Feasibility of using Cocoa Pod Husk Ash (CPHA) as a stabilizer in the production of Compressed Earth bricks

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Abstract—Indiscriminate disposal of cocoa pod husks has been a threat to the environment especially in cocoa growing communities thus the need to explore alternative ways of utilizing this waste product. This paper examined the suitability of CPHA as a stabilizer in the production of stabilized earth bricks. Laboratory experiments were conducted on compressed earth bricks to investigate the effects of the CPHA on their compressive strength, dry density, abrasion resistance and water absorption characteristics. The earth bricks were moulded with different percentages of Cocoa Pod Husk Ash consisting of 0%, 5%, 10%, 15%, 20% and 25%. Using a mould dimension of 200mm x 100mm x 75mm, earth bricks were manually casted and cured for 28 days. Data results showed remarkable improvement in all the properties studied on the earth bricks but varied depending on the ash content. The study also revealed that cocoa pod husk ash can be used as a stabilizer in the production of earth bricks especially when the Cocoa pod husk ash content is 10% by weight as higher ash contents slightly decline the engineering properties.

Keywords— Cocoa Pod Husk Ash (CPHA), Stabilization, Earth bricks, Water Absorption, Abrasion resistance, Compressive strength, Cocoa

INTRODUCTION

Earth has been used as a building material for various types of houses with notable advantages in the tropics. These houses which include adobe, wattle and daub and others act as heat and cold absorbers thus making them more comfortable to live in. Even though, it is the most abundant construction material globally, its use has been limited due to its poor mechanical and durability properties when used as masonry blocks. These challenges associated with the use of earth blocks have over the years been minimized by stabilizing. Stabilization entails modifying any property of earth in order to improve its engineering performance. The art of stabilization is not new as Indians have stabilized earth from pre-historic times up to 600 BC although in recent times, the process has been conducted popularly with cement and lime [14]. Studies conducted on stabilized earth have shown remarkable improvement which includes increase in strength, water repellant and cohesion with reduced permeability, shrinkage and expansion [22].

With the skyrocketing prices of these stabilizing agents, studies have been tilted to the area of using agricultural and industrial byproducts and wastes which possess cementitious properties. Some of the notable byproducts with such properties include the ashes of rice husk, groundnut and coconut shells, corn cob and husks, wheat husk among others [26]. Aside, the enormous benefits derived from these agricultural byproducts, the process of utilizing them as stabilizing agents also minimizes the negative effects on the environment due to improper disposal mechanisms. One abundant agricultural byproduct indiscriminately disposed on most Ghanaian farms for decades is cocoa pod husks.

Regarded as the Food of the Gods or *Threobroma* cacao L., cocoa has been an indispensable part of our lives through its use for a wide variety of edible products. The fat from cocoa (cocoa butter) is used in the cosmetics and pharmaceutical industries [9]. Aside these benefits, local indigenes have substantial benefits such as the use of the cocoa pod husk in the production of soaps, fertilizer [19] and as poultry feed whiles the juice is used for vinegar and other alcoholic beverage production [17]. Others benefits attached to cocoa include the use of the shells of the Cocoa beans, a by-product of chocolate production are commonly sold as mulch for landscaping [11] whiles cocoa pulp can also be used in soft drink, alcohol and pectin (for jelly, marmalade and jam) production. It is stunning to know that the numerous benefits associated with cocoa plant could be attributed to the cocoa beans which constitute only 10% by weight of the cocoa fruit [2] whiles the remaining 90% predominately the cocoa pulp and cocoa pod husk are regarded as wastes with minimal commercial values in Ghana.

Even though, cocoa has been cultivated in Ghana for long, adequate information on the use of Cocoa Pod Husk Ash in stabilizing earth blocks is rare. This study seeks to determine the feasibility of utilizing the ash of cocoa pod husk as a stabilizing agent in the production of compressed earth bricks for masonry purposes.

MATERIALS AND EXPERIMENTAL STUDIES

The materials used in the investigation consisted of:
Earth: The earth was sourced from Nchaban - Nkwanta, a suburb of Sekondi-Takoradi. The samples were dried in the open before sieving through a 5mm mesh sieve whiles lumps present were pulverized (depicted in Fig. 1). This was done to eliminate outsized particles including gravels and stones could negatively impede on the bricks properties [27]. The physical properties of the earth as presented in Table 1 were obtained in accordance with [7].

Figure 3 Before and after pulverizing the earth sample

Water: The water was potable as supplied by Ghana Water Company.

Cocoa Pod Husk Ash: Dried Cocoa Pod Husks were obtained from Wassa - Mampong in the Western Region. They were gathered in the open and burned into ashes (as shown in Fig. 2). The ashes obtained were allowed to cool before sieving using a 300µm mesh sieve. This was aimed at removing all partially burnt carbon particles so as to obtain the reactive form of the ashes which are mostly in very fine forms.

Figure 4 Dried Cocoa Pod Husks before and after combustion

CHEMICAL COMPOSITION OF THE COCOA POD HUSK ASH

The chemical composition of the Cocoa Pod Husk Ash (CPHA) was determined by 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 (SPECTOR X-LAB 2000). The compositions of the ash have been presented in Table 1.

PREPARATION OF BRICK SPECIMEN

The production process of the bricks involved batching, mixing and casting of bricks using a manually operated moulding machine having a mould dimension of 200mm x 100mm x 75mm. The earth samples and the Cocoa Pod Husk Ash (CPHA) were batched by weight. Bricks specimen were categorized into batches. The batches consisted of earth sample with varying percentages of Cocoa Pod Husk Ash in steps of 5% which ranged from 0% to a maximum of 25%. This was done to determine the effects of the CPHA on the properties of compressed earth bricks and to aid in possible predictions of higher percentages of the ash.

The batched materials (earth and CPHA) were manually mixed in a tray to prevent harmful materials that could alter and affect the properties of the produced specimen. After a thorough mix, water was added in piecemeal until the optimum water content of the batch was attained using the ball test as explained by [21]. The wet homogenously mixed material was placed in the mould box and tamped to ensure maximum compaction before inscribing reference marks on them for easy identification. In total, 18 compressed earth bricks stabilized with Cocoa Pod Husk Ash were produced for each batch which were 0% representing the control batch and 5%, 10%, 15%, 20% and 25% representing bricks specimen with the corresponding ash content.

After casting, bricks were air dried under a shade and covered with polyethylene sheets. This was done with the aim of preventing dry shrinkage and rapid evaporation of water which would cause cracks and affect the dried bricks. The bricks were then transferred into the laboratory where they were cured for the remaining 21 days before investigations were conducted on them.

TESTING OF EARTH BRICKS SPECIMEN

The study sorts to determine the suitability of CPHA as a stabilizer in the production of compressed earth bricks. Investigations carried out on the dried earth bricks properties were the dry density, compressive strength and some durability properties. For each investigation, randomly selected bricks were used after curing for 28 days.

Density: The selected bricks were cleaned with a non-absorbent cloth to remove all loose matter stuck on them. Their weights and dimensions (i.e. length, breadth and thickness) were deduced before calculating the density using the formula outlined in Eqn. 1 before deducing the average for the batch.

$$Density = \frac{\text{Dry Mass}}{\text{Volume}} \quad \text{... Eq. 1}$$

Compressive Test: Earth bricks specimen from each batch were tested for their compressive strengths using an ADR 2000 Compression Testing machine after 28 days curing age.

The durability properties of the bricks specimen focused on the water absorption and resistance to abrasion characteristics of the compressed earth bricks. They were deduced using African Regional Standards for Compressed Earth Blocks as recommended and described in [1]. The water absorption test focused on the change in weight of the bricks after immersing in water for 10 minutes. Literally, earth bricks with higher absorption values tend to be more porous and unsuitable as a masonry unit. The abrasion result on the other hand centered on the ability of the bricks specimen to resist tear and wear arising from brushing with a metal brush at a constant pressure. Earth bricks with higher resistance values shows bricks specimen with better bonds between soil particles whiles those with lower resistance values tends to be poorly bonded thus unsuitable as a masonry unit.

EXPERIMENTAL RESULTS AND DISCUSSION

The results of the experimental study on the earth sample, cocoa pod husk ash and the stabilized earth bricks have been outlined below.

CHEMICAL COMPOSITION OF THE COCOA POD HUSK ASH

Studies on the chemical composition of the Cocoa Pod Husk Ash (CPHA) were conducted using the X-ray Fluorescence technique with focus on its Pozzolanic properties has been presented in Table 1 below. According to [6], materials regarded as Pozzolanic in nature should have compounds such silica (SiO_2), Alumina (Al_2O_3) and Iron Oxide (Fe_2O_3) exceeding 50% by composition. Data results showed a combined sum of 13.618% for the SiO_2, Al_2O_3 and Fe_2O_3 which were far below the minimum quantum of 50% indicating the CPHA does not have adequate amount of siliceous or aluminous compounds to exhibit Pozzolanic characteristics. It is also evident that the quantum of K_2O was relatively high which is likely to result in a weaken bonds between the particles in the soil matrix due to alkali reaction in higher variations. This undesirable amount of K_2O present in the CPHA makes it an ideal natural source of alkaline for soap production as seen in most rural communities in Ghana.

Table 1 Oxides Composition of Cocoa Pod Husk Ash (CPHA)

Oxides	**Mass (%)**
SiO_2	9.727
Fe_2O_3	0.447
Al_2O_3	3.444
CaO	0.000
MgO	4.299
SO_3	2.171
P_2O_5	0.276
Cl	0.155
K_2O	25.61
MnO	0.09

CHARACTERISTICS OF THE EARTH SAMPLE

A number of tests were performed on the earth sample to determine its basic characteristics as presented in Table 2. The varying nature and their quantity in ideal amount of the particle sizes influence the engineering properties of earth bricks. The earth sample was described as well graded with uniformity coefficient (Cu) and coefficient of curvature (Cc) of 23.1 and 0.92 respectively [24]. The specific gravity of the earth sample was 3.75 which fell within the recommended range of 2.55 and 4.00 for lateritic soils [15].

Table 2 Characteristics of the Earth sample

Properties	**Results**
Shrinkage limit	8.3%
Liquid limit	46.4%
Plastic limit	29.6%
Plasticity index	16.8%
Natural moisture content	4.8%
Maximum dry density	1860kg/m^3
Optimum moisture content	8.6%
Sand/Gravel content	54.55%
Silt content	32.72%
Clay content	12.73%
Specify gravity	3.75
Soil description	Lean clayey soil
Particle size	Cu = 23.1; Cc = 0.92

The sedimentation test is among standardized field test used to determine the approximate volume percentages of constituents of soil. The result showed silt content of 32.72%, clay content of 12.73% and sand/gravel content of 54.55%. It is important to indicate that for an effective stabilization of soil, the clay fraction is essentially responsible due to its ability to provide cohesion within a soil matrix. Although, the clay fraction was within the limit of 8% - 30%, its silt content exceeded the range of 10% - 25%, which is likely to inhibit an effective bond between the various particles within the soil matrix [23]. Such soils are referred as lean clayey soil [16].

The Atterberg consistency limit test conducted on the soil sample revealed a liquid limit of 46.4%, plastic limit of 29.6% and a plasticity index of 16.8%. The shrinkage limit was also 8.3% within the recommended range of 8% - 18% suitable for engineering applications. The plots of plastic index against liquid limit on the plasticity chart (as depicted in Fig. 3 below) shows the earth (soil) falling beneath the A-line but within the intermediate plasticity zone making it ideal for construction and other engineering works [12].

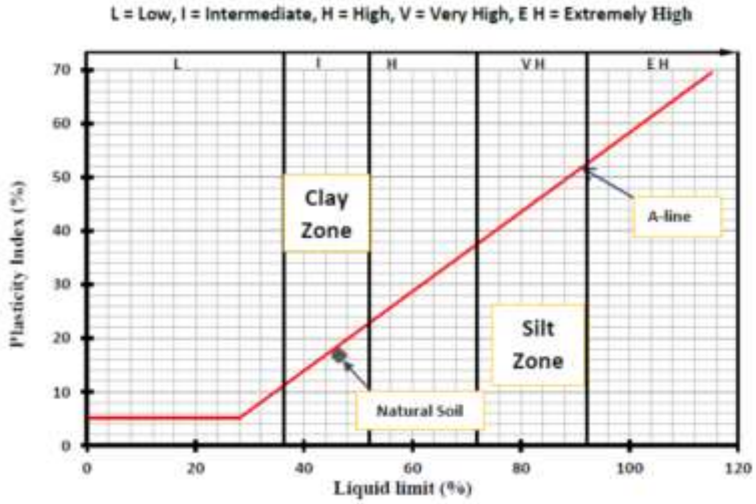

Figure 5 Earth (Natural soil) shown on the Plasticity chart

PROPERTIES OF THE EARTH BRICKS

The properties studied were; compressive strength, density, abrasion coefficient and water absorption rise of each variation level after 28-days curing age.

COMPRESSIVE STRENGTH

The mean compressive strengths of the various earth bricks ranged between 2.4148N/mm^2 and 4.2234N/mm^2 (as shown in Table 2). Earth bricks with 5% CPHA showed some improvement over the control group (earth bricks with no stabilizer) as much as 49% as the mean compressive strength increased from 2.4148N/mm^2 to 3.5964N/mm^2. As the CPHA content increased to 10% the earth bricks recorded the highest average compressive strength of 4.2234N/mm^2 which was almost 75% better than the control specimen. Earth bricks with 15% CPHA caused a slight dip as the compressive strength of 3.731N/mm^2 but this was found to be 54.5% better than bricks without stabilizer. Furthermore, bricks with 20% and 25% CPHA content had compressive strengths of 3.572N/mm^2 and 3.538N/mm^2 respectively which were found to be 47.9% and 46.5% higher than the compressive strength of the control batch group.
The ANOVA result shown in Table 2 displays the F-ratio, which in this case equals 248.888, indicating a statistically significant difference between the mean compressive strengths from one level of CPHA to another at the 95% confidence level. Analysis of the relationship between the mean compressive strengths and varying CPHA contents gave a Pearson's correlation coefficient of 0.449 indicating a slightly weak positive correlation between the mean compressive strengths and the CPHA. This relationship was best described by the regression model which had an R-Squared adjusted of 0.174, indicating that the CPHA explains 17.4% of the variability in the compressive strengths of the earth bricks.

Compressive strength = 3.152 + 0.029*CPHA ……………………… Eq. 2

The model expressed by Eq. 2 further indicated that a unit percentage change in the CPHA causes a corresponding increase in the compressive strength of the bricks by 0.029N/mm^2 whiles the rest may also be attributed to method of compaction, curing process, water content and other factors.

Table 3 Summary of the compressive strength results of Earth bricks with varying CPHA

CPHA Content	Mean Stress	SD	R-Squared	R^2 –Adjusted	F-ratio	P-value
Soil + 0% CPHA	2.4148	0.03095	0.2020	17.4	248.888	0.000
Soil + 5% CPHA	3.5964	0.05737				
Soil + 10% CPHA	4.2234	0.13832				
Soil + 15% CPHA	3.7310	0.11149				
Soil + 20% CPHA	3.5720	0.06221				
Soil + 25% CPHA	3.5380	0.05450				

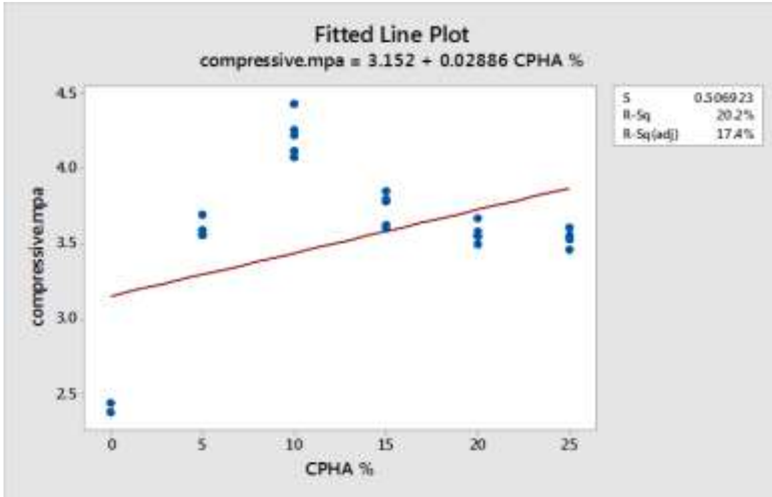

Figure 6 Compressive strength results of earth bricks with varying CPHA

Earth bricks stabilized with CPHA varied in their acceptability to the minimum requirement for masonry purposes. It was evident that the control batch did not meet the minimum requirement as recommended by [10]. Bricks with 5%, 15%, 20% and 25% CPHA contents were able to meet the minimum compressive strength of 3.00N/mm^2 for Class B masonry units. Finally, earth bricks with 10% CPHA content qualified as a Class A masonry unit which required a minimum 4.00N/mm^2.

Generally, all earth bricks had significant improvements as the CPHA content was introduced portraying a trait exhibited by some agricultural and industrial wastes ashes such as rice husk ash [20], sugar cane bagasse ash among others [18]. Earth bricks gradually increased from 2.4148N/mm^2 to 4.2234N/mm^2 a as the CPHA content increased from 0% to 10%. The increase could be attributed to the presence of compounds (K_2O, Fe_2O_3, Al_2O_3, SiO_2) which tend to react with the clays to form cementitious matrix in small quantities [4].

Quite surprisingly, as the CPHA content exceeded 10%, there was a slight decline from 4.1964N/mm^2 to 2.832N/mm^2 as the CPHA increased from 10% to 25%. This dip in compressive strengths was attributed to the high content of the Potassium ions (K+). This phenomenon could be attributed to the replacement of strong cautions in the clay minerals with substantial amount of K+ which tend to weaken the bonds among clay minerals invariably, reducing the compressive strengths of the earth bricks.

DENSITY

The dry density of a masonry unit is largely a function of the constituent material's characteristics, moisture content during pressing and the degree of compaction load applied. Deducing from the data, bricks without CPHA (control batch) had the least average density of 1592.94kg/m^3 which increased to 1654.498kg/m^3 when CPHA content increased to 5%. An extra 5% addition of CPHA (making 10% CPHA) resulted in bricks with the highest mean dry density of 1809.048kg/m^3. However, specimens with 15%, 20% and 25% CPHA declined as they recorded mean dry densities of 1742.294kg/m^3, 1711.528kg/m^3 and 1716.68kg/m^3 respectively. The increase in the dry densities of the earth bricks associated with the increasing CPHA content was attributed to the fact that the pores in the earth bricks were filled by the ash and subsequently increase the weight of the bricks. After attaining, the optimum quantity (most pores filled), the CPHA tend to displace the soil particles instead, thereby causing a reduction in the densities of the earth bricks as seen with bricks with higher CPHA content (> 10%).

Table 4 Summary of the dry density results of Earth bricks with varying CPHA

CPHA Content	Mean Density	SD	R-Squared	R^2 –Adjusted	F-ratio	P-value
Soil + 0% CPHA	1592.9420	38.45751	0.2200	19.3	20.657	0.000
Soil + 5% CPHA	1654.4980	20.96443				
Soil + 10% CPHA	1809.0480	34.10533				
Soil + 15% CPHA	1742.2940	19.02670				
Soil + 20% CPHA	1711.5280	27.49890				
Soil + 25% CPHA	1716.6800	61.54743				

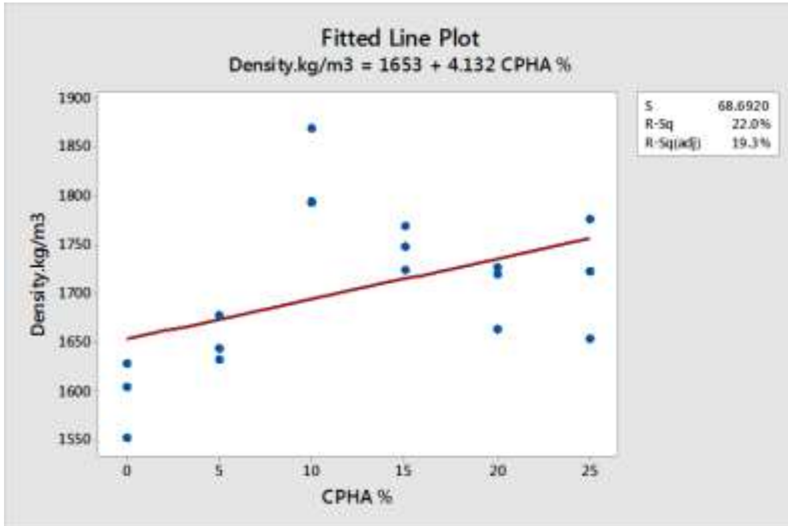

Figure 7 Dry densities of earth bricks with varying CPHA

A one-way analysis of variance shows F-value of 20.657 indicating that the stabilizer (CPHA) had an effect on the dry densities statistically. Further analysis on the relationship between CPHA content and the earth bricks was conducted using a regression model (as depicted in Eq. 3). The result of a linear regression model to describe the relationship between Density and CPHA is given as:

$$\text{Density} = 1653 + 4.132 * \text{CPHA} (\%) \qquad \text{............................} \quad \text{Eq. 3}$$

The Adjusted R-Squared of 0.193 of Eq. 3 as presented in Fig. 5 indicates 19.3% of the variability in Density was explained by the CPHA. The Pearson's correlation coefficient equals 0.469, indicating a slightly weak but positive relationship between the CPHA content and the densities of the bricks. The equation also depicts that an increase of 4.132kg/m^3 in the density of the bricks as the level of CPHA was increased by a percentage unit.

DURABILITY PROPERTIES

The durability properties of the specimens studied in this research consisted of the abrasion test and the water absorption by capillarity.

ABRASION COEFFICIENT OF THE EARTH BRICKS

The abrasion resistance coefficients of the stabilized earth bricks was determined using the procedures proposed by African Regional Standards for Compressed Earth Blocks. It measures the resistance of the specimen to abrasion or wear. Literally, specimen with higher abrasion resistance coefficients, have better resistance to wear and the vice versa. The abrasion coefficients were deduced using Eq. 4.

$$Ca = \frac{S}{M1 - M2} \qquad \text{...} \quad \text{Eq. 4}$$

Earth bricks specimen showed an improvement in the abrasion resistance as the content of the CPHA increased from 0% to 10% before declining as presented in Table 5 and depicted in Fig. 6. Earth bricks with 10% CPHA content gave the highest resistance to abrasion while the control batch (earth bricks with no CPHA) had the least resistance to abrasion.

Generally, the CPHA influenced the ability of the bricks to resist wear as the F-ratio from a one-way ANOVA equaled 108.337. Further analysis on the relationship between the abrasion coefficients and the CPHA was explored using a Pearson's correlation coefficient gave 0.351, indicating a weak positive relationship between the abrasion coefficients and the CPHA contents.

Table 5 Summary of the Abrasion results of Earth bricks with varying CPHA content

CPHA Content	Mean Abrasion	SD	R-Squared	R^2 –Adjusted	F-ratio	P-value
Soil + 0% CPHA	0.3546	0.03993	0.2312	9.2	240.288	0.000
Soil + 5% CPHA	0.5024	0.04241				
Soil + 10% CPHA	1.2088	0.06457				
Soil + 15% CPHA	0.8494	0.03172				
Soil + 20% CPHA	0.7248	0.04011				
Soil + 25% CPHA	0.6858	0.02744				

Earth bricks showed an improvement in their resistance to tear and wear (abrasion) as the content of the CPHA increased from 0% to 10% before declining, similar to the trends exhibited by other properties studied. Generally, this pattern was in agreement with other studies conducted on most agricultural-based stabilizing agents [26], [3], [25].

Literally, bricks with higher abrasion resistance coefficients showed higher resistance to disintegration than bricks with lower abrasion coefficients. Increasing abrasion coefficients of the stabilized bricks associated with increasing CPHA content was attributed to the improved bonding between the soil particles facilitated by both the low K+ ions and the clay particles. As the K+ ions increased, clay particles necessary for effective bonds between all the particles were weakened resulting in weak bonding between particles which were easily displaced by wear (abrasion).

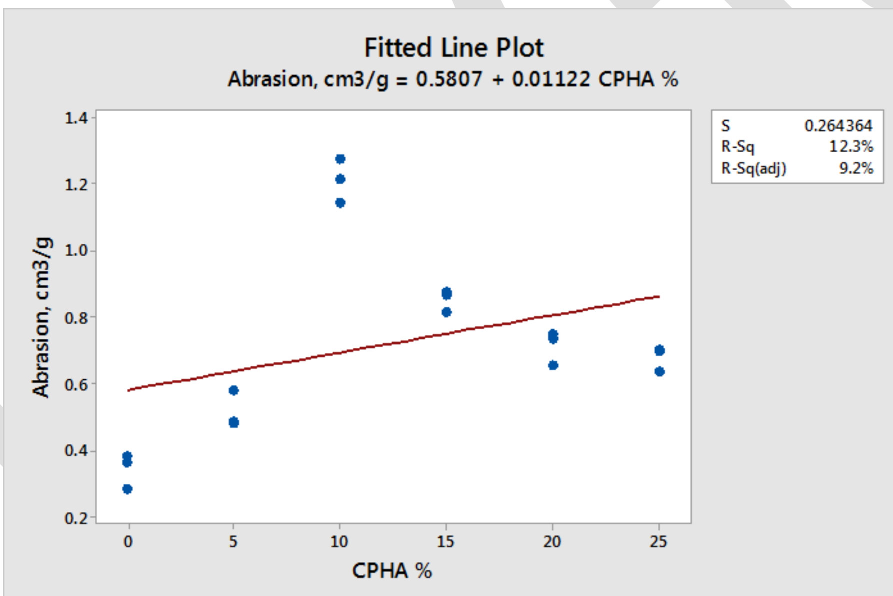

Figure 8 Abrasion coefficients of earth bricks with varying CPHA

This relationship was best predicted by the equation of the fitted model in Fig. 6.

Abrasion = 0.581 + 0.011*CPHA ………………………………… Eq. 5

With an Adjusted-R squared of 0.92, it can be observed that the CPHA explains 9.2% of the variability in the abrasion coefficients.

WATER ABSORPTION COEFFICIENTS OF THE EARTH BRICKS

Literally, stabilized bricks with low absorption coefficients (low initial rate of absorption) absorbs minimal amount of water which enhances better bonding between masonry units as some water is retained for proper hydration. Bricks without physical cracks were selected for this test per the procedures outlined by the African Regional Standards for Compressed Earth Blocks and deduced using the formula indicated in Eq. 6.

$$Cb = \frac{100 \times (M1 - M2)}{S\sqrt{10}} \quad \text{...} \quad \text{Eq. 6}$$

Generally, the use of CPHA as a stabilizer reduced the water absorption capacity of the bricks (as presented in Table 6 and Fig. 7). This was evident as earth bricks with no stabilizer (control batch) recorded the highest water absorption coefficient of 22.1856g/cm^{2}min. As the CPHA content increased to 5% the absorption coefficient of the earth bricks reduced to 19.067g/cm^{2}min (representing almost 16%) whiles those made with 10% CPHA an absorption coefficient of 4.6866g/cm^{2}min indicating about 373% reduction in their capability to absorb water when compared to the controlled specimen. Furthermore, as the percentage of CPHA content increased to 15%, the absorption coefficient of the earth bricks increased slightly to 8.4464g/cm^{2}min indicating about 163% reduction in water absorption whiles earth bricks with 20% CPHA content recorded an average absorption coefficient of 12.288g/cm^{2}min (80.5% reduction in absorption when compared with controlled group's average) whilst those made from 25% CPHA had absorption coefficients of 13.324g/cm2min (66.5% reduction in absorption when compared with controlled group's average).

Analysis of the results using a one-factor ANOVA showed F-ratio of 57.507 which was statistically significant at 95% confidence level indicating that the water absorption coefficients of the earth bricks were influenced significantly by the different percentages of the ash.

Table 6 Summary of absorption results of Earth bricks with varying CPHA content

CPHA Content	Mean Absorption	SD	R-Squared	R^2 –Adjusted	F-ratio	P-value
Soil + 0% CPHA	0.3546	0.03993	0.2312	0.1234	57.507	0.000
Soil + 5% CPHA	0.5024	0.04241				
Soil + 10% CPHA	1.2088	0.06457				
Soil + 15% CPHA	0.8494	0.03172				
Soil + 20% CPHA	0.7248	0.04011				
Soil + 25% CPHA	0.6858	0.02744				

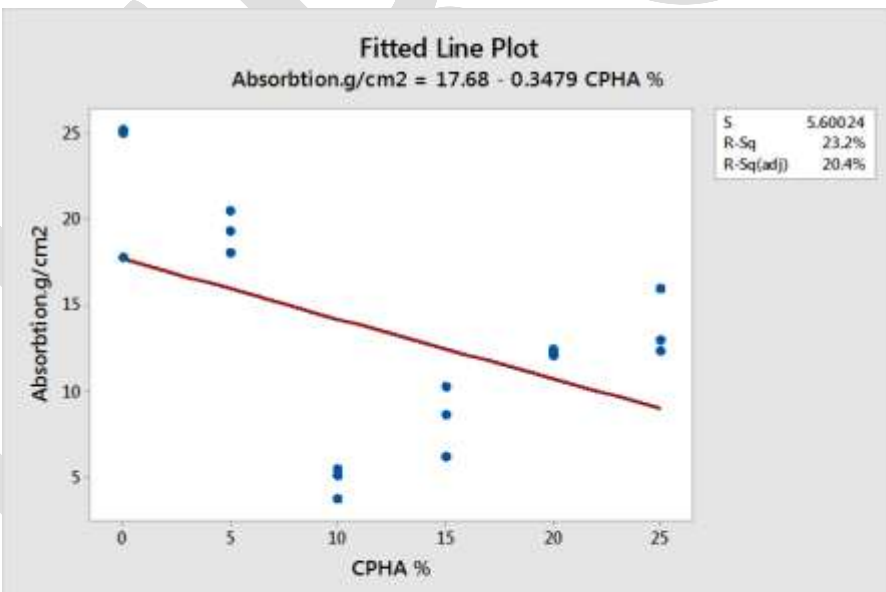

Figure 9 Abrasion coefficients of earth bricks with varying CPHA

The relationship between the CPHA content and the water absorption coefficients of the earth bricks was proved by a correlation coefficient of - 0.481, indicating a slightly strong negative relationship between them. This relationship indicated that as the percentage of CPHA increases, the water absorption capabilities of the bricks reduces which is best described by the equation.

Absorption = 17.68 - 0.348*CPHA ………………………………………… Eq. 7

To this end, the model (Eq. 7) reveals that a unit percentage change in CPHA results in 0.348g/cm2min decrease in absorption capabilities of the bricks. This decrease in the absorption coefficients associated with increasing CPHA could be attributed to the decreasing volume of voids which have been filled with the fine particles of the CPHA therefore minimizing the permeability of the earth bricks. Further increase in the CPHA content after 10% addition resulted in a divergence by increasing the water absorption coefficients as seen earlier with the previous properties studied. Such sudden change in pattern according to [13] might be attributed to the declining bond strength between the soil particles caused by the substantial amount of K+ ions present as the CPHA content increase resulting in a porous material.

CONCLUSION

The contents of the CPHA did not satisfy the recommendations of ASTM C 618 for Pozzolanic materials as the SiO_2, Fe_2O_3, Al_2O_3 contents totaled only 13.618%. It was evident that Potassium (K_2O) was relatively the highest constituting 25.61% by weight making the ash a natural source of alkaline. Data showed a gradual increase in in the engineering properties of the stabilized earth bricks as the CPHA content increased from 0% to 10% before declining slightly after subsequent additions. Data showed that the optimum amount of ash required for stabilizing the earth is 10% by weight.

Based on the study, effective stabilization of earth with similar characteristics for bricks production requires lower CPHA contents as higher content reduces the engineering properties.

REFERENCES:

[1] Adam, E. A., and Agip, A. R. A. (2001). "Compressed stabilized earth blocks manufactured in Sudan". United Nations Education Scientific and Cultural Organization (UNESCO). 7 Place de fontenoy, 75352 Paris 07 SP, France. pp 4-27.
[2] ADM Cocoa (2009). "The deZaan: Chocolate and Cocoa Manual". 40th Anniversary Edition. ADM Cocoa.
[3] Agbede, I. O. and Joel, M. (2011). "Effect of Rice Husk Ash on the Properties of Ibaji Burnt Clay Bricks". American Journal of Scientific and Industrial Research. Pp. 674 - 677. 2011.
[4] Amoanyi, R., (2012). "The study of alternative chemical stabilization of clays with agricultural waste materials for rural housing". An unpublished thesis submitted to the Department of Materials Engineering in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Materials Engineering.
[5] Amu, O. O., Ogunniyi, S. A. and Oladeji, O. O. (2011). "Geotechnical properties of lateritic soil stabilized with sugarcane straw ash". American Journal of Scientific and Industrial Research. Vol. 2 (2): 323-331.
[6] ASTM C 618-78. (2012). "Standard Specification for Coal Fly Ash and Raw or calcined Natural Pozzolan for use in concrete".
[7] British Standard Institution. (1990). "Methods of Test for Soils for Civil Engineering Properties". British Standard Institution: (BS 1377). London, UK.
[8] Das, B. M. (2000). "Fundamentals of Geotechnical Engineering". 4th edn. Thomson Learning, USA.
[9] Fapohunda S. O. and Afolayan A. (2012). "Fermentation of Cocoa Beans and Antimicrobial Potentials of the pod Husk Phytochemicals". Journal of Physiology and Pharmacology Advances. Vol. 2(3): 158-164.
[10] Ghana Standard Authority. (2010). "Building and construction materials-specification for blocks". Part 1: Precast sandcrete blocks: GS 297-1: 2010.
[11] Hansen, S., Trammel, H., Dunayer, E., Gwaltney, S., Farbman, D. and Khan, S. (2003). "Cocoa bean mulch as a cause of methylxanthine toxicosis in dogs". ASPCA Animal Poison Control Center, Urbana, IL Reterived from http//www.apcc.aspca.org
[12] Houben, H., and Guillaud, H. (1994). "Earth construction: A comprehensive guide. CRATerre-EAG". Intermediate Technology Publications. London, England.
[13] Kabiraj. K. and Mandal, U. K. (2012). "Experimental investigation and feasibility study on stabilized compacted earth block using local resources". International Journal of Civil and Structural Engineering Volume 2, No 3. ISSN 0976 – 4399.
[14] Kulkarmi, R. P. (1973). "Soil Stabilization by Early Indian Methods". Maharashtra Engineering Research Institute, Nasik, Maharashtra. Pp 53, 8.
[15] Magnien, R., (1966). "Laterite and Lateritic soils and other problem soils in Africa. An Engineering Study for Agency for International Development. AID/csd-2164. Lyon Associates, Inc. Baltimore, MaryIand, U. S.A
[16] Minke, G. (2006). "Building with earth: design and technology of a sustainable architecture". Birkhauser Publishers for Architecture. Boston.
[17] Nfor, B. K. Forton, O. T., Thomas A. Bemu, T. A. and Verhaert, P. D. E. M. (2012). "Valorization of the byproducts of cocoa production – Towards a more sustainable cocoa value chain in Cameroon".
[18] Ogunbode, E. B. and Apeh, J. A. (2012). "Waste to wealth: A study of laterite bricks produced using blended incinerated corn-cob ash cement". West Africa Built Environment Research (WABER) Conference, 4.1023-1031.
[19] Oladokun, M. A. O. (1986). "Use of cocoa pod husk as fertilizer for maize production". Nigerian Journal of Agronomy, 1 (1986) 103.
[20] Olaoye, G. S. and Anigbogu, N. A. (2000). "Properties of compressed earth bricks stabilized with termite mound materials". Nigerian Journal of Construction Technology and Management. Vol. 3:1
[21] Raheem, A. A., Bello, O. A. and Makinde, O. A. (2010). "A comparative study of cement and lime stabilized lateritic interlocking

blocks". Pacific Journal of Science and Technology. Vol. 11 (2): 27-34.
[22] Reddy, K. (2008). Engineering properties of soils based on laboratory testing. UIC
[23] Rigassi, V. (1985). "Compressed Earth Blocks: Manual of Production". Volume 1. Manual of Production. Deutsches Zentrum fur Entwicklungstechnologien GATE in: Deutsche Gesellschaft fur Tecchnische Zusammenarbeit (GTZ) GmbH in coordination with BASIN. Reterieved from: http://www.gtz.de/basin/publications/books/cebvol1.pdf
[24] Viswanadham, B. V. S. (2003). "Soil Mechanics". Department of Civil Engineering Indian Institute of Technology, Bombay. Lecture – 7. Retrieved from: http//www.textofvideo.nptel.litm.ac.in
[25] Walker, P. (1995). "Strength, durability and shrinkage characteristics of cement stabilized soil blocks". Cement and Concrete Composites. Vol. 17: 301-310.
[26] Yalley, P. P. K. and Asiedu, E. (2013). "Enhancing properties of earth brick by stabilizing with corn husk ash". Civil and Environmental Research. Vol. 3(11): 43-52. Retrieve from http://www.iiste.org
[27] Oshodi, O. R. (2004). "Techniques of producing and dry stacking interlocking blocks". Nigerian Building and Road Research Institute Workshop on local Building Materials. Ota, Ogun State Nigeria.