Evaluation of Stabilised-Earth Block (STEB) As Alternative to Sancrete Blocks for Housing Provision and Construction in South East Nigeria

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Abstract- ***Shelter has been considered as the basic physiological need of a man after food and clothing. The use of stabilized earth soil as construction materials have solved and sustained the housing need of most communities because of its affordability prior to the use of the recent sandcrete block work in our modern construction technology. The research work aimed at evaluating stabilized-earth block (STEB) as alternative to sandcrete blocks for low-cost housing provision and construction in south east Nigeria. The objectives include to assess the volume of materials availability in the study area; evaluate the comparative advantages of the usage of stabilized-earth blocks (STEB) and sancrete blocks (SSB) for housing construction in the study area, compare the quality of the soil block such as strength and analyzing empirical evidence of economic benefits of stabilized-earth blocks (STEB) utilization in construction. Materials were collected of red earth soils and sharp sand from different location i.e. one per state in the south eastern geopolitical zone of Nigeria. Ranking, correlation and regression analysis were used to achieve the stated objectives. It was observed that the earth materials are readily available in the study area to an average of 68%. It is cool and therefore gives thermal comfort. The cost analysis carried out affirmed that earth blocks are cheaper alternatives to convectional blocks, with a 46% reduction in the total production cost. The result of the compressive strength shows that all the tested samples attained above 1.50N/mm^2 ^{at} twenty-eight (28) days. The strength of the stabilized earth blocks (STEB) compared favourably to solid sancrete blocks (SSB), thus could serve as effective alternatives to convectional.***

Indexed Terms- ***Construction, low Income Housing, Sandcrete Blocks (SSB), Stabilized Earth Blocks (STEB), Strength.***

I. INTRODUCTION

The use of stabilized earth soil as a construction material for shelter dates back to ancient times when our ancestors used it for housing construction. These soil are excavated at source location, pounded and used to erect walls of building structures. There is virtually no location in this country, Nigeria where you cannot get the availability of this material. It depends on the location and culture of the people but this practice spread over the nook and crannies of Nigeria and beyond (Ashley, 2013). The difference is that some communities may add some additives depending on the texture of the soil where they are excavated to suit the same purpose. These practices have span from, North east, North West, south south, south west and south eastern states and all the geographical zones of Nigeria. There is virtually no part of Nigeria you will not see mud walls constructed prior to advent of this modernized construction technology methods. These are the major access to the provision of shelter in ancient times.

These locally constructed houses are achieved through self-help community efforts. The passage of time led to the invention of block mould for moulding the stabilized earth blocks for the purpose of erecting walls of buildings. Oyekan and Kamiyo (2011) opine that hollow sandcrete blocks containing a mixture of sand, cement and water are used extensively in many countries of the world especially in Africa. In many parts of Nigeria, sandcrete block is the major cost component of the most common buildings. The high and increasing cost of constituent materials of

sandcrete blocks has contributed to the non-realization of adequate housing for both urban and rural dwellers. Hence, availability of alternatives to these materials for construction is very desirable in both short and long terms as a stimulant for socio-economic development proposed to replace the stabilized earth blocks. Although the earth soil are stabilized with different types of materials depends on the need of the users and what they want to achieve, the use of sharp sand and cement mixture for moulding of sancrete blocks was in vogue. The arduous process of extracting earth soil manually discouraged many from its use because sharp sand can easily be harvested (Makusa. 2015). The use of stabilized earth blocks extracted from natural sources are more sustainable in terms of thermal comfort and other advantages. Some of these stabilized earth soils are moulded in their natural forms, allowed to dry or burnt in fire (fired) and used for constructing walls in buildings without additions of any binding agent like cement. In some communities the earth soil is mixed with some plant and grass leaves which helps to improve on the building properties for moulding as blocks. The arduous process of extraction of earth soils can be alleviated by the use of modern excavation equipment. Although the practice of the use of earth soils for walls of buildings are phasing out because of changes in technology, recent studies have shown that they are still relevant when cement is added as binding agent to reduce the cost of building houses for low income group.

II. REVIEW OF RELATED LITERATURE

One of the basic needs of life is Housing. Research has shown that about 3% of the world population lives in urban areas. Adenuga (2013), states that public housing is a term used to describe a provisioning scheme that emphasises the role of the government and its agencies in helping to provide housing, particularly for the poor, low-income earners, and more vulnerable groups in the society. With a population of over 140 million people, the population density in Nigeria on average is at 124 persons per kilometre square. The reason for this high density is due to the inadequate housing and this has forced low-income earners in the urban area to live in such high density and environmental state (Olotuah & Aiyetan, 2006). It is due to this impoverished state and the level of citizens that they cannot afford to own a house. This is why the cost of indigenous construction materials are reviewed to allow the poor access to housing facilities by using low-cost alternatives (Gabriel Fadairo & Olotuah, 2015). Also, due to high cost of conventional building materials, it will be of great important to adopt the sustainable materials.(Danso, 2016). Critical review is necessary to when considering sustainable construction to know the materials and technique to be adopted in order to improve the housing problem in Africa(Ambrose A. Adebayo, 2002). In order to adopt the sustainable construction efforts have been made in the area of soil/earth construction. The introduction of stabilized and enhanced soil block was a success in many research. The stabilized earth building blocks when mixed with cement in a proportion twice or more depending on the source location, yields more blocks that compares with that of sandcrete cement blocks which in turn reduce the cost of housing construction. The cost of cement and modern construction materials makes it difficult for low income earners to own a house of their own. Despite the modern building technology, the old practice of self-help construction in some villages persists. Adekola (1992) posited that earth has been one of the major materials used in construction of houses in Nigeria. Since time immemorial, earth block houses have been found to be very efficient and responsive to natural surroundings in terms of protection against heat and cold. This obviously calls for the search for cheap acute feasible materials which can be used to solve the consequent problem of acute housing shortage for the ever increasing population (Achuenu, 1999).

Quality of the materials has major psychology effect in the choice of block to use. It is necessary therefore to carry out a comparative study of strength of conventional blocks and stabilized earth blocks in South east Nigeria. The designers can always determine the standard of workmanship for standard sandcrete blocks and clay bricks but stabilized earth blocks does not have statutory recognition. The assessment of stabilized earth blocks (STEB) strength and sandcrete blocks used in housing construction can serve as a platform for integrating stabilized earth blocks (STEB) into the design and development process of the building industry. This will enhance the realization of the government on housing for all

especially the low income group. Some developing countries like Kenya has modified her building codes to include earth block as a building material. The cooperation between the Nigerian National Commission for Museum and Monument and the French Embassy in Lagos in 1997 has led to the revival and development of the use of earth building materials for low income housing (Ujene, 1999). The compressed earth blocks is formed by compressed earth in mould by means of a small pestle or ramming energetically with a heavy lid to the mould (United Nations, 1984). The stabilization of earth is modifying the properties of earth in relation to its water, texture and air system in order to obtain permanent properties compatible with a particular application. Stabilization of compressed earth has been achieved by the use of binders, which include cement, lime, pulverized fuel ash, earth worm cast and others (Achuenu, Olaoye and Ujene, 2007).

The cost of materials in Nigeria is unpredictable therefore making planning and forecast to be difficult. The resultant effect is on the low income earner that found it difficult to build affordable homes. The research work thus aimed at evaluating stabilized-earth block (STEB) as alternative to sandcrete blocks for low cost housing provision and construction in south east Nigeria. The objectives include to assess the availability of the materials; evaluate the comparative advantages of the usage of stabilized-earth blocks (STEB) and sancrete blocks (SSB) for housing construction, compares of the quality of the soil block such as strength and analyzing empirical evidence of economic benefits of stabilized-earth blocks (STEB) utilization in construction. Assessment was carried out by visiting different location of both materials within the region. Soil samples were also collected at the stated locations and used for the production of the stabilized earth blocks. The soil samples used for the stabilized earth blocks were collected at two locations in Enugu State and one location each in Anambra, Abia, Ebonyi and Imo States. The locations collection points were captured respectively as follows:

Enugu State (a. Behind Primary Health Centre Amutenyi in Obollo Eke, Udenu Local Government Area; Latitude: 6.937662 and Longitude: 7.519797 and b. Law School Quarters, Agbani in Nkanu West LGA, Enugu; Latitude: 6.322725, Longitude: 7.543568).

Anambra State at Umuokpu Awka by Enugu Onitsha Express way, Awka South LGA.
Abia State (Umuanyi Uturu in Isikwuato LGA); Abia State (Okigwe-Afikpo road, Latitude: 5.821792 (5º 49′18″.4N); Longitude: 7.420424 (7º25′13.5″E))
Ebonyi State- (Sharp sand – Uwana beach, Afikpo North LGA, Latitude: 5.791856 (5º 47′30.7″.4N); Longitude: 7.937815. (7º56′16.1″E), Red Soil-Ogbu Edda, Afikpo South LGA Latitude: 5.822811 (5º 49′ 22.1″N); Longitude: 7.892510 (7º53′30.0″E)).
Imo State at Obioha in Ihube Okigwe LGA (Beside SETRACO, along Enugu-Umuahia road). Latitude: 5.880657 (5º 52′50.4″N); Longitude: 7.381957 (7º22′55.0″E)

The red soil collected were mixed with cement at a mix ratio of 1:12 to get blocks of 450 × 225 × 100 mm while the mix ratio for cement and sharp sand is 1:6. The sandcrete blocks and stabilized earth blocks were cured for fourteen (14) days while the test was carried out. The crushing to determine the compressive strength was done for seven (7) days, fourteen (14) days, twenty one (21) days and twenty eight (28) days respectively. These tests were carried out at Standard Organization of Nigeria (SON) office in Enugu with their universal testing machine/automatic compression machine. Zami (2011) opined that stabilized earth is the enhancement of soil as an alternative building material which is comparatively cheaper than conventional building material in the construction of urban low cost housing In addition, stabilization of earth building materials has been suggested as a way out in obtaining affordable building materials (Alagbe, 2010). The results obtained were analyzed and compared with the standard values. Meanwhile previous work by Nnadi, Okwu-Delunzu and Ezemerihe (2022) assert that earth materials are available in all the part of the country with largest deposit in south east and least in the south-south states. The cost analysis carried out on the convectional blocks and stabilized earth block affirmed that earth blocks are cheaper alternatives to convectional blocks with N98.03 cost difference. The authors' finding revealed further that earth block has 60% economic stability. That is, has lesser fluctuation effect. Earth

blocks is thus recommended for achieving sustainable and cost affordable housing delivery in Nigeria thereby solving deficiency in the system. It was noted that compressed stabilized earth block are more workable than other building materials such as brick and sandcrete blocks (Riza, Rahman, Mujahid, & Zaidi, 2010)

Dabaieh (2014) affirms that earth production is more economical in developing countries in so also its maintenance. Productivity of rammed earth construction depends on several factors like site circumstances, weather conditions, workers proficiency and formwork system. The earth - ramming requires little water, which can be an important consideration in dry climates with scarcity of fresh water. They require few other resources like aggregates or additives to improve their properties. Earth can be recycled, is easy and agreeable to work. It has good insulating properties if built with high thermal mass especially for hot climate. Known fact is that earth gives off no harmful emissions. It is good for noise reduction and insulation. Earth doesn't burn, so rammed earth walls are fire proof. It is load bearing, which reduces the need for structural supports, therefore reducing building costs. Standard 400mm thick rammed earth walls can be used as load bearing in constructions up to four stories high. - Termites and other pests are of little concern to rammed earth walls.

III. RESULTS AND FINDINGS

Availability of Earth Block Materials in Nigeria

Previous work by Nnadi et. al established that earth blocks are readily availability in Nigeria as shown in fig 1

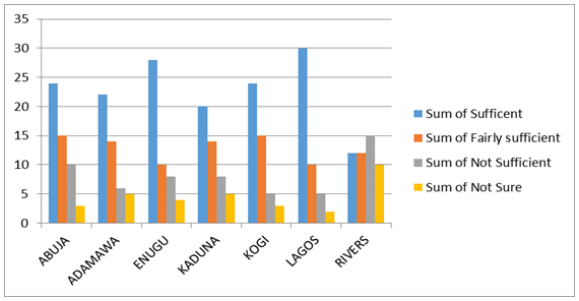

Fig. 1: showing the availability of earth materials in Nigeria

Source: Nnadi, Okwu-Delunzu and Ezemerihe (2022)

The result in fig 1 above shows that there is sufficient availability of earth block materials in Abuja, Adamawa, Enugu, Kaduna, Kogi and Lagos; but not sufficient in river state.

Table 1: Results of force in KN of stabilized earth blocks test samples

	Period in days			
Location	7 days	14 days	21 days	28 days
Amutenyi	30.68	33.04	59.34	69.00
Agbani	16.52	19.78	63.45	76.36
Ebonyi	30.68	36.45	45.92	71.30
Imo	25.96	30.42	53.81	72.68
Anambra	28.32	34.02	54.28	74.52
Abia	30.68	36.24	59.48	68.54

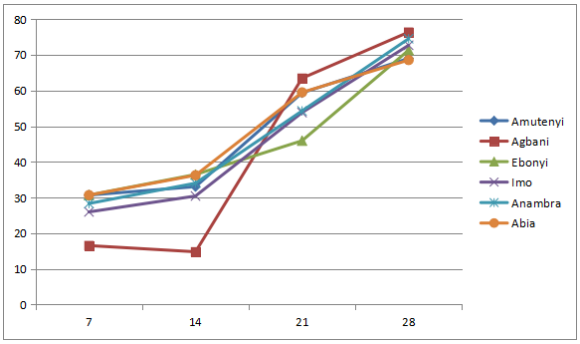

Figure 2: Graph of force in KN of stabilized earth blocks test samples

Table 1 and figure 2 shown the results as an upward trend from seven (7) days to twenty eight (28) days for the samples collected in all the locations. There is always a quantum jump in force developed from fourteen (14) days to twenty eight (28) days. The result for samples of 30.68 KN from Amutenyi in Enugu, Ebonyi and Abia states are the same while we have 28.32KN in Anambra, 25.9 KN and 16.52 KN in Imo state and Agbani in Enugu state in seven (7) days respectively. However at twenty eight (28) days we have 76.36, 74.52, 72.68, 71.30, 69.00 and 68.54, from Agbani in Enugu state, Anambra, Imo, Ebonyi, Amutenyi in Enugu and Abia states respectively.

Table 2: Comparison of Ultimate Strength in 28 days for stabilized Earth Blocks (STEB) (X variables) and Solid Sandcrete Blocks (SSB) (Y variables)

Location	X	$X-\overline{X}$	$(X-\overline{X})^2$	Location	Y	$Y-\overline{Y}$	$(Y-\overline{Y})^2$
Amuteny i	1.50	-0.07	0.0049	Enugu	2.39	-0.33	0.1089
Agbani	1.66	0.09	0.0081	Ebonyi	2.46	-0.26	0.0676
Ebonyi	1.55	-0.02	0.0004	Imo	2.68	-0.04	0.016
Imo	1.58	0.01	0.0001	Anambra	3.01	0.29	0.0841
Anambra	1.62	0.05	0.025	Abia	3.05	0.33	0.1089
Abia	1.50	-0.07	0.0049	Total	13.58		0.3711
Total	9.40		0.01865				

$$Mean = \frac{9.4}{6} = 1.57N/mm^2$$

$$Mean = \frac{13.58}{5} = 2.72N/mm^2$$

Comparison of the ultimate strength of STEB and SSB at various site locations are indicated in the following analysis

$$\text{Mean value of STEB} = \frac{9.4}{6} = \mathbf{1.57N/mm^2}$$

$$\text{Variance}\left(S_x^2\right) = \frac{\sum(X-\overline{X})^2}{N} = \frac{0.01865}{6} = \mathbf{0.00311}$$

$$\text{Standard deviation}\left(S_x\right) = \sqrt{\frac{\sum(X-\overline{X})^2}{N}} = \sqrt{\frac{0.01865}{6}} = \sqrt{0.00311} = \mathbf{0.0056}$$

$$\text{Mean value of SSB} = \frac{13.58}{5} = \mathbf{2.72N/mm^2}$$

$$\text{Variance}\left(S_y^2\right) = \frac{\sum(Y-\overline{Y})^2}{N} = \frac{0.3711}{5} = \mathbf{0.07422}$$

$$\text{Standard deviation}\left(S_y\right) = \sqrt{\frac{\sum(Y-\overline{Y})^2}{N}} = \sqrt{\frac{0.3711}{5}} = \sqrt{0.07422} = \mathbf{0.2724}$$

When computing a regression equation from table 2, the average results of the two locations for stabilized earth blocks were used to compare the strength of sandcrete blocks in Enugu i.e. 1.66 + 1.50= 3.16 ÷ 2 = 1.58.

Table 3: Regression and Correlation Analysis of STEB and SSB

Let the results of the sandcrete blocks strength in 28 days be X and stabilized earth blocks (STEB) at various location be Y as shown in table 3.

S/N	Location	SSB (X)	STEB (Y)	XY	X^2	Y^2	Y_x
1	Enugu	2.39	1.58	3.778	5.71	2.50	1.50
2	Ebonyi	2.46	1.55	3.81	6.05	2.40	1.51
3	Imo	2.68	1.58	4.243	7.18	2.50	1.56
4	Anambra	3.01	1.62	5.002	9.06	2.62	1.63
5	Abia	3.05	1.50	4.578	9.30	2.25	1.64
	Total	13.59	7.83	21.42	37.30	12.27	

$$\bar{x} = \frac{\sum x}{N} = \frac{13.59}{5} = \mathbf{2.72}, \bar{y} = \frac{\sum y}{N} = \frac{7.83}{5} = \mathbf{1.57},$$

The equation for linear regression is Y_x= a +bx. The constant, a, represents the intercept on the Y-axis and parameter b, which represents the slope of the regression line is the regression coefficient of Y on X. The coefficient of regression, b, is very important parameter for the regression function. It measures the average change in the variable, Y as a result of a unit change in X.

Y_x, represents the average value of Y computed from the relationship for any given value of X. Although it is an imperfect relationship, it only expresses the average relationship between X and Y.

From the above data, the arithmetic means as calculated are $\bar{x} = 2.72;\ \bar{y} = 1.57$

To find the value of a and b in the straight line formula,

$$b = \frac{\sum xy - n\bar{x}\bar{y}}{\sum x^2 - n\bar{x}^2} = \frac{21.42 - (5)(2.72)(1.57)}{37.3 - (5 \times 2.72^2)} = \mathbf{0.22}$$

$a = \bar{y} - b\bar{x}$. Substituting the values for $\bar{y}$, $\bar{x}$, and b,

we have, a = 1.57 – 0.22(2.72) = 0.971 ≈ 0.97.

$\therefore Y_x = .97 + 0.22\ X$

(i)

Testing the Variables

A test can now be done to discover the measure of the degree of association between the two variables i.e. how well they are correlated. The measure usually adopted for this purpose is the "sample coefficient of determination"(r^2) which is given by the following formula:

$$r^2 = \frac{a\sum y + \sum xy - n\bar{y}^2}{\sum y^2 - n\bar{y}^2}$$

Source: Hamburg, M NBasic Statistics (Harcourt Brace and Jovanovich Inc.)

$$r^2 = \frac{0.97(7.83) + 0.22(21.42) - 5(1.57^2)}{12.27 - 5(1.57^2)} = \frac{-0.17}{-0.0545} = 0.3119$$

$$r = \sqrt{r^2} = \sqrt{0.3119} = \mathbf{0.5584\ or\ 55.84\ \%}$$

This shows that approximately 31.19 % of the total variation in the dependent variable (stabilized earth blocks) is explained by the relationships between the sandcrete blocks and STEB (Y) expressed in the regression line.

Using another measure, the "coefficient of correlation (r)" which is the positive square root of the coefficient of determination, it confirms the result from the first test.

This measures the probability that there is a genuine relationship between the variables and that it has not risen by chance i.e. r = $\sqrt{r}_2 = \sqrt{0.3119}$ = 0.5585 or 55.85%

Note: The closer the values of r are to plus one or minus one, the narrower the range of predicted values of the dependent variable. In estimating r or r^2, values over 0.9 should be expected, which should be preferably higher still if a multiplier is to be applied to the resultant estimate.

Referring to the values of r^2 =0.3119 and r = 0873.5585, additional variable require to be introduced which suggest that it is not a linear relationship.

- The Coefficient of Non Determination

The value of (1-r^2) is called the coefficient of non-determination. It measures the proportion of the variability of the Y values that has been explained by the regression equation, that is, the variation in Y due to factors other than X. the square root of the coefficient of non- determination, T = $\sqrt{1 - r^2}$ is called the Coefficient of alienation. This measures the extent of departure from perfect correlation. Using the above data, the coefficient of non- determination 1-r^2 = 1- 0.3119=0.6881 or 68.81%. The coefficient of alienation of T = $\sqrt{1 - r^2}$ = $\sqrt{0.6881} = 0.8295$ or 82.95%

- Interpretation

The computed coefficient of determination (r^2 =0.3119) shows that 31.19% of the total variation in the strength of STEB used in the analysis is explain by the variation in the strength of sandcrete blocks while 68.81 percent of the variation in STEB is attributable to the influence of other factors not explained by the regression function (the coefficient of non – determination, 1-r^2 =0.6881).

The computed coefficient of correlation (r=0.5585) shows that there are 55.85 percent probability that a genuine relationship exists between the variable and that it has not risen by chance. The coefficient of alienation (T=0.8295) shows that there is 82.95 percent departure from perfect correlation.

Referring to the value of r^2 ie 0.3119 and r ie 0.5585 ; 1-r^2 = 0.6881 and T= 0.8295 indicates that there are additional variables that affects the strength of STEB obtained at various site location compared to the strength of sandcrete blocks at similar location hence the relationship is not a linear one.

CONCLUSION AND RECOMMENDATIONS

The findings revealed that stabilized earth materials are available in the study area in large quantities. However, the inhabitants are scared because of the arduous process of harvesting the materials. The extent of usage is limited while some who constructed their houses are seeing them as outdated technology and are opting for the use of new technology products and materials. The stabilized earth blocks (STEB) have obvious advantages when compared to sandcrete blocks but the result of test shows that their strength is comparable to sandcrete blocks for low income housing development even when the quantity of STEB is twice that of sandcrete blocks. Analyzing the empirical evidence of economic benefit of stabilized earth blocks will result to a very sharp reduction in the cost of housing construction because;

The costs of concrete works, (i.e. concrete, formwork and reinforcement) can reduced because local timber material can be used for lintels and beams. The comfort of the inhabitants is more guaranteed in terms of thermal comfort and other related advantages etc. Since some of the materials are sourced locally and not readily available in our markets, the risk of inferior material is reduced. There is a fluctuation in strength, force and weight of stabilized earth blocks from fourteen (14) days to twenty-one (21) days, but sandcrete blocks have a progressive increase in strength while ultimate strength in twenty-eight (28) days follows the same similar trend.

Government and other construction stakeholders should create more awareness to enhance the adoption and usage of earth blocks as alternative to conventional blocks. More research works are expected at the universities and research institutes to promote the qualities of the earth blocks. Government policies should promote local content especially on low housing production.

- Value added to knowledge:

1. The research has created more awareness of the relative abundance of red earth and its low cost for low-income housing provision.
2. The result also shows that the STEB has a similar progressive strength when compared to solid sandcrete blocks (SSB) from the samples collected and used for experiment in the study area.
3. That earth block is affordable and rarely affected by fluctuation which is key economic threat to Nigeria construction industry.
4. Stabilizing the red earth materials with cement materials can be a new trend in our construction which will be of immense benefit to all.

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