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Improving Compressed Laterite Bricks using Powdered Eggshells

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ABSTRACT
Eggshells are notable agricultural wastes indiscriminately disposed on the environment. Coupled with their foul smell they tend to create an unpleasant environment wherever they could be found. As a way of improving this situation, an alternative use for these products have found identified by using it to improve the engineering properties of compressed laterite bricks for masonry purposes. This paper reports the results of a study evaluating the use of powdered eggshells on the compressive strength and durability characteristics of compressed laterite bricks. Laterite bricks were produced with varying quantities of eggshells which comprised of 0%, 10%, 20%, 30% and 40% by weight of laterite. Compressed laterite bricks showed improvements in all the tests conducted after the inclusion of the powdered eggshells. Powdered eggshells were deemed appropriate for improving the general characteristics for compressed bricks although the optimum quantity was attained at 30%.

Keywords *– Compressed bricks, laterite, powdered eggshells, soil improvement.*

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I. INTRODUCTION

The focus of a good national development is to look inward with the intent of mobilizing all natural resources for economic purposes. Although, one of the policy thrusts of governments over the years in Ghana has been to provide affordable housing for the citizenry. Studies have indicated that, this has hardly materialized due to the billowing prices of conventional building materials. Due to this, studies and researches have been focused on indigenous materials which can adequately wholly or partially replace conventional walling units such as sandcrete blocks and bricks in the building construction industry.

Such indigenous alternative is the use of laterite which for years has been a dependable building material for various types of houses with notable advantages especially in Sub-Saharan Africa. Although, laterite is one of the naturally occurring building materials in Ghana it potentials are yet to be fully exploited. Major hindrances to its use for building purposes have been attributed to its low compressive strength and its vulnerability to moisture especially in its compressed (unburnt) state.

Although, laterites used for producing bricks for masonry walls have been improved by the use of cement, bitumen or lime the quest for alternative cost effective replacement materials cannot be underrated due to their price hikes. Studies (King'ori, 2011 Gowsika *et al.*, 2014; Karthick *et al.*, 2014; Bashir and Manusamy, 2015) have over the years revealed that the chemical composition of lime is relatively similar to the of poultry eggshells indicating the potential that they could also be effectively recycled to improve the engineering properties of laterites. Eggshells are residues from the poultry industry and more specifically a popular waste found in homes, restaurants and fast foods industries. These residues possess environmental nuisance as they increase the cost of managing disposal sites, creates foul smell and flies in areas where they are found in large quantities. The shells of poultry eggs according to Murakami and Rodrigues (2007) are approximately 11% of the total weight of the egg. Studies (Hassan *et al.*, 2012; Dhaliwal *et al.*, 2013) conducted on eggshells shows high calcium contents ranging between 94% and 98% whiles the reminder consists of other micro elements such as sodium, magnesium, phosphorus, boron and carbon in traced amounts. King'ori (2011) reiterated that the calcium content found in eggshells is more absorbable than those from limestone or coral sources.

The concept of utilizing eggshells to improve compressed laterites bricks tends not only to improve the engineering properties of the bricks but also reduce wastes and associated costs and lessen landfills. Strategically, this alternative use of eggshells could create substantial revenue for both potential recyclers and communities where poultry farming is their priority. Even though, eggshells are common wastes materials in Ghana, its suitability as a laterite improving material have not been fully investigated. This study sorts to explore the feasibility of utilizing powdered eggshells to improve the properties of compressed laterite bricks for masonry purposes.

II. EXPERIMENTAL MATERIALS AND METHODS

The main materials used in this study were laterite and eggshells whiles water was used for mixing. The various materials have been discussed in this section.

2.1 Processing of Laterite

The laterite samples used in the study were sourced from an excavation pit in Cape Coast where laterites are obtained on commercial basis for construction purposes. Laterite samples were bagged and taken to the laboratory before processing. The materials were sieved using 10mm mesh to eliminate stones and gravels which tend to bond poorly when producing compressed bricks Oshodi (2004). The index properties of the laterite were investigated according to BS 1377 (1990) before bricks production.

2.2 Processing of Eggshells

The empty broken eggshells were procured from local restaurants and fast food vendors within the Cape Coast municipality. The broken eggshells (as shown in Fig. 1) were boiled in water to remove any egg residue which might still be attached onto the surface of the shells membrane before drying them in the sun. Dried eggshells were milled into fine particles using a laboratory milling machine (grinder) as depicted in Figure 1.

Figure 1 Processing of Eggshells (Before and after powdering)

2.3 Water

Drinkable water without dirt or deleterious materials was used in the mixing.

2.4 Chemical Composition of Powdered Eggshells

The Oxides present in the powdered eggshells were analysed using the X-ray Fluorescence technique. This was done by mixing 4.0g of the ash sample homogenously with 0.9 grams of Hoechst wax in a mill before pressing with a hydraulic press at 15 tons to a 32mm pellet. Multi-element determinations from the prepared pellet were carried out using an energy-dispersive polarizing X-ray Fluorescence Spectrometer (Manu *et al.*, 2015). The compositions of the powdered eggshells have been presented in Table 3.

2.5 Preparation of Compressed bricks Specimen

Batching of materials was done by weight. The powdered eggshells and laterite samples were thoroughly mixed together in different proportions by varying the eggshells contents. The powdered eggshells were added in stages of 10%; thus ranging from 0% (being the least) to the highest of 40%. This was done to determine the influence of the powdered eggshells on the compressed bricks so that other higher quantities could be predicted.

Mixing of materials was done in a clean tray before a predetermined water content (attained after conducting the compaction test) was added. Table 1 demonstrates the quantity of each sample used in the production of each batch. The carefully batched materials were initially mixed before adding water. Further, mixing was done until a wet homogenous material was obtained. The moist specimen was placed in a metal mould box with dimension; 200mm × 100mm × 75mm after which it was compressed using a manually operated moulding machine.

After compacting, the compressed bricks were covered with plastic sheets under ambient conditions with the sole aim of reducing rapid evaporation of moisture which could cause dry shrinkage, cracks and other undesirable defects on the bricks. The compressed bricks were cured for 28days before investigating their properties and suitability for masonry applications.

Table 1 Quantity of Materials used for moulding each Batch

Variations	Laterite (kg)	Eggshells (kg)	Water (kg)
Laterite with 0% PES (Control batch)	7.88	0	0.559
Laterite with 10% PES	7.88	0.79	0.746
Laterite with 20% PES	7.88	1.58	0.946
Laterite with 30% PES	7.88	2.36	1.167
Laterite with 40% PES	7.88	3.15	1.324

2.6 Testing of Compressed bricks

The study sorts to determine the suitability of using eggshells to improve the properties of compressed bricks. Tests conducted comprised of the crushing tests, water absorption by capillarity rise and abrasion resistances characteristics. The dry density of the bricks was also explored. In all, five bricks specimens with good appearance were randomly selected from each batch for each test as stipulated by most standards. All experimental studies were conducted after curing the compressed bricks for 28 days.

The dry densities of the compressed bricks were taken after drying the specimen in the oven for 24 hours at a temperature of 105ºC. The compressive strength of the bricks were conducted as per GS 297-1 (2000) specification. The durability properties studied which included the water absorption and abrasion resistance characteristics were investigated as specified by the African Regional Standards for Compressed Earth Blocks (Adam and Agip, 2004).

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

Preliminary tests on the laterite revealed the following (as presented in Table 2) as the index properties. Generally, the laterite used was found suitable for construction and other engineering applications as it had sufficient amount of clay content to ensure effective bonding between the various particles within the soil matrix. Calcium oxide (CaO) was detected as the highest oxide in the powdered eggshells as seen in other studies (Karthick et al., 2014; Gowsika, 2014).

Table 2: Properties of Laterite used

Properties	Results
Particle size Classification	Cu = 2.60: Cc = 0.83
Plasticity Chart Classification	Organic clay of high plasticity
Colour	Reddish-Brown
Natural moisture content	5.1%
Organic Matter	1.10%
Free Swell Index	10.7%
Specific Gravity	2.58
Linear Shrinkage	8.4%
Liquid Limit	54.5%
Plastic Limit	37.5%
Plasticity index	17%
Clay Content	14.8%
Silt Content	29.6%
Sand / Gravel content	55.6%
Maximum Dry Density	2088g/cm^3
Optimum Moisture Content	7.1%

Table 3 Oxide present in the Powdered Eggshells

Oxides Present	Result
Calcium Oxide (CaO)	64.83%
Sodium Dioxide (Na_2o)	1.48%
Silicon Dioxide (SiO_2)	0.79%
Magnesia Oxide (MgO)	0.29%
Aluminium (Al_2O_3)	0.13%
Chlorine (Cl)	0.09%
Potassium (K_2O)	0.08%
Sulphate (SO_3)	0.06%
Ferrous Oxide (Fe_20_3)	0.06%
% Retained in 425um	14.4%

Table 4: Properties of Compressed Laterites samples with Powdered Eggshells

Batch	Density (Kg/m^3)	Compressive Strength (N/mm^2)		Water absorption (g/cm^{2}min)	Abrasion resistance (cm^2/g)
		28 days	56 days		
Laterite + 0% PES	1976.44	1.79	1.84	16.89	0.32
Laterite +10% PES	2001.12	2.36	2.67	15.54	0.50
Laterite +20% PES	2014.6	2.74	3.01	6.06	0.97
Laterite +30% PES	2043.2	2.87	3.05	3.94	1.56
Laterite +40% PES	2044.2	1.82	2.72	7.23	0.53

Compressive Strength: The test was to determine the strength development of specimens with varying eggshells at both primary and secondary curing ages (28 and 56 days curing ages). Compressive strength is arguably the most important requirement a walling unit for both load and non-load bearing walls must have. The compressive strengths of brick specimens generally increased as the eggshells contents increased. Data also showed an increase as the curing ages increased from 28 days to 56 days a phenomenon common with materials used as binders such as cement, lime, fly ash etc.
After 28 days curing age, only compressed laterite bricks with 20% and 30% eggshell content met the acceptability limit for masonry purposes as stipulated by GS 297-1 (2000). As the curing age increased, only laterite without eggshells failed to meet the recommended minimum compressive strength of 2.5N/mm^2.
The increase in the strength characteristics with increasing eggshells was attributed to the calcium ions which react with the clay to form cementitious matrix thus improving the bond between the soil particles.

Density: Bricks used in the study had their densities within the range of 1500kg/m^3 – 2400kg/m^3 as specified by BS 6073 for dense aggregates masonry units. The mean dry density of the ricks increased steadily as the eggshells content increased as depicted in Table 4. The increase in the dry density of the bricks could be attributed to the increasing eggshell content which influenced the overall density of the batch as the quantity increased.

Water Absorption by Capillarity: This test investigated the ability of the bricks specimen to absorb water after partially immersing them in water for 10 minutes. Generally, specimen with high coefficients indicates high absorption rate thus high porosity whiles specimen with low coefficients are less porous thus absorbing lesser amount of water. Data as presented in Table 4 shows a gradual dip as the eggshells increased from 0% to 30% before rising slightly. This phenomenon associated with increasing eggshells could be attributed to the decreasing volume of voids which have been filled with the eggshell particles therefore minimising the permeability of the bricks. It could also be affiliated to the increasing calcium ions which tend to improve the cementing properties within the soil matrix similar to that of conventional lime.

Abrasion Resistance: Bricks specimens were subjected to abrasion by brushing for 60 continuous cycles using a wire brush. Higher abrasion resistance coefficients showed higher bond strength between particles whereas specimen exhibiting lower coefficients showed weaker bonds. Data derived from the study (in Table 4) showed that bricks with 30% eggshells exhibited higher resistance to abrasion (wear) whiles the control batch (without eggshells) were showed the least resistance to wear.

IV. CONCLUSION

The results of the study showed that the powdered eggshells has substantial amount of Calcium compounds (64.8%). At 28 days curing age, compressive strength of the bricks increased by 31.8%, 53.7%, 60.3% and 1.6% as the eggshells content were 10%, 20%, 30% and 40% respectively. The powdered eggshells significantly improved the density, compressive strength and durability characteristics of the laterite bricks when compared with the conventional compressed laterite bricks. Data from the study revealed that the optimum amount of powdered eggshells was attained after 30% addition. Furthermore, the use of powdered eggshells for construction applications could reduce environmental pollution, and improve the quality of compressed laterite bricks. This can also help to effectively manage this agro-waste material by turning it into an additive or stabilizer.
Further studies are recommended to be conducted using eggshells ash as a stabilizer for soils with different properties for masonry purposes.

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