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EXPERIMENTAL EVALUATION OF THE MECHANICAL PROPERTIES OF LATERITE BRICKS PRODUCED WITH PLASTIC WASTE AS BINDER

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ABSTRACT
Three key issues bordering developing nations such as housing deficit, waste management and depletion of environmental resources are rampant in Nigeria. Perhaps utilising plastic wastes as alternative materials, specifically in brick production, can be a viable approach to solving these issues. This paper seeks to apply plastic waste as a binder to completely replace cement with the view of producing Stabilised Earth Bricks. Laterite soil was combined with melted plastic to produce brick specimens. The specimens were cured in open air and tested for Densification (D_f), Compressive Strength (C_s) and Flexural Strength (F_s). An average compressive strength of 8.20N/mm² at 3 days was recorded for the Laterite Plastic Bricks (LPBs). LPBs have been discovered to be light in weight yet possessing compressive strength comparable to standard requirements of Compressed Stabilised Earth Bricks. This indicates that LPBs can be considered as appropriate building materials.

KEYWORDS: *Alternative materials, Bricks, Laterite, Plastics, Waste management.*

INTRODUCTION
Compressed Stabilised Earth Bricks (CSEBs) are considered as green building materials, which supports climate resilience and aligns with the global push for sustainable development in Nigeria (Building, 2023). Plastic waste has gained recognition in the built environment where it serves as substitute to aggregates, workability modifier in concrete, and binder in sandcrete blocks/bricks production (Awoyera & Adesina, 2020). Distinct from sandcrete blocks and fired clay bricks, it is economical to recycle waste products such as plastic water bottles with laterite for brick production because very little materials, tools and labour are required. The cost of transportation is eliminated as well since production can take place on site (Khalil, 2017). Compared to fired clay bricks, the production of Laterite Plastic Bricks (LPBs) would only involve melting plastic bottles at temperatures as low as 105^0C. Curing of LPBs is by air drying, thereby making the process less labour intensive and environmentally friendly.

The largest industry across all economies and the biggest consumer of raw materials is the construction industry thus making it a potential sector where Plastic Waste (PW) can be used advantageously for a variety of purposes. Due to the beneficial properties of plastic, which include adaptability, light weight, hardness, and resistance to chemicals, water, and impact acclaimed by Amit, *et al*., (2012), the potential utilization of plastic waste in the construction sector will assist the sector in achieving its sustainability goals (Schwartz, 2012).

White, Franke, & Hindle, (2018), defined recycling as the process of turning waste materials into new materials that can be used to make new products after they have served their present and imminent use. Plastic recycling according to (Hopewell, Dvorak, & Kosior, 2019) involves collecting instead of discarding plastic trash and putting it through a series of processes to create new, usable goods. Effective recycling of plastic can decrease the need for landfill space and safeguard the environment from plastic pollution and emission of greenhouse gases (Al-Salem, Lettieri, & Baeyens, 2019). According to Isaac & Manasseh, (2020), recycled polyethylene terephthalate (PET) bricks can be fire resistant and bulletproof. Normally, water bottles and soft drink bottles are made up of PET (Rishabh, Mohit, Inder, & Deepa, 2021).

In developing countries such as Nigeria and Sudan to mention a few, there is an imbalance between the demands for housing and expensive conventional building materials coupled with the depletion of traditional ones (Abolo, 2019). To address this situation, attention has been focused on low-cost alternative building materials and methods. Plastic has been used to stabilise sand in the production of interlocking pavers and walling bricks as well, however, sand is expensive and its acquisition may lead to depletion of the environment. The machineries involved in the recycling and production of plastic bricks are also expensive that the poor cannot afford. Thus, this study improvises a local method of mixing laterite, which is abundant and inexpensive in conjunction with plastic waste also cheaper and easy to acquire for the production of Compressed Stabilised Earth Bricks (CSEBs). This can go a long way to address the housing needs in developing nations as well as provide a sustainable way to manage plastic wastes in the environment.

MATERIALS AND METHODS

Materials

The materials used in the production of LPBs are the waste plastic water bottles made up of polyethylene terephthalate (PET) capable of being molded and remolded repeatedly; and laterite soil. Identical water Bottles of the same brand (Ever Table Water) bottles were sorted, washed to remove impurities and dried.

The laterite soil was obtained from a borrow pit about 2 metres below ground level in Area G Samaru Campus, Ahmadu Bello University Zaria and subjected to preliminary engineering property tests such as sieve analysis (SA), moisture content (MC) bulk density (BD), and specific gravity (SG). The laterite was then batched to obtain a consistent soil mix for brick production.

Methods

LPBs production made use of a few improvised common tools. These are:

1. A 5kg gas burner
2. A large size aluminium cooking pot
3. A 25kg stirring/compaction iron rod
4. The ELE International – three gang mould (50mm cube)

Preliminary Tests Results

The relationships between the specific gravities (2.38:1.38) and bulk densities (1703:1398); (Laterite to Plastic) respectively, are close, table 1, thus mix proportions were carried out by weight.

Table 1: Specific Gravity (SG) and Bulk Density (BD) Results

SN	Material D (kg/cn^3)	SG	BD
1.	Laterite	2.38	1703
2.	Plastic	1.38	1398

NOTE: SG = Specific Gravity; BD = Bulk Density

Trial Mixes

In the preparation of sandcrete brick or block mortar, cement to sand ratio is usually in the ratio 1:6. Although, ratios of 1:3; 1:4 and 1.5 have worked according to Uche, Oko, & Martin, (2022) for cement/sand mortars, there are no records for plastic/laterite proportions as at now. Hence, trail tests were necessary so as to achieve a consistent sticky mix for the production of LPBs. As shown in table 2, the weights in grammes of plastic were varied while keeping the weights of laterite and final melting temperatures constant.

Table 2: Mix Proportions

SN	Materials Content in a Mould			IMP (^{0}C)	Liquid State (^{0}C)	Remarks
	Ratio	P (g)	L (g)			
1	1:10	22.5	225	68	300	Un-sticky Mix
2	1:5	45	225	68	300	Partially Sticky Mix
3	1:4	56.25	225	68	300	Sticky brittle Mix
4	1:3	75	225	68	300	Consistent Sticky Mix
5	1:2	112.5	225	68	300	Fluidly Mix

Note: P = Plastic; L = Laterite; IMP = Initial Melting Point

From table 2, it can be observed that the ratio of plastic to laterite that produced consistent sticky mix, ideal for bricks production is 1:3. Ratios 1:10 t0 1:4 produced weak binding effect on laterite while 1:2, turned out to be difficult to compact in the mould due to fluidity, hence the adoption of the 1:3 mix ratio.

Laterite Plastic Bricks Production Process

The empty metal pot provided for this work was pre-heated on the gas burner for about two minutes, after which plastic content of 22.5g representing 10% of the weight of laterite, was placed in the pot and allowed to completely melt into liquid state at 300^{0}C, which took nine minutes. The weighed laterite 225g, calculated for one mould, was then carefully introduced into the melted plastic and mixed thoroughly with the 25kg iron rod. When the mixture was observed to be consistent, the content of the pot was emptied into the mould and the same iron rod was used to tamp the mixture in the mould twenty-five times. Prior to this, engine oil was applied to the inside surfaces of the mould before each casting. This was to prevent the specimen from sticking to the sides of the mould during extrusion. Every test specimen was left to cool and set for roughly fifteen minutes before de-moulding and curing in open air.

Trial Test Result

After three days of open-air curing of specimens, the average compressive strengths for each ratio including the control samples are given in table 3. The lowest early strength at 3days (0.77N/mm^2), was recorded for the control sample while the least strength (3.01N/mm^2) for plastic stabilised bricks was measured at the ratio 1:10 and hence-on, the strengths improved as plastic increased to 1:5; 1:4; and 1:3, (5.82; 7.26; and 8.20N/mm^2) in that order. The strength ($4.48N/mm^2$) for ratio 1:2, has dropped even below the 1:5 ratio, an indication of the excess content of plastic in the mix.

Table 3: Densities and Compressive Strength of Brick Specimens at 3days

Specimen	Control (L)	LPB				
Ratio (P:L)	**100%**	**1:10**	**1:5**	**1:4**	**1:3**	**1:2**
Density (Kg/cm^3)	1694.08	1123.12	957.13	904.25	895.24	745.32
C_S (N/mm^2)	0.77	3.01	5.82	7.26	8.20	4.48

Note: LPB = Laterite Plastic Brick; **L** = Laterite; **P** = Plastic; **C_S** = Compressive Strength.

Experiment

The main experiment was conducted to evaluate the mechanical properties of LPBs alongside control samples for 3, 7, 14, 28 and 56days. The properties considered are Compressive Strengths (C_S), Flexural Strengths (F_S) and Densities (D) of all specimens, table 4.

Table 4: Experimental Schedule

S/n	Test	Sample Type	Curing days	No of samples CONTROL	LPB
1	C_S	(50×50×50) mm Cube	3, 7, 14, 28, 56	15	15
2	F_S	(160×40×40) mm bar	3, 7 ,14, 28, 56	15	15
3	D	(50×50×50) mm Cube	3, 7 ,14, 28, 56	–	–
Totals				30	30
Overall Total Number of Specimens				**60**	

NOTE: C_S = Compressive Strength; **F_S** = Flexural Strength; **D** = Density

The property tests in table 4 were carried out by subjecting 6 cubes to the same test at a time for each curing period the average of which is recorded for presentation in tables and figures. For C_S and F_S, a total of 15 specimens each were produced for the control and 15 for LPBs while the samples for density test are the same specimens for C_S test since each sample was weighed before crushing. An overall total of 60 specimens were prepared.

RESULTS

Compressive Strength

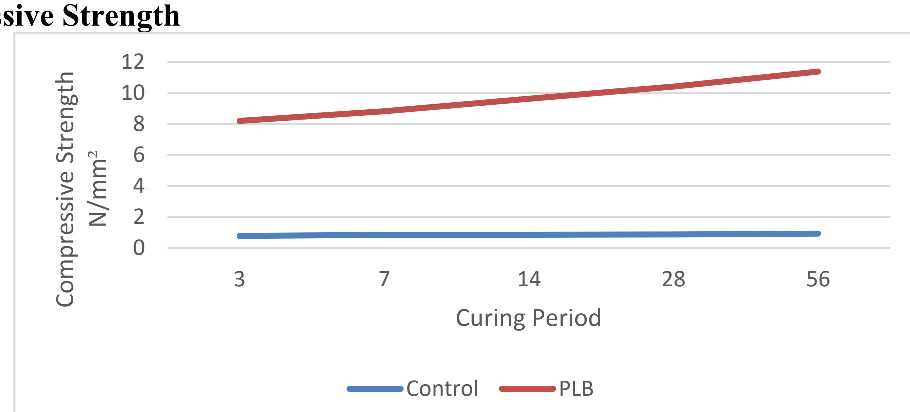

Figure 1: Compressive strength of specimens

The average compressive strengths of laterite plastic bricks are shown in figure 1. Early strength developed at 3days of curing recorded 8.20N/mm^2 for LPB, which is 965% higher than that of the control specimen (0.77N/mm^2). This trend continued through the curing periods where LPB improved by 1,137% over the control; (11.38N/mm^2:0.92N/mm^2; LPB to Control) at 56days.

Flexural Strength

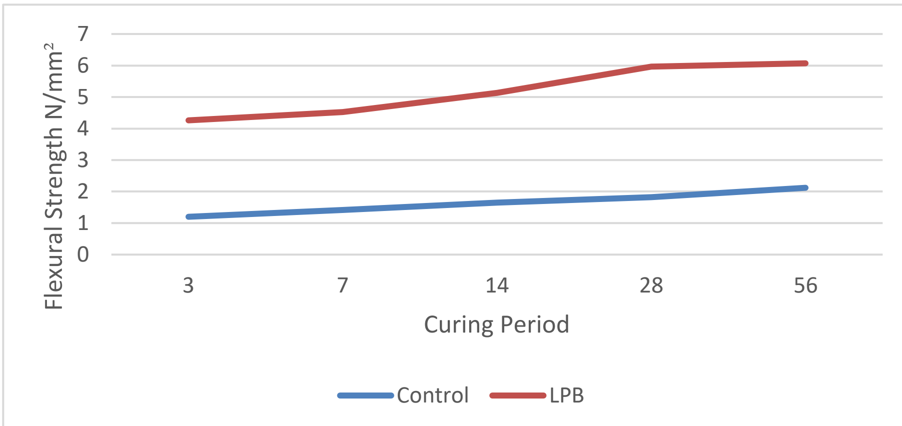

Figure 2: Flexural strength of specimens

At 3days, the early strength developed by LPB is 255% higher than that of the control (4.26N/mm^2:1.20N/mm^2) while at 56 days, the margin of strength differences between LPB and control dropped from 255% to 184%. (6.07N/mm^2:2.14N/mm^2) respectively.

Density

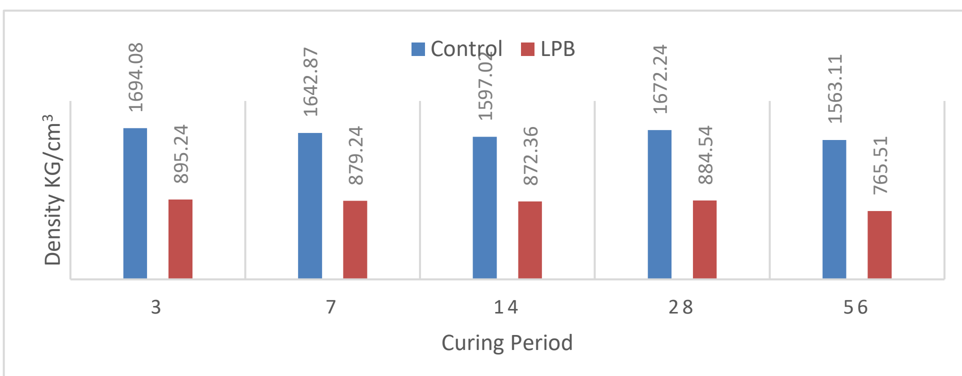

Figure 3: Relationship between Density of specimens and curing period

The average density of the control specimens of 1633.96kg/cm^3 is almost twice the average density of LPBs (859.38kg/cm^3) across the curing periods.

DISCUSSION OF RESULTS

The compressive strength results displayed tremendous strength achievements of LPBs over un-stabilised bricks. Moreover, it is also evident that as LPB ages on, the compressive strength increases. This indicates that the setting of the plastic continued gradually from the surface of the brick towards its inner part in concordance to hydration of cement paste. Similarly, LPBs have attained about 530%

compressive strength increase (10.41N/mm²), over the Nigerian Building and Road Research Institute (NIBRRI) standard requirement of cement stabilised bricks (1.65N/mm²) at 28days. This implies that LPBs can be adopted as viable walling units' materials similar to Plastic/Sand blocks for wall construction in Developing Countries (Alexander, Mohammed, Tagbor, Tulashie, & Cheeseman, 2023).

The average flexural strength of brick specimens as seen in figure 2, further confirms the positive binding effect of plastic on the mechanical properties of CSEBs, although there is a drop in the flexural strength at 56 days in contrast to the marginal rise in compressive strength. This can be attributed to the fact that PET plastic is malleable and ductile when heated but on cooling and setting, it becomes hard and brittle. Its hardness gives it the ability to withstand compressive strength which progresses with time. However, its brittleness makes it a bit weak at taking up bending stress which was measured by flexural strength test where specimens are subjected to a three-point loading. From figure 2, it can be readily observed that there is steady steeper gradient in the LPB graph from 7 to 28days, but from 28 to 56days, the gradient is shallow. This is an indication of the negative effect of brittleness on resistance of LPB to bending stress.

As depicted in figure 3, densities of LPBs are lower than those of the control indicating that the addition of plastic (a lightweight material) to laterite, has significantly influenced weights of the bricks. This implies that density is not a function of strength in LPBs. It is also observed here that curing has no influence on the density of bricks. Only the plastic binder influenced densities of LPBs inversely.

It was expected that LPBs can practically enhance housing delivery in developing countries and with the forgoing findings in this paper, the goal is achievable due to the ease of materials acquisition, labour and overall cost implications.

CONCLUSION AND RECOMMENDATIONS

Conclusion

Recycling of used plastic water bottle as an alternative building material is one positive way of sustaining waste management which in turn can support efforts towards reducing environmental degradation. The method of preparing and casting laterite plastic bricks can be said to be appropriate, sustainable and cost effective since energy demand in the whole process is minimal in the sense that the source of heating and melting the plastic binder is a gas burner generating steady heat at about 105^0C and the temperature at which the plastic changed to liquid state is 300^0C.

Recommendations

The high compressive strength exhibited by LPB despite its low density 11.38N/mm^2, makes it a load bearing walling unit that can also withstand dampness since plastic has water proofing property. The optimum proportion of plastic to bind laterite soil for the purpose of brick production is 1:3 (plastic to laterite) by weight. Plastic laterite bricks should not be exposed to high heat say 200^0C for long period as it may lead to deterioration of the bricks, thus the need for attempts to establish the temperature at which LPB starts to disintegrate as a result of melting of the binder.

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