Advanced Journal of Science, Technology and Engineering
ISSN: 2997-5972
Volume 4, Issue 4, 2024 (pp. 1-9)
www.abjournals.org

ASSESSMENT OF THE PROPERTIES OF COMPRESSED EARTH BRICKS STABILIZED WITH LOCUST BEAN POD POWDER

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Cite this article:

Markus, U. B., Muhammed, I. Y., Ya'u, J. (2024), Assessment of the Properties of Compressed Earth Bricks Stabilized with Locust Bean Pod Powder. Advanced Journal of Science, Technology and Engineering 4(4), 1-9. DOI: 10.52589/AJSTE-AQP0ZUHB

Manuscript History

Received: 14 Jul 2024

Accepted: 16 Sep 2024

Published: 24 Sep 2024

ABSTRACT: *The high cost of cement and the associated environmental impact has necessitated many researchers to conduct investigations on alternative stabilizers. The research was aimed at assessing the properties of compressed earth bricks stabilized with locust bean pod powder (LBPP). It involved the addition of LBPP in 0%, 2.5%, 5%, 7.5%, and 10% for a curing period of 3, 7, and 14 days. The laterite used had sand (58%), silt (31%), clay (10.0%), and organic matter (1%). The liquid limit was 30.13%, plastic limit 15.46%, plasticity index 14.67%, shrinkage 1.7%, maximum dry density 1.7 g/cm^3, and optimum moisture content 10%. Chemical oxide composition showed SiO_2 to be 16.3%, CaO 13.6%, K_2O 35.8%, SO_3 4.18%, Cl_2 3.16, F_e2O_3 16.6%, and P_2O_5 7.64%. Results obtained from stabilized bricks showed that the compressive strength improved from 0.52 N/mm^2 for 0% LBPP content at age 3 days to 2.7 N/mm^2 for 10% LBPP content at 14 days. The bending strength also increases from 0.02 N/mm^2 for 0% LBPP content at age 3 days to 0.25 N/mm^2 for 10% LBPP content at 14 days curing age. The researcher concludes that LBPP contains cementitious properties and chemical oxides similar to that of Portland cement and that it improves the compressive and bending strengths of CSEB. The researcher recommends 10% LBPP content and a 14-day curing period for practical applications.*

KEYWORDS: Locust Bean pods, Laterite, Stabilizer.

Article DOI: 10.52589/AJSTE-AQP0ZUHB
DOI URL: https://doi.org/10.52589/AJSTE-AQP0ZUHB

INTRODUCTION

Though laterite as a construction material is cheaper and more sustainable, the majority of people are still skeptical about its durability, especially within tropical regions. Over the years, the ability of earth buildings to resist wear and deterioration due to harsh weather conditions such as rain, snow, sun, and wind was improved through the use of Portland cement stabilization. Cement consumes a high amount of energy which is about 110-120 kWh per ton coupled with the associated emission of harmful gasses into the atmosphere (Madlool, Saidur, Hossain & Rahim, 2011).

Recent research on alternative building materials has led to research on cement replacement which over the years has been the conventional stabilizer. Locust bean pods are by-products of agricultural activities obtained from a deciduous tree known botanically as *Parkia biglobosa* which is mostly grown and harvested in sub-Saharan Africa as well as the northern part of Nigeria (Adama & Jimoh, 2012). Zievie and Yalley (2016) discovered that the addition of locust bean pods solution (LBPS) in the soil bricks improved its strength and durability by 66%. Aguwa, J. I.; Alhaji, B.; Jiya, A.; and Kareem, D. H. (2016) concluded that LBPS is economical and effective in the production of sandcrete blocks for buildings with up to 25% reduction in the quantity of Portland cement. Ojewumi, M. E.; Ayomide, A. A.; Obanla, O. M.; Awolu, O. O. and Ojewumi, E. O. (2017) researched and discovered that locust bean pod ash LBPA has similar properties to that of Portland cement and can suitably be used as a stabilizer. Ndububa and Uloko (2018) analyzed the locust bean pod ash and found that the chemical oxide of a solid sample of LBPA is similar to that of Portland cement. However, none of the researchers have used the LBPs in their natural powdery state.

LITERATURE/THEORETICAL UNDERPINNING

Laterite is the most common and important building material used in the construction industry, especially in rural and semi-urban settlements. Today, the earth remains an important building material globally as nearly 30 % of the world's population currently lives in buildings made of earth (Costa, Rocha, & Velosa, 2016). But Champire (2016) identifies the difficulty in ascertaining and predicting the earth's structural long-term behavior as one major issue of concern. Maskell, Heath, and Walker (2014) identified poor durability of the laterite products when exposed to high moisture content as a problem. Medvey and Dobszay (2020) identified a loss of strength due to water saturation. Kebao and Kagi (2012) reported poor water erosion resistance and, generally, poor durability as limitations of laterite as a construction material. Portland cement is usually added to the laterite mixture in order to achieve higher compressive strength and better durability (Vyncke, J.; Kupers, L.; & Denies, N., 2018). Recently, the high cost of cement and the associated environmental impact has led to the quest for other alternative materials that are environmentally friendly and of low cost.

African locust bean, botanically known as *Parkia biglobosa*, is a leguminous plant mostly found in the northern region of Nigeria. Locust bean pods (LBPs) are waste by-products of agricultural processing of locust bean fruit which is known as "Kalwa" in Hausa. A very large quantity of LBPs can be found across northern Nigeria during the harvest season between the months of March and June every year. Zievie and Yalley (2016) and Aguwa *et al.* (2016) discovered that locust bean pod solution steadily improved the strength and durability of laterite bricks. Ojewumi *et al.* (2017) and Ndububa and Uloko (2018) opined that locust bean ash has properties similar to that of Portland cement and can be used as a stabilizer. This research

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intends to use the LBPs in their natural state completely away from the environment in the compressed earth bricks (CEBs). The LBPs will be collected, screened, sun-dried, and finely ground into powder form in order to have the locust bean pod powder (LBPP) which will be mixed with the selected laterite prior to CEBs moulding.

METHODOLOGY

The research design is quantitative in nature. Laboratory tests on research materials, including brick moulding and curing, were carried out at the Department of Building Technology laboratory in the Faculty of Environmental Technology, Abubakar Tafawa Balewa University (ATBU), Bauchi, Bauchi State, Nigeria. Chemical oxide test was carried out at the Chemistry Department Laboratory of Gombe State University, Tudun-wada, using the X-ray Refraction (XRF) machine through the fundamental parameters (FP) method of analysis. The CEBs were stabilized with LBPP in percentages (%) of 0, 2.5, 5, 7.5, and 10%. The bricks were tested for a total curing period of 14 days at curing intervals of 3, 7, and 14 days. The materials for this research work underwent preliminary tests. Sedimentation test and sieve analysis of laterite as per BS 1377 - 1: 1990 and Atterberg limits corresponding to BS EN 17892-12:2018 were carried out. Additionally, the locust bean pod powder underwent chemical oxide composition test by X-ray Refraction (XRF) and sieve analysis as per BS 1377 - 1: 1990. Water used for these research works was clean and fit for drinking as stipulated in BS 8680:2020.

The manually operated ClNVA-ram hand press machine was used for the brick production. A total number of 180 plain brick specimens of dimensions 300 mm x 140 mm x 115 mm were moulded. Laterite was sourced within Rafin Zurfi in Bauchi metropolis and locust bean pods were sourced from Kauru, Kaduna state. The moulded bricks were covered with a polythene sheet immediately after moulding for three days before being opened and allowed to dry under normal room temperature. The Compressive Strength test was carried out as per BS EN 772-1:2000. Modulus of Rupture**,** also known as bending or flexural strength, was determined in accordance with Annex F ARS 1333:2018(E) and Center for Development Enterprise (2000) guidelines.

RESULTS/FINDINGS

Table 1: Properties of laterite soil used

SN	Soil properties	Result
1	Sand fraction	58.0%
2	Silt fraction	31.0%
3	Clay fraction	10.0%
4	Organic matter content	1.0%
5	Liquid limit	30.13%
6	Plastic limit	15.46%.
7	Shrinkage limit	1.7%
8	Optimum moisture content	10%
9	Plasticity Index	14.62%
10	Type of soil	Sandy loam

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11	Maximum dry density	1.7g/cm^3

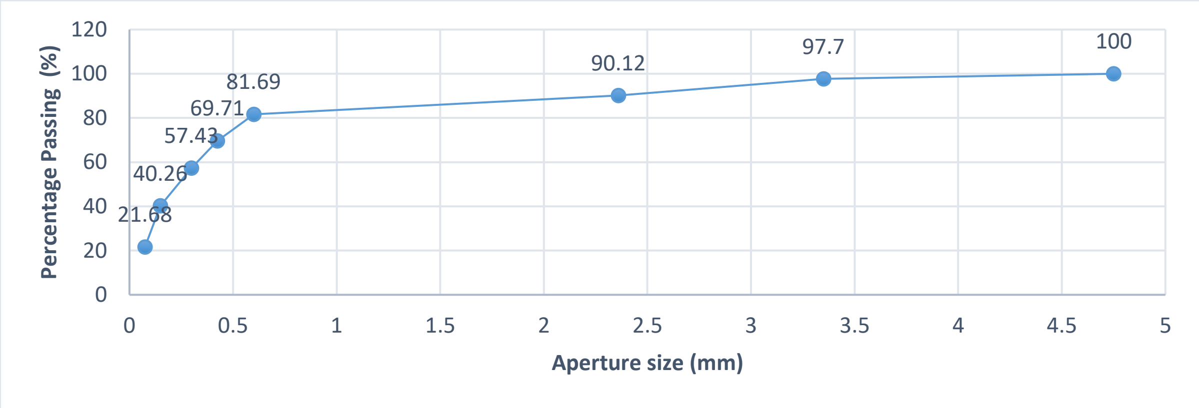

Fig. 1: Laterite sieve analysis

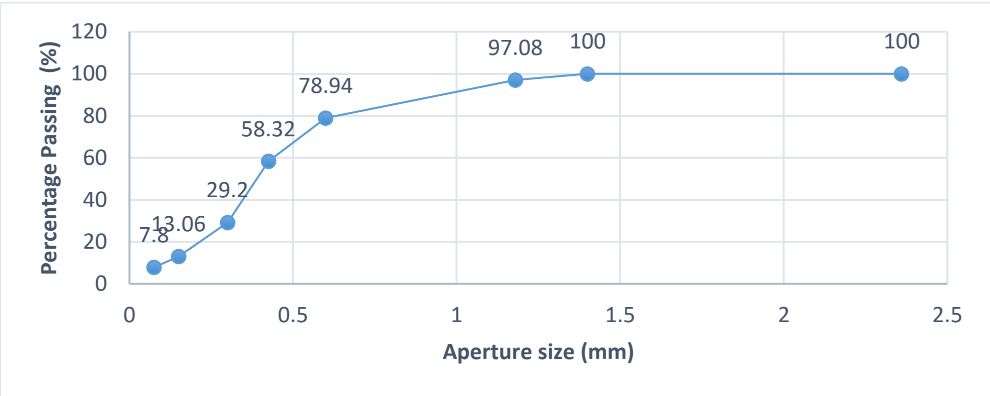

Fig. 2: Locust beans sieve analysis

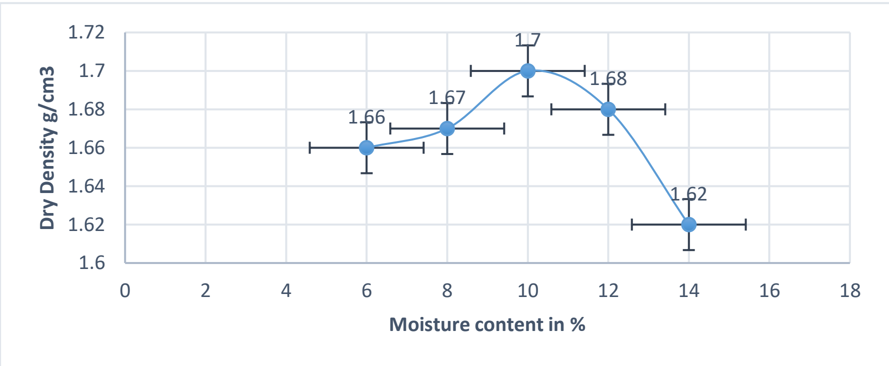

Fig. 3: Optimum moisture content of laterite soil

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Table 2: Chemical oxides composition of LBPP using the XRF Machine

SN	Component	Result	Unit
1	Na_2O	ND (0)	% mass
2	SiO_2	16.3	% mass
3	Al_2O_3	ND (0)	% mass
4	P_2O_5	7.64	% mass
5	SO_3	4.18	% mass
6	Cl	3.16	% mass
7	K_2O	35.8	% mass
8	CaO	13.6	% mass
9	Fe_2O_3	16.6	% mass
10	ZnO	0.213	% mass
11	MnO	0.339	% mass
12	TiO_2	0.717	% mass
13	BaO	0.0730	% mass
14	NiO	0.0120	% mass

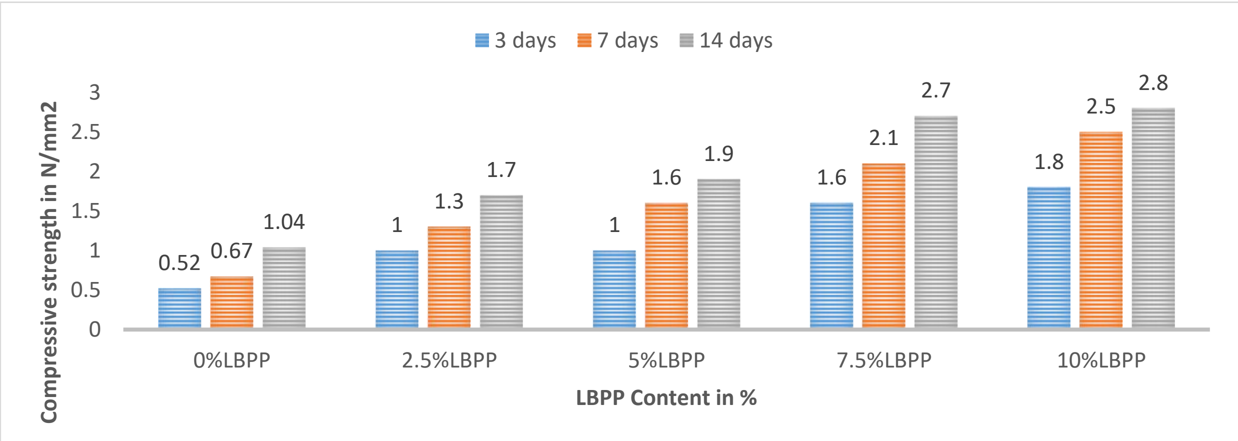

Fig. 4: Relationship between compressive strength and LBPP content

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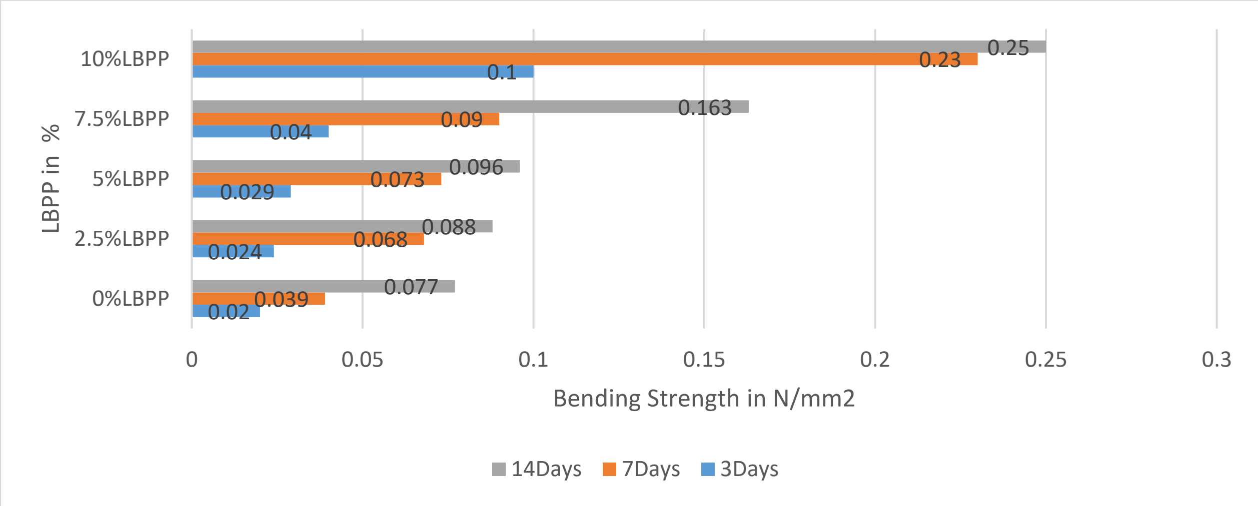

Fig. 5: Relationship between bending strength and LBPP content

DISCUSSION

The findings of the sedimentation tests revealed that the laterite contain 58% sand, 31% silt, 10.0% clay, and 1% organic matter. The textural percentages are in conformity with Duggal (2008), ARS 1333:2018(E), ISO: 14688-2:2017, and Al-sakkaf and Abdullah (2021). The laterite soil sample can be classified as a well-graded fine-grained soil because it contains not more than 10% of it mass retained on a 2 mm test sieve as stipulated by BS 1377-1:1990. Hence, the laterite used for the research work is good and cohesive. The result from Casagrande device at 25 blows shows that the liquid limit of the soil sample is 30.13% of the water content. This outcome is in agreement with the provision of ARS 1333:2018 (E) which suggests 25% to 50%. Therefore, the soil has a good LL. The laterite has a plastic limit PL of **15.46.** The outcome was above that of Waziri, B. S.; Lawan, Z. A.; and Mala, M. M. (2013) who got 14.3% PL, and below Gutty and Musa (2017) who obtained 24.3% PL. The laterite is low plastic from the plasticity chart. Plasticity Index (PI) is 14.67%, which does not exceed 15% as stipulated by Fetra and Zaidi (2011).

According to the Commonwealth Experimental Building Station, plasticity index should be between 10% and 20%. Shrinkage limit SL is 1.7%. Zievie and Yalley (2016) suggested up to 6% SL. Hence, the laterite has a good shrinkage limit. The results from sieve analysis of LBPP have shown that only 7.8% pass through sieves 75 microns, 13%, 29%, 58%, and 78% pass through sieves 150, 300, 425, and 600-micron meters respectively. The sample only passed 100% through sieves 2.36 mm and 1.4 mm. This indicates that the ground LBPP was not finely ground as cement because IS: 4031-1:1996 recommends a fineness modulus of not more than 10%. The optimum moisture content OMC is 10% with a maximum dry density of 1.7 g/cm^3. The OMC meets the requirement of ARS 1333:2018 which stipulates 3.5-14% OMC for laterite. The compressive strength for 0% stabilization for ages 3, 7, and 14 days were 0.52, 0.76, and 1.0 N/mm^2 respectively. 2.5% LBPP stabilization values were 1.0, 1.3, and 1.7 N/mm^2 for 3, 7, and 14-day curing periods respectively. When the percentage of LBPP was increased to 5% and 7.5% for the same curing periods, 1.0, 1.6 1.9 N/mm^2 and 1.6, 2.1, and 2.7 N/mm^2 compressive strengths were obtained respectively. At 10% LBPP stabilization, the

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bricks produced average compressive strengths of 1.8, 2.5, and 2.7 N/mm^2 for 3, 7, and 14-day curing periods respectively. This outcome meets the British Standard Institute BSI compressive strength requirement of 2.0 N/mm^2 and NBRRI 1.65 N/mm^2 for low-rise buildings. It also agrees with the outcomes of Zievie and Yalley (2016), Ojewumi *et al.* (2014), Aguwa *et al.* (2016), and Ali *et al.* (2019). The result of bending strength shows a gradual but steady increase in resistance to bending force as the percentage of LBPP and the age of bricks increases. For 0% at age 3, 7, and 14 days, the bending strengths were 0.02, 0.039, and 0.077 N/mm^2 respectively. 2.5% produced bending strengths of 0.024, 0.068, and 0.088 N/mm^2 respectively; 5% produced 0.029, 0.073, and 0.099 N/mm^2 respectively; and 7.5% gave flexural strengths of 0.04, 0.09, and 0.16 N/mm^2 respectively. When LBPP content was increased to 10%, the flexural strengths recorded were 0.1, 0.23, and 0.25 N/mm^2 all for curing periods of 3, 7, and 14 days respectively. This result falls below the 0.5 N/mm^2 minimum bending strength at 28 days for laterite bricks recommended by ARS 1333:2018. This failure may be attributed to the curing age limit adopted for this research work.

IMPLICATION TO RESEARCH AND PRACTICE

The present research study has contributed to the existing body of knowledge by confirming that LBPP possesses cementitious properties. As part of knowledge contribution on alternative building technologies and materials, individuals, private developers, professionals in the built environment, and government relevant agencies will find this outcome useful because previous researchers based their work on locust bean pods ash (LBPA) and locust bean pods solution (LBPS) while this research was based on LBPP. This has confirmed that locust bean pods (LBPs) in their entirety (ash, solution, and powder) are suitable for laterite brick stabilization.

CONCLUSION

The locust bean pod powder contains cementitious properties and chemical oxides similar to that of Portland cement. Potassium oxide (K_2O) is the major chemical oxide in LBPP with 35.8%. The addition of LBPP steadily improves the hardened properties of the laterite bricks. The 10% content of LBPP produced the highest compressive and bending strengths of the stabilized bricks. The compressive and bending strengths of brick increase with age of curing and LBPP content. Fourteen days (14 days) curing period and 10% LBPP give the highest coefficients of compressive and bending strengths of stabilized bricks that meet the British Standard Institute BSI and NBRRI specifications.

FUTURE RESEARCH

The researcher recommends further studies thus:

1. Assessment of the effect of locust bean pods powder on the properties of concrete.
2. Assessment of the optimum locust bean pods powder content for laterite bricks stabilization.

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