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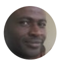
Article · April 2013

DOI: 10.15580/GJSETR.2013.4.020313426



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GREENER JOURNALS

Greener Journal of Science, Engineering and Technological Research

ISSN: 2276-7835 Impact Factor 2012 (UJRI): 0.7563 ICV 2012: 5.62

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Research Article

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ABSTRACT

This paper presents the results of the experimental assessment of the Flexural performance of Fly ash Laterized concrete (FA-LATCON). Test were conducted on concrete mixtures which was obtained by replacing 0 and 20% by weight of ordinary portland cement (OPC) with Fly ash (FA) and replacement of fine aggregate (sand) with Laterite (Lat.) by 0%, 10%, 20% and 30% for hydration period of 7, 21, 28 and 56days. Series of tests on fresh and hardened properties on FA-LATCON was carried out. The design mix was made for 28days target strengths of 25N/mm^2 with 0.65 water to Binder ratio. The Flexural strength measured after 28days of curing increase with age but decrease with increase in Laterite and FA content respectively. The FA-LATCON Flexural strength performance was satisfactory having achieved a least ratio of 28days Flexural strength to 28-days design compressive strength of 0.273.

Keywords: Blended Flyash Cement, Flexural performance, Fly ash Laterized concrete (FA-LATCON), Laterite (Lat.).

INTRODUCTION

Flexural strength of a concrete is described as its aptitude to survive failure from bending. It is generally measured by loading 150 x 150 x 460 mm concrete beams, also Flexural strength is defined as one of the tests to measure the tensile strength of concrete to resist failure in bending such as beam and slab. According to Megson, (2007), the materials ultimate strength in bending is defined by the modulus of rapture (MOR). He further explained that this can be taken to be the maximum direct stress in bending (σx,u) which corresponding to the ultimate moment (Mu) and is assumed to be related to ultimate moment by elastic relationship in equation 1.

$$\sigma x,\ u=[Mu/I]Y_{max} \qquad \text{........................} \quad \textbf{Equation 1}$$

where, Mu = Moment of resistance at the section
I = Second moment of area of the section
Y_{max} = Distance of the layer under stress from the neutral axis
σ = Stress

Two of the standards for testing concrete beams for flexural strength are: ASTM C 78 (CSA A23.2-8C) and ASTM C 293. In ASTM C 78 (CSA A23.2-8C) a simple concrete beam is tested by third-point loading. In ASTM C293 a simple concrete beam is tested by center-point loading. The flexural strength found is expressed as the "Modulus of Rupture" (MR) in MPa or psi or N/mm^2. The flexural MR can vary from about 12% to 20% of the compressive strength of the concrete. Designers of concrete structures, where bending is an integral function of the structure, must take into consideration flexural stresses. Designers of concrete pavements, runways, other slabs on ground and prestressed concrete must design according to a theory, which is based on flexural strength.

Today, many agencies use compressive strength of concrete as an index of flexural strength. An empirical relationship is established between compressive strength and flexural strength based on a given set of materials and conditions as well as the size of the concrete member. This relationship is usually accomplished through laboratory testing or the use of a cement content based on experience to yield the needed MR.

The fact that the concrete industry and the inspection agencies are much more familiar with the traditional concrete cylinder compression test for control and acceptance does not mean that flexural strength is not important. The most important underlying factor for the acceptance of any concrete in flexure is still its ability to resist failure from bending, and this is measured by testing its flexural strength.

The Flexural strength represents the ultimate strength of materials in bending and is taken to be corresponding to the ultimate moment by the elastic relationship (Megson, 2007). It is measured in terms of stress. The proposed flexural strength where at the time of delivery to the work site, the average flexural strength in the test specimens shall be 4.5 MPa, with no individual unit less than 4 MPa (National Concrete Masonry Association, 2002). For slab construction, the flexural strength must be identified, because the design of slab or pavement is based on the theory of flexural strength. Therefore, laboratory mix design based on flexural test may be required.

Experimental work

Materials and methods

Material collection

The Fly ash used in this investigation was collected from waste dump of the PHCN thermal plant in Oji River, Enugu State. Enugu State is situated in the south Eastern part of Nigeria known as the ‘Coal City’. The cement used was locally manufactured Ordinary Portland cement with a brand name called Burham conforming to ASTM Type I. The Laterite used was obtained from Gidan kwano as raw from source and was dried and crushed to smaller grains and larger particles and other debris were judiciously removed. The sand was obtained from Sarkin pawa, while Crushed granite coarse aggregate of maximum size 20mm was obtained from Dikko Quary, all in Niger state, Nigeria.

The physical and chemical properties of the Laterite and cementing materials was presented in Table 1. Also the result of the Grain size distribution of the aggregates is presented in Table 2.

The water used served as an important ingredient of concrete to initiate the chemical reaction within the cement, the mix water was ensured to be completely free from chlorides and sulphates. This water was ordinary potable water and it was used throughout the investigation as well as for curing concrete specimens and was obtained from Bore Hole in Federal University of Technology Minna (FUT Minna) campus.

Concrete Mixture Proportions

The mix design adopted for the production of the 25N/mm^2 grade of FA-LATCON was based on the guideline given in the design of Normal concrete mixes (Design of normal concrete mixes, Department of environmental (1988), United Kingdom) with a slight modification to adapt to the available and intended local raw materials. In a bid to achieve a concrete grade of 25N/mm^2 at 28days target strength, water to Binder (W/B) ratio of 0.65 was used. The concrete mix design (mix-proportion) of FA-LATCON used in this study is shown in Table 3, The resulting concrete consists of a two phase material, namely mortar and aggregate phases. In this investigation the two phases were assessed together. The FA/OPC Laterized concrete mixtures was made up of varying amount of Laterite up to 30% by weight of sand as fine aggregate (0%, 10%, 20%, 30%) while the fly ash content was introduced as cement replacement at 0%proportion and 20% by weight in all the concrete mixture. This is in consonance with the limits in literature to which the part replacement was found adequate to produce structural concrete (Varghese, 2006; Ogunbode and Olawuyi, 2008; Olusola, 2005). The performance characteristic of all the FA-LATCON was compared with reference concrete containing 0% lat/0%FA.

Test specimen, curing conditions and Testing Details.

A rotating pan mixer (capacity 0.05m^3) was used for mixing the constituent Material. Fresh concrete was then cast in a 150x150x500mm beam mould and left for 24 hours before demoulding. Immediately after demoulding, the specimens were kept in the curing Tank at 21±0.5 ^{0}C for an hydration period of 7, 14, 21, 28 and 56days and were then transferred to a relative humidity until testing. Comprehensive series of tests on fresh and mechanical properties of FA-LATCON such as slump, density and Flexural strength were carried out. Workability of each mix was assessed using the slump values of fresh FA-LATCON mixture in accordance with ASTMC 143-00, and no air entraining admixtures was used. Flexural strength test was performed on 150x150x500mm beams at an age of 7, 14, 21, 28 and 56days as per ASTM C-39. Three specimens were tested for each mix proportion and the mean values were reported in Table 6.

The modulus of rupture (fbt) is given by Osunade, etal (1990) and osunade (2002) as: **fbt=pl/bd^3**.

This formula was used as a basis for computing the Flexural strength of the experimental samples.
Where p= max total load on the beam , L= length of the beam (span), B= width of the beam, D= depth of the beam

RESULTS AND DISCUSSION

Fly ash and Laterite

A good pozzolan is described to possess not less than 70% of a total content of Silicon Dioxide (SiO_2), Aluminium Oxide (Al_2O_3) and Iron Oxide (Fe_2O_3) as specified in ASTM C 618-78 requirement for chemical composition of pozzolanas, FA used in this research work met these requirement as it possess 73.04%, see Table 1. Fly ash (FA) also contains cementitious compounds like calcium oxide, alumina and iron oxide (total about 30%). The amount of oxides of sodium and potassium known as 'alkalis' in FA is found to be 0.35% which is within the range of 0.2-1.3 as presented by Neville, (2006) and 0.6% maximum specified in ASTM C150-00 for OPC and also a maximum of 1.5% specified in ASTM C-618 for Fly ash in Cement and concrete. Higher alkali presence in the Fly ash may have deleterious effects leading to disintegration of concrete due to reaction with some aggregate and affect the rate of gain in strength of cement (Neville, 1959). Table 1, however, shows the specific gravity of the FA sample as 2.25, a value less than that of cement (3.15) as provided by Neville, (2006).

Table 1, also presents the results of the physical properties of the constituent concrete material. The Laterite (lat) sample has a specific gravity of 2.60, bulk density of 1564.05 kg/m^3, moisture content of 12.7%, fineness modulus of 3.32, coefficient of uniformity Cu of 6.20 and coefficient of curvature Cc of 0.70. It has Silica: Sesquioxide ($SiO_2/Al_2O_3+Fe_2O_3$) ratio which is also simply referred to as Silica Ratio (SR) as 0.97 as shown in Table 3 which presents the result of Chemical Analysis carried out on the Laterite sample. The S-S ratio is less than 1.33 indicating a true Laterite classification as specified by Fermor (1981). The sand on the other hand has a specific gravity of 2.57, bulk density of 1368.6 kg/m^3, moisture content of 5.4%, fineness modulus value of 3.06, Cu of 2.60, and Cc of 1.00. These results reflect that both the Laterite and sand samples are well graded. The granite sample has a specific gravity of 2.71, bulk density of 1570.29 kg/m^3, Cu of 4.16, and Cc of 1.11, reflecting a uniform sample. All the aggregates conformed to the BS 812.

Fresh properties of fresh paste and concrete

Setting time

The initial and final setting time of FA/OPC (cementitious) paste are presented in Tables 4. The table shows that the setting time increased with the 20% introduction of FA (i.e. from 0% to 20%). The setting times of the replacements is within the provision of BS EN 196-3 limits of not less than 45 min initial setting time and not more than 10 hours of final setting time and also satisfy the requirements of both Fly ash and Portland cement. Due to increase of setting time, the heat of hydration is less in FA/OPC than normal Portland cement, hence it is possible to manufacture blended FA/OPC equivalent to Type C of Portland cement and Type FC of Portland Fly ash cement using up to 20% FA content (AS 2350.3, 1980).

Slump values

The slump values of non-air entrained FA-LATCON are presented in Table 5, All the mixtures were produced at a slump that range between 35 and 40mm. From the results of the slump test performed on the mixes, it can be deduced that, to attain the required workability, the mixes containing FA and Laterite required higher water content than their corresponding conventional mixes (i.e. concrete without Laterite and Fly ash substitution).

Properties of Hardened concrete

Density of FA-LATCON

A slight decrease in density with the increase of Laterite and 20% FA was observed due to the replacement of comparatively heavier cement and sand by lighter FA and Laterite (Table5). however 20% FA and varied percentage replacement of Laterite (0%,10%,20% and 30%) give a decrease of 9.1% compared to control concrete (0%, lat/ 0% FA). The 28day density of FA-LATCON ranged between 2205 and 2425Kg/m^3.

Flexural Strength/performance of FA-LATCON

The variation of Flexural strength with age for all percentages of replacement of Fly ash and Laterite is represented in Table 6. The rate of strength gained as shown in Table 7 indicates that Flexural strength of the conventional (i.e. Control; concrete without Laterite and fly ash substitution) is higher than that of Fly ash Laterized concrete. It was also observed that flexural strength decreases with increase in Laterite content from 0% to 30% and the introduction of FA at 20%, and it was observed that Flexural strength continued to increase with age. The reduced strength of the initial stages of hydration confirms that Laterite and FA acts as retarder. The effect being the retardation of the initial process of hydration which invariably affects the initial process of strength development. The progressive increase in Compressive and Flexural strength with age could be adduced to a very large extent on its physical structure (Neville, 2006). The physical structure of concrete at an advanced age is significantly different from that of the same concrete at an early age; the former consists of a compact network of aggregates strongly held together by cement gel while the latter consists of a fairly discrete pack of aggregates, stiffened cement paste, capillary water and a relatively small proportion of cement gel which ton a large extent Laterite as an aggregate as provided and Fly ash as a potential cementitious material also inject into the product. It is the increase in the gel/ space ratio (a function of physical structure) of concrete at advanced age that accounts for the increase in the Strength. This phenomenon was also noticed in the case of FA-LATCON.

It is remarkable to note that the flexural strength performance of Blended OPC/FA Laterized concrete was adequate, having attain a least ratio of 28 day compressive strength of 0.273, this ratio is usually required to be above 0.07 (Neville, 2006),

Table 1: Chemical and physical properties of Laterite, Sand and cementing materials.

Oxide compounds	**Laterite (Lat.)**	**Sand**	**Coarse Agg.**	**Fly ash**	**ASTM C 618 requirement for fly ash (Class N)**	**Portland cement (PC) ASTM Type I**
Calcium oxide (CaO)	-			4.24		64.10
Silica (SiO_2)	29.10			60.20		21.40
Alumina (Al_2O_3)	20.30			4.98		5.70
Iron oxide (Fe_2O_3)	33.50			6.57		3.50
SiO_2+Al_2O_3+Fe_2O_3	82.90			71.75	Minimum =70	30.60
Al_2O_3+Fe_2O_3	53.80					
Sulphur trioxide (SO_3)					Maximum =4 2.1	4 2.10
Magnesia (MgO)				5.14		2.10
Tin oxide (TiO_2)	1.30					
Sodium oxide (Na_2O)	0.02					0.50
Potassium oxide (K_2O)	0.14					0.60
Equivalent alkali (Na_2O)						0.89
Free lime (CaO)						0.60
Silica Ratio (SR)	0.97					
Loss on ignition	-			0.20	Maximum =10	1.10
Physical properties						
Density, kg/m3 *Loose Bulk Density* *Compact Bulk Density*	 1145.30 1564.05	 1148.2 1368.6	 1348.421 570.29		Maximum=34	3150
Specific Gravity	2.6	2.57	2.71	2.25		
Finess modulus	3.32	3.06	3.06			
Coefficient of curvature (Cc)	0.70	1.0	1.16			
Coefficient of Uniformity (Cu)	6.20	2.6	4.55			
Natural Moisture content (%)	12.7	5.4				
Liquid limit (%)	31.4					

Table 1 Continues

Plastic limit (%)	48.2					
Plastic index (%)	17.0					
%Void	35.4	19.12				
Colour	Reddish-brown					
AASHTO Classification	A-7-6					

Table 2: Sieve analysis of Aggregates

Sieve size mm	**Fine % passing (Sand)**	**Fine % Passing (Laterite)**	**Coarse % passing (Granite)**
20	100.0	100.0	87.3
14	100.0	100.0	22.3
6.3	100.0	100.0	0.7
4.75	98.2	92.4	0.0
2.36	95.0	80.0	-
1.18	92.0	73.0	-
0.600	78.4	58.6	-
0.300	30.6	36.0	-
0.150	2.4	17.0	-
0.075	0.4	5.0	-
Pan	0.0	0.0	-

Table 3: Mix proportions of FA/OPC Laterized concrete mixtures

Mix Designation	**FA**	**W/B**	**Materials (Kg/m^3)**					
			Water	**Cement**		**Aggregates**		
	(%)		**(Kg)**	**OPC**	**FA**	**Fine**		**Coarse**
FA/Lat						**Sand**	**Laterite**	
0%FA/0Lat	**0**	**0.65**	**170**	**309.0**	**0.0**	**556.0**	**0.0**	**1430**
0%FA/10Lat	**0**	**0.65**	**170**	**309.0**	**0.0**	**500.4**	**55.6**	**1430**
0%FA/20Lat	**0**	**0.65**	**170**	**309.0**	**0.0**	**444.8**	**111.2**	**1430**
0%FA/30Lat	**0**	**0.65**	**170**	**309.0**	**0.0**	**389.2**	**166.8**	**1430**
20%FA/0Lat	**20**	**0.65**	**170**	**247.2**	**61.8**	**556.0**	**0.0**	**1430**
20%FA/10Lat	**20**	**0.65**	**170**	**247.2**	**61.8**	**500.4**	**55.6**	**1430**
20%FA/20Lat	**20**	**0.65**	**170**	**247.2**	**61.8**	**444.8**	**111.2**	**1430**
20%FA/30Lat	**20**	**0.65**	**170**	**247.2**	**61.8**	**389.2**	**166.8**	**1430**

Numerics in mix designation represent percentage of Fly ash (FA) and Laterite (Lat); B: Binder, 0%FA/0%Lat.:is Control OPC concrete.

Table 4: Initial and Final Setting Time of FA/OPC Paste

Fly ash (FA) Content (%)	INITIAL (hr.+min)	FINAL (hr.+min)
0	1+35	2+00
20	2+35	3+05

Table 5: Slump, Density and Compressive Strength properties of FA/OPC Laterized concrete.

Mix ID FA/Lat (%)	Slump (mm)	28-day *density* (Kg/m^3)	28-day *compressive strength* (N/mm^2)
0%FA/0Lat	**38**	**2425**	**35.09**
0%FA/10Lat	**38**	**2467**	**35.01**
0%FA/20Lat	**37**	**2327**	**31.46**
0%FA/30Lat	**36**	**2257**	**27.15**
20%FA/0Lat	**37**	**2301**	**21.94**
20%FA/10Lat	**35**	**2288**	**21.91**
20%FA/20Lat	**34**	**2256**	**19.88**
20%FA/30Lat	**34**	**2205**	**15.02**

Table 6: Variation of Flexural strength properties of FA/OPC Laterized concrete

Flyash content (%)	Laterite content (%)	7days	14days	21days	28days	56days
		Modulus of Rupture (N/mm^2)				
0	0	6.30	8.40	8.95	9.04	10.40
	10	4.55	7.49	8.35	8.76	9.52
	20	3.68	6.72	8.46	8.57	11.56
	30	2.71	5.10	6.87	9.57	12.14
20	0	4.77	5.53	6.95	7.65	9.70
	10	3.10	4.25	4.35	4.95	9.00
	20	2.63	5.15	4.05	4.80	9.94
	30	2.55	4.10	3.25	4.10	8.70

Table 7: Rate of Flexural strength Gain

Fly ash (%)	Laterite (%)	14:7days Strength	21:7days Strength	28:7days Strength	56:7days Strength
0	0	1.33	1.42	1.43	1.65
	10	1.65	1.84	1.93	2.09
	20	1.83	2.30	2.32	3.14
	30	1.88	2.54	3.53	4.48
20	0	1.16	1.46	1.60	2.03
	10	1.37	1.40	1.60	2.90
	20	1.96	1.54	1.83	3.78
	30	1.61	1.27	1.61	3.41

CONCLUSION

From the test carried out to determine the flexural performance (behavior) of Laterized concrete made with 20% Fly ash, the following conclusions were drawn.

- Non-air entrained FA-LATCON having a slump value that ranged between 34 and 38mm showed satisfactory workability with no segregation or excessive bleeding which gives a positive acceptance of the product.
- There is an increase in both the initial and final setting times of cement paste upon the addition of Laterite (at 0%, 10%, 20% and 30%) and fly (at 20% all through) and the setting times are within the range recommended for plain cement paste.
- The flexural performance (behavior) of FA-LATCON was satisfactory, having achieved a least ratio of 28day design compressive strength of 0.273 which is not less than 0.07.

Plate 1: simple concrete beam tested

Plate 2: third-point loading system by third-point loading

REFERENCES

AS 2350.3, Australian Standard, Standards Association of Australia, Sydney, 1980.

ASTM C 150-00, Standard specification for Portland Cement. Annual Book of ASTM Standards, Philadelphia, USA.

ASTM C 618-08, Standard specification for coal fly ash and raw or calcined natural pozzolan for use as a mineral admixture in concrete, Annual Book of ASTM Standards, Philadelphia, USA.

British Standard Institution, Method for Determination of Particle Size Distribution, BS 812: Part 103, 1985, London.

British Standard Institution, Methods of testing cement: Determination of setting times and soundness, BS EN 196: Part 3, 2005, London.

Fermor L L(1981). "What is Laterite?"Geology Magazine, 1981; 5 (8): 453 – 462.

Megson T H G (2007). "Structural and Stress Analysis". Second Edition. United Kingdom : Elsevier Ltd.

National Concrete Masonry Association (2002). "Evaluation of Paver Slab Flexural Strength Testing". Research and Development Laboratory : USA

Newman J and Ban S C (2003). "Advanced Concrete Technology : Constituent Materials". Elsevier Ltd : London.

Newman J and Ban S C (2003). "Advanced Concrete Technology : Concrete Properties".Elsevier Ltd : London.

Neville A M(1959). Role of cement in creep of mortar, J. Amer. Concrete Institute, 1959; 55(1): 963-84.

Neville A M (2006). Properties of Concrete, 4th Edition, copyright © 2000, Asia, Person Education Pte. Ltd., 2006
Ogunbode EB and Olawuyi BJ (2008). Strength Characteristics of Laterized Concrete Using Lime-Volcanic Ash Cement, Environmental Technology & Science Journal (ETSJ), 3(2) (2008) 81-87.
Olusola KO (2005). Factors Affecting Compressive Strength and Elastic Properties of Laterized Concrete, Ph.D. Thesis, Department of Building, Obafemi Awolowo University, Ile-Ife.
Osunade JA, Adeyefa PO and Lasisi F (1990). Shear and Tensile Strength of Unreinforced Laterized Concrete, Ife Journal of Technology, 2(1), pp. 8-17.
Osunade JA (2002). Effect of Replacement of Lateritic Soils with Granite Fines on the Compressive and Tensile Strengths of Laterized Concrete, Building and Environment, 37(1), pp. 491-496.
Varghese P C (2006). Building Materials, New Delhi, Prentice – Hall of India.