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Performance of Compressed Earth Brick in Comparison With the Prevailing Sand-Cement Wall Construction in Nigeria

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Abstract: **The construction industry in Nigeria is dominated by the use of cement. The decades of dominance has created an attachment to sand-cement walls with a negative impact on alternative wall materials. The impact on earth is particularly fierce as it is further regarded as cheap, weak and obsolete. This research is aimed at the assessment of the performance of compressed earth wall in comparison with the common sand-cement block wall. Basic engineering tests were conducted on the common mixes of specimens of sand-cement block, mortar and plaster. The tests which were directed towards issues of public concern include the compressive strength, water absorption, durability/surface erosion tests. The results of 8 percent cement stabilisation of Aviele laterite soil were compressive strength of 10.3N/mm^2 and coefficient of water absorption of 9 [kg/(N^2 x min)]; while Sand-Cement block of ratio 1:4:2 gave a strength of 8.2N/mm^2 and coefficient of water absorption of 5.3 [kg/(N^2 x min)]. A surface abrasion test of 10 per cent cement stabilisation of earth, gave an impressive performance higher than sand-cement block. This investigation is a part of an on-going research in the development of Compressed Earth Block.**

Keywords: **Compressed Earth, Performance, Acceptability, Durability, Sustainability.**

I. INTRODUCTION

Cement is used in the construction of over 95 per cent of private and public buildngs in Nigeria [1]. The compressed earth block wall is rarely adopted for housing development in urban areas of Nigeria [2]. Surveys conducted in Nigeria revealed that though earth construction is sustainable, majority of developers are sceptical of the long term performance in the tropical climatic conditions [3], [4]. The ability of earth walls to resist wear due to weather is improved when stabilised by cement [5], [6]. It is expected that with adequate stabilisation of earth a comparable performance can be achieved in addition to the sustainable properties of earth. The choice or modification of soil is also relevant in this regard as cement is more suitable for soil with less clay content, while lime is more appropriate with a clayey soil [7]. However due to non-availability of lime in Nigeria, cement is regarded as the only stabilising agent.

The aim of this research is to assess the performance of earth in comparison with the sand-cement block wall, which is so trusted by users over the years. The achievement of durable and wear resistant wall using earth construction will motivate developers who have long relegated earth to resume the use of what was once the main wall construction material in Africa. This paper examines the durability issues in earth construction in comparison with the prevailing sand-cement mixes for vibrated blocks and mortar/rendering in Nigeria.

II. MATERIALS AND METHODS

The earth selected for this experiment was Aviele laterite Soil [2]. Compressed earth blocks were produced with an improvised laboratory kit of suspended mould and hand hydraulic jack of considerable and consistent pressure [8]. The earth blocks were produced with cement content varied from 0 to 12 per cent. Specimens were cured for the first seven (7) days in sealed polythene bags; and then air-dried at ambient room temperature of 20 ± 18^{o}C and maximum relative humidity of 60 ±5% until the 28th day to achieve maximum performance. Drying to constant mass is always in a ventilated oven at 75^{o}C; after which specimens are allowed to cool to ambient room temperature. Sand-cement cubes were

produced with the Nigerians' common mix for vibrated block of 1:4:8 (one part of cement to four parts of fine sand and eight parts of coarse river sand). Cubes were also cast of the common mix for mortar and plaster of ratio 1:4:2 (one part of cement to four parts of fine sand and two parts of coarse river sand). The compressive strength after 28 days was taken as control and basis for comparison. Tests conducted include Compressive strength test, Water absorption by capillary action, Wet and Dry abrasion and Drip test.

Compressive strength test was conducted in accordance with BS EN 772-1:2011**.** Specimens were placed on a supportive steel block in the lower platen. This lifted the block within the ambient range of operation of the compressive machine. The specimens were also placed in an orientation where the bed faces of the block rested on the platen; which was the same orientation of the compaction pressure during block production. The normalised compressive strength, $f_{b,}$ was obtained by multiplying the air-dry compressive strength reading with a shape factor, d, of 0.9 for the laboratory specimens' width of 100mm and height of 75mm [9]. The test was to determine the rate of water absorption of shelled compressed earth block with increase in percentage of cement stabilization of the shell in accordance with BS EN 772-11:2011 [10].

Wet and dry abrasion test was conducted in accordance with ASTM D559, 1989 [11]. A stiff wire brush made of 50 of 1.6mm flat 26-gauge wire bristles assembled in 50 groups of 10 and mounted to form 5 longitudinal and 10transverse rows is used to brush the blocks surface in a straight stroke. Two firm strokes were applied to the whole block surfaces. Block specimens were then submerged in water for a period of five hours after which they are returned to the oven all in a circle of 24 hours. The process is repeated for a total of 12 cycles of wetting, drying and brushing. A final mass reading is taken.

Durability was also assessed by subjecting the conditioned block specimens to a simulation of rain of continuous downfall [12]. Jets of water released from a height of 3 metres 'impacted' on samples at vertical angle of 15 degrees for a period of 6 hours a day for 7 days. The repeated exposure was intended to reveal an appreciable erosion. The specimens were dried, at the end of the 7 days test, to constant mass with ventilated oven at 75^{o}C. The average dry weights of each set before the simulated rain test were recorded against the average dry weights after test and the differences were taken as the eroded mass.

III. RESULTS AND DISCUSSIONS

The compressive strength test results (Figure 1) shows that the sand-cement mix for block (1:4:8) which constitutes the bulk weight of Nigerian wall is weaker than soil of 3 per cent cement stabilisation. However, the mortar and rendering mix of ratio 1:4:2 had a higher compressive strength of 8.4 N/mm^2. The stabilised earth displayed an impressive compressive strength ranging from 3.74 N/mm^2 for 3 per cent cement stabilisation to 16.49 N/mm^2 for 12 per cent cement stabilisation. The 8 per cent cement stabilisation gives a higher compressive strength than the rendering and mortar mix of sand-cement.

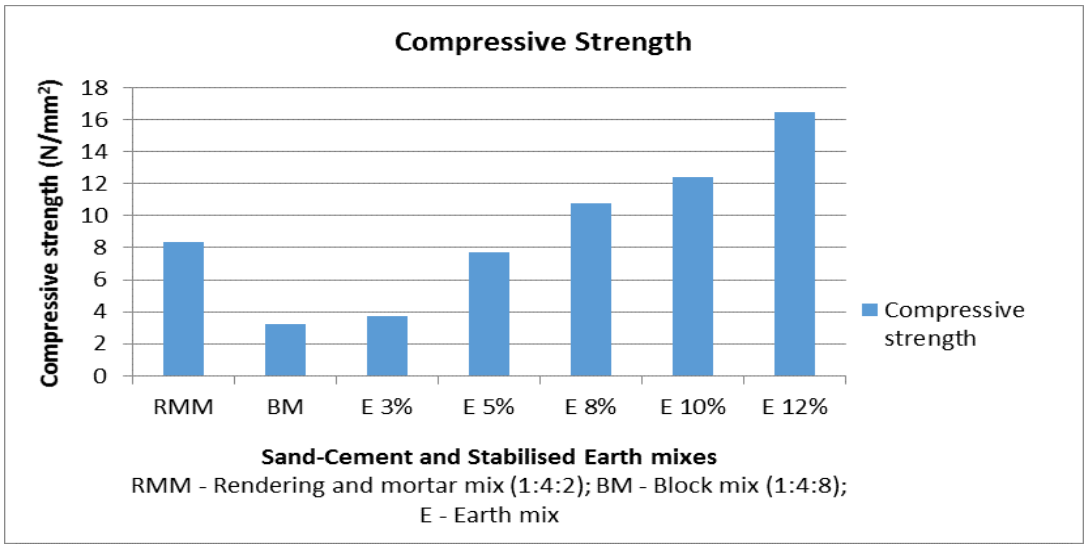
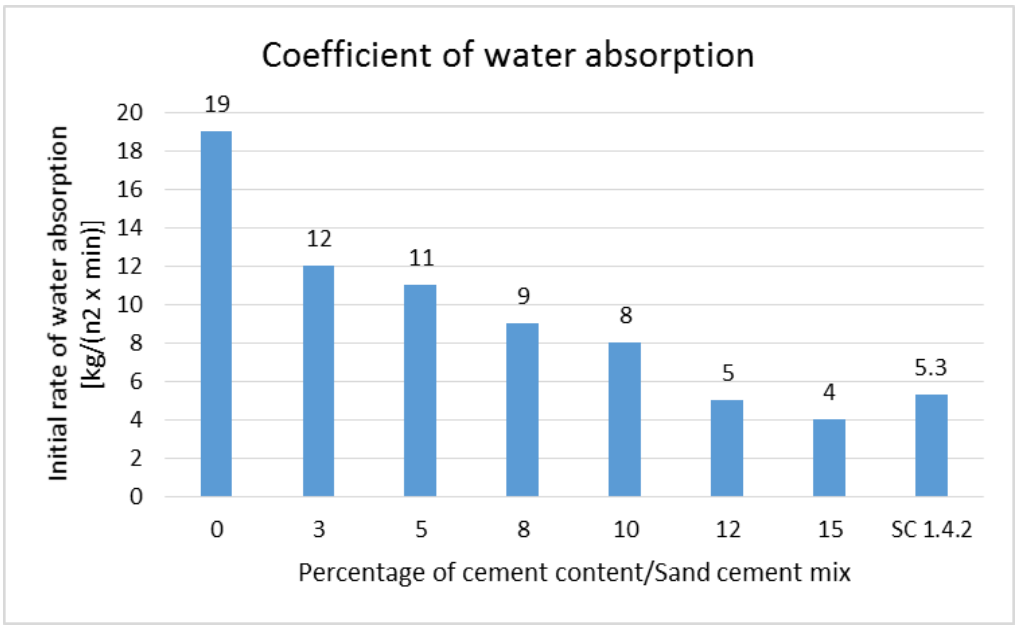


Fig. 1: Comparative result of compressive strength of common sand-cement block and mortar mix in Nigeria with earth of varied cement content

The results of water absorption by capillary action revealed a proportional reduction in water absorption with increase in cement content as shown in Figure 2. The sand-cement block has a coefficient of water absorption comparable to compressed earth block of 12 per cent cement content in Aviele laterite soil.



SC 1.4.2 – Sand Cement block of mix ratio 1.4.2

Fig. 2 Initial rate of water absorption for different percentages of cement content

The results of the Drip test show that sand-cement specimens and compressed earth block specimens of 5 to 12 per cent did not erode after 6 hours of simulated rainfall. The 0 per cent (unstabilised) block eroded considerably while 1 to 3 per cent cement stabilisation eroded less as shown in Figure 3.

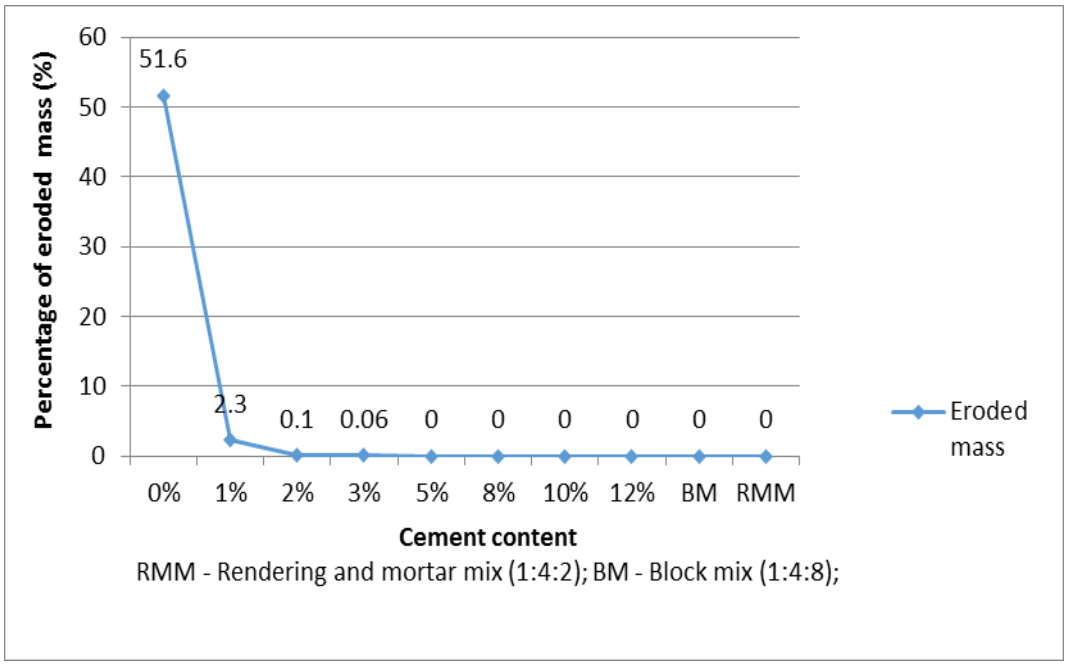


Fig. 3: Drip test chart shows eroded mass as percentage of dry mass of blocks.

The drip test is apparently not effective enough to reveal surface resistance characteristics of blocks with appreciable cement content. A more rigorous test is the wet and dry abrasion with results shown in Figure 4. The percentage mass loss decreased with increase in cement content. The surface resistance of sand-cement of mix ratio 1.4.2 is comparable with compressed earth block of 8 per cent cement content in Aviele laterite soil.

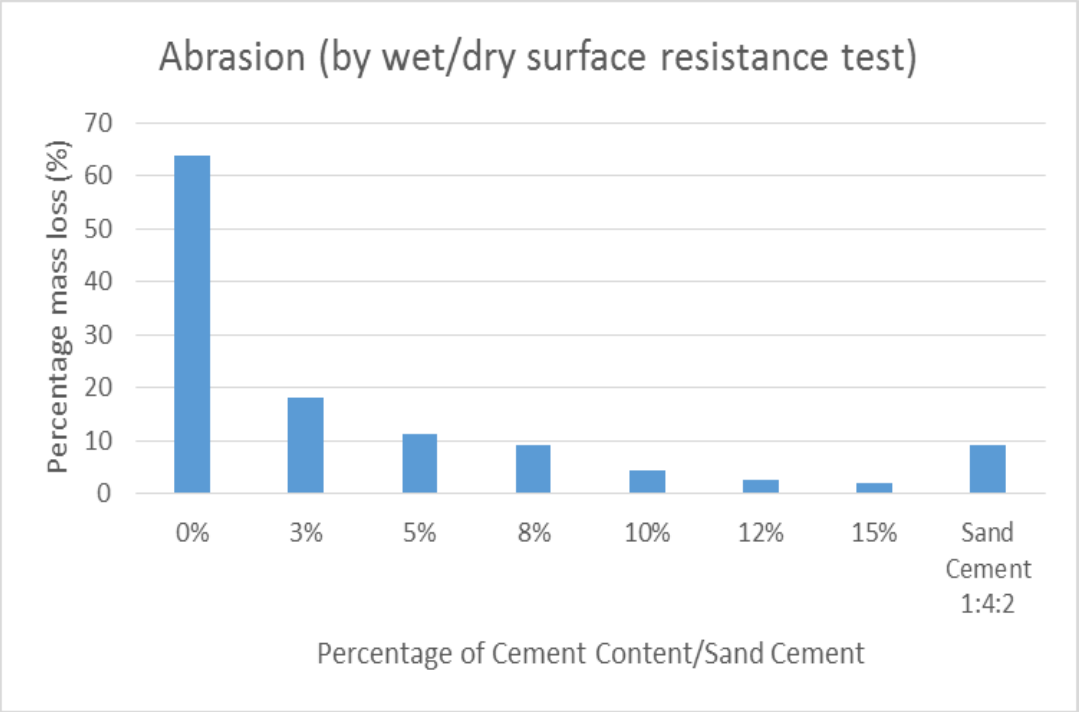


Fig. 3 Showing percentage mass loss from compressed earth blocks of different cement content in comparison with sand-cement block

The combined results of drip test and wet/dry abrasion tests are summarised in Table I.

TABLE I - RESULTS OF SURFACE RESISTANCE TESTS

% Cement content in CEB specimens and ratio of Sand cement specimen	% Loss by Abrasion Test		% Loss by Drip Test	
	Aviele laterite soil (%)	Sand cement block (%)	Aviele laterite soil	Sand cement block (%)
0 %	63.9		Dis-integrated	
3 %	18.2		30.5	
5%	11.4		5	
8%	9.1		0	
10%	4.35		0	
12%	2.46		0	
15%	1.87		0	
Sand Cement (1:4:2)		9.32		0

IV. CONCLUSION

The assessment is of compressed earth of varied cement content, in comparison with the sand-cement mixes for vibrated blocks and mortar/rendering commonly adopted in Nigeria. Basic durability tests were conducted to ascertain performance, which is the contention of many Nigerian against earth construction. The result of the experimental research revealed that Compressed Earth Block produced with 8 per cent cement content in Aviele laterite soil, compares favourably in performance with sand-cement block of high ratio of 1.4.2. A compressed earth brick wall is capable of exhibiting higher performance than sand-cement block wall when adequately stabilised. These capabilities combine the numerous sustainable advantages of 'earth'.

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