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Strength Improvement of Mud Houses Through Stabilization of the Lateritic Materials

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ABSTRACT

This paper reports an experimental investigation of the compressive strength of laterite stabilized with cement (CSL), lime (LSL) and rice straw (RSL) respectively. The laterites were collected from borrow pit used by locals in Bauchi, Nigeria to build mud houses. Unfortunately the mud houses experienced massive failures ~~by~~ through wall collapses over the years during the flooding cycles of the rainy seasons. An attempt is made to stabilize the lateritic soil materials used for the mud house walls in order to strengthen them against rains and flood erosions. Briefly discussed are factors that affect performance and strength, this include mix proportions, compaction, characteristics of the lateritic soil, mix procedure and curing. The results showed that the lateritic soils in the investigated area were relatively high on sand and lower on clay thereby promoting cement as the best stabilizer for strength. It increased the compressive strength by 661% from 0.61 N/mm^2 at zero stabilization (ZSL) to 4.64 N/mm^2 at 8% cement content after 28 days of curing. LSL and RSL at the same contents had strengths of 1.21 N/mm^2 (98.4% increase) and 0.71 N/mm^2 (16.4% increase) respectively. At 6% contents strength values were 4.33 N/mm^2, 1.16 N/mm^2 and 0.66 N/mm^2 respectively. The values reduced at 4% contents reporting 3.14N/mm^2, 0.82N/mm^2 and 0.44N/mm^2 respectively. While CSL increased non-linearly in density with increase in cement content, LSL and RSL decreased with increase of the respective contents. The results show that with cement as the stabilizer, mud house walls constructed with CSL bricks will resist collapse failures due to the perennial flooding in the area. Moreover by their relatively high compressive strengths they can be used for load bearing walls as much as sandcrete blocks.

Keywords: *Laterite, compressive strength, cement, lime, rice straw*

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I. INTRODUCTION

Mud houses are found in large numbers in both urban and rural Bauchi, North East Nigeria and in deed all over Africa. They are the commonest dwelling places for low income earners in the continent. Unfortunately they are easily destroyed by the perennial floods that accompany the seasonal rains each year. For example, a total of 5,300 houses were reported to have collapsed in Kano alone in North West Nigeria due to flooding generated by rainfall that lasted for hours on 8th of August 2016 (Odogwu, 2016).

Plain Earth Bricks (PEB) have been used for centuries in the building of mud houses (Bahar, Benazzoug, & Kenai, 2004). The soil type from which theses bricks are made are laterites. Laterite is a type of soil found in hot and wet tropical regions of the world. It was formed from weathered rocks under high temperature and rainfall with wet and dry spells. The high rainfall leached away the silica component and thereby making it rich in iron and aluminium oxides. Due to the presence of iron oxide, it varies in colour from red to brown and yellow. It becomes hard when exposed to the atmosphere and have become a popular building material utilized in these regions of the world because of its availability and economical benefit compared to other natural earth materials. In addition to its cost effectiveness, it is also considered to possess better energy efficiency when compared to conventional modern building materials in tropical countries (Kasthurba, Krishna, & Venkat, 2014).

A study of mud house failures in Bauchi showed that wall collapses in buildings constructed with plain earth bricks without plastering was 100%. What this meant was that all the mud houses had at least a portion of the mud wall collapsed (Ndububa & Mukkadas, 2016). Consequently stabilization of the lateritic soils used for the houses was one of the recommendations made to stop the massive failures. If this is done, it will serve to upgrade mud houses to become brick houses. The need to switch over from plain mud houses to houses built with Stabilized Lateritic Soils (SLS) becomes imperative as the Federal Government of Nigeria recently announced a plan "to do away with mud houses in a not too distant future" (Editorial Board, 2016). It goes to show that research on better alternative materials that will meet the requirements of strength, economy and durability is important. The Government has already thrown the challenge to the Nigerian Building and Road Research Institute (NBRRI).

The need usually arise where the most economical and engineering solution to soil problem is to improve the in situ soil before construction such that it could provide the desired performance. In practice, there are various ways in which soil characteristics may be improved. Mechanical stabilization through compaction is one way. This approach has produced better performance when machines were used (Ogunsusi & Kolawole, 1994). Another is Chemical stabilization which involves the mixing of stabilizing chemical material to the soil. However where chemical stabilizers are used, compaction is still applied to derive maximum performance. For example, the findings of a research on flexural strength of Compressed Stabilized Earth (CSE) bricks stabilized with cement indicate that the minimum flexural strength was 0.25 N/mm^2 which is comparable with conventional masonry such as burnt clay brickwork (Jayasinghe & Mallawaarachchi, 2009).

Common chemical stabilizers for soils and laterites are cement, lime and bitumen or combinations of these. Others are pozzollanic and agro-waste materials like Rice Husk Ash (RHA) and straw. Various efforts in the past showed the following: that lateritic soil stabilized with RHA gave an optimum unconfined compressive strength (UCS) of 0.298N/mm^2 at 8% RHA by weight which was marginally above 0.290N/mm^2 value obtained from the plain sample (Alhassan, 2008). When cement was introduced into the mix, the optimum UCS was at 4% RHA. This gave values of 0.65, 1.75 and 2.3N/mm^2 for 4, 6 and 8% cement respectively by weight (Alhassan & Mustapher, 2007). Similar work with cement, lime and termite-hill stabilizers produced results that showed that cement was a best stabilizer with a compressive strength of the bricks given as 2.3N/mm^2 at 8% by weight, lime was given as 1.57N/mm^2 and termite-hill stabilized laterite gave 1.44N/mm^2 (Awoyera & Akinwumi, 2014). All reported strengths were given after 28 days of curing.

This paper reports a laboratory test programme to determine the compressive strength of laterite stabilized with cement, lime and rice straw respectively. Lime is a dry Cementations product obtained by calcining a limestone containing silica and alumina to a temperature short of incipient fusion, so as to form sufficient free lime (Calcium Oxide) to permit hydration and at the same time leaving un-hydrated sufficient calcium silicates to give the dry powder. The tests were carried out after 28 days of curing. For ease of reference the materials were abbreviated as follows: CSL for cement stabilized laterite, LSL for lime stabilized laterite, RSL for Rice Straw Stabilized Laterite and ZSL for Zero Stabilized Laterite.

II. MATERIALS AND METHODS

2.1 Preparation of Materials

Ordinary Portland Cement (OPC) was used. It was procured in 50kg bags, free from moisture. It exhibited all the qualities of a good cement by visual means, touch and hydration.

A good quality lime brand purchased from a building market was used. It was also free from moisture and ground to avoid granules among them before use.

The lateritic soil used was obtained from borrow pits patronized by the local people for brick making in Bauchi, North East Nigeria. The soil, red in colour was dried sufficiently to be crumbled and broken up using rubber pestle without crushing individual particles.

Rice Straw is the agro-waste vegetable fibre that were sometimes left in heaps to rot away after each rice harvesting season in Bauchi. They were allowed to dry sufficiently and chopped to lengths of 15-30mm before use.The portable tap water used was clean, clear and free from impurities.

2.2 Soil suitability tests

Atterberg Limits and compaction tests were carried out in accordance with British Standards (BS1377, 1990). A hydrometer test was also conducted to ascertain the relative proportions of sand, silt and clay for the purpose of comparing with acceptable limits for building purposes. Five specimen were used for each test and the average determined.

2.3 Mixing

The “dry mix process” (Ndububa, 1995) was used. It involved thorough mixing of any of the stabilizers with laterite in their dry states before gradually adding water while the mixing process continued to a required consistence.

The mix proportions used for the stabilizers were 4%, 6% and 8%. The mixing was done mechanically and thorough to avoid segregation.

2.4 Compaction and Curing

The mixed samples were introduced into 150mm cubes in three layers with hand trowel, each layer received a thorough compaction using the 2.4kg rammer. Five samples were prepared for each experiment from which averages were determined. The specimen were demoulded after 24 hours and cured by plastic sheeting with black polythene bag to ensure air tightness and prevent evaporation of water for 28 days.

2.5 Compressive Strength Test

Compressive strength tests were carried out on the cubes by crushing. British Standards (BSI, 1983) was adopted. Also weighing and dimensioning of samples were conducted before crushing to determine the densities. An example of failed cube due to crushing is shown in Plate 1.

III. RESULTS AND DISCUSSION

The results of the Atterberg Limits, Compaction (Procto) and Compressive Strength tests were determined. For the laterite, the optimum moisture content (OMC) was 11.4% with average bulk and dry densities of 2048kg/m^3 and 1840kg/m^3 respectively. These values placed the laterite in the SM-SC group in the Universal Soil Classification System (USCS) which is described as sandy silt clay mix with slightly plastic fine (ASTM, 2006). The average Liquid Limit (PL) and Plastic Limit (PL) were 39.2% and 33.3% respectively. This brings the Plasticity Index (PI) to a value of 5.9. This places it also in the A-2-4 group in the AASHTO system (AASHTO, 1986) of soil classification, which is described as "silty or clay gravel and sand as usual types of significant constituent materials" (Amadi, et al, 2015). Table 1 shows the result obtained from hydrometer (wet sieving) test. It shows that while sand exceeded recommended proportion limits for building soil blocks, silt and clay slightly fell below the limits as enunciated by Norton (Norton, 1986). This shows that local mud house builders inadvertently have been using inadequately graded soil for the purpose of mud house walling. This may have contributed to the very high mud failures through wall collapses. There is therefore the very need to stabilize the laterite used by the locals in order to strengthen the walls against collapse.

Table 2 show the densities of plain and stabilized cubes. The trend with CSL is that there is non-linear increase in density with increase in cement content, from 1985kg/m^3 at ZSL to 2211kg/m^3 at 8% content. This does not confer lightweight advantage on CSL. This is not the case for LSL and RSL which had non-linear decrease in density with increase in lime and rice straw contents respectively. Their lower densities confers reduced dead weight advantages on them. This is more so with RSL which had a density of 1888 kg/m^3 at 8% straw content, a reduction of 4.9% from ZSL. The RSL values are lower than those obtained from laterites stabilized with grass straw from an earlier work (Ndububa,1996).

Table 3 and Figure 1 show the compressive strength values. They show that CSL improved in strength from 0.61N/mm^3 at ZSL to 4.64N/mm^3 at 8% cement content, an increase of 661%. The increase for LSL within the same range is 98.4% and 16.4% for RSL. The trend of the results show that cement proved to be the best stabilizer among the three for compressive strength after 28 days period of curing. The relatively higher strength of CSL over LSL and RSL is contributed by the relatively higher sand content in lateritic soil in the research area (see Table 1) with which cement binds well and better. However it is expected that if longer period of curing was allowed, LSL will possibly have gained more strength because of the slower curing rate with lime which bonds better with the smallest granular clay content.

IV. CONCLUSION

This paper reports the problem of collapsed mud houses in Bauchi during each rainy season cycle as a result of floods usually generated. The mud walls have over the years been incapable of resisting the flood waters. This is why the strengthening of the wall materials ~~are~~ is imperative. The results of stabilizing the mud walls materials (laterites) with cement (CSL), lime (LSL) and rice straw (RSL) show that though with higher density, the CSL had the highest compressive strength. At values ranging from 3.14N/mm^2 at 4% cement content to 4.6N/mm^2 at 8% content CSL met the minimum requirements for load bearing partition walls. These were in excess to the requirement for sandcrete blocks, which is 2.5N/mm^2 (NSO, 1975)

V. RECOMMENDATIONS

Further work in addition to compressive strength such as flexural strength, water absorption capacity, permeability and abrasion due to erosion need be done in order to ascertain the full performance of the stabilized laterite.

The results obtained from laterite stabilized with cement have an appreciable strength and therefore can be recommended for use as sub-base materials.

More research should be carried out with higher percentages of stabilizers to determine optimum percent contents for strength, durability and economy.

Longer curing periods should be introduced in a subsequent work to ascertain the appropriate limit of hydration by lime and durability of rice straw in the cement medium.

Table 1: Percentage Proportions of Soil Samples from the Bauchi borrow pit as given from Hydrometer Soil Tests.

Location of Borrow pit	Sand Fraction (0.06-2.00mm) %	silt Fraction (0.002-0.06mm) %	Clay Fraction (0.002mm) %	Total %
Bauchi Birshi	76.6	8.9	14.8	100
Specified Fractions (Norton, 1986)	40-75	10-30	15-30	

Table 2: Density of Cube samples (Kg/m^3)

Cube Type	% of Stabilizer			
	0	4	6	8
CSL		2157	2187	2211
LSL		2193	2104	2038
RSL		1916	1906	1888
ZSL	1985			

Table 3: Compressive Strength of Cube samples (N/mm^2)

Cube Type	% of Stabilizer			
	0	4	6	8
CSL		3.14	4.33	4.64
LSL		0.82	1.18	1.21
RSL		0.44	0.66	0.71
ZSL	0.61			

Plate 1: Crushing of cube to determine compressive strength in the laboratory

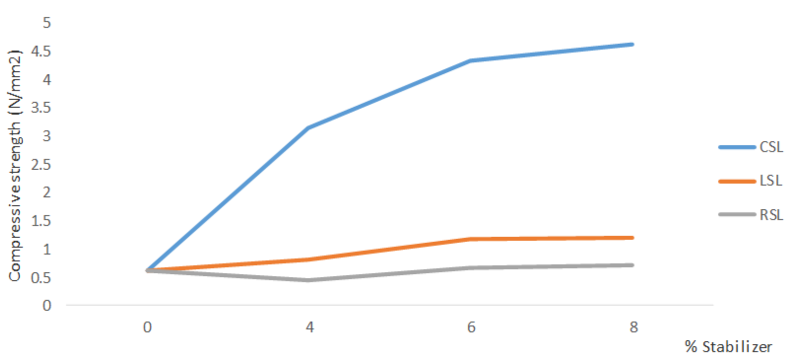

Figure 1: Compressive strength of stabilized laterite

REFERENCES

[1]. AASHTO, (1986). Standard Specifications for Transportation Materials and Method of Sampling and Testing. *Amer. Assoc. State Highway and Transportation Officials,* Washington, DC, USA

[2]. Alhassan, M. (2008, April). Potentials of Rice Husk Ash for Soil Stabilization. *Assumption University Journal of Technology, 11*(4), 246 - 250.

[3]. Alhassan, M., & Mustapher, A. M. (2007, July - December). Effect of Rice Husk Ash on Cement Stabilized Laterite. *Leonardo Electronic Journal of Practices and Technologies*(11), 47 - 58.

[4]. Amadi, A. N., Akande, W. G., Okunlola, I. A., Jimoh, M. O., & Francis, O. G. (2015). Assessment of the Geotechnical Properties of Lateritic Soils in Minna, North Central Nigeria for Road design and Construction. *American Journal of Mining and Metallurgy, 3*(1), 15 - 20.

[5]. ASTM, I. (2006). *Standard Practice for CLassification of Soils for Engineering Purposes (Unified Soil Classification Systems).* Philadelphia: American Standards for Testing and Measurements.

[6]. Awoyera, P. O., & Akinwumi, I. I. (2014). Compressive Strength Development for Cement, Lime and Termite-hill Stabilised Lateritic Bricks. *The International Journal Of Engineering And Science, 3*(2), 37 - 43.

[7]. Bahar, R., Benazzoug, M., & Kenai, S. (2004, October). Performance of Cement - stabilized Soil. *Cement and Concrete Composites, 26*(7), 811-820.

[8]. BS1377, (1990). *Part 2, Methods of Tests for Soils for Civil Engineering Purposes.* London: British Standards Institution.

[9]. BS 1881, (1983). *Part 116, Method of Determination of Compressive Strength of Concrete Cubes*. London: British Standards Institution.

[10]. Editorial Board, (2016, July 31). On Building Materials. *The Guardian, 33*(13729), p. 12. Retrieved from www.guardian.ng/opinion/on-building-materials/

[11]. Jayasinghe, C., & Mallawaarachchi, R. S. (2009, October). Flexural Strength of Compressed Stabilized Earth Masonry Materials. *Materials and Design, 30*(9), 3859 - 3868.

[12]. Kasthurba, A. K., Krishna, R. R., & Venkat, R. (2014, August). Use of Laterite as a Sustainable Building Material in Developing Countries. *International Journal of Earth Sciences and Engineering, 7*(4), 1251-1258.

[13]. Ndububa, E. E. (1995). *An Appraisal of Vegetable Fibre Reinforcement in Construction.* Nsukka: University of Nigeria.

[14]. Ndububa, E. E. (1996). Study of Soil Blocks Stabilized with Straw and Wood Shavings for Low Cost Housing. *Proceedings of Maiden National Engineering Conference. 1*, pp. 229-235. Bauchi: The Federal Polytechnic, Bauchi.

[15]. Ndububa, E. E., & Mukkadas, A. M. (2016). Mud House Failures and Mitigation Options in Bauchi, North East Nigeria. Accepted in *Journal of Engineering Technology, 1*(1).

[16]. Norton, A. (1986). *Building with Earth.* London: Intermediate Technology Publications.

[17]. NSO. (1975). *Specification for Sandcrete Blocks - Nigerian Industrial Standards.* Lagos: Nigerian Standards Organization.

[18]. Odogwu, T. (2016, August 9). Flood Destroys 5,300 Houses in Kano. *The Punch*, p. 3. Retrieved from www.punchng.com

[19]. Ogunsusi, V., & Kolawole, P. (1994). *Compressed Earth Bricks Masonry - Brick Production 2.* Jos: Centre for Earth and Construction Technology (CECTEC).