EFFECTS OF PARTIAL REPLACEMENT OF SAND WITH LATERITIC SOIL IN SANDCRETE BLOCKS

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***Abstract*:** Of recent, the attention of most researchers is shifting towards the optimization of building materials by using local contents; the use of indigenous materials; and local industrial by-products unique and abundant in certain localities. This study therefore explored ways in which lateritic soil could be utilised in hollow sandcrete block production in Ota, Ogun State, Nigeria. Sandcrete blocks were made with lateritic soil taken from different sources replacing the conventional fine aggregate (local river sand) in steps of 10% up to 60%. Their compressive strengths determined to check for conformity with standard sandcrete block as specified in the Nigerian National Building Code (2006) with a view to determine the acceptable percentage replacement. Soil tests were performed on the lateritic soil samples to characterise the soils. Classification of the lateritic soil samples within Ota, revealed that the lateritic soils are mostly sandy clay of high plasticity and may replace sand by up to 20%, though an approximate linear decrease in strength with increasing sand replacement with lateritic soil was observed. This percentage replacement can be recommended to the block making industries within Ota with a view to encouraging utilization, though it is encouraged to confirm the percentage before embarking on mass block production.

***Keywords*:** Laterised blocks, Laterite, Sandcrete blocks, Soilcrete and Lateritic soil.

Introduction

High cost of building materials has been the bane of construction industry in the developing countries of the world as a result of importation of most of the building materials. As prices increase sharply, there is a growing awareness to relate research to local materials as alternatives for the construction of functional but low-cost dwellings both in the urban and rural areas of Nigeria. One of such local material that is being researched is lateritic soil. Lateritic soil has been one of the major building materials in Nigeria for a long time. The main reason lies on the fact that it is readily available and the cost of procuring it is relatively low.

Lateritic soil possesses other advantages which makes it potentially a very good and appropriate material for construction, especially for the construction of rural structures in the developing countries. These merits include little or no specialized skilled labour required for laterized sandcrete blocks production and for its use in other construction works; and laterized concrete structures have potentially sufficient strength compared with that of normal concrete (Lasisi and Ogunjimi,1984).

This study is part of the continuing effort to investigate the characteristics of lateritic soils, stabilized (mostly with cement or lime) or unstabilized, reinforced or unreinforced, with the view to improving such characteristic. This study is specifically focused on the effects of replacement of the conventional fine aggregate (sand) with lateritic soils found in Ota on the compressive strengths of laterized sandcrete blocks.

Lateritic soils are essentially the products of tropical weathering usually found in areas where natural drainage is impeded (Amu *et al.*, 2011; Lasisi and Osunade, 1984). From an engineering point of view, laterite or lateritic soil is a product with red, reddish brown and dark brown colour, with or without nodules, ability to self-harden, concretions, and generally (but not exclusively) found below hardened ferruginous crusts or hard plan (Ola, 1983). Lasisi and Ogunjide (1984) assert that the degree of laterization is estimated by the silica sesquioxides ratio (SiO_2/ (Fe_2O_3 + Al_2O_3)). Silica-Sesquioxide (S-S) ratio less than 1.33 are indicative of laterites, those between 1.33 and 2.00 are lateritic soils and those greater than 2.00 are non-lateritic types.

According to Akintorinwa *et al.*, (2012), lateritic soil abounds locally and its use is mainly limited to civil engineering works like road construction and land fill operations. It is less utilised in the building industry except in filling works. In lieu of the abundance of lateritic soils and its availability, its optimum use in building production could positively affect the cost of buildings leading to the production of more affordable housing units (Joshua and Lawal, 2011). Its use in the building production is not yet generally accepted because there are no sufficient technical data on it, hence limiting its wider application in building construction work (Udoeyo *et al.*, 2006).

Studies are currently going on in the use of lateritic soil in concrete production where laterite is made to partly or wholly replace conventional fine aggregate in the production of concrete known as laterized concrete; and in the production of brick units such as Compressed Laterized Brick (CLB) usually stabilised with cement. Presently, these applications are mostly limited to buildings in rural areas and low income housing projects which are mostly situated at satellite areas (outskirts) of Central Business Areas (CBA's).

This study is aimed at investigating the effects of partial replacement of conventional fine aggregate, sand, with lateritic soil in the production of sandcrete blocks. It sought to compare the various percentage replacements with the standard requirements of a sandcrete block as specified in the Nigerian National Building Code (Federal Republic of Nigeria, 2006) and derive the maximum replacement that will satisfy the code.

Literature Review

Laterite is often used to describe the clinkered siliconized clay material. According to Amu *et al.*, (2011), it could be described as material with no reasonable constant properties while Villan-Co Chin *et al.*, (2003) and Amu *et al.*, (2011) described it as a red friable clay surface, a very hard homogenous vescular massive clinker-like material with a framework of red hydrated ferric oxides of vescular infill of soft aluminum oxides of yellowish color. Villain- Cocina*et al.*, (2003) opined that mechanical stability is an important factor that should be considered in the use of lateritic materials. On the other hand, mechanical instability may manifest in form of remoulding and recasting and breakdown of cementation and structure. The mechanical instability can affect engineering properties of laterite, such as particle size, Atterberg's limits, moisture content, grain size among others which in turns affect the strength of laterized products (Middendorf *et al.*, 2003 and Day, 2003).

These properties can however be improved through stabilization in order to improve the characteristics and strength. O'Flaherty (2002), Villain-Cocina *et al*., (2003) and Amu *et al*., (2011) described soil stabilization as any treatment applied to a soil to improve its strength. Different methods have been used in laterite stabilization in recent years, mechanical and chemical stabilization being the two most popular methods in operation all over the world. Laterite stabilization using mechanical approach involves blending of different grades of soils to obtain a desired standard. Chemical stabilization on the other hand, is the use of silicon friendly material in blending of natural clay with chemical agents such as pozzolana, soda ash, fly ash cement among others. It is against the antecedents that this study researched into laterite stabilization with a view to reducing production cost.

The term "laterite" is used to describe a ferruginous, vesicular, unstratified and porous material with yellow ochre caused by its high iron content, occurring abundantly in Malabar, India (Osunade, 2002). It was locally used in making bricks for buildings, and hence the name "laterite" was derived from the Latin word "later" meaning "brick".

Although laterite is a material that has been used in the building construction industry in Nigeria for a very long time, especially in the rural areas, there is a paucity of data describing the behaviour of this material. There is therefore the need to improve indigenous technology on the practical usefulness of lateritic soils in the construction industry. A lot of research activities are now being carried out on lateritic soils. Previous works on laterized concrete appear to have been a study in which the strength properties of normal concrete were compared with those of laterized concrete (Adepegba, 1975). The conclusion of that study was that concrete in which laterite fines are used instead of sand can be employed as a structural material in place of normal concrete.

According to Balogun and Adepegba (1982), when sand is mixed with laterite fines, the most suitable mix for structural applications is 1:1.5:3 (Cement: sand plus laterite fines: gravel) with a water-cement ratio of 0.65, provided that the laterite content is kept below fifty percent (50%).

It has also been established by Lasisi and Osunade (1984) that the finer the grain size of lateritic soils, the higher the compressive strength of the unstabilized cubes made from such soils. That also reported that the possible formation processes form a factor in the strength determination and that the compressive strength of lateritic soils is dependent on the source from which they were collected.

In a study on the effect of mix proportion and reinforcement size on the anchorage bond stress of laterized concrete, Osunade and Babalola, (1991) established that both mix proportion and the size of reinforcement have a significant effect on the anchorage bond stress of laterized concrete specimens. The richer the mix proportion, in terms of cement content, the higher the anchorage bond stress of laterized concrete (Osunade and Babalola, 1991). Also, the anchorage bond stress between plain round steel reinforcement and laterized concrete increases with increase in the size of reinforcement used.

The study by Osunade (1994) found out that increase in shear and tensile strengths of laterized concrete were obtained as the grain-size-range and curing ages increased. Also, greater values of shear and tensile strengths were obtained for rectangular specimens than those obtained for cylinders. Stabilized and unstabilized lateritic soils have been reinforced with different reinforcements (e.g. rope, grass, sawdust, etc.) and results have generally shown that performance characteristics of lateritic soils can greatly be improved using such reinforcements.

Study Justification.

From preliminary works, the closest construction element with laterite as part of its material in masonry is the compressed laterized earth brick stabilized usually with cement or lime. The use of this brick is either in the rural areas or in a low cost housing project. Unfortunately, despite the establishment of about twenty brick manufacturing plants in Nigeria since 1976 and the low-cost of locally produced bricks, their application in the building construction industry has not gained much popularity except in very few occasions where the government took the initiative to deliberately utilise stabilized compressed lateritic and clay soil like the case of Aco Hi Tech in Lugbe, Abuja and few others (Joshua and Lawal, 2011). Hence, this study seeks to find a way of incorporating laterite in the production of sandcrete hollow blocks.

Sandcrete blocks are constructional masonry units that have been generally accepted to the extent that when an average individual thinks of building, the default mind-set is the use of sandcrete hollow blocks. Hence, this research seeks to find a way of incorporating the use of laterite in its production for a probable cost reduction, local content utilisation, creation of local employment and development of indigenous technology as a result of its ready availability.

Materials and Research Methodology

Hollow sandcrete blocks were produced with fine aggregate (sand and laterite) and cement. Ten percent (10%) of the conventional fine aggregate (sand) was replaced with the lateritic soil and then 20%, 30% until the lateritic soil completely replaced the sand. Four (4) blocks at each percentage replacement of the conventional fine aggregate with the lateritic soil content were produced, cured weighed and tested for the twenty-eight (28) day compressive strength and the average values of the closest three (3) strength range values taken as actual parameters. For control, four blocks were moulded without replacement, that is, with 100% conventional sand. They were prepared to have water/cement ratio that will ease moulding as this is to simulate site conditions. They were cured by sprinkling with water for 28 days and crushing test was performed on the samples to determine their compressive strengths.

The machine used in this work was the HFI compression machine and coronet block moulding vibrating machine for the compressive tests and block moulding, respectively. These compressive strength values were compared with the 28-day strength requirements of a standard sandcrete block as specified in the National Building Code (2006) and the maximum lateritic soil replacement that still falls within the standard sandcrete block requirement was taken as the maximum permissible replacement that can be recommended for practice in the sandcrete block moulding production.

Compaction test to determine the bulk density, sieve analysis, hydrometer test, Atterberg's limit test and specific gravity test were performed on the lateritic soil samples and the results were used to characterise the soil samples used in the current research. The whole process was repeated with lateritic soil sourced from two other different locations in Ota and the final average of the three (3) averages from the different lateritic soil sample sources be computed as actual values. The lateritic soil samples that were used in this research work were obtained from three different locations within Ota, Ogun State. The first two samples were obtained from Canaanland, Km10, Idiroko Road Ota, Ogun State, with the first behind the Daniel Hall of Covenant University and the second in the Canaanland Camp grounds. The third and last sample was obtained from Chelsea, Km 14, Idiroko Road Ota. The soil samples were then labelled Samples A, B and C respectively.

The other materials used were Dangote cement, bore-hole water suitable for drinking sourced from Canaan land and the sharp sand obtained by Water Side beside the Lagos-Abeokuta Express way. The fine aggregate samples (sharp sand and the lateritic soil) were sieved with a 5mm sieve size and spread indoors for about a week. The choice of Dangote cement in preference to other cement products lies on its strength and reliability amongst the locally produced cement in Nigeria (Yahaya, 2009). The mix ratio of the laterised sandcrete block was 1:6 by volume, that is, one part of cement to six parts of fine aggregate (combination of sand and lateritic soil). As this ratio (1:6, cement to sand) is the recommended standard for the production of sandcrete by the Nigerian National Building Code (2006). When the permissible lateritic soil replacement was established from the results, cost analysis was then conducted on the basis of current cost of the materials to ascertain the cost reduction level in this perspective.

In almost all construction cases, the walls of buildings are usually plastered and rendered and this tends to minimise the effects of weather and other environmental condition on the durability of walling materials in the study area.

Observations

Block Moulding

It was observed during the process of making the blocks that the volume of water needed to produce the control mix and the 10% replacement had to gradually increase as the percentage replacements with laterite increases to attain a consistency that could make the blocks. Otherwise, the fresh sandcrete (mortar) would not discharge from the mould and every further discharge attempt resulted to the fresh sandcrete shattering out of the mould thereby loosing the desired shape of the blocks.

Despite the increase in water content for effective moulding, perfect blocks could not be moulded beyond sixty percent replacement with the lateritic soil and the sixty percent replacement was done repeatedly before arriving at a perfect shape after the mould was heavily lubricated with diesel. This was not unconnected with the fact that the adhesion of the mortar-mix to the mould was greater than the cohesion between the partials of the blockings-in-making despite the fact that the mould was heavily lubricated.

Soil Classification

The soil was classified according to the Unified Soil Classification System (USCS). From the grain size distribution curve (Fig. 1) and the Atterbergs limits in Table 1, the results show that greater percentage were retained in #200 sieve (75μm) in all samples signifying that they are all coarse grained aggregates.

Greater than 50% passed the #4 sieve (4.36μm) in all samples thereby classifying all samples as sandy soils.

From Fig. 1, C_u (coefficient of uniformity) and C_c (coefficient of curvature) for samples A, B and C are as shown in Table 1. They are all classified as well graded soils since all C_u are greater than 15 and all C_c between the ranges 1-3 (Holtz and Kovacs, 1981).

In all samples, greater than 12% passed the #200 sieve size as indicated in Fig.1 and the values of the liquid limit (LL) and plastic limit (PL) in Table 1 were used to generate the plasticity index (PI). The liquid limits and the plasticity indexes on the Casagrande’s plasticity chat shows that they are on the A-line and above the hatch zone on the chat signifying that all samples are clay of high plasticity (Holtz and Kovacs, 1981).

Discussion of Results

Lateritic Soil Characteristic Test Results

The physical properties of the lateritic soil (Table 1) show that the Atterberg's limits, specific gravity and densities of the lateritic soils. These properties were used in classifying the soils and the implications of their characteristic values are discussed in proceeding properties below.

Grain Size Analysis Result (Gradation).

To further classify the lateritic soil samples, the Casagrande Plasticity chart was used. The lateritic soil samples fall within the CH zone and since greater than 12% pass the #200 sieve and their positions on the chart are above the A-line, meaning the samples are sandy clay of high plasticity.

All samples meet the grading requirements for fine aggregate to BS 1377: 1975.

Figure 1 depicts a combined graphical representation of Sieve analysis and Hydrometer test results from which D_{10}, D_{30} and D_{60} were obtained to determine C_u and C_c. Since C_u is greater than 15 and C_c between 1 and 3 for all samples, the samples are well graded soils. The result lends credence to a similar work by Holts and Kovacs (1981)

Specific Gravity Result

The results in Table 1 show that the lateritic soil samples A, B and C have a specific gravity of 2.69, 2.62 and 2.67 respectively which classifies them as normal aggregates. This is premised on the fact that they fall within the range of 2.6 and 2.7 for normal aggregate as specified by Neville and Brooks (1987). Also, the silt/clay content present in the lateritic soil samples are greater than 8% specified by BS882:1992. This can be attributed to be one of the reasons for the reduction in strength of the sandcrete blocks with increased replacement of the mix with the lateritic soils. Gradation curve (Figure 1). The lateritic soil samples are sandy clay of high plasticity.

Densities Results

The results of the compaction test according to BS 1377: 1975 for the three soils are as shown in Fig.2. The Maximum dry densities and the optimum moisture contents are as follow:

Sample A and B share the same maximum points as observed from Fig. 2.

Also from Fig 2, maximum dry densities for samples A, B and C were 1.86, 1.86 and 1.875 respectively and optimum moisture contents were 17.5% for samples A and B and 13% for sample C.

The bulk densities for A, B and C corresponding to the maximum dry densities are 2.16

Mg/m^3, 2.14 Mg/m^3 and 2.10 Mg/m^3 respectively.

Compressive Strength of Blocks

The results of the compressive strength tests are shown in Fig 3. It was observed that the strength curve is approximately linear and negative with increasing replacement with lateritic soil. From Fig. 4, the greater the percentage replacement with the lateritic soil, the lighter the blocks produced and lower the compressive strength indicating that lateritic soils are lighter than sand. It was observed that the higher the density of the blocks, the greater their compressive strengths.

Conclusion and Recommendation

Tests have been conducted to evaluate the suitability of lateritic soils within the boundaries of Ota and its effect on the strength of sandcrete blocks when used to replace the conventional fine aggregate. The study recommends that block moulding Industries within Ota need to adhere strictly adhere to standard practice by incorporating lateritic soil not greater than 20% of the aggregate used in their sandcrete block production as a way of reducing the production cost as well as a corresponding reduction in the market price of sandcrete blocks.

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