Evaluation of Strength and Moisture Absorption Characteristics of Lime Treated Clay Interlocking Bricks

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Abstract. The durability and stability of masonry structures throughout usage can be affected by producing process, material properties and environmental conditions such as moisture hence finding out the factors affecting durability of clay bricks is vital so as to produce bricks of high strength which will absorb less water. The effect of stabilizing clay for the production of interlock bricks using lime at various percentages was investigated. Soil type used in the production of interlocking bricks was A-6 soil using the AASHTO system of soil classification. Maximum reduction in Liquid Limit and Plastic Limit of the clay material was observed at 8% addition of lime. The Specific Gravity rose from initial of 2.71 at 0% to 2.85 at 10% addition of lime. The maximum reduction of Average Water Absorption (AWA) of clay modified with lime was observed at 8% and the value of AWA recorded was 13.3%, which brought the clay brick to the first class designation from the second class designation of 0% of lime addition. The compressive strength reduced at 8% for all the sampling period of 28 days, the compressive strength test is lower than specification as such the bricks can be used in non-structural member in construction

Keywords: Interlocking Bricks; moisture absorption; Lime; compressive strength

1. Introduction

Around the globe, the usage of cement for infrastructural progression is a key to the advancement of various economies [1]. Regardless, production of cement is the second biggest wellspring of CO₂ generated around the world. It contributes around 5-8% of overall CO₂ emissions, generally from the usage of non-sustainable energy source for calcination [2]. One ton of cement production is obligated for one ton of CO₂ spread: half of the CO₂ is from the chemical process of clinker production and the rest on account of the calcinations of limestone [3]. A critical source is lime-stone for the production of cement which creates CO₂ has essential depleting factor in the ozone layer.

To help decrease the shortfall in construction of low cost housing for the masses, in Ghana, the Building and Road Research Institute (BRRI) of the Council for Scientific and Industrial Research (CSIR) has made tremendous progress in research towards the development and advancement of locally–developed building materials. Among the materials are burnt clay bricks ([4]; [5]). To this end, broad research has been carried out to establish bricks and tile processing plants and the preparation of craftsmans on brick production ([4]; [6]). Burnt clay bricks have been acclaimed to have a few specialized, financial and ecological favorable circumstances. They are sturdy and have great aesthetic intrigue.
Lime is the by-product from burnt limestone. It is the most established created material utilized for development works, being utilized by human for over 2000 years. Additionally, Lime has been utilized by Romans for road construction. Soils stabilization with lime is broadly utilized in different construction works, for example, foundation base, highways, railroads, air terminals, embankments, slope protection, trench lining etc. Lime is utilized tremendously for stabilizing soil as it is economic, easy construction just as innovation is straightforward that gives attraction for the specialists in building and road constructions.

The sturdiness or stability of brick work structures during use can be influenced by manufacturing process, material properties, and environmental conditions, for example, dampness and salt attack just as upkeep culture ([7]; [8]). One of such extreme conditions which can cause intense disintegration of properties in brick work structures is marine environment. Therefore studying these variables influencing durability of burnt clay bricks produced and utilized locally is imperative. Durability properties incorporate physical behaviour like porosity, pore size distribution, bulk density and mechanical strength. These are subject to the kinds of raw material, the forming process and firing condition utilized in assembling. These when assessed will inform proper choice regarding building materials in construction, guarantee quality and performance during serviceability life when subjected to aggressive and unfavourable environmental condition.

2. MATERIALS AND METHODOLOGY
The apparatus used were compression machine, Oven, electric weighing balance and tray. The soil type in this experiment is laterite and was gotten from a new site under construction behind SEMS building in FUTA. The bigger lumps were crushed into smaller particle sizes and the soil sample was sieved using 6mm sieve to obtain finer particles. The lime was gotten locally from a laboratory specifically Vectra Scientific Laboratory, Ilesha Road, Akure. Treatment of soil sample with different quantity of lime varied from 2% to 10% of the total dry weight of the soil sample-lime mixture. All laboratory experiments were performed in the Kure Geotechnical laboratory, Federal University of Technology, Akure.

2.1. METHODOLOGY
Physical property tests were carried out on the lateritic soil in conformity with relevant standards. Laboratory index properties tests were used to categorise the sample. The tests are the moisture content [9], Atterberg limit [10], grain size distribution [10], specific gravity [9] and linear shrinkage [11].

2.1.1. Water Absorption Test (WAT)
The water absorption test (WAT) was performed according to specifications by [12] and [13]. Samples were selected randomly and prepared by drying at a temperature of 105°C to 115°C for 48 hours in a ventilated oven till it achieves constant mass and then cool to room temperature, the weight of the bricks were measured and recorded as (M1).

The samples were then immersed in clean water at room temperature for 24 hours. After 24 hours, samples were removed with a damp cloth and weighed after 3 minutes of removing from the water and recorded as (M2). Equation 1 was used to calculate the percentage of water absorption (PWA) of the brick by its mass.

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PWA = \frac{(M_2 - M_1)}{M_1} \times 100
\]

Where: PWA is Percentage water absorption, M1 is the mass of brick after drying, M2 is the mass of brick after immersion in water.
2.1.2. Compressive Strength Test
The strength test was directed according to the specifications of BS EN 772-1 [14]. The sample two sides were topped with steel plates to guarantee that the two faces have a level surface for pressure from the compression machine. All samples were oven dried for 24 hours to accomplish a consistent mass in the samples before curing was done for 28 days. Tests were done on selected samples periodically for 7, 14, 21 and 28 days. Compressive strength was determined utilizing the total load applied to the brick divided by the net gross area.

3. RESULTS AND DISCUSSION
3.1. Chemical Composition of Lime
Table 1 presented the chemical composition of the lime used in this research, it was observed the lime contained about 74% CaO as highest composition of the material.

| Lime Composition | Amount |
|------------------|--------|
| CaO (%)          | 73.77  |
| MgO (%)          | 3.300  |
| SiO₂ (%)         | 0.291  |
| P₂O₅ (%)         | 0.202  |
| Al₂O₃ (%)        | 0.170  |
| Cl (%)           | 0.131  |
| K₂O (%)          | 0.040  |
| SrO (%)          | 0.029  |
| MnO (%)          | 0.031  |
| SO₃ (%)          | 0.022  |
| TiO₂ (%)         | 0.012  |
| ZnO, ppm         | 91.20  |
| CuO, ppm         | 47.00  |
| ZrO₂, ppm        | 3.00   |

3.2. Geotechnical index characteristics of Unmodified and Modified Sample
From the Atterberg test carried out on the unmodified sample shows that the soil sample has an average plastic limit of 27.36%, the Liquid Limit for the sample is 40%, and the plasticity index recorded was 12.64%. The specific gravity and natural moisture content recorded was 2.71 and 9.85% respectively. In accordance with AASHTO M145, the soil can be classified as A-6 soil because more than 36% of the soil particles passes sieve no 200 (Figure 2). The liquid limit of the soil is <40% while the plasticity index is >11%. This signifies that the soil is a clayey soil and the general subgrade rating is fair to poor. According to ASTM D854, the inorganic clay generally range from 2.70 to 2.80. The above specific gravity test result of 2.71 therefore signifies that the soil sample is a clay soil.

Figure 1 displayed the atterberg limits and specific gravity results of soil sample with the addition of lime at varying percentages. The declined in liquid limit within 2% to 8% addition of lime is as a result of exchanges among the free calcium of the lime and the absorbed cations of the clay mineral. This will cause a decrease in size of the diffused water layer encircling the clay particles. The decrease in size of the diffused water layer makes closer contact among the clay particles resulting in flocculation/agglomeration of these particles.

The specific gravity (SG) for the control (untreated) and treated samples is displayed in Figure 1, the S.G of the sample rose from 2.71 at 0% of lime (untreated) to 2.85 at 10% of addition of lime content which is
in agreement with [15] and this is as a result of the molecular reshuffling of soil matrix due to the higher density of lime over the clay sample.

![Figure 1. Plot of Atterberg limits, Specific Gravity against lime content](image)

Figure 2. Particle size distribution of laterite used in brick production

### 3.3. Absorption Characteristics

Figure 3 presented the average water absorption characteristics of the brick with different proportion of lime content. It was observed that at 0% of lime the brick average water absorption recorded was 16.5% which falls within the second class brick designation (IS 1992)[12]. The addition of lime to the brick reduced the average water absorption steadily to fall within the first class brick category from 6% to 10%. The maximum reduction in the water absorption was observed at 8% addition of lime. From the results, increase in lime percentage reduced the absorption of water by the bricks which displayed the hydrophobic characteristics of lime.
3.4. Compressive Strength Characteristics

Figure 4 displayed the compressive strength of the bricks with different proportion of lime and curing days. At 7th day curing of brick, the compressive strength increased from 1.43 N/mm² at 0% lime content to 1.99 N/mm² at 6% lime content, a slight decrease was observed at 8% addition of lime, the strength reduced to 1.81 N/mm². The same trend was observed in 14, 21 and 28 day compressive strength. The results from the compressive strength are contrary to the results from the experiments of [16], that the minimum compressive strength of load-bearing concrete masonry is 5 N/mm². The results obtained from the compressive test is lower than the specification as such the bricks can be used in non-structural member in construction.
4. CONCLUSION

During the investigation, clay material was mixed with varying percentages of lime in order to recognize the behaviour of the material. It was established that:

1. reduction in the liquid limit, plastic limit was observed up to 8% addition of lime.
2. the specific gravity level rose from the initial 2.71 at 0% of lime content to 2.85 at 10% content of lime.
3. addition of lime to the brick reduced the average water absorption to fall within the first class brick category from 6% to 10%. The maximum reduction in the water absorption was observed at 8% addition of lime.
4. the compressive strength test results is lower than specification as such the bricks can be used in non-structural member in construction.

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