portland-limestone cement (PLC) which is the main ingredient used as binder in the production of concrete. Unfortunately, production of cement involves emission of large amount of carbon-dioxide gas ($C0_2$) into the atmosphere a major contribution for green House effect and global warming. It is inevitable either to search for another material or partly replace cement by some other material [1]. Industrial wastes, such as blast furnace slag, fly ash and silica fume are being used as partial replacement of cement in concrete and recently, agricultural wastes such as palm oil fuel ash (POFA), silica from rice husk and rice husk ash are also being used as pozzolanic materials in concretes [2].

To solve and minimize environmental issues, research works attempting to employ the wide availability of agricultural wastes, such as sugar cane bagasse, rice husk, sugar cane straw, and palm oil fuel, among others are being investigated as partial replacement of cement in concrete production. The inclusion of agricultural wastes as partial replacement of OPC reduces the emission of green- house gas to the atmosphere by reducing the amount of clinker in the production of cement. Calcination temperature of agricultural wastes is lower (600°c to 1000°c), thereby reducing CO_2 emissions from the fossil fuel used to heat up the cement kilns. This temperature is substantially lower than 1450°c which is needed for the calcination of limestone to produce cement [3].

Bamboo leaf ash (BLA), Rice Husk Ash (RHA) and Sugar Cane Bagasse Ash (SCBA) obtained by burning the biomass are known to have an amorphous nature with high silica, and show a high pozzolanic reaction when used as binder to produce concrete [4]. The pozzolanic nature of SCBA and RHA refines the pore structure in mortar and concrete, which significantly reduce permeability against water, sulfate and chloride penetration [5]. When pozzolana is incorporated in concrete, the silica in the pozzalana reacts with the calcium hydroxide released in the process of cement hydration and produce additional cementitious material called calcium silicate hydrate [2]. The use of agricultural wastes in the partial replacement of cement will also motivate farmers to increase production which ultimately will ensure food security in the country.

Aside environmental issues, the price of cement has been on increase over the years making it unaffordable to low and medium income earners. The continuous increase in the price of cement has geared researchers to investigate the viability of some pozzolanic materials as substitutes, which would be used as partial replacement for cement so that more people can afford to build their houses [6].

Olive Seeds found abundantly at various farm sites across Nigeria are treated as wastes materials. The ash is obtained by the combustion of Olive Seed. Olive seed ash if properly burnt can be used as an admixture or supplement of cement in mortar and concrete [7].

This study investigates the properties of Olive Seed Ash (OSA) as partial replacement of cement in concrete. Compressive, flexural and split tensile strengths of OSA concrete were determined. Workability and water absorption of OSA concrete were also investigated.

2.0 MATERIALS AND METHODS

Materials that were used include ordinary Portland cement, fine aggregates, coarse aggregates, olive seed ash (OSA) and water. Olive seeds were collected in large amounts from Pankshin Local Government Area of Plateau State, Nigeria where olive trees are grown in large numbers and olive oil is produced locally. The seeds were collected and sun dried in open air to make them ready for easy and thorough burning. The seeds were burnt under a controlled temperature in a kiln at Abubakar Tafawa Balewa University, Bauchi at temperature of approximately 600 ˚C to 700˚C to obtain the ash. The ash was sieved through a standard 150*u*m sieve. Figure 1-2 show the fresh olive seeds and sundried burnt and sieved ash respectively.

Chemical analysis and specific gravity test were performed on the ash. The chemical analysis of the sample was carried out at National Metrological Development Centre (NMDC) Jos, Plateau State, Nigeria using Energy Dispersive X-ray Fluorescence Spectrometer (EDXRF). The apparent specific gravity of the fly ash was 2.24, which was less than that of cement.

Figure 1: Fresh Olive seeds

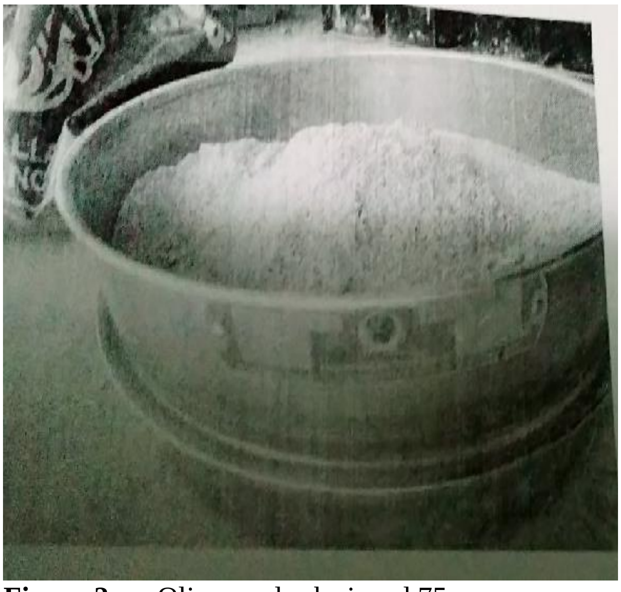

Figure 2: Olive seed ash sieved 75 um

The cement used in this study was “Dangote” brand of grade 42.5 ordinary Portland cement conforming to [8]. The sand used was clean river sand. The sieve analysis result shows that the sand fall under zone II as stipulated in [9]. The fineness modulus, specific gravity and water absorption of the fine aggregate were 4.87, 2.62 and 0.72 respectively. The coarse aggregate was machine crushed granite having nominal size of 19mm. Clean tap water was used.

Concrete mix of 1:2:4 (Binder: Fine aggregate: Coarse Aggregate) and water-cement ratio of 0.44 were adopted in this study. Olive seed ash was used to replace cement at various levels of 0%, 5%, 10% and 15% by mass. The 0% replacement of Ordinary Portland Cement is the control mix. Initial and final setting time tests were conducted to evaluate the effect of the Olive seed ash on the initial setting time and final setting time of cement paste in accordance with [10]. Slump test was conducted on the OSA concrete in accordance with [11]. Figure 3 shows measurement of the slump. The slump test results were used to determine the workability of the concrete.

Figure 3: Measurement of the Slump Value

Batching, mixing and casting were done adopting a standard procedure. The fine aggregates and coarse aggregates were accurately weighed first. The concrete mixing was done by hand mixing on a watertight platform. The fine aggregates were firstly mixed with the required quantity of cement to a uniform colour before the coarse aggregates were added. For mixtures in which Portland cement were partially replaced with olive seed ash, the olive seed ash, and cement were mixed dry to uniform colour separately. The required amount of water was weighed and added carefully so that no water was lost during mixing. The moulds were oiled and filled with the mixtures. Mechanical vibration using table vibrator was adopted. The top of surface of the specimen were levelled and finished. After setting for 24 hours, the specimens were demoulded and were transferred to the curing tank where in they were allowed to cure for up to 28 days.

Figure 4: Compressive Strength Test

Figure 5: Flexural Strength Test

Concrete cube specimens of 150mm × 150mm × 150mm were cast and test for compressive strength at 7, 14 and 28 days curing durations. The compressive strength test was performed in accordance with [12]. The flexural strength test was performed in accordance with [13]. Concrete prism beams of 100mm × 100mm × 500mm were cast, cured and tested at 7, 14, and 28 days. Split tensile strength test was performed in accordance with [14]. Concrete cylinders 100mm diameter and 200mm long is placed horizontally between loading surfaces and loaded along its diameter. The tests were conducted at 7, 14 and 28 days curing durations. Water absorption test was carried out on the OSA concrete in accordance to [15]. Figures 4, 5 and 6 show testing of a typical concrete cube and beam prism; and weighing of wet cube for water absorption test respectively.

Figure 6: Weighing Wet Cube for Water Absorption Test

3.0 RESULTS AND DISCUSSION

3.1 CHEMICAL COMPOSITION OF OLIVE SEED ASH

The result of chemical analysis of Olive seed ash (OSA) is similar to that of Rice Husk Ash (RHA), Groundnut Husk Ash (GHA) and Saw Dusk Ash (SDA) as presented in Table 1. They all meet the requirements of good pozzolanic materials. The chemical composition of RHA, GHA and SDA were obtained from [16]. Olive seed ash has combined percentages of Silicon Oxide, Aluminium Oxide and Iron Oxide (SiO_2+Al_2O_3+Fe_2O_3) of 70.92% indicating that the material is a good pozzolanic material. The sum of SiO2, Al2O3 and Fe2O3 contents of ash is required to be at least 50% to have pozzolanic properties in nature according to [17].

Table 1: Chemical Composition of OSA and other Agricultural Waste Ashes

Constituent	Agricultural Waste Ashes			
	OSA (%)	**RHA (%)**	**GHA (%)**	**SDA (%)**
SiO_2	65.17	84.59	58.25	52.50
Al_2O_3	4.25	0.89	22.02	20.55
Fe_2O_3	1.50	0.66	2.85	6.61
CaO	6.17	0.9	6.61	6.75
MgO	4.15	1.64	4.02	4.45
SO_3	3.78	ND	0.09	ND
K_2O	8.28	0.82	0.37	1.5
Na_2O_3	1.27	0.63	2.65	3.44
PK_2	3.81	ND	ND	ND

3.2 EFFECT OF OLIVE SEED ASH SETTING TIME OF CEMENT PASTE

The results of setting time of cement pastes at different percentage replacements of OPC with OSA are presented in Figure 7. The results show that increase in the percentage replacement of cement with OSA generally resulted in increase in both initial and final setting times. Slight decrease in initial setting time was observed at 5% replacement level. The increase in setting time observed is attributed to low rate of hydration with decrease in Ca_3SiO_5 (C_3S) and Ca_3SiO_6(C_3A) contents. At all levels of replacement, the minimum initial setting time (60mins.) and the maximum final setting times (600mins.) specified by the [18] were not violated.

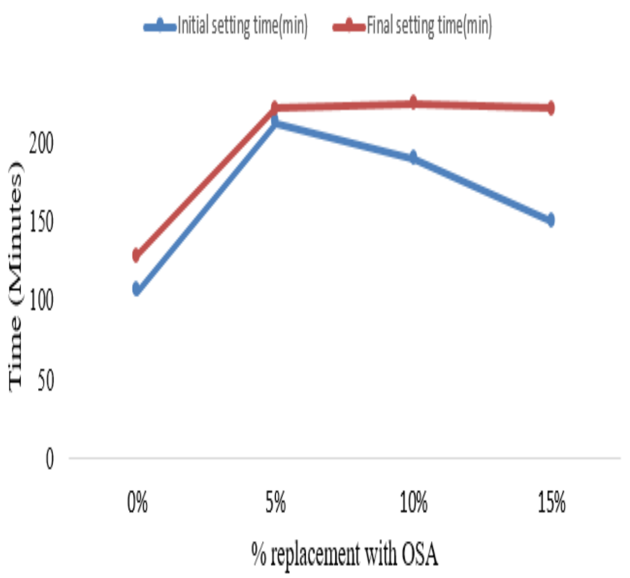

Figure 7: Initial and Final Setting Times of Cement Pastes

3.3 SLUMP TEST RESULT

The slump test results which indicate workability of concrete is presented in Figure 8. The results show that the slump value increased with increase in the percentage replacement of cement with OSA. The range of the slump is between 21-25mm. This indicates that OSA improves the workability of the concrete.

3.4 COMPRESSIVE STRENGTH TEST RESULTS

The results for the compressive strength test are shown in Figure 9. The compressive strength of OSA concrete decreased as percentage of OSA is increased. The concrete achieved compressive strengths of

34N/mm^2, 31N/mm^2, 28N/mm^2 and 23N/mm^2 at 0%, 5%, 10% and 15% level of replacement of PLC with OSA respectively at 28 days curing age. At 10% replacement of cement with OSA, compressive strength of 28N/mm^2 was achieved after 28 days and this surpasses the minimum compressive strength of 25N/mm^2 recognized by [19] for reinforced concrete design. It is expected that the compressive strength of OSA concrete will increase further as curing age increases due to continuous pozzolanic reactions between PLC and OSA in the concrete. Similar study on usability of Hazelnut shell ash as pozzolana in concrete found 10% as the optimum percentage replacement of cement with Hezelnut shell ash [20].

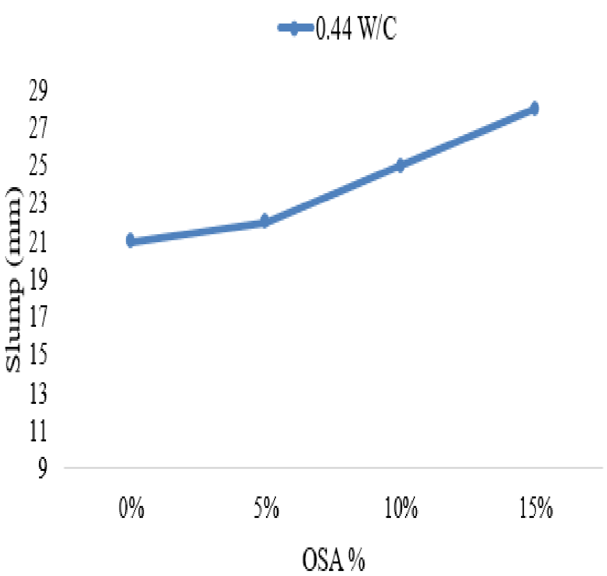

Figure 8: Slump of OSA/Cement Concrete

3.5 FLEXURAL STRENGTH TEST RESULTS

The results of flexural strength tests were presented in Figure 10. The results show that the flexural Strength of the concrete increases with curing age and decreases with increase in percentage replacement of cement with OSA. This is because porosity is increased and also hydration reduced due to decrease in cement content. The flexural strengths at 28 days were 10.00N/ mm^2, 8.20N/ mm^2, 7.67N/ mm^2 and 4.03N/ mm^2 for 0%, 5%, 10% and 15% levels of replacements of cement with OSA respectively. These results follow similar trend as flexural strength results of studies on use of other agricultural waste concretes [16]. Reinforcement bars were not used. Flexural strength of concrete may be required by designers of pavements [21]. Flexural strengths of concrete is of value when designing pavements which requires a minimum flexural strength of 4.1N/mm^2 for medium or average traffic and 4.5 N/mm^2 [22]. All the samples meet the minimum flexural strength requirement for pavement designs except samples with 15% replacement of PLC with OSA which has flexural strength of 4.03 N/mm^2.

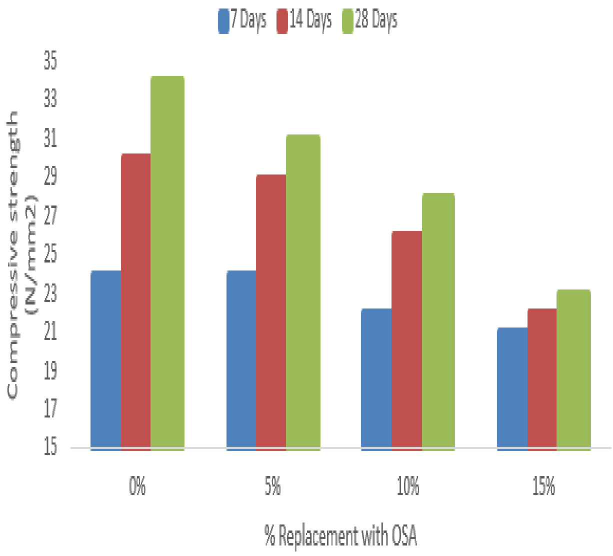

Figure 9: Compressive Strength Test Results

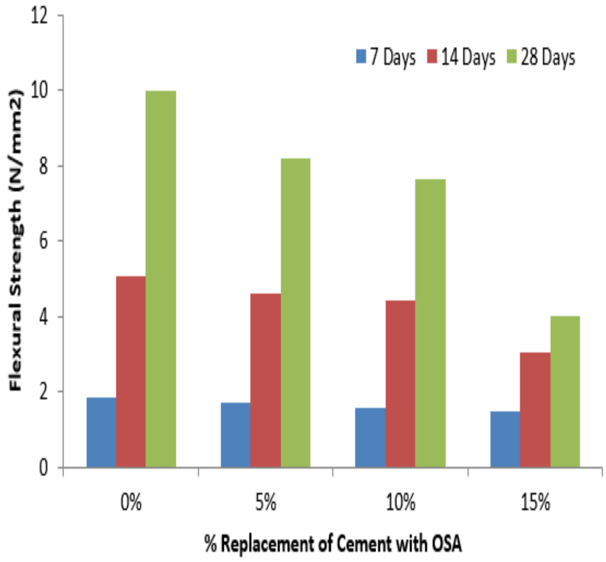

Figure 10: Flexural Strength Test Results

3.6 SPLIT TENSILE STRENGTH TEST RESULTS

The results of split tensile strength tests were presented in Figure 11. The results show that the split tensile Strength of the concrete increases with curing age and decreases with increase in percentage replacement of cement with OSA. The split tensile strengths at 28 days were 3.39N/ mm^2, 2.94N/ mm^2, 2.60N/ mm^2 and 1.64N/ mm^2 for 0%, 5%, 10% and 15% levels of replacements of cement with OSA respectively. This indicates a reduction of split tensile Strength by 13.27%, 23.30% and 51.62% at 5%, 10%

and 15% levels of replacements of cement with OSA respectively. [23] also reported reduction in split tensile strength of concrete when cement was partially replaced with groundnut shell ash.

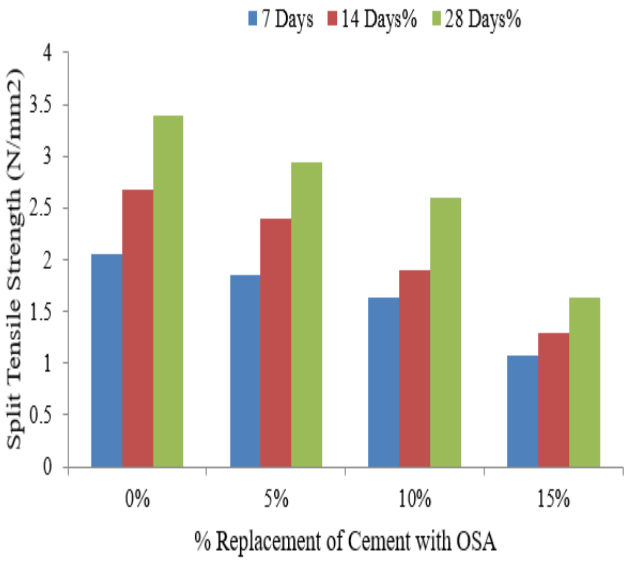

Figure 11: Split Tensile Test Results

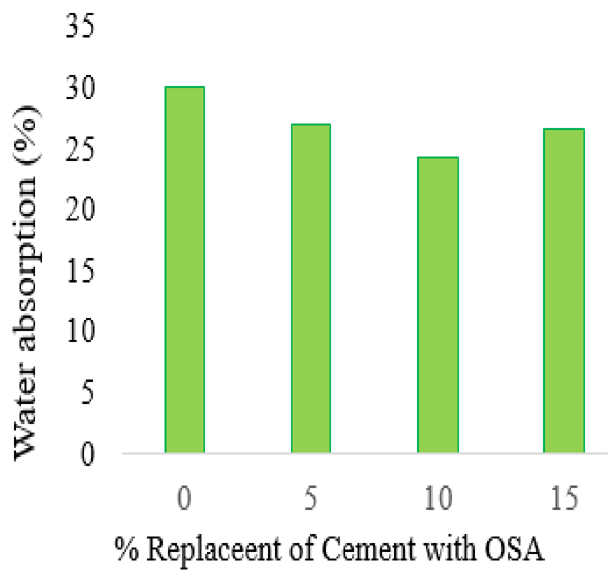

Figure 12: Water Absorption (%)

3.7 WATER ABSORPTION TEST RESULTS

The results of the water absorption tests are presented Figure 12. Water absorption decreased with an increase in the percentage replacement of cement with Olive Seed Ash showing that partially replacing OPC with olive seed ash in concrete had higher durability potentials. The reduction in water absorption in concrete containing OSA is due to pozzolanic reaction between OSA and OPC which produced additional cementitious gel (C-S-H gel) that reduced the volume of pores in the concrete. The least water absorption of 24.37% was recorded at 10% replacement of cement with olive seed ash.

4.0 CONCLUSION

From the various tests carried out on the concrete samples the following conclusions were made:

1. Olive seed ash is pozzolanic and suitable for use as partial replacement of cement in concrete.
2. Partial replacement of cement with OSA generally resulted in increase in both initial and final setting times. However the values of both initial and final setting times at all replacement levels fall within acceptable limits.
3. Slump test results showed that the workability of concrete increases with increase in percentage of OSA.
4. The compressive strength of OSA concrete decreased as percentage of OSA is increased. At 10% replacement of cement with OSA, compressive strength of 28N/mm^2 was achieved after 28 days and this surpasses the minimum compressive strength of 25N/mm^2 recognized by [19] for reinforced concrete design.
5. The results show that the flexural Strength of the concrete increases with curing age and decreases with increase in percentage replacement of cement with OSA.
6. The split tensile strength of the concrete increases with curing age and decreases with increase in percentage replacement of cement with OSA.
7. Water absorption decreased with an increase in the percentage replacement of cement with Olive Seed Ash showing that partial replacement of cement with olive seed ash in concrete had higher durability potentials.

5.0 RECOMMENDATION

Based on the findings of this study, it is recommended that cement should be partially replaced with at least 10% OSA in concrete.

REFERENCES

[1] Balakrishna, M. N. and Nataraja, M. C. “Proportioning of Fly Ash Concrete Mixes: A Comprehensive Approach”. International Journal of Emerging Science and Engineering, Vol. 1 (issue 8), 2013; 46-51.

[2] Olutoge, F. A, Quadri, H. A. and Oladipupo, S. O. "Investigation of the Strength Properties of Palm Kernel Shell Ash Concrete". Engineering, Technology & Applied Science Research, 2012; 2(6), 315-319.

[3] Yang, S. "To improve today's concrete, do as the Romans did". Retrieved from www.news.berkeley.edu/2013/06/04/roman-concrete/ 2013; 1-8.

[4] Villar, E., Morales, E., Santos S., Savastano, H., Frias, M. and Junior, H. S. "Pozzalanic behavior of bamboo leafash: Characterization and determination of the Kinetic Parameters". Cement concrete compos 2011; 33,68-73.

[5] Alsubari, B., Shafigh, P., Ibrahim, Z., Aalnahhal, M. F., and Jumaat, M. Z. "Properties of eco-friendly self-compacting concrete containing modified treated palm oil fuel ash". Constr. Build.Mater. 2018; 158: 742-754.

[6] Mujedu, K. A. and Adebara, S. A. "The use of groundnut shell ash as a partial replacement For cement in concrete production". International Journal of Sciences, Engineering and Environmental Technology, 2016; 1(3), 32-39.

[7] Ahmed, E. "Properties of Concrete Incorporating Recycled Post-Consumer Environmental Wastes". International Journal of Concrete Structures and Materials volume, 2014; 8, 251–258.

[8] American Society for Testing and Materials, ASTM C595/C595M. "Specification for Blended Hydraulic Cements", USA: ASTM International, 2016.

[9] British Standard Institution. BS EN 12620. "Aggregates for concrete", 2002.

[10] British Standards Institution, BS EN 196-3. "Methods of Testing Cement: Determination of Setting Times and Soundness". London, England, 2016.

[11] British Standards Institution, BS EN 12350-2. "Testing Fresh Concrete. Slump Test". 2019; 1-26.

[12] British Standards Institution, BS EN 12390-3. "Testing Hardened Concrete. Compressive strength of test specimens". 2019; 1-24.

[13] British Standards Institution, BS EN 12390-5. "Testing Hardened Concrete. Flexural Strength of Test Specimens". 2019; 1-14.

[14] British Standards Institution, BS EN 12350-6. "Testing Fresh Concrete. Tensile Splitting Strength of Test Specimens". 2019; 1-12.

[15] American Society for Testing and Materials, C1585. "Standard Test Method for Measurement of Rate of Water Absorption in Hydraulic Cement Concrete". ASTM International, 2016.

[16] Ketkukah, T. S., Onyechokwa, E and Bot, P. J. "Comparison of Engineering Properties of Mortar using Agricultural Wastes as Pozolanas". Yankari National, 2009; 5. 121-126.

[17] American Society of Testing and Materials. ASTM C618-19. "Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete", 2019: 1-5.

[18] American Society for Testing and Materials ASTM C595/C595M. "Standard Specification for Blended Hydraulic Cement", STM International, 2016.

[19] British Standards Institution, Eurocode 2. EN 1992-1-1. "Design of Reinforced Concrete structures, part 1-1, General Rules and Rules foe Buildings". CEN, Brussels, 2004.

[20] Ozacak, M. and Sisman, C. B. "Usability of Hazelnut shell ash as pozzolana in concrete". Fresenius Environmental Bulletn, 2020; 29(12), 10366-10375.

[21] Supe, J. D and Gupta, M. K. "Flexural Strength - A measure to control quality of rigid concrete pavements". International Journal of Scientific & Engineering Research, 2014; 5(11). 46-57.

[22] American Concrete Pavement Association (ACPA). "Concrete Pavement Field Reference Pre-paving". Skokie; Illinois, 2008; www. pavement .com.

[23] Buari T. A, Ademola, S. A, and Ayegbokiki S. T. "Characteristics Strength of groundnut shell ash (GSA) and Ordinary Portland cement (OPC) blended Concrete in Nigeria". IOSR Journal of Engineering, 2013; 3(7), 1-10.