Strength and Durability Properties of Cow Dung Stabilised Earth Brick

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Abstract
This research, reports on the investigation into the strength and the durability properties of earth brick stabilised with Cow dung. A local earth was stabilised chemically by Cow dung. A better compressive strength at the dry state and after 10 minutes of immersion in water was obtained with cow dung stabilisation at content of 20% by weight of earth. Bricks stabilised with 20% Cow dung contents by weight of earth has a dry and wet compressive strength of 6.64 and 2.27MPa respectively. There is an increased of about 25% in the dry compressive strength of bricks stabilised with 20% cow dung content over that of the plain earth brick without stabiliser The 20% cow dung content resulted in lower migration of water into the brick (i e. lower permeability). Also the abrasive resistance increased with increase in the cow dung content up to 20%. The highly decreased in compressive strength after 10 minutes of immersion in water, even with optimum Cow dung content, indicated that appropriate building design that would prevent stabilised earth bricks from coming into direct contact with rainwater is important. The study recommends that appropriate construction specification is necessary to prevent cow dung stabilised earth bricks from coming into any prolonged direct contact with rainwater.
Keywords: cow dung; compressive strength; abrasive resistance; absorption; earth.

1. Introduction

Earth is one of many alternative materials that can be used in place of residential stick building. A number of binders have been used to stabilise earth, for construction. Such binders are aimed to improving water proofing or wear resistance properties of vulnerable earth based construction. Such binders include cements, lime, tars and bitumen's, sodium silicate, casein, oils and fats, molasses, and certain locally specific plant-based materials such as gum arabic, other specific resins and the sap, latexes and juices from specific trees and other (Corum, 2005). Blast furnace slag and pulverised fuel ash are the two waste materials which are being used to the greatest extent in construction. These materials can make a particular contribution in conserving energy in the manufacture of cementitious materials and of lightweight aggregates. A study on the reuse of paper de-inking sludge, undertaken in Spain, showed that, it has the potential as raw material for producing a binding material with pozzolanic properties (Asavaspisit and Chotklang, 2004; García , Vigil de la Villa, Vegas, Frías and Sánchez de Rojas, 2008). A research conducted by García , et. al.,(2008) showed that calcination paper sludge has higer pozzalnic characteristics as compared to other industrial pozzolanic by-products, such as fly ashes normally used in cements. Another research results on paper sludge as pozzolanic addition in cement manufacturing, indicated that a significant gain of compressive strengths (approximately 10%) was achieved; when 10% calcined paper sludge was blended with ordinary Portland cement (Moisés Frías Iñigo Vegas, Raquel Vigil de la Villa and Rosario García Giménez, 2012).

In recent years, the use of solid waste derived from agricultural products as pozzolans in the manufacture of blended mortars and concrete has been the focus of researchers in the construction materials sector. The addition of ashes from combustion of agricultural solid waste to concrete is at present, a frequent practice because of the pozzolanic activity of the ashes toward lime. One of the most interesting materials is the ash obtained from the combustion of sugar cane solid wastes (Yalley and Bentle, 2009; Martins, et. al., 2012).

In Ghana Mud mortars have, traditionally, been improved by the addition of organic matter such as cow dung and ashes from agro processing waste. Whether these organic materials enhance the desirable properties of the earths or not are not yet scientifically ascertained. If they do, the weight or volume fraction of these organic matters in earth is not yet known. The searching for alternate construction material to conventional construction materials, out of waste and low energy materials is the main purpose of this research. This study investigated into the strength and durability properties of cow dung as stabilisers for unfired mud bricks.

Two main factors that were taken into account in the search for new construction materials and techniques were ecological impact and production costs. This study seeks to investigate the optimum cow dung weight fraction (by Weight of earth) that would give the maximum mechanical and durability properties of cow dung as stabilisers for earth bricks production.

2. Experimental study

2.1 Materials

The earth used was from local earth from Sunyani Polytechnic area of Ghana. The characteristics of earth used are presented in Table 1. The properties of the earth were obtained through laboratory investigation in accordance with BS 1881: part 1, 3 and 7; (1990) Cow dung used was from Sunyani slaughter house of Ghana. Tap water was used in all mixes.

Table1. Summary of characteristics of earth used

Earth properties	**Values**
Moisture content	10%
Liquid limit	35%
Plastic limit	24%
Plasticity index	11%
Maximum shrinkage at 7 days	2.18%
Organic content	1.9%
Maximum dry density	1762kg/m^3
Moisture content	12%
Clay content	11%

2.2 Test methods

A few small-sized bricks without stabiliser were produced as a preliminary test to assess the optimum compression pressure that might be required to produce a brick of maximum strength. The optimum moisture content of earth in its natural state (not dried in oven) and also the mass of earth required to produce a batch of 15 bricks were also required. A BREPAK earth brick press (see Figure 1) that could deliver pressures of up to 35 MPa, was used at Sunyani Polytechnic, Civil Engineering the laboratory, for the bricks production

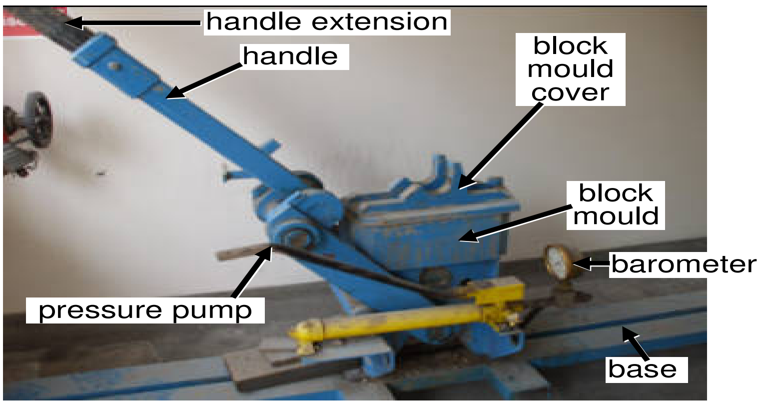

Figure 1 Brick moulding equipment

Preliminary tests such as dry density and moisture content of the earth in the natural state were first conducted on the earth bricks without stabilisation and with 15%, 20%, 25%, and 30% cow dung stabilisation to ascertain the optimum water content for each batch. Afterwards investigation was conducted on bricks with 0%, 15%, 20%, 25%, and 30% of cow dung by weight of earth material and its effect on the dry density, compressive strengths, abrasive resistance and water absorption coefficients at the optimum moistures contents were analysed after 28-

days of air curing. Five batches of 15 bricks per batch were produced for the study. In all a total of 75 bricks were used in the studies.

2.2.1 Density test

The objective of this test was to determine how the moisture content influences the density of the bricks and the effect of cow dung on density of the bricks. Three bricks from each batch were selected after four weeks of curing. These bricks were gently wiped with non-absorbent cloth in order to remove any dust or loose matter stuck to them. Each dimension of these bricks in the middle of each face was measured and the average calculated (see Figure 2). Their volumes were then calculated. These bricks were then oven-dried at a temperature of 105°C until constant masses of the bricks were obtained (BS1880, *Code of for earth*, 1990). The mass of the bricks were considered to be constant when the difference between two weighings at 24 hour intervals was less than 0.1% of the initial masses. On removal from the oven the bricks were left open to ambient air to cool (typically for two hours). After cooling, the bricks were weighed and then the densities were calculated and the average was then taken from each batch.

Length, $L = \dfrac{L_1 + L_2}{2}$ Height, $h = \dfrac{h_1 + h_2}{2}$ Width, $w = \dfrac{w_1 + w_2}{2}$

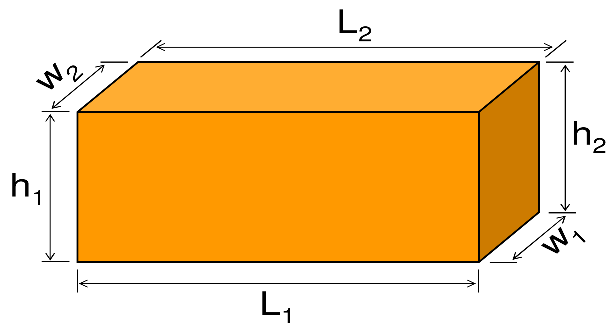

Figure 2. Illustration of brick dimension

2.2.2 Dry Compressive strength test

Three bricks which had no surface cracks visible to the naked eye were selected from each batch of moulded bricks. The bricks were oven-dried to a temperature of 40°C until constant masses were obtained (BS1880, *Code of for earth*, 1990). The bricks were then removed from the oven and left to cool in open air, and gently wiped of any dust or loose dirt stuck to them. The bricks were then tested for their dry compressive strength using a compression test machine.

2.2.3 *Wet Compressive strength*

Buildings are often exposed to the effect of water, particularly as a result of capillarity and of spraying from rain water. The mechanical strength of wet bricks is found to be weaker than those of dry bricks.

The main purpose of this test was to find the minimum strength of the bricks and also to improve on the strength of the wet bricks if they were found to be unsatisfactory. Again three bricks were selected from each batch and oven-dried at 40°C until constant masses were obtained. The bricks were then air cooled. The bricks were dusted and then fully immersed in water of temperature of about 20°C in the laboratory for 10 minutes. The bricks were then remove from water and dried with a tissue. The bricks were then tested for their compressive strength using compression test machine.

2.2.4 Abrasive strength

The aim of this test was to ascertain the effect that weathering would have on the bricks. Wind, rain storm and other factors generally have wearing effect on building walls. It is useful at this stage to know how the bricks would stand the test of the weather conditions so as to improve the stabilisation of the bricks.

In these tests the bricks were subjected to mechanical erosion applied by brushing, with a metal brush at a constant pressure over a number of cycles on the face of the bricks, which would be used as facing. Three bricks for the test were weighed (m_1) and each was placed on a table and the surface of the brick was brushed in turns with wire brush at one forward and backward motion per about a second for 60 cycles. Care was taken so that the brushed width of the brick did not exceed the width of the brush by more than 2 mm and the brushing took place along the whole length of the brick. When brushing was completed, all loose matter was then removed from the bricks, by using soft sweeping brush, and weighed after the test, (m_2). The mass of the detached matter (i.e. m_1–m_2) was recorded and the abrasive coefficient was then calculated using the following formula:
Abrasion coefficient:

$$C_a = \frac{A}{m_1 - m_2} cm^2 / g$$

where,
A = Area of brushed surface
m_1= mass of brick before brushing
m_2 = mass of brick after brushing.

2.2.5 Water absorption by capillary
Water absorption was measured by the increase in weight for a specimen stored for 28 days in a laboratory environment and then immersed in 5mm depth of water for 10 minutes in accordance with BS 1881; part 1- 1990 as shown in Figure 3

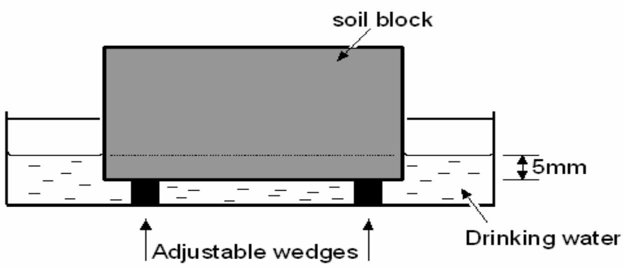

Figure 3 sketch of set up for measuring capillary rise

3.0 Test results and discussion

3.1Preliminary test

To obtain an optimum water content that would be suitable for the production of bricks with maximum strength and durability properties, a preliminary test was conducted on bricks with/without certain level of earth stabilisation with cow dung. The trial water content used in the preliminary test were 10%, 11% and 12% for various degree of cow dung content for earth bricks stabilisation by weight of earth and the effects of moisture on dry density was determined.

3.1.1 The effects of moisture on Dry Density

Table 2 shows the results of the preliminary test. It could be seen that there were different optimum moisture contents for earth bricks with cow dung as stabiliser compared to those without any stabiliser. The optimum water content for the earth bricks without stabilisation and for bricks with 15% cow dung content was 10% by weight of earth. The corresponding maximum densities were 1748 kg/m^3 and 1841 kg/m^3 respectively. The optimum moisture content for earth brick stabilised with 20%, 25% and 30% of cow dung at 28-day curing age was found to be 11% and had maximum densities of 1847 kg/m^3, 1861 kg/m^3 and 1910 kg/m^3 respectively. Although 1% addition of water seemed only a small amount (about 450g), it was possible that 1% additional water added permitted more complete hydration of the cow dung. The 1% addition of water gave water to cow dung ratio of 0.2, 0.25 and 0.33 for earth bricks with cow dung content of 30%, 25%, and 20% respectively. The minimum water/cement ratio for adequate hydration is between 0.22 and 0.5 (Akroyd, 1962, Lea, 1970 as cited in Yalley and Bentle, 2009). The 1% excess water gave water/cow dung ratio values between 0.2 and 0.33 for bricks with cow dung stabiliser, which thus fall within the range of water requirement for adequate hydration for stabilised Lateritic Earth.

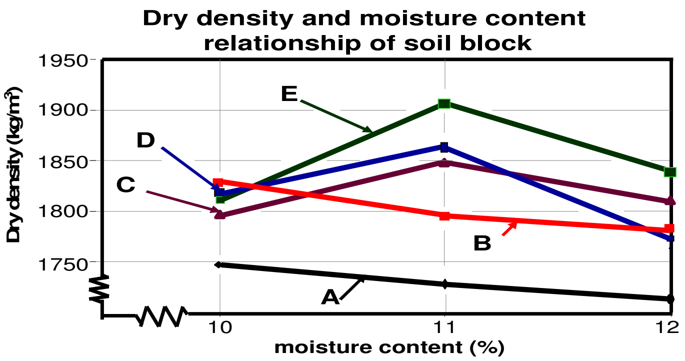

Figure 4. Optimum Moisture content and try density of earth brick

The batches are labelled such that X_i represents batch X with i% of water content by weight of earth.

Specimens	Dry density (kg/m^3)
A_{10}	1748
A_{11}	1739
A_{12}	1713
B_{10}	1841
B_{11}	1797
B_{12}	1766
C_{10}	1797
C_{11}	1847
C_{12}	1807
D_{10}	1817
D_{11}	1861
D_{12}	1758
E_{10}	1813
E_{11}	1910
E_{12}	1837

Furthermore, batches with 0%, 15%, 20%, 25% and 30% of cow dung content were assigned letters A, B, C, D and E respectively

3.2 Main experiment

Results from the preliminary test gave a fair idea on the optimum water content that would be suitable for the production of earth bricks stabilised with/without cow dung. Hence the bricks in this study were produced with the required optimum water content. Table 3 details the results of various test conducted.

3.2.1 Density of bricks

Comparing cow dung content and density in Figures 5 and Table 3 shows that there was a possible relationship between the two variables. The increase in cow dung content was in some way connected to the increase in the density. The density stabilisation increased from 1748 kg/m^3 for the un-stabilised brick to1910 kg/m^3 for 20% cow dung stabilised earth brick, which was about 9% increase.

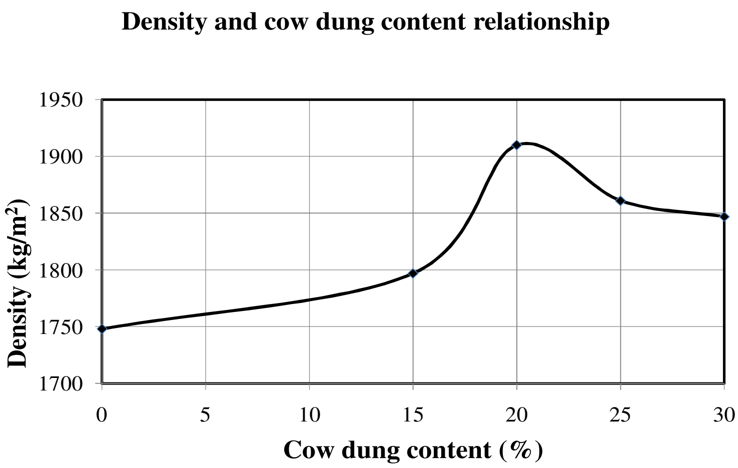

Figure 5. Density of earth brick with Variable cow dung content at OMC

Table 3 Mechanical characteristics and strength of Cow dung Stabilised Earth Brick (CSEB)

Specimens	Dry density (kg/m^3)	Dry compressive strength (MPa)	Wet compressive strength (MPa)	Coefficient of abrasion, C_a (%)	Water absorption coefficient, C_b (%)
A	1748	4.56	0.00	1.45	16.80
B_{15}	1797	4.70	0.85	1.57	19.90
B_{20}	1910	5.77	2.76	3.40	10.40
B_{25}	1861	5.14	2.25	2.64	11.00
B_{30}	1847	4.62	1.94	2.25	12.0

NB. The batch with 0%, of cow dung content is assigned letters A and those with certain level of cow dung content are labeled such that B_i represents batch B with i% of cow dung content by weight of earth.

3.2.2 Dry Compressive strength

The compressive strength at the dry state is given in Table 3 and as depict in Figure 6. It could be seen that bricks with 20% of cow dung content had the highest dry compressive strength of 5.77 MPa which was an increased of about 67% over un-stabilised earth brick but beyond that, there were decrease in dry compressive strength to 5.14 and 4.62 MPa for bricks stabilised with 25% and 30% cow dung content respectively. This then implies that the optimum cow dung content for compressive strength is 20% by weight of earth. This might be attributed to the fact that the hydration products of the cow dung up to 20% was just enough to filled in the pores of the matrix and enhanced the rigidity of its structure by forming a large number of rigid bonds connecting earth particles.

3.3 Wet Compressive strength

The compressive strength after immersion in water for 10 minute at the age of 28 days is given in Figure 6. The immersion in water for 10 minutes reduced the compressive strength by an average of 67% for cow dung-stabilised samples compared to the compressive strength in their dry state. Furthermore, complete disintegration of un-stabilised specimens was observed in a few minutes after immersion in water. Again bricks with 20% cow dung content as stabiliser had the highest wet compressive strength of 2.76 MPa. Specimens with cow dung content above 20% did not give any significant improvement of strength of the wet samples. The lower strength of the wet samples could be prevented by treating the surface with cow dung render, with polymers or cow dung–lime renders, especially when the construction is to be exposed to water.

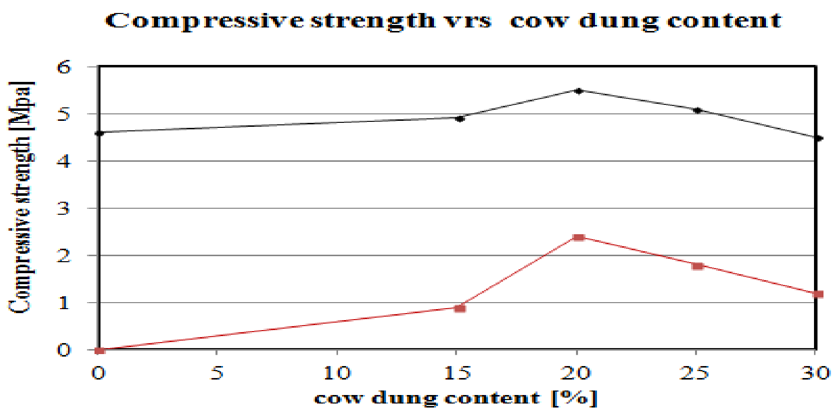

Figure 6. Compressive strengths earth bricks versus cow dung contents at the OMC

3.4 Abrasive strength

The results of the abrasion coefficient are recorded in Table 3 and the relationship between the abrasive resistance coefficient and the cow dung content is expressed graphically in Figure 7. It could be seen from Figure 7 that the abrasive resistance increased with increase in the cow dung content up 20%. As defined, a high abrasive coefficient shows a large brushing area is required to yield a certain amount of discarded material, i.e. the higher the abrasion coefficient the lesser the discarded materials. This then implied that the cow dung in the brick helped to reduce wear of the bricks from external factors. However, abrasive resistance again started decreasing when the cow dung content was beyond 20%. This is expected because the bricks with 20% cow dung content have the highest density, and thus resulted the best resistance to abrasion from rain water and from any form of rubbing against the bricks.

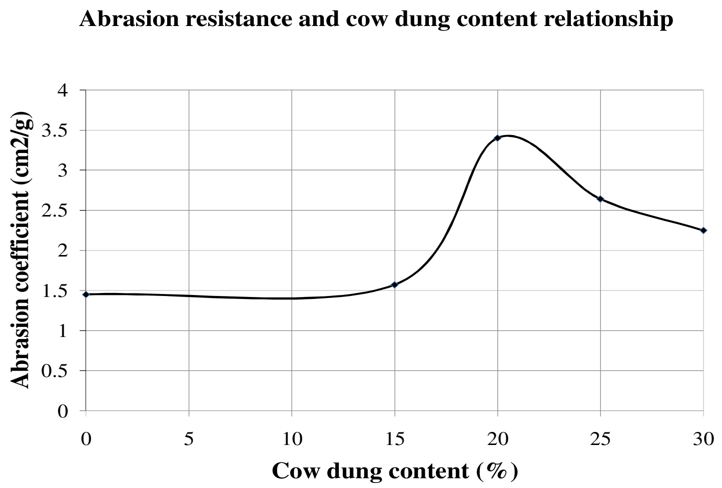

Figure 7 Abrasive strength versus cow dung content at OMC

3.5 Water absorption by capillary

Cow dung stabilisation reduced substantially the water absorptivity from 16.8% for 0% cow dung content to 14.2%, 10.4%, 11 and 11.36%, when cow dung contents were 15%, 20%, 25% and 30% respectively (Figure 8). The 20% cow dung content thus resulted in lower migration of water into the brick (i e. lower permeability). This could be explained that the presence of cow dung up to 20% eventually led to higher hydrated cow dung and higher mortar content. The higher mortar content makes the brick with some amount of cow dung less porous and more impermeable than the earth matrix, probably by infilling the voids and displacing some of the earth with far less permeable cow dung hydration products, thereby reducing paths for water ingression. Again increasing cow dung content above 20% did not much improve the impermeability of the bricks.

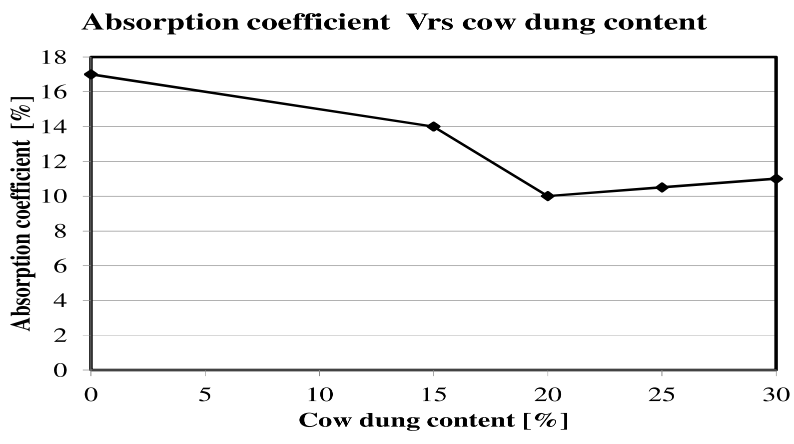

Figure 8 Absorption coefficient-cow dung content graph

4.0 Conclusion

A local Sunyani earth was chemically stabilised by cow dung. A better compressive strength at the dry state, and after 10 minutes of immersion in water, was obtained with cow dung stabilisation, and best values were obtained at cow dung content of 20%. The highly decreased compressive strength of the cured bricks after 10 minutes of immersion in water, indicated that appropriate construction specification is necessary to prevent stabilised earth bricks from coming into any prolonged direct contact with rainwater. Cow dung stabilisation reduced substantially the absorptivity from 16.8% for 0% cow dung content to 10.4%, when cow dung content was 20%. The abrasive resistance increased with increase in the cow dung content up to 20%.

The earth used in the experiments was from Sunyani in Ghana. This earth texture can be different from the earth texture in other part of Ghana and the world as a whole. Once the percentages of sand, silt and clay are determined from basic earth identification tests, the technology acquired in this study can be transferred to other part of Ghana Africa and to other parts of the world.

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