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EFFECTS OF SAND ON THE PROPERTIES OF CEMENT-LATERITE INTERLOCKING BLOCKS

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In recent years, the attention of researchers is shifting towards the optimization of building materials by using local contents, indigenous materials, and local industrial by-products that are abundant in certain localities. This study investigates the effect of sand on the properties of cement–laterite interlocking blocks. Cement-laterite interlocking blocks were prepared with lateritic soil which was replaced with conventional fine aggregate (sand) from 5 to 25% by weight. Cement-laterite interlocking blocks without sand (0%) served as control. The blocks produced were tested to determine their density, compressive strength, and tensile strength. The average density of cement-laterite interlocking blocks increased as the percentage of sand content in the blocks decreases. The highest compressive strength (9.1 MPa) at 28-day curing of the cement-laterite interlocking blocks was obtained at 5% sand replacement, which is about 13% increase in strength over the control blocks. It was further revealed in the stress-strain relationship result that the 5% sand replacement of laterite achieved the highest stress while the 15% replacement achieved the highest strain of the cement-laterite interlocking blocks. The highest tensile strength (0.707 MPa) at 28-day curing of the cement-laterite interlocking blocks was also obtained at 5% sand replacement, which is about 9% increase strength over the control blocks. The study concludes that the sand replacement laterite in cement-laterite interlocking blocks have the potential of supporting the sustainable housing concept, and therefore recommends to manufacturers 5% sand replacement of laterite in producing cement–laterite interlocking blocks.

Key words: compressive strength, interlocking blocks, laterite, tensile strength

INTRODUCTION

Cement-Laterite Interlocking Block (CLIB) masonry has the propensity to provide sustainable construction around the world (Adedeji, 2008; Harris, et al., 1992; Amado, et al., 2007; Chwieduk, 2003); (Calkins, 2009). Comprised of inexpensive materials, such as laterite, the interlocking blocks can be used to provide housing and other facilities at low cost (Ferguson, 2008; Raheem, A. A. ; Bello, O. A.; Makinde, O. A., 2010). By creating interlocking joints between layers of blocks,

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Interlocking Compressed Earth Blocks (ICEBs) allow for the blocks to be dry-stacked, without the need for mortar (Adedeji, 2012).

In the developing world, especially in metropolitan African cities, scarcity of living accommodation has always been an issue. According to Adebakin et al. (2012), the available housing stock is diminishing by the day due to the high level of rural drift to urban centers. The scarcity and high cost of building materials and the need to drastically reduce critical housing shortages, especially in the urban areas, and developing modern housing setups in the rural areas have encouraged the search for alternative, innovative, and cost-effective building materials. One of such local materials that are being researched is lateritic soil.

According to Akintorinwa et al. (2012), lateritic soil abounds locally and its use is mainly limited to civil engineering works like road construction and landfill operations. It is less utilized in the building industry except in filling works. Irrespective of the abundance of lateritic soils and their availability, their optimum use in building production could positively affect the cost of buildings leading to the production of more affordable housing units (Joshua & Lawal, 2011). Their use in building products is not yet generally accepted because there is no sufficient technical data on it, hence limiting its wider application in building construction work (Danso, 2015; Udoeyo et al., 2006). Laterite is described as a product of in-situ weathering in igneous, sedimentary, and metamorphic rocks commonly found under unsaturated conditions (Rahardjo et al., 2004). Laterite stabilization using a mechanical approach involves the blending of different grades of soils to obtain the desired standard. These properties can however be improved through stabilization to improve the characteristics and strength (Danso, 2017a). Amu et al. (2011) described soil stabilization as any treatment applied to a soil to improve its strength.

Recently there has been a worldwide resurgence of interest in earth building, especially in developing countries where local earth is the most accessible source of building material. However, most soils do not contain the mix of clay, silt, and sand required for good earth building (Roux & Alexander, 2007). The attention of researchers is shifting towards the optimization of building materials by using local contents, indigenous materials, and local industrial by-products unique and abundant in certain localities. This study, therefore, explored ways in which sand could be utilized in cement–laterite interlocking block production. One of the early works on laterite was by Udeoyo et al (2006) who studied the Strength performance laterite concrete. They found that partial replacement of lateritic soil for concrete was good.

Joshua et al. (2011) studied the cost of sandcrete blocks through partial replacement of sand with lateritic soil. They found that partial replacement of sand with lateritic soil blocks was cheaper. Osunade (2002) studied the effect of replacement of lateritic soils with granite fines on the compressive and tensile strengths of laterized concrete. He also found that the strength for compressive and tensile were good.

Raheem et al. (2010) investigated a comparative study of cement and lime stabilized lateritic interlocking blocks. They established that for lateritic soils to be economical in the industry, the range of particle sizes used in moulding blocks must tend towards the silt fraction. This study, therefore, fills this gap by investigating the effect of sand on the properties of cement- laterite interlocking blocks. In order to achieve this, cement-laterite interlocking blocks were prepared with lateritic soil which was replaced with 5, 10, 15, 20 and 25% sand by weight and the blocks were tested to determine their density, compressive strength, and tensile strength.

MATERIALS AND METHODS

Materials

Sand

The sand was obtained from Chiraa in Sunyani, and met the requirement specified by British Standard Institution (BS EN 12620:2002+A1:2008). After procurement, the sand was air dried to constant weight in the Building Department Workshop at Sunyani Technical University.

Cement

The cement used is ordinary Portland cement manufactured by Dangote Cement Company. The Cement with grade 42.5R is a fine mineral powder manufactured with very precise processes.

Laterite

Laterite used for preparing the interlocking blocks was obtained from Koutokrom in Sunyani. The large lumps were crushed and sieved through ASTM sieve No.8 (aperture2.36mm). The lateritic samples were reddish in colour as shown in Figure 1. The general properties of the laterite were determined by laboratory tests. These tests were conducted in accordance with British Standard specifications (BS1377-9:1990). Wet sieving and sedimentation were carried out to determine the grain-size distribution of the laterite with different sizes of sieves.

Figure 1: Laterite used for moulding interlocking blocks.

Water

The water used for this study was clean and did not contain any dangerous organic or chemical content. It was obtained from free flowing tap, supplied by Ghana Water Company limited.

Production of cement-laterite interlocking blocks

A mix proportion of 1:6 of cement: laterite by weight (Figure 2) was used in the work. The sand replacement of proportion 0, 5, 10, 15, 20 and 25% to the weight of laterite was used. The mixing was done by the use of shovel to provide a very plastic paste. The laterite samples were mixed with cement and water-cement ratio of 0.7 was used as control sample. For the experimental blocks, the laterite, cement and sand replacement percentage ranging from 5 to 25% were mixed to desired consistency. The mixture was then loaded into the block mould for the interlocking blocks of size 220 x 185 x 120 mm, and hydraulically moulded at a constant pressure of 10 MPa as shown in Figure 3, and then cured for up to 28 days.

Figure 2: Batching of the materials.

Figure 3. Hydraform interlocking blocks machine with single mould and blocks

Thirty-six (36) blocks each at varied percentage (5, 10, 15, 20 and 25%) of sand replacement of the laterite were produced, cured, and tested on 7, 14, 21 and 28 days for density, compressive strength and tensile strength. For control, Thirty-six (36) interlocking blocks were moulded, thus 100% laterite, which can be seen in Table 1. The total number of blocks produced for the test was two hundred and sixteen (216).

Table 1: Types of Test and Number of the interlocking blocks moulded

Test	Sand (%)	Curing days				Total
		7	14	21	28	
Compressive	0	3	3	3	3	12
	5	3	3	3	3	12
	10	3	3	3	3	12
	15	3	3	3	3	12
	20	3	3	3	3	12
	25	3	3	3	3	12
Tensile	0	3	3	3	3	12
	5	3	3	3	3	12
	10	3	3	3	3	12
	15	3	3	3	3	12
	20	3	3	3	3	12
	25	3	3	3	3	12
	0	3	3	3	3	12
Density	5	3	3	3	3	12
	10	3	3	3	3	12
	15	3	3	3	3	12
	20	3	3	3	3	12
	25	3	3	3	3	12
	Total	54	54	54	54	216

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 started by sprinkling water on the blocks in the morning and evening each day, and covered with polythene sheet to prevent

rapid drying as shown in Figure 4.

Figure 4: Curing of the specimen with water and polythene sheets.

Testing of blocks

The experimental tests carried out are density, compressive strength and tensile strength. Details of the tests are explained below.

Density

The density of the blocks was determined as per BS EN 771-1:2011+A1:2015. Three blocks from each mix were selected and oven dried at a temperature of 105°C after each curing age until a constant mass was recorded, indicating a normal dried block. The dried blocks were weighed (Figure 5), their dimensions measured and the density calculated.

Figure 5: Measuring the weight of the block

Compressive strength

Compressive strength was performed in accordance with BS EN 12390-6 (2009) and was carried out with a Universal Testing Machine (Model: 50_C34A2, serial no: 0294910). The blocks were tested at the curing ages of 7, 14, 21 and 28 days. A 25mm thick rectangular timber platen having the same shape of the interlocking blocks were placed on top and bottom of the block and placed in the test machine as shown in Figure 6. The blocks were then crushed and the matching failure load recorded. The crushing force was divided by the cross sectional area of the block to determine at the compressive strength. Stress-strain values were obtained from the compressive strength test and were used to explain the stress-strain relationship of the blocks.

Figure 6: Compressive Strength test set up

Tensile strength

The splitting tensile strength test was performed in accordance with BS EN 12390-6 (2009). This was carried out with the testing machine (CONTROLS 50-C46G2), and splitting jigs were positioned centrally above and below the block as shown in Figure 7. The loading was applied constantly at a study rate of 0.05 N/mm2/s until the split of each block. The maximum load applied at which each of the blocks failed were recorded and splitting tensile strength calculated.

Figure 7: Tensile Strength Test

RESULTS AND DISCUSSION

Density of sand-cement-laterite interlocking blocks

The average density of the sand-cement-laterite interlocking blocks at various days of curing is shown in Table 2.

Table 2: Density of sand-cement-laterite interlocking blocks

Curing Day	Density of blocks (kg/m^3)					
	0%	5%	10%	15%	20%	25%
7	1937	1853	1863	1873	1941	1932
14	1864	1843	1852	1859	1893	1862
21	1795	1780	1785	1788	1799	1790
28	1784	1757	1774	1780	1790	1782

Table 2 shows the summary of the average density of cement-laterite interlocking blocks. It can be seen that as the curing days increase, the density decreases with each percentage of sand replacement. This is means that as the curing days were increasing the blocks were also losing their moisture contents gradually in order to gain their strength, so as the days are increasing the blocks also lose their weight at the drying stage (Danso, 2017b). In these results, the minimum density in day 7 was 1853kg/m3 (5% sand) whereas the maximum density recorded 1941 kg/m3 (20% sand), the minimum density in day 14 was 1843kg/m3 (5% sand) whereas the maximum density recorded 1893 kg/m3 (20% sand), the minimum density in day 21 was 1780kg/m3 (5% sand) whereas the maximum density recorded 1799 kg/m3 (20% sand), the minimum density in day 28 was 1757kg/m3 (5% sand) whereas the maximum density recorded 1790 kg/m3(20% sand).

Compressive strength of sand-cement-laterite interlocking blocks

The results of the compressive strength tests of the sand-cement-laterite interlocking blocks are shown in Figure 7.

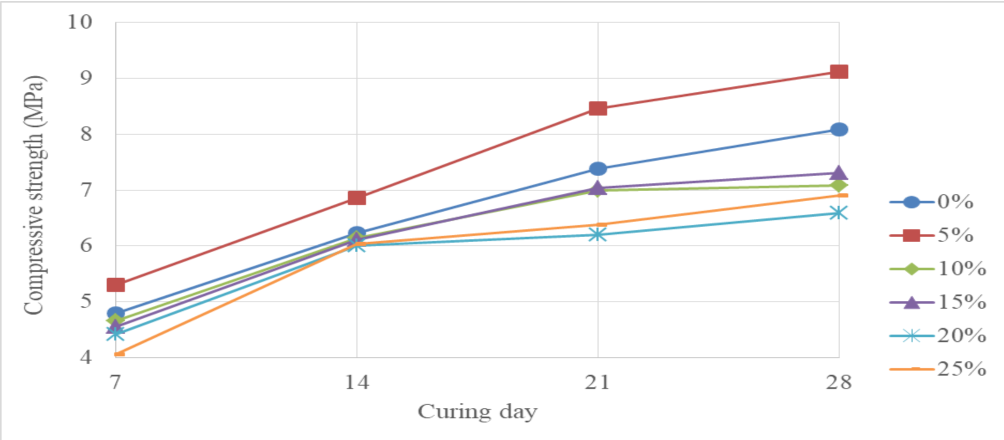

Figure 7: Compressive strength tests results

The effect of curing ages on the compressive strength of sand replacement of laterite presented in Figure 4.1 indicates that all the percentage of sand replacements show continuous increase with increased curing age. However, only 5% sand replacement yielded higher strength above the control specimen (0%) and the rest were all below the control specimen. This is because the sand content in the laterite were more and does not need any sand replacement exceeding 5%. The results show that blocks slowly gained strength at early curing age. This is in line with previous findings that blocks containing sand content at high quantities gained strength slowly at early curing ages (Hossain, 2005; Adesanya & Raheem, 2009a). At 28 days, there was continuous increase in compressive strength for all the percentages of blocks with values ranging from 8.089 MPa for the control to 6.197 MPa for 20% sand replacement. The highest compressive strength (9.1 MPa) at 28-day curing of the cement-laterite interlocking blocks was obtained at 5% sand replacement, which is about 13% increase in strength over the control blocks.

Stress-strain relationship of the blocks

Figure 8 shows the stress-strain relationship of the cement-laterite interlocking blocks after 28-day curing.

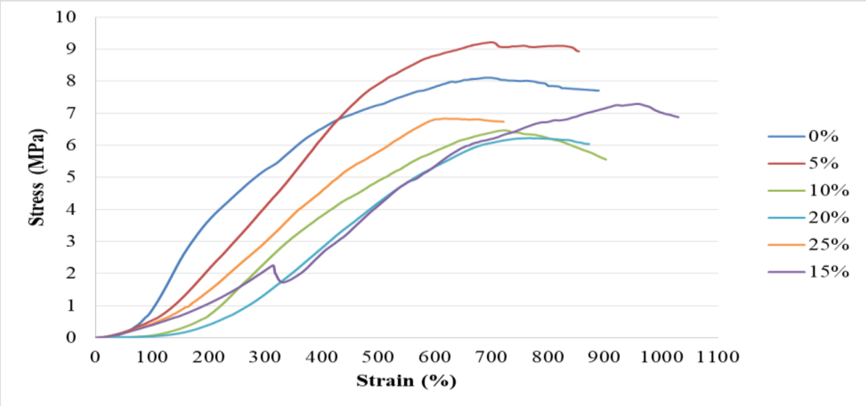

Figure 8: Stress-strain relationship of the blocks at 28-day curing

It can be seen from the stress-strain curves shown in Figure 8 that 5% sand replacement yielded the highest stress above the control level of 0% and the rest of the percentages of sand replacement were below the control. This is due to the fact that there was enough sand content in the laterite so in this case it was only sand content from 0% to 5% which were needed for optimum strength. Similar findings are also shown in a previous study (Fatemeh et al., 2012). The 10% and 15% sand replacement were subjected to higher deformation above the control and the rest of the percentages of sand replacements are below.

Tensile strength of sand-cement-laterite interlocking blocks

The results of the tensile strength tests on sand-cement-laterite interlocking blocks are shown in Figure 9.

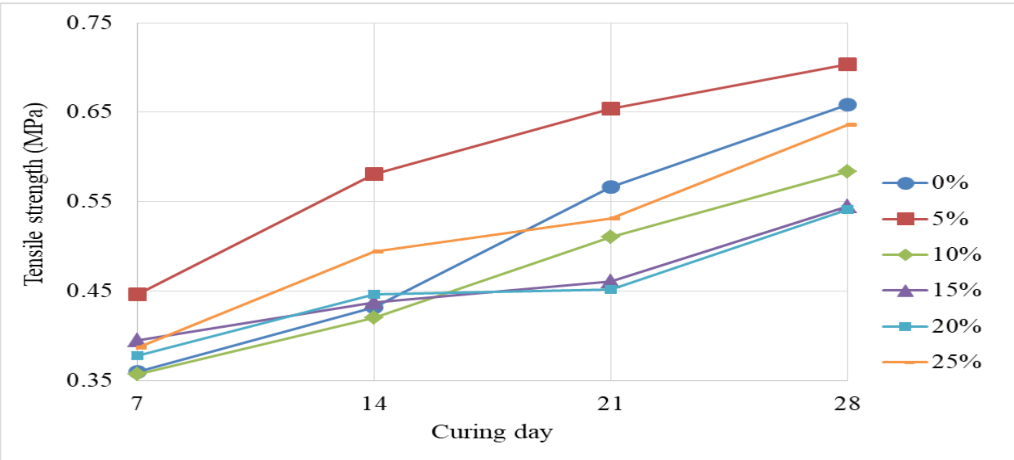

Figure 9: Effect of Sand content on Tensile Strength Test Results

The results indicate that all the percentage of sand replacements show continuous increase with increased curing age. The highest tensile strength (0.707 MPa) at 28-day curing of the cement-laterite interlocking blocks was obtained at 5% sand replacement, which is about 9% increase strength over the control blocks. However, it is observed that the tensile strength of all the sand replacements from 10% to 25% were below the control specimen, which could be due to the fact that the sand content in lateritic soil were high and does not need additional sand content exceeding 5% which will result in the blocks specimen creating more pores. Studies by Bahar et al. (2004) and Morel (2001) and Medjo Eko et al. (2012) with cement as stabilizer in soil blocks recorded similar trend.

CONCLUSIONS

The following conclusions are drawn from the results:

- It was observed that the densities for cement-laterite interlocking blocks produced with sand replacement at 20% were the highest.
- The results indicated that the highest compressive strength of 9.1 MPa at 28-day curing was obtained at 5% sand replacement of the cement-laterite interlocking blocks, which resulted in about 13% increase in compressive strength over the control blocks.
- Again, it was observed that the highest tensile strength of 0.707 MPa at 28-day curing of the cement-laterite interlocking blocks was achieved at 5% sand replacement, which was about 9% increased strength over the control blocks.
- On the basis of the above, it can be concluded that the sand replacement of laterite in cement-laterite interlocking blocks has the potential of being used as building units for sustainable application. The study recommends 5% sand replacement of laterite for cement-laterite interlocking blocks for construction block producers. Lastly, further investigation on the use of cement laterite interlocking blocks should be made with emphasis on the effect of addition of natural fibres on the strength of the blocks.

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