STRENGTH CHARACTERISTICS OF LATERIZED CONCRETE USING LIME – VOLCANIC ASH CEMENT

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ABSTRACT

Effect of calcium oxide on volcanic ash laterized concrete was investigated. A total of 60 cubes of 150mm dimensions were cast with volcanic ash (V.A) and calcium oxide (CaO) combination of 90%:10% and 80%:20% respectively while the ordinary Portland cement (OPC) based concrete for 28-day target strength of 25N/mm^2 served as control. Sand replacement by laterite also varied between 0% and 20% for the laterized specimens. The cubes were cured in water and tested for compressive strength at 7, 14, 21 and 28 days. The result showed that the compressive strength increased as the hydration period increased and that the presence of calcium oxide boosted the strength properties of volcanic ash laterized concrete. The compressive strength of the laterized concrete specimens was higher at the various hydration days for the 20%lat/20%CaO: 80%V.A. sample than the 10%lat/10%CaO: 90%V.A sample. The 28-day strength for 20%lat/20%CaO: 80%V.A sample gave a value of 22.07N/mm^2 (i.e. 81.74%) as against the 21.53N/mm^2 (79.74%) gotten for the 10%lat/10%CaO: 90%V.A. sample, while the control mix gave a 28-day strength value of 27.0N/mm^2 (100%). The volcanic ash – lime cement in the laterized concrete specimens therefore reflects good pozzolanic activity and can be adopted for construction of buildings and rural infrastructure.

KEYWORDS: Volcanic Ash, Laterized Concrete, Calcium Oxide, Compressive Strength, Replacement.

INTRODUCTION

The provision of housing is governed by the need for shelter among other factors and according to ***Fitch and Branch (1960)***, the need for shelter must be met by materials that the environment can afford. Such materials must therefore be widely and readily available, appropriate (economically, that is affordable and physically) to the environmental demands, thermally efficient and socially acceptable (***Olusola, 2005***). 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 fits into these descriptions are cement replacement materials such as rice husk ash, corncob ash, sawdust ash, volcanic ash and conventional sand replacement materials such as erosion sand and laterite, This study focuses on possible replacement of ordinary Portland cement by lime -volcanic ash cement and partial replacement of sand by laterite in concrete production.

Concrete is associated with high strength, hardness, durability, imperviousness and mould ability. It has poor thermal insulation, but has a high thermal capacity (***F.A.O. reports, 2002***) .It is not flammable and has good fire resistance but there is a serious loss of strength at a high temperature. Concrete made with ordinary Portland cement has low resistance to acid and sulphate but high resistance to alkali (***Neville, 1992***). Its compressive strength depends on the proportion of the ingredients i.e. the water- cement ratio and the cement- aggregate ratio. Since the aggregate form the bulk of hardened concrete, its strength will also have some influence; direct tensile strength of concrete is generally low, only about 1/8 to1/4 of the compressive strength and is normally neglected in design calculation especially in design of reinforced concrete (***F.A.O reports, 2002***). Compressive strength is measured by crushing cubes having 150mm dimensions with the cube cured for 28days under standardized temperature and humidity and then crushed in a hydraulic press.

Laterized concrete was defined as concrete in which stable laterite fines replace sand wholly or partially, whole replacement is also referred to as terracrete (***Olusola, 2005***). ***Adepegba (1975)*** was the first to consider the possibility of replacing sand in concrete with Laterite in Nigeria. He studied the effect of using laterite fines instead of sand in relation to the density, compressive strength, tensile strength, modulus of elasticity and resistance to exposure to high temperature .He concluded that their properties fared well in comparison with those of normal concrete, thereby offering that Laterite fines in place of sand can be used for structural members. ***Balogun and Adepegba (1982)*** discovered that the most suitable mix of laterized concrete for structural purpose is 1:1.5:3 using batching by weight with a water/cement ratio of 0.65, provided that the laterite content is kept below 50% of the total aggregate content .The water/cement ratio used conforms to the recommendation of ***Lasisi and Ogunjide (1984)*** who obtained a linear relationship between the laterite-cement ratio (Y) and the optimum w/c ratio (X). The equation was given as Y=0.9+3.85X. ***Chandrakaran et al.,* (1996)** also reported that for fully laterized concrete, the compressive strength is 50% of that of normal concrete.

Laterite is defined by ***Encarta English Dictionary (2008)*** as red tropical soil: a reddish mixture of clayey iron and aluminium oxides and hydroxides formed by weathering of basalt under humid, tropical conditions. ***Fermor, (1981)*** defined various forms of laterite soils on the basis of the relative contents of the constituents (Fe, Al, Ti, Mn) in relation to Silica. A chemical definition based on the Silica Sesquioxides (S-S) ratio ($SiO2/Al_2O_3+Fe_2O_3$) has been proposed, the conclusion being an s-s ratio$\leq$ 1.33 implies a true laterite; an s-s ratio between 1.33 and 2.0 refers to a lateritic soil; and an s-s ratio $\geq$ 2.0 indicates a non-lateritic typically weathered soil.

Lime is a generic term referring to the calcium oxide component of a material, when the term lime is used, it should always be followed by another word, for instance lime in terms of rock type is lime stone and lime in the concrete or mortar is quick lime, lime putty and hydrated lime (***Neville, 1992***).

Calcium oxide (Ca0) is an ideal accelerator being an industrial bulk product. In the words of ***Neville (2006)***, long term strength increases if pure calcium oxide is used as set accelerator. This increases very early strength (e.g. 8hrs) but not 1 day strength; the long term strength (from 28 days and onwards) is however, often increased in spite of equal porosity as noticed in previous researches after 220days.

Volcanic ash is formed during explosive volcanic eruption when gases dissolved in molten rock (magma), expand and escape violently into the air and also when water is heated by the magma and abruptly flashes into steam. The force of escaping gas violently shatters solid rocks. Expanding gas also shreds magma and blasts it into the air, when it solidifies into fragment of volcanic rock and glass. Once in the air, wind can blow the tiny ash particles from tens to thousands of kilometers away from volcano (***Shoji et al., 1993***). Volcanic ash is a finely fragmented magma or pulverized volcanic rock, measuring less than 2mm in diameter, that is emptied from the rent 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. In their opinion, the average grain size of rock fragment and volcanic ash erupted from an exploding volcanic rent 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. Shoji, et al., (1993) argues that ash particles will compact close together after they fall to the ground. The compaction will increase the bulk density of an ash deposits sometimes as much as 50% within a few weeks of eruption. The thickness of ash deposited may correspondingly decrease slightly over time. Volcanic ash is made of different particles i.e. pumice fragments, volcanic glass shards, crystals and minerals and other rock fragment; the density of the particle are as given in Table 1:

Table 1: Density of Individual Ash Particle

Types of particle	Density of particle
Pumice fragment	700 – 1200 kg/m^3
Volcanic glass shards	2350 – 2450 kg/m^3
Crystal and minerals	2700 – 3300 kg/m^3

Source: *Shipley and Saran-Wojcicki (1982)*.

MATERIALS AND METHODS

Laterized concrete mixtures with two levels of volcanic ash (V.A.) – lime combinations and three levels of laterite replacement also ranging from 0 to 20% (i.e. a total of 4 levels of samples produced in triplicates) were investigated. The control mixture was proportioned for a target concrete strength of 25 N/mm^2 and had a cementitious material content of 292 kg/m^3 fine aggregate content of 680 kg/m^3, a coarse aggregate content of 1158 kg/m^3 and a water cementitious materials ratio of 0.65 giving a free water content of 190 kg/m^3. The cement and sand replacement by V.A and laterite respectively was thereby computed for by weight as required.

The volcanic ash used was obtained from Kerang in Mangu Local Government Area of Plateau State in Nigeria as a solid mass. This was ground and sieved with a 75μm sieve at the Civil Engineering Laboratory of the Federal University of Technology, Minna. As shown in Table 2, the total content of Silicon Dioxide (SiO_2), Aluminium Oxide (Al_2O_3) and Iron (II) Oxide (Fe_2O_3) can be said to range between 64% reported by ***Lar and Tsalha (2005)*** and 68% ***Hassan (2006)***, which is slightly below the minimum of 70% specified in ***ASTM C618***.

Table 3 shows the specific gravity of the V.A sample as 3.04, which is similar to 3.05 as given by ***Hassan (2006)***, a value less than that of cement (3.15) as provided by ***Neville (2006)***. The fine aggregate used were sand and laterite. The lime used for this study was quick lime (CaO) purchased from the building materials market in Kuta road, Minna. The laterite was obtained from Julius Berger (Nigeria Plc.) burrow pit at Maikunkele, Minna, Niger State, Nigeria. While sand used was river sand, free from deleterious substances (obtained from Bosso area of Minna); the coarse aggregate used was granite obtained from Tri-Acta quarry in Minna with maximum size 19mm (3/4in) specified. Table 3, presents the results of the physical properties of the aggregates. The laterite sample has a specific gravity of 2.54, a bulk density of 1375 kg/m^3, moisture content of 15.79%, a fineness modulus of 2.91, a coefficient of uniformity (C_u) of 8.68 and a coefficient of curvature (C_c) of 1.20. It has a Silica: Sesquioxide ($SiO_2/Al_2O_3+Fe_2O_3$) ratio also simply referred to as Silica Ratio (SR) of 0.97 as shown in Table 4 which presents the result of Chemical Analysis carried out on the laterite sample in the Chemistry laboratory of West African Portland Cement Company (WAPCO) - Shagamu Works Department via an X-ray Fluorescent Analysis using a Total Cement Analyzer model ARL 9900 XP. The S-S ratio is thereby less than 1.33 indicating a true laterite classification as specified by Femor (1981).

Table 2: Chemical Analysis of Kerang's Volcanic Ash Sample

Elements	% Composition by weight	
	KG1	KG2
SiO_2	39.64	48.75
Al_2O_3	11.18	16.26
Fe_2O_3	12.92	2.13
CaO	10.43	11.67
MgO	18.79	4.24
K_2O	1.64	5.71
Na_2O	0.95	3.83
P_2O_5	0.48	0.81
TiO_2	2.52	
MnO	0.08	
SO_3	0.02	
Cr_2O	0.04	
L.O.I		2.71
Total $SiO_2+Al_2O_3+Fe_2O_3$	63.74	67.14

Source: ***KG1- Lar and Tsalha (2005)***

KG2- Hassan (2006).

Table 3:Summary of Physical Properties of Constituent Materials

Parameter	V.A	Sand	Laterite	Granite
Specific Gravity	3.04	2.59	2.54	2.64
Bulk Density(kg/m^3)				
Uncompacted	1394	1337	1267	1792
Compacted	1649	1458	1375	1287
% Void	18.29	9.05	7.85	28.18
Moisture Content		3.67	15.79	
Sieve Analysis				
Fineness Modulus		2.41	2.91	
Coefficient of Uniformity		8.00	8.68	1.42
Coefficient of Curvature		1.04	1.23	0.94

The sand on the other hand has a specific gravity of 2.59, a bulk density of 1458 kg/m^3, moisture content of 3.67%, fineness modulus value of 2.41, C_u of uniformity of 8.00 and C_c of 1.57. These results reflect that both the laterite and sand samples are well graded. The granite sample has a specific gravity of 2.64, bulk density of 1287 kg/m^3, C_u of 1.42 and C_c of 0.92, reflecting a uniform sample. All the aggregates conformed to the British Standard Specification ***(BS 812- Part 103, 1985)***. The cement used was Dangote Portland cement produced in Obajana factory, Kogi State, Nigeria and conformed to ***BS EN 197-Part 1, 2000***.

Table 4: Result of Chemical Analysis of Laterite Sample

Elements	% Composition by weight	Others	Values
SiO_2	40.95	Cl^-	0.00
Al_2O_3	20.38	L.O.I	
Fe_2O_3	21.95	SUM	83.76
CaO	-0.65	LSF	-0.34
MgO	-0.62	SR	0.97
K_2O	0.32	AR	0.93
Na_2O	0.23	C3S	-487.34
P_2O_5	0.03	C2S	-481.23
TiO_2	1.14	C3A	16.92
Mn_2O_3	0.16	C4AF	36.45
SO_3	-0.14	Al_2O_3+Fe_2O_3	42.33
Total SiO_2+Al_2O_3+Fe_2O_3	83.28		

Source: ***Olawuyi (2008)***

Tests to determine slump, density and comprehensive strength were carried out in this study.

For the comprehensive strength tests, 150mm cube specimens were used. A total of 60 specimens were cast and cured in water at room temperature in the laboratory for 7, 14, 21 and 28 days. At the end of each curing period three specimens of each mixture were tested for compressive strength and the average was recorded.

RESULTS AND DISCUSION

The workability of the concrete specimens decreased as the content of laterite and volcanic ash increased. The compressive strength of the concrete samples increased as the days of hydration increased as reflected in Tables 5 & 6 and as displayed in Figure 1.The 20%lat/20%CaO: 80%VA sample consistently has a higher strength than the 10%lat/10%CaO: 90%VA sample for all the curing days.

Table 5: Summary of Compressive Strength

Curing day's	**C25**		
	100%OPC	***10%Lat/CaO:90%VA***	***20%Lat/VA:80%VA***
7 day‘s	10.93	8.21	8.44
14day's	15.69	10.92	11.44
21day's	20.80	13.08	14.06
28day's	27.00	21.53	22.07

Table 6: Percentage of 28-Day Strength

Hydration Period	***100%OPC***	***10%Lat/CaO:90%VA***	***20%Lat/CaO:80%VA***
7 day‘s	40.48	30.41	31.26
14day’s	58.11	40.44	42.37
21day’s	77.04	48.44	52.07
28day’s	100.00	79.74	81.7

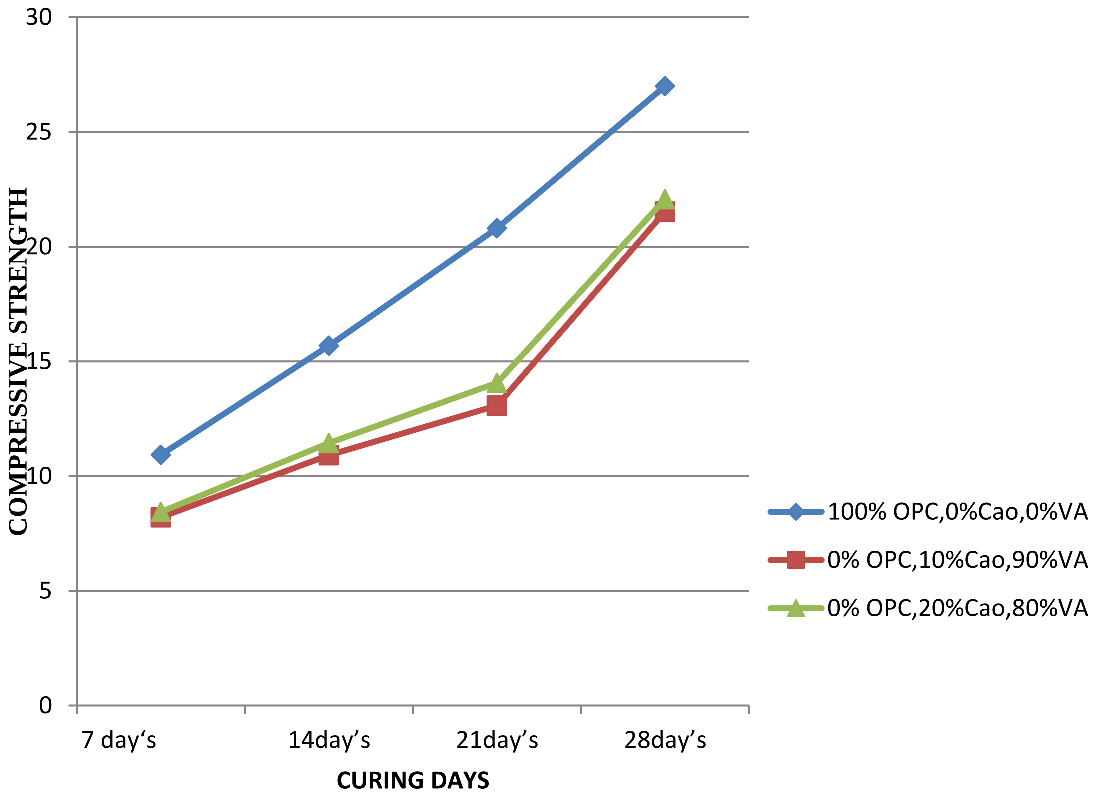

Fig 1:Effect of calcium oxide on performance charateristic of volcanic ash Laterized concrete.

The 28-day strength of the 20%lat/20%CaO: 80%VA sample gave a value of 22.07N/mm2 about 82% of the control sample value of 27N/mm2, while the 10%lat/10%CaO: 90%VA gave a 28-day strength value of 21.53N/mm2 about 80% of the control sample value. This implies that the introduction of the quick lime to the volcanic ash laterized concrete improves the compressive strength of the concrete sample while it can be said that the volcanic ash – lime cement in the laterized concrete shows a good pozzolanic activity having caused the laterized concrete to have gathered a strength value of above 80% from the initial 7-day strength value of about 30%. The development conforms to the requirements of ***ASTM C618 08a*** and hence can be hoped to have strength similar to the normal concrete (i.e. the control) at later days of hydration such about 60 or 90 days as is experienced for pozzolanas or pozzolanic cement in general.

CONCLUSIONS

From the studies carried out on the effect of calcium oxide on volcanic ash laterized concrete the followings can be deduced:

(i).The specific gravity of volcanic ash is 3.04 which is close to 3.15 for cement as provided by Neville(2006), while the chemical analysis from previous studies on the volcanic ash sample reveals the total of SiO_2, Al_2O_3 & Fe_2O_3 is around 68% which is just below 70% as required by ASTM C618.

(ii).The setting time was slower compared to conventional ordinary Portland cement concrete.

(iii).Volcanic ash – cement can indeed become a viable alternative to ordinary Portland cement.

(iv).The 20%lat/20%CaO: 80%VA sample gave a good strength value and can be adopted for construction of buildings and infrastructures in the rural areas.

The following are hereby recommended for further studies

(i). An investigation into higher content of quick lime (CaO) possibly up to 40% and effect of varying proportions of VA – Lime cement on varying laterite content on the laterized concrete sample.

(ii). An investigation into effect of CaO on the compressive strength of the volcanic ash laterized concrete at curing age beyond 28-days as required for pozzolanas to confirm its pozzolanic tendency.

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APPENDIX: Plot of the Particle Size Distribution for Granite, Sand and Laterite