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Evaluating the effectiveness of Corncob Ash as a replacement of Cement in stabilising Lateritic Blocks

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Abstract: *Unstabilised lateritic blocks are low in compressive strength and dimensional stability. There is need to improve the quality of the blocks before utilisation. Corncob is an agricultural waste the disposal of which is not properly managed, constitutes environmental hazard, but, the ash possesses high binding qualities. Thus, this study evaluated the effectiveness of corncob ash as a stabilising agent in the production of lateritic blocks for building production. Physical and mechanical properties of the blocks were tested. A total of one hundred and five (105) blocks of size 110mmx220mmx70mm were produced. Samples were prepared for 0%, 30%, 40% and 50% separately for corncob ash and cement stabilisation. Compaction, Water Absorption and Compressive strength tests were conducted. An Optimum Moisture Content of 12.9% was achieved at the maximum dry density of 2.09 g/cm^3. At 40% cement and 50% corncob ash addition to laterite, the water absorption results were 7.8% and 7.7% respectively. At 50% corncob ash addition, the day 7 compressive strength of the block was 1.90 N/mm^2 which satisfied the requirements of the Nigerian National Building Code specifications.*
Keywords: *Compressive Strength, Corncob ash, lateritic block, National Building Code, Stabilisation.*

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I. Introduction

Materials are essential components of project cost. 55%-65% of total cost of projects is accounted for by materials [1]. Therefore, cheaper local building materials of acceptable quality standard and availablility in sufficient quantities could significantly reduce the ultimate building project's cost. Sandcrete block is a major building component used in large quantity in building production. The National Building Code [2] prescribed a Cement to Sand mix ratio of 1:6 or 1:4.5 where mixed fine aggregates are used. Cement and Sand attract high prices in the market thereby resulting in the high prices of sandcrete blocks. Cement is a binder of aggregates and the most expensive input in the production of sandcrete blocks [3].

This research investigated alternatives to both materials (cement and sand). Many researchers had studied the chemical properties of Corncob Ash (CCA) and confirmed its appreciable binding quality. Corncob is an agricultural waste the disposal of which is not properly managed and, thus, constitute environmental hazard. Laterite is also available in sufficient quantities spread all over Nigeria and cheaper to procure than other fine aggregates. Stabilising laterite improved its volume stability, strength, permeability and durability [4]. Therefore, lateritic blocks were prepared, stabilised with varying percentages of CCA and their engineering properties studied for suitability as alternative to sandcrete blocks in building production.

II. Literature Review

Corncob is an agricultural material that is hapharzardly disposed especially in Africa which produced about 7% of the World's total maize output [5]. This disposal method presents a serious ecological problem to the processing industries [6]. Therefore, recycling from waste to wealth is imperative to effective management. Empirical analysis [7] confirmed the high Silica content of corncob as well as the binding properties of corncob ash. In construction, laterite is used in the production of Compressed Earth Blocks (CEB) for walls that meet the building requirements for structural performance and that the quality of laterite used for construction purpose could be improved by stabilisation. Untreated laterite blocks lack strength and dimensional stability [8].

The basic guidelines for cement stabilisation were proposed by Walker [9] where a range of 5% - 10% cement additive was recommended for manual pressing to achieve a compressive strength range of 1.0 – 3.0 N/mm^2. The use of mechanical pressing could further improve the quality of compacted soil by increasing the density and hence the compressive strength of the block [10]. However, the Nigerian Industrial Standard [11] specified minimum strength for blocks tested at 28 days is 2.5 N/mm^2. For single storey buildings, 2.76 N/mm^2 will be adequate. Most other recommendations for soil blocks vary from 2.0 N/mm^2 – 3.50 N/mm^2. The National Building Code [2] recommended compressive strength range of 1.70 N/mm^2 – 2.75 N/mm^2 and, also, 1.60 N/mm^2 as suitable only for the construction of one storey building.

III. Materials and Methods

The materials used were sourced locally. They were laterite, cement, corncob and water. The laterite was collected from the borrow pit at the Ministry of Agriculture Quarters, Aba Erifun, Ado-Ekiti. The sample was sundried for seven days and the impurities that could impair the binding were removed before it was pulverised. The corncob samples were collected from the waste dump site also at Aba Erifun. The corncob fibre was pretreated in hot water at 80^0C for one hour to remove the sugar content which is a debonding agent and other impurities which may result in fungi growth. This is in accordance with the recommendations of Forestry Research Institute [12]. The pretreated samples were sundried, crushed and grinded into ash. Ordinary Portland Cement, Dangote brand was used. The cement conformed to NIS [13]. Potable water was obtained from the Soil laboratory of the Civil Engineering Department of the Federal Polytechnic, Ado-Ekiti.

3.1 Preparation of Block Samples:

Manual block moulding machine was used. The molds were oiled and filled to the brim and compacted using 35 blows of a standard rammer weighing 2.5Kg and a fall height of 30cm at a force of 3.0 N/mm^2. The mold has a capacity to produce two blocks size 110mmX220mmX70mm simultaneously. Samples were prepared for 0%, 30%, 40% and 50% corncob ash as stabilisers to the laterite. A total of one hundred and twenty (120) blocks were produced out which one hundred and five (105) were used for tests (35 for Water Absorption; 105 for Compressive Strength). Plates 1, 2 and 3 show corncob during sundrying, corncob ash and lateritic block samples respectively.

Plate 1: Corn Cob during sun drying

Plate 2: Corncob Ash

Plate 3: Lateritic Block samples

3.2 Curing the Blocks:

The blocks were stacked under shade for twenty four (24) hours to minimise cracking. The blocks were covered with polythene sheet after sprinkling with water morning and evening for seven days. All blocks were ensured dry before testing.

IV. Tests

The NIS [14] specified two tests in addition to the appearance and dimensional characteristics for blocks. These are the Compressive Strength and Water Absorption tests. However, the Compaction test was also included to determine the Optimum Moisture Content (OMC) of the laterite sample.

4.1 Compaction test:

This test was carried out on the laterite sample to determine the Optimum Moisture Content (OMC).

Moist Unit Weight, $y = (w_2 - w_1) / 943.895$ g/cm^3…………………………………….(1)

Compaction M.C., $w = (w_4 - w_5)/(w_5 - w_3) \times 100\%$...(2)

Dry Density , $y_d = y/[1+(w\%/100)]$……………………………………………...…(3)

Where

w_1 = weight of mold; g
w_2 = weight of mold + compacted moist soil; g
w_3 = mass of moisture can; g
w_4 = mass of can + moist soil; g
w_5 = mass of moisture can + dry soil; g
y = moist unit weight; g/cc
w = compaction moisture content; %
y_d = Dry unit weight; g/cc

The Optimum Moisture content is the moisture content that corresponds to the maximum dry density.

4.2 Water Absorption Test:

This test evaluated the water absorption capacity variations between cement stabilised blocks and corncob ash stabilised blocks at 0%, 30%, 40% and 50% of additives. Manual Pressing Machine was used. The average Water Absorption was determined from:

W.A. = $[(w_2 - w_1)/w_1] \times 100\%$..(4)

Where;

W.A. = water absorption; %
W_1 = Dried weight; g
W_2 = Soaked weight; g

4.3 Compressive Strength Test:

Seventy (70) 220mmx110mmx70mm blocks were prepared at 35 each for the 7 and 14 day testing. The laterite to binder ratios were: 100:0; 70:30; 60:40 and 50:50 by volume respectively for cement and corncob ash. The crushing test was conducted after proper curing according to BS [15].

$$\text{Compressive Strength} = \frac{\text{load at failure (N)}}{\text{Bearing Area of Block (mm}^2\text{)}}$$

V. Statistical Analysis of Data

Microsoft Excel Spreadsheet and Statistical Packages for Social Sciences (SPSS) were used to analyse the obtained data. The analysis included both descriptive and graphical presentations. The descriptive involved the collation of primary data and presenting them in tabular form while the graphical presentation showed the inter-relationship between the various factors investigated.

VI. Results and analysis

Table 1: Compaction Test Results

Weight of mold; (g) (W_1)	3200	3200	3200	3200	3200
Mold + soil; (g) (W_2)	4700	4800	5000	5200	5100
Weight of compacted moist soil (W_2-W_1); (g)	1500	1600	1800	2000	1900
Volume of mold (1/30ft^3) 943.895cm^3	943.895	943.895	943.895	943.895	943.895
Moist unit weight, y,(g/cm^3)	1.589	1.695	1.907	2.119	2.013
Can Nos.	GG	V	E	Dd	T
Can weight (g); w_3	22.3	24.4	23.4	20.2	23.0
Wt of can + wet soil (g); w_4	68.6	56.4	45.3	85.1	64.5
Wt of can + dry soil (g); w_5	66.4	54.4	43.0	77.7	58.6
Weight of water (g); (w_4-w_5)	2.2	2.0	2.3	7.4	5.9
Wt of dry soil (g); (w_5-w_3)	44.1	30	19.6	57.5	35.6
Compaction Moisture content, w, (%)	***5.0***	***6.7***	***11.7***	***12.9***	***16.6***
Dry density, y_d	***1.51***	***1.59***	***1.88***	***2.09***	***1.98***

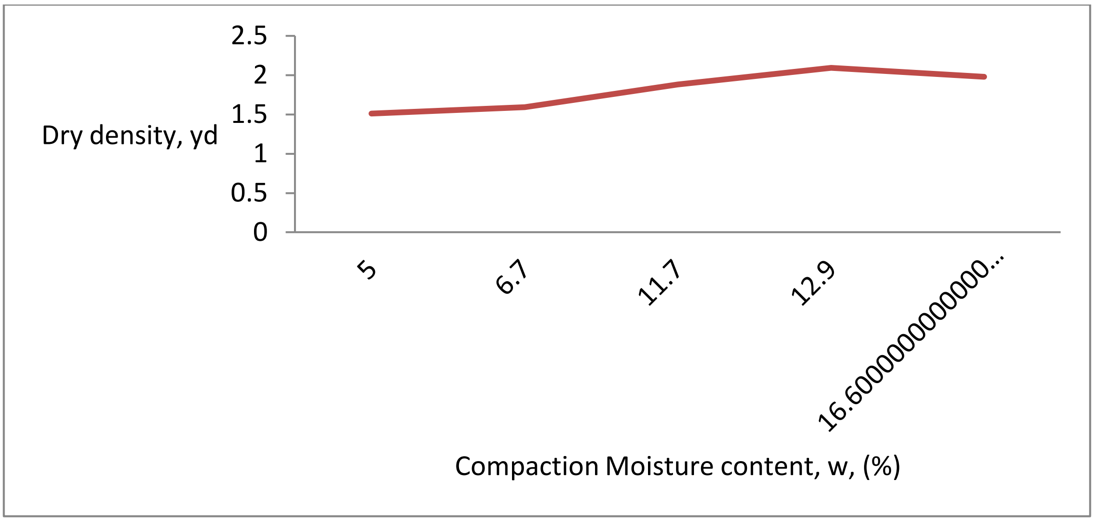

Fig.1 shows the determination of the Optimum Moisture Content (OMC).

Table 2: Water Absorption results for stabilized laterite blocks

% Binder	Binder:Laterite (%)	Binder	W_1 (g)	W_2 (g)	W_2-W_1 (g)	W.A. (%)
0	0:100	Nil	2.24	2.68	0.44	19.6
30	***30:70***	***CCA***	***2.42***	***2.71***	***0.34***	***10.3***
		CEMENT	2.66	2.91	0.25	9.4
40	***40:60***	***CCA***	***2.64***	***2.89***	***0.25***	***9.5***
		CEMENT	2.68	2.89	0.21	7.8
50	***50:50***	***CCA***	***2.72***	***2.93***	***0.21***	***7.7***
		CEMENT	3.25	3.43	0.18	5.5

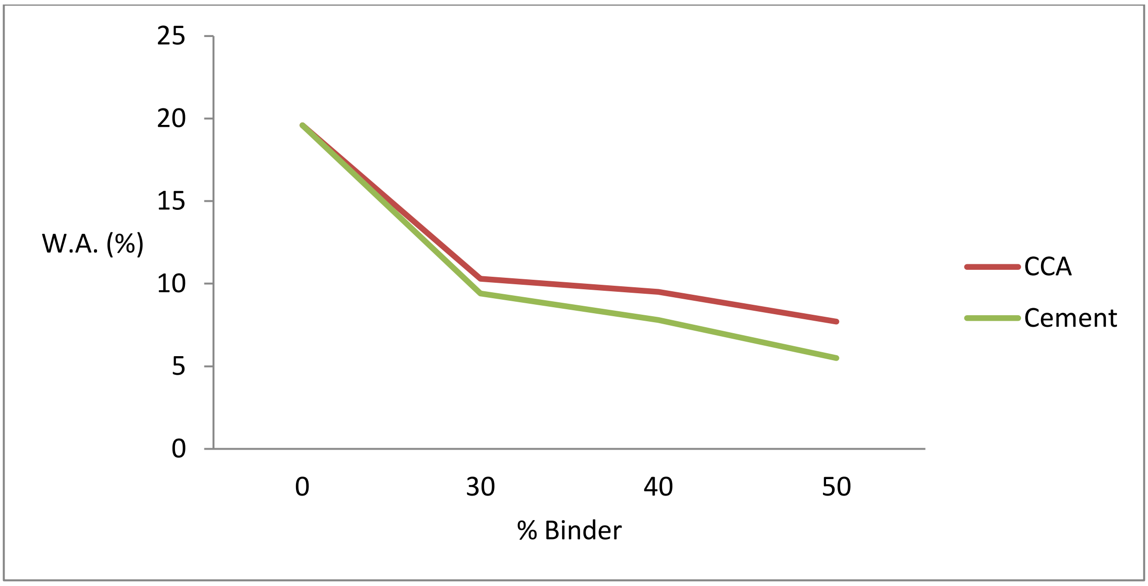

Fig. 2: Variations in Water Absorption by laterite blocks using Corncob Ash and Cement as additives

The corncob Ash stabilised laterite blocks absorbs more water than the ones stabilised with cement. Though, the cement stabilisation is expectedly more efficient, both additives played significant roles in reducing the tendency to water absorption of the blocks. The rate of absorption reduced with increased percentage of the additives.

Table 3: Compressive Strength test results for days 7 and 14 curing

Day	Binder:Laterite (%)	Binder	Weight (Kg)	Failure Load (KN)	Compressive Strength (N/mm^2)
7	0:100	Nil	2.16	8.0	0.33
	30:70	***CCA***	***3.2***	***25***	***1.03***
		Cement	3.6	30	1.24
	40:60	***CCA***	***3.8***	***35***	***1.45***
		Cement	4.2	60	2.48
	50:50	***CCA***	***4.1***	***46***	***1.90***
		Cement	4.6	70	2.89
14	0:100	Nil	2.24	9.0	0.37
	30:70	***CCA***	***2.8***	***40***	***1.65***
		Cement	3.1	40	1.65
	40:60	***CCA***	***3.2***	***50***	***2.07***
		Cement	3.6	60	2.48
	50:50	***CCA***	***3.7***	***70***	***2.89***
		Cement	4.0	80	3.31

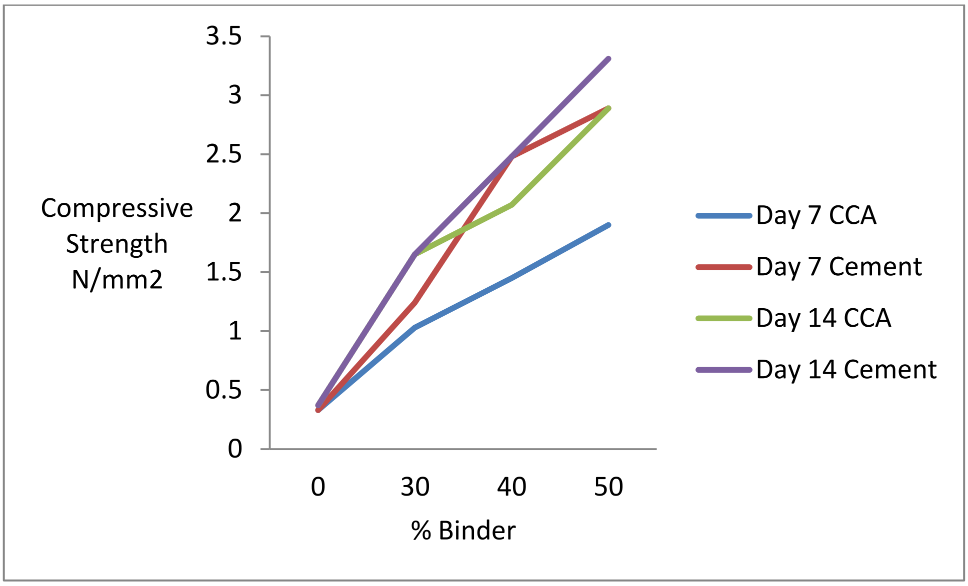

Fig. 3: graph of compressive strength against days

VII. Discussions of Findings

7.1 Compaction test results:

As shown in figure 1, the maximum dry unit weight of 2.09 g/cc was achieved at a Moisture Content of 12.9%; thus, indicating an Optimum Moisture Content (OMC) to ensure zero void in the soil. This was used as the water: corncob ash ratio in mixing the stabilised blocks.

7.2 Water absorption test results:

Rising dampness is a serious problem caused especially through the action of capillarity of underground water and driving rain effect. The rate of water absorption of aggregates influences the bond between aggregates and the additives paste, resistance of concrete to freezing and thawing, chemical stability, resistance to abrasion and the specific gravity [16]. It is, thus, important to ensure that materials susceptible to water ingress be of low water absorption capacity. This is especially true for blocks in the blockwalls. It was observed that blocks with nil percentage of binder had an average of 19.6% water absorption compared with blocks stabilised with binders. The degree of resistance to water absorption increased with the increment of the percentage of the binders. Though better results were obtained with cement, acceptable results were also obtained with corncob ash as the variations in results were considerably low. Almost equal results were obtained with 40% addition of cement and 50% addition of Corncob Ash with results standing at 7.8% and 7.7% respectively.

7.3 Compressive strength test results:

Lateritic block with zero binder had low compressive strength at 0.33 N/mm^2 after 7 day curing and 0.37 N/mm^2 on day 14. However, when binders were added, the blocks developed strength that increased with the percentage content of binder as well as the binder type. At 40% binder addition and at age 7says, Corncob Ash stabilised had a compressive strength of 1.45 N/mm^2 which is lower than the minimum 1.67 N/mm^2 that the

National Building Code specified for single storey buildings. Cement stabilisation satisfied this requirement having developed 2.48 N/mm^2 compressive strength at day 7. At 50% Corncob Ash addition also on day 7, 1.90 N/mm^2 strength was developed. On day 14, both Corncob Ash and Cement stabilised lateritic blocks satisfied the strength requirements using 40:60 binder:laterite ratio reaching 2.07 N/mm^2 and 2.48 N/mm^2 respectively thereby falling within the range of 1.70 N/mm^2 and 2.75 N/mm^2 which is the general specification by the National Building Code.

Because the cost of materials is an essential component of building construction as it constituted between 55% and 60% of the total building completion cost, it is important to consider cost at evaluating the significance of this research findings. A 50Kg bag of Dangote cement costs about N2750.00 whereas corncob ash could be produced at a considerably lower cost due to its availability as wastes in our environment. Therefore, as observed, a 50:50 corncob ash:laterite that had been tested adequate for compressive strength requirements at day 7 is cheaper and more affordable than the 40:60 cement:laterite ratio of near equal value.

VIII. Conclusions

1. A moisture content 12.9% was the optimum required in order to ensure zero void in the soil sample.
2. At 50:50 corncob ash:laterite ratio and 12.9% optimum moisture content, a water:corncob ash ratio of 0.4 was adequate.
3. Both cement and corncob ash have good binding properties and as their percentages increased, the water absorption capacity of the stabilised blocks reduced considerably and the compressive strength increased.
4. Water absorption and compressive strength properties attained at 40% cement addition were nearly achieved at 50% addition of corncob ash.

IX. Recommendations

1. The use of corncob ash to stabilise lateritic blocks should be encouraged due to its physical and mechanical properties and affordability for low cost housing schemes.
2. It could be adopted as an indirect means of managing corncob as an item of solid waste in the country. No special budget is required as corncob will automatically become an article of trade.
3. It will stimulate the growth of the Micro/Small Scale Enterprises that will involve in the processing of corncob to corncob ash for use by the Block industry.
4. It will generate employment for a mass of the unemployed who will move round to collect them for sale to the factories that demand them.

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