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Improving the Properties of Laterite Bricks using Locust Bean Husk addition

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ABSTRACT: The study was conducted to assess the influence of pulverized locust bean husk (PLBH) on the strength and durability properties of laterite bricks.Five different levels of stabilization using PLBH were adopted for this study. Thirty bricks were produced for each stabilization level using a 250KN/m^2"hydraform" brick making machine. The bricks were tested for compressive strength, abrasion resistance and water absorption, after curing for 28 and 56 days. Testing of the properties of the soil was conducted in accordance with, BS 1377 (1992). The results indicated that the constituents of pozzolana in the PLBH, namely: Iron, silica and aluminum oxide all put together is about 42%. A maximum compressive strength of 4.0N/mm^{2}was obtained when 15% PLBH was added to the soil and cured for 56 days, a value,28% higher than that of the 2.9KN/mm^2 brick specimens without stabilization. As the quantity of locust bean husk in the soil bricks increased, the ability of the soil bricks to resist abrasion and influx of water into the bricks increased significantly. The results of the study support the conclusion that, soil bricks stabilized with 15% PLBH content is suitable for low-rise buildings as it meets the minimum compression strength of 2.8N/m^2 recommended by BS 3921 (1985) for low-rise buildings. It is recommended that adequate render/plaster finishing be given the brick walls in dry and moderately damp environments.

***KEYWORDS*:** Laterite Bricks,Pulverized locust bean husk,Abrasion resistance, Compressive strength and Water absorption Resistance.

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I. INTRODUCTION

Ghana as a third world country was in 2006 described as having only1 out of 3 persons sheltered (UN-Habitat, 2006). The shortfall, as observed earlier by Lilly et al. (2001) was blamed on the use of expensive materials that are imported into the country. In order to correct the anomaly the suggestion was made for the use of locally available materials so as to cut down on costs and subsequently make more housing available (Lilly et al., 2001).

The major locally available materials, according to Okereke (2003) that can be exploited include natural deposits such as stones, laterite, agricultural and industrial wastes. Laterite,as observed by Gidigasu (2005) is abundant, cheap and used without any environmental hazards in Ghana.

In tracing the transfer of its technology alongside the migration of the Ewe tribes from Timbuktu, upon the collapse of the Songhai Empire in 1670, to southern Ghana, Schreckenback (1981) explained how traditional lateritic walls evolved using laterite alone to build sunburnt brick walls or laterite stabilized by palm fronts to build Atakpame walls. Another type is the Wattle and Daub walls built with laterite using timber as reinforcement. The adobe wallevolved with the use of laterite and stones as stabilizers. Muhammed and Yamusa (2013) also mentioned the use ofLocust bean husk as stabilizers for mud wall construction among traditional people of Northern Ghana. The majorreason given bySchreckenback (1981) for the sustenance of this kind of architecture over the centuries was the thermal comfort lateritic walls provided in the hot tropical climate owing to the large thermal capacities they have.

Laterite walls tend to be the least preferred materials by builders in recent times due to some challenges associated with their use. They are known to be lacking compressive strength, having low resistance to abrasion and highly susceptible to water ingress (Riza, 2011 and Adogla et al., 2016). These attributes, according to Mahgoub (1997) culminate in making the walls deficient in satisfying newneeds in architecture; Adzraku et al.(2016) confirmed that designers become apprehensive and fail to provide adequate functional spaces lest the corresponding roof structures collapse given the span and the weak walls supporting them. Since the walls are not strong enough to hold conduits, supply of water and electricity become difficult. Owing to problems relating to water ingress designers, when using lateritic walls, avoid creating any functional relationships betweenwet areas such as bathrooms and dry areas such as bedrooms even when the closeness of these spaces is deemed very necessary and convenient for the user.According toSchreckenback(1981) laterite walls assume compressive strength only when constructed in a circular plan or form but Adzraku et al.(2016) observed that the round or circular shape or form in construction always entails the wasteful cut-offs of such items as floor, ceiling and roof finishes to fit. Owing to the long list of defects associated with these wallsstatutory authorities fail to recognize them and grant permits for their use in construction (Botchie, 2000 andNyenke, 2004).

The ultimate goal for usinglocally available walling materials is to erect structures which one would describe as sustainable.The specific factors ensuringsustainability includelow initial and running costs of the buildings, comfort and convenience experienced by users, freedom from environmental hazards, the ease at which modern functions, features and services can be inculcated into the buildings using these local walls (Rumana, 2007; Humberto et al., 2012 and Adzraku et al., 2016).

Various binders in recent times have been added to laterite to successfully attain technical qualities and these include the combination of Cow dung and ash from agricultural wastes to serve as an effective binder (Yalley and Manu, 2013). In a separate experiment Yalley and Asiedu (2013) combined cement, lime and bitumen to form a formidable binder. Adesanya and Raheem (2009) also combined Industrial by-products and agricultural wastes to serve as stabilizer of laterite.

For this study Pulverized Locust Bean Husk (PLBH) in its raw or organic (unburned) form has been chosen to produce a stabilizer for the improvement of strength and durability properties of lateritic bricks for low cost housing schemes in Northen Ghana.

II. MATERIALS AND METHODS

Materials

Pulverized Locust Bean Husk

Samples of the locust bean husks were air-dried to remove the moisture in the husk for easy pounding. The husks were then crushed and pounded using wooden mortar and pestle and sieved through BS 5mm sieve to obtain coarsely powdered material. The coarsely powdered material was further grinded in a mill to obtain fine locust bean husks. X-Ray fluorescence laboratory test was conducted to determine the chemical composition of the oxides in the PLBH.

Properties of Soil used

To avoid plants matter hampering the properties of soil bricks the top soil which harboured plants matter was first scraped-off before the samples were dug (Maniatidis andWalker, 2003). The following soil tests were conducted in accordance with BS 1377-1(1990): sieve analysis, Atterberg limit, linear shrinkage, sedimentation, organic content and compaction test.

Tables 2 and 3 are the summary results of the soil properties investigated and the optimum moisture content with corresponding dry densities while Figures 4, 5 and 6 indicate particle size characteristics of natural soil, liquid limit determination and plastic chart of natural soil respectively.

Water

Portable water which was free from contaminants either dissolved or in suspension was usedto conduct tests (BS 3148, 1980).

Test Methods and Procedures

Compaction Test

Compaction test was conducted to determine the optimum moisture content required to produce bricks with maximum dry density. The tests were conducted in batches with 0%, 10%, 15%, 20% and 25% of PLBH (by volume of the soil). Figure 1 shows the mechanical compaction machine setup. The tests were conducted in accordance with BS-377-1 (1990)

Figure 1 Compaction testing machine setup

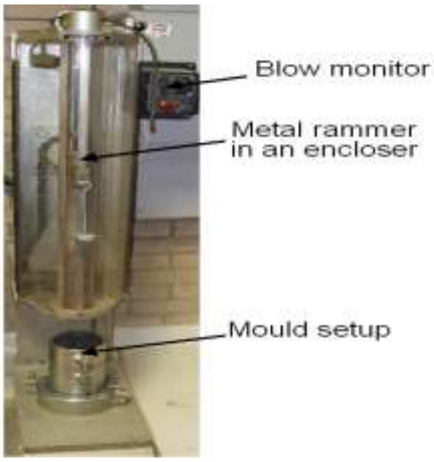

Figure 1 Compaction testing machine setup

Production of Laterite Bricks

Bricks were produced by a 250KN/m^2 capacity "hydraform" mould with sizes 205mm × 175 mm × 105 mm. Batch of materials was thoroughly mixed to obtain a uniform colour and thirty bricks were produced for each batch. The bricks in green state were carefully labeled for easy identification. The soil bricks were initially covered with damp plastic sheets for the first 3 days to prevent surface shrinkage cracking due to rapid evaporation which tends to promote undesirable loss and uneven distribution of moisture in the bricks. The bricks were then uncovered under a shade for normal air dry for the remaining 25 and 53 days before testing.

Figure 2a Moulded Soil Bricks at green stage,

Figure 2b Curing of Bricks using Plastic Sheets

Testing Of Laterite Bricks
Compressive Strength Test

The compressive strength was determined after28 - day and 56 -day curing ages. Compressive strength test was conducted in accordance with BS 1881 (1983) Part 116 using a Seidner compression machine to determine the load bearing capacity of the soilbricks. Five bricks from each batch were weighed and the weight of each brick was then taken before placing on the compression testing machine for testing. The corresponding loads and compressive strength we're recorded. Figure 3 shows the compression machine.

Figure 3 Compression Machine

Abrasion Test

The abrasive resistance test was conducted in accordance with African Regional Standard of Compressed Earth Bricks (2000) specifications to find out the ability of thebricks to resist wearing due to environmental factors like wind and rain. At the curing age of 28 and 56 days.Five bricks from each batch were weighed and their weight recorded as M1. To ensure uniform load on wire brush, a 3Kg brick was tied firmly at the back of the wire brush. The bricks were then placed on a smooth and firm surface and then wire-brushed to and fro on the surfaces for 60 times. After brushing, the bricks were weighed, and their weight recorded as M2. **T**his procedure was repeated for all bricks produced at various batches.

Water Absorption by Complete Immersion of Soil Bricks

After the soil bricks had attained the curing ages of 28 and 56 days.Bricks were weighed and their weight recorded as dry mass Md, (dry mass) for each brick. These bricks were then immersed completely in reservoir containing clean water at a temperature of 27 + 2$^{\circ C}$ for 24 hours. The bricks were removed and reweighed and their weight recorded as Mw (wet mass) for each brick.

III. RESULTS AND DISCUSSIONS

Chemical Analysis PLBH

Table 1 Chemical Analysis of the Major Oxides in PLBH

Major Oxides	**Amount (%)**
MgO	23.33
Al_2O_3	1.30
SiO_2	10.20
P_2O_5	5.09
SO_3	1.50
CI	3.06
K_2O	2.78
CaO	34.60
TiO_2	0.60
MnO	0.004
Fe_2O_3	30.1
Na_2O	0.1
Total	**84.83**

Neville and Brooks (1990) recommended pozzolan content ranges from 30% to 50% as binding agent. Hence, the constituent of pozzolan in the PLBH was 41.6% (namely: Iron 30.1%, silica 10.20% and aluminium oxide 1.30%) that meets the recommended requirement as binding agent. Also, Fe_2O_3, SiO_2, Al_2O_3 and SO_3 composition 30.10%, 10.20%, 1.30% and 1.5% respectively were within the recommended range of ASTM C6I8-78 (2004) making PLBH suitable as a binding agent of soil.

Classification of Soil used

From Table 2, the sum of clay and silt is 23%. The maximum fine content should be about 25% for better workability of the mixture and consolidation of soil bricks (YalleyandBentle, 2009). Hence, the percentage of the clay and silt content satisfy the recommendation. The Commonwealth Experimental Building Station (1970) suggested a preferred plasticity index of between 10% and 20% for a soil to be used in Ghana for lateritic bricks. Therefore, the soil used in this research with plasticity index of 20% is within the recommended value for lateritic bricks.

Table 2 Summary of the Results of the Soil PropertiesInvestigated

General Properties	**Results**
Clay fraction (%)	10
Silt fraction (%)	13
Soil gravel fraction (%)	76
Liquid limit (%)	52.4
Plastic limit (%)	24.33
Plasticity index (%)	20
Soil type	Well graded
Organic content (%)	1.4
Linear shrinkage (%)	8.89
Natural moisture content (%)	8.3
Specific gravity	2.

Dry Density and Moisture Content

From Table 3, the sample without the addition of PLBH has the highest dry density of 4336 kg/m^3. Theaddition of PLBH reduced the dry density.

Table 3 Optimum Moisture Content and Maximum Dry Densities

Percentage PLBH Stabilization	Dry Density (Kg/m^3)	Water Content (%)
Soil + 0%	4336	12
Soil + 10%	3988	13
Soil + 15%	3737	14
Soil + 20%	3471	16
Soil + 25%	3309	18

There was about 24% reduction in the dry density when 25% of PLBH was added. At 10% PLBH addition, there was reduction in the dry density from 4336 to 3988kg/m^{3}having a reduction of 8%. The higher the percentage addition, the lower the dry density. This trend could be to the fact that lighter weight PLBH is replacing heavier weight lateritic material hence decreasing the dry density of sample with addition of PLBH. It could also be seen from Table 3 that the addition of PLBH increase the optimum moisture content of the soil sample. This could be attributed to the possibility that PLBH absorbed water, hence additional water is needed for chemical reactions between the PLBH and the lateritic material.

Density of Bricks

Table 4shows the results of densities of the bricks, which indicatedthat the density of the control specimen at 28 days curing age was 1862Kg/m^3. The density increased with increased PLBH content to 20% level of addition. However, at 25% level of addition, the density decreased. The density increased by 6.4% over the controlled specimen, when 20% of PLBH was added to the laterite for the bricks production. There was a reduction in the percentage increase from 6.4% to 0.3% when the PLBH content was increased to 25%.Generally, up to 56 days curing age, it was observed that the densities of the bricks were lighter compared to their counterparts at 28 days curing age. This might be due to the fact that there was lost of moisture in the bricks with time.

At 28 days curing age, the optimum PLBH content is 20%, while that of 56 days is 15%. This could be explained that the longer the curing age, the better the performance of the PLBH as a binder hence less quantity is needed for better performance.

Table 4.Test Results for Density (Kg/m^3)

Percentage PLBH stabilisation	Density 28 days	56 days
Soil + 0%	1862	1795
Soil + 10%	1875	1833
Soil + 15%	1981	1890
Soil + 20%	1981	1876
Soil + 25%	1857	1828

Compressive Strength

Table 5shows summary of resultsfor compressive strength.It is evident that at 28 days curing age, the plain specimens obtained compressive strength of 2.70N/mm^{2}lower than those bricks stabilised with PLBH.The compressive strength of bricks increased as the level of stabilisation increased up to 15%.At 15% level of stabilization,the comprenssivestrength is 3.5N/mm^{2}anincrease of about 23% higher than the bricks without any stabilisation. However,beyond 15% stabilisation, the compressive strength started reducing. The trendof thecompressive strength at 28- day curing age was not different from the 56-day curing age.The strength of bricks at 56days curing age were higher than their corresponding batches at 28-day curing age. This might be attributed to maturity of the bricks with age.For example15% PLBH addition recorded thecompressive strengths of 3.5N/mm^2 and 4.0N/mm^{2}for 28-day and 56- daycuring ages respectively.

Table 5. Compressive Strength

Specimen	Comp. strength N/mm^2) 28 days	56 days
B_0	2.7	2.9
B_{10}	3.0	3.4
B_{15}	3.5	4.0
B_{20}	3.2	3.8
B_{25}	3.1	3.6

B_x -bricks with x% of PLBH content

Table 6 Coefficients[a] of Compressive Strength Test

Model	Unstandardized coefficient β	R^2 (adj)	t	sig
Constant	2.94		8.74	0.00
PLBH content	0.14	0.64	4.04	0.050
Curing time	+0.01		-0.66	0.050

The resultwas statistically validated using SPSS (Table 6). Deducingfrom the regression equation:CS (N/mm^2) = 2.94 + 0.14 PLBH (%) +0.01CA (days), PLBH positivelyinfluencedthe compressive strength. It could be deduced that if PLBH is increased by1%,compressive strength will increase by 0.14N/mm^2,whenthe curing age remains constant. It should be noted that this equation is valid up to 15% addition of PLBH. Again, it could be said that if the curing age is extended by a day, when PLBH content is kept constant, the compressive strength would increase by 0.01N/mm^2. PLBH presence and curing contributed to 64% of the variance in the compressive strength, with the T-value of PLBH = 4.04 making PLBH presence the main factor that influenced the compressive strength.

Abrasion Resistance

Table7presents a summary of thevalues of abrasion materials.The plain specimens attained a percentage of abrasion of 1.2%. However, with the addition of PLBH the percentage of abrasion reduced to 0.6%,0.4%, 0.3% and 0.3% respectively for 10%, 15%, 20% and 25% PLBH addition. It is clear that the increase in abrasion resistance of the bricks as the PLBH increase is attributed to the improved cementetious action between the PLBH and that of the laterite resulting in an enhanced bond strength which holds the particles in the matrix

Table 7 AbrasionResistance

Percentage PLBH stabilisation	Percentage abraded Curing time (days) 28	56
B_0	1.2	1.2
B_{10}	0.6	0.5
B_{15}	0.4	0.2
B_{20}	0.3	0.2
B_{25}	0.3	0.2

Water Absorption

The results in Table 8 indicate that at 28 days curing age, the percentage of water absorption by the plain specimens after complete immersion in water for 20 minutes was disintegration. When the PLBH was added up to 25%, the percentage of water absorption reduces as the PLBH content increased.At 25% of PLBH addition,the water absorption coefficient reduced to 8%from 11% when PLBH content was 10%. Further curing of the bricks did not improve the absorptivity resistance.

Table 8 Water Absorption Test

Curing time (days)	Percentage of water absorbed (%)
-	-
11	10
9	8
8	8
8	8

IV. CONCLUSIONS

- The constituent of pozzolana in the PLBH namely: Iron, silica and aluminium oxide was 41.6%, which meets the recommended requirement as binding agent.
- Pulverized locust bean husk enhances the strength and durability characteristics of bricks produced with laterite
- The maximum compressive strength of 4.0N/mm^{2}was obtained at 15% PLBH content stabilizationwhich exceeds the BS 3921 (1985) recommended value of 2.8N/mm^{2}for low rise buildings and 1.4N/mm^2 for bungalowsand non-load bearing walls.
- The bricks stabilised with PLBH generally showed a remarkable improvement in their durability properties (abrasion and water absorption by capillarity). As the quantity of locust bean husk in the soil increased, the ability of the soil bricks to resist abrasion also increased appreciably while, bricks also tend to be highly impermeable to water as the quantity of locust bean husk increases making it suitable as a masonry wall unit.This supports an earlier study by Maniatidis and Walker (2003) that, the amount of agro waste stabilisers influence the abrasion and water absorption properties of soil bricks.
- Thefindings of the study regarding the technical qualities or specifications of the lateritic bricks stabilized by PLBH should be published for acceptance by statutory authorities so as to promote their production and subsequent use in the building industry.
- The use of the lateritic bricks stabilized by PLBH is recommended to architects practicing south of the Sahara in search of walling materials which are responsive to the climate. Owing to the large thermal capacities, as confirmed by Schreckenback (1981), the lateritic brick wall, unlike the sand-cement wall, is envisaged to withstand the high diurnal temperatures in the region and in the process provide users thermal comfort indoors. The rampant thermal movements in the wall fabric which lead to the development of cracks and in turn render walls structurallyweak as well as aesthetically unattractive are also expected to be checked.
- Given the observation Kern(2004) made that materials alone contribute about 50% of cost input into any building projects, developers are likely to make substantial savings on their projects if they consider the use of the sunburnt lateritic bricks stabilized by PLBH since this study expects the material to become the cheapest and the most suitable within Northern Ghana. The basic components which are laterite and PLBH, a waste obtained from the staple food of the indigene, are considered to be cheap and abundant in the localities. Unlike the situation of burnt clay bricks where complex and expensive production processes are involved with the use of furnaces that also come with environmental hazards the manufacture of sundried bricks are simple, less expensive and not beyond the skills of the ordinary man. Costs associated with the use of houses built with the bricks are also expected to be minimal since clients are not expected to resort to the use of air- conditioners because the materials naturally ensure thermal comfort indoors. Due to the absence of cracks maintenance costs are envisaged to be minimal.

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