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Use of Local Stabilizers for Earth Bricks Production for Low-Cost Housing: A Review

Elijah Akaakase Hime
Department of Vocational and Technical Education
Benue State University Makurdi
Email: akaakase63@gmail.com

ABSTRACT

Housing stock in Nigeria is grossly inadequate with low-income group mostly affected. The paper reviewed the status of efforts made by researchers to indentify. Local stabilizers for earth bricks productions which are cost effective to help bridge the gap between demand and supply in housing profile. Local stabilizers such as groundnut husk ash, termite mound, earthworm cast, Rice husk ash, sawdust, achahusk ash among others have potentials to improve the compressive strength, total water absorption and other durability properties of earth bricks. It was recommended that efforts should be made to transfer laboratory result to industries or land by undertaking pilot low-cost housing as basis for improvement and development.

INTRODUCTION

Housing and development are mutually supportive. Housing provides a base for achieving crucial goals in other sectors of the economy and upgrades the quality of life (Most Clearing House, 2000). Majority of developing countries are today faced with an ever increasing problem of providing adequate and affordable housing in sufficient numbers. In the past four decades, shelter conditions have been worsening; resources have remained scarce; housing demand has risen and the urgency to provide immediate practical solutions has become more apparent. United Nations Organization through its commissions at various instances in conferences held on human settlements in Vancouver Canada, 1976; Nairobi 1993; Turkey, 1996 and Istanbul, 2001 emphasized the need for all nations to provide shelter for their citizens. It was in recognition of housing needs in African countries that the United Nations estimated an annual construction rate of 8 to 10 dwelling units per thousand populations.

Many nations of the world, especially developing countries, are pursuing this mandate which Ode (2005) lamented that they are not about to win. The mandate for housing is getting illusive by the day despite the seemingly spirited efforts by government to place Nigeria on the map of countries with sufficient shelter for her citizens.

The proportion of households living in single rooms in urban centres remain high, the proportion of housing unit needing major repairs continues to rise while the prices of building materials continue to sky-rocket. For instance, the price of a bag of cement, which is one, if not, the major components of building materials increased from ₦405 in 1995 to ₦650 in 2002, and now the current price ranges between ₦2700 and ₦3000 depending on location.

No country without strategies for cost-effective materials is likely to meet its shelter targets. Developing countries planning to expand their housing stock for the low in-come groups will inevitably need to identify the lower feasible unit housing costs. The main costs of shelter are land, building materials and labour. The building components comprises about 50-70% of actual construction cost and considerable cost reduction can be achieved using cheaper alternative materials by carefully choosing materials for construction (Lawis, 1981; UNCHS, 1993 and Kamang, 1998). In Nigeria and many other developing countries the biggest problem besetting housing delivery is the high cost of building materials (Ashworth, 1994; Anigbogu, 1999; and Olaoye & Anigbogu 2000). Strategies are therefore urgently needed for development of cost-effective readily available and durable building materials. A naturally abundant material such as soil that is found everywhere on earths surfaces should be the ideal resources in developing countries like Nigeria.

Morris & Booyen (2000), Maini (2005) and Reddy (2007) made claims which supported earth construction as being economically beneficial. Auroville Building Centre/Earth Unit (2007) compared wire cut, fired, rammed earth and non-cement stabilized earth bricks and found that non-cement stabilized earth bricks were 61.0% cheaper than wire cut bricks and 45.3% cheaper than fired bricks.

The idea of stabilizing earth to improve its quality and performance in form of moulded bricks or blocks for housing delivery is not new, world over.

This basic raw material remains abundant which facilitate direct site-to-service application thereby lowering cost associated with acquisition, transportation and production process. Secondly, the initial performance characteristics of the stabilized earth such as wet compressive strength, dimensional stability, total water absorption (TWA), block dry density (BDD) and durability are technically acceptable and also comparable similar rival materials (Houben & Guillaund, 1994; Houben, Ragassi & Garnier, 1996; Wayne, n.d).

Despite these advantages however, there are shortcomings associated with their use especially in tropical environments. These regions are known for frequent and high rainfall, relative humidity and temperature changes. Earth blocks or bricks are made- from over 95% soil as a bulk material. Soil is known to have a poor resistance to erosion, high water absorption, low tensile strength, and low resistance to abrasion. High water absorption and retention causes dimensional instability during cyclic wetting and drying. The vulnerability of the soil has in turn led to blocks showing considerable defects over short period under conditions of normal and severe exposure in humid tropics. This implies that though the initial building cost might be low, the subsequent maintenance costs or early rebuilding cost are high. This early premature deterioration contradicts its acclaimed high degree of long-term technical performance.

Though the problem is higher in humid tropics than in arid zones, it has not been seriously addressed by research. The stabilization of soil with agro-based stabilizers to improve on its functional performance is a more recent development in the construction industry. Current research efforts are geared towards improving the engineering properties of earth construction materials. Nigeria's National Urban Development and Housing have among its goals the need to promote the use of locally produced building materials as a means of reducing construction costs. It is this international and national drive to come up with cheaper building materials that the researcher became interested in earth bricks/ blocks stabilization using agro- wastes.

Local Stabilizers, Properties and Preparation

Pozzolanic materials are siliceous or siliceous and aluminous materials, which in themselves posses little or no cementious value, but when finely divided form and in the presence of moisture, chemically react with calcium hydroxide liberated on hydration at ordinary temperature to form compounds possessing cementious properties (Neville, 1995; Ageyi, 2005; &S hetty, 2005). These materials are divided into two groups, natural possolana as clay and shales, diatomaceous earth, volcanic tuffs and pumicities. Artificial pozzolanans include fly ash, blast furnace slag, silica fume and rice husk ash. Other include baggasse and sawdust ash (Adeagbo, 1999), bottom fly ash (Dockter, Eylands & Hamre, 1999), pulverised fuel ash (Kedsarin, Mathaias, Kochberger and Wurss, 2001). The list include groundnut husk ash (Awar i& Elinwa, 2001) maize comb ash (Udoeyo & Abubakar, 2003) cow dung (Stulz & Mukerji, 1988) earthworm cast (Kamang, 1998) termite moud, (Olaoye & Anyibogu 2000) among others. Artificial pozzolana ash is produced through burning in controlled environments or systems such as kiln or incinerator (Osha, 2006). This system has the advantages of controlling many variables such as quality of the ash produced. This method does not make the final product cost-effective considering the high energy requirements needed to operate the plants. In addition, such plants are not locally available.

Artificial pozzolana can also be produced by open burning (Metha 1998, Elinwa & Awari, 2001, Zubariu & Okoli 2002). This method is cost-effective as the same materials constitute the fuel required in burning. More so that it does not requires specific plants. Many researchers such as Stulz, 1978 abdOsha, 2006 describe ash produced through this method as being of poor quality since it is difficult to control other variables. Patents filed by Metha in United States of America in 1978 & 1994 on RHA production threw its supports for open burning with the following precautions: the ash must be burnt at low temperature for long burning times to help preserve the amorphous nature of the silica. Das (1994) modified the kiln and open burning method by use of a kettle or pan. The pan consists essentially of four tiled brickwalls, 1 meter high forming a rectangle of 2 by 4 meters. This structure is covered with a roof of steel sheets. On top of the roof, the materials (gypsum, lime, pozzolana etc) to be calcined and placed in layers. It is then heated to the required temperature by fire in the space below. This process is suitable for small scale production, while precautions should be taken to regulate the quality and characteristics of the burnt materials.

There are basically two properties of pozzolana ash. These consists of physical and chemical properties. The physical properties include, moisture content, specific gravity, loose bulk density, pozzolana activity index and setting time (BS6588, BS6610:1985, ASTMC618 & NBC 10:14:4).

The chemical properties include the determination of the chemical composition. The chemical composition is done using X-ray diffractometry or electron probe micro-analysis or spectroscopy. The minimum and maximum limits o the Constitute chemical are provided in the British and American Standards for Testing Materials. ASTM C618 specified minimum of 70% oxide content of silicon, Aluminum and iron, maximum of 1.5% and 5% of sodium and Sulphur respectively while loss on ignition should be less than 12%.

LOCAL STABILIZERS APPLICATION IN EARTH BRICKS

Kamang (1996) investigated the strength properties of compressed earth bricks (CEB) stabilized with earthworm cast (a biological waste obtained from earthworm as stabilizer). The investigator used seven replacement levels 0,2,4,6,8,10,and 12 percent. The 0 percent was the control variable, which was not stabilized. One sample was used at each replacement level for both control and experimental groups. The sample were thoroughly mixed manually and moulded in a mechanical press and cured by covering with polythene sheet for twenty-eight days. The dropping test was used to check moisture content on the mixed laterite. The result indicated adequate compressive strength of 2.36N/mm^2 at 8% stabilization. It was found that the bricks hand low or poor resistance to water penetration.

Olaye and Anigbogu (2000) studied the stabilizing properties of termite modified soil from termite mound and evaluated its potential use as a substitute to cement in the production of compressed earth bricks. The lateriate and termite mound were excavated crushed and sieved through 5mm wire mesh. Three field tests were carried out on the laterite, the smell/washing/tough test to detect the presence of organic impurities, the sedimentation test to determine sand clay proportions and cigar test to verify the consistency of the laterite. Nine replacement level of 0,5,10,15,20,30,50,80 and 100 percent were used. Six bricks were moulded at each replacement level including the control group three bricks were tested at each replacement level for compressive strength and bulk dry density.

The result revealed that most of mixes resulted in compressed earth bricks with strength ranging from 0.96N/mm^2 to 2.15N/mm^2 at 28 days, which makes them suitable for construction of low-rise buildings. It was noted that the strength of the bricks increased consistency with increase in termite mound content and was at maximum when the bricks were produced with termite mould only. This means that termite mound is not a suitable stabilizer since it cannot be used at low does apart from poor percentage water absorption.

The result of the tests indicated that block within 6% OPC and 2% bitumen by weight were good and had dry compressive strength of 2/1N/mm^2 at 28 days. The wet average compressive strength at 7 days was 1.12N/mm^2 while water absorption percentage was only 7.6% at 28days. The study implies that more effective results can be obtained when the two stabilizers are combined though the researchers did not give insights into the physical properties of the used laterite.

The work of Adeagbo and Anigbogu (2002) drew attention to the fact that in the process of developing earth or latrite based materials, the curing procedures and strength testing more often than not follows the standards set for cement-based mixes. However, the hardening process of materials other than cement requires different approach to curing to achieve high strength that will be attained for a considerable time period. The researchers used compressed earth bricks (CEB) stabilized by 10 percent volume of bitumen. Each set of CEB was subjected to dry curing, one day wet curing, three days wet curing and seven days wet curing. It was found that there were significant variations in crushing strength at 28 days. The results presented in appendix B_4 imply that the development of appropriate curing procedure for earth based or laterite materials stabilized with additives other than cement should be an integral part of the research should be explored with the use of alternative stabilizer.

Rice milling generates a by-products known as rice husks. When burnt, produces rice hsuk ash (RHA). Paya (2001) asserted that this ash is a suitable pozzoanic material. James &Rao (1986) and Neville (1991) cautioned that the quality of rice husk ash depends on the burning time, temperature, cooling time and grinding conditions. This implies that the result obtained from any study will be affected positively or negatively if those variables are not properly controlled and manipulated.

Zubairus and Okoli (2002) investigated the properties of compressed earth bricks (CEB) stabilized with RHA. The rice husks were burnt in an open air and the resulting ash was dark grey/whitish in colour and was sieved using British standard sieve of 4µ5m. Only the particles, retained on the 45µ sieve were used.

Thirty blocks (24x11x10) cm^3 were produced from graded laterite. The first set of blocks were made of unstabilized laterite soil, the second were stabilized with 5% cement, the third with cement and rice husks ash. All blocks were wet cured for one week and sundried for two weeks. The blocks were tested for compressive strength and wash ability the RHA stabilized blocks ranged from 0.72 to 1.72N/mm^2 in strength corresponding to densities ranging between 1591 to 1818kg/m^3. However, a combination of 5 percent cement and RHA and 90% laterite produced blocks with compressive strength of 2.1N/mm^2 and a higher resistance to erosion. The result of this study must have been affected by the quality of RHA used. The retained on a 45µm sieve used for the study indicated that the fineness was low. Open air burning, according to Okerke and Obeng (1985), has temperatures of 400 to 500^{0}C as against an incinerator, which has temperatures over 1000^{0}C (Metha, 1984). The burning temperature must have affected the quality of RHA produced as cautioned earlier by James and Rao (1986).

The work of Kerali (2001) examined the interplay between the three main factors: constituent materials, quality of block processing methods and the effects of natural exposure conditions. The work concluded that it is possible to significantly raise the strength, improve the dimensional stability and wear resistance of cement-soil stabilized bricks to the extent that humid tropics. This improvement can be achieved by inter granular bonding, reduction in voids and lowered absorption.

Udoeyo & Abubakar (2003) studied the use of maize cob ash as filler in concrete. The MCA in the range of 0.30% was used as a partial replacement in concrete for ordinary Portland cement. The fresh properties of concrete, compressive strength, spilt tensile strength and modulus of rupture were measured for concrete mixes with MCA within the investigated replacement levels. The result indicated that setting times of concrete increased with MCA higher ash content, while compressive strength, spilt tensile strengths and modulus of rapture showed a reverse trend. It was further observed that almost all the studied specimens attained over 70% of their 28 days strength at seven days curing. This work has provided good opportunity to study the effect of MCA as a stabilizer for earth bricks production.

Hime (2006) studied the physical properties of soil crete bricks stabilized with groundnut husk ash using three samples of varying composition. The replacement levels used were 0,5,10,20,30 and 40. The study determined the wet and dry compressive strengths and density at 28 days. Approximate method of water content was used through the ball and drop test. It was found that the unstabilized bricks had low compressive strength in range of 1.70 to 1.26N/mm^2 with densities 1798kg/m^3 to 1903kg/m^2 and crumbled in water. Wet compressive strengths in ranges of 1.35N/mm^2 to 3.6N/mm^2 were obtained from the mix ratios of 10,15 and 30 percent. There was no significant increase in the compressive strength, densities and total water absorption at 40% replacement level. The most suitable mix proportions were found to be 15% and 30%.

The study did not vary the curing methods while the duration selected was that of cement (28 days). The three soil samples were of the GHA. The effects of water content and reaction time and compaction pressure on the bulk properties were not studied. Efforts were not made to establish the relationship between compressive strength and other bulk properties.

Oyetola and Abdulahi (2005), studied the strength characteristics of rice husk ash/ordinary Portland cement sandcrete blocks. The rice husk ash used for the study was burnt in a small enclosure so that heat can be concentrated in the rice husk. Charcoal obtained from firewood was used as fuel at a temperature of 483^{0}C. The total percentage oxide composition was iron oxide (Fe_2O_3= 0.95%), Silicon dioxide (SiO_2= 67.30%) and (Al_2O_3= 4.90%) was found to be 73.15%. This value was within the 70% minimum for pozzolanas recommended by ASTM C61803-78. The loss on ignition was 17.78% which is more than the maximum of 12% required.

Sumailia & Job (1999) empirically investigated the possibility of using saw dust ash as construction materials for block production. The sawdust ash used for the study was produced by open burning at a temperature of about 700^{0}C. The oxide contents were 0.004%, 15.65% and 49.18% respectively for Al_2O_3, FeO_3 and SiO_2 respectively. This value resulted to 64.87% oxide content which is less the minimum value of 70%, the loss on ignition was 10.10%. This implies that open burning is not suitable for all types of pozzolanas.

Dashan and Kamang (1999) worked on a cha husk ash in the production of concrete. The acha husk ash used for the study was burnt in a carbonite electric furnace at the Jos Metallurgical Development Centre. The temperature was 700^{0}C. The fitness of the ash produced passed through BS sieve 75µm. The chemical composition of the ash indicated that it contained silicon oxide (SiO_3-40.46), aluminiம oxide (Al_2O_3-5.5%), and iron oxide (Fe_2O_3-2.4%). The total oxide composition was 48.36%. This is less than 70% as required for pozzolanas. The loss on ignition was 43.57% which also did not satisfy the ASTMC618-78 limit of 12% maximum.

WATER CONTENT, MIX RETENTION AND CURING OF STABILISED EARTH BRICKS

The purpose of water is to hydrate the binder (cement, lime, gypsum, pozzolanaetc) and enable the mix to be compacted at optimum water content. Determination of the right amount of water in stabilised earth blocks/bricks to achieve both aims is still an area requiring more research.

Most Researchers, Houben and Guilland (1994) Riggassi (1995) and Adam (2001) recommended trial and error method in which the use of ball and drop test determines water content on stabilised earth blocks. This test requires the sprinkling of water on the dry mix to enhance wet mixing. The resulting wet mix is made into a ball by pressing through hands and dropped at a height of one meter. When the ball scatter completely it means it is too dry, but when it squashes into a flattened ball or disc on impact it implies too high water content, however, when it breaks into four or five lumps, this shows that water content or soil mix is close to the optimum moisture content. Consistency tests such as slump test carried out on fresh concrete are not recommended or suitable for earth bricks for the near dryness state of mix (Houben and Guilland (1994), Adam (2001) Kerali (2001) noted that high water content affects the strength of the green bricks as well as increase handling difficulties. This leads to shrinkage, warping, cracking and breakages.

Mix hold- back or retention time refers to the delay time after wet mixing before moulding of bricks (Adam 2001, Kerali 2001). Montgomery (2002) refers to mix hold-back time as delay before compaction. Montgomery cautioned that this gap should be as short as possible (between 5 to 10minutes) when cement is used as it has effect on the final properties. This variable is also ignored according to Kerali because of large batches of mixes made in order to produce many bricks at a time. Other sources of mix hold back time occur during lunch breaks and other human needs. In view of these it would be useful to know whether a significant loss of strength penalty is incurred, this would enhance establishment of optimum processing time when using ash as stabilizer.

Most researchers (Building Materials and Technology Promotions (Council (2003) Auroville Building Centre/Earth Unit (nd) Anigbogu & Adeagbo (2002) have suggested different curing procedures and duration for non-cement stabilisers. Curing methods recommended include protection against evaporation by keeping the green bricks under a shade, covering with polythene, jute bags, sun drying, sprinkling water at alternate periods. Other methods include covering with sand, total or partial immersion in water. A curing duration of 14 to 56 days has been recommended by the authors.

CONCLUSION AND RECOMMENDATION

Soil is a composite material with physical, biological and chemical properties. The physical properties of soil such as particles size, grading, density and consistency exert a lot of influence on its use as a construction material for bricks production so it must be established before using it. The use of laterite, earth soil or mud as material for house provision has began for long, however, limitations in its performance characteristics has called for improvement in its compressive strength and other durability variables.

Soil stabilization is one of the strategies for improving performance characteristics of laterite as a construction material. Soil stabilization for bricks production involves three processes. These include: particle size distribution, densification and application of chemical stabilizer. The three processes must all be applied for effective results. Stabilizers such as biological wastes and pozzolanas such as rice husks, acha husks are used. Groundnut husk among others are tired. These stabilizers produces bricks with low compressive strength in the ranges of 1,4-2.4N/mm^2, the water adsorption is very poor with bricks crumbling at low dose or mix proportions.

The production of pozzolana ashes from agricultural waste is less expensive than cement. The raw materials can be burnt under different conditions. Temperature in ranges of 400^{o}c and above can produce good pozzolanic ashes. Optimum results can be obtained when the resultant ash complies with ASTM requirement for pozzolans. Most researches on use of pozzolana ash stabilized earth brick production have concentrated on stabilizer content and degree of improvement of loading or compressive strength. Other production variables such as optimum mix- time optimum water content, curing methods and age are not investigated. The relationship existing among the bulk properties of bricks are also not investigated.

Efforts should be made by various governments to set up research institute that will facilitate technology transfer from laboratory to industry and land. This will also facilitate disseminating information on cost effective technologies to be adopted.

Pilot low-cost housing projects based on local stabilized bricks should be undertaken by appropriate courses which will serve as case studies and bases for improvement and development.

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