EFFECT OF CALCINATION ON OXIDES COMPOSITION OF DUTSIN DUSHOWA VOLCANIC ASH OF JOS PLATEAU

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ABSTRACT

This study investigates effect of calcination on oxide composition of Volcanic Ash (VA) sample obtained from Dutsin Dushowa, Kerang in Mangu Local Government Area of Plateau State, Nigeria. VA sample was collected as a lump, pounded, grounded, sieved with a 75 µm sieve and calcinated in a furnace at five temperatures levels (i.e. 500, 600, 700, 800 and 1000 º C) before packaging for Chemical Analysis in Sagamu works Department of West African Portland Cement Company (WAPCO) via an X-ray fluorescent Analysis using a Total Cement Analyser model ARL 9900 XP with control being Pulverized VA sample in the natural state. The result reflects that Silicon Dioxide (SiO_2) content and total Silicon Dioxide, Iron Oxide, and Aluminium Oxide ($SiO_2+Fe_2O_3+Al_2O_3$) content improved at a decreasing rate as the temperature of calcination increases. Values varied from 41.13% (at natural state) through 42.41% (at 500 º C) to 43.36% (at 1000 º C) for SiO_2 and from 70.99 % (at natural state) through 73.13% (at 500 º C) to 74.65% (1000 º C) for $SiO_2+Fe_2O_3+Al_2O_3$. All the samples were noted to satisfy the requirements of ASTM C618:2008 and IS 3812:1981 on basis of oxide composition.

Keywords: *Volcanic Ash (V.A.), Calcination, Chemical Analysis, Oxide Composition, Pozzolan*

INTRODUCTION

One of the major aspirations of human beings in life is to own a house. This is however frustratingly becoming a goal unattainable in Nigeria as in most other developing countries. This can be attributed to factors such as the present global economic recession, the disabled purchasing power, diminishing national income, lack of soft loans for housing finance, the rapidly expanding population of the nation, failed government policy, high cost of land, astronomical increases in the cost of conventional building materials, especially sand, cement and other 'concrete' components and lack of government or private sector in serious investment in building materials research development, mass production and patronisation (Olateju, 1991; Anthonio, 2002; Olusola and Adesanya, 2004). The worst hit in this trend is the low-cost housing sector, while history reveals that man made his home from locally available material using the technology at his disposal. The return to the true principle of local material utilisation and familiar technology as it was in Africa before colonisation therefore may hold the key to the dream of housing for all.

Basic conventional building materials like cement and sand are becoming increasingly expensive to obtain because of high cost incurred in cement production, sand excavation process, pre-treatment and transportation. A 50kg bag of cement, which sold for #280 and #480 in December 1994 and April 1995 respectively (Olawuyi, 1995), now sell for #1850 as of September, 2008 in Minna market. Umoh (1990) reported that in spite of the large cement factories in Nigeria, the yearly supply does not match the demand for cement. To worsen the situation, most of the factories do not produce at full installed capacity and because the importation of cement is economically inadvisable, the difference between demand and supply invariably has an effect on the cost of cement. Research trends globally in materials development has therefore been that of sourcing for alternatives necessitated by the high cost of conventional materials, difficulty in accessing fund for construction/ building development, the need to recycle agricultural waste materials for construction, the bio-degradability of the materials, the need to maintain ecological balance and population growth and the challenges of housing amongst the many other reasons (Falade, 1999; Olusola and adesanya, 2004; Anthonio, 2002; Olawuyi, 2011). The development of supplementary cementitious materials (SCMs) is said to be fundamental to advancing low-cost construction materials to be used in the production of self-sufficient means of shelter especially in developing countries.

The need for shelter as argued by Olusola (2005) must be met by materials that the environment can afford. Such materials must therefore be widely and readily available, appropriate to the environmental demands, thermally efficient and socially acceptable. Besides, the building system derived from such materials must allow participation from the community and thereby improving the cash economy of that community. This is what Adegoke and Ajayi (2003) referred to as appropriate technology. Examples of such locally available building materials that fit into these descriptions are cement replacement materials such as rice husk ash, corncob ash, sawdust ash, and volcanic ash –usually referred to as “original pozzolan” (Neville and Brooks, 2002). Chemical analysis for oxide composition is reccommended by the codes (ASTM C618-2008, IS 3812-1981 and KS-02-1261) as means of assessing the comformity of a material qualities for consideration as SCM also known as pozzolan. Neville (2006), asserts that some pozzolanic materials are known to improve in their properties when calcinated at temperature ranges between 500^{o}C and 1100^{o}C. This paper therefore reports the effect of calcination on oxide composition of volcanic ash sample obtained from Dutsin Dushowa hill in Kerang, Mangu Local Government Area of Plateau State, Nigeria.

LITERATURE REVIEW

According to ASTM C125 – 05, a pozzolan is defined as a siliceous or siliceous and aluminous material, which in itself, possess little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties. It is essential that pozzolan be in a finely divided state as it is only then that silica can combine with calcium hydroxide (produced by the hydrating Portland cement) in the presence of water to form stable calcium silicates which have cementitious properties (Neville, 2006). Neville (2006) further stated that the silica has to be amorphous, that is glossy, because crystalline silica has very low reactivity. Hossain (2005) submitted that these pozzolanic materials can improve the durability of concrete and rate of gain in strength thus reducing the rate of liberation of heat, which is beneficial for mass concrete.

Pozzolanas are a class of material that combines with calcium hydroxide and water to produce calcium silicate hydrate (CSH), which is the glue in Portland cements. The chemical composition and pozzolanic activities of those materials vary depending on the source (Pekmezci and Akyuz, 2004). However, there is a common denominator for any material to qualify as a pozzolan.

Syagga *et al.*, observed in 2001(cited in Raheem, 2006) that the Kenya Standard (KS-02-1261) recommends that a good pozzolan for manufacture of pozzolanic cement should have a combined SiO_2 + Al_2O_3 of at least 70%. The ASTM C618-2008 on the other hand requires that a good pozzolan should have a combined percentage of SiO_2 + Al_2O_3 + Fe_2O_3 of more than 70%. Similarly, the Indian Standard (IS 3812: 1981) also stipulates combined silica (SiO_2), alumina (Al_2O_3) and iron oxide (Fe_2O_3) composition of not less than 70% of the entire constituents for Fly Ash for use as pozzolana and admixture, while silica alone is expected to be 35% minimum of the total oxide composition (Shetty, 2004). Table 1 shows the chemical composition of a pozzolan according to Indian Standard (IS 3812: 1981) while Table 2 also presents the physical and chemical requirement for pozzolanas according to American Standard (ASTM C618 - 2008).

Pozzolanic materials can be classified into two groups:

a) Natural pozzolanas
b) Artificial pozzolanas

Natural pozzolanas are of volcanic origin with volcanic ash referred to by Neville (2006) as the original pozzolan. Others include pumicite, tuff, trass, opaline shale and cherts, calcined diatomacceous earth and burnt clay; they are described by ASTM C 618 – 2008 as class N. According to Neville (2006), some natural pozzolanas may create problems because of their physical properties e.g. diatomaceous earth, because of its angular and porous forms, requires high water content. He further stated that certain natural pozzolanas improves their activity by calcinations in the range of 550 to 1100^{o}C, depending on the material.

Table 1: Chemical Composition of Pozzolan according to Indian Standard (IS 3812)

S/N	Characteristic	Requirement
i)	Silicon dioxide (SiO_2) plus aluminium oxide (Al_2O_3) plus iron oxide (Fe_2O_3) percent by mass, Min	70.0
ii)	Silicon dioxide (SiO_2), percent by mass, Min	35.0
iii)	Magnesium oxide (MgO), percent by mass, Max	5.0
iv)	Total sulphur as sulphur trioxide (SO_3), percent by mass, Max	2.75
v)	Available alkalis, as sodium oxide (Na_2O), percent by mass, Max	1.5
vi)	Loss on ignition, percent by mass, Max	12.0

Source: Shetty, 2004

Table 2: Physical and Chemical Requirement for Pozzolan as offered by ASTM C618

S/N	Property of Pozzolan	Class		
		N	F	C
i)	Silicon dioxide(SiO_2) + Aluminium oxide (Al_2O_3) + Iron oxide (Fe2O3)	70.0	70.0	70.0
ii)	Sulphur Trioxide (SO3), Max%	4.0	5.0	5.0
iii)	Moisture Content, Max%	3.0	3.0	3.0
iv)	Loss of ignition (LOI) Max. %	10.0	6.0	6.0
v)	Fines: Amount retained when wet sieve Number 325 (45μm) Max%	34	34	34
vi)	Increase in drying shrinkage of Portland pozzolan cement mortar bars at 28days (Max %).	0.03	0.03	0.03
vii)	Water requirement (Max % of control)	115	105	105
viii)	Pozzolanic activity index with Portland cement at 28days (Min. % of control)	75	75	75

Source: ASTM C618-2008

Artificial pozzolanas are mainly products obtained by heat treatment of natural materials. Examples are fly ash (PFA), Blast furnace slag, Silica fume, Metakaolin, Rice husk ash (RHA), Saw dust ash (SDA), Acha husk ash (AHA), Bagasse ash, Groundnut husk ash (GHA) and Corn cob ash (CCA) as mentioned in Matawal (2005), Alabadan *et al.*, (2006), Raheem (2006) and Neville (2006).

Matawal (2005) discussed the reasons for employment of ashes to clinker in cement under three headings:

i) Technological
ii) Economical and
iii) Environmental

Technologically, it can modify the properties of cement by increasing or decreasing its durability and resistance to aggressive agents as well as to lime (Talero, 1990; Gaspar and Sagrera, 1987). Improved behaviour is a function of the activity of the additions and this varies from one pozzolan to another.

Economically, active additions reduce the quantity of cement required, while environmentally, employing such additions, utilizes waste materials.

Other advantages of using pozzolanic material as partial replacement of cement highlighted by Matawal (2005) are as follows:

- Improved placeability or workability: a vital consideration in the assessment of fresh concrete;
- Improved sulphate resistance particularly in marine environment;
- Improve resistance to freezing and thawing in temperate environment;
- Increased cohesiveness or bonding strength of the concrete;
- In a few instance, there is an increased long-term strength;
- A reduction in the water content of mortar and concrete mixes resulting in less shrinkage and cracking;
- A reduction in the heat of hydration: a particularly potent advantage in hot weather concreting;
- Decreased permeability and water tightness;
- High resistance to alkaline-aggregate reactions.

These advantages vary from one pozzolanic material to another; a detailed discussion on the pozzolan of concern to us (volcanic ash) is thereby of great importance.

Volcanic ash is a finely fragmented magma or pulverised volcanic rock, measuring less than 2 mm in diameter, that is emptied from the vent of a volcano in either a molten or solid state. The most common state of ash is vitric, which contains glassy particles formed by gas bubble busting through liquid magma (Encarta, 2008).

In the words of Shoji, *et al.*, (1993), volcanic ash comprises small jagged piece of rock minerals and volcanic glass that was erupted by a volcano. Volcanic ash is opined not to be a product of combustion like soft fluffy material created by burning wood, leaves or paper. Volcanic ash is hard, does not dissolve in water and is extremely abrasive, mildly corrosive and conducts electricity when wet. Shoji, *et al* (1993) further stated that the average grain size of rock fragment and volcanic ash erupted from an exploding volcanic vent varies greatly among different eruption. Heavier and large size rock fragment typically fall back to the ground or close to the volcano while smaller and lighter fragments are blown farther from the volcano by wind.

Wright (1970) observe that although a significant proportion of Nigeria's volcanic rock are found in the Jurassic younger granite province, the tertiary to quaternary phase of volcanism (the process by which molten rock or magma rises from interior of the earth to or toward its surface and by which associated gases are released to the atmosphere) was most mid spread and voluminous in Nigeria.

Salau (2008) also outlined the spread of Basalt formations (the parent material from which volcanic-ash forms) in Nigeria. According to Salau (2008), basalt formations are found in the South and West of Biu Plateau, Namu, Gindiri, Pankshin and Runka areas and also in Jos Plateau in Plateau State.
They also occur in Rabah, Gwaini, Wurno and Sokoto Plateau of Sokoto State. Traces of basalt can also be found in the Yoruba Plateau (Salau, 2008). This study hereby focuses on the Jos Plateau Volcano.

The Jos Plateau lies precisely within the North Central Basement Complex of Nigeria. The Basement Complex rocks of the lower Palaeozoic to Precambrian ages underlie about half of its entire landmass. These rocks are represented by gneiss-migmatites and intrusive into these Basement rocks are the Pan-African granites and the predominant Jurassic non-organic alkaline Younger Granites (Turner, 1976).

Tertiary and Quaternary basaltic volcanoes are the youngest rocks in the area and overlie directly in the basement and in places of the Younger Granites (Wright, 1970). According to *MacLeod et al* (1971) two main basalt subtypes have been distinguished based on these periods of replacement and textural differences. They are the Older (Tertiary) and the Newer (Quaternary) basalts.

The Newer basalts occupy nearly 150 km^2 in the western and southern Jos Plateau. They also extend towards the Kafanchan area and Southwards down to the Shemankar valley. They occur as cones and lava flow characterised sleep-sided central craters rising a few meters above their surroundings.

The Newer Basaltic cones are aligned in NNW-NNE direction, corresponding to the trend of dolerite dykes (MacLeod *et al.*, 1971). They are mainly built of basaltic scoria and pyroclastics, with the vesicles filled with a variety of inclusions (olivine, Iherzolite, websterite etc).

Partly decomposed basaltic boulders, plugs or dome-like out-crops represent the Older Basalts. They are very visible from the Werram valley southward of Jos extending to the Keffi-Abo area to Rukuba, Ganawuri, South Ropp, Mbar and Mangu. The laterized basalt represents the product of weathering of mainly the Older Basalts (MacLeod *et al.*, 1971)

Volcanic Ash chemistry is directly related to the chemistry of the source magma. Volcanic glass is relatively high in silica compared to mineral crystals, but relatively low in non-silica elements (especially Mg and Fe). Both glass and most minerals almost always contain Si, Al, K, Na, Ca, Mg, & Fe (Shoji *et al.*, 1993).

Lar and Tsalha (2005) present the result of chemical analysis of the Jos Plateau Basalts as shown in Table 2.7 with the SiO_2 content ranging between 39.8 to 46.49 wt.%, a total SiO_2 + Al_2O_3 + Fe_2O_3 content ranging between 53.13 to 71.07 wt.%. The sample taken from Kerang environments (KG1) has a total SiO_2 + Al_2O_3 + Fe_2O_3 content of 63.74 wt. % by the analysis. Hassan (2006) on other hand present a report of analysis of sample taken from Kerang having total SiO_2 + Al_2O_3 + Fe_2O_3 content of 67.14 wt. % as shown in Table 3. This study thereby investigates effects of calcination on the chemical constituents of the sample from Kerang and assess suitability for use as a Pozzolan.

Table 3: Major Elements (w %) Abundances in Basaltic Rocks from Jos Plateau

Wt.	KG1	HP2	AM1	AH1	RY2	RY1	VM1	KS1	HP1	RH1	GS1	APW1	KS2	KS3
SiO_2	39.64	40.9	45.89	44.94	46.38	46.49	42.37	38.85	40.43	42.58	29.97	39.08	40.46	42.75
Al_2O_3	11.18	13.11	12.4	14.4	14.15	13.99	14.1	15.85	13.45	14.04	14.28	14.44	13.67	13.53
Fe_2O_3	12.92	9.93	10.36	9.75	10.28	9.79	12.66	12.68	13.85	13.86	12.88	13.63	12.37	12.18
TiO_2	2.52	2.43	2.71	2.37	2.62	2.84	2.36	2.36	2.39	2.39	2.89	2.56	2.51	2.47
CaO	10.43	0.77	8.57	9.72	8.53	8.64	9.71	9.71	9.78	8.78	8.85	10.92	10.29	10.66
MgO	18.79	21.66	17.82	16.3	14.98	15.3	15.87	15.87	16.48	16.48	28.44	15.88	17.56	15.33
MnO	0.08	8.07	0.09	0.07	0.07	0.07	0.02	0.09	0.07	0.07	0.08	0.07	0.08	0.08
K_2O	1.64	1.64	0.97	1.42	1.67	1.47	1.96	1.86	1.96	1.84	0.87	1.84	1.50	1.55
P_2O_5	0.48	0.62	0.57	0.48	0.48	0.46	0.35	0.76	0.68	0.61	0.44	0.71	0.54	0.54
SO_3	0.02	0.01	0.04	0.01	0.02	0.02	0.01	0.05	0.02	0.02	0.12	0.02	0.11	0.08
V2O	0.00	0	0.02	0.02	0	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.00	0.02
Na_2O	0.95	0.62	0.32	0.77	0.76	0.85	0.36	0.88	0.76	0.63	0.86	0.63	0.75	0.85
Cr_2O	0.04	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.03	0.20	0.03	0.03
Total%	98.69	99.79	99.78	100.28	99.97	99.97	99.82	99.01	99.91	101.34	99.73	100.00	99.87	100.07

Legend: KG1=Kerang; HP1&2=Heipang; AM1=Amper; AH1=Assop Hausa; RY1&2=Riyom; VM1=Vom; KS1,2&3=Kassa; RH1=Richa; GS1=Gumshir; APW1=Ampang West
Source: Lar and Tsalha (2005)

Table 4: Chemical Composition of Volcanic Ash from Kerang

Elements	**% Composition by weight**
SiO_2	48.75
Al_2O_3	16.26
Fe_2O_3	2.13
CaO	11.67
MgO	4.24
K_2O	5.71
Na_2O	3.83
P_2O_5	0.81
L.O.I	2.71
Total SiO_2+Al_2O_3+Fe_2O_3	67.14

Source: Hassan (2006)

MATERIALS AND METHODS

Experimental Procedure

The volcanic ash (VA) used was obtained from Kerang in Mangu Local Government Area of Plateau State in Nigeria as a solid mass. This was collected as a lump, pounded, grounded, sieved with a 75 μm sieve and calcinated for two hours (2hrs) in a furnace at five temperatures levels (i.e. 500, 600, 700, 800 and 1000 ^{o} C) before packaging for Chemical Analysis in Sagamu works Department of West African Portland Cement Company (WAPCO, now LAFARGE Cement) via an X-ray fluorescent Analysis using a Total Cement Analyser model ARL 9900 XP. Pulverized VA sample at the natural state served as the control for this experiment, hence the samples were labeled VAN1 for the natural state pulverized VA sample; BJA2 for the sample calcinated at 500 ^{o}C for 2hrs; BJB2 for 600 ^{o}C, 2hrs sample; BJC2 for 700 ^{o}C, 2hrs sample; BJD2 for 800 ^{o}C, 2hrs sample; BJD2 for 900 ^{o}C, 2hrs sample and BJE2 for the sample calcinated at 1000 ^{o}C, 2hrs in the furnace.

Determination of Chemical Composition of Volcanic Ash

The VA sample was prepared in F.U.T, Minna and then taken to WAPCO, Sagamu Works for analysis. About 150 g of the prepared sample was packaged in small transparent nylon bag.

The determination of the chemical composition at WAPCO was by the use of an X-ray Fluorescent Analyser called Total Cement Analyser (Model ARL 9900 XP) connected to a computer system. This involved drying, grinding, pressing and analysing. The materials were dried in an oven at 105 ^{0}C for about two hours until a constant weight (±0.01 g) was obtained after which the sample was placed in a desiccator to cool for about 30 minutes before grinding commences. In order to aid grinding and to prevent sticking of the sample to dish, 0.8 g of stearic acid was weighed into sample dish before adding 20.0 g of the material (VA sample) into it. Grinding was done on a gyro-mill grinding machine (Model HSM 100H, Serial Number MA 11566-5-1, 2004), which stops automatically after grinding for a pre-set time of 3 minutes. The sample is then ready for pressing.

The ground sample plus 1.0 g of stearic acid to ensure adequate binding, was used to fill the pellet cup to the brim. The pellet cup was then placed in an automatic hydraulic press (Model TP 40/2D), with 20 tons load applied for a 30 seconds hold time. The pressed pellet after removal was placed in the X-ray analyser sample holder ready for analysis.

The pressed pellet was loaded in the sample port of the analyser and the assembly left for about three minutes after which the values of oxides concentration were displayed on the monitor. The computer automatically prints the result of the analysis.

RESULT AND DISCUSSION

Table 5 below presents the result of chemical analysis conducted on the pulverised calcinated VA sample gotten from Dutsin Dushowa in Kerang, Mangu Local Government Area of Plateau State. It reflects that as the heat of calcination increased the SiO_2 content of the VA increased at a decreasing rate, so does the Al_2O_3 and Fe_2O_3 contents. The total SiO_2 + Al_2O_3 + Fe_2O_3 was therefore on a consistent increase as the heat of calcination increased from natural state (i.e. 23 ^oC or room temperature) through 500 ^oC to 1000 ^oC at a decreasing rate.

Table 5: Result of Chemical Analysis Conducted at WAPCO (Sagamu Works Dept.)

Sample No	VAN 1	BJA 2	BJB 2	BJC 2	BJD 2	BJE 2	BJF 2
SiO_2	41.13	42.41	42.62	43.09	43.04	43.13	43.36
Al_2O_3	18.36	18.87	18.84	19.14	19.18	19.14	19.29
Fe_2O_3	11.5	11.85	11.89	11.97	11.99	11.98	12.00
CaO	6.57	6.82	6.83	6.91	6.87	6.98	6.95
MgO	4.24	4.49	4.70	4.63	4.68	4.61	4.75
SO_3	-0.13	-0.13	-0.13	-0.13	-0.13	-0.12	-0.11
K_2O	1.12	1.13	1.13	1.15	1.14	1.15	1.15
Na_2O	1.29	1.36	1.33	1.31	1.33	1.37	1.36
Mn_2O_3	0.29	0.3	0.3	0.3	0.31	0.31	0.31
P_2O_5	1.00	1.02	1.02	1.03	1.03	1.03	1.03
TiO_2	3.56	3.65	3.65	3.70	3.69	3.70	3.70
Cl-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SUM	88.92	91.77	92.17	93.1	93.13	93.29	93.81
LSF	4.64	4.68	4.66	4.66	4.63	4.70	4.64
SR	1.38	1.38	1.39	1.38	1.38	1.39	1.39
AR	1.60	1.59	1.58	1.60	1.60	1.60	1.61
SiO_2+Al_2O_3+Fe_2O_3	70.99	73.13	73.35	74.20	74.21	74.25	74.65

The SO_3 content remained constant althrough the natural state up to calcination temperature of 800 ^oC with a very slight increase of 0.01% at both 900 ^oC and 1000 ^oC, so are the minor oxides MgO, Na_2O, P_2O_5 and Mn_2O_3 while CaO content was observed to be increasing too at a decreasing rate as the calcination temperature increased. The Lime Saturation Factor (LSF), Silica Ratio and Aluminium Ratio can be adjudged constant althrough the various temperature levels. The oxide cotents were noticed to meet the requirements of both the American Standard (ASTM C618-2008), and the Indian Standard (IS 3812: 1981) with SiO_2 values of 41.13% (VAN1); 42.41% (BJA2); 42.62% (BJB2); 43.09% (BJC2); 43.04% (BJD2); 43.13% (BJE2) and 43.36% (BJF2) which are greater than the 35% value provided as the codes minimum required. The total SiO_2 + Al_2O_3 + Fe_2O_3 are 70.99%; 73.13%; 73.35%; 74.20%;

74.21%; 74.25% and 74.65% respectively. The MgO on the other hand are 4.24%; 4.49%; 4.70%; 4.63%; 4.68%; 4.61% and 4.75% respectively, all having values below 5% given as the maximum MgO content in the codes. The calcination temperature of 800 ^{o}C for two hours is however noted to be the point of contra-flexure by the curve of trend for oxide contents, implying this as the optimum point for effective calcination. Going by the margin of influence of calcination on oxide composition, it can be adjudged that calcination of the volcanic ash sample might not be worth the stress, considering the cost of energy required for calcination as compared to the minimal benefit derived in terms of improvement to oxide composition.

CONCLUSION

The volcanic ash sample obtained from Dutshin Dushowa (a hill) in Kerang Local Government Area of Jos, Plateau State, Nigeria is a suitable material for use as a pozzolan at the natural (uncalcinated) state as well as at the calcinated state (for all the various temperatures of calcination considered). All the samples satisfied the requirements for such a material as spelt out in ASTM C618-2008 and IS 3812:1981 by having a combined SiO_2, Al_2O_3 and Fe_2O_3 values above 70% (the minimum required). 800 ^{o}C for two hours is adjudged the optimum temperature of calcination, while attempting to calcinate the Dushin Dushowa volcanic ash sample is seen as un-necessary on economic basis considering the cost of energy for calcination since the volcanic ash sample is found suitable for use at the natural state.

REFERENCES

Adegoke, C.O. and Ajayi, J.A. (2003); "Manufacturing and Industrial Capacity Building in Nigeria: Imperative of Appropriate Technology", Proceedings of National Engineering Conference on the Engineer in the Nigerian Society, NSE, 8th – 12th Dec., Ibadan, Pp. 67–71.

Alabadan, B.A; Njoku, C.F. and Yusuf, M.O. (2006); "The Potentials of Groundnut Shell Ash as Concrete Admixture", Agricultural Engineering International, the CIGR, Journal, Vol.III, Feb.

Anthonio, J. O. (2002); "Housing for All by the Year 2015", A paper presented at 2002 Building Week Seminar of Ife Association of Building Students, Obafemi Awolowo University, Ile-Ife, 23rd April.

American Society for Testing and Materials (2005); Terminology Relating to Concrete Aggregates, ASTM C125.

American Society for Testing and Materials (2008);Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete, ASTM C618.

Encarta English Dictionary (2008); Website: www.microsoft encarta.com.

Falade, F. (1991); "Influence of Method and Duration of Curing and Mix Proportion on Strengt of

Concrete Containing Laterite Fine Aggregate", Building and Environment, Vol.26, No.4, Pp.453-459.

Gaspar, D. and Sagrera, J. L. (1987); Rev. Material de Construction No. 168-207, Eduardo Torrojo Institute, Madrid, Spain.

Hassan, I. O. (2006); "Strength Properties of Concrete obtained Using Volcanic Ash Pozzolan as Partial Replacement of Cement", Unpublished M.Sc. Thesis, Department of Building,University of Jos.

Hossain, K. M. A. (2005); "Chloride Induced Corrosion of Reinforcement in Volcanic Ash and Pumice Based Blended Cement", Cement and Concrete Composites, Vol. 27, Pp. 381-390.

Indian Standards Code of Practice - IS 3812 (1981); Specification for Fly Ash for Use as Pozzalana and Admixture Calcined Clay Pozzolana (1st Revision)

Lar, U. A. and Tsalha, M. S. (2005), "Geochemical Characteristics of the Jos-Plateau Basalts, North-Central Nigeria", Global Journal of Geological Sciences, Vol.3, No.2, Pp.187-193.

MacLeod, W. N; Tuner, D.C. and Wright, E.P. (1971); "The Geology to the Jos Plateau (Vol.1)", Geological Survey, Nigeria, Bull. No.32.

Matawal, D. S. (2005); "Application of Ashes as Pozzolan in Mortar and Concrete Production", 1st National Academy Conference, 31st August -2nd September 2005.

Neville, A.M and Brooks J.J (2002); Concrete Technology, 2nd Edition (Second Indian Reprint) copyright © 1987, Pearson Education (Singapore) Pte. Ltd, Indian Branch, Delhi, Pp.438.

Neville, A.M. (2006); Properties of Concrete, 4th Edition, copyright © 2000, Asia, Person Education Pte. Ltd. 844p.

Olateju, O. T. (1991); "The Performance of Locally Sourced Materials in Low-cost Housing Component Development", Proceedings of National Conference on Engineering Infrastructures for Rapid Industrialisation, NSE, 3rd-7th Dec.

Olawuyi, B.J. (1995); "Production of Paint Using Locally Available Materials within Kebbi State", Unpublished Corporate Membership Thesis, The Nigerian Institute of Building (NIOB), Lagos.

Olawuyi, B. J. (2011), "Strength Characteristics of Volcanic Ash Blended Cement Laterized Concrete", Unpublished M.Phil. Building (Structures) Thesis, Department of Building, Obafemi Awolowo University, Ile-Ife.

Olusola, K. O. (2005); "Factors Affecting Compressive Strength and Elastic Properties of Laterized Concrete", Unpublished Ph.D. Thesis, Department of Building, Obafemi Awolowo University, Ile-Ife.

Olusola, K. O. and Adesanya, D. A. (2004); "Public Acceptability and Evaluation of Local Building Materials for Housing Construction in Nigeria", Journal of Property Research and Construction, Vol.1, Pp.83-98.

Pekmezci, B. Y. and Akyuz, S. (2004); "Optimum Usage of a Natural Pozzolan for the Maximum Compressive Strength of Concrete", Cement and Concrete Research, Vol.34, Pp. 2175-2179.

Raheem, A. Y. (2006); "An Investigation of Corn Cob Ash Blended Cement for Concrete Production", Unpublished Ph.D. Thesis, Department of Building, Obafemi Awolowo University, Ile-Ife.

Salau, M. A. (2008); "Abundant Local Structural Engineering Material Without Affordable Structures", An Inaugural Lecture Delivered at University of Lagos, Wed. 23rd April.

Shetty, M. S. (2004); "Concrete Technology – Theory and Practice", New Dhelhi, India, S. Chand and Company Limited, 637p.

Shoji, S.; Nanzyo, M. and Dahlgren, R. (1993); "Volcanic Ash Soil: Genesis, Properties and Utilisation; Developments in Soil Science 21, Elsevier, Amsterdam.

Talero, R. (1990); "Qualitative Analysis of Natural Pozzolans, Fly Ashes, and Blast Furnace Slags by XRD", Journal of Materials in Civil Engineering 2(2), Pp. 106-117.

Turner, D. C. (1976); "Structures and Petrology of the Younger Granite Ring Complexes", Geology of Nigeria (2nd ed.)

Umoh, A. A. (1990); "Strength Characteristics of Concrete Incorporating Rice Husk Ash as Partial Replacement of Cement", Unpublished B.Sc. Thesis, Department of Building, University of Jos.

Wright, J. B. (1970); "Volcanic Rocks in Nigeria", In: The Geology of Nigeria, C.A. Kogbe (Ed.) Lagos, Elizabethan Publishers, Pp. 125 – 173.