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Research Article

Consequences of Fractional Substitution of Laterite with Sand on Elastic Properties of Building Blocks in Relation to their Water Absorption Rate

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Abstract: A good number of structural failures can been traced to the quality of blocks used as walling materials (which provide lateral stability) in the construction of these structures. Some elastic properties which have been neglected to an extent with regards to block moulding technology were considered in this work. Blocks were produced with readily available and affordable laterite (in some locations) and fractionally substituted with river sand to reduce the effect of rising cost of river sand and also embrace the various advantages of laterite. The consequence of this substitution (10% - 40%) was considered on these elastic properties as well as the water absorption rate and the results show that inclusion of sand in the mix improved the elastic properties but reduced the durability assessed by the water absorption rate. The use of laterite in producing building blocks provides good thermal insulating and water resistance qualities as well as natural beauty and even resistance to termites, bacteria and fungi. This is beneficial in tropical regions.

Keywords: Elastic properties, laterite blocks, water absorption, fractional substitution, Poisson's ratio, static modulus of elasticity, shear modulus

INTRODUCTION

Shelter, which is one of the basic needs of man is provided primarily in form of housing units. The available units are not adequate to cater for the rising population all over. This is as a result of rising cost of building materials. Building blocks as the name implies, are primarily used as building materials in the construction of walls. They can also be referred to as masonry units. In West Africa, the construction of most housing units depends largely on these building blocks which ultimately affects the total cost of construction. Building materials constitute about 60 to 75% of total cost of construction (Adegun, O.B. and Adedeji, Y.M.D., 2017). Different varieties of blocks exist, depending on the raw materials adopted in their production. The raw materials ranges from conventional ones like include cement, water, fine aggregates (river sand, clay, laterite), coarse aggregates (gravel), to unconventional ones like granulated coal, volcanic cinders, expanded clay, shale or slate, quarry dust, admixtures, etc. The choice of material depends largely on preference, availability and affordability of the material, desired strength, weight of the finished block and even aesthetics.

The production method includes three major steps namely, mixing, molding and curing. The manufacturing process involves compaction of newly mixed constituent materials in a mould followed immediately by extrusion of the pressed block so that the mould can be used repeatedly. The finished blocks are required to be self-supporting and able to withstand any movement and vibration from the moment they are extruded. The final stage of block production is curing just as it is in concrete production.

In this paper, we would be considering some conventional materials based on availability and affordability. Laterite is readily available and affordable in most parts regions. Similarly river sand is accessible in most riverine areas although the cost of dredging can skyrocket the final cost of river sand. The use of laterite in block production is proposed in areas where it is in abundance. Literature has identified some other properties and benefits of laterite that makes it a desirable material. These include thermal insulating and water-resistant properties, relatively low degree of porosity, natural beauty and even resistance to termites, bacteria and fungi (Agbede, I.O. and Manasseh, J., 2008; Boeck, L. et. al., 2000; Aguwa, J.I., 2010; Adams, E.A.,2001; Komolafe, O.S., 1986). Laterite was replaced partially with river sand and this leads to reduced dependence on river sand which is costly and scarce (in some areas), in block production. Also, it is economical to use laterite in block production because very little cement is required unlike using river sand which requires more quantity of binder. These will lead to reduction in production cost of blocks and consequently housing units will be affordable by most people.

Nigerian Building and Road Research Institute (NBRRI) proposed a compressive strength value of 1.65N/mm^2 for laterite blocks (Madedor, A.O., 1992). It is interesting to note that the author has already ascertained that laterite blocks could be produced with 10% cement content to yield a compressive strength value of 2.1N/mm^2. This is greater than the recommended value by NBRRI. Moreover, this obtained value of compressive strength of laterite block can compete favourably with the recommended value of Nigerian Industrial Standard (NIS) for hand- compacted sandcrete blocks which is 2.0N/mm^2 (Okere, C.E. 2017).

Blocks belong to the same household with concrete which is one of the major Civil Engineering materials and they have similar properties at the hardened state. These properties are their basic qualities or characteristics. Strength property, elastic property and durability are the major ones. According to Ahmed, S.H. (1994), strength is an instantaneous or short term property while durability is a long term property. Recall that blocks are used as walling units in construction of civil infrastructures. Walls which are load bearing act as a form of bracing to structural frames and also provide lateral stability to structures. Some structural failures can be traced to poor/low quality blocks. Blocks fail by shearing.

Durability is the ability of concrete to withstand the conditions for which it has been designed, without deterioration, over a period of years. Concrete should be dense, reasonably water tight (or less permeable), able to resist changes in temperature as well as wear and tear from weathering. Penetration of concrete by materials in solution may adversely affect its durability. This penetration depends on the permeability of the concrete. Permeability can be in form of water permeability, air and vapour permeability. Water absorption rate will be the yard stick for measuring the durability of the blocks produced in this work. Water absorption is a measure of the difference in weight of the specimen before and after immersion in water for a specified time, expressed as a percentage of weight before immersion (Okere C.E. and Onwuka, D.O., 2016).

The elastic properties include Poisson's ratio, static modulus of elasticity and shear modulus/modulus of rigidity.

Poisson's ratio is the ratio of lateral strain to axial strain. Poisson's effect can be felt in the realm of structural geology. Concrete/blocks are subject to Poisson's effect while under stress. The material will expand or contract in the vertical direction as a direct result of the applied stress and it will also deform in the horizontal direction as a result of Poisson's effect. This change in strain can affect or form joints and dormant stresses in the material. Poisson's ratio is a measure of the Poisson effect, the phenomenon in which a material tends to expand in directions perpendicular to the direction of compression. Conversely, if the material is stretched rather than compressed, it usually tends to contract in the directions transverse to the direction of stretching.

Modulus of elasticity is the ratio of stress to strain. It is a measure of stiffness or resistance to deformation in hardened concrete. It also assesses the resistance of concrete to freezing and thawing. Hooke's law for normal stress and strain states that stress is directly proportional to strain. The constant of proportionality is Young's modulus of elasticity.

Shear modulus is the ratio of shear stress to shear strain. Hooke's law for shearing stress and strain which states that shear stress is directly proportional to shear strain for a member under shear deformation. The constant of proportionality here is the shear modulus.

The elastic properties of building blocks have been ignored to an extent with regards to block moulding technology. Apart from the compressive strength of blocks, very little is known about these elastic properties of blocks produced in Nigeria. There is little documentation with regards to these structural characteristics which are required by structural engineers and related scientists for structural design computations. The lack of information on these leaves room for much speculation, approximations and arbitrariness, which could be detrimental to the design of structures.

This work presents a fractional substitution of laterite with river sand using 10% to 40% substitution and the consequences of this was considered on the elastic properties of the blocks as well as the durability defined by the water absorption rate.

EXPERIMENTAL SECTION

Materials

The following materials were used for the experimental investigation.

Laterite: This was sourced from Ikeduru L.G.A. Imo State. The grading and properties conformed to BS 882 (1992).

River sand: This was got from Otamiri river, in Imo State. The grading and properties of this fine aggregate conformed to BS 882.

Cement: Eagle cement brand of ordinary Portland cement with properties conforming to British standard was used (BS 12 1978).

Water: Potable water conforming to the specification of EN 1008:2002 was used

Methods

The materials for the experimental investigation were sourced and transferred to the laboratory where they were spread and allowed to dry. Various tests and analysis were carried out on the laterite and river sand samples before the blocks were produced.

Physical property tests

The laterite was observed and tested to determine the physical properties. These include sieve analysis, specific gravity, moisture content, bulk density and plasticity index. The sieve analysis was carried out according to standard procedures (BS 812: Section 103.1:1985 and BS 1377: 1975). The plasticity index test was carried out in accordance with BS 1377(1975).

Chemical property tests

Chemical analysis was carried out on the laterite sample to determine the chemical composition of the laterite. The quantities of various elements per kilogram of laterite sample were determined. These include calcium, iron, magnesium, potassium, sulphate, aluminium, etc.

Preparation of test specimens

The mix proportions were measured by weight and blocks of size 450mm x 150mm x 225mm (solid) were produced. The blocks were demoulded immediately after manual compaction of newly mixed constituent materials in a mould. The blocks were cured for 28 days after 24 hours of demoulding using the environmental friendly method of covering with tarpaulin/water proof devices to prevent moisture loss.

The mix ratios prescribed for the laterite blocks made without river sand (used as control) are presented on Table 1.

Table 1: Mix ratios prescribed for the laterite blocks made without river sand (Control)

Exp no.	Mix ratios(w/c: cement: laterite)	Cement content (%)
1	0.8:1:8	10
2	1:1:12.5	8
3	1.28:1:16.67	6

Laterite was substituted fractionally with river sand using 10%– 40% substitution to produce the sand-laterite blocks. The mix ratios prescribed for the sand-laterite blocks are presented on Table 2.

Table 2: Mix ratios for Sand-laterite blocks

Exp. No	Mix ratios(w/c: cement: sand: laterite)	% Replacement	Cement content (%)
1	0.8: 1: 3.2: 4.8	40	10
2	1: 1: 3.75: 8.75	30	8
3	1.28: 1: 3.334: 13.336	20	6
4	2.2: 1: 2.5: 22.5	10	4

Characteristics tests

In accordance to BS 2028, 1364, (1968), the blocks were tested for Poisson's ratio, static modulus of elasticity, shear modulus/modulus of rigidity and water absorption as follows:

A. Poisson's ratio

The initial cracking load in flexure was recorded and used to calculate tensile stress at cracking in flexure. The initial cracking load in compression specimen was recorded and used to calculate compressive stress at cracking in compression specimen. With these two parameters known, Poisson's ratio was calculated using the following equation:

$$\mu = \sigma_t / \sigma_c \qquad (1)$$

where μ = Poisson's ratio
σ_t = tensile stress at cracking in flexure
σ_c = compressive stress at cracking in compression specimen

Three blocks were tested for each point and the average taken as the Poisson's ratio of the point.

B. Static modulus of elasticity

Blocks were tested for static modulus of elasticity using the following relationship:

$$E_c = 1.7\rho^2 f_{cu}^{0.33} \times 10^{-6} \qquad (2)$$

Where ρ = density
f_{cu} = compressive strength

Three blocks were tested for each point and the average taken as the static modulus of elasticity of the point.

C. Shear modulus/modulus of rigidity

The modulus of rigidity or shear modulus is not normally determined by direct measurement. It is the ratio of shear stress to shear strain. However the following equation was used for its calculation:

$$G = E_c / 2(\mu + 1) \qquad (3)$$

where G = shear modulus
E_c = Static modulus of elasticity
μ = Poisson's ratio

Three blocks were tested for each point and the average taken as the shear modulus of the point.

D. Water absorption

The blocks for this test were weighed and immersed in water for 24 hours. On removal from water, they were reweighed to determine the quantity of water absorbed. Water absorption was calculated as a measure of the difference in weight of the specimen before and after immersion in water for the specified period expressed as a percentage of weight before immersion. Three blocks were tested for each point and the average taken as the water absorption of the point.

RESULTS AND DISCUSSION

Laboratory results

The results of the various tests conducted in the laboratory are presented as follows:

Physical property tests results of laterite

The physical property tests results are presented on Tables 3 to 8. The summaries of physical properties are presented on Table 8.

Table 3: Grain size distribution of laterite

Sieve size (mm)	Weight of Sieve (g)	Weight of Sieve & Sample (g)	Weight of Sample Retained (g)	Cumulative Weight of Sample Retained (g)	Percentage Finer
4.75	496.00	496.00	-	-	100
2.00	410.00	427.00	17.00	17.00	96.60
1.18	402.00	485.90	83.00	100.00	80.00
0.850	384.00	474.20	90.00	190.00	62.00
0.600	381.20	516.00	134.80	324.80	35.04
0.425	486.00	561.00	75.10	399.90	20.02
0.300	366.00	413.30	47.30	447.20	10.56
0.150	312.00	358.00	46.00	493.20	1.36
0.075	345.10	350.90	5.80	499.00	0.20
Pan	273.00	274.00	1.00	500.00	-

Table 4: Bulk density of laterite

Property	Content (Sample A)	Content (Sample B)
Mass of cutter (kg) and wet sample (kg)	0.290	0.286
Mass of cutter (kg)	0.096	0.096
Mass of sample (kg)	0.194	0.190
Volume of sample (m^3)	9.817	9.817
Bulk density = mass of sample/ volume of sample (Mg/ m^3)	1.98	1.83
Average Bulk Density (Mg/ m^3)	1.91	

Table 5: Moisture content of laterite

Property	Content (Sample A)	Content (Sample B)
Weight of can and wet sample (g)	77.00	77.50
Weight of can and dry sample (g)	71.00	71.30
Weight of can (g)	25.00	26.08
Weight of dry sample (g)	46.00	45.22
Weight of water loss (g)	6.00	6.20
Moisture content %	13.04	13.71
Average moisture content %	13.38	
Dry density ρ_d = Bulk density / (1 + Moisture content) (Mg/ m^3)	1.68	

Table 6: Specific gravity of laterite

Property	**Content (Sample A)**	**Content (Sample B)**
Mass of bottle + soil + water[M3] (g)	388.00	387.00
Mass of bottle + soil [M2] (g)	153.80	154.40
Mass of bottle full of water only[M4] (g)	369.30	368.20
Mass of bottle [M1] (g)	123.80	124.40
Mass of water used [M3 - M2] (g)	234.20	232.60
Mass of soil used [M2 - M1] (g)	30.00	30.00
Volume of soil [M4 – M1] – [M3 – M2] = M5 (ml)	11.30	11.20
Specific gravity of soil particles Gs = [M2 –M1] / M5	2.65	2.68
Average specific gravity	2.67	

Table 7: Liquid and plastic limit determination of laterite

Type of test…Liquid Limit	**Content (Sample A)**	**Content (Sample B)**	**Content (Sample C)**
No of blows	22	27	30
Weight of wet soil + can (g)	36.82	36.89	30.46
Weight of soil + can (g)	29.00	31.00	25.10
Weight of can (g)	16.93	16.50	15.70
Weight of dry soil (g)	12.07	14.60	14.76
Weight of moisture (g)	6.92	5.89	5.36
Water content %	57.33	40.34	36.31
Average liquid limit	49.00		
Type of test….Plastic Limit	Content (Sample A)	Content (Sample B)	
Weight of wet soil + can (g)	34.00	33.90	
Weight of soil + can (g)	32.00	31.80	
Weight of can (g)	25.00	24.30	
Weight of dry soil (g)	17.00	17.50	
Weight of moisture (g)	2.00	2.10	
Water content %	11.76	12.00	
Average Plastic limit	11.88		

Liquid limit = 49.00 Plastic limit = 11.88 Plasticity Index = 37.12

Table 8: Summary of physical properties of laterite

Property	**Unit**	**Content**
Colour		Reddish brown
Consistency		Easily mouldable
Bulk density	Mg/ m^3	1.91
Initial Moisture Content	%	13.38
Dry Density	Mg/ m^3	1.68
Specific Gravity		2.67
Liquid Limit	%	49.00
Plastic Limit	%	11.88
Plasticity Index	%	37.12

Chemical property tests results of laterite

The results from the chemical property test are presented on Table 9.

Table 9: Chemical analysis of laterite

Component	**Unit**	**Content**
pH		6.04
Fe	Mg/kg	29.5
Zn	Mg/kg	22.26
$S0_4^{2-}$	Mg/kg	6.08
Ca	Mg/kg	120.11
Mg	Mg/kg	100.44
K	Mg/kg	0.00
$H^+ + Al^{3+}$(Exchangeable acidity)	Mmoles/kg	15.67

CEC (Cation Exchange Capacity)	Mmoles/kg	22.86

Characteristics tests results of blocks

The characteristics test results were determined and calculated using equations given in methods section and then presented on Tables 10 to 17.

Table 10: Experimental values of Poisson's ratios of laterite blocks made without river sand (Control)

Exp No	Mix ratios (w/c: cement: laterite)	Repli-Cates	Initial Cracking Load in Flexure (KN)	Tensile Stress at Cracking in Flexure σ_t (N/mm^2)	Initial Cracking Load in Compression (KN)	Compressive Stress at Cracking in Flexure σ_c (N/mm^2)	Poisson's Ratio $\mu = \sigma_t/\sigma_c$	Average Poisson's Ratio μ
1	0.8:1:8	A	15.5	0.230	80	1.185	0.194	
		B	17.5	0.259	90	1.333	0.194	0.174
		C	16.0	0.237	120	1.778	0.133	
2	1:1:12.5	A	2.5	0.037	20	0.296	0.125	
		B	3.5	0.052	25	0.370	0.141	0.135
		C	2.8	0.041	20	0.296	0.139	
3	1.28:1:16.67	A	2.5	0.037	20	0.296	0.125	
		B	2.3	0.034	40	0.593	0.057	0.110
		C	3.0	0.044	20	0.296	0.149	

Table 11: Experimental values of Poisson's ratios of sand-laterite blocks

Exp. No	Mix ratios (w/c: cement: sand: laterite)	Repli-cates	Initial Cracking Load in Flexure (KN)	Tensile Stress at Cracking in Flexure σ_t (N/mm^2)	Initial Cracking Load in Compr (KN)	Compressive Stress at Cracking in In Flexure σ_c (N/mm^2)	Poisson Ration $\mu = \sigma_t/\sigma$	Average Poisson's Ratio μ
1	0.8:1:3.2:4.8	A	8.0	0.119	120	1.778	0.067	
		B	21.5	0.319	120	1.778	0.179	0.112
		C	10.0	0.148	110	1.630	0.019	
2	1:1:3.75:8.75	A	13.5	0.200	130	1.926	0.104	
		B	12.0	0.178	110	1.630	0.109	0.110
		C	14.0	0.207	120	1.778	0.116	
3	1.28:1:3.334:13.336	A	6.5	0.096	90	1.333	0.072	0.077
		B	3.5	0.052	100	1.482	0.035	
		C	9.9	0.147	80	1.185	0.124	
4	2.2:1:2.5:22.5	A	6.0	0.089	60	0.889	0.100	
		B	5.0	0.074	80	1.185	0.062	0.082
		C	5.0	0.074	60	0.889	0.083	

Table 12: Experimental values of static modulus of elasticity of laterite blocks made without river sand (Control)

Exp. No	Mix ratios (w/c: cement: laterite)	Replicates	Compressive Strength f_{cu} (MPa)	Density ρ (kg/m^3)	Static Modulus of Elasticity E_c (GPa)	Average Static Modulus of Elasticity E_c (GPa)
1	0.8:1:8	A	2.148	1553.91	5.283	
		B	2.074	1527.57	5.047	5.149
		C	2.222	1520.99	5.118	
2	1:1:12.5	A	1.037	1448.56	3.610	
		B	1.022	1481.48	3.758	3.584
		C	0.830	1455.14	3.385	
3	1.28:1:16.67	A	0.889	1428.81	3.338	
		B	1.111	1428.81	3.593	3.349
		C	0.741	1422.22	3.115	

Table 13: Experimental values of static modulus of elasticity of sand-laterite blocks

Exp. No	**Mix ratios (w/c: cement: sand: laterite)**	**Replicates**	**Compressive Strength f_{cu} (MPa)**	**Density ρ (kg/m^3)**	**Static Modulus of Elasticity E_c (GPa)**	**Average Static Modulus of Elasticity E_c (GPa)**
1	0.8:1:3.2:4.8	A	2.667	1613.17	6.115	
		B	3.259	1626.34	6.640	6.414
		C	3.111	1619.75	6.486	
2	1:1:3.75:8.75	A	1.926	1448.06	4.673	
		B	2.074	1652.67	5.907	5.297
		C	2.074	1567.08	5.311	
3	1.28:1:3.334:13.336	A	1.482	1514.40	4.439	
		B	1.630	1520.99	4.621	4.591
		C	1.778	1514.40	4.714	
4	2.2:1:2.5:22.5	A	1.185	1520.99	4.159	
		B	1.333	1547.35	4.475	4.317
		C	1.259	1534.16	4.317	

Table 14: Experimental values of shear modulus of laterite blocks made without river sand (Control)

Exp. No	**Mix ratios (w/c: cement: laterite)**	**Replicates**	**Static Modulus of Elasticity E_c (GPa)**	**Poisson's Ration μ**	**Shear Modulus G (GPa)**	**Average Shear Modulus G (GPa)**
1	0.8:1:8	A	5.283	0.194	2.212	
		B	5.047	0.194	2.113	2.195
		C	5.118	0.133	2.259	
2	1:1:12.5	A	3.610	0.125	1.604	
		B	3.758	0.141	1.647	1.572
		C	3.385	0.139	1.465	
3	1.28:1:16.67	A	3.338	0.125	1.484	
		B	3.593	0.057	1.700	1.513
		C	3.115	0.149	1.356	

Table 15: Experimental values of shear modulus of sand-laterite blocks

Exp. No	**Mix ratios (w/c: cement: sand: laterite)**	**Replicates**	**Static Modulu of Elasticity E_c (GPa)**	**Poisson's Ration μ**	**Shear Modulus G (GPa)**	**Average Shear Modulus G (GPa)**
1	0.8:1:3.2:4.8	A	6.115	0.067	2.866	
		B	6.640	0.179	2.816	2.889
		C	6.486	0.019	2.973	
2	1:1:3.75:8.75	A	4.673	0.104	2.116	
		B	5.907	0.109	2.663	2.386
		C	5.311	0.116	2.397	
3	1.28:1:3.334:13.336	A	4.439	0.072	2.070	
		B	4.621	0.035	2.232	2.133
		C	4.714	0.124	2.097	
4	2.2:1:2.5:22.5	A	4.159	0.100	1.890	
		B	4.475	0.062	2.107	1.997
		C	4.317	0.083	1.993	

Table 16: Water absorption test results of laterite blocks made without river sand (Control)

Exp. No.	**Mix ratios (w/c: cement: laterite)**	**Replicates**	**Dry Mass (kg)**	**Wet Mass (kg)**	**Absorption %**	**Average Absorption %**
1	0.8:1:8	A	23.6	24.4	3.39	
		B	23.0	23.5	2.17	2.72
		C	23.2	23.8	2.59	
2	1:1:12.5	A	22.5	23.7	5.33	
		B	22.1	23.3	5.43	5.57
		C	21.8	23.1	5.96	
3	1.28:1:16.67	A	21.7	23.1	6.45	
		B	21.8	22.0	5.5	6.14
		C	21.6	22.9	6.48	

Table 17: Water absorption test results of sand-laterite blocks

Exp. No.	Mix ratios (w/c: cement: sand: laterite)	Replicates	Dry Mass (kg)	Wet Mass (kg)	Absorption %	Average Absorption %
1	0.8:1:3.2:4.8	A	24.3	25.5	4.90	
		B	24.7	26.1	6.07	5.42
		C	24.5	25.8	5.30	
2	1:1:3.75:8.75	A	22.9	24.4	6.55	
		B	24.8	23.6	6.05	6.85
		C	23.9	25.8	7.95	
3	1.28:1:3.334:13.336	A	23.3	25.1	7.73	
		B	23.6	25.1	6.36	7.19
		C	23.4	23.35	7.48	
4	2.2:1:2.5:22.5	A	22.9	24.1	5.24	
		B	23.1	24.5	6.06	5.49
		C	23.2	24.4	5.17	

ANALYSIS OF RESULTS

Physical analysis of laterite

The laterite used in this work is reddish-brown in colour. It has an easily mouldable consistency. A study of the particle size distribution curve shows that the laterite is well graded. The bulk density of laterite is 1.91 Mg/m^3. From literature, soil which shows massive structure and less porosity will show high bulk density from 1.6 to 1.7 Mg/m^3. Movement of water is hindered in such soils. Bulk density value of the laterite used in this work, is higher than this range of value stipulated. Bulk density, which is an indicator of soil compaction, is inversely related to porosity of the same soil. It reflects the soil's ability to function as structural support, water and solute movement.

The specific gravity of the laterite is 2.67. According to the British Soil Classification System (BSCS), the general range for specific gravity of clay and silty clay is 2.67 – 2.9. Therefore, the laterite falls under this category. Specific gravity number indicates how much heavier or lighter a material is than water.

The liquid limit value of the laterite is 49%. From BSCS, soils having liquid limit between 35% and 50% are said to have intermediate plasticity. Thus, with a liquid limit of 49%, the laterite used in this work can be said to have intermediate plasticity.

The plasticity index (PI) of the laterite is 37.12%. PI is the measure of the plasticity of a soil. It is the size of the range of water contents required for the soil to exhibit plastic properties. Its value is determined by measuring the difference between the liquid limit and plastic limit. According to BSCS, soils with plasticity index between 20 and 40% are said to be of high plasticity which tend to be clay. Therefore, the laterite used in this work falls under this category of high plasticity.

Using the American Association of State Highway and Transportation Officials (AASHTO) classification system, this laterite can be described as clayey sand under group A-2-7.

Chemical analysis of laterite

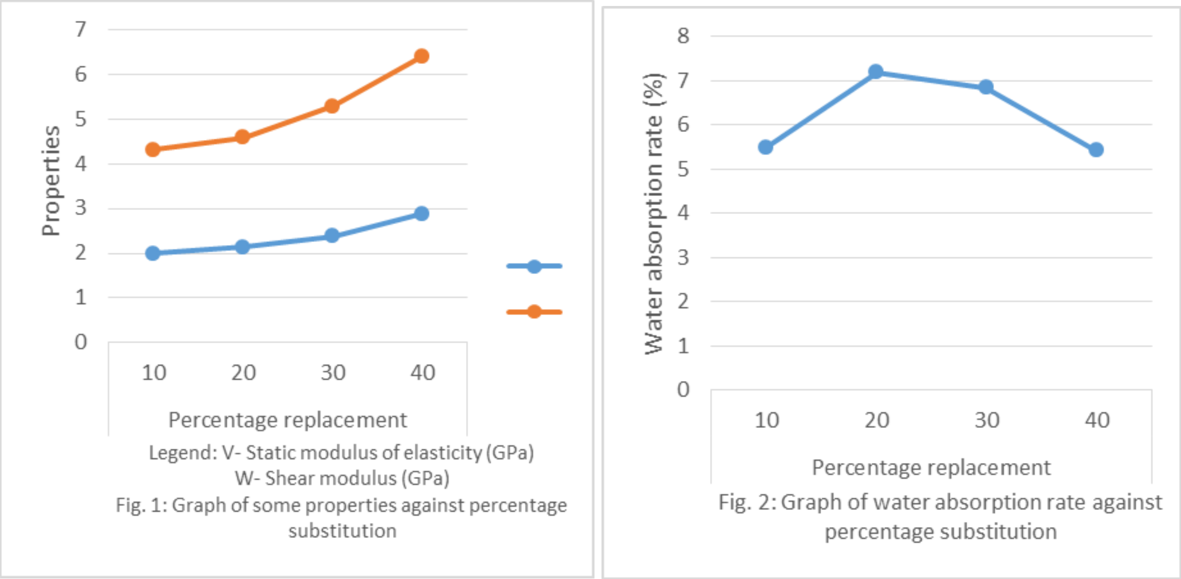
Table 9 shows the results of the chemical analysis of laterite. It shows that the laterite contains 120.11mg of calcium (Ca) per kilogram of laterite sample. The oxide of the element, calcium constitutes about 63% of Ordinary Portland Cement (OPC). The presence of calcium (Ca) in the laterite enhances the complete hydration of OPC and consequently, the development of strength. According to Neville, A.M. (1981), the raw materials used in the manufacture of Portland cement, consist mainly of lime, silica, alumina and iron oxide. Generally, the chemical analysis of the laterite reveals that it contains some quantities of these elements.

The iron content is 29.5mg/kg (a high range value), and this accounts for the reddish colour of the laterite. About 0.5 to 6.0% of oxide of iron is present in OPC.

The laterite contains 15.67mmoles of $H^+ + Al^{3+}$ per kilogram of laterite sample. In addition, 3 to 8% of the oxide of aluminium is present in OPC. Table 9 also shows that the laterite contains 100.44mg of magnesium (Mg) per kilogram of laterite sample. OPC contains about 0.1 to 4.0% of magnesium oxide.

The laterite contains 6.08mg of sulphate (SO_4^{2-}) per kilogram of laterite sample. A combination of calcium, sulphate and water gives gypsum ($CaSO_4.2H_2O$). Gypsum is usually added to cement clinker to prevent 'flash set' (immediate stiffening of paste).

Potassium (K) was not detected in the analysis. The oxide of potassium is a minor compound which is not of importance as far as strength is concerned. The Cation Exchange Capacity (CEC) is 22.86mmoles/kg which is very effective.



Legend: V- Static modulus of elasticity (GPa)
W- Shear modulus (GPa)
Fig. 1: Graph of some properties against percentage substitution

Fig. 2: Graph of water absorption rate against percentage substitution

Fig.1 Effect of fractional substitution of laterite with sand on the elastic properties of the blocks

Generally, it can be observed from the tests results and graghs in Figs. 1 and 2 that the fractional substitution of laterite with sand improved the quality of the blocks. Comparing the results from the control samples with the samples made with a percentage of sand, the static modulus of elasticity and shear modulus values increased significantly with inclusion of sand in the mix. Furthermore, the graphs showing the variation of these properties with percentage replacement show increasing trends in the properties as the percentage substitution increased.

The Poisson's ratio values (comparing Tables 10 and 11) reduced with the inclusion of sand in the mix. This also confirms that the strength of blocks increased with the fractional substitution of laterite with sand. This is because high strength concrete has lower Poisson's ratio value than low strength concrete.

However, the laterite blocks (control) have lower water absorption values than the sand-laterite blocks which contain sand in the mix. Considering experiment number one, the laterite blocks attained a saturation of 2.72% while the sand-laterite blocks attained a saturation of 5.42% under 24 hours of total immersion in water. This shows that laterite blocks are less permeable than sand-laterite blocks.

In as much as the elastic properties increased with inclusion of sand in the mix, it should be noted that the permeability increased with addition of sand hence reducing its durability.

CONCLUSIONS

1. Laterite blocks were produced and sand-laterite blocks were produced using a 10%-40% fractional substitution of laterite with river sand.
2. Elastic properties which include Poisson's ratio, static modulus of elasticity and shear modulus of the blocks were determined as well as the water absorption rate.
3. The consequence of the fractional substitution was checked on the elastic properties and the water absorption.
4. The values of the stated elastic properties increased significantly with the inclusion of sand in the mix. Furthermore, the variation of these properties with percentage replacement show increasing trends in the properties as the percentage substitution increased.
5. However, the laterite blocks (control) have lower water absorption values than the sand-laterite blocks which contain sand in the mix. This shows that laterite blocks are less permeable than sand-laterite blocks.
6. In as much as the elastic values of the blocks increased with inclusion of sand in the mix, it should be noted that the permeability increased with addition of sand hence reducing its durability.
7. The use of laterite in producing building blocks provides good thermal insulating and water resistance qualities as well as natural beauty and even resistance to termites, bacteria and fungi. This is beneficial in tropical regions.

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