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FLY ASH-LIME LATERITIC COMPRESSED STABILIZED EARTH BRICKS FOR LOW COST HOUSING

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ABSTRACT: *This study assessed the mechanical and durability properties of compressed stabilized earth bricks (CSEB) made from laterite soil, stabilized with various proportions of fly ash and lime (4% to 12%). Tests conducted on the soil sample and fly ash used for the research proved that the soil is True Laterite (S-S=1.03<1.33) and the fly ash is Class F pozzolana (SiO_2 + Al_2O_3 + Fe_2O_3 =74.69%>70%). A total of 165 CSEB samples were produced and the research identified various properties as a result of changing the proportion of the stabilizers. The findings of the study revealed that compressive strength values of CSEB 8 (5% fly ash, 5% lime) at the 28th day and CSEB 11 (6% fly ash, 6% lime) at the 14th and 28th days as 1.72 N/mm^2, 1.69 N/mm^2 and 2.02 N/mm^2 respectively met the requirement for construction material in rural houses, bungalow houses and low rise buildings. The mean bulk density values ranged from 1727.35 to 1865.35 kg/m^3. for all curing age. From water absorption test results, all values obtained fell below the maximum recommendation except for CSEB 1 (2% fly ash, 2% lime) and CSEB 2 (4% fly ash, 2% lime) as specified by NIS 87 (2004) and NBRRI (2008).*

KEYWORDS: Compressed Stabilized Earth Bricks, compressive strength, construction, water absorption, abrasion.

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INTRODUCTION

The United Nations had projected that by 2050, the population of Nigeria would be about 400 million (UN, 2017). Expectedly, the absence of a proactive strategy to curtail the implications of the exploding population and urbanization growth rate will lead to rapid deterioration of housing and living conditions. At the regional level, sub-Saharan Africa, including Nigeria, many households cannot afford basic formal housing or access mortgage loans, and the cost of obtaining formal housing is high (World Bank, 2015). Despite institutional interventions from both the fiscal and monetary authorities, the Nigerian housing deficit still remains a subject of concern to the government, housing sector stakeholders and the citizens. The most recent of the Federal Government of Nigeria intervention in combating the deluge of housing deficit is an innovative Family Homes Fund. It is a housing initiative intended to support the development of up to 500,000 homes in five years targeted at low-income earners over the next five years (Federal Mortgage Bank of Nigeria, 2018). The affordability and sustainability is still a question yet to be answered. Overtime, government's efforts at solving the problem of housing shortage proved futile because it ended in providing unaffordable houses.

Akinradewo, F.O. and Adedokun, D.O. (2019) suggested that to solve the problem of inadequate housing, new or improved construction materials must be considered. It was suggested that the solution to the housing problem is in the production of housing through the use of affordable local materials. They reported about 50.0 per cent cost reduction on walling elements if local materials are used. Studies and subsequent use of materials such as fly ash (residue of the burning of coal during the generation of electricity in thermal power plants) and lime in stabilizing the laterite soil for production of compressed stabilized earth bricks may lead to the reduction of the environmental impact, reduce cost of construction, reduce house shortage, cement sources and provide data to encourage their utilization.

Fly Ash Stabilization for CSEB was at 5%, 10%, 15%, 20% and 25%. The result obtained from 28 days of curing with 10% of fly ash incorporated into the mix proportion showed the highest compressive strength of CSEB which was 1.09 MPa (Noorbaya & Muhammed, 2015) .

Lime at 5%, 10%, 15%, 20% and 25% stabilization of lateritic soil type showed compressive strength values of 0.92, 1.25, 1.15, 1.06 and 0.94 MPa respectively. The peak compressive strength was obtained at 10% Stabilization but it decreased with further increment (Raheem et al., 2010).

A study was carried out by Malkanthi et al. (2021) for the enhancement of the properties of compressed stabilized earth blocks through the replacement of clay and silt with fly ash. The results revealed that fly ash addition up to 10% improves the properties of CSEB.

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MATERIALS AND METHOD

Materials Sampling

The fly ash used for this research was obtained from an old stockpile at Oji River thermal station, through Project Development Institute (PRODA), Enugu State and it was sieved through BS sieve NO 200. An industrial Hydrated Lime was also obtained from a local supplier at Flyover Kongila, Zaria. Laterite soil was extracted from existing earth builders soil pits and at depths not less than 750 mm below ground level in Bayara, Bauchi State (Latitude 10^{o}1547 "N and Longitude 9^{o}49 06 "E), Nigeria.

Figure 1: Fly Ash and Lime

Methods

Oxides present in the fly ash and the laterite soil were determined using x-ray fluorescence (XRF) at National Steel Raw Materials Exploration Agency, Kaduna. Field settling test, particle size distribution, specific gravity, and Atterberg limits were performed on the lateritic soil following British Standard, BS 1377:2 (1990), and the soil was classified according to Unified Soil Classification System (USCS) standard. The bricks were produced with a CINVA RAM press brick moulding machine by mixing fly ash, lime and laterite soil in varying proportions, as shown in Table 1. The optimum moisture content of the mixture was determined by drop test (Nigerian Building and Road Research Institute, 2006). The CSEB were cured by covering them with a polythene sheet after which they were air dried at ambient temperature for 7th, 14th and 28th days. The compressive strength of the CSEB was done using a compression testing machine.

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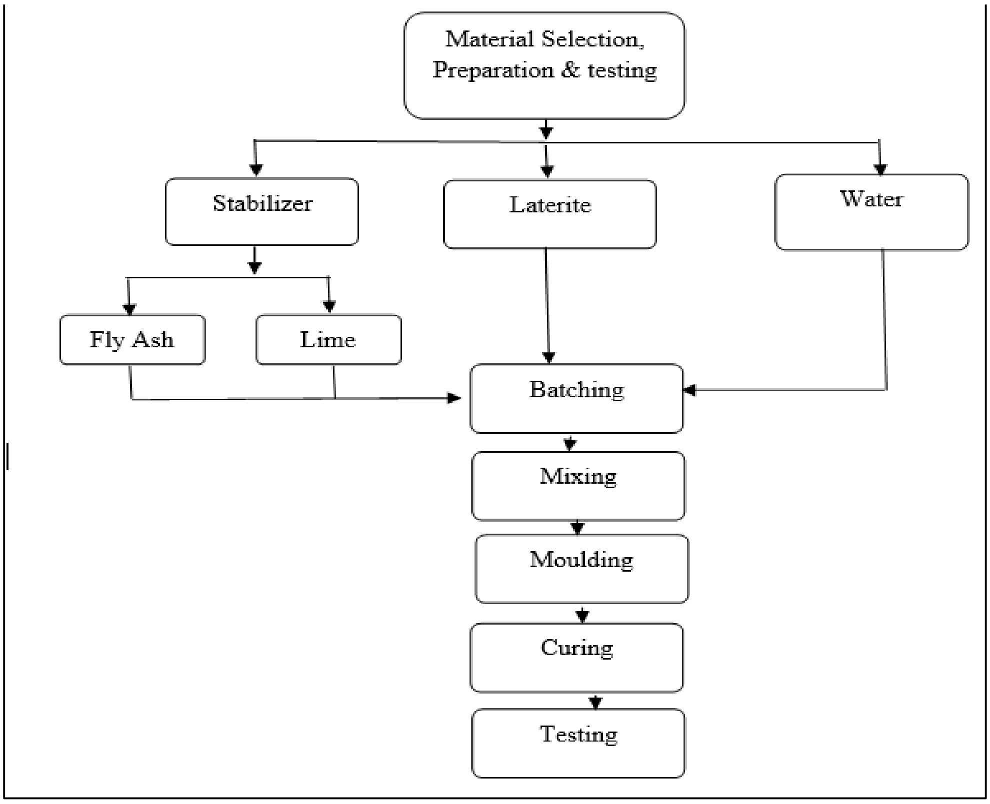

Figure 2: The Research Framework

Table 1: Mix Proportions for Samples of the CSEB

Baseline Mixes	Stabilization %	Fly Ash	Lime	Laterite Soil
CSEB 1	4%	2%	2%	96%
CSEB 2	6%	4%	2%	94%
CSEB 3		3%	3%	
CSEB 4	8%	6%	2%	92%
CSEB 5		4%	4%	
CSEB 6		8%	2%	
CSEB 7	10%	6%	4%	90%
CSEB 8		5%	5%	
CSEB 9		10%	2%	

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CSEB 10	12%	8%	4%	88%
CSEB 11		6%	6%	

RESULTS AND DISCUSSION

Chemical Properties of Fly Ash

Table 2 shows the result of chemical composition analysis of fly ash. It was observed that the chemical composition of fly ash indicates Class F pozzolana ($SiO_2 + Al_2O_3 + Fe_2O_3$ =74.69%). This result satisfies the requirement of ASTM C136/C136M-19 (2019) for a material to be used as a pozzolan in concrete. ASTM C-168 can be classified as Class F pozzolan, which possesses pozzolanic properties.

Table 2: Chemical Composition of the Fly Ash

Compound	SiO_2	V_2O_5	MnO	Fe_2O_3	CuO	Nb_2O_3	P_2O_5	SO_3	CaO
Concentration unit (%)	47.36	0.20	1.07	13.18	0.09	0.03	-	8.28	8.73
Compound	K_2O	BaO	Al_2O_3	Ta_2O_5	MgO	SnO_2	TiO_2	ZrO_2	ZnO
Concentration unit (%)	8.73	0.26	14.15	0.09	-	-	5.26	0.18	0.02

Physical and Chemical Properties of Laterite Soil

The laterite soil sample index properties are presented in Table 3. The laterite sample had specific gravity of 2.63, moisture content of 35%; silt/clay and sand contents of the laterite soil sample were 33% and 67% respectively. It had a liquid limit and plastic limit of 38% and 20% respectively with a plasticity index of 18%. The laterite soil was classified using the Unified Soil Classification System (USCS) systems which belong to CL soil groups. On the basis of silica/sesquioxide ratio, according to Bell (1993), the soils can be classified as true laterite soil because the value of the silica/sesquioxide ratio is 1.03 < 1.33, as shown in Table 4.

The characteristics shown by the laterite soil used in the current study showed that the soil met the standards recommended for use in compressed earth bricks by African Regional Standard (African Standard 1333:2018).

Table 3: Physical Properties of the Laterite Soil

S/NO	Physical Properties	Values
1	Specific gravity	**2.63**
2	Natural moisture content	**35%**
3	Silt/clay content	**33%**

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4	Sand content	**67%**
5	Liquid limit	**38%**
6	Plastic limit	**20%**
7	Plasticity index	**18%**
8	USCS	**CL**

Table 4: Chemical Composition of the Laterite Soil

Compound	SiO_2	V_2O_5	MnO	Fe_2O_3	CuO	Nb_2O_3	P_2O_5	SO_3	CaO
Concentration unit (%)	41.72	0.22	0.25	18.21	0.06	0.02	0.002	0.47	9.46
Compound	K_2O	BaO	Al_2O_3	Ta_2O_5	MgO	SnO_2	TiO_2	ZrO_2	ZnO
Concentration unit (%)	4.49	-	21.59	0.1	-	0.1	2.12	0.35	0.04

Bulk Density of CSEB

The mean bulk density values ranged from 1727.35 to 1865.35 kg/m^3 as shown in Figure 3. The results affirm earlier findings by Taallah and Guettala (2016) and Nshimiyimana et al. (2020). These authors reported that bulk density of CEB ranged from 1700 to 2000 kg/m^3.

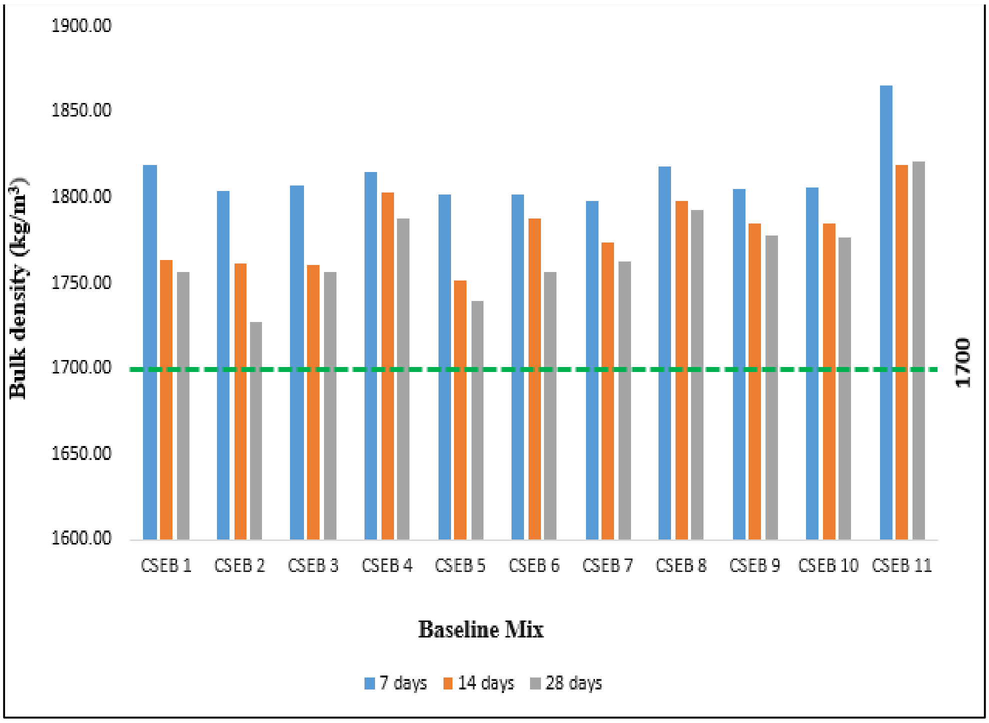

Figure 3: Bulk Density of CSEB Produced with Varying Proportions of Fly Ash and Lime

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Compressive Strength of CSEB

Mean values of compressive strength ranged from 0.66 N/mm^2 being the lowest and 2.02 N/mm^2 being the highest. The observed trend is consistent with the findings of NBRI (2006) that an increase in curing age results in a corresponding increase in strength, as shown in Figure 4. Nigerian Building and Road Research Institute (NBRRI) proposed specification for laterite bricks with compressive strength of 1.65 N/mm² with maximum cement content fixed at 5% as minimum compressive strength for construction purposes. Also, at the 7th, 14th and 28th days curing age of all baseline mix, only CSEB 8 (5% fly ash, 5% lime) at the 28th day and CSEB 11 (6% fly ash,6% lime) at 14th and 28th days with compressive strength of 1.72N/mm², 1.69 N/mm² and 2.02 N/mm² respectively, met the requirement, as indicated by the target line shown in Figure 4.5, and such bricks can be used for the construction of bungalows.

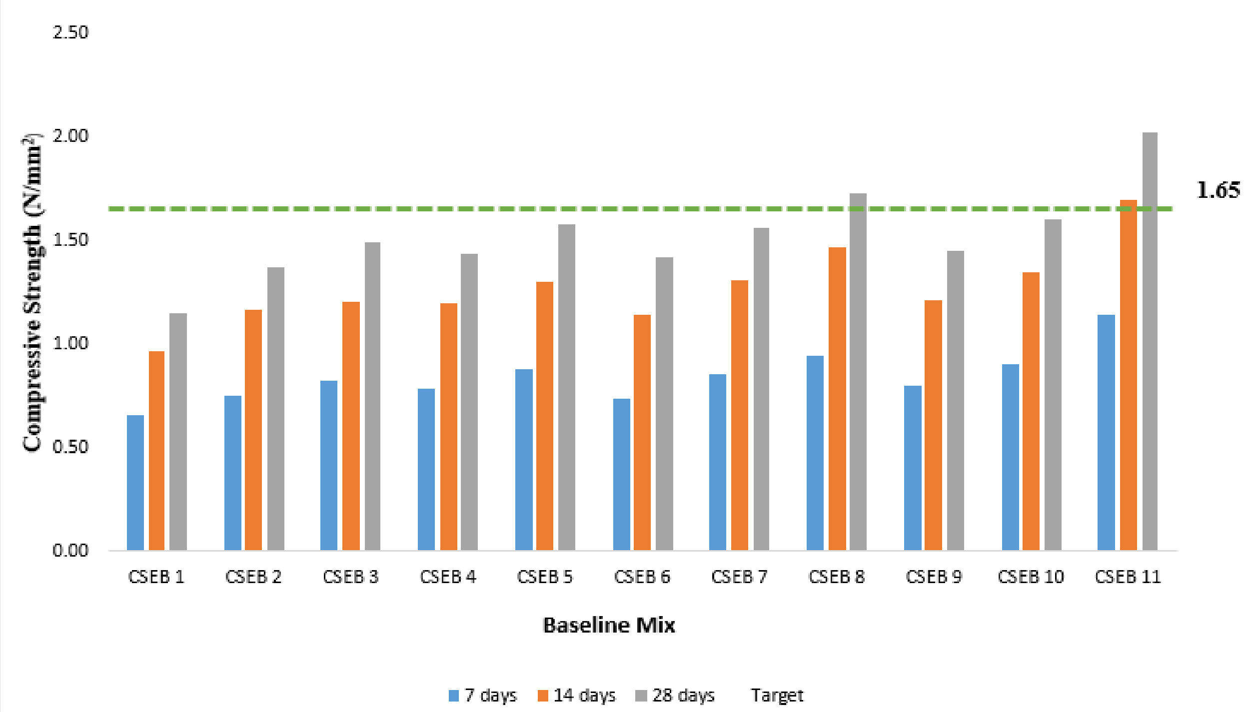

Figure 4: Compressive Strength of CSEB Produced with Varying of Proportions of Fly Ash-Lime and Curing Age

Water Absorption

The water absorption was only considered at the 28th day due to the low rate of early strength development experienced at a lower curing age, which may be due to weather conditions at the time of experiment. Considering the influence of Fly Ash-Lime content, the results show that the values varied from (low) 9.31% for the group CSEB 11 with 6% fly ash and 6% lime inclusion to (high) 14.10% for group CSEB 2 with 2% fly ash and 2% lime inclusion. According to Nigeria Industrial Standard (2004) and NBRI (2006) for laterite bricks, the average water absorption should be a maximum of 12.5%. All the values obtained fell below the maximum recommendation except baseline mix of group CSEB 1 and CSEB 2, as indicated by the target line shown in Figure 5. Similar findings were reported in other works in earlier studies by Kolawole et al. (2020) and Narayanaswamy (2020).

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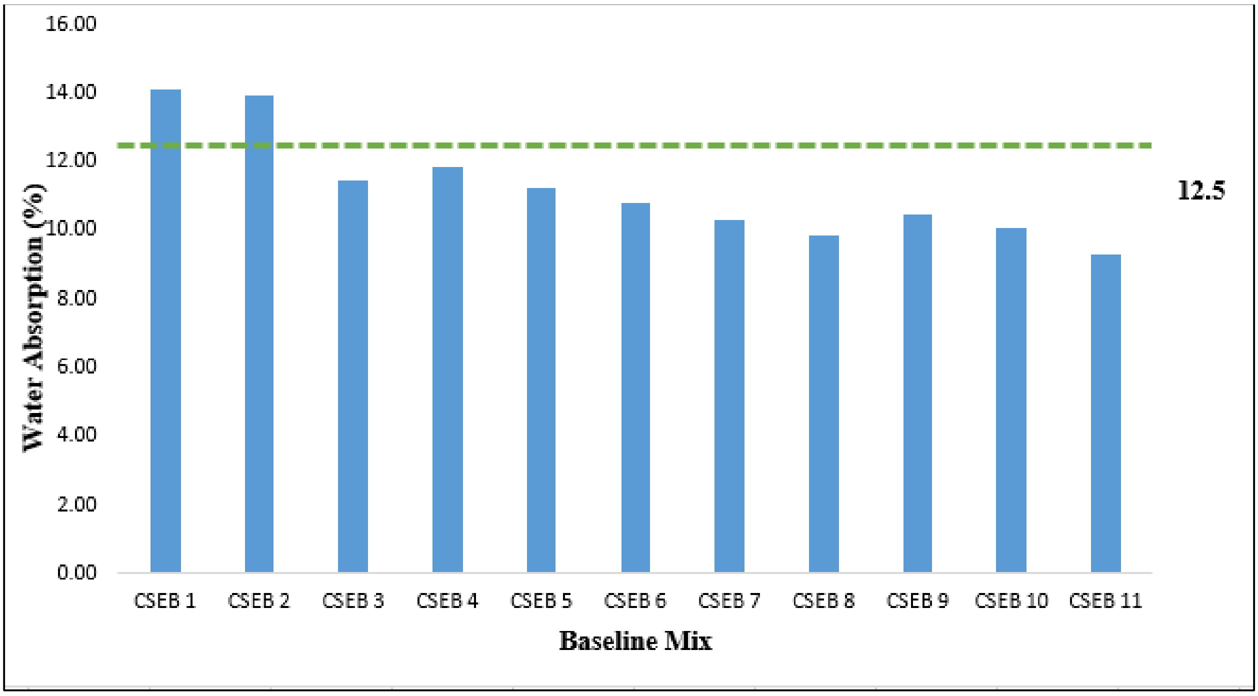

Figure 5: Effect of Fly Ash-Lime Inclusion on the Water Absorption of CSEB at 28 Days Curing Duration

CONCLUSIONS

- The physical and XRF chemical analysis of soil sample used in the current study showed that the soil met the standards recommended for use in compressed earth blocks based on the African Regional Standard (ARS 1333:2018).
- The geochemical properties of the fly ash based on XRF test used in this research work is a good pozzolan as specified in ASTM C 618-78 requirement for chemical composition of pozzolana and classified as Class F fly ash.
- The compressive strength mix baseline group of CSEB 8 (5% fly ash, 5% lime) at the 28th day, CSEB 11 (6% fly ash, 6% lime) at the 14th and 28th days, with compressive strength of 1.72 N/mm^2, 1.69N/mm^2 and 2.02 N/mm^2 respectively, met the requirement for construction material in rural houses, bungalows and low rise buildings.

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REFERENCES

African Standard 1333:2018(E). Compressed stabilized earth blocks Requirements, production and construction. ICS 91.100.15

Akinradewo, F. O. & Adedokun, D. O. (2019). Comparative Cost Analysis of Using Conventional Blocks and Interlocking Bricks for Mass Housing in Nigeria

ASTM C136/C136M-19. (2019). Standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete. ASTM International: West Conshohocken, PA, USA

Bell, F.G., (1993); Engineering Geology, Blackwell Scientific Publications, Oxford, London. 359p.

British Standard. BS 1377: 2. Methods of test for soils for civil engineering purposes,1990.

Federal Mortgage Bank of Nigeria (2018). FMBN Funded Estates Available for Off Takers as at 2018: Summary Report. Available at https://www.fmbn.gov.ng/doc/borno.html.

Kolawole, J. T., Olalusi, O. B. & Orimogunje, A. J. (2020) Adhesive bond potential of compressed stabilised earth brick. Structures, 23, 812-820.

Malkanthi S.N,A.Perera,H.Galabada,P.Dhammika Dharmaratne.(2021) ."Enhancement of the Properties of Compressed Stabilized Earth Blocks theough the Replacement of Clay and Silt with Fly Ash."Engineering Technology & Applied Science ResearchVol.11 No.6,2021,7927-7931www.etasr.com

Narayanaswamy, A. H., Walker, P., Venkatarama Reddy, B. V., Heath, A. & Maskell, D. (2020) Mechanical and thermal properties, and comparative life-cycle impacts, of stabilised earth building products. Construction and Building Materials, 243, 118096.

NBRRI (Nigerian Building and Road Research Institute) (2006) NBRRI interlocking block making machine. NBRRI Newsletter 1(1): 1517.

Nigeria Industrial Standard. (2004). (NIS 87:2004)Standard for Sandcrete Blocks. Standards Organisations of Nigeria, Lagos, Nigeria.

Noorbaya,M.S and Muhammed,H.R.(2015). The Stabilization of Compressed Earth Block Using Fly Ash.Infrastructure University Kuala Lumpur Research Journal Vol.3 No.1 2015

Nshimiyimana, P., Fagel, N., Messan, A., Wetshondo, D. O. & Courard, L. (2020) Physico-chemical and mineralogical characterization of clay materials suitable for production of stabilized compressed earth blocks. Construction and Building Materials, 241, 118097 .

Raheem, A.A., Bello, O. A., & Makinde, O. a. (2010). A Comparative Study of Cement and Lime Stabilized Lateritic Interlocking Blocks., 11(2), 2734.

Taallah, B. & Guettala, A. (2016) The mechanical and physical properties of compressed earth block stabilized with lime and filled with untreated and alkali-treated date palm fibers. Construction and Building Materials, 104, 52-62.

United Nations (2017). New Urban Agenda Third World Conference on Housing and Sustainable Urban Development (Habitat III) held at Quito, Ecuador, on 20 October.

World Bank (2015). Stocktaking of the Housing Sector in Sub-Saharan Africa:Summary Report. Available at www.worldbank.org

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