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Properties of Compressed Stabilized Earth Blocks (CSEB) For Low-Cost Housing Construction: A Preliminary Investigation

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Abstract

Materials used for the construction of walls are normally required to possess adequate strength and erosion resistance. The study investigates the suitability of stabilized laterite soils for the production of compressed earth blocks for low-cost housing construction. Soil samples for the experiment were obtained at two different locations. Sample I was obtained at a borrow pit along Gujba road in Damaturu Yobe state while Sample II was taken at a borrow pit near lake Alau in Borno sate, Nigeria. The results of the study revealed that the specific gravity, bulk density, moisture content and plasticity index of both samples showed satisfactory performance. Different cement stabilization levels of 0%, 2.5%, 5% and 7.5% were used to prepare the specimens for testing. The blocks were moulded using hand operated CINVA-Ram machine. The maximum compressive strength of 2.48N/mm^2 was obtained with stabilization level of 7.5% with sample I at 28 days curing. The strength of the specimens increases with increasing cement content with an average value of 0.35N/mm^2. For higher strength requirements different stabilization options can be considered.

Keywords: *Stabilized earth block, low cost housing, Construction, Nigeria*

1.0 Introduction

The investigation of alternative materials for the construction of low cost housing has been the focus of many studies in many developing countries. The present rate of construction in developing countries according to [1] is generally sufficient to meet the needs of only 10% of the net increase in population per year. This is partly due to the unavailability and the soaring costs of conventional building materials. As this shortage of building is becoming worse, more efforts are being made to develop cheap, serviceable and energy efficient construction materials for the construction of affordable sustainable buildings.

Masonry is one of the most popular materials for housing construction due to its useful properties such as durability, relatively low cost, good sound and heat insulation, acceptable fire resistance, adequate resistance to weathering and attractive appearance [2, 3]. The global interest about the environment according to [4] has increased the use of earth as a building material. The direct use of earth without modification for wall construction in any form has the disadvantage of low performance. The shortcomings principally are low mechanical characteristics, unsatisfactory resistance to weathering and liability to volume change especially in the case of clay. These disadvantages can be improved to make the material compatible with desired application in construction by combined chemical and mechanical action technically known as stabilisation [1, 2, 3, 5, 6]

Compressed Stabilized Earth Blocks (CSEB) offer a number of advantages which includes increased utilization of local material and reducing the cost of transportation as the production is in situ, makes quality housing available to more people, and generates local economy rather than spending for import materials [2, 4]. Other advantages are faster and easier construction method resulting in the lesser requirement of skilled labour, good strength, insulation and thermal properties, less carbon emission and embodied energy in the production phase, create extremely low level of waste and cause no direct environmental pollution during the whole life cycle. Earth bricks have the ability to absorb atmospheric moisture which creates healthy environment inside a building for its occupants. One of the drawbacks of using earth alone as a material for construction as posited by [7] is its durability which is strongly related to its compressive strength. Because most soil in their natural condition lack the strength, dimensional stability and durability required for building construction. These properties can be enhanced through stabilization [8 - 9].

2.0 Literature Review

2.1 Cement Stabilization

Soil stabilization according to [1] is the alteration of any property of a soil to improve its engineering performance. The chief factors affecting stabilization are soil type, cement content, compaction and method of mixing with soil type being the most important [1]. The modification of the properties of soil-water-air system makes the soil compatible with desired applications in construction [2]. One of the main functions of the stabilizing medium is to reduce the swelling properties of the soil through forming a rigid framework with the soil mass, enhancing its strength and durability [10]. Portland cement is the most widely used stabilizer for earth stabilization. Cement has the ability to reduce liquid limit (LL) and increase plasticity index (PI) and hence increases the workability of soil. The addition of chemical stabilizers like cement and lime has twofold effects of acceleration of flocculation and promotion of chemical binding. The chemical binding depends upon the type of stabilizers employed [11]. The study of [7] revealed that soils with Plasticity Index (PI) less than 15% are suitable for cement stabilization. In cement stabilization [12] observed that the content of the cement binder in the mix ranges between 4% and 10% of the soil dry weight. However, [4] posited that if the content of the cement binder is greater than 10% it becomes uneconomical for the production of CSEB.

2.2 Stabilized Pressed Blocks

The materials used for the construction of wall are normally required to possess adequate compressive strength and erosion resistance. Such properties of the soil can be improved by stabilizing it with cementious admixtures such as cement and lime [1]. The strength of stabilised soil can further be improved by the process of compaction which leads to higher densities, thereby higher compressive strength and better resistance to erosion. Exploring the stabilization and compacting techniques, a cheap yet strong and durable material for wall construction is the stabilized earth block. The merit of these blocks is low-cost, use of locally available material, blocks can be made at site with no transportation cost and simplicity in manufacture [1, 2, 3, 6, 13]. As noted by [6] the strength of such blocks increases with density. CSEB brick requires compaction whether it is static, dynamic or vibro-static methods [4]. In preparing the soil for block production, there is need for careful and correct selection of the soil to get the best result and after the mix was put in the mould, it should be given proper compaction. Proper curing should also be made which prevents rapid drying.

A striking contrast between CSEB and conventional bricks is the energy consumed during the production process and carbon emission. CSEB creates 22 kg CO_2/tonne compare to that of concrete blocks (143 kg CO_2/tonne), common fired clay bricks (200 kg CO_2/tonne) and aerated concrete blocks (280-375 kg CO_2/tonne) during production [15]. In average, cement stabilized earth bricks consumed less than 10% of the input energy as used to manufacture similar fired clay and concrete masonry unit [8]. Production of CSEB requires moderate to low skilled worker since the CSEB manufacture is very simple. It only takes 3 stages process which are: soil preparation, mix compression and the curing [2, 4, 6, 13].

3.0 Materials and Methods

The soil samples for the experiment were obtained at two different locations. Sample I was obtained at a borrow pit along Gujba road in Damaturu, Yobe state, Nigeria. Sample II was obtained at a borrow pit near Lake Alau in Borno State, Nigeria. Different tests were conducted to determine the characteristics of the soils (specific gravity, bulk density, loose density and moisture content). Sieve analysis was conducted using the BS set of sieves in accordance with [15]. The atterberg limit test (plastic limit, liquid limit and the plasticity index) were determined in accordance with [16]. Compaction test (standard proctor test) was performed to determine the optimum moisture contents and dry densities of the soil samples. For the determination of the OMC a series of soil mixes were prepared over a range of moisture contents. When the dry density was plotted against the respective moisture content, the two samples produced typical moisture-density curves with clearly identifiable optimums. The specimens were prepared with the desired levels of stabilisations of 0%, 2.5%, 5%, and 7.5% of Ordinary Portland Cement (OPC) in accordance with [16]. The blocks were moulded using the CINVA-Ram machine which is a hand operated press for block making. The CINVA-ram machine delivers a capacity pressure of 2 N/mm^2. The CINVA-Ram was also considered to represent an achievable and economic option [17]. The machine comprises of a rammer and a lever arm which is used to push out the finished blocks of geometry 210mm×100mm×80mm from a four compartment box. The blocks were then cured for 28days.

Finally the compressive strength test for the different levels of cement stabilization at the optimum w/c ratio at different curing ages for the two soil samples was undertaken. The objectives being to investigate the suitability of blocks made with stabilized soil at the optimum w/c ratio for use as masonry units. The crushing strengths of the blocks were tested using the universal testing machine. A total of 64 blocks were prepared and crushed at different curing ages of 7, 14, 21 and 28 days. A metal plate that measures 250 mm×120×10mm was placed on top and bottom of the sample to allow for even distribution of the load. The load was then applied at a constant rate of displacement. The bottom plate advancing at 1.02 mm/min following the failure of the specimen, the maximum load was recorded and crushing strength was evaluated on the basis of equation below:

$$P = \frac{F}{A}$$

Where;

P is the crushing stress (N/mm^2)

F is the failure load (N)

A is the area of specimen (mm^2)

4.0 Results and Discussion

4.1 Characteristic Properties

The results of the different properties of the soil samples are presented in Table 1. The evaluation of the different properties revealed that the S.G of 2.67 and 2.71 of sample I and Sample II are within the range of 2.55 and 4.0 recommended by [18]. The values are greater than the value obtained for earth worm cast by [13]. The bulk densities for the samples I and II were found to 1736 kg/m^3 and 1758kg/m^3 respectively. The natural moisture contents of the two samples were found to be 15.3% and 21.2%. The results of the tests on the properties of the two samples revealed that the soil samples exhibit similar properties.

Table 1: Characteristic Properties of soil Samples

Properties	Sample I	Sample II
Bulk Density(kg/M^3)	1736	1758
Moisture content (%)	15.3	21.2
Liquid Limit (%)	26.9	32.1
Plastic Limit (%)	14.3	17.8
Plasticity Index	12.6	14.4
Specific gravity	2.67	2.71

4.2 Particle size Distribution

The result of the particle size distribution carried out in accordance with [15] for sample I and Sample II are presented in Table 2 and Table 3 respectively.

Table 2: Particle Size distribution for Sample I

S/No	Sieve Size	Wt Retained	%Wt Retained	Cum. % Wt Retained	% Wt passing
1	4.75mm	2.0	0.56	0.56	99.44
2	1.70mm	7.5	2.11	2.67	97.33
3	1.18mm	4.5	1.27	3.97	96.06
4	425µm	14.0	3.94	7.88	92.12
5	300 µm	7.0	1.97	9.85	90.15
6	212 µm	14.0	3.94	13.79	86.21
7	150 µm	1.50	0.42	14.21	85.79
8	75 µm	35.5	10.0	24.21	75.79

Table 3: Particle size distribution for Sample II

S/No	Sieve Size	Wt Retained	%Wt Retained	Cum. % Wt Retained	% Wt passing
1	4.75mm	0	0	0	100
2	1.70mm	4.3	1.21	1.21	98.79
3	1.18mm	6.1	1.72	2.93	97.07
4	425µm	13.4	3.77	6.7	93.30
5	300 µm	8.3	2.34	9.04	90.96
6	212 µm	12.9	3.63	12.67	87.33
7	150 µm	2.0	0.56	13.23	86.77
8	75 µm	31.6	8.9	22.13	77.87

The result indicates that the particles of both samples are greater in the fine category (600 µm - 750µm). Using the [19] method of classification, both samples fall into group A2-6 (silty or clayey gravel and sand).

4.3 Atterberg limit

Atterberg limit test by the casagrande method was performed in accordance with [16] to ascertain plasticity index (PI) of the soil samples. The results are presented in Table 3. The PI of 12.6% and 14.4% for sample I and II does not exceed the maximum value of 35% stipulated by

[16] thus indicating a good laterite soil that is cohesive and hence able to receive proper compaction to enhance the strength and durability characteristics of the laterite. Both samples are suitable for cement stabilization as their PI values does not significantly exceed 15% as stipulated by [4].

4.4 Optimum Moisture content (OMC)

For the determination of the OMC a series of soil mixes were prepared over a range of moisture contents. When the dry density was plotted against the respective moisture content, the two samples produce typical moisture density curves with clearly identifiable optimums as shown in Fig. 3. Subsequent samples were moulded at these optimum values. The OMC of a soil at the time of compaction significantly affects the dry density which in turns affects at least the strength of the sample [17]. The OMC serves as a guide for the preparation and mixing of the block units. Moisture contents affect strength development and durability of the material and have a significant influence on the long term performance of stabilized soil material especially on bonding with mortars at the time of construction. When the brick is dry, water is rapidly sucked out of the mortar preventing good adhesion and proper hydration of the cement and when the brick is very wet the mortar tends to float on the surface without gaining proper adhesion [8 and 20]. Different types of compaction have influence on the optimum water content in the stabilized mixes. As reported by [21] dynamic compaction can reduce the optimum water content from 12% to 10% with about 50% increase in the compressive strength. And optimum water content range between 10 to 13% for static compaction [21].

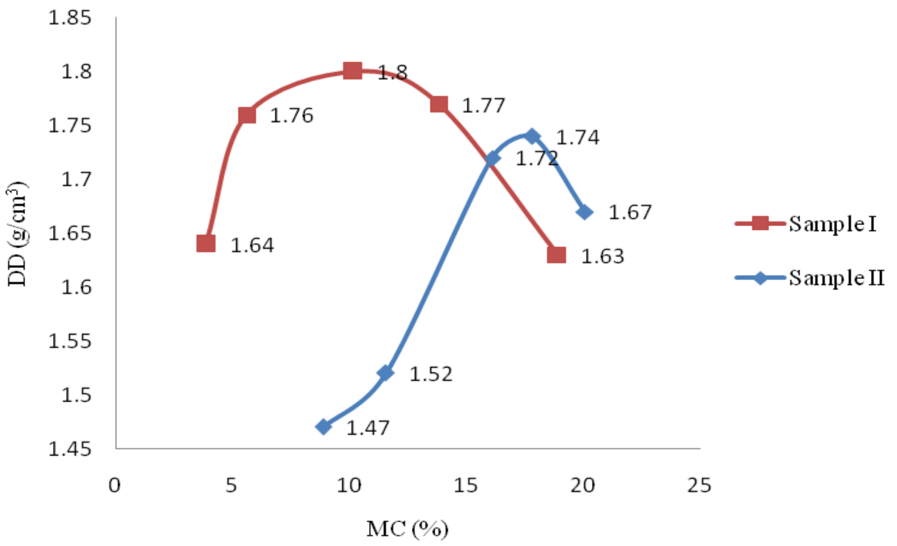

Figure 1: Compaction Curves for Sample I and II

4.5 Compressive Strength

The compressive strength is the most universally accepted value for determining the quality of bricks. Nevertheless, it is intensely related with the soil type and the content of stabilizer. The crushing strengths of the blocks were tested using the universal testing machine. A total of 64 specimens were prepared and crushed at different curing ages of 7, 14, 21 and 28days. Compressive tests were conducted on the blocks at different ages to indicate the rate of strength gain and the strength at a point in time [22].The results for the compressive strength against curing ages for sample I and Sample II are presented in Fig 2 and 3 respectively. The result shows that the highest compressive strength of 2.84N/mm^2 was obtained from sample I with 7.5% cement content at the curing age of 28 days. According to [4] the optimum cement content is in the range of 5%-10%. The strength obtained also compares favourably with the minimum British Standard requirements of 2.8N/mm^2. For the different stabilization levels from 0% -7.5%, the average value of compressive strength decrease by about 0.35N/mm^2.

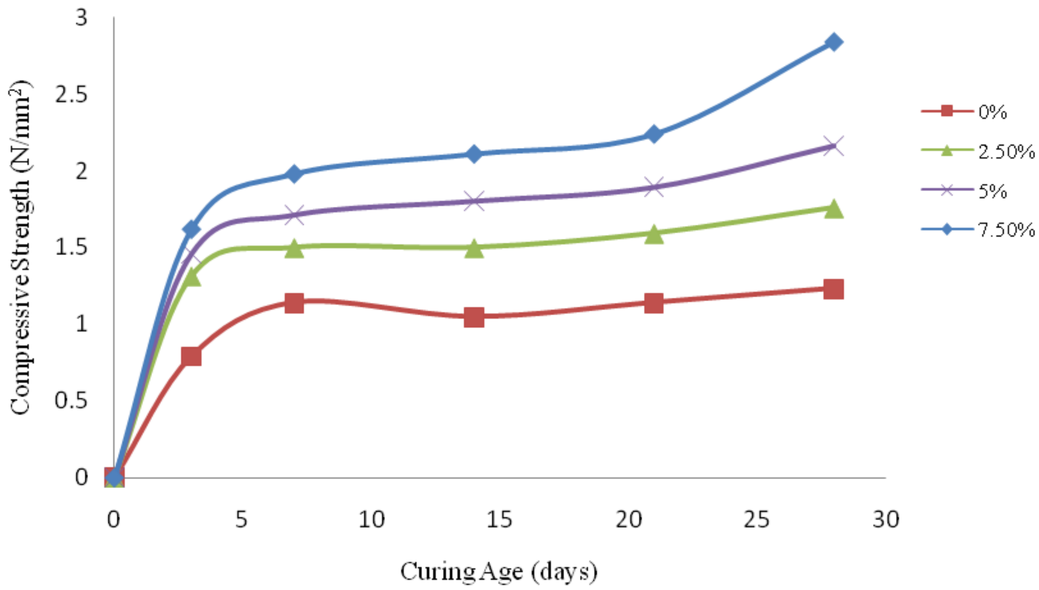

Figure 2: Compressive Strength Against Curing Age for Sample I

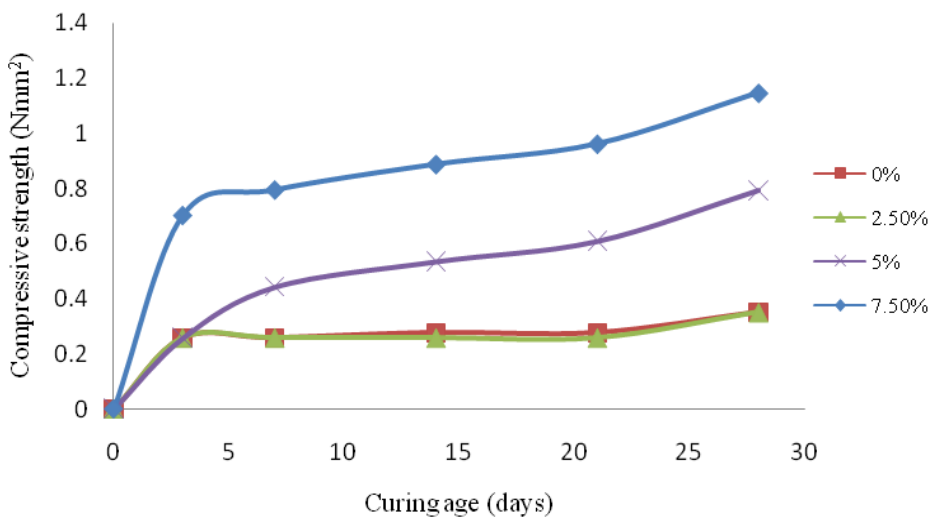

Figure 3: Compressive Strength against Curing Age For Sample II

5.0 Conclusions

From the investigation the following conclusions were drawn.

1. Both the soil samples have significant characteristics that make them suitable for cement stabilization with plasticity index of 12.4% for sample I and 14.6% for Sample II.
2. The strength of both samples increased with increasing stabilisation level from 0% through 7.5% with an average value of 0.35N/mm^2.

3. The highest compressive strength of $2.84N/m^2$ was achieved with 7.5% cement stabilization level of Sample I at the curing age of 28days.
4. Both the samples exhibit similar characteristics and are all suitable for the production of compressed stabilised soil blocks for walling in low cost sustainable buildings.
5. The maximum strength obtained at 28 day strength for both samples are within the minimum strength requirement recommended for the construction of low-rise buildings.

References

[1] S. Krishnaiah, and P. S. Reddy, "Effects of Clay on Soil Cement Block," The 12th International Conference of International Association for Computer Methods and Advances in Geomechanics (IACMAG) October 2008, Goa, India. pp. 4362-4368, 2008
[2] S. Deboucha, and R. Hashim, "Effects of OPC and PFA Cement on Stabilised Peat Bricks," International Journal of the Physical Sciences, vol. 5 (11), pp. 1671-1677, 2010.
[3] S. Deboucha, and R. Hashim, "A Review on Bricks and Stabilized Compressed Earth Blocks," Scientific Research and Essays, vol. 6 (3), pp. 499-506, 2011
[4] V. R. Fetra, I. A. Rahman and A. M. Zaidi, "Preliminary Study of Compressed Stabilised Earth Block (CSEB)," Australian Journal of Basic and Applied Sciences, vol. 5 (9), pp. 6-12, 2011
[5] O. F. Job, "Cement Made with Pulverised Burnt Clay as Partial Replacement," Nigerian Journal of Construction Technology and Management, vol. 1 (1), pp. 29-33, 1998
[6] E. E. J. Kamang, "Effects of Water-Cement Ratio on the Strength Properties of Stabilised Laterite soils," Nigerian Journal of Construction Technology and Management, vol. 1 (1), pp. 58-62, 1998
[7] A. Guettala, H. Houari, B. Mezghiche, and R. Chebili, "Durability of lime stabilized earth blocks," Courrier du Savoir, vol. 2, pp. 61-66, 2002.
[8] P. J. Walker, "Strength, Durability and Shrinkage Characteristics of Cement Stabilized soil blocks," Cement and Concrete Composites, vol. 17 (4), pp. 301-310, 1995
[9] N. Billong, U. C. Melo, F. Louvet, and D. Njopwouo, "Properties of Compressed Lateritic soil stabilized with a Burnt Clay-Lime Binder: Effect of Mixture Components," Construction and Building Materials, vol. 23 (6), pp. 2457-2460, 2008.
[10] A. Y. B. Anifowose, "Stabilisation of Lateritic Soils as a Raw Material for Building blocks," Bulletin of Engineering Geology and the Environment, vol. 58, pp. 151-157, 2000.
[11] M. Janz, and S. E. Johansson, "The Function of Different Building Agents in Deep Stabilisation," Swedish Deep Stabilisation Research Centre. Linkoping, 2002
[12] A. Mesbah, J. C. Morel, P. Walker and K. Ghavami, "Development of a Direct Tensile Test for Compacted Earth Blocks Reinforced with Natural Fibres," Journal of Materials in Civil Engineering, vol.16 (1), pp. 95- 98, 2004
[13] E. E. J. Kamang, "Strength Properties of Compressed Earth Brick with Earthworm Cast as Stabilizers," Journal of Environmental Sciences, vol. 1 (2), pp. 65-70, 1998
[14] T. Morton, "Earth Masonry Design and Construction Guidelines," Berkshire: Construction Research Communications Limited, 2008
[15] B. S. 812, "Methods of sampling and Testing of Mineral aggregates, sands and fillers," British Standard Institution, London, 1975
[16] B. S. 1377, "Soil Classification," British Standard Institution, London 1975.
[17] Y. G. Balami, and Y. D. Izam, "Soil-Bitumen as a Walling Materials," Journal of Environmental Sciences, vol. 1 (2), pp. 29-34, 1998.
[18] R. Maignien, "Review of Research on Laterite," Natural Resource Research IV. UNESCO Paris, France, p. 148, 1966.
[19] AASHTO, "Standard Specification for Transportation Materials and Methods of Sampling and Testing," 14th Edition. American Association of State Highway and Transportation Officials (AASHTO), 1986
[20] J. E. Oti, J. M. Kinuthia, J. Bai, "Stabilised Earth Masonry Technology incorporating Industrial By-Products," Proceedings of the 11th International Conference on non-Cementious Material and Technology, Bath UK, 2009
[21] R. Bahar, M. Benazzoug and S. Kenai, "Performance of Compacted Cement-Stabilised Soil," Cement and Concrete Composites, vol. 26 (7), pp. 811-820, 2004.

[22] O. S. Abejide, "Assessment of the Performance of Soil Soil-CementBlocks with Plant Extract Additive," Construction Focus, vol. 1, pp. 55-63, 2007