



## MECHANICAL STUDY OF CEMENT STABILISED EARTH BRICKS PARTIALLY REPLACED WITH BURNT PLANTAIN PEELING ASH

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**ABSTRACT:** *The durability and affordability of buildings could be attained in a more environmentally friendly manner if Compressed Stabilized Earth Bricks (CSEB) are used. These bricks, when appropriately formed with the right amount of stabilizer and pressure, could be more sustainable. The aim of this study was to examine the mechanical property of CSEBs when produced with different percentages of cement, burnt plantain peeling ash (BPP), of the French horn plantain and a mixture of burnt plantain peeling ash and cement. Soil samples were gotten from mile 4 Menteh, Bamenda III in the North West Region of Cameroon and were analysed using standard methods. The bricks were stabilized with Dangote cement CPJ 42.5, ash from burnt plantain peeling ash, partially replacing cement. The bricks of dimensions 30x15x12cm, produced with a machine of 20MPa pressure, were stabilized with varying percentages at 0%, 2%, 4%, 6%, 8%, and 10% of cement. After getting the optimum compressive strength of CSEBs stabilised with 6% of cement we did a partial replacement of cement with burnt plantain peeling ash of 5%, 10%, 20%, 30%, 40%, and 50%. Curing was done for 7days and 28days and later air-dried before crushing. The compressive strength showed that bricks of 5% burnt plantain peeling ash in the partial stabilisation of earth bricks gives a compressive strength of 2.21MPa after 28days of curing. Also, as the percentage of ash increased from 5% to 10% the compressive strength of compressed stabilised earth bricks reduced due to the fact that burnt plantain peeling ash is hygroscopic. This study suggested that CSEBs, stabilised with 5% burnt plantain peeling ash could be used for partial replacement for cement in the production of earth bricks.*

**KEYWORDS:** CSEBs, Cement, plantain peeling ash, Compressive Strength.



## INTRODUCTION

Concrete is most widely used as a construction material due to its high compressive strength & durability. It is the most used man-made material on the earth for construction work. The main factor which determines the strength of concrete is the amount of cement used and water/cement ratio in the mix (Jugal and Aman, 2018). Concrete is attractive for use as a construction material, due to its advantages such as built-in-fire resistance, high compressive strength and low maintenance, (Onyeka et al., 2019). Recently, the technology of traditional earth construction has undergone considerable developments that have enhanced the earth's durability and quality as a construction material for low-cost buildings (Adam and Agib, 2001). With the increase in population and high demand for dwelling houses the price of such houses has increased, and is increasing tremendously in recent years. This is compounded by the fact that the available land for this development is becoming scarce, especially in the urban and suburban areas. Many people, especially those in the lower- and middle-income groups can no longer afford to buy them, (Onyeka et al., 2019). One of the factors which contribute to this problem is the high cost of building materials, which currently use the conventional materials and method of construction. (Noorbaya and Muhammad, 2015), One of the ways to alleviate the problem is to use cheap building materials, available locally. This can be done either by using re-cycled or sustainable raw materials for houses which are comparable to the conventional materials made from cement, sand and aggregates to give an acceptable level of quality and comfort, (Onyeka et al., 2019). Short natural and synthetic fiber soil composites have recently attracted increasing attention in geotechnical engineering. The most common and readily available Pozzolanic material that can be used to partially replace cement without economic implications are "agro based wastes", notable ones being Acha husk ash (AHA), Bone powder ash (BPA), Palm oil fuel ash (POFA), Palm kernel shell ash (PKSA), groundnut husk ash (GHA), Rice husk ash (RHA), banana leaves ash, sawdust, periwinkle shell ash (PSA), (Onyeka et al., 2019). This research uses burnt plantain peeling ash (BPP) as a partial substitute for cement in CSEBs. Plant ash is the powdery residue that remains after plants are burned; chemically the ash is alkaline ( $\text{pH} > 10$ ) and composed primarily of calcium carbonate and, secondarily, most often, of potassium chloride (interestingly, alkaline derives from the Arabic word meaning plant ashes), (Onyeka et al., 2019). One of the major problems of developing countries is improper management of large amounts of waste generated from the various human activities, (Robert, 2012). Therefore, this study will add in improving plantain peeling which is also waste to an impactful low-cost use.

### Compressed stabilized earth blocks

Compressed stabilized earth blocks (CSEBs) are comparatively new earth-based materials similar to rammed earth, adobe, and bricks. The compressed earth block is one of the most important modern building materials which has enough production flexibility to let it be integrated into both formal and informal sectors of structural activities (Rigassi, 2000). Recently, the technology of traditional earth construction has undergone considerable developments that have enhanced the earth's durability and quality as a construction material for low-cost buildings (Abdulrahman, 2009). The earth compressed blocks only became widely used around the world in the last 30 years or more, not only in third world countries, but also in developed countries like the USA, France, Canada, and Austria, (Abdulrahman, 2009). The performance of the stabilized compressed earth block was comparable with others in terms of their strength characteristics. Meanwhile, the reduction of transportation time, cost, and attendant pollution can also make earth blocks more environmentally friendly than other



materials. The main ingredient of CSEBs is the soil and it is visible everywhere, (A. P. Asha and C. Anbalagan, 2023). Roughly 65% of the soil on the planet can be used to make CSEBs and it can be found in many locations. This means that, CSEB is an earth-friendly material because, it is not too expensive in manufacturing unlike in making the concrete hollow block. CSEB is having a thermal mass that naturally provides homes with some passive heating and cooling and provides increased comfort for its inhabitants, (Lola and Alexandra, 2023). Regarding the durability and strength of the structures using CSEB, both stabilized CEB and unsterilized CEB are appropriate for buildings and meet the US Building Code Standard for compression and modulus for ruptured tests. The fact is that the durability of a CSEB building will allow it to last for centuries. The evidence is that, as we all know, ancient earthen structures still stand today in many parts of the world. CSEB has proven to be waterproof, fireproof, and bulletproof, (S. Elavarasan, et al., 2023). These structures can be built to resist earthquake damage in a seismic zone. By utilizing soil and coconut fiber, CSEB would be an incredible building material, (Bikash et al., 2023). Good production could be performed by increasing compressive strength and using improved curing.

## Material and Methods

### Materials

The main constituent materials used in the production of CSEBs were: cement, soil, burnt plantain peeling ash and water.

- Soil samples for the experiment were collected from a Borrow pit at mile 4 - Menteh Bamenda in Bamenda in the North West Region of Cameroon with GPS Coordinates of N5°58' 42.63932" and E10°12' 1.80252. During sampling, the organic part of the soil (topsoil) was removed by digging 1.20 m deep to expose the sub-soil. A large quantity of the sub-soil samples were collected and air dried. The soil was homogenized by removing coarse fragments and sieved using a 2.5 mm mesh sieve.
- The cement used was Dangote CEM II 42,5R
- Burnt plantain peeling ash (BPP) of Ripe French horn plantain peelings.
- Pipe borne water used for mixing the components together.

### Methods

The soil samples were identified following the Cameroonian norms (NC 102-114, 2002) and were tested in the Material Laboratories of BEGL, Physical test such as smell (organic matter), touch (texture), hand washing (stickiness), cigar (clay content), grain size distribution (percentage of sand, silt and clay portions) and Atterberg's limits were performed. Mechanical tests were performed using the proctor test (for optimum water content and optimum dry density- NF P 94-093). Laboratory tests such as Natural moisture content (NF P 94-050), grain size analysis (NF EN 933-1), Specific Gravity NF P 94-054), Atterberg limit tests (NF 94-051), Soil PH and proctor tests. The samples were moulded using the Cameroon code NC 102 – 115: 2002-2006.

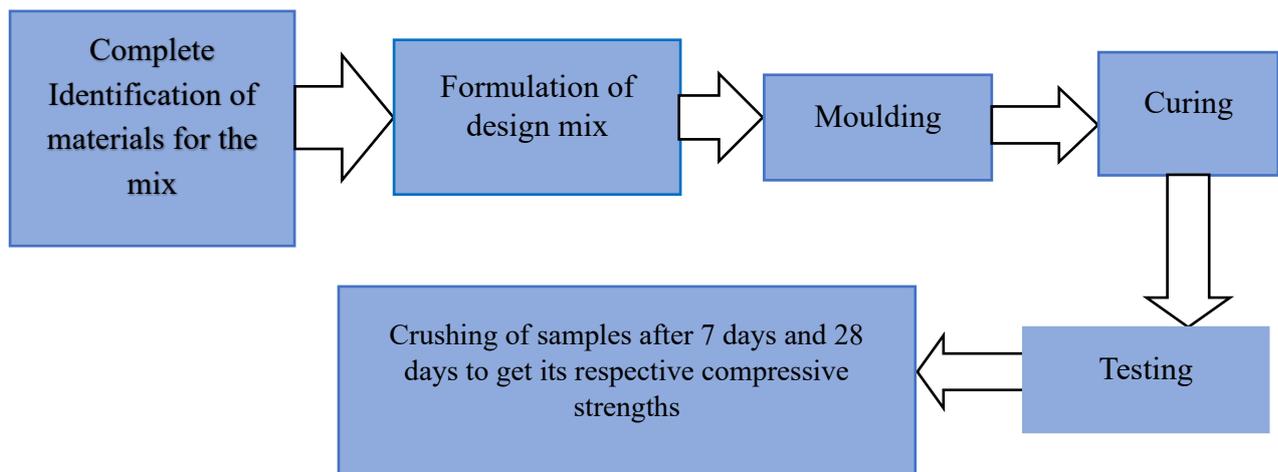


Figure 1: diagram of the major steps carried out in the study

### Preparation of Ash sample

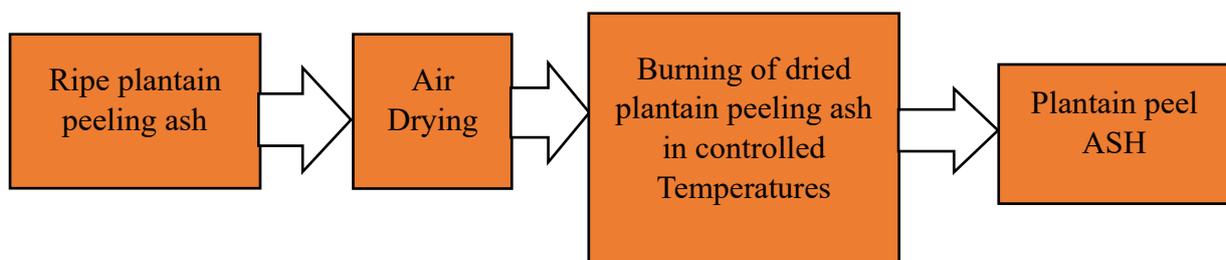


Figure 2: Preparation of Ash sample

## RESULTS

### Physical parameters

The soil had a dusty smell which implies it didn't contain organic material. This type of soil is good for brick production. The soil was not too sharp to touch which implies that the sand content of the soil wasn't too high. Hand washing revealed that the soil was not sticky and washed off easily indicating the presence of gravel, sand and/or silt content. Summary of soil test results.

Table 1: Results for sieve analysis of soil

INITIAL HUMID WEIGHT OF SAMPLE	1150g
DRY WEIGHT OF SAMPLE	1000g



Table 2: Sieve Analysis Results

MODULE AFNOR	SIEVES (mm)	CUMM RETAINED WT	% RETAINED	% PASSING
50	80			
49	63			
48	50			
47	40			
46	31.5			
45	25	21.00	2.1	97.9
44	20	71.11	7.11	92.9
43	16	102.73	10.27	89.7
42	12.5	140.03	14.00	86.0
41	10	170.51	17.05	82.9
40	8	176.36	17.64	82.4
38	5	377.26	37.73	62.3
35	2.5	422.44	42.24	57.8
34	2	517.11	51.71	48.3
32	1.2	561.75	56.18	43.8
31	1	641.39	64.14	35.9
29	0.6	679.94	68.00	32.0
28	0.5	838.89	83.89	16.1
26	0.4	851.89	85.19	14.81
24	0.2	868.11	86.81	13.2
23	0.16	884.77	88.48	11.5
20	0.08	982.01	98.20	1.8

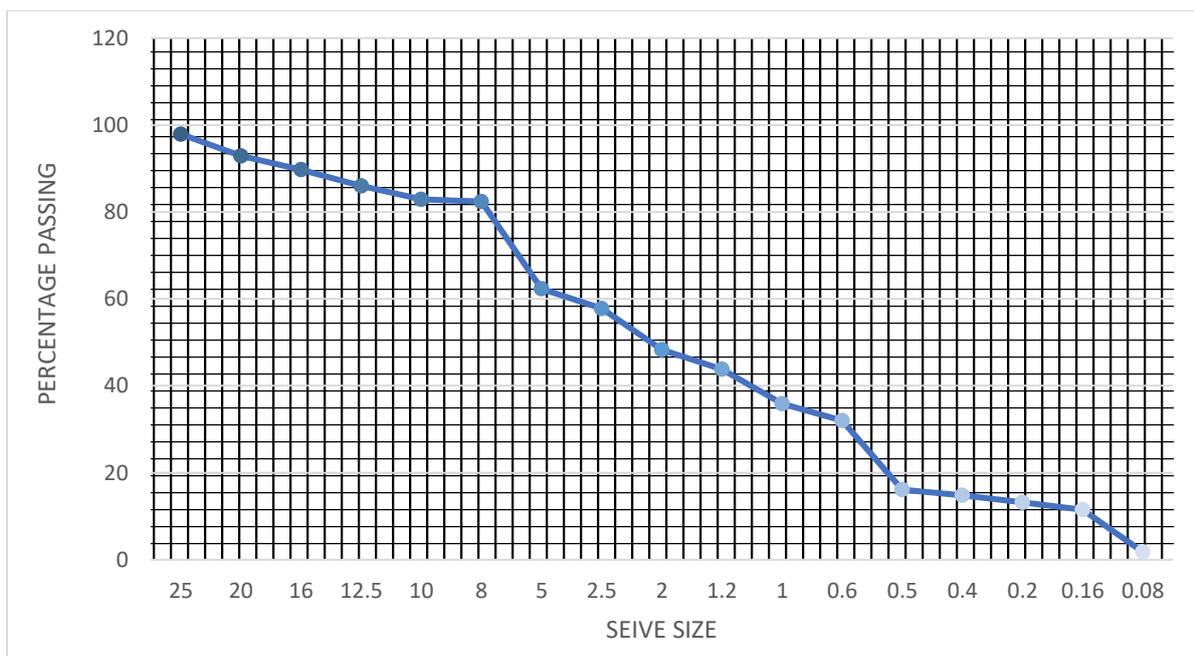
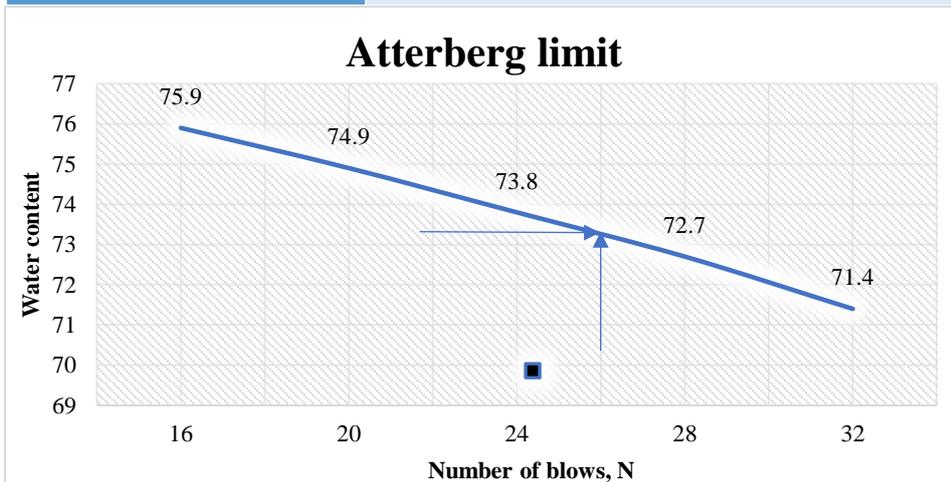


Figure 3: Sieve Analysis curve of soil sample



**Table 3: Liquid Limit determination**

Number of blows	16	20	24	28	32
Can N°	K	Y	A5	F	J1
Total Humid Weight	22.04	24.67	20.83	20.05	19.94
Total Dry Weight	20.31	23.28	19.57	19.08	19.16
Weight of Water	1.73	1.39	1.26	0.97	0.78
Weight of Can	18.03	21.43	17.86	17.75	18.07
Dry Weight of soil	2.28	1.85	1.71	1.33	1.09
Water content (%)	75.9	74.9	73.8	72.7	71.4
<b>LIQUID LIMIT</b>	<b>73.2</b>				



**Figure 4: Atterberg limit graph of soil sample**

**Analysis of the Proctor test**

**Table 4: Water content determination**

Can Number	X1	18	A1	C1	24	29	M	87
Total Weight	200	200	200	200	200	200	200	200
Dry Weight	178.02	177.94	174.5	173.2	171.71	172.01	170.15	169.45
Weight of can	21.89	25.79	29.55	28.58	25.94	25.69	31.33	25.51



<b>Mass of Water (Mw)</b>	21.98	22.06	25.5	24.80	28.26	27.99	29.85	30.58
<b>Mass of soil (Ms)</b>	146.13	152.15	144.15	146.62	145.8	146.32	138.82	143.91
<b>Moisture content (%)</b>	15.0	14.9	17.6	16.9	19.4	19.1	21.5	21.2
<b>Average</b>	<b>15.0</b>		<b>17.3</b>		<b>19.3</b>		<b>21.4</b>	

Table 5: Dry density determination

<b>Mould Number</b>	<b>09</b>	<b>09</b>	<b>09</b>	<b>09</b>
<b>Total Weight</b>	7200	7560	7900	7820
<b>Weight of Mould</b>	3420	3420	3420	3420
<b>Weight of soil</b>	3780	4140	4480	4400
<b>Volume of Mould</b>	2262	2262	2262	2262
<b>Humid density of soil</b>	1.671	1.830	1.981	1.945
<b>Dry density of soil</b>	<b>1.453</b>	<b>1.560</b>	<b>1.661</b>	<b>1.602</b>

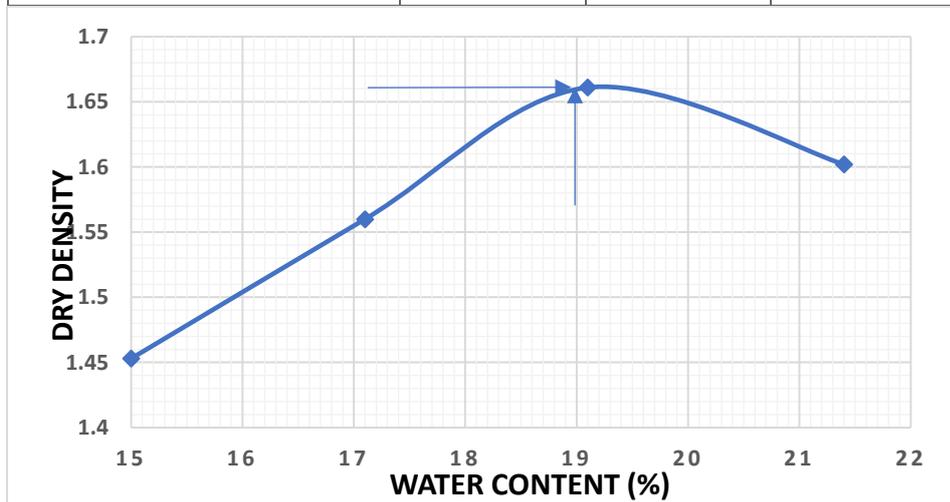


Figure 3.5: Proctor curve of soil sample

Optimum Moisture Content = **18.9 %**

Maximum Dry Density = **1.668g/cm<sup>3</sup>**

**Table 6: Summary of Laboratory test results**

<b>Specific Gravity</b>	<b>2.30</b>
<b>Liquid Limit</b>	73.2
<b>Plastic Limit</b>	31.0
<b>Plasticity Index</b>	42.2
<b>Soil PH</b>	6.95
<b>Optimum moisture content</b>	18.9%
<b>Maximum dry density</b>	1.668g/cm <sup>3</sup>
<b>Type of soil</b>	Clayey soil

Evaluation of Compressive strength of CSEB

### 3.2.1 Analysis of the compressive strength

Table 7: water absorption for CSEBs stabilized with cement 7days of curing

%	Dry Weight (M1) g	Wet Weight (M2) g	Water absorption
5	14000.24	15845.96	12.47
10	16045.35	16125.48	16.86
20	15578.44	16956.54	21.21
30	16556.08	17145.15	25.35
40	16458.11	17458.11	27.00
50	17640.22	18000.20	29.30

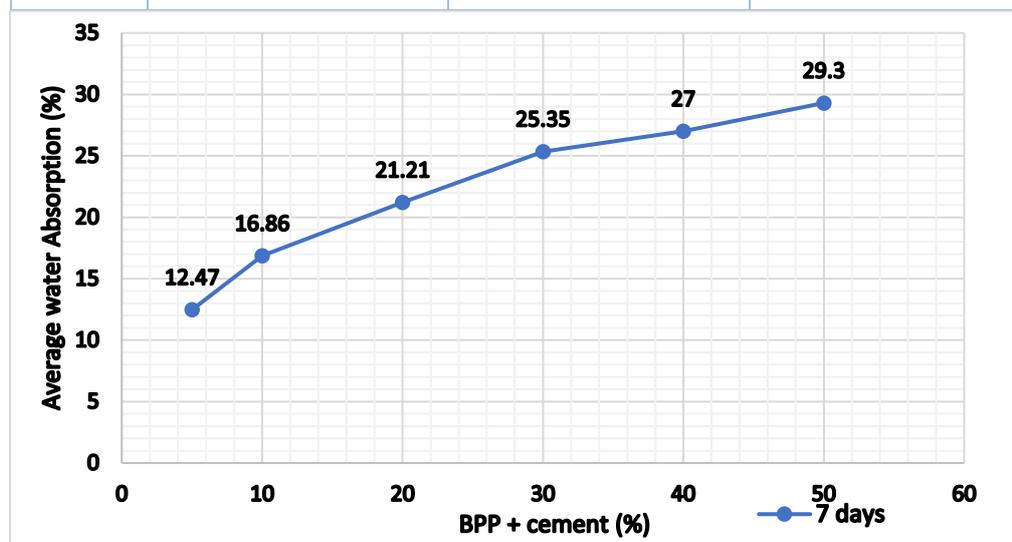


Figure 6: Water Absorption curve



### Analysis of the compressive strength

Table 7: Compressive strength of blocks with cement after 7days of curing

Cement (%)	Force (kN)	Compressive strength (MPa)	Average Compressive strength (MPa)
<b>0</b>	10.05	0.24	0.29
	14.77	0.33	
<b>2</b>	24.46	0.64	0.55
	23.33	0.47	
<b>4</b>	30.78	0.64	0.68
	31.22	0.71	
<b>6</b>	34.43	0.78	0.77
	34.33	0.76	
<b>8</b>	28.00	0.69	0.62
	27.55	0.68	
<b>10</b>	22.60	0.60	0.50
	20.50	0.45	

Table 3.8: Compressive strength of blocks with cement after 28 days of curing

Cement (%)	Force (KN)	Compressive strength (MPa)	Average Compressive strength (MPa)
<b>0</b>	10.05	0.64	0.67
	14.77	0.70	
<b>2</b>	24.46	0.94	0.99
	23.33	1.50	
<b>4</b>	30.78	1.41	1.52
	31.22	1.61	
<b>6</b>	34.43	2.62	2.59
	34.33	2.58	
<b>8</b>	28.00	1.45	1.40
	27.55	1.30	
<b>10</b>	22.60	0.9	1.0
	20.50	1.10	

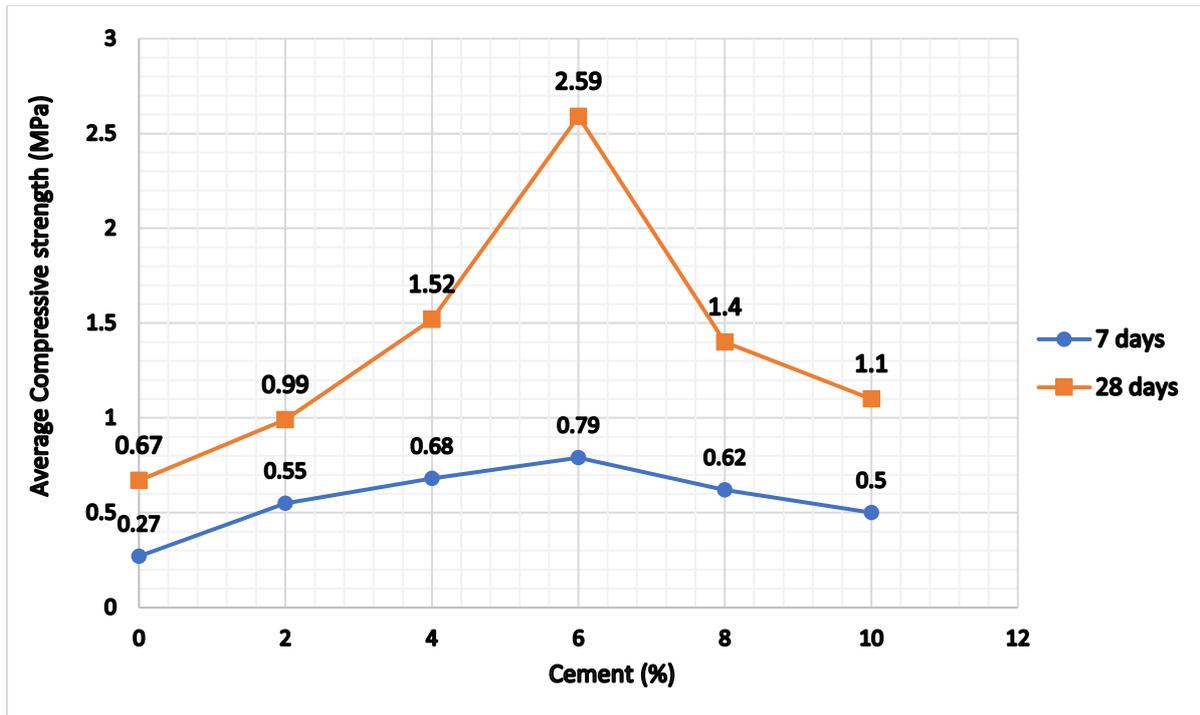


Figure 7: compressive strength chart for cement

Table 9: Compressive strength of blocks with BPP after 7days of curing

BPP (%)	Force (KN)	Compressive strength (MPa)	Average Compressive strength (MPa)
0	10.05	0.24	0.27
	14.75	0.30	
2	14.28	0.35	0.33
	14.10	0.30	
4	14.65	0.45	0.35
	14.22	0.26	
6	16.50	0.57	0.37
	15.78	0.21	
8	20.5	0.45	0.45
	21.6	0.47	
10	14.28	0.32	0.32
	14.77	0.33	



Table 10: Compressive strength of blocks with BPP after 28days of curing

BPP (%)	Force (KN)	Compressive strength (MPa)	Average Compressive strength (MPa)
0	21.60	0.47	0.57
	23.54	0.66	
2	14.28	0.84	0.82
	14.10	0.80	
4	14.65	0.89	0.88
	14.22	0.86	
6	16.50	0.88	0.90
	15.78	0.93	
8	20.5	1.32	1.30
	21.6	1.28	
10	14.28	1.10	0.71
	14.77	0.95	

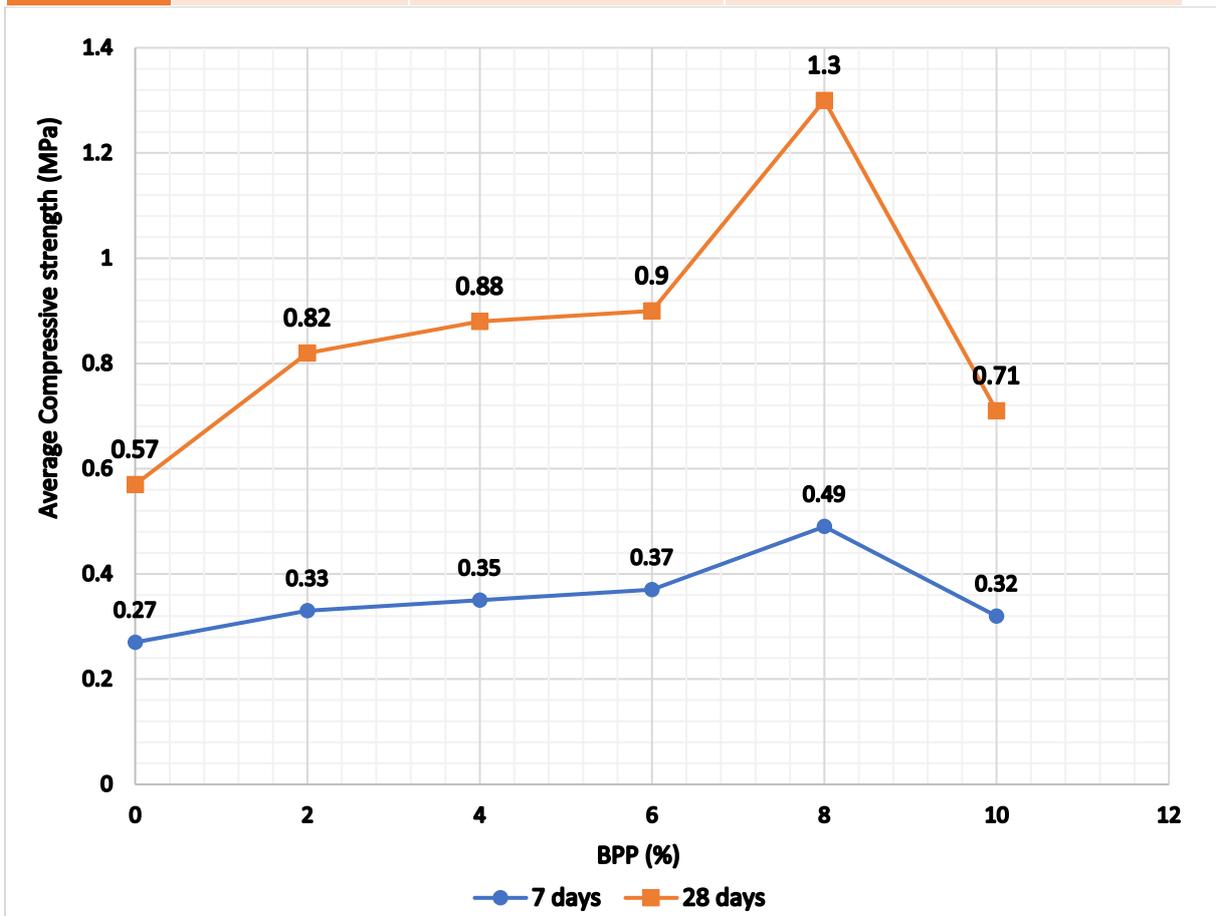


Figure 8: Compressive strength chart for PPA



Table 11: Compressive strength of blocks with BPP and cement after 7 days of curing

BPP (%)	Force (KN)	Compressive strength (MPa)	Average Compressive strength (MPa)
5	33.53	0.75	0.73
	31.74	0.71	
10	15.90	0.60	0.62
	28.61	0.64	
20	25.48	0.57	0.59
	27.27	0.61	
30	25.04	0.56	0.54
	23.25	0.52	
40	22.35	0.50	0.49
	21.46	0.48	
50	19.22	0.43	0.41
	17.88	0.40	

Table 12: Compressive strength of blocks with PPA and cement after 28days of curing

BPP and cement (%)	Force (KN)	Compressive strength (MPa)	Average Compressive strength (MPa)
5	10.05	2.15	2.21
	14.75	2.25	
10	14.28	1.99	1.93
	14.10	2.01	
20	14.65	1.72	1.74
	14.22	1.76	
30	16.50	1.40	1.47
	15.78	1.54	
40	20.5	1.17	1.21
	21.6	1.24	
50	14.28	1.01	1.16
	14.77	1.21	

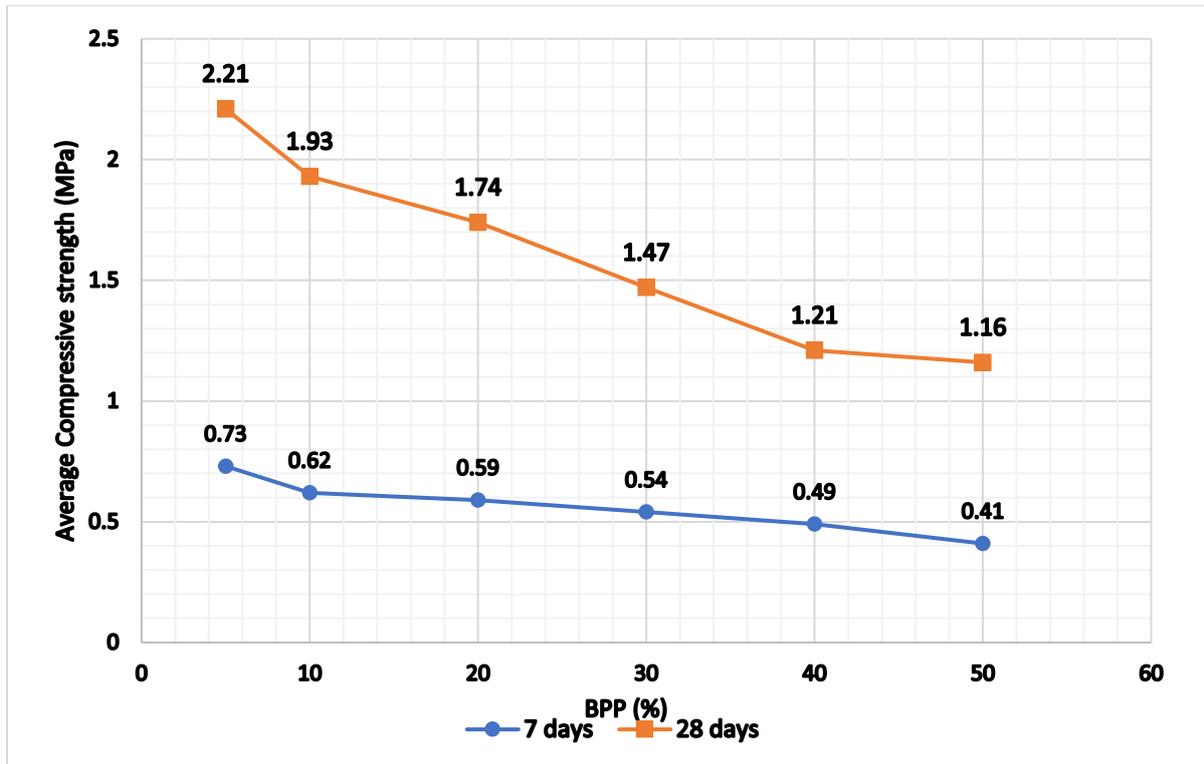


Figure 9: compressive strength chart for BPP and cement

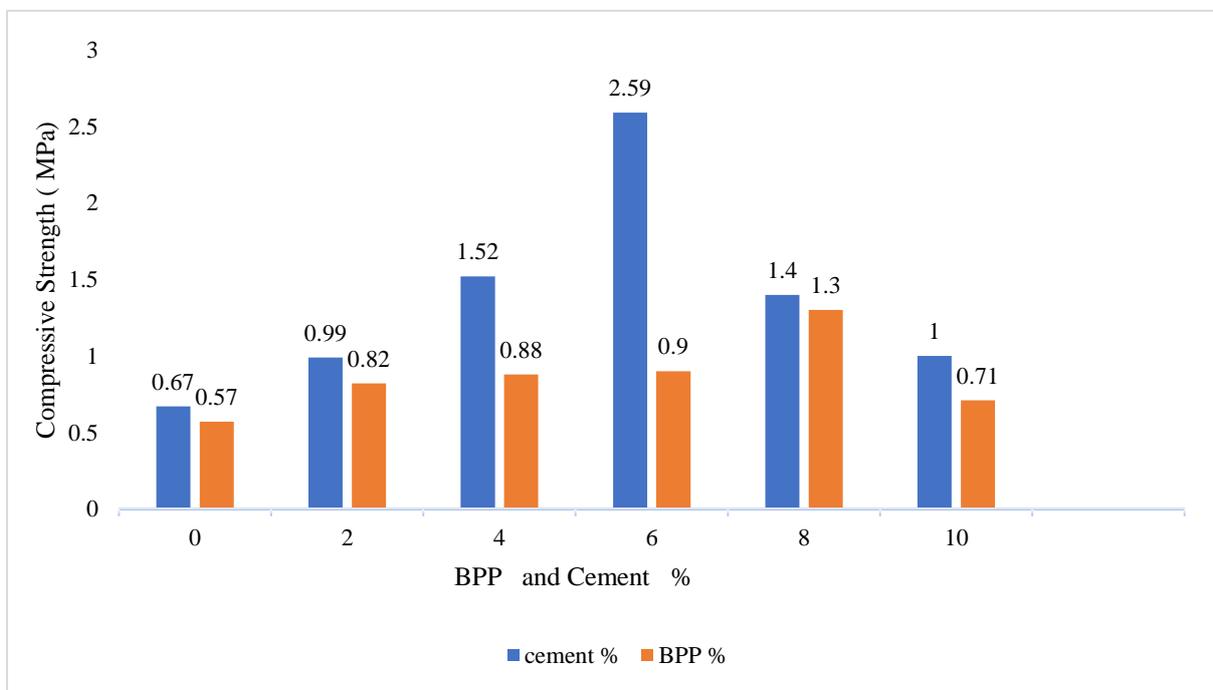


Figure 10: Comparism between compressive strength of CSEBs stabilised with cement and BPP

## DISCUSSIONS

The water absorption rate of the blocks increased as the percentage of ash in the partial replacement increased, from 12.47% at 5% BPP replacement to 16.86% at 10% partial replacement. Hence, the bricks cannot be used to build foundations or retaining walls due to the high percentage of water absorption. The water absorption rate for the blocks is high because of the fact that BPP is hygroscopic. Compared to the work of (P. Walker, 2011), the water absorption values range between 13.4% at the highest clay content and 8.2% at the lowest clay content. Hence the results we got were not appropriate for blocks used in foundation works.

At 6% cement content, we had a maximum compressive strength of 2.59 MPa and the compressive strength decreased at 8% with 1.4 MPa after curing for 28 days. For blocks produced with BPP only, the compressive strength continuous to increase with 8% having a maximum compressive strength of 1.3 MPa and it decreases at 10% with 0.7 MPa. For the compressive strength of the partial replacement of cement with BPP, the strength continuous to decrease with the addition of BPP, with 5% having a maximum compressive strength of 2.2 MPa and it drops to 10% with a compressive strength of 1.93 MPa. Jugal, and Aman, (2018), worked on an experimental investigation on the properties of concrete by partial replacement of cement with Banna leaves Ash, and this investigation proved that banana leaves ash increases the compressive strength of cement and the optimum percentage of cement for partial replacement with banana leave ash is 15%, which gave a compressive strength of 30.13N/mm<sup>2</sup>, contrary to the 8% optimum for earth bricks.

According to Baba S.W., *et al*, (2013), who worked on the stabilisation of earth bricks, at 0%, 2.5%, 5%, and 7% of cement, 5% had a maximum compressive strength at 2.48 MPa, 28 days after curing, which is similar to our findings. Other works on stabilisation of earth bricks at 0%, 2%, 4%, 6%, and 8% had a 6% cement content as maximum compressive strength of 2.32 MPa and the compressive strength decreased at 8% with 0.67 MPa after 28 days. Mbuh, M. K., *et al* (2020a), in an article titled Compressed Stabilized Earth Bricks (CSEB) As Building Construction Elements suggested that CSEB with 5.56% cement stabilisation should be used for thermal comfort because of its resistance to elevated temperatures

Comparing our results to that of these other researchers we will realize that, compressed stabilized earth bricks have compressive strengths between 2MPa to 3MPa after being property cured at room temperature for 28 days. As more ash is added to the quantity of cement stabilizer the compressive strength decreases continuously whereas using only BPP or only cement the compressive strength increases to maximum then decreases.



Table 2: Research process



## CONCLUSION

This research was directed at assessing the extent to which cement could be replaced with BPP, to enhance the mechanical performance of earthen masonry units and how the blocks can be used for sustainable construction. It focused specifically on investigating the influence of incorporating cement and BPP, on the compressive strength of CSEB. The samples of dimension 30x15x12 cm were produced with 0, 2, 4, 6, 8, and 10% cement and BPP dosages by mass. The specimens were tested for compressive strength according to IS Code 3495 part 1. The strength of cement-reinforced CSEBs is influenced by cement type and quantity, soil type, level of compaction of the mixture, curing conditions, and testing procedures. Within the limits of the experimental program used, the main conclusions have been outlined below:

The addition of either cement or BPP increases the compressive strength of the blocks, and too much of the binder tends to decrease the strength of the blocks, but an addition of a partial replacement of the cement with BPP, decreases the compressive strength of CSEBs. This is due to the fact that BPP is acidic and acids generally reduces the strength of cement in concrete hence, the reason why the compressive strength of CSEBs falls with the partial replacement of cement with BPP.

To conclude,

- An addition of cement into CSEBs improves the compressive strength as well BPP.
- A partial replacement of cement with BPP reduces the compressive strength of the bricks.
- BPP equally act as a light weight material in CSEBs as compared to cement.
- The optimum percentage for the total replacement of cement with BPP is 8%
- The optimum percentage for the partial replacement of cement with BPP is 5%

Therefore, an optimum of 5% BPP can be used to partially replace cement in the production of CSEBs and bricks produced as a result of this partial replacement should be used in civil engineering works like partition walls.

### List of Abbreviations

<b>ASTM:</b>	American Society for Testing and Materials
<b>BEGL</b>	Bambuuy Engineering Geotechnical Laboratory
<b>BPP</b>	Burnt Plantain peeling ash
<b>CSEBs:</b>	Compressed Stabilized Earth Bricks
<b>CTM:</b>	Compression Testing Machine
<b>MPa:</b>	Mega Pascal



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