

Full Paper

# PERFORMANCE OF NATURAL RUBBER LATEX STABILIZED ADOBE BRICKS

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## ABSTRACT

This study investigated the stabilization of adobe bricks with natural rubber latex (NRL). The laterite used was characterized using thermogravimetric analysis (TGA) and X-ray diffraction (XRD). The effects of using NRL at 0, 1.25, 2.5, 3.75, 5 and 6.25 % by weight of laterite on compressive strength, modulus of rupture and water absorption properties of adobe bricks were examined. Three hundred and seventy-eight specimens were cast, cured and tested for the above-mentioned tests at 7, 14, 21, 28, 56, 90 and 120 days. The results showed that NRL enhanced the properties of adobe bricks and 5% natural rubber stabilized adobe bricks gave the optimum results of all the tested properties. At 120 days of curing, the maximum compressive strength, the maximum modulus of rupture and the minimum percentage of water absorption at 0% NRL stabilizations are 0.69 N/mm<sup>2</sup>, 0.48N/mm<sup>2</sup> and 18.50% respectively while at 5% NRL stabilization, the maximum compressive strength, the maximum modulus of rupture and the minimum percentage of water absorption are 2.25 N/mm<sup>2</sup>, 1.66 N/mm<sup>2</sup> and 7.01% respectively.

**Keywords:** adobe bricks, natural rubber latex, compressive strength, modulus of rupture, water absorption

## 1. INTRODUCTION

The problems (shortage, low quality, high cost, etc.) of housing in the world are more predominant in developing countries. In the year 2005 alone, United Nation estimated housing deficit to about 1.3 billion. Nigeria for instance, is faced with both quantitative (short supply) and qualitative (low quality) housing (Olotuah *et al.*, 2013; Mabogunje, 2003). It would be necessary to use all available procedures best possible to improve the existing traditional building materials, construction methods and technological advancement to ameliorate the situation. Earth is the one of the oldest and most abundant sources of construction materials which is used in the production of adobe bricks. The term adobe generally is used to describe various building materials made of earth (Banjongkliang *et al.*, 2015; Bharath *et al.*, 2014; Rigassi, 1995).

Adobes are dried mud or bricks that have been used for several thousands of years in the construction of living and other structures. Thus, earth structures are a viable alternative to meet housing demand of low-income earners and in line with the concept of self-sufficiency economy, which in turn promotes the community sustainability.

The mechanical properties of traditional adobe bricks are low and required to be improved to meet the standard for use, adobe bricks have poor water resistance and the low strength which may cause problems during its service life as reported by Banjongkliang *et al.* (2015), because most soils in their natural condition lack the strength, dimensional stability and durability required for building construction. Recent studies have investigated the use of cement, lime, bitumen and calcium silicate to improve the mechanical properties and water resistance of adobe bricks (Al-Sakaaf, 2009; Aguwa, 2009; Otoko, 2014; Bharath *et al.*, 2014; Begum *et al.*, 2014). Natural rubber (NR) is produced by plants belonging mainly to families of *Euphorbiacea composita*, *Moracea* and *Apocynacea*. It is industrially extracted mainly from the tree called *Hevea Brasiliensis* belonging to *Euphorbiacea* family. It is grown in plantations in warm (average monthly temperature (25 – 28°C) and humid (humidity around 80%) climate of South-Eastern Asia (Malaysia, India, China, Sri Lanka, Vietnam), in West Africa (Nigeria) and in the northern part of South America (Brazil, Guatemala). Annual production of rubber is presently varying around 3000 – 3500 kg per ha and it depends on weather, soil quality, age of trees and other external factors. In Nigeria, Survey reports up to year 2000 indicate that the total area of rubber plantations is about 200,000 hectares; with a minimum ratio of 3: 1 for small holdings and large estate plantations respectively (Okwu *et al.*, 2015).

In Nigeria, natural rubber latex production has grown at a rate of 30% for three decades (Okwu *et al.*, 2015). Hence, the need to explore potential of using natural rubber latex in stabilizing adobe bricks for housing construction in Nigeria. Laterite is a soil and rock type rich in iron and aluminium, and is commonly considered to be formed in hot and wet tropical areas. Laterite contribute to the economic development of the regions where they are found. Laterite have a wide variety of use in the following fields, these include civil engineering, agronomy, mining research (iron, aluminium and manganese) deposits. The use of laterites as a building material has been, and is still very common in Africa Zangato (1995). Lateritic soils deposits are largely available in Nigeria in particular and Africa in general and thus can be used as construction materials, one of the process is the production of adobe bricks. The production for adobe bricks provides a modern way of utilization of lateritic soils for walls to meet the building requirements for structural performance; in addition, high aesthetics quality buildings can be achieved that promote low cost and environmentally friendly housing according to Otoko (2014).

## 2. MATERIALS AND METHODS

### 2.1. Materials:

Materials used for this research are laterite, potable water and natural Rubber latex (NRL). Laterite was collected from a laterite deposit in Ifewara with a GPS location of 7°27'29"N, 4°40'46"E in Atakumosa East local Government Area of Osun State, Nigeria. Natural rubber latex was extracted from a rubber plantation in Utagba uno with a GPS location of 5°53'40.9"N, 6°23'6.8"E in Ndokwa, Delta State, Nigeria.

### 2.2. Method:

The laterite sample was air dried and subjected to sieve analysis according to the BS 1377:2 (1990). Atterberg limit tests were conducted on the sample in accordance to ASTM D4318 (2005) to determine the plasticity index of the soil sample. The laterite was characterized using thermogravimetric analysis (TGA) and X-ray diffraction (XRD). Rietveld method of analysis was used to quantify the phases present in the laterite. Adobe brick samples were prepared using natural rubber latex (NRL) at 0, 1.25, 2.5, 3.75, 5 and 6.25 % by weight of laterite, the mix ratios are presented in Table 1. The mixing was done using a mechanical mixer to achieve a uniform mix, thereafter the materials were compacted in four (4) cycles into 300 mm x 150 mm x 75 mm bricks using Eco-Maquinas hydraulic brick moulding machine. The samples were cured in open air at 7, 14, 21, 28, 56, 90 and 120 days and thereafter subjected to compressive strength, modulus of rupture and water absorption tests in accordance to ASTM C67-02c (2001). The compressive strength, modulus of rupture and water absorption tests were conducted on the cast adobe bricks at the stated curing ages.

## 3. RESULTS AND DISCUSSION

The results of sieve analysis presented in Table 2 shows the different percentages of the particle sizes contained in the laterite, largest percentage of the soil is sand and clay portion is 12.65%. Since clay content is low in comparison to sand, volumetric variation in the presence of moisture would be limited.

Table 1 Mix proportion of adobe brick samples

Sample	L: NRL	L: W	NRL: W
L <sub>0</sub>	0: 0.000	1: 0.67	0: 0.000
L <sub>1</sub>	1: 0.0125	1: 0.48	1: 4.270
L <sub>2</sub>	1: 0.0250	1: 0.37	1: 1.470
L <sub>3</sub>	1: 0.0375	1: 0.27	1: 0.710
L <sub>4</sub>	1: 0.0500	1: 0.15	1: 0.300
L <sub>5</sub>	1: 0.0625	1: 0.03	1: 0.048

Table 2 illustrates the plasticity index of the soil material, which shows that the soil possesses a fair amount of clay content and the material is homogenous and medium plastic according to Das (2002, 2006). The result of the characterization of the laterite carried out through thermogravimetric analysis showing the dehydroxylation of kaolinite from 350 to 550°C is presented in Figure 1. The X-ray diffraction that gives crystalline phases and the positions of the main peaks of Kaolinite (K), muscovite (M), Quartz (Q), Microcline (Mi), Anatase (A) and Hematite (H) are indicated in Figure 2. The Kaolinite and other constituent minerals of clay fraction are shown in Table 3. The sample contains high contents of Alumina (Al<sub>2</sub>O<sub>3</sub>) and Silica (SiO<sub>2</sub>) with minor contents of Fe<sub>2</sub>O<sub>3</sub> and TiO<sub>2</sub>, moderately Kaolinitic with no muscovite as primary minerals. The secondary minerals are Quartz, Cristoballite, Hematite and Anatase with Quartz as most dominant minerals and the lateritic clay fractions are amorphous above 550°C. The material compares well that laterite investigated by Otoko (2014) for the production of soil-cement blocks and the percentage composition of the

kaolinite minerals of (20-40%) was within the range suggested by Das (2002), that shows Hydrogen bond in kaolinite mineral is strong. The Kaolinite crystals consist of many sheet stacking that are difficult to dislodge. Hence Kaolinite is easily moulded because it is plastic, stable and expands when it comes in contact with water and does not shrink when dry.

### 3.1. Compressive Strength:

The adobe bricks without stabilization at 0% natural rubber latex, (L<sub>0</sub>) were used as the control sample for the study. In Figure 3, it was observed that most of the compressive strengths were gained within 28 days of curing age. For the control specimen L<sub>0</sub>, the compressive strength increased by 24% after 14 days of curing, the strength increased by 15.7% at 21 days and 15.3% at 28 days of curing. At 56 days of curing age, the activity of the clay constituent of the laterite which is medium plastic and medium grained. For specimen L<sub>1</sub>, there was increase in compressive strength by 27.1% after 14 days of curing; at 21 days the strength increased by 32.8% and the increased by 25.9% at 28 days of curing.

Table 2 Laterite soil fractions

Soil Fractions	Total %
Gravel	2.90
Sand	66.25
Silt	18.20
Clay	12.65

Table 3 Results of the preliminary analysis of soil samples

Parameters	Properties
Natural water content (%)	6.60
Specific gravity	2.69
Liquid Limit (LI) %	24.70
Plastic Limit (PI) %	12.98
Plasticity Index (Pi) %	11.72
Condition of sample	Air dried
Colour	Red

Table 4 Kaolinite and other constituent minerals of clay fraction

Lateritic Clay	Proportion (%)
Kaolinite	23.7
Quartz	35.6
Muscovite	-
Cristobalite	3.1
Hematite	4.0
Microcline	-
Rutile	-
Anatase	2.8
Amorphous	30.8

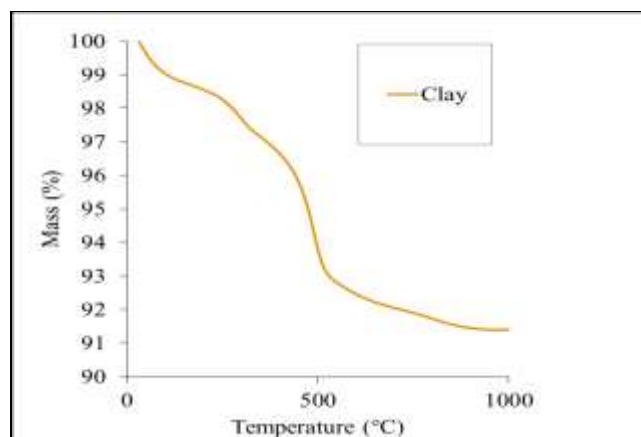


Figure 1 TGA of clay showing the dehydroxylation of Kaolinite from 350°C to 550°C

At 56 days, the strength increased by 3% and the same strength was gained for 90 and 120 days. The strengths increase up

to 56 days of curing and its stability up to 120 days of curing was attributed to the activities of natural rubber latex in aqueous medium. The same process of reactions were experienced for specimens L<sub>2</sub>, L<sub>3</sub>, L<sub>4</sub> and L<sub>5</sub> stabilized at 2.5, 3.25, 5 and 6.25 % respectively. The strengths increase up to 56 days of curing and their stability up to 120 days of curing were attributed to the activities of natural rubber latex in aqueous media of the bricks. The results of the compressive strength tests of the adobe brick specimens L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub>, L<sub>4</sub> and L<sub>5</sub> were compared with the adobe brick specimen L<sub>0</sub> at 28 and 120 days of curing age. It was observed that at 28 days of curing, the compressive strength at specimen L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub>, L<sub>4</sub> and L<sub>5</sub> increased by 33.33, 37.61, 58.28, 69.64 and 60.69 % respectively. The maximum compressive strength of 0.68N/mm<sup>2</sup> was achieved at 56 days of curing for the control mix and was constant for 90 and 120 days of curing. The maximum compressive strength recorded during the investigation was for specimen L<sub>4</sub> which increased by 69.64% when compared to the control. Similarly, at 120 days of curing the increase in compressive strength for specimens L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub>, and L<sub>5</sub> were 34.29, 36.71, 57.57 and 63.87 % respectively as shown in Figure 3. The compressive strength results obtained were within the range of results of stabilization of adobe bricks reported by Khamput et al. (2011). Specimen L<sub>4</sub> prepared with at 5% natural rubber latex (NRL), has the maximum compressive strength.

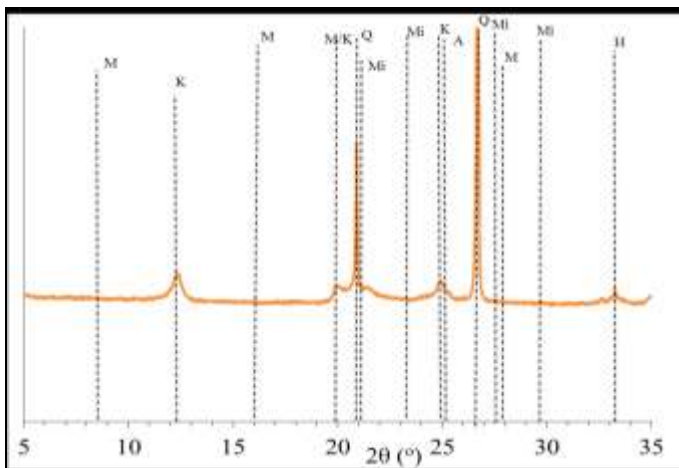


Figure 2 XRD patterns of clay fraction. The positions of the main peaks of kaolinite (K), muscovite (M), quartz (Q), microcline (Mi), anatase (A) and hematite (H) are indicated by dashed line.

### 3.2. Modulus of Rupture:

The results of the modulus of rupture strength tests of the adobe brick specimens conducted are presented in Figure 4. It was observed that the bricks gained much of the strengths within 28 days of curing age. For specimen L<sub>0</sub> (adobe bricks stabilized at 0% of NRL), there was 31% strength increase after 14 days of curing, the strength increased by 7.9% at 21 days and 4.4% at 28 days of curing. At 56 days of curing age, the strength increase was 11.6% and there was decrease of 2.1% at 90 days curing and further increase of 2.1% at 120 days of curing age. The maximum strength of 0.48N/mm<sup>2</sup> was achieved at 120 days of curing ages. For specimen L<sub>1</sub>, there was increase in strength by 18.1% after 14 days of curing; at 21 days the strength increased by 4.4% and the increment was 4.2% at 28 days of curing age. It was observed that the strength increased by 12.24, 50.00, 57.00, 70.55 and 61.26 % for specimens L<sub>1</sub> (0.49 N/mm<sup>2</sup>), L<sub>2</sub> (0.86 N/mm<sup>2</sup>), L<sub>3</sub> (1.00 N/mm<sup>2</sup>), L<sub>4</sub> (1.44 N/mm<sup>2</sup>) and L<sub>5</sub> (1.11 N/mm<sup>2</sup>) respectively for 28 days of curing and the maximum modulus of rupture strength was observed at specimen L<sub>4</sub>. A similar increase was observed at 120 days of curing at 22.58, 48.39, 53.41, 71.08 and 62.51 % for L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub>, L<sub>4</sub> and L<sub>5</sub> respectively. Also the maximum

modulus of rupture strength was observed at specimen L<sub>4</sub> of 5% (NRL) stabilization.

### 3.3. Water Absorption:

The results of the water absorption tests of the adobe brick specimens conducted are presented in Figure 5. It was observed that at 7 days of curing age, the percentage water absorption for specimen L<sub>0</sub> was 21.5; it was reduced to 20.1, 19.5, 19.02, 18.79 and 18.5% at 14, 21, 28, 56 and 90 days of curing ages respectively. After 90 days of curing, the water absorption remained constant up to 120 days of curing at 18.5%. It was also observed that specimen L<sub>1</sub> (adobe bricks stabilized with 1.25% of NRL), the percentage water absorption was 17.05 at 7 days of curing, the water absorption further reduced as the curing days increased. The reductions were 16.11, 15.21, 14.13 and 13.46 % at 14, 21, 28 and 56 days of curing respectively. The reduction of water absorption was constant at 56 days up to 120 days of curing because of the binding and confinement ability of natural rubber latex. Specimens L<sub>2</sub>, L<sub>3</sub>, L<sub>4</sub> and L<sub>5</sub> followed similar trend in reductions of water absorption of adobe brick specimen L<sub>1</sub>. The results of water absorption tests of adobe bricks stabilized with natural rubber latex were within the range of results reported by Bharath et al. (2014).

The results of water absorption tests of adobe brick specimens L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub>, L<sub>4</sub> and L<sub>5</sub> were compared with the results of adobe brick specimen L<sub>0</sub> at 28 and 120 days of curing. It was found that water absorptions were reduced by 25.71, 41.69, 62.57, 67.67 and 55.11 % for L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub>, L<sub>4</sub> and L<sub>5</sub> respectively at 28 days of curing, which shows that maximum water reduction was observed in specimen L<sub>4</sub>. Also, at 120 days of curing, the percentage reduction of 27.14, 43.35, 62.11, 68.16 and 55.03 were observed for specimens L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub>, L<sub>4</sub> and L<sub>5</sub> natural rubber latex, hence, the minimum water absorption of adobe bricks were achieved at 5% of natural rubber latex stabilization. The maximum values of compressive strength and modulus of rupture as well as the minimum water absorption were achieved at 5% natural rubber latex (NRL) stabilization, hence, 5% natural rubber latex was optimum for stabilizing adobe bricks is 5%.

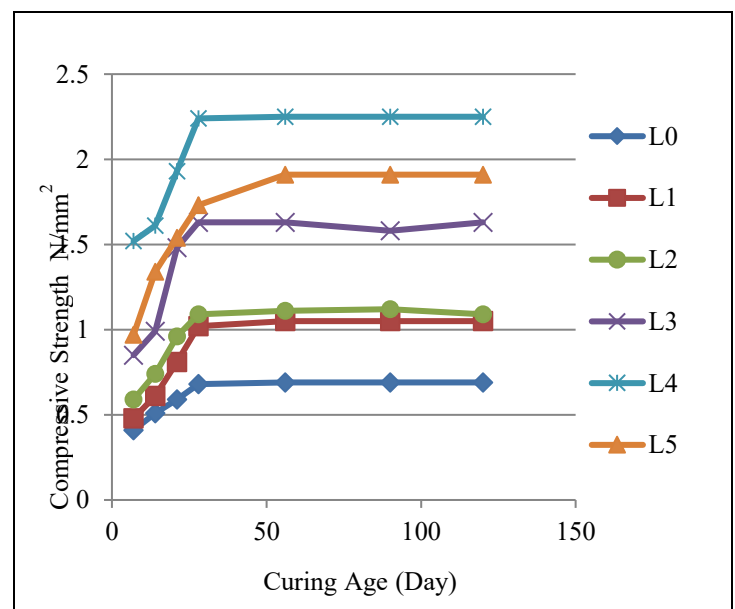


Figure 3 Compressive strength at different curing ages.

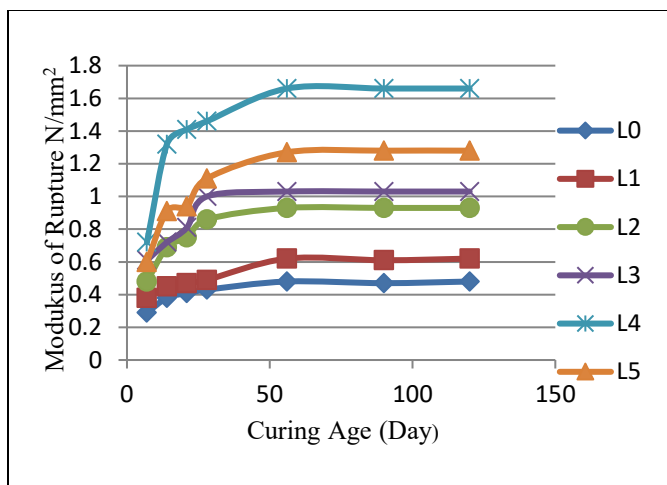


Figure 4 Modulus of rupture at different curing ages

### 3.4. Effects of Natural Rubber Latex (NRL):

Natural rubber latex formed a stable dispersion of the rubber particles in an aqueous medium for a smaller rubber aggregates which is called serum, other non-rubber minerals constituent such as protein, carbohydrate and lutoid are absorbed partially forming a layer of protection around the rubber particles, also the negative charges of carboxylate ( $\text{RCOO}^-$ ) in protein induce the pushing force between the particles Khamput *et al.* (2011). When the latex is mixed with the laterite the setting of latex due to loss of its stability forms the film layer infiltrating into the laterite thereby increasing the film layer covering the aggregates and reducing the voids in adobe resulting in strength increase and improves the waterproof properties which cause the reduction of water absorption.

However, the increase in rubber latex can leads to increase of water absorption. This can be explained that the increase of latex leads to self-grouping of rubber particles and then the number and size of voids in adobe mortar are increased which results in the increase of water absorption and corresponding increase of voids in adobe mortar resulting in reduction of strength of adobe bricks Khamput *et al.* (2011). Based on the conventional 28 days of curing of construction materials, the maximum values of compressive strength and modulus of rupture as well as the minimum water absorption were achieved at 5% natural rubber latex (NRL) stabilization, hence, optimum percentage of natural rubber latex (NRL) for stabilizing adobe bricks is 5%.

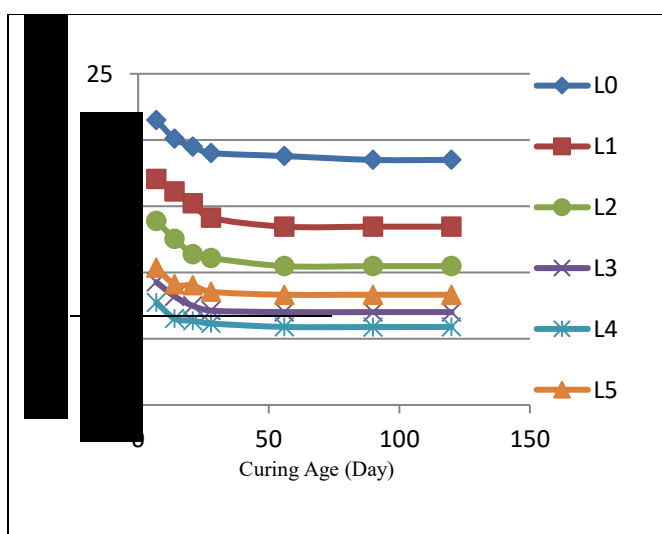


Figure 5 Water absorption at different curing ages

## 4. CONCLUSION

Kaolinite mineral of clay fraction of the laterite was 23.7% and is suitable for use in the production of adobe bricks and is in accordance with the recommendation of Das (2002). The clay fractions of laterite used for the production of adobe bricks was 12% of laterite and the absence of muscovite mineral constituent of clay fraction shows the material is suitable for adobe brick productions because muscovite expand readily in the presence of water. In order to obtain the best values of compressive and modulus of rupture, 5% of natural rubber latex (NRL) should be used. The results obtained showed that natural rubber latex (NRL) is suitable for the stabilization of adobe bricks making.

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