A Comparative Study of Cement and Lime Stabilized Lateritic Interlocking Blocks.

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ABSTRACT

This paper reports the results of a comparative study of cement and lime stabilized lateritic interlocking blocks produced with laterite samples from the Olomi area in Ogbomoso, Oyo State, Nigeria. The stabilizing agents were added at 5%, 10% 15%, 20%, and 25% by weight replacement levels. The blocks were tested for compressive strengths, water absorption, and resistance to abrasion. The results showed that average dry compressive strength at 28 days for cement stabilized blocks at 5%, 10% 15%, 20%, and 25% stabilization were 1.63 N/mm^2, 2.60 N/mm^2, 2.78 N/mm^2, 2.82 N/mm^2, and 3.12 N/mm^2, respectively, while those of lime stabilized blocks were 0.92 N/mm^2, 1.25 N/mm^2, 1.15 N/mm^2, 1.06 N/mm^{2,} and 0.94 N/mm^2, respectively. The Nigeria Building and Road Research Institute (NBRRI, 2006) specified that the minimum 28 days strength should not be lower than 2N/mm^2. Only cement stabilized blocks satisfied this requirement at 10% and above stabilization level. It was concluded that cement stabilized interlocking blocks are of better quality and cheaper than those stabilized with lime.

(Keywords: laterite, interlocking block, ordinary Portland cement, lime, compressive strength)

INTRODUCTION

Soil stabilization may be defined as any process aimed at improving the performance of a soil as a construction material. Bell (1993), referred to soil stabilization as the process of mixing additives with soil to improve its volume stability, strength, permeability and durability. The soil that is of concern in this study is laterite. Laterite is a red tropical soil that is rich in iron oxide and usually derived from wide variety of rock weathering under strongly oxidizing and leaching conditions. It forms in tropical and sub-tropical regions where the climate is humid. Laterite is very abundant in Ceylon, India, Burma, Central Africa, West Africa and Central America (Encyclopedia Britannica, 2001). The two most commonly used stabilizers are cement and lime.

Cement stabilization involves the addition of small amount of cement to modify the soil properties. The amount of cement needed to stabilize soil may range from 3 to 16% by dry weight of soil, depending on the soil type and properties required. Any type of cement may be used for soil stabilization but ordinary Portland cement is mostly used according to Bell (1993).

Lime stabilization refers to the process of adding burned limestone products either calcium oxide (i.e. quicklime) or calcium hydroxide ($Ca(OH)_2$) to soil in order to improve its properties. This process is similar to cement stabilization except that according to Bell (1993); lime stabilization is suitable for soils with high clay contents. Lime was used throughout the world by the ancient civilization as a binding agent for brick and stone.

Nowadays, improved technology induced people to use lateritic interlocking blocks as an alternative for sandcrete blocks in building houses because they do not require cement mortar in bonding the blocks during construction, thereby reducing the building cost. This study compares the properties of lateritic interlocking blocks stabilized with cement and lime in order to ascertain which is more effective structurally and economically.

EXPERIMENTAL PROCEDURE

Collection of Laterite Samples

Laterite samples were collected from the Olomi area in Ogbomoso North Local Government Area of Oyo State, Nigeria; based on previous work which stated that the samples obtained from this place produced good interlocking blocks that met minimum standards (Falola and Adeyeye, 2007). These samples were stabilized with ordinary Portland cement and lime using 0%, 5%, 10%, 15%, 20%, and 25% by weight of the binder; 0% stabilization being the control. The stabilized samples were then used to produce interlocking blocks which were tested for strength and durability. All the processes were carried out with reference to the International Labour Organization manual (1987) Nigeria Building and Road Research Institute (NBRRI, 2006) and National Building Code (2006) specifications.

Preparation of Laterite Samples

The laterite samples were air–dried for seven days in a cool, dry place. Air drying was necessary to enhance grinding and sieving of the laterite. After drying, grinding was carried out using a punner and hammer to break the lumps present in the soil. Sieving was then done to remove over size materials from the laterite samples using a wire mesh screen with aperture of about 6mm in diameter as recommended by Oshodi (2004). Fine materials passing through the sieve were collected for use while those retained were discarded.

Production of Lateritic Interlocking Blocks

The interlocking blocks were produced using a locally fabricated steel mould of size 250x130x220mm (Figure 1). The production process comprises batching, mixing, casting and compaction of the blocks. The materials used for the production of lateritic interlocking blocks were measured by weight in accordance with the predetermined percentages of stabilization (5%, 10%, 15%, 20%, and 25%) and the optimum moisture contents determined from the field.

Tables 1 and 2 showed the batching information for laterite samples stabilized with cement and lime, respectively.

The mixing was done on an impermeable surface free of all harmful materials which could alter the properties of the mix. The required quantity of laterite sample was measured and spread using a shovel to a reasonably large surface area. Cement or lime was then spread evenly on the laterite and mixed thoroughly with the shovel. The dry mixture was spread again to receive water which was added gradually while mixing, until the optimum moisture content of the mixture was attained. The optimum moisture content (OMC) of the mixture was determined by progressively wetting the soil and taking handful of the soil, compressing it firmly in the fist, then allowing it to drop on a hard and flat surface from a height of about 1.10m. When the soil breaks into 4 or 5 parts, the water is considered right (National Building Code, 2006).

Figure 1: Locally Fabricated Steel Mould

Table 1: Batching Information for Laterite Samples Stabilized with Cement.

Percentage of stabilization	Laterite (kg)	Cement (kg)	Water (kg)	Water cement ratio
0	215.00	-	-	-
5	204.25	10.75	26.34	2.45
10	193.50	21.50	52.67	2.45
15	182.75	32.25	79.01	2.45
20	172.00	43.00	105.35	2.45
25	161.25	53.75	131.69	2.45

Table 2: Batching Information for Laterite Samples Stabilized with Lime.

Percentage of Stabilization (%)	Laterite (kg)	Lime (kg)	Water (kg)	Water lime ratio
5	204.25	10.75	26.34	2.45
10	193.50	21.50	52.67	2.45
15	182.75	32.25	79.01	2.45
20	172.00	43.00	105.35	2.45
25	161.25	53.75	131.69	2.45

Having rid the steel mould of all impurities, it was coupled together and oiled to enhance demoulding of the blocks. The wet mixture was filled into the mould in 3 layers, each layer being compacted with 35 blows of 4.5kg rammer on a level and rigid platform. The excess mixture was scraped off and the mould leveled using a straight edge. The mould and its content were left for 2 hours before the removal of the mould. Identification marks were inscribed on the blocks for easy referencing.

Curing of Lateritic Interlocking Blocks

The blocks were first allowed to air dry under a shade made with polythene sheet for 24 hours. Thereafter, curing was continued by sprinkling water morning and evening and covering the blocks with polythene sheet for one week to prevent rapid drying out of the blocks which could lead to shrinkage cracking. The blocks were later stacked in rows and columns with maximum of five blocks in a column until, they were ready for strength and durability test (Figure 2).

Testing of Lateritic Interlocking Blocks

The tests performed on the blocks are Durability, Water absorption and compressive strength. The durability of the blocks was determined through abrasive test. After the interlocking blocks have attained the specified age, two blocks were selected at random and weighed in the laboratory and their weight recorded. The blocks were placed on a smooth and firm surface and then wire-brushed to and fro on all the surfaces for 50 times, to and fro making a stroke. After brushing, the blocks were weighed again to determine the amount of material or particles abraded. This procedure was repeated for all blocks produced at various cement and lime contents and ages.

The water absorption was performed by randomly selecting two blocks from each group at the specified age, and weighing them on a balance. These blocks were then immersed completely in water for 24 hours, after which they were removed and weighed again. The percentages of water absorbed by the blocks were estimated as follows:

$$Wa = \frac{Ws - Wd}{Wd} \times 100 \quad \textbf{(1)}$$

where:
Wa = percentage moisture absorption
Ws = weight of soaked block
Wd = weight of dry block

Figure 2: Stacking of Lateritic Interlocking Blocks.

Compressive strength test was carried out to determine the load bearing capacity of the blocks. Dry compressive strengths were determined. The blocks that have attained the ripe ages for strength test of 3, 7, 21, and 28 days were taken from the curing or stacking area to the laboratory, two hours before the test was conducted, to normalize the temperature and to make the block relatively dry or free from moisture. The weight of the each block was taken before being placed on the compression testing machine (Model: 50_C34A2, serial no:0294910) such that the top and bottom as moulded lie horizontally on a flat metal plate and the recessions filled with metal plate of the exact size to prevent sheaving of the block during testing. The block was then crushed and the corresponding failure load recorded. The crushing force was divided by the sectional area of the block to arrive at the compressive strength.

RESULTS AND DISCUSSION

Durability

The abrasive test results at 28 days for cement and lime stabilized blocks are shown in Tables 3 and 4, respectively. It could be observed from the results that the resistance of the blocks to abrasion increases with the addition of both cement and lime as stabilizing agent. Laterite interlocking blocks without stabilization (The Control), recorded high percentage of materials abraded away in both cases. This is an indication that one form of stabilization or the other is required to enhance the durability of the blocks. However, cement stabilized blocks were of better resistance than lime stabilized blocks which is an indication of higher durability.

Water Absorption

The results of the water absorption tests are presented in Tables 5 and 6 for cement and lime stabilized blocks, respectively. Generally, the results indicate that water absorption decreases with increase in the percentage of stabilization. This is expected as the stabilizing agents (cement and lime) bond the laterite particles together thereby reducing the pores through which water could flow into the blocks. There was no result for the Control (0% stabilization) as the blocks were dissolved in the surrounding water.

Table 3: Result of Abrasive Test for Cement Stabilized Lateritic Interlocking Blocks.

Cement stabilization (%)	Mass before abrasion (kg)	Mass after abrasion (kg)	Abraded away (%)	Average abraded away (%)
0	14.001 13.839	13.821 13.669	1.29 1.23	1.26
5	14.061 13.928	13.981 13.838	0.57 0.65	0.61
10	13.960 13.820	13.890 13.750	0.50 0.53	0.52
15	14.340 14.286	14.290 14.226	0.35 0.42	0.39
20	14.390 13.926	14.370 13.896	0.14 0.22	0.18
25	13.955 13.811	13.945 13.791	0.07 0.14	0.11

Table 4: Result of Abrasive for Lime Stabilized Lateritic Interlocking Blocks.

Lime stabilization (%)	Mass before abrasion (kg)	Mass after abrasion (kg)	Abraded away (%)	Average abraded away (%)
0	14.001 13.839	13.821 13.669	1.29 1.23	1.26
5	13.619 13.870	13.739 13.720	0.88 1.08	0.98
10	13.830 13.544	13.935 13.674	0.76 0.96	0.86
15	13.820 13.760	13.720 13.650	0.75 0.80	0.78
20	14.028 13.174	14.098 13.244	0.50 0.53	0.52
25	13.010 12.940	12.960 12.900	0.38 0.31	0.35

The average water absorbed by cement stabilized blocks at 28days for 5, 10, 15, 20, and 25 % stabilization were 7.23%, 6.15%, 5.33%, 3.83%, and 2.90%, respectively while those of lime stabilized blocks were 11.18%, 10.02%, 7.68%, 6.02%, and 4.08%, respectively. These results showed that lime stabilized blocks were more permeable than cement stabilized blocks of similar percentage of stabilization. However the maximum water absorption of 12% as recommended by Nigerian Industrial Standard (2004) was satisfied by all blocks.

Table 5: Result of Water Absorption Test for Cement Stabilized Interlocking Blocks.

Cement stabilization (%)	Dry mass (kg)	Wet mass (kg)	Water absorbed (%)	Average Water absorbed (%)
5	14.140 14.325	15.168 15.353	7.27 7.18	7.23
10	14.010 14.308	14.870 15.118	6.14 6.15	6.15
15	14.000 13.982	14.740 14.732	5.29 5.36	5.33
20	13.781 13.640	14.281 14.190	3.63 4.03	3.83
25	13.190 13.365	13.570 13.755	2.88 2.92	2.90

Table 6: Result of Water Absorption Test for Lime Stabilized Interlocking Blocks.

Cement stabilization (%)	Dry mass (kg)	Wet mass (kg)	Water absorbed (%)	Average water absorbed (%)
5	13.910 13.826	15.510 15.326	11.50 10.85	11.18
10	13.760 13.974	15.191 15.326	10.35 9.68	10.02
15	14.180 14.629	15.280 15.740	7.76 7.59	7.68
20	14.455 14.303	15.365 15.123	6.30 5.73	6.02
25	14.600 14.194	15.150 14.815	3.77 4.38	4.08

Compressive Strengths

The results of the compressive strengths are presented in Figures 3 and 4 for cement and lime stabilized blocks respectively. It can be observed from Figure 3 that the compressive strength of cement stabilized interlocking blocks increases as the percentage of stabilization increases. For lime stabilized blocks, Figure 4 showed that the compressive strength initially increases as the percentage of stabilization increases up to 10% stabilization and thereafter decreases as percentage of stabilization increases from 15% to 25%.

The compressive strength of unstabilized interlocking blocks (The control) varies from 0.37 N/mm^2 to 1.48 N/mm^2 as the curing age increases from 3 to 28 days. For cement stabilized interlocking blocks it varies from 0.64 N/mm^2 to 1.63 N/mm^2, 1.19 N/mm^2 to 2.60 N/mm^2, 1.25 N/mm^2 to 2.78 N/mm^2, 1.52 N/mm^2 to 2.82 N/mm^2 and 1.98 N/mm^2 to 3.12 N/mm^2 for 5%, 10%, 15%, 20%, and 25% stabilization, respectively, during the same period.

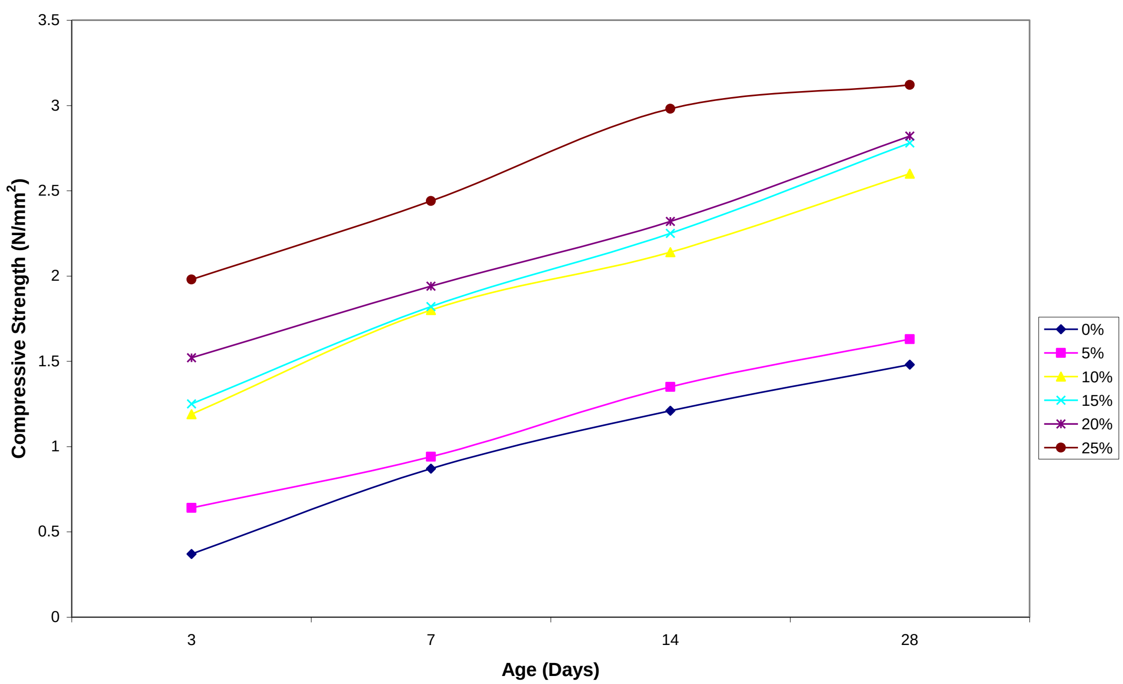

Figure 3: Compressive Strength of Cement Stabilized Lateritic Interlocking Blocks.

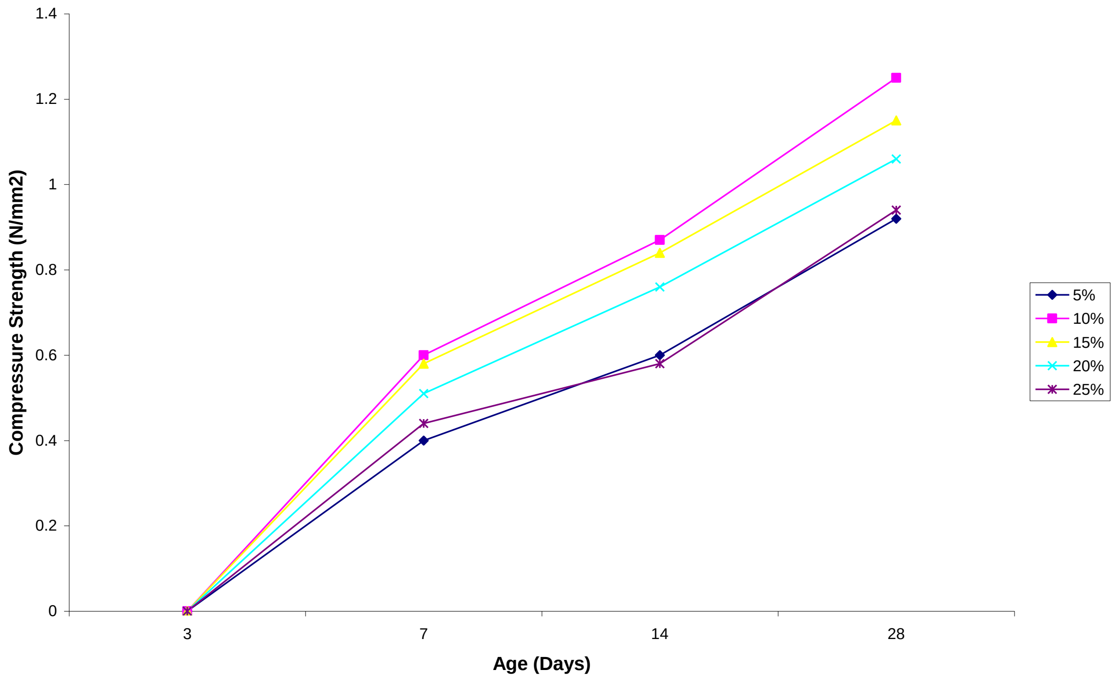

Figure 4: Compressive Strength of Lime Stabilized Lateritic Interlocking Blocks.

The minimum 7 days dry compressive strength for 5% cement stabilized blocks of not less than 1.60N/mm^2 as recommended by National Building Code (2006) could not be satisfied. However, with 10% cement stabilization, this requirement was satisfied with a recorded value of 1.80N/mm^2. The 28 days dry compressive strength of manually produced blocks with 5% cement stabilization, of not less than 2.0N/mm^2 as recommended by NBRRI (2006) was also not satisfied.

Beyond 5% cement stabilization however, all the blocks satisfied the minimum 28 days dry compressive strength. Since lateritic interlocking blocks with 5% cement stabilization do not satisfy the minimum requirements as specified by the operating codes, 10% stabilization is recommended for use. The extra 5% cement content over what was used by Madedor (1992) is compensated for by the non usage of mortar in laying the interlocking blocks.

The compressive strength of lime stabilized interlocking blocks do not follow a regular pattern as discussed above. The 3 days strengths could not be determined as the cubes were very weak to be crushed. The compressive strength varies from 0.40 N/mm^2 to 0.92 N/mm^2, 0.60 N/mm^2 to 1.25 N/mm^2, 0.58 N/mm^2 to 1.15N/mm^2, 0.51 N/mm^2 to 1.06 N/mm^2 and 0.44 N/mm^2 to 0.94 N/mm^2 for 5%, 10%, 15%, 20%, and 25% stabilization respectively as the curing age increases from 7 to 28 days. None of the blocks met the minimum requirements at 7 and 28 days as specified by the available codes. In fact, the compressive strength of the blocks was decreasing as the percentage stabilization go beyond 10%. This result indicated that lime stabilization is not suitable for laterite interlocking blocks due to the low clay content in the soil. According to Bell (1993), lime stabilization is suitable for soils with high clay contents.

COST ANALYSIS

Cost of Stabilizing with Cement

		₦ : K
Cost of Laterite		1,000 : 00
Cement: 2 bags @ ₦1,750 each		3,500 : 00
Total		4,500 : 00
Labour cost		1,600 : 00
Total cost of production		6,100 : 00

Total number of blocks produced	=	80 blocks
Cost per cement interlocking block	=	Total cost of production / Total number of blocks produced
	=	6100 / 80
	=	₦ 76:25

Cost of Stabilizing with Lime

		₦ : K
Cost of Laterite		1,000 : 00
Lime: 2 bags @ ₦2,850 each		5,700 : 00
Total		6,700 : 00
Labor cost		1,600 : 00
Total cost of production		7,300 : 00

Total number of blocks produced	=	80 blocks
Cost per lime interlocking block	=	Total cost of production / Total number of blocks produced
	=	7.300 / 80
	=	₦ 91:25

From the above estimation, it can be observed that the cost of stabilizing with cement is cheaper than the cost of stabilizing with lime. This is due to the high cost of lime per bag.

CONCLUSION

Based on the findings from this study, it can be concluded that:

(i) Cement stabilized block is of better quality in terms of compressive strength, water absorption and durability than those stabilized with lime.

(ii) 10% cement stabilization is recommended for lateritic interlocking blocks in other to meet the minimum standards as stated by the available codes.

(iii) Cement interlocking block is cheaper than lime interlocking block.

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