Evaluation of the Effect of Volcanic Ash on the Properties of Concrete

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Abstract
Effect of volcanic ash on the properties of concrete was assessed in the study. Preliminary tests were carried out on the different properties of materials used. The concrete samples were prepared using 0%, 5%, 10%, and 15% volcanic ash replacements and nominal mix of 1:2:4 with a 0.5 w/c ratio. Concrete sample specimen was subjected to workability test. Thereafter, Cube mould of size 100mm x 100mm x100mm and cylinder mould of size 200mm x 100mm were used to cast a total of 405 concrete samples, 162 cubes were used to assess compressive strength test while 162 cylinders were used to determine the tensile strength by the split tensile method. The specimens were cured and tested at 7, 14, 21, 28, 56 and 90 days. The results show setting time and soundness test of Miango volcanic ash satisfied the necessary requirements. Also, increase in compressive strength and split tensile strength of about 7.99% and 6.14% respectively, for concrete samples with 10% volcanic ash replacements after 28days of curing. It was concluded that Miango volcanic ash retards the setting time of concrete and enhances the properties of concrete. Hence it was recommended that it should be used to produce a strong and dense concrete and serve as an admixture.

Keywords: *Concrete, compressive strength, volcanic ash, partial replacement, workability.*

Introduction

Concrete is a mixture of Portland cement or any other hydraulic cement, fine aggregate, coarse aggregate, and water, with or without admixtures. It is the most widely used construction material and it is second only to water as the most utilized substance all over the world (Dahiru 2013).According to Shoubi, Barough and Amirsolemani, (2013) it was estimated that the concrete industry produces annually about 12 billion tons of concrete and uses about 1.6 billion tons of Portland Cement (PC) throughout the world. Thus on average, approximately 1 ton of concrete is produced each year for every human being in the world.

While the United Nation Centre for Settlement survey (2016), observed that roughly 25 billion tonnes of concrete are manufactured globally each year, thus amounting to over 1.7 billion truck loads each year, or about 6.4million truck loads a day, or over 3.8 tonnes per person in the world each year. Harley (2007) noted that the amount of concrete used in construction industries around the world is more than double that of the total of all other building materials, including wood, steel, plastic and aluminum. It has become most widely used due to the availability of its constituents, flexibility, strength, durability, impermeability etc. (Duggal, 2008 and Neville 2012). As a composite material it is commonly used in the construction of buildings and infrastructures.

The extensive use of concrete has led to the ever increasing demand and hence excessive consumption of the individual ingredients used in concrete production. According to Muhammad (2010) cement is one of the essential ingredients of concrete. However, cement as an important constituent of concrete is rare and expensive compared to other ingredients of concrete. The mining of its raw materials leads to depletion of natural resources and degradation of environment. Its production pollutes the environment due to the emission of CO_2. The emission of CO_2 is such that for every ton of cement produced almost a ton of CO_2 is emitted (Dahiru, 2010).

In view of this and other problems associated with production and use of cement, a lot of research efforts were made to find an alternative material that will partially or fully replace cement in concrete production. Dadu (2011) asserted that there is global move currently to reduce the amount of Portland cement contents used in the concrete mixtures with cheaper Supplementary Cementitious Material

(SCM)/pozzolans to improve certain durability properties of concrete. As part of such efforts, numerous researches were carried out on various materials – most especially agricultural waste such as groundnut shell ash, rice husk ash, bagasse ash, millet ash, corncob ash and wood waste ash have being tested as pozzolana or supplementary cementitious material. Some of such efforts include: Udoeyo, Inyang, Young and Oparadu, (2006). Dahiru and Zubairu (2008), Badarul, Ramadhansyah and Hamidu (2009); Ramezanianpour, Mahdi and Ahmadibeni (2009); Alireza, (2010) Samson, (2010); Harunur, Rashid, Keramat and Tarif (2010); Manasseh, (2010); Ibrahim, (2011); Job & Adole (2011); Nwofor & Sule. (2012) Kartini, Rashid, Keramat and Tarif (2012), Abalaka, (2012) and Karm, Zain, Jamil, Lai and Islam (2012)

In view of the fact that current effort towards attainment of sustainability emphasizes changing the pattern of consumption from linear fashion to circular mode, research effort has extended to other wastes. According to Atkinson and Butlin (1993) waste in the construction industry and the use of rejected materials is the subject of worldwide research. For example Dahiru (2007) investigated the use of carbide waste as partial replacement of waste. Musa (2015) has undertaken a study on the impact of cereal flours on properties of Ordinary Portland cement concrete.

While Yusha'u (2017) has undertaken a comparative study of strength and durability properties of Kaolin and Metakaolin cement concrete. Besides that, there are on different materials as partial or full replacement of cement – for example, there are various studies on the use agro waste as partial replacement of cement (Manasseh, 2010). Besides that, corn cob ash was also examined as partial replacement of cement by Zubairu, Dahiru and Sheikh – Abdullahi, (2010). While Job and Adole (2011) have undertaken a study on the use of millet ash as partial replacement of cement, study on the use of groundnut shell ash as partial replacement of cement by Nwofor and Sule (2012); research by Raheem, Olasunkanmi, and Folorunso (2012) on the use of saw dust as partial replacement of cement. Results of most these studies show encouraging outcome that many of them can be used as partial replacement of cement in concrete production.

One of such materials that have received researchers' attention is Portland volcanic ash. Dadu (2011); Olawuyi, Olusola and

Babafemi (2012) carried out a research on Jos Plateau volcanic ash where the results showed that the volcanic ash possessed pozzolanic characteristics of natural pozzolans and recommend that it can be used to partially replaced cement in concrete..

Volcanic ash, being one of the classifications of natural pozzolans, is environmentally friendly, economical and accessible than artificial pozzolan. According to Ogunbode & Hassan (2011) volcanic ash are formed as a result of volcanic eruption which can be found in volcanic areas around the world e.g. Japan, USA, Iranian plateau, Adamawa Highlands extending to Cameroonian Highlands, some Local Government Areas in Jos, Plateau State, Mkomon District of Kwande Local Government Area of Benue State etc.

However one problem associated with most of the studies on SCM especially Portland volcanic ash, is the failure of most researchers to undertake an in – depth study of the numerous properties of concrete – most especially durability properties, and to consider the fact that change in space has influence on such materials. As such, there is the need to carry out an in-depth study of such material for a particular area. This is report on a detailed study on Miango JP Portland volcanic ash as a partial replacement of cement in concrete. Result of a study carried out by Dadu (2011) was used as a base for further investigation.

Materials and Methods

Preamble

The experimental study was achieved following these major steps:

1. Determination of the properties of individual constituents of Portland cement volcanic ash concrete.
2. Assessment of the property of Portland cement volcanic ash concrete at fresh stage.
3. Evaluation of the mechanical properties of Portland cement volcanic ash concrete.
4. Establishment of the suitability of Portland cement volcanic ash as partial replacement of cement in concrete production.

In view of the fact that the research involves laboratory investigations, details of the materials and methods used in the study are presented as follows:

Materials

The materials used for this research work were; Jos Plateau volcanic ash, Dangote

Portland cement, sharp river sand, crushed granite stone and curing media. Each of the materials used for this research were obtained from a single source; this has helped to limit the likely discrepancies that might occur in the characteristics of the materials. Materials preparation and testing of concrete samples were done in adherence to appropriate B.S. standard. The chemical composition tests of the Jos Plateau volcanic ash were conducted at National Geological Survey Agency, Barnawa Kaduna. The Milling of Jos Plateau volcanic ash was carried out in the Department of Chemical Engineering ABU Zaria, while all other experimental works were conducted in the concrete laboratory of the Department of Building ABU Zaria. Details of the materials are as follows:

Jos Plateau Volcanic Ash

The Jos Plateau volcanic ash used in this research was obtained from Miango Twin Conical Hills (JP 3) in Bassa Local Government Area in Plateau State. They were obtained in October 2015. The materials were first ground using metal mortar and pestle to fine particles. They were then taken to Chemical Engineering Department, A.B.U. Zaria, for milling using electronic balls milling machine and sieved through 75µm sieve aperture. Plate I shows volcanic ash sieved to 75µm.

Plate I: Volcanic ash sieved to 75µm

Cement: Blended Limestone Cement brand obtained from Sabon Gari Market of Sabon Gari Local Government Area was used for this research. Tests were undertaken so as to ensure that it complies with the British standards BS 12 (1996).

Fine aggregates: The fine aggregates used in this research was clean and saturated surface dried sharp river sand obtained from Samaru, Zaria. It was sieved through 5mm sieve to take away any impurities and larger size aggregates in accordance to BS EN 933-1 (1997).

Coarse aggregates: Totally crushed granite stone that conformed to BS EN 933-5 (1998) was used for this research and it was obtained from quarrying area along Zaria – Sokoto road. It was also sieved passing through 20mm sieve and retained on 10mm sieve.

Concrete Mix Details

Optimum water cement ratio (w/c) was determined by producing four different types of concrete samples with different w/c; 0.40, 0.45, 0.50 and 0.55. The test shows that 0.50 w/c is the most suitable and was used for the research. Another four different types of replacement of Portland cement volcanic ash concrete were produced; 5%, 10%, 15% and 20% with 0% as control to determine the most appropriate replacement. The results show that 5% and 10% volcanic ash replacement is the best and were used for the research. Batching and mixing of fresh concrete was conducted using 1:2:4 nominal mix ratios were in accordance to BS 1881-125 (1986) and dry room temperature was recorded.

Table1: Mix details for cube samples

Percentage Replacement (%)	Mass of materials/cube (kg)				
	Volcanic ash	Cement	Sand	Crushed granite	Water
0%	0.00	0.39	0.84	1.61	0.20
5%	0.02	0.37	0.84	1.61	0.20
10%	0.04	0.35	0.84	1.61	0.20

Table2: Mix details for cylinder samples

Percentage Replacement (%)	Mass of materials/cylinder (kg)				
	Volcanic ash	Cement	Sand	Crushed granite	Water
0%	0.00	0.61	1.31	2.52	0.31
5%	0.03	0.58	1.31	2.52	0.31
10%	0.06	0.55	1.31	2.52	0.31

Mixing and Curing Water

Clean tap water fit for drinking supplied from ABU water board was used for the production and curing of concrete samples for this research. The water conforms to BS EN 1008-2 (2002).

Preliminary Tests of Materials

The preliminary tests of materials that were carried out are, as follows: determination of chemical composition of Jos Plateau volcanic ash using EDXRF method, specific gravity and bulk density test for Jos Plateau volcanic ash, OPC, sharp sand and crushed granite stone. Also sieve analysis, and moisture content for sharp sand and crushed granite stones, setting time and soundness test for Jos Plateau volcanic ash and OPC were carried out.

Chemical composition of materials

The chemical composition test of Jos Plateau volcanic ash was carried out at National Geological Survey Agency

Barnawa Kaduna using EDXRF method. The machine used to carry out this test was Minipal 4 Energy Dispersive X-Ray Fluorescence. The primary filter used was kapton, x-ray current was 14kv, air as the current gas medium, and the time used to measure the sample was 100seconds. Fresh portion of the Jos Plateau volcanic ash was crushed and ground to pass through 100 micro mesh sieve. 10g of the powdered sample (Miango JP 3) was weighed into a given sample cup and was carefully placed on the sample charger of the x-ray fluorescence machine. The major oxides and Lost on Ignition (LoI) were measured and recorded.

Bulk density of materials

Bulk density of aggregates was determined in accordance to BS 812-2 (1995). The apparatus used were density wooden cube, trowel, rammer and weighing balance. The bulk density for aggregate sample was computed using the equation:

$$D = \frac{m}{v} \text{ ------------------------------ (2)}$$

Where

D = Density of the aggregate specimen in kg/m^3

m = Mass of the aggregate specimen in kg

v = Volume of the aggregate specimen in m^3

Also mass of the aggregates sample was determined by subtracting the weight of empty container from the weight of container plus aggregate sample as:

$$m = B - A \text{ -------------------------- (3)}$$

Where

m = Mass of the aggregate specimen in kg

A = Weight of the empty container in kg

B = Weight of container plus aggregate sample in kg

Specific gravity of materials

Specific gravity of the fine and coarse aggregates were determined using pyknometre method, the procedure used where in accordance with BS 812-2 (1995). The apparatus used during the test include density bottle and stopper, funnel, spatula and weighing balance.

The specific gravity of aggregates was calculated using the following formula:

$$G_s = \frac{C - A}{(B - A) - (D - C)} \text{ ------------------- (4)}$$

Where:

A = Weight of empty density bottle and it is stopper which it was clean and dried

B = Weight of empty density bottle plus water

C = Weight of empty density bottle plus aggregate sample

D = Weight of empty density bottle plus water plus aggregate sample

Sieve analysis of materials

In accordance to BS EN 933-1 (1995) 6kg of coarse aggregates was weighed and then poured on different sizes of sieves passing through 20mm, 13.2mm, and 9.50mm. Weight of aggregates retained and passing on each sieve was taken down and percentage passing was calculated. Also the same procedure was used for fine aggregates of 6kg passing through sieve sizes 4.75mm, 2.36mm, 1.18mm, 600μm, 300μm, 150μm and pan. Fineness modulus of fine and coarse aggregates were determined as sum of cumulative percentage of aggregates retained on each of a series of sieves (each sieve having a clear opening that is half of the preceding one) and the total divided by 100.

Moisture content of materials

One (1) kg of coarse aggregates was weighed as (A) using weighing balance, the material was then poured on wide metal container, spread and put inside an electric oven for 24hours at 105^0C. After 24hours the aggregates was removed from the oven and allowed to cool down at room temperature, and then the aggregates was weighed again as (B). The same procedures was applied for 0.5kg of fine aggregates and finally the moisture content were determined in accordance to BS 812-109 (1990) using the equation:

$$\text{Moisture content} = \frac{A - B}{B} \times 100\% \text{ ------------------- (5)}$$

Setting time and soundness of materials

As described in BS EN 196-3 (1995) setting time and soundness test were conducted in which consistency, initial setting time and final setting time were carried out using Vicat apparatus plunge, needle and le chartelier apparatus. Three different mix; 0%, 5% and 10% replacement of Portland cement volcanic ash paste was prepared for both setting time and soundness.

Consistency

Consistency was determined using the formula:

$$\text{Consistency} = \frac{\text{Water consumed}}{\text{Weight of cement sample}} \times 100\% \text{ ----- (6)}$$

Testing of Fresh Portland Cement Volcanic Ash Concrete

Fresh property of Portland cement volcanic ash concrete was assessed to test its level of fluidity and mobility using slump test method as;

Slump test

Slump test method was used to test the workability of the fresh Portland cement volcanic ash concrete as provided in BS 1881-102 (1983). The apparatus used to carrying out this test consist of mould, scoop, sampling tray, trowel, tamping rod, and rule. The slump test is shown in Plate II.

Plate II: Slump test method

Testing of hardened concrete samples

The concrete samples produced were cured. The concrete specimens were tested after 7, 14, 21, 28, 56, and 90 days.

Density test

The concrete specimens were removed from the curing container and placed outside to surface dried, then weighed using weighing balance to determine the mass of the samples in accordance to BS EN 12390-7 (2000).The density of concrete specimens was calculated, using the formula:

$$D = \frac{m}{v} \quad \text{--------------------------(7)}$$

Where:

D = Density of the concrete specimen in kg/m^3

m = Mass of the concrete specimen in kg

V = Volume of the concrete specimen in m^3

Compressive strength test

The concrete samples (cubes) were removed from the curing basin and placed outside to surface dried, weighed and positioned at the centre of hydraulic manual compression machine for crushing. Packing was not used in this type of testing and the force was applied at the specimen by swinging the handle of the crushing machine till it failed. The force exerted on the specimen was recorded and compressive strength was computed in conformity with BS EN 12390-3 (2002) using the equation:

$$f = \frac{F}{A} \quad \text{----------------------------(8)}$$

Where:

f = Compressive strength, in KN/m^2

F = Maximum load at failure, in KN

A= Cross-sectional area of the specimen on which the compressive force acts calculated.

Split tensile test

The concrete samples (cylinders) were removed from the curing vessel and placed outside to surface dried, weighed and positioned at the centre of hydraulic manual compression machine for splitting. In this type of testing two strips packing were applied at the bottom and top of the cylinder and the force was applied at the specimen by swinging the handle of the crushing machine till it failed. The force exerted on the specimen was recorded and split tensile strength was computed in conformity with BS EN 12390-6 (2000) using the equation:

$$f_{ct} = \frac{2 X F}{\pi X L X d} \text{ --------------------(9)}$$

Where :

f_{ct} '= Tensile splitting strength, in KN/m^2

F = Maximum load, in KN

L = Length of the line of contact of the specimen, in m

d = Designated cross-sectional dimension, in m.

Method of Data Analysis

The results obtained for different tests carried out in this research work were analysed using simple statistical tools (mean and percentage). According to Tavakoli (2012) mean also called arithmetic mean, represented by M, X is the most commonly used measure of central tendency which is the sum of scores divided by the total number of scores, often represented by the following formula:

$$X = \frac{\sum X}{N} \text{ ------------------------(11)}$$

Where:

X (read as *X*-bar) is the symbol for the mean

A percent or percentage is a proportion multiplied by hundred. It is used in this research to anlysed the results of abrasion resistance test and water absorption.

Results and discussions

Presentation of Results of Preliminary Test

The results for preliminary tests that were conducted for this research work were; chemical composition of Miango (JP 3) Jos Plateau volcanic ash, trial test of water cementitious materials ratio (w/c) and Portland cement volcanic ash replacement.

Others were; specific gravity and bulk density, moisture content, sieve analysis of the aggregates, setting time and soundness test and also the slump test of fresh concrete.

Table 3: Oxides composition of Miango (JP 3) Volcanic Ash

Elements	% Composition
Aluminum Oxide (Al_2O_3)	18.00
Silicon Oxide (SiO_2)	28.10
Iron Oxide (Fe_2O_3)	35.11
Potassium Oxide (K_2O)	0.26
Calcium Oxide (CaO)	0.29
Titanium Oxide(TiO_2)	1.76
Vanadium Oxide (V_2O_5)	0.21
Chromium Oxide (Cr_2O_3)	0.051
Manganese Oxide (MnO)	0.03
Magnesium Oxide (MgO)	0.26
Nickel Oxide (NiO)	0.03
Sodium Oxide (Na_2O)	0.02
Sulphur trioxide (SO_3)	-
Loss On Ignition (LOI)	15.87
ASTM C681-05 Limits Al_2O_3 + SiO_2+ Fe_2O_3 =70.0% minimum 18.00 +28.00 +35.11 = 81.11 – This over and above the minimum (70%), hence it has satisfied ASTM C681-05 requirement.	

Table 3 presents the chemical composition of Miango (JP 3) volcanic ash and has a sum of 81.21% of Aluminum Oxide (Al_2O_3), Silicon Oxide (SiO_2) and Iron Oxide (Fe_2O_3). It satisfied the requirement of ASTM C618-05 which stated that for a material to be a pozzolan the summation of Aluminum Oxide (Al_2O_3), Silicon Oxide (SiO_2) and Iron Oxide (Fe_2O_3) must be 70.0 % minimum. The Loss on Ignition (LoI) and presence of sulphur trioxide (SO_3) of the material not complied with the standard.

Table 4: Density and Compressive strength of Portland volcanic ash concrete

Replacement	Density (kg/m^3)	Average Compressive Strength (N/mm^2)
0%	2310	15.00
5%	2290	15.25
10%	2290	15.75
15%	2320	13.50
20%	2320	12.50

The Table 4 presents the results of density and compressive strength tests. The compressive strength tested after seven days shows that 5% and 10% are higher than 0%, 15% and 20% which agrees with the result of similar study by Dadu, (2011). Therefore 5% and 10% replacement were used to further investigate the various properties of concrete containing Portland volcanic ash as partial replacement.

Table 5: Trial Test of Water Cementitious Materials Ratio (w/c)

w/c	Density (kg/m^3)	Average Compressive Strength (N/mm^2)
0.40	1980	1.90
0.45	1860	7.80
0.50	1960	13.80
0.55	1960	8.00

The Table 5 shows the trial test of water cementitious material ratio (w/c) for the research work. It presents that 0.50 w/c was the best with average compressive strength of 13.80N/mm^2 at seven days with high compressive strength than the other w/c and hence it was used for the research.

Table 6: Physical properties: Specific Gravity and Bulk Density of Materials

No	Materials	Specific Gravity (kg)	Bulk Density (kg/m^3)
1.	Granite	2.83	1363
2.	Sand	2.78	1385
3.	Portland cement	3.43	1278
4.	Volcanic ash	2.33	1310

The Table 6 presents specific gravity and bulk density of materials used for the research. The test carried out has satisfied the requirements of ACI E1-99 which specified the range for normal weight aggregates between 2.30 to 2.90kg for specific gravity and 1280 to 1920 kg/m^3 for bulk density.

Table 7: Physical properties of Portland Cement Volcanic Ash Paste

Properties	Replacement Levels		
	0%	5%	10%
Soundness	2mm	0	0
Setting time			
Initial	169mins	196mins	200mins
Final	260mins	293mins	307mins
Consistency	33%	33.3%	33.5%

The Table 7 shows soundness and setting time of Portland cement volcanic ash paste. The setting time for Portland cement volcanic ash paste conformed to Garba (2008) assertion which stated that the initial setting time of cement should not be less than 45 minutes and final setting time of cement should not be more than 10 hours. The soundness test of Portland cement volcanic ash concrete has satisfied the requirement of BS EN 197-1 (2000) which specified that it should be $\leq$ 10mm otherwise the cement is unsound.

Table 8: Physical properties: Moisture Content of the Research Materials

No	Materials	Weight of material before oven dry (kg)	Weight of material after oven dry (kg)	Percentage (%)
1.	Granite	1.000	0.995	0.50
2.	Sand	1.000	0.948	5.49
3.	Portland cement	0.500	0.499	0.20
4.	Volcanic ash	0.500	0.473	5.71

The Table 8 presents results of moisture content test for the research materials. According to ACI E1-99 moisture content for coarse aggregates should be within 0 to 2% and for fine aggregates should be within 0 to 10% which denote that the test on the aggregates has being satisfied.

Table 9: Sieve Analysis of Fine Aggregates

BS Sieve Size	Weight Retained (kg)	Weight Passing (kg)	Percentage Passing (%)
4.75mm	0.36	5.64	94
2.36mm	0.54	5.10	85
1.18mm	3.28	1.82	30
600µm	1.40	0.42	7
300µm	0.12	0.30	5
150µm	0.00	0.00	0
Pan	0.00	0.00	0

The Table 9 shows results of sieve analysis of fine aggregates which has been used to determine the fineness modulus and calculated as 2.92. This is within the allowable range of 2.0 – 3.5 (± 0.2) hence it has satisfied the requirement (Garba 2008).

Table 10: Sieve Analysis of Coarse Aggregates

BS Sieve Size	Weight Retained (kg)	Weight Passing (kg)	Percentage Passing (%)
19.00mm	0.32	5.68	95
13.20mm	1.94	3.74	62
9.50mm	1.50	2.24	37
4.75mm	1.88	0.36	6
2.36mm	0.24	0.12	2
1.18mm	0.04	0.08	1.3
600µm	0.02	0.06	1
300µm	0.007	0.053	0.88
150µm	0.000	0.053	0.88
Pan	0.000	0.053	0.88

The Table 10 presents results of sieve analysis of coarse aggregates which has been used to determine the fineness modulus calculated as 6.01. Garba (2008) stated that fineness modulus of coarse aggregates should fell within the range of 5.5–8.0 (± 0.2) and therefore the coarse aggregates used for this research was in conformity with this assertion.

Table: 11: Slump Test of Portland Cement Volcanic Ash Concrete Samples

Concrete sample	Slump (mm)	Room temperature (^{0}C)
0%	10	25.5
5%	15	25.5
10%	23	25.5

The Table 11 shows slump test of Portland cement volcanic ash concrete samples at 25.5^{0}C room temperature. From the values of the three mixes, the degree of workability of this Portland cement volcanic ash concrete was very low fell within 0-25mm. Mixes with 5% and 10% volcanic ash replacement were more workable than mix with 0% replacement (control).

Presentation of Results of Tests on Hardened Concrete

Density of Hardened Concrete Samples

Table 12: Average Density of Concrete Samples Cured in H_2O

Replacements	7 days	14 days	21 days	28 days	56 days	90 days
0%	2360	2480	2540	2527	2500	2507
5%	2420	2447	2373	2593	2533	2513
10%	2660	2447	2420	2447	2587	2527

The Table 12 presents the average density of Portland cement volcanic ash concrete samples cured in normal water (H_2O) and weighed at 7, 14, 21, 28, 56 and 90 curing days. The density of concrete cube samples varies from 2360 kg/m^3 to 2660 kg/m^3 and it increase with increase in curing periods. Concrete samples with density higher than 2600kg/m^3 are called as higher density concrete samples (Kazjonovs, Bajare and Korjakins, 2010). Therefore, Portland cement volcanic ash concrete is a concrete with ordinary density, though samples with pozzolanic material replacements were denser than the control samples.

Compressive Strength Test of Hardened Concrete Samples

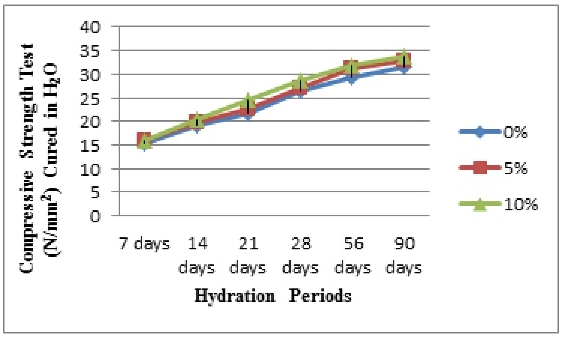

Figure 1: Compressive Strength of OPC and OPC/VA Concrete Specimens Cured in H_2O

The Figure 1 shows compressive strength of Portland cement volcanic ash concrete specimens cured in normal water (H_2O) and crushed at 7, 14, 21, 28, 56 and 90 hydration periods. Concrete samples with 5% and 10% replacement of Portland cement volcanic ash achieved 27.1 N/mm^2 and 28.8 N/mm^2 while 0% replacement achieved 26.5 N/mm^2 at 28 days which represents 7.99% increase in compressive strength. The compressive strength achieved for both control and volcanic ash replacement were below the BS EN 197-01 (2000) requirement which stated that concrete sample should achieved 32.5 N/mm^2 at 28 days. This could be due to the method of compaction applied (manual compaction) during the research. However, the standard requires the use of mechanical compaction to achieve this result.

Split tensile strength test of hardened concrete samples

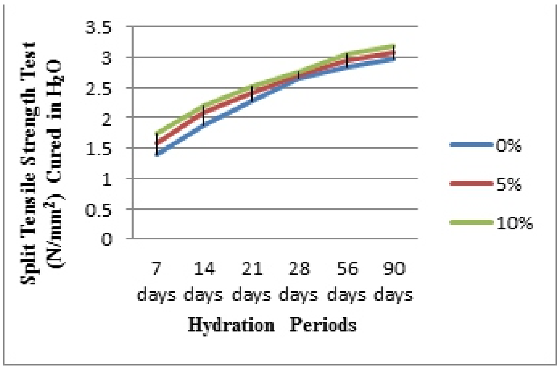

Figure 2: Split Tensile Strength of OPC and OPC/VA Concrete Specimens

Figure 2 shows split tensile strength of Portland cement volcanic ash concrete specimens cured in normal water (H_2O) crushed at 7, 14, 21, 28, 56 and 90 curing days. From the results it shows that 0% replacement was the lowest against 5% and 10% replacement attaining 2.64 N/mm^2 against 2.70 N/mm^2 and 2.77 N/mm^2. This means that 5% and 10% replacement has higher tensile strength than 0% replacement with about 4.69% increase. The split tensile strength of concrete specimen should be 1/12 to 1/13 of compressive strength as observed by Neville (2011). Both the results of control concrete samples and volcanic ash replacement concrete samples have conformed to this requirement

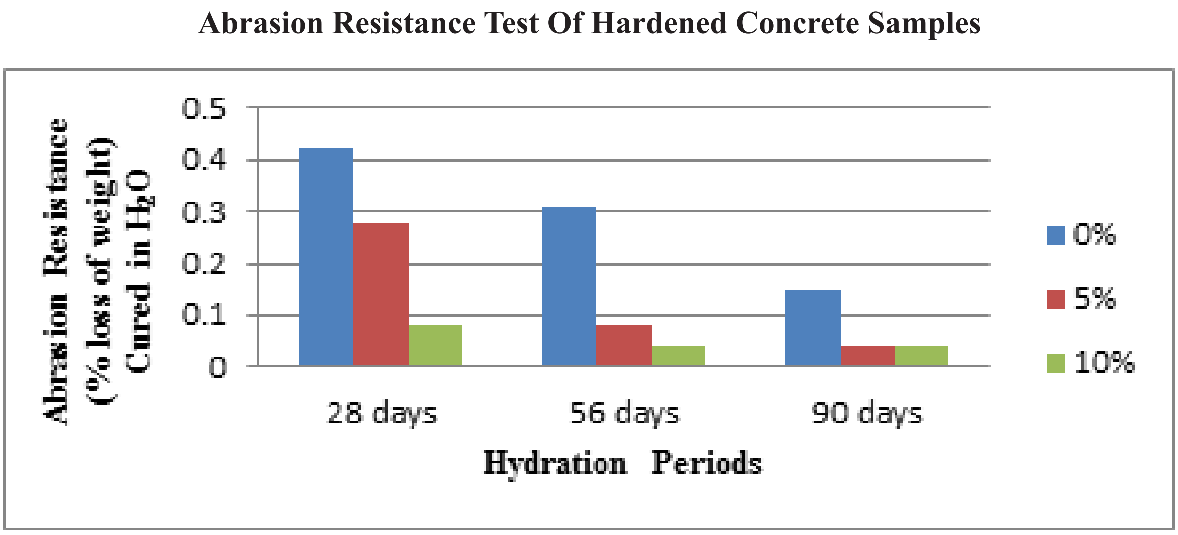

Figure 7: Abrasion resistance tests of OPC and OPC/VA concrete specimens cured in H_2O

Figure 7 presents the abrasion resistance of Portland cement volcanic ash concrete specimens cured in normal (H_2O) and tested at 28, 56 and 90 hydration periods. There was loss of weight of the concrete samples where 0% replacement has high loss of weight as 0.15% than 5% and 10% replacement which both have 0.04% respectively at 90 days. Thus 5% and10% replacements resist abrasion impact than 0% replacement.

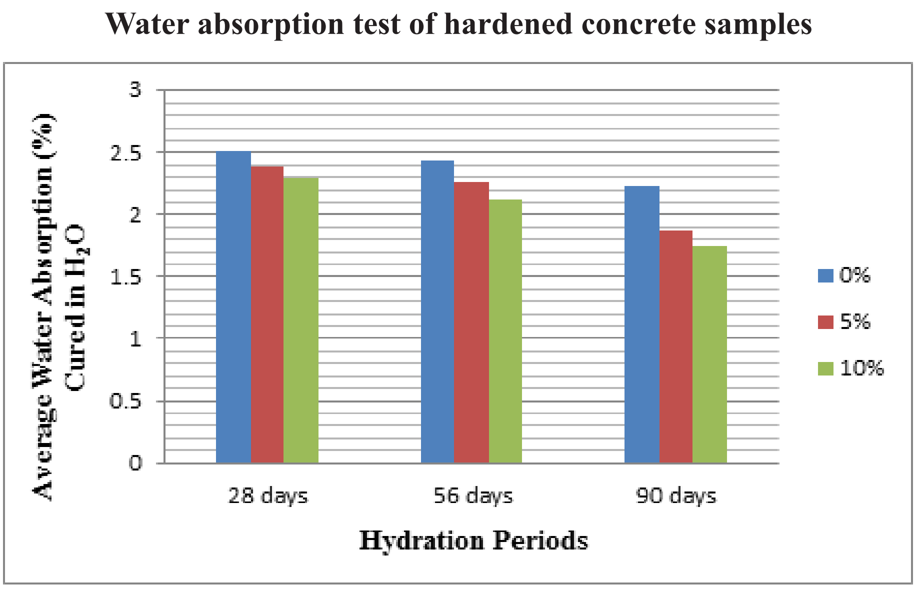

Figure 10: Water absorption tests of OPC and OPC/VA Concrete Specimens Cured in H_2O

Figure 10 shows water absorption test of Portland cement volcanic ash concrete specimens cured and tested at 28, 56 and 90 curing days. The degree of sorption of Portland cement volcanic ash concrete in the three curing media has satisfied the assertion made by Pitroda and Shah (2014) which stated that the average absorption of the concrete test specimens shall not be greater than 5%.The level of sorptivity of concrete samples reduced with increase in curing days where 0% replacement absorbed more curing agent than 5% and 10% replacement. Concrete samples with 0% replacement absorbed 2.23% while 5% and 10% replacement absorbed 1.87% and 1.75% at 90 days. This means that 5% and 10% replacement absorbed less amount of curing agent than 0% replacement.

Conclusions and Recommendations

Conclusions

1. Based on the results of the research the following conclusions were drawn:
   The EDXRF chemical analysis of miango (JP 3) shows that it has satisfied the ASTM C618-05 requirement as a pozzolanic material.
2. The physical properties such as bulk density, specific gravity and moisture content of volcanic ash were found to be in conformity with ACI E1-99. Setting time and soundness test of Portland cement volcanic ash satisfied the BS EN 197-1 (2000) requirements.
3. Concrete samples with volcanic ash replacements have higher strength both in normal and chemical environments than control concrete samples.
4. Concrete samples made with pozzolanic material have high resistance to abrasion and less sorptivity in normal.

Recommendations

From the results of this research, the following recommendations were made:

1. The research recommends the use of Miango (JP 3) as a volcanic ash to replace OPC in concrete production for economy and environmental protection.
2. The use of 10% Miango (JP 3) is the optimum OPC/VA replacement level that can be used to produce durable concrete for construction purposes in both normal and chemical environment.
3. Use of Miango (JP 3) volcanic ash as an admixture to retard initial and final setting time of OPC/VA concrete is recommended.

Recommendations for further research

1. It is recommended that testing of Portland cement volcanic ash concrete produced with 5% and 10% replacement be

extended to 180, 360 or possibly 720 days to further determine the pozzolanic ability of the concrete both in normal and chemical environment.

2. It is recommended that the concentration of the chemical curing media for Portland cement volcanic ash concrete samples be increase to more than 2.0% and tested up to 90 curing days to further assess the severity of the deterioration on the concrete samples.
3. Durability properties are many and varied; therefore further research should be carried out to assess the suitability of this material on fire resistance, shrinkage etc.
4. Detailed cost analysis should be carried out to determine the level of savings possible from the use of JP 3 volcanic ash in concrete.

References

Abalaka, A. E., (2007). Effects of Sulphuric Acid on Compressive Strength of Concrete Produce with Ordinary Portland Cement. *Nigerian Journal of Construction Technology and Management, 8(1)*, 14-19.

AbdulWasiu, I. (2015) characteristics of ternery concrete produced with rice husk ash and wood waste ash as partial replacement of cement. An *Unpublished M.Sc. Thesis.* Department of Building, Ahmadu Bello University Zaria, Nigeria.

American Concrete Institute (1999). Aggregates for Concrete. ACI Committee 201 2R-01, *American Concrete Institute,* Farmington Hills, Michigan, USA, 1-41.

American Concrete Institute (2001). Guide to Durable Concrete. ACI E1-99 Committee Report E-701, *American Concrete Institute,* Farmington Hills, Michigan, USA,1-26.

American Society for Testing and Material. (2005). Specification for Fly Ash and Raw or Calcined Natural Pozzolana or Use in as a Mineral Admixture in Portland cements Concrete. *American Society for Testing and Materi*al, West Conshohocken, No C618. USA.

Atkinson, C.J. and Butlin, R.N. (1993): *Ecolabelling of building Material and Building products*. BRE Information Paper IP 18/91 Building Research Establishment, U.K.

Badarul. H.A., Ramadhansyah, P. and Hamidu, A. (2009). Malaysian Rice Husk Ash Improving the Durability and Corrosion Resistant of Concrete: Pre-review. *Concrete Research Letters Vol (1) 2010*. Retrieved from www.ccl.issres.net

Bisschop, J. (Anonymous). *Concrete Durability II:* Concrete Corrosion, Sulphate Attack, Salt Sealing and Strength Reduction. (Unpublished Lecture Note). Swiss Federal Institute ofTechnology Zurich, Switzerland.

British Standard, (1983). Testing concrete; Method for determination of slump. *BS 1881-102,* BSI, Linfordwood, Milton Keynes MK14 6LE, U.K..British Standard, (1983).

Testing concrete; Method for determination of water absorption. *BS 1881-122,* BSI, Linfordwood, Milton Keynes MK14 6LE, U.K.

British Standard, (1986). Testing concrete; Methods for mixing and sampling fresh concrete in the laboratory. *BS 1881-125*, BSI, Linfordwood, Milton Keynes MK14 6LE, U.K.

British Standard, (1990). Testing aggregates; Methods of determination of moisture content. *BS 812-109*, BSI, Linfordwood, Milton Keynes MK14 6LE, U.K.

British Standard, (1995). Testing aggregates; Methods of determination of density. *BS 812-2*, BSI, Linfordwood, Milton Keynes MK14 6LE, U.K.

British Standard European Norm, (1995). Cement; Composition, specification and conformity criteria for common cements. *BS EN 197-1,* BSI, Linfordwood, Milton Keynes MK14 6LE, U.K.

British Standard European Norm, (1995). Methods of testing cement; Determination of setting time and soundness. *BS EN 196-3,* BSI, Linfordwood, Milton Keynes MK14 6LE, U.K.

British Standard European Norm, (1997). Tests for geometrical properties of aggregates; Determination of particle size distribution-Sieving method. *BS EN 933-1,* BSI, Linfordwood, Milton Keynes MK14 6LE, U.K.

British Standard European Norm, (1998). Tests for geometrical properties of aggregates; Determination of percentage of crushed and broken surfaces in coarse aggregate particles. *BS EN 933-5,* BSI, Linfordwood, Milton Keynes MK14 6LE, U.K.

British Standard European Norm, (2000). Testing hardened concrete; Shape, dimensions and other requirements for specimens and moulds. *BS EN 12390-1,* BSI, Linfordwood, Milton Keynes MK14 6LE, U.K.

British Standard European Norm, (2000). Testing hardened concrete; Tensile splitting strength of test specimens. *BS EN 12390-6,* BSI, Linfordwood, Milton Keynes MK14 6LE, U.K.

British Standard European Norm, (2000). Testing hardened concrete; Density of hardened concrete. *BS EN 12390-7,* BSI, Linfordwood, Milton Keynes MK14 6LE, U.K.

British Standard European Norm, (2002). Testing hardened concrete; Compressive strength of test. *BS EN 12390-3,* BSI, Linfordwood, Milton Keynes MK14 6LE, U.K.

British Standard European Norm, (2002). Mixing water for concrete; Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete. *BS EN 1008-2,* BSI, Linfordwood, Milton Keynes MK14 6LE, U.K.

Dahiru, D. (2007) "An investigation on Carbide Waste as Partial Replacement of Cement in Concrete" *Construction Focus – Journal of Construction Management and Engineering,* 1(2)

Department of Building, 1Ahmadu Bello University, Zaria – Nigeria. Pp. 1 - 8

Dadu, D. W. (2011). Investigation into Pozzolanic Characteristics of Jos Plateau Volcanic Deposits for Partial Replacement of Portland Cement in Concrete. *An Unpublished Ph. D Dissertation Work*. Department of Building Faculty of Environmental Design, Ahmadu Bello University Zaria, Nigeria.

Dahiru, D. (2010). Problem of Ready-Mix Concrete Production in the Construction Industry in Nigeria and its Cost Implication. *Paper presented in West Africa Built Environment Research (WABER) Conference 27-28 July, 2010,* Accra, Ghana, 445-457.

Dahiru, D. (2013). Assessment in Non-Destructive Testing of Concrete. *Unpublished Ph. D Dissertation Work*. Department of Civil Engineering, Faculty of Engineering, Ahmadu Bello University, Zaria, Nigeria.

Duggal, S. K. (2008). *Building Materials.* New Age International Publishers, New Delhi, India. 142-300.

Garba, M. M. (2008). Concrete Technology. *Unpublished Lecture Note* Department of Building Faculty of Environmental Design Ahmadu Bello University, Zaria, Nigeria.

Gambhir, M.L. (2006). *Concrete Technology.* Second Edition Tata McGraw Hill, New Delhi, India

Gambo, S. (2014). Assessment of Durability Properties of Ternary Cementitious Matrix Concrete Containing Rice Husk Ash and Saw Dust Ash as Partial Replacement of Cement. *Unpublished M.Sc Thesis Work,* Department of Building Faculty of Environmental Design, Ahmadu Bello University Zaria, Nigeria.

Gupta, B.I. and Gupta, A. (2008). *Concrete Technology.* Standard Publishers Distributors. New Delhi, India.

Harunu, R A. Md., Rashid B. Md., Keramat A. M. and Tarif U. A. (2010). Long Term Effect of Rice Husk Ash on Strength of Mortar. *World Academy of Science, Engineering and Technology,* 43: 542-545.

Harley, J. (2007). The Impact of Cement Kilns on the Environment. Briefing Paper South Africa, 1-12.

Ibrahim A. (2011).*Investigation into the Effect of Ammonia Solution on the Characteristics of Rice Husk Ash Blended Concrete* (Unpublished Undergraduate's Project). Ahmadu Bello University Zaria, Nigeria.

Job, O.F., Adole, M.A. (2011). Effect of Chemicals on the Properties of Millet Husk Ash Blended Cement concrete. In *Sourcing, Development And Utilization Of Appropriate Building Material For Sustainable Enviroment:41st Annual Conference of the Nigerain Institute of Building* (pp. 46-49).

Joergensen, S. W. (2014). *Grinding of Clinker Replacement Materials.* Special Report by General Manager Grinding Technology, 1-15.

Kazjonovs, J.,Bajare, D. and Korjakins, A. (2010). Designing of High Density Concrete by Using Steel Treatment Waste. *Paper Presented* on Modern

Building Materials Structure & Techniques. International Conference . May 19 – 21, Vilnius, Lithuania.

Kartini, K., Rashid B. Md., Keramat A. M. and Tarif A. G., (2012). Effects of Silica in Rice Husk Ash (RHA) in producing High Strength Concrete. *International Journal of. Engineering and Technology,* 2(12): 1951-1956

Karim, M.R., Zain, M.F., Jamil, M.l., Lai F.C., and Islam M.N. (2012) Strength of Mortar and Concrete as Influenced by Rice Husk Ash. *World Applied Sciences Journal*, 19 (10): 1-13.

Manasseh, J. (2010). A Review of Partial Replacement of Cement with Some Agro Wastes. *Nigerian Journal of Technology*, 29(2): 12-20. Mehta, K.P. and Monterio, P.J.M. (2006): C*oncrete: Microstructure, Properties and Materials.* McGraw Hill Ltd, California .U.S.A.

Mohammad, N.F., (2010). Performance of Concrete by Using Pulverized Fuel Ash (PFA) as Cement Replacement Material. *Unpublished B.Sc Research Work*. Department of Civil Engineering and Earth Resources, University of Malaysia Pahang.

Monteiro, P. J. M. (Anonymous). Durability.*(Unpublished Lecture Note*. Department of Civil Engineering University of California Berkeley USA.

Nagesh, M. (2012). Notes on Concrete Durability.*Unpublished Lecture Note*.Government Engineering College Ramanagara, India.

Neville, A.M. and Brooks, J.J., (2010). *Concrete Technology.* 2nd edition. Long man Group United Kingdom Limited, 30-269.

Neville, A.M. (2011). *Properties of Concrete* 4th Edition, Addison Wesley Longman Ltd, Edinburgh Gate, Harlow Essex CM 20 2jE, England.

Neville, A.M. (2012). *Properties of Concrete.* 5th Edition, Addison Wesley Longman Ltd, Edinburgh Gate, Harlow Essex CM 20 2jE, England.

Nwofor, T.C., and Sule, S. (2012). *Stability of Groundnut Shell Ash/Ordinary Portland cements Concrete in Nigeria.* University of PortHarcourt Nigeria, pp.2283 -2287

Ogunbode, E. B. and Hassan, I. O. (2011). Effect of Addition of Calcium Nitrate on Selected Properties of Concrete Containing Volcanic Ash. *Leonardo Electronic Journal of Practice and Technologies,*29-38. Retrieved from http://www.lejpt.academicdirect.org

Olawuyi, B. J., Olusola, K. O., and Babafemi, A. J., (2012). Influence of Curing Age and Mix Composition on Compressive Strength of Volcanic Ash Blended Cement Laterized Concrete. *Civil Engineering Dimension*, 14(2), 84-91.

Osei, D. Y. and Jackson, E. N. (2012). Compressive Strength and Workability of Concrete Using Natural Pozzolan as Partial Replacement of Ordinary Portland Cement. *Journal of Advances in Applied Science Research,* 3(6), 3658-3662. Retrieved from http://www.pelagiaresearchlibrary.com

Pitroda, J. and Shah, D. S. (2014). An Experimental Study on Durability and Water Absorption Properties of Pervious Concrete. *International Journal of Research in Engineering and Technology, 3(3)*, 439-444. Retrieved from http://www.ijret.org

Ramezanianpour, A. A., Mahdi, K. M. and Ahmadibeni, G.H. (2009). The Effect of Rice Husk Ash on Mechanical Properties and Durability of Sustainable Concretes. *International Journal of Civil Engineering*, 7(2): 83-91

Raheem, A.A., Olasunkanmi, B.S., Folorunso, C.S. (2012). Saw Dust as Partial Replacement for Cement in Concrete. *Organization Technology and Management in Construction an International Journal,* 4(2): 474-480.

Samson, (2010). Effect of Elevated Temperatures on Compressive Strength of Rice Husk Ash.(RHA) Concrete. *Unpublished Undergraduate project*. Department of Building, Ahmadu Bello University Zaria, Ngeria

Shetty, M. S. (2009). *Concrete Technology; Theory and Practice*, S Chad and Company, New Delhi, India, 174-418.

Shoubi, M. V., Barough, A. S. and Amirsolemani, O. (2013). Assessment of the Roles of Various Cement Replacements in Achieving the Sustainable and High Performance Concrete. *International Journal of Advances in Engineering and Technology,* 6(1), 68-77.

Tavakoli, H. (2012). *A Dictionary of Research Methodology and Statistics in Applied Languistics.* Rahnama Press, Tehran, Iran, 346-347.

Tomlinson, M.J. (2001) *Foundation and construction* Pearson Education, Edinburgh Gate, Harlow, Essex CM20 2JE, England. 38 – 54

Udoeyo, F.F., Inyang, H., Young, D.T., Oparadu, E.E. (2006) Potential of wood waste ash as an Additive in concrete. *J Mater Civil Engineering*, 18(4): 605–11.

United Nations Centre for Human Settlement Survey (2016). *Executive Summary of the Global Report on Human Settlements* (45)(HS/129/88E)

Yusha'u, M. (2017) Comparative study of strength and durability properties of Kaolin and Metakaolin cement concrete. *Unpublished B, Sc. Project.* Department of Building, Ahmadu Bello University Zaria, Nigeria

Zubairu, I.K.,Dahiru, D. and Sheikh – Abdullahi, F (2010) "Properties of Concrete Production By Partial Replacement of Cement with Corn Cob Ash *Environ – Journal of Environment Studies* Vol.2. N12 Faculty of Environmental Design, Ahmadu Bello University, Zaria – Nigeria Pp 21 – 33