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Cost Optimization of Sandcrete Blocks through Partial Replacement of Sand with Lateritic Soil

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Abstract

This work finds a way in which lateritic soil within Ota, Ogun State of Nigeria could be used in the production of hollow sandcrete blocks. This replacement is intended to develop more economic sandcrete blocks since the cost of lateritic soil in Ota is much less than the cost of the conventional fine aggregate used in the production of sandcrete blocks without compromising the intergrity of the blocks. It was deduced from literatures that inclusion of lateritic soil in sandcrete block production results in a lesser quality blocks. However, this work found the maximum permissible replacement that still makes the blocks to be within the recommended standard. The blocks were produced with each lateritic soil sample from different sources replacing sand in steps of ten percent to 60% and their compressive strengths determined and compared with that of a standard sandcrete block to check for the acceptable percentage replacement. In the compressive strength test, 72 numbers of 225 x 225 x 450mm hollow laterised sandcrete block sizes were produced, cured and crushed to determine their twenty-eight-day compressive strength. Cost analysis was performed discovered that the inclusion of the lateritic soil saves the cost of production by 11.89%. This percentage replacement can be recommended to the block moulding industries within Ota with a view to reducing the production costs of the blocks.

Keywords: Economic block, laterized brick, laterized sandcrete block, lateritic soil.

1. Introduction.

A major factor affecting the construction industry in developing countries is the cost of building materials most of which have to be imported. Frequent increases in prices of building materials across Nigeria has reawakened serious awareness to relate research to production, especially in the use of local materials as alternatives for the construction of functional but low-cost dwellings both in the urban and rural areas of Nigeria. One such local material that is being researched is lateritic soils. Lateritic soil has been one of the major building materials in Nigeria for a long time. The main reason is because it is readily available and the cost of procuring it is very low.

Lateritic soil has other advantages which make it potentially a very good and appropriate material for construction, especially for the construction of rural structures in the developing countries. These advantages include non-requirement of specialized skilled labour for the production of laterized sandcrete blocks and for its use in the construction of structures. Laterized concrete structures are known to have potentially sufficient strength compared with those of normal concrete.

This study is part of the continuing effort to investigate the properties of lateritic soils, stabilized or unstabilized, reinforced or unreinforced, with the view to improving such properties. Specifically, the study looks into the effect of replacement of the conventional fine aggregate, sand, with lateritic soils within Ota on the compressive strengths of laterized sandcrete blocks with the purpose of reducing its unit cost of production. Sandcrete blocks are constructional masonry units that have been generally accepted to the extent that when an average individual thinks of building, the default mindset is the use of sandcrete hollow blocks. Sand, the main constituent of sandcrete block, is, according to Sengupta (2008), a natural product obtained from riverbeds, the mining of which is expensive. This 'cost' aspect is why this research explores cost reduction options without compromising quality by way of using mixtures of sand and laterite in block moulding. Cost reduction which leads to cost optimization is one of the most crucial aspects of construction project planning which Shi et al. (2009) and Wu and Lo (2009) regarded as a multi objective optimization problem.

Laterite, derived from the Latin word"later" is essentially the product of tropical weathering. It is usually found in hot and wet tropical areas where natural drainage is impeded (Lasisi and Osunade, 1984; Wikipedia, 2003). From an engineering point of view, laterite or lateritic soil is a product of tropical weathering with red, reddish brown and dark brown colour, with or without nodules or concretions and generally (but not exclusively) found below hardened ferruginous crusts or hard plan (Ola, 1983). Generally, the degree of laterization is estimated by the silica sesquioxides (S-S) 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 (Lasisi, 1983).

In Nigeria, lateritic soil abounds locally and its use is mainly limited to Civil engineering works like road construction and land fill operations but it is less utilised in the building industry except in filling works. Because of the abundance of lateritic soils and its ready availability, its optimum use in building production could positively affect the cost of buildings which can lead to the production of more affordable housing units. However, because laterites and lateritic soil have no sufficient technical data, it is not yet a generally accepted building constructional material and this contributes to its limited application in building block production (Udoeyo, 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. These applications are currently 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 partially replacing conventional fine aggregate, with lateritic soil in the production of sandcrete blocks and comparing the various percentage replacements with the standard requirements of a sandcrete block as specified in standard codes and concludes at a maximum replacement that satisfies the standard. It is believed that this work will contribute to the existing data available on the use of lateritic soil in Building production, especially the lateritic soil within Ota, Nigeria.

2. Justification for the Study.

From findings, 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. And 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.

3. Review of Previous Works

According to Osunade (2002), the term "laterite" was used to describe a ferruginous, vesicular, unstratified and porous material with yellow ochre caused by its high iron content, occurring abundantly in Malabar in India. It was locally used in making bricks for buildings, and hence the name "laterite" from the Latin word "later" meaning "brick". Although laterite is a material that has been used in the building construction industry of Nigeria for a very long time, especially in the rural areas, there is lack of adequate data to fully understand the behavior of this abundant material. There is need to improve indigenous technology on the practical usefulness of lateritic soils in building and allied industries. A lot of research activities are now being carried out on lateritic soils. Earlier published 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 this study was that a concrete in which laterite fines are used instead of sand, can be used 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. They have 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, it was 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, in terms of cement content, the mix proportion, 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.

According to Osunade (1994), it was found that increase in shear and tensile strengths of laterized concrete was obtained as grain size ranges and curing ages increased. Also, greater values of shear and tensile strengths were obtained for rectangular specimens than those obtained for cylinders. Studies have also been carried out on how the performance characteristic of laterite can be improved. Stabilized and unstabilized lateritic soils have been reinforced with different reinforcements such as rope, grass, sawdust, etc; and results have generally shown that performance characteristics of lateritic soils can greatly be improved using such reinforcements.

4. Research Method.

Hollow sandcrete blocks were moulded with fine aggregate and cement. Ten percent (10%) of the fine aggregate replaced with the lateritic soil and then 20%, 30% until the lateritic soil completely replaces 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, i.e., with 100% conventional sand. They were prepared to have water/cement ratio that will ease moulding and other preparation like curing methods the same. They were cured for 28 days and crushing test was performed on them to determine their compressive strengths. These compressive strength values were compared with the 28 day strength requirement 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 be 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 their results were used to characterise the soil samples used in this work. This whole process was repeated with lateritic soil sourced from two (2) other different location 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 tagged A, B and C respectively where :

Sample A: lateritic soil sample from behind the Daniel hall, Covenant University.
Sample B: lateritic soil sample from the Camp ground, Covenant University; and
Sample C: lateritic soil sample from Chelsea, two kilometres west of Covenant University.

The other materials used are the 'Dangote' cement (ordinary Portland cement to BS 12), bore-hole water fit for drinking sourced from Canaanland and the sharp sand obtained by water side beside the Lagos-Abeokuta express. The fine aggregate samples (sharp sand and the lateritic soil) were sieved with a 5mm sieve size and spread indoors for about a week in order to keep them as dry as possible since it was in the raining season that the experiments were done. The mix ratio of the laterised sandcrete block was 1:6 by volume, i.e., one part of cement to six parts of fine aggregate (combination of sand and lateritic soil) as recommended in the Nigerian National Building Code (2006). When the permissible lateritic soil replacement is established from the results, cost analysis will then be prepared based on current cost of the materials so as to ascertain how much cost is reduced.

5. Presentation and Discussion of Results.

5.1 Block moulding observations.

After the trial mix as described in section 1.3.1.2 to determine the quantity of water needed to mix a batch, it was observed that the quantity of water with same volume as the trial mix was only possible to produce the control mix and the ten percent (10%) lateritic soil replacement and more volume of water was needed to produce higher replacements of lateritic soil. If the water was not increased, the fresh sandcrete will not come out of the mould and if forced out by vibrating while removing from the mould, the fresh sandcrete will shatter out of the mould thereby not maintaining the mould-shape. The higher the lateritic soil replacements, more water content were needed to effectively mould them to a perfect sandcrete block shape. But despite the increase in water content for effective moulding, perfect blocks could not be moulded beyond sixty percent (60%) replacement with the lateritic soil and the sixty percent (60%) replacement has to be done several times before finally getting a perfect mould after the mould was heavily lubricated with diesel.

5.2 Compressive strength test results.

The results of the compressive tests are shown in Table 1 below and in Figure 1.

Table 1: Compressive Strength Results

Sample A

	Mass of blocks (Kg).					Compressive forces (KN).					CSB
LR(%)	1st	2nd	3rd	4th	Average	1st	2nd	3rd	4th	Average	(N/mm^2)
10	22	22	22	21.5	21.875	115	100	115	100	107.5	2.29
20	21.5	21.5	21.5	21	21.375	95	95	95	93	94.5	2.01
30	21.5	21	21	20.5	21	75	73	68	68	71	1.51
40	19	19.5	19.5	19.5	19.375	43	45	48	45	45.25	0.96
50	18.5	19	19	19	18.875	40	33	40	35	37	0.79
60	18	18.5	18.5	18	18.25	30	33	30	28	30.25	0.64

Sample B

	Mass of blocks (Kg).					Compressive forces (KN).					CSB
LR(%)	1st	2nd	3rd	4th	Average	1st	2nd	3rd	4th	Average	(N/mm^2)
10	22.5	22	22.5	22.3	22.325	110	115	115	110	112.5	2.39
20	21.5	21.8	21	21.5	21.45	98	95	95	93	95.25	2.02
30	21	21.5	20.5	21.5	21.125	75	75	70	70	72.5	1.54
40	20	20	19.5	19.5	19.75	48	48	43	45	46	0.98
50	19.3	19	19	19	19.075	35	38	40	38	37.75	0.80
60	18.5	18.3	18	18.5	18.325	30	30	33	30	30.75	0.65

Sample C

	Mass of blocks (Kg).					Compressive forces (KN).					CSB
LR(%)	1st	2nd	3rd	4th	Average	1st	2nd	3rd	4th	Average	(N/mm^2)
10	22	22	21.5	21	21.625	100	100	113	100	103.25	2.20
20	21	21	21.5	21	21.125	93	93	95	93	93.5	2.00
30	20.5	20.5	20.5	21	20.625	70	68	73	70	70.25	1.49
40	18.5	19	19	19.5	19	38	43	40	43	41	0.87
50	18	18.5	18.5	18.5	18.375	35	33	38	35	35.25	0.75
60	18	18	17.5	18.3	17.95	30	28	30	30	29.5	0.63

Control sample

	Mass of blocks (Kg).					Compressive forces (KN).					CSB
LR(%)	1st	2nd	3rd	4th	Average	1st	2nd	3rd	4th	Average	(N/mm^2)
0	23	23.5	24	23.5	23.5	115	130	125	130	125	2.66

Note: LR – Laterite Replacement CSB – Compressive Strength of Block

Source: Authors' Field Work 2009.

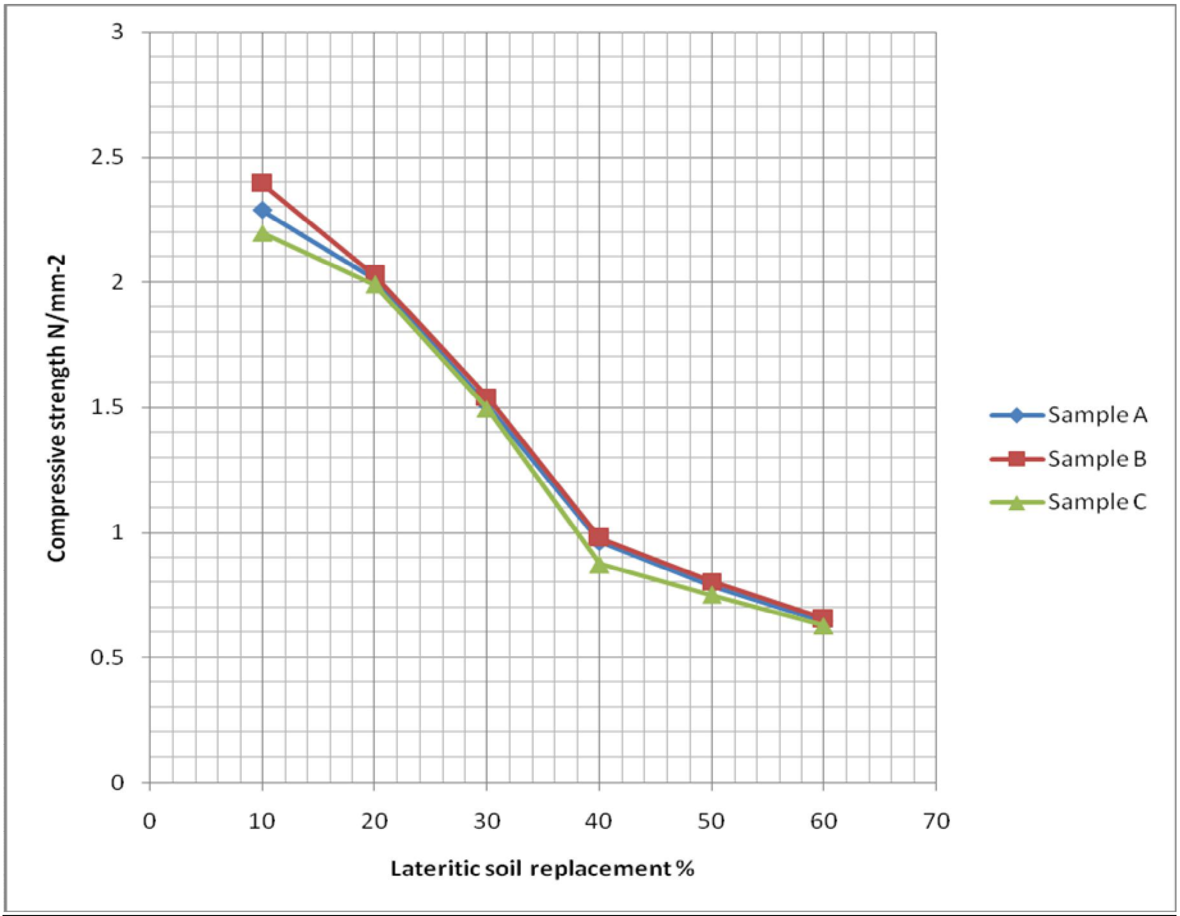

Figure 1 Comparison of Compressive Strength for samples A, B and C.

5.3 Analysis of costs of different sand combinations in hollow sandcrete blocks.

Volume of sand required in 1 No. 450 x 225 x 225mm hollow sandcrete block.

Gross volume of block = 0.45 x 0.225 x 0.225m = 0.02278m^3

Net volume of 1 No. Block = 0.02278 - 0.00819 = 0.01459m^3

Normal (100% sharp sand + cement) 450 x 225 x 225 sells for ₦120.00

Cost of sand in 1 No. 100% sand and cement = ₦$\frac{3700}{68}$ = ₦54.41

Also, cost of laterite in 1 No. 100% laterite and cement block = ₦$\frac{1500}{68}$ = ₦22.06

For a 450 x 225 x 225mm block made of 80% sand and 20% laterite + cement, the cost is reduced by

$$\frac{440}{3700} \times 100 = 11.89\%$$

Assumptions made: The bulking factors of the two (2) types of soil were taken to be negligible and have no effect on the results.

6. Conclusions/Recommendations.

Tests have been conducted to evaluate the suitability of lateritic soils within the boundaries of Ota and their effect on the strength of sandcrete blocks when used to replace the conventional fine aggregate, the following conclusions can be drawn from the analysis of the results:

The sieve analysis results of the three lateritic soil samples meet the British Standard requirements for fine aggregate under the fine grading zone as specified in BS882:1992 and therefore suitable for use in the production of sandcrete block. It was also observed from Table 1 that the higher the density of the blocks, the greater their compressive strengths. There was a reduction in the compressive strength of the sandcrete blocks produced with increased percentage replacement of the conventional fine aggregate with the lateritic soils.

To produce a standard block to the requirement of Nigerian National Building Code (2006) of minimum compressive strength 2.00N/mm^2, the average tolerable replacement of fine aggregate with the lateritic soil within the boundaries of Ota in Ogun state is 20%. Beyond this percentage replacement, the strength of the sandcrete block produced falls below the standard recommended strength. See Table 1. This percentage replacement can be recommended to the block moulding Industries within Ota that strictly adhere to standard practice to incorporate lateritic soil not greater than 20% of the aggregate used into their sandcrete block production as this will reduce the production cost which will translate to reduction in the market price of blocks. This eventually results in reduction of the cost of building production within the market coverage of the block manufacturers.

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