RESEARCH ARTICLE OPEN ACCESS

Enhancing the Mechanical Properties of Lateritic Brick for Better Performance

O.A. Olowu, (A) A. A. Raheem(B) E.M Awe,(C) G.O. Bamigboye (D)
(A & C)Department Of Building Technology, School Of Environmental Studies, Yaba College Of Technology, Yaba Lagos Nigeria
(B & D)Civil Engineering Department, Ladoke Akintola, University Of Technology, Ogbomoso, Nigeria

ABSTRACT
The research considered the production of improved stabilized lateritic Bricks (ISLB) with enhanced mechanical properties. The research data were derived from laboratory experiments which include capillary test, erosion test, abrasion test, density test and compressive strength test. Three batches of 290mm x 140mm x 100mm brick samples were produced which are: the Adobe Unstabilized Lateritic Bricks (AULB), Improved Stabilized Lateritic Brick (ISLB) and the Control Stabilized Lateritic Bricks (CSLB). Brick stabilization was maintained at 5% by weight of cement. Compaction of the bricks were carried out manually; the moulded bricks were carefully extruded in good shape and placed on clean, hard flat surface to allowed to dry under normal atmospheric temperature and pressure . The ISLB was divided into four groups of 12 bricks samples immersed in solution of zycosil and water in the following proportion by volume: (1:100),(1:200),(1:300) and (1:400) for 30 minutes and dried under normal atmospheric temperature and pressure before curing commenced. The result of the capillary test on bricks samples after 24 hours showed that AULB and CSLB has (0.35 and 0.15)kg weight difference equivalent of (0.00599 and 0.00256) kg/m^2/min suction rate while the ISLB have 0.05kg weight difference equivalent to 0.000855kg/m^2/min suction rate. The result of erosion test for brick durability ranked between very firm for ISLB of 1:100, 1:200 and 1:300 Zycosil Water Solution (ZWS), firm for ISLB of 1:400 ZWS; firm for CSLB and loose for AULB. The abrasion test result showed that the ISLB have abrasion value of (1,2,2 and 2)% while the CSLB and AULB have (3 and 12)% abrasion value. The density of ISLB are (1933.50, 1921.18, 1916.26 and 1908.87) kgm^{-3} at 28 days while the density of CSLB and AULB were (1926.11 and 1800.49) kgm^{-3}. Density results conform to minimum specification requirement for lateritic bricks of bulk density of 1810kgm^{-3} as recommended by the Nigeria Building and Road Research Institute (NBRRI). Compressive strength test for the ISLB are (3.16, 3.10, 3.07 and 3.08) Nmm^{-2} at 28 days while the compressive strength test for CSLB and AULB stood at (3.15 and 2.41) Nm^{-2} which conforms to NBRRI recommended value of compressive strength ranges of (3 to 3.5) Nmm^{-2} at 5% stabilization level. It was concluded that the mechanical properties of improved stabilized lateritic brick are better than CSLB and AULB in terms of capillary rise, erosion, abrasion, density and compressive strength.
Keywords: Lateritic Soil, Compressive Strength, Zycosil.

I. INTRODUCTION

Bricks are single unit building block, they have approximately cuboidal shape. The major materials used in production of different types of bricks are clay, siliceous aggregate and laterite. A study of brick's materials properties is important as bricks are widely used in construction industry and its behavior under different atmospheric conditions can readily be predicted. BS 3921 recognizes three varieties of brick, which are differentiated on the basis of function. These are: common, for general building purposes; facing, manufactured for acceptable appearance; and engineering, for use where high strength and/ or low water absorption are required.

The brick industry uses a great variety of clays, laid down at different geological periods and ranging from soft, easily moulded glacial deposit to much older, relatively harder shale (kneeling, 1963); clay bricks can be Sun dried (Adobe) or burnt. Burnt clay bricks are porous and the degree of porosity depends on the temperature the bricks are subjected to during production. Aguwa (2009) asserted that firing ultimately produces consolidated but porous mass and impaired physical appearance with high production cost.

The need for alternative materials for brick production became imperative hence, lateritic soil, a reddish brown soil type rich in iron and aluminum formed in hot and wet tropical areas, from parents rocks (sedimentary rock, igneous rock and metamorphic rock) by a process called "leaching" was used extensively by researchers for the production of lateritic bricks (Morin and Peter,2010). Like clay soil the mineralogical and chemical compositions of laterites are dependent on their parent rocks. Laterites consist mainly of quartz, zircon and oxides of titanium, iron, tin, aluminum and manganese. Lateritic soil gives very good results for brick moulding especially when stabilized (Aguwa, 2009). The purpose of stabilizing laterite is to alter its physical properties, increase its strength and increase its durability for better performance. Different types of materials and admixtures have been used by researchers to stabilized laterites among which are: white hydrated lime (Metcalfe, 1977); cement (Aguwa, 2009); cement-sand admixture (Agbede and Manasseh, 2002) and wood ash and sawdust (Emmanuel, 2008). Research conducted by Agbede and Manasseh (2002) indicated that soil index parameters such as the Atterberg limits, grain-size distribution and linear shrinkage do not reliably indicate the amount of cement which would be required for satisfactory stabilization of the soil. Generally, the amenability of the soil tested to economical and satisfactory cement stabilization was readily deduced by Agbede and Manasseh (2002) recommend cement stabilization with soil having a plasticity index of 15 or less and a percentage passing the No. 200 Sieve of no more than 25 percent. Stabilizing laterite bricks with ordinary portland cement though prevent ingrain of water to a limited extent the research is burden with increasing the non-permeability of the brick with the application of Zycosil Water Solution (ZWS) which provides an impermeable membrane over the surface of the brick; improves its compressive strength, abrasion and density.

II. EXPERIMENTAL PROCEDURE

2.1 MATERIALS

For the purpose of the study the major materials used are: Ordinary Portland Cement (OPC) which conformed to (BS EN 206-1, 2000) was use as the stabilizer; the actual source was from the West African Portland Cement Company, Ewekoro, Ogun State, Nigeria. Water used conformed to BS 3148 (1980) and was obtained from Lagos State Water Corporation. Zycosil an organic water proofing compound was obtained from Dow Chemical, Midland, Michigan, United State. Laterite soil was obtained from Ikorodu area of Lagos State, Nigeria. The index properties of laterite soil used is summarized in Table 1.

2.2 SPECIMEN PREPARATION

Three batches of brick samples were produced; the first batch called Improved Stabilized Lateritic Brick (ISLB) contained 48 stabilized brick samples immersed in Zycosil Water Solution (ZWS) of different ratio. The second batch called Control Stabilized Lateritic Brick (CSLB) contained 12 stabilized brick samples while the third batch called Adobe Unstabilized Lateritic Brick (AULB) contained 12 unstabilized brick samples. Cement-laterites stabilization was maintained at 5% by weight.

The bricks samples were produced manually and cured under laboratory conditions for 7, 14, 21 and 28 days. To ensure even distribution of blows in mould, approximately 290mm x 140mm sheet of 12.5mm thick plywood was placed on the mixture in the mould and compaction was carried out in accordance to BS 1377 (1990). The moulded bricks were carefully extruded in good shape and placed on a clean, hard flat surface allowed to dry under natural atmospheric temperature and pressure. The ISLB was divided into four groups of 12 bricks samples which were immersed in ZWS of different concentration of 1:100, 1:200, 1:300 and 1:400 by volume for 30 minutes. The bricks samples were removed from the ZWS and allowed to dry under atmospheric temperature and pressure before curing commenced.

2.3 TESTING OF SPECIMEN

Laboratory tests were conducted on laterites soil for the purpose of characterization, test conducted include natural moisture content, compaction, Atterberg limits, and specific gravity and particle size distribution were carried out in accordance to British Standard (BS 1377, 1990) .Table 1.0 showed the Index Properties of Lateritic Soil. Other Laboratory tests conducted on the bricks samples includes: abrasion test, erosion test, capillarity test, density test and compressive strength test.

2.3.1 ABRASION TEST

The brick sample was weighed before the test was conducted. The brick sample was placed on a flat horizontal table-top secured against sliding. The top side of the brick sample was given 20 strokes of wire brush after which the sample was reweighed, the depth of abrasion measured and recorded. Abrasion test was conducted in accordance to American Association of State Highway and Transportation Officials (AASHTO - T96, 2010).

Abrasion value was computed thus:

$$Abrasion\, value\,\% = \left(\frac{Diff.in\, weight}{Original\, weight} \times \frac{100}{1}\right)$$

2.3.2 EROSION TEST

The brick specimen was placed on a smooth horizontal table; 5ml of water was poured onto the top side of the brick samples and rubbed gently with fingers. Observation noticed was recorded. Erosion test was conducted in accordance to American Society for Testing and Materials (ASTM- G76, 1995).

2.3.3. CAPILLARY TEST

The brick sample was weighed and recorded. A towel was spread on the stone placed on a bowl of water such that the stone was slightly above the water level. The brick sample was placed vertically on the spread towel and left in position for 24 hours. The brick sample was reweighed and recorded. Capillary test was conducted in accordance to Indian Standard (IS 3495 part 2,1992). The suction rate and water absorbed was computed thus:

Suction rate = $$Suction\ rate\left(\frac{Weight\ Diff.(\frac{kg}{m^2})}{1440(\min)}\right)$$

$$Water\ Absorption\ \% = \left(\frac{Weight\ Diff.}{Original\ weight} \times \frac{100}{1}\right)$$

2.3.4. COMPRESSIVE STRENGTH TEST

Measure and record average weight of three brick samples of size 290mm x 140mmx 100mm. The brick Samples were crushed on a manually operated hydraulic machine with maximum capacity of 3000KN, types SWP 300 EM 1, Masch Nr. 6329. Average maximum compressive force for the 3 brick samples was determined and recorded for computation of compressive strength. Compressive strength test was conducted in accordance to British Standard (BS 1881, 1983) and computed thus:

$$Compressive\ strength = \frac{Maximum\ Compressive\ Force}{Normal\ Cross\ Sectional\ Area}$$

2.3.5 DENSITY TEST

Three brick samples of sizes 290mm×140mm×100mm from ISLB,CSLB and AULB were weighed and average weight recorded. The volume of the brick sample was determined as the product of its length, breadth and height. The densities of the brick samples were determined at 7, 14, 21 and 28 days. Density test was carried out in accordance to Nigerian Industrial Standard (NIS 87, 2004).

The density of the brick sample was computed thus:

$$\boldsymbol{Density = \left(\frac{Average\ weight\ of\ brick\ samples}{Volume\ of\ brick\ sample}\right)}$$

III. RESULTS AND DISCUSSION

3.1 ABRASION TEST ANALYSIS

Table 2 showed the Abrasion Test result for brick samples. The result showed that Improved Stabilized Lateritic Brick (ISLB) offer resistance to abrasive forces in relative to the concentration of the Zycosil Water Solution (ZWS) used in its production; that is, the higher the concentration of ZWS the higher the resistance offered by the brick against abrasive forces. ISLB produced with ZWS of 1:100 have abrasion value of 1%, CSLB have abrasion value of 3% and AULB have abrasion value of 12%.

3.2 EROSION TEST ANALYSIS

Table 3 showed the erosion test result for brick samples. The result showed that the Improved Stabilized Lateritic Brick (ISLB) offered highest resistance to erosion and ranked very firm on durability scale; Control Stabilized Lateritic Bricks (CSLB) was next in rank, and on the durability scale was rated firm and Adobe Unstabilzed Lateritic Brick (AULB) was rated loose on durability scale.

3.3 CAPILLARY TEST ANALYSIS

Table 4 showed the capillary test result for brick samples. The result showed that both AULB and CSLB has (0.35 and 0.15)kg weight difference equivalent to (4.7 and 1.91)% of water absorbed and suction rate of (0.00599 and 0.00256) kg/m^2/min. ISLB have 0.05kg weight difference equivalent to (0.63, 0.66, 0.63 and 0.64)% of water absorbed and suction rate of 0.000855kg/m^2/min.

These result agreed with the optimum suction rate of 1.5kg/m^2/min specified by IS 3495 (1992). The result showed that AULB absorbed more water than of the brick samples while ISLB absorbed the least water because it was coated with Zycosil Water Solution (ZWS).

3.4 COMPRESSIVE STRENGTH TEST ANALYSIS

Table 5 and Figure 1.0 showed the Compressive Strength test for brick samples. The result showed that compressive strengths of ISLB depends on the Zycosil Water Solution (ZWS) used for it production. At 28 days ISLB produced with ZWS of 1:100 have compressive strength value of 3.16Nmm^{-2} while, ISLB produced with ZWS of 1:400 have compressive strength value of 3.08Nmm^{-2}. AULB have the least compressive strength value of 2.41Nmm^{-2} at 28 days. The result conforms to compressive strength range of (3 to 3.5) Nmm^{-2} recommended by the Nigeria Building and Road Research Institute, NBRRI (Madedor and Dirisu, 1992).

3.5 DENSITY TEST ANALYSIS

Table 6.0 and Figure 2.0 showed that the densities of brick samples appreciate with age of brick samples and the concentration of ZWS used in its preparation. The densities of ISLB appreciate from 2014.78 kg^{-3} at 7 days to 1916.26kgm^{-3} at 28 days; while the densities of CSLB appreciate from 1995.07kgm^{-3} at 7 days to 1926.11kgm^{-3} at 28 days. The densities of AULB appreciate from 1908.87kgm^{-3} at 7 days to 1800.49kgm^{-3} at 28 days. All the density conforms to minimum requirement of 1810kgm^{-3} recommended by NBRRI.

IV. 4.0 CONCLUSION

From the results of the various tests conducted the following conclusion can be drawn: Improved Stabilized Lateritic Brick (ISLB) have better performance in terms of it mechanical properties than CSLB and AULB. It was also concluded that the higher the concentration of ZWS used for the production of ISLB the more the mechanical properties are enhanced.
Finally, the result showed that the density of the bricks produced appreciates with age of curing and the concentration of ZWS.

5.0 RECOMMENDATION

Based on a close investigation of the effect of Zycosil Water Solution (ZWS) on the mechanical properties of stabilized lateritic brick the following recommendations are made: Zycoil Water Solution (ZWS) should be applied to stabilized lateritic brick to improve its mechanical properties in respect of abrasion, erosion, capillary rise and compressive strength.

Table 1.0 Index Properties of Lateritic Soil

Property	**Laterite**
Natural moisture content (%)	3.19
% Passing BS No 200 sieve (75µm) (%)	32
Liquid limit (%)	57.24
Plastic limited (%)	35.1
Linear shrinkage	12
AASHTO Classification	A-2-6
Max. Dry Density (Kg/m^3)	2015
Optimum Moisture Content (%)	12
Specific Gravity	2.68
Condition of sample	Air-dried
Colour	Brownish Red

Table 2.0 Abrasion Test Result for Brick Specimen

Brick specimen		**Weight Before Test (N)**	**Weight After Test (N)**	**Weight Difference (N)**	**Abrasion Index (%)**
Improved Stabilized Lateritic Brick (ISLB)	ZWS 1:100	79.0	78.21	0.79	1
	ZWS 1:200	77.5	75.95	1.55	2
	ZWS 1:300	77.0	75.46	1.54	2
	ZWS 1:400	80.5	78.89	1.61	2
Control Stabilized Lateritic Brick(CSLB)		79.0	76.63	2.37	3
Adobe Unstabilized Lateritic Brick (AULB)		73.0	64.24	8.76	12

Table 3.0 Erosion Test Results of Bricks Samples

Brick samples		**Durability Rating**	**Remark**
Improved stabilized Lateritic Brick (ISLB)	1:100	Very Firm	No sign of erosion can be used for external wall.
	1:200	Very Firm	Ditto
	1:300	Very Firm	Ditto
	1:400	Firm	Ditto
Control Stabilized Lateritic Brick (CSLB)		Firm	Ditto
Adobe Unstabilized Lateritic Brick (AULB)		Loose	Cannot be used for external wall; when used must be plastered

Table 4.0 Capillary Test Result for Bricks Specimen

Brick samples		**Area of Sample (m^2)**	**Original Weight (kg)**	**Final Weight after 24 Hours kg**	**Difference in Weight (kg)**	**Water Absorption**	**Suction Rate $kg/m^2/min$**
Improved Stabilized Lateritic Brick (ISLB)	1:100	0.0406	7.90	7.95	0.05	0.63	0.000855
	1:200	0.0406	7.60	7.65	0.05	0.66	0.000855
	1:300	0.0406	8.00	8.05	0.05	0.63	0.000855
	1:400	0.0406	7.80	7.85	0.05	0.64	0.000855
Control stabilized Lateritic Brick (CSLB)		0.0406	7.85	8.00	0.15	1.91	0.000256
Adobe Unstabilized Lateritic Brick (AULB)		0.0406	7.45	7.80	0.35/470	4.70	0.00599

Table 5.0 Compressive Strength Test Result for Brick Specimen.

TYPES OF BRICK SAMPLE	**IMPROVED STABILIZED LATERITIC BRICK (ISLB)**				**CONTROL STABILIZED BRICK (CSLB)**	**ADOBE UNSTABILIZED LATERITIC BRICK (AULB)**
PROPERTIES OF BRICKS	ZWS 1:100	ZWS 1:200	ZWS 1:300	ZWS 1:400		
Surface Area of Brick mm^2	40600	40600	40600	40600	40600	40600
Average maximum compressive Force at 7 days $\times 10^3$ (N)	108.0	93.0	90.0	83.0	90.0	50.5
Average maximum compressive Force at 14 days $\times 10^3$(N)	123	122.7	121.9	121.8	112.0	60.8
Average maximum compressive Force at 21 days $\times 10^3$(N)	124	121.5	130.9	120.4	117.0	80.6
Average maximum compressive Force at 28 days$\times$ 10^3(N)	128.5	125.7	125.6	125.2	127.89	97.8
Compressive strengths at 7 days (Nmm^{-2})	128.5	125.7	124.6	125.2	127.89	97.8
Compressive strengths at 14 days (Nmm^{-2})	3..03	3.02	3.00	3.00	2.76	1.49
Compressive strengths at 21 days (Nmm^{-2})	3.05	2.99	2.98	2.97	2.88	1.99
Compressive strengths at 28 days (Nmm^{-2})	3.16	3.10	3.07	3.08	3.15	2.41

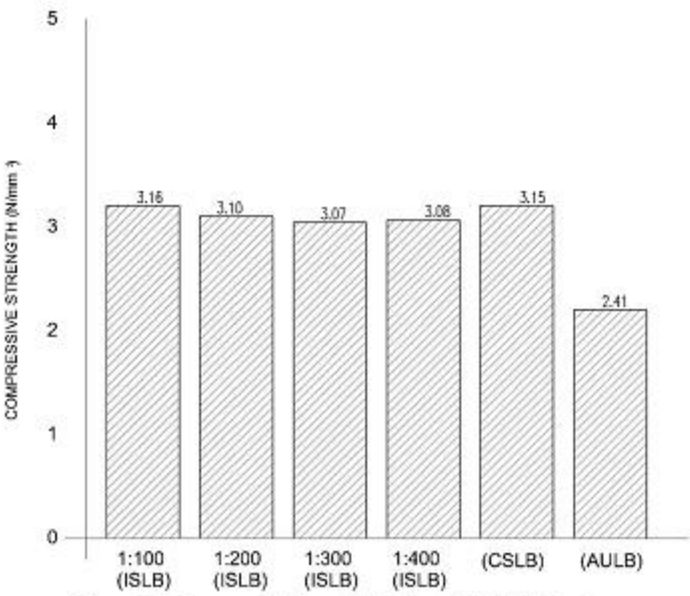

Figure 1.0 Compressive Strength Test Result for Brick Specimen.

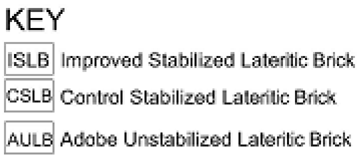

Table 6 Density Test Results for Brick Specimen

Types of brick samples	**Improved Stabilized LATERITIC Brick (ISLB)**				**Control Stabilized Lateritic Brick (CSLB)**	**Adobe Unstabilized Lateritic Brick (AULB)**
Property of Brick	1:100	1:200	1:300	1:400		
Vol. of Brick (M^3)	0.00406	0.00406	0.00406	0.00406	0.00406	0.00406
Average weight at 7 days (kg)	8.18	7.87	8.32	8.20	8.10	7.75
Average weight at 14 days (kg)	7.957	7.92	7.98	7.88	7.93	7.07
Average weight at 21 days (kg)	7.82	7.67	7.85	7.89	7.88	7.20
Average weight at 28 days (kg)	7.85	7.80	7.78	7.75	7.82	7.31
Density of Brick at 7 days (kg m^{-3})	2014.78	1938.42	2049.26	2019.70	1995.07	1908.87
Density of Brick at 14 days (kg m^{-3})	1958.13	1950.74	1965.52	1940.89	1953.20	1741.38
Density of Brick at 21 days (kg m^{-3})	1926.11	1889.16	1933.50	1943.35	1940.88	1773.40
Density of Brick at 28 days (kg m^{-3})	1933.50	1921.18	1916.26	1908.87	1926.11	1800.49

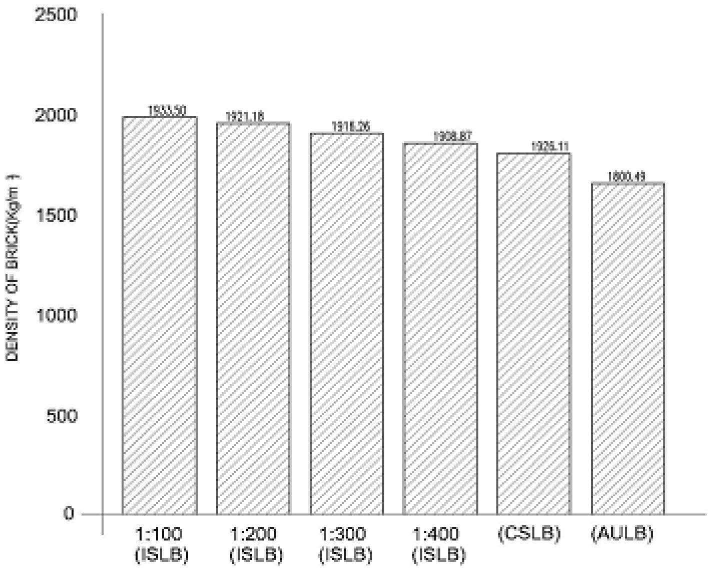

Figure 2.0 Density Test Results for Brick Specimen.

KEY

ISLB Improved Stabilized Lateritic Brick
CSLB Control Stabilized Lateritic Brick
AULB Adobe Unstabilized Lateritic Brick

REFERENCES

[1] AASHTO - T 96 -02 (2010): *Standard Method of Test for Resistance to Degradation of small size coarse Aggregate* by Abrasion and Impact in the Los Angeles Machine (ASTMC 131-01), Washington D.C. USA.

[2] Aguwa, J.I. (2009): *Study of Compressive Strengths of Laterite-Cement Mixes as Building Materia*l, A U Journal of Technology Assumption University of Thailand; Vol 13(2) pp 114-120.

[3] Agbeda I.O. and Manasseh J. (2002): *Use of Cement-Sand Admixture in laterite Brick Production for low cost Housing.* Department of Civil Engineering, University of Agriculture, Makurdi, Benue State, Nigeria.

[4] ASTM G 76-13 (1995): *Standard Test Method for conducting Erosion Tests* by Solid Particles Impingement using Gas jets.

[5] *British Standards Institution European Norm* (2000) BS EN 206-1: Concrete- Part 1: specification, performance, production and conformity. BSI, London.

[6] BS 3148 (1980): *Tests for water for marking Concrete*, British Standards Institutions, British Standard House, 2 Park Street, London, WIY 4AA.

[7] BS 1377 (1990): Methods of Testing soils for civil Engineering Purposes, British Standards Institution, 2 Park Street, London.

[8] BS 1881 Part 116, (1983): *Methods for determining compressive strengths of concrete cubes*, British Standard Institution, 2 Park Street, London.

[9] Emmanuel A.O., (2008): *The effect of wood Ash and sawdust Admixture on the Engineering properties of a Burnt Laterite clay Brick*, Journal of Applied Science, vol. 8: PP1042-1048.

[10] IS 3495 (1992): *Methods of tests for water absorption of burnt clay building bricks, Indian Standard*, First Revision, Indian.

[11] Keeling, P.S. (1963): *The Geology and Mineralogy of brick clays*, Brick Development Association Monograph.

[12] Madedor, A.O and Dirisu, A. O (1992): " *Research and development in the promotion of standards and specifications for stabilized soil blocks*", Nigerian Building and Road Research Institute (NBRRI), Lagos.

[13] MetCalfe, J.B. (1977): *A laboratory investigation of strength/age relations of five soils stabilized with white hydrated lime and ordinary portland cemen*t RN/3435/JBM, DSIR, RRI.

[14] NIS 87 (2004): *Standard for sandcrete blocks, Nigerian Industrial Standard, approved by Standard Organization of Nigeria*