Suitability of Laterite Fines as a Partial Replacement for Sand in the Production of Sandcrete Bricks

Asiedu Emmanuel¹, Agbenyega Allan²

¹Lecturer, ²Student, Department of Building Technology, Takoradi Polytechnic, P. O. Box 256, Takoradi, Ghana

Abstract—The provision of affordable housing units from indigenous building materials has been the focus of most researchers in recent times.

This paper focuses on the utilisation of laterite fines as replacement for sand in the production of sandcrete bricks as masonry units.

With a mix ratio and a water/cement ratio of 1:6 and 0.50 respectively, batches with 0% (control specimens), 10%, 20%, 30%, 40% and 50% laterite fines replacing the sand were adopted in this study. In all, 96 bricks were cast, tested and compared with those of conventional sandcrete bricks (control specimens). Tests studied were density, compressive strengths (wet and dry) and water absorption.

Data results revealed that the laterite fines used could satisfactorily replace the sand up to 30% for the production of structural masonry units even though bricks need to be protected when used in waterlogged areas or below ground level.

Keywords—Composite bricks, Compressive strength, Laterite fines, Sand, Water absorption.

I. INTRODUCTION

Most African countries are confronted with acute housing problems regardless of their socio-economic and developmental challenges. While the situation is felt by majority of the population, the most affected are the low-income earners, the unemployed and rural dwellers. This has been attributed to the adaptation of highly mechanized and capital-intensive production facilities in an attempt to meet the ever-increasing demand for building materials [22]. One way to improve this situation is by making basic materials available in sufficient quantities, and at affordable prices, to prospective builders, including low-income earners.

One building material which has arguably revolutionize the construction industry in Ghana is sandcrete block or brick normally used as a walling unit. These walling materials has been an essential element in the housing delivery in Ghana [24] predominately due to their affordability, availability, versatility and durability characteristics.

In Ghana, the supply of quality sand for construction purposes has seen a sudden surge in demand which has unequivocally been associated with numerous environmental and habitat damage not forgetting the skyrocketing cost of procuring this material. Some of these challenges has compelled researchers to intensify works on alternative building materials which could satisfactorily perform wholly or partially as a substitute for the natural sand in the production of sandcrete blocks so as to bring down the cost of construction. One of the forefront suggestions [19, 10, 6] has been the provision of local alternatives to the use of natural sand as fine aggregates.

One such material is the fines of laterite (particle sizes < 10mm) known to have some similar physical characteristics as conventional sand. Previous works [21] on laterites shows a sharper variations in the particles sizes than sand after preliminary assessment of the particles size distribution. This has quicken interest on the use of laterite in structural masonry works especially concrete as the particle sizes contribute significantly to the strength properties of building materials.

Lateritic soils undergoes weathering and laterization processes which involve chemical and physico-chemical transformation of primary rock-forming minerals that are rich in secondary oxides of iron, aluminium or possibly both laterite constituents and clay minerals [8]. These processes occurs predominately in the tropics by intensive and long-lasting weathering of the underlying parent rock. It is nearly devoid of base and primary silicates but may contain large amount of quarts, and kaolinite [21]. It has been used in the construction of Adobe, Wattle and daub and making bricks for buildings. Although, its use as a construction material has been extensive, it is hardly accepted due to insufficient technical data, hence limiting its wider application in the analysis and design of structures built of laterites [20].

In recent times, researchers [2] have shifted focus on the alternative material like laterite for sand in the production of concrete referred to as laterized concrete. The use of laterite as fine aggregate was first studied by [1].
He concluded that concrete containing laterite fines in place of sand could satisfactorily be used for structural members. It was also discovered that the most suitable mix of laterized concrete for structural purposes is (1:1½:3), using batching by weight with a water/cement ratio of 0.65, provided that the laterite content is kept below 50 percent of the total fine aggregate content [3]. Using a combination of crushed granite, sharp sand and fine laterite was used in their experiment, they further asserted that compressive strength of not less than 25N/mm² was obtained at 28days for the mix with laterite content between 25-50%. It was also reported [12] that incorporating laterite soil should not exceed 20% of the sand used in their sandcrete block production in Ota, Nigeria.

Whilst the use of laterite as a substitute for sand in concrete has been extensively documented, the same cannot be said of its use in the production of sandcrete bricks especially in Ghana. Since laterite varies extensively, [13] averred that the compressive strength of lateritic soil is dependent on the source from which they were collected. It is therefore imperative to find an avenue of utilizing laterite in the production of sandcrete bricks which can reduce cost and environmental destruction due to its availability.

This research thus seeks to determine the feasibility of using laterite fines as a partial replacement material for sand in the production of bricks for building construction works.

II. EXPERIMENTAL METHOD

A. Materials

The materials used in this study includes Ordinary Portland Cement (Ghacem Brand) which conforms to BS 12. The sand used for the study was also obtained from Ehyiam a suburb of Sekondi-Takoradi in the Western Region of Ghana. It was sieved with the 5mm sieve and deliberately kept in the laboratory to exclude it from the rain. Laboratory tests (presented in Table II) were conducted to know the basic characteristics and suitability of the sand for masonry works.

Water for the manufacture of the blocks was portable water from the laboratory supplied by Ghana Water Company Limited was used in the study.

The laterite fines on the other hand was obtained from the Takoradi. The top soil was scraped-off to do away with the harboured plant matters before the actual sample was dug. Soil lumps present in the soil were broken into smaller particles with the help of a laboratory mortar and pestle.

The laterite fines for the purposes of this study refers to soil particles passing through a 5mm sieve mesh as [13] reported that finer particles sizes of lateritic soils tend to yield higher compressive strengths. The index properties of the laterite fines were thoroughly investigated in accordance with [4] and have been presented in Table I.

B. Moulding and Casting of Specimens

Batching of materials was done by the volume method using mix proportions of 1:6. Bricks of size 200mm×150mm×100mm were produced with the sand and laterite fines such that the laterite fines partially replacing the sand were in steps of 10% to a maximum of 50%. These were designated as B₀, being the control, B₁₀, B₂₀, B₃₀, B₄₀, and B₅₀ which respectively represent specimen with 10%, 20%, 30%, 40% and 50% laterite fines.

After conducting some trial tests, a water-cement ratio of 0.50 was found to be appropriate for the all batches, hence used for the production of the composite bricks. Hand mixing was adopted in this study whiles moulding of the bricks was done by a production brick machine operated manually. The materials were thoroughly mixed before the cement and water added in turns. Further mixing was done until a homogenous consistency was obtained. The sample was placed in a mould and compacted well.

It was observed that at higher percentage replacement with laterite fines, the batch becomes dryer. This was attributed to the increasing fines as the water was kept constant. In total, 96 bricks were produced for various laboratory tests which consisted of water absorption, density and compressive strength tests. The bricks were cured for a period of 14, 28 and 52 days before testing for their compressive strength characteristics whiles the other properties were conducted after 28 days curing age. The moulded specimens were cured in sealed plastic bags in the laboratory to prevent loss of moisture by evaporation.

C. Tests on Specimens

1) Density: Four bricks from each batch were randomly selected after the 28 days curing age. They were gently wiped with non-absorbent cloth in order to remove any dust or loose matter stuck to them before measuring their dimensions (i.e. length, breadth and thickness). The bricks were weighed and then the densities were calculated after which the average were deduced.

2) Compression test: This test was conducted in two areas; dry compression and wet compression test. Both tests used four bricks from each batch which were without cracks and selected at random.
Bricks used for the wet compression test were immersed totally in water for 24 hours after the 28 days curing age. They were wiped after removal and air-dried for 15 minutes determining their compressive strength using an electronic ADR 2000 Compressive Strength Machine (CSM) with a pace rate of approximately 6.80kN/s until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. This test was performed to investigate the performance of the bricks after extreme moisture/humid condition.

On the other hand, randomly selected bricks for the dry compression test were wiped and crushed for their compressive strength using the same process.

3) Water Absorption property: The water absorption property of a specimen determines the extent to which the test piece is susceptible to seepage of water through its pores when immersed in water [5]. This test focused on the change in weight of the specimen as [16] indicated that this provided a useful measure of the durability of bricks building materials. This property was measured by the change in specimen weight after 28 days curing age in laboratory environment. Specimens for this test were randomly selected from each batch, cleaned and oven dried. They were then oven dried for 24 hours at the temperature 110°C until the mass became constant and again weighed. This weight was noted as the dry weight (M₀) of the block. Specimen were then immersed totally in water at normal temperature for 24 hours [18]. The bricks were later removed and its weight recorded as the wet weight (M₂). The absorbed water expressed in percentage is deduced from Equation 1 below.

\[
\frac{M_2 - M_0}{M_0} \times 100
\]

……..Eqn. 1

III. RESULTS AND DISCUSSION

The results of the preliminary studies on the materials used (Table I and II) and some engineering properties of the composite bricks have been discussed below.

A. Materials

The grading curve for the laterite fines shown in Figure 1 revealed a coefficient of curvature (Cᵥ) of 2.401 and uniformity coefficient (Cᵤ) of 15.56 suggesting that the laterite fines used was a well graded with sizes ranging from 0.063mm to 10mm.

The natural soil was thus classified as intermediate plasticity as such soils have liquid limit between 35% and 50% according to [25]. The linear shrinkage limit of 14.07% on the other hand fell within the range of 4 - 25% as specified in [7].

The specific gravity of 2.63 fell within the range of 2.55 and 4.6 which was recommended by [23] for lateritic soils and also suitable for masonry units whiles that of the sand was 2.98.

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>PROPERTIES OF LATERITE FINES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Properties</td>
<td>Results</td>
</tr>
<tr>
<td>Soil classification</td>
<td>Well-graded soil</td>
</tr>
<tr>
<td>Casagrande plasticity chart</td>
<td>Clay of Intermediate plasticity</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>2.63</td>
</tr>
<tr>
<td>Shrinkage limit</td>
<td>14.07%</td>
</tr>
<tr>
<td>Liquid limit</td>
<td>43.22%</td>
</tr>
<tr>
<td>Plastic limit</td>
<td>14.95%</td>
</tr>
<tr>
<td>Plasticity index</td>
<td>28.27</td>
</tr>
<tr>
<td>Optimum Moisture Content</td>
<td>18.2%</td>
</tr>
<tr>
<td>Maximum Dry Density</td>
<td>1794kg/m³</td>
</tr>
<tr>
<td>Coefficient of curvature (Cᵥ)</td>
<td>2.401</td>
</tr>
<tr>
<td>Uniformity coefficient (Cᵤ)</td>
<td>15.56</td>
</tr>
<tr>
<td>Clay</td>
<td>11.1%</td>
</tr>
<tr>
<td>Silt</td>
<td>4.6%</td>
</tr>
<tr>
<td>Sand</td>
<td>83.3%</td>
</tr>
<tr>
<td>Organic matter content</td>
<td>4.9%</td>
</tr>
<tr>
<td>Natural moisture content</td>
<td>6.4%</td>
</tr>
</tbody>
</table>
B. Properties of Composite Bricks in Hardened State

1) Density: The graph shown in Figure 3 illustrates the variation of the density of specimen with different replacement percentage of natural sand by laterite fines. Bricks produced had densities above the minimum of 1600kg/m$^3$ as indicated by [6] as the minimum for a masonry unit.

![Figure 3 Variations of density for the different replacement levels](image3)

Generally, there was a gradual decrease in the densities of the soil bricks as the laterite content increases. The highest density was 1963kg/m$^3$ which was recorded by the control bricks (no laterite fines) whiles those with 10%, 20% and 30% replacements recorded an average density of 1922kg/m$^3$, 1909kg/m$^3$, and 1847kg/m$^3$ respectively. Bricks with 40% laterite fines on the other hand had an average density of 1836kg/m$^3$ whiles bricks with 50% laterite fines recorded the least density of 1798kg/m$^3$.

Obviously, this signifies that bricks with high amount of laterite fines were less dense or lighter than those with only conventional sand. This is attributed to the lower specific density of the laterite fines when compared to that of the natural sand as presented in Table I and II.

2) Compressive Strength: The compressive strength characteristics of the bricks with increasing replacement levels with laterite fines have been presented Table III. The compressive strength of the dry bricks were determined after crushing dry bricks at 14, 28 and 56 days curing age. It was observed that as the curing age increased, there was an increase in the compressive strengths of the different batches whiles bricks also showed decreasing strengths as the laterite fines increases as seen in the graph plotted in Figure 4. This trend conforms to an earlier studies [12] conducted on sand-laterite blend. At 28 days curing age, bricks were found to have strengths above 3.5N/mm$^2$ as recommended by most standards and the ASTM C129 as suitable masonry units [9].
### Table III

<table>
<thead>
<tr>
<th>Batch</th>
<th>Dry Compressive Strength N/mm²</th>
<th>Wet Compressive Strength N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14 days</td>
<td>28 days</td>
</tr>
<tr>
<td>B₀</td>
<td>7.75</td>
<td>9.97</td>
</tr>
<tr>
<td>B₁₀</td>
<td>4.76</td>
<td>5.72</td>
</tr>
<tr>
<td>B₂₀</td>
<td>4.33</td>
<td>5.43</td>
</tr>
<tr>
<td>B₃₀</td>
<td>3.73</td>
<td>4.81</td>
</tr>
<tr>
<td>B₄₀</td>
<td>3.42</td>
<td>4.17</td>
</tr>
<tr>
<td>B₅₀</td>
<td>3.15</td>
<td>3.51</td>
</tr>
</tbody>
</table>

Furthermore, crushing bricks after immersing the bricks (wet compression test) also revealed that bricks with high quantity of laterite fines had relatively lower compressive strengths although they were suitable for non-structural masonry purposes. This low strength characteristics exhibited by these bricks with high quantities of laterite fines can be attributed to the clay particles in the fine particles which increases as the laterite fines increases. These clay particles which are hygroscopic tend to take up water and subsequently maintain a dynamic equilibrium of water content by absorbing water from the environment or desorb it. This behaviour leads to a weaken bond between the aggregate particles and the cement paste resulting in a lower compressive strength.

This findings confirms an earlier preposition made by [15] which stated that aggregates absorption capacity, porosity and permeability influence the bond between the particles and the cement paste resulting in a low strength attainment.
The declining compressive strengths as the laterite fines increases could also be attributed to the increasing fine particles which is expected to bond with the same quantity of cement paste for effective hydration process, thereby resulting in strength reduction.

Results shown suggest that partial replacement of sand with laterite fines for structural purposes could be done under dry conditions but for conditions where humidity is relatively high, replacement should not exceed 30%.

3) Water Absorption: The variations in the water absorption characteristics of the bricks as the laterite fines increase has been shown in Figure 6. Deducing from the data, it was observed that there was a positive correlation between the percentage laterite fines and the quantity of absorbed water. It was observed that bricks with higher quantity of laterite fines replacing the sand were more permeable indicating that bricks with high quantity of laterite fines tend to be more porous in nature. High water permeability in the bricks was found to be associated with lesser density, low compressive strength and durability. According to [5], masonry units with lower water of absorption restricts the amount of water which could cause deterioration. Water existing in the pores of units tend to cyclically expand and contract creating stresses within the material thereby resulting in the weakening of masonry units.

This characteristics exhibited by the bricks with high quantities of laterites fines can be attributed to the numerous pores left as a result of the clay content which swells when wet making packing less efficient but shrinks when dry thereby leaving pores in the brick matrix. These pores tend to absorb water which tends weaken the bonds between particles. Significantly, bricks with laterite fines from 0% to 30% fell within the recommendable water absorption limit of 20% increase in weight specified by [17] as suitable for building bricks.

Figure 6 Variation of water absorption characteristics of bricks with varying laterite fines

IV. Conclusion

The following conclusions were drawn from the study.

1) The use of laterite fines as a partial replacement has a significant influence on the engineering properties of bricks.

2) Even though, the densities and compressive strength characteristics of the bricks were found to be inferior to bricks with only natural sand and cement (control bricks), they were found to be suitable for both load and non-load bearing masonry units after 28 days curing age.
3) Although, composite bricks are recommended for both load bearing and non-load bearing wall construction, they should be well rendered to ensure protection from moisture ingress especially when used for external walls or below ground level.

4) Bricks with laterite fines replacing the natural sand can satisfactorily perform as a masonry unit when the laterite fines content does not exceed 30%.

REFERENCES


