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Evaluation of Engineering Properties of Fired Cement Lateritic Brick

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Abstract. The construction industry is really concerned with producing better and durable building materials. Hence, the high cost of conventional building materials have resulted into use of locally available materials. This study assess the effect of varying cement content on engineering properties of fired lateritic bricks. The lateritic soil samples were stabilized with cement at 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7 and 7.5%, cast in moulds and later fired for 8 hours at a 1000^0C. Index properties (natural moisture content, specific gravity, particle size distribution and atterberg limit tests) were determined on the natural lateritic soil. While compressive strength, water absorption, abrasion and impact value test were determined on the cement fired bricks. The lateritic soil in its natural form were classified as A-6 and clay of high compressibility in accordance to ASTM D-3282. The results of the index properties are within acceptable limits for lateritic soil. The effect of varying cement content on the mechanical properties showed that the compressive strength of the bricks increases from 4.0 N/mm^2 at control (un-stabilized brick) to 7.3 N/mm^2 at 5% soil stabilization with cement. However, significant reductions in value was witnessed in the water absorption, abrasion and impact value results between the un-stabilized brick (control) and 5% cement fired bricks. The study concluded that fired bricks stabilized with 5% cement was found to be the best and most suitable for load and non-load bearing walls.

Introduction

The present construction industry is really concerned with discovering and producing strong and durable building materials to accommodate the increasing need for shelter, prevent devastating forces of construction and safe guard against fast polluting environment [1]. The problems influencing construction industry as highlighted by Hashim [2] and Olaoye [3] are numerous. These include scarcity and cost of construction materials, high demand for housing, lack of promotion of use of locally available materials and so on.

Solid or hollow sandcrete blocks are mostly used as walling unit (either as load bearing or non-loading bearing wall) in the construction of houses [4-7]. However, there is need to focus on some other materials that could serve the same purpose. One of these endowments with tremendous potential for economic utilization is lateritic brick. A clay brick is a walling material produced by a brick dough, which consists of clayey soil and water. It is formed primitively, naturally dried, and fired in the kilns [8]. Clay brick masonry is an ancient and durable construction material used by man [9]. Fired bricks are one of the long lasting and good building materials, sometimes referred to as artificial stone, and have been used since 5000 BC. Air-dried bricks, also known as mud bricks has straws as additional ingredient. Bricks are laid in courses and numerous patterns known as bonds, collectively known as brickwork, and may be laid in various kinds with mortar holding them together to form a whole. Clay bricks can be sun dried (Adobe) or burn in a controlled or uncontrolled temperature. Burnt clay bricks are porous and the degree of porosity depends on the temperature the bricks are subjected to during production. Odeyemi *et al.,* [10] asserted that firing ultimately produces consolidated but porous brick mass and impaired physical appearance with high production cost.

Many different techniques have been developed in using earth as a construction material. It was observed that these techniques vary according to the local climate and environment as well as local traditions and customs [11].

The scarcity and high cost of conventional building materials have resulted into use of locally available materials as alternative and as well as construction techniques to enhance access to housing for all. The use of Compressed Stabilized Earth Blocks (CSEB) as a walling material is a sustainable construction technique as it is affordable, durable and accessible. However, one of the major constraints has been the availability of suitable clay for making high strength bricks in Nigeria and the available ones are of varying grades and characteristics [12]. Das [13] found out that the specific gravity of clay materials ranges between 2.0 to 3.2. According to National Building Code [14], the maximum value for moisture absorption of lateritic bricks is 25%. Generally, soil could be classified as granular or silt-clay material on the basis of the percentage of fines passing through sieve number 200 (75 microns) for a value less than 35% granular. Furthermore, soils are classified into groups A-1 to A-7, with A-1 to A-3 being granular and A-4 to A-7 as silt-clay based on the value of Liquid Limit (LL) and Plasticity Index (PI). Soil with maximum LL value of 40% and minimum PI of 11% is classified as A-6 in accordance to ASTM D-3282 [15].

The necessity for locally made building resources has been discussed and analysed in several countries across the globe. Sourcing for suitable raw materials from the huge natural gifts of nature in Nigeria for construction works and to combat the hike in cost of building materials in construction world today, giving rise to high cost of erecting a building for an average man who deserves a shelter and to help reduce failure in buildings is the main reason for this research. The objectives are characterization/classification of the lateritic soil and in addition, determination of the effects of varying percentage of cement on the properties of fired bricks.

Materials and Methods

Sample collection

Dry laterite soil was taken from a borrow pit on coordinates 80 21.281N and 70 54.921E along Central Bank of Nigeria, new Iyin Road, Ado-Ekiti, Nigeria. The lump of the soil was crushed into loose materials using pestle in order to have fine particles. Thereafter, it was sieved until particle size of soil that passed through 1.18 mm were achieved. Drinking water in compliance to NIS-554 [16] was used for block production.

Methods

Natural Moisture Content (NMC), specific gravity, particle size distribution analysis and atterberg limit tests were carried out on the soil in order to determine the index properties of the sample in its natural state.

The NMC of the soil were determined in accordance to BS EN ISO 17892-12 [17]. Three weighing containers were cleaned and weighed to the nearest 0.01g as M_1 before use. The natural sample as collected were crumbled and placed loosely in the containers and the containers with the samples were weighed together to the nearest 0.01g as M_2. The containers were placed in the oven and dried at 105°C - 110°C for 24 hours before the containers with the samples were removed and weighed dry to the nearest 0.01g as M_3. The NMC was calculated using in Equation 1.

$$NMC = \frac{M_2 - M_1}{M_3 - M_1} \times 100 \tag{1}$$

Specific gravity test was done in accordance with BS EN ISO 17892-12 [17]. The samples were screened on British Standard sieve in order to remove unwanted particles and other materials. The weight of empty density bottle was recorded as W_1. The sample was filled into the density bottle and weighed; the weight was recorded as W_2 (weight of bottle + dry sample). The density bottle was then filled with distilled water to gauge mark, soon after the end of soaking, air entrapped and bubbles on the surface of the aggregate sample was removed by shaking the density bottle and the weight was recorded as W_3 (weight of bottle + dry sample + distilled water), after which the bottle was emptied and oven dry. The density bottle was then filled up with distilled water and weighed as W_4 (weight of bottle + distilled water). Equation 2 was used to determine the specific gravity of the soil.

$$Specific\,Gravity = \frac{w_2 - w_1}{\left(w_4 - w_1\right) - \left(w_3 - w_2\right)} \tag{2}$$

The particle size distribution was conducted in accordance with BS EN 933-1 [18]. The test sample was oven dried at temperature of $110 \pm 5°C$ and weighed. The sample was sieved with a set of BS sieves and electric sieve shaker. On completion of sieving, the materials on each sieve were weighed. Cumulative weight passing through each sieve was calculated as a percentage of the total sample weight.

The atterberg limits (LL, Plastic Limit and PI) tests were determined in accordance to ASTM, D-4318 [19]. For the Liquid Limit (LL), 200g oven dried sample of the soil passing the 425mm sieve was mixed with water on a glass plate in order to properly saturate it and was covered for about 24 hours. At the end of the period, the sample was properly remixed using spatulas. The cone penetrometer was properly adjusted in position in readiness for the test. The sample cup was filled with the mixed sample and the initial reading was observed. It was allowed to penetrate into the sample for five seconds and the final reading was equally noted. Some quantity of soil was then taken from the cup for moisture content determination. The soil in the cup was returned to the glass plate. The soil in the cup was returned to the glass plate. The water content was slightly increased and the soil was properly re-mixed, the cup was properly cleaned. The whole process was repeated five times. From the same soil sample, threads of about 3mm diameter were obtained by kneading and rolling and the moisture content was determined to achieve Plastic Limit (PL). The Plasticity Index (PI) is the difference between the liquid limit and the plastic limit of the soil.

Fired cement lateritic bricks were produced using 250 x 110 x 60 mm mould (Fig 1). Varying percentages of cement (3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, and 7.5%) by weight of laterite were used to produced (Three samples each) stabilized and un-stabilized (control) fired lateritic bricks. Moulding of mud was done through mixing of the lateritic clay at its natural moisture content with water. The mixture was kneaded by hand for until it becomes ready for moulding. The machine moulds were first coated with sand to prevent the mixture from sticking. The prepared mixture were then placed and pressed into the coated moulds. Thereafter, removal of the excess material from the mould and smoothening the brick using trimming tools was done. The formed bricks in the moulds were lined in a certain order on the compressed earth and allow to dry. The compressed bricks were removed from the mould and allowed to dry naturally for 3 days and were fired for 8 hours at a 1000^0C using kiln. A total number of One Hundred and Thirty-Two (132) fired bricks were produced. The bricks were cured by sprinkling with water for 28 days. Thirty-three (33) samples each were subjected to compressive strength, Water Absorption Capacity (WAC), abrasion and impact tests.

Fig. 1: Moulding of Cement Stabilized Lateritic Bricks

Compressive strengths of the bricks were determined using CR2-030 hydraulic compression machine of 2000kN Capacity in accordance to ASTM C773-88 [20]. The WAC, abrasion and impact tests were determined in accordance to National Building Code [14]. The tests on the fired bricks were carried out on both the cement stabilized and un-stabilized fired lateritic bricks at the Geotechnical Engineering Laboratory, Federal Polytechnic Ado-Ekiti, South Western Nigeria.

Results and Discussion

Index properties

The result of the NMC of the soil sample was 5.4% which varied from findings of Oyelami [21], Olofinyo *et al.,* [22] and Ige *et al.,* [23]. Variation in NMC of lateritic soils are influenced by climate, hydrological condition of the area and the topography of the area [24].

The results of the specific gravity of the soil samples in this study was 2.66. The result is in agreement with previous studies by Ademila [24], Oyelami [21], Olofinyo *et al.,* [22] and Ige *et al.,* [23].

The particle size distribution analysis of lateritic soil is as presented in Table 1. The index properties of the natural lateritic soil sample classified the soil as fair to poor (A-6) and Clay of High compressibility (CH) according to ASTM D-3282 [15] and USCS Classification system as per ASTM D-2487 [25].

Table 1: Result of particle size distribution analysis of lateritic soil

Sieve Size (mm)	Weight Retained (g)	Weight Retained (%)	Passing (%)
9.50	0	0	100
4.75	0	0	100
2.36	0	0	100
1.18	30	15	85
0.60	22	11	74
0.30	38	19	55
0.15	24	12	43
0.075	06	03	40

The results of the atterberg limits were 48%, 33% and 15% for LL, PL and PI, respectively. Soil samples with LL of < 30% are considered to be of low plasticity and compressibility, those with LL between 30 and 50% exhibits medium plasticity and compressibility while those with LL >50% exhibits high plasticity and compressibility. LL of the soils used in this study are medium plasticity which are suitable for earth buildings [21, 26].

Compressive strength of bricks

The average compressive strength of the cement stabilized and un-stabilized fired lateritic bricks are presented in Fig. 2. The 28th-days compressive strength shows that the strength of the bricks increases from 4.0 N/mm^2 at 0% cement replacement (un-stabilized bricks) to 7.29N/mm^2 at 5% cement stabilized bricks. Thereafter, a fall in strength from 6.96N/mm^2 at 5.5% stabilized bricks to 5.19 N/mm^2 at 7.5% stabilized bricks. Hence, 5% cement stabilized bricks have the highest compressive strength. Based on this, the bricks are suitable for use as load bearing walling material in accordance to NIS 87 [27]. The results in this study are within the minimum values recommended for characteristic compressive strengths for non-load-bearing and load-bearing fired clay bricks which are 3 to 5 N/mm^2 and 5 to 10 N/mm^2, respectively [28, 29]. The Nigerian National Building Code [14] specifies minimum value of 3N/mm^2 for fired clay burnt bricks. This further satisfies the usefulness of the fired cement lateritic bricks as a walling material.

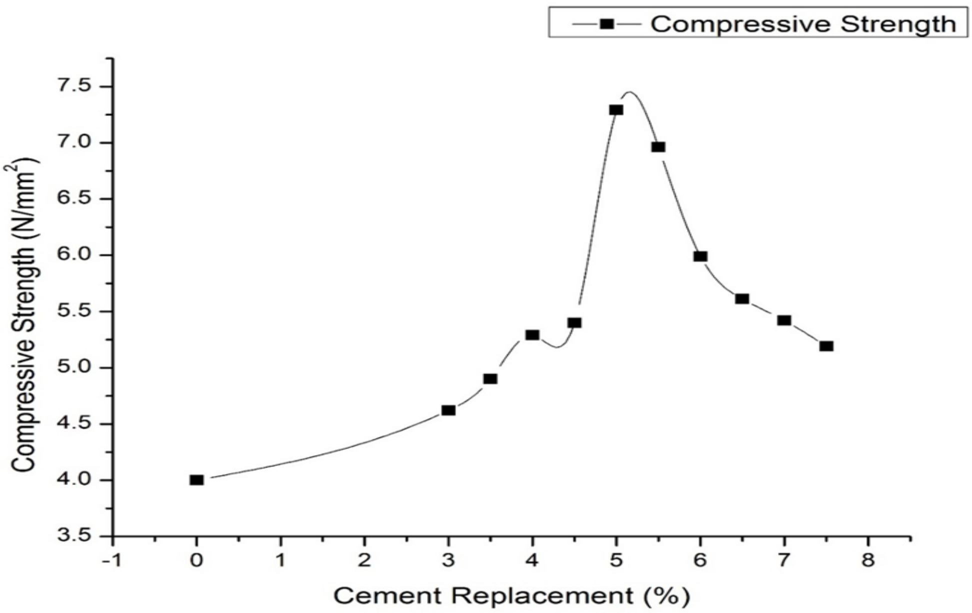

Fig. 2: Result of Compressive Strength of Lateritic Bricks

Water absorption capacity of bricks

The result of the WAC (Fig. 3) shows that the water absorbs by the bricks decreases from 16% at control (un-stabilized fired bricks) to 3.6% at 5.5% cement stabilized fired bricks but later increases from 3.65% at 6% cement stabilized fired bricks to a constant value of 5.5% WAC between 6.5-7.5% cement stabilized fired bricks. The maximum absorption was attained at control mix (un-stabilized fired bricks) where the minimum strength was attained. The un-stabilized bricks and cement stabilized bricks are within 20% maximum value of WAC for clay bricks reported by Timothy *et al.,* [29] and, Bassah and Joshua [30]. The WAC of the bricks are also in agreement with the recommended value of 25% specified National Building Code [14]. The presence of cement in the lateritic soil lead to reduction in water absorption of the fired bricks, and similar trend was established by Phonphuak *et al.,* [31].

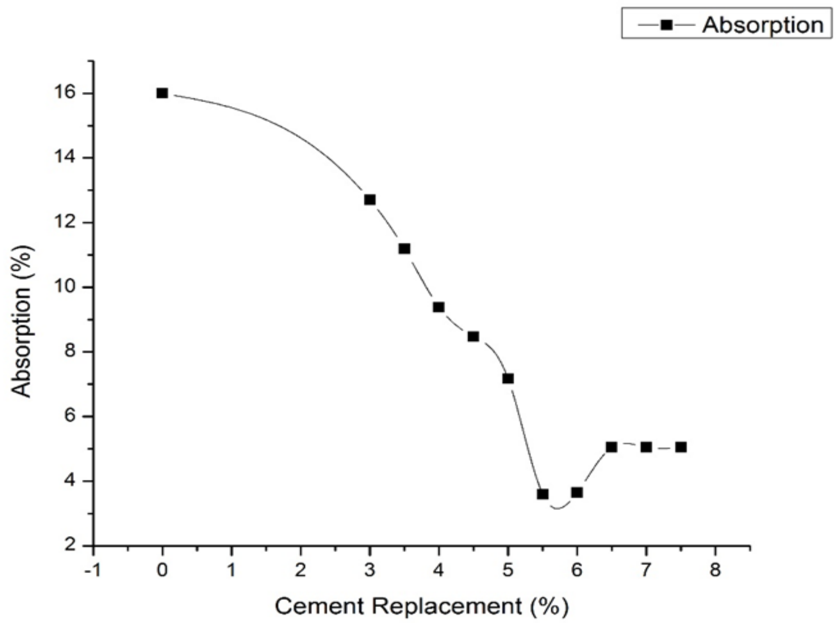

Fig. 3: Water Absorption of Lateritic Bricks

Abrasion of bricks

The abrasion test result of the cement stabilized and un-stabilized fired lateritic bricks varied between 1.03% and 13.79% (Fig. 4). The maximum abrasion was attained at 0% cement addition where the minimum compressive strength was attained while the minimum abrasion value was attained at 5% cement addition where the maximum compressive strength was attained which indicate a better surface wearing. The implication of the above results is that the stabilized fire brick has better resistance to wearing effect due to low weight loss which makes it more suitable for construction purpose.

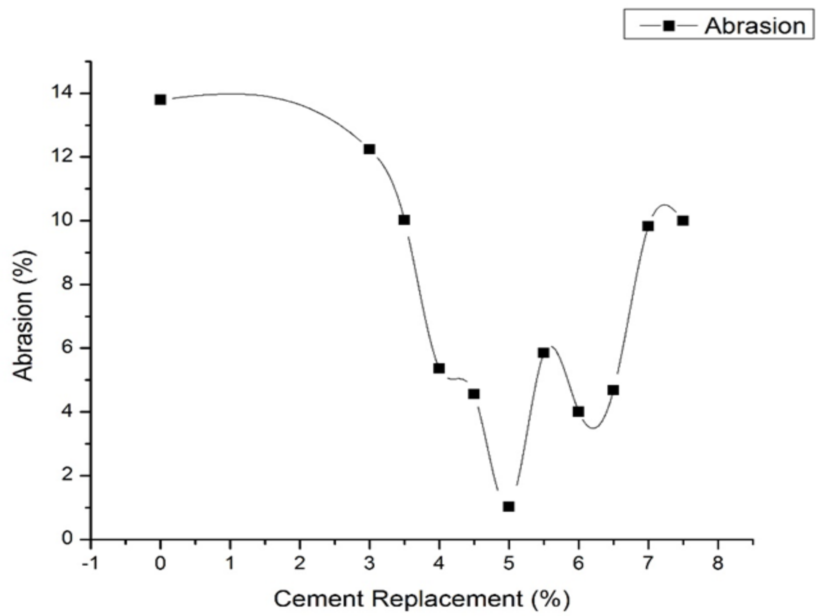

Fig. 4: Graph of Abrasion of Bricks

Impact value of bricks

The result of the impact value test performed on the bricks as shown in Fig. 5 varied between 12 and 38% for all the cement variation in the mix. The maximum impact value was attained at 0% cement addition (un-stabilized fired bricks) where the minimum compressive strength was attained while the minimum impact value was attained at 5% cement stabilized fired bricks where the maximum compressive strength was attained. The lower the impact value, the more the strength of the bricks to withstand external force (high resistance to sudden shock). This implies that the bricks at 5% cement stabilized fired bricks will reduce shattering effects of bricks when subjected to sudden external force.

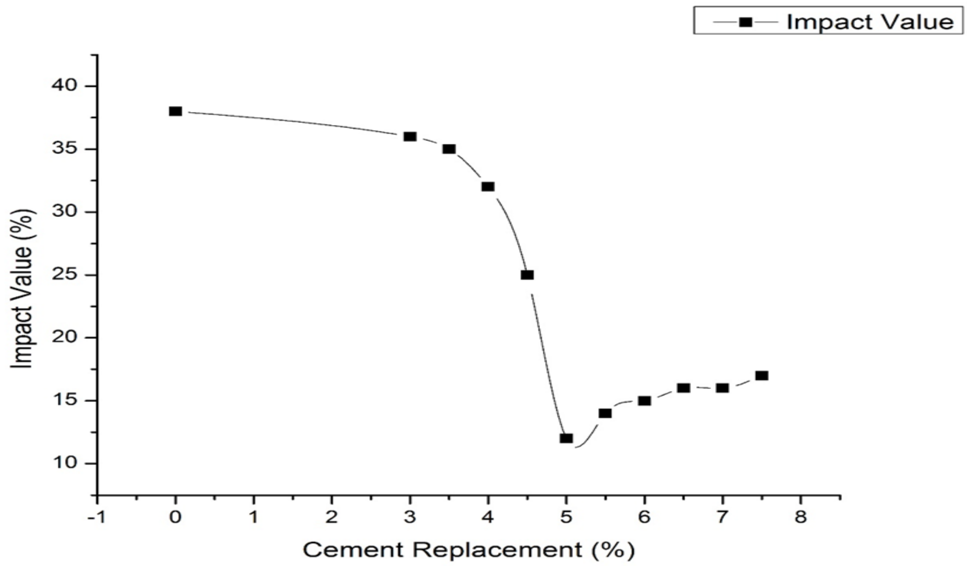

Fig. 5: Result of Impact Value of Lateritic Bricks

Conclusion

From the findings, it was observed that the lateritic soil belongs to the category of silty clay. The NMC and specific gravity results of the lateritic soil is in agreement with stipulated recommended values. The LL of the soils used belongs to medium plasticity category which are suitable for building construction. It could also be inferred that as the percentage of cement increases from control (un-stabilized cement fired bricks) to 5% (stabilized cement fired bricks), the compressive strength also increases. However, further increment in cement percentage after 5% resulted into a decrease in the compressive strength of the bricks. In addition, the water absorption capacity decreased up to 5.5% and further increased at 6%; the abrasion value indicates an irregularities in deduction while the impact value decreased up to 5% and further increased at 5.5%. Based on these, it is recommended that 5% cement stabilized fired brick should be used as walling materials since it possess the optimum strength, low water absorption rate and better resistance to surface wearing and sudden shock (impact). Hence, 7.5% cement stabilized fired brick is also suitable for use as walling materials since the compressive strengths is above the minimum strength specified by Nigerian National Building Code.

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