Open Access Journal

Journal of Sustainable Research in Engineering Vol. 2 (4) 2015, 121-126

Journal homepage: www.jkuat-sri.com/ojs/index.php/sri/index

Characteristics of Earth Blocks Stabilized With Rice Husk Ash and Cement

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Abstract For construction purposes, soil is usually stabilized using lime and/or cement, both of which are expensive. This study investigated the feasibility of using Rice Husk Ash (RHA) as a partial replacement of cement in the stabilization of black cotton soil (clay soil) for the production of compressed earth blocks. The soil used in this study was excavated from a construction site in Juja. RHA was collected from rice mills in Mwea, where RHA is produced through open fire burning of rice husks. Particle size distribution, Atterberg limits, Standard Proctor Compaction and compressive strength tests were carried out according to British standard procedures. The soil used was classified as A-7-5 in the AASHTO classification system. Stabilization was done using different quantities of RHA and cement. This study established that to achieve minimum strength of soil blocks (2.5 MPa), soil should be stabilized with at least 5% cement and 7.5% RHA. When the quantity of RHA exceeded 7.5%, the compressive strength went below the 2.5 MPa required by Kenya Bureau of Standard. Nevertheless stabilized blocks are generally not resistant to wetting and should be used in situations where there is minimum wetting. Use of RHA can reduce the cost of producing stabilized blocks by as much as 30%.

Keywords: Stabilize, Soil, Rice Husk Ash, Pozzolanic, Compressive strength

1. Introduction

Sustainable solid waste management enhances maintenance of a healthy, aesthetic, and ecologically sound environment. Most people either dump waste in open spaces or burn it, creating water and air pollution. Waste management involves waste collection, sorting, storage, recycling and disposal [1]. To solve the problem of inadequate housing and waste management, new construction materials must be considered and determined if they can provide a cheaper alternative to conventional building materials. According to [2], the use of these alternative construction materials has the potential to lower construction costs due to less conventional materials required and faster completion times.

Traditionally, stabilization of deficient or marginal soil is done with conventional materials like lime, cement, bitumen or combinations. The cost of these stabilizers increase in ever increasing construction work in the tropics thus the need to substitute with local additives become imperative, [3]. Rice husk is an agricultural waste obtained from milling of rice. About 10^8 tons of rice husks are generated annually in the world [4]. Hence, use of RHA for soil stabilization should be encouraged as it will considerably reduce the cost of construction and as well reduce the environmental hazards. Rice husk ash has been categorized under pozzolana given its 67-70% silica, approximately 4.9% Alumina, and about 0.95% iron oxides [5]. The silica contained in RHA is in amorphous form meaning it can readily react with the CaOH that liberates during hardening of cement to form cementations compound.

The manufacture of cement produces carbon dioxide (CO_2), which is a prime contributor to global warming. Typically, cement production results in CO_2 emissions of about 0.9% [6]. Therefore, utilization of rice husk ash (RHA) as a secondary cementitious material to partially replace proportions of the Ordinary Portland cement in soil stabilization will reduce the overall environmental impact of the soil stabilization process. Literature shows that RHA has potential to improve the geotechnical properties of soils for sub-grade purposes [4], [7], [8]. Thus, this study focused on the performance of compressed interlocking soil blocks stabilized using uncontrolled burnt rice husk ash (RHA) and cement. RHA can only be used as a partial replacement for the more expensive stabilizing agents (cement/lime) because it has inadequate cementation property required to bind the material to a satisfactory durability [4].

This study investigated the effect of Rice Husk Ash and cement stabilization on the compressive strength of compacted black cotton soil. This will lead to reduction in the amount of cement required for stabilization and provision of more durable low-cost compressed earth blocks for housing in Kenya.

2. Methodology

2.1. Materials

The raw materials used in this research include Rice Husk Ash (RHA), Black cotton soil, Ordinary Portland cement, and tap water. Rice husk ash was obtained from Mwea Tebere scheme millers. The ash was sieved through 0.6mm sieve to remove unburnt particles and finally sieved through 150μm sieve to get the fine ash used. Cement used was Ordinary Portland Cement (OPC) from Bamburi cement factory (Kenya Bureau of Standard, KS-02:1976). Black Cotton Soil was sourced from a construction site in Juja. The sample was left to dry and the lumps formed were crushed into small pieces and sieved through 5mm mesh sieve in accordance with British Standard, [10].

2.2. Laboratory Tests

Particle size distribution and Atterberg limits tests. The Particle Size Distribution and Atterberg limits for the soil sample were determined in accordance with the British Standard procedures as outlined in BS 1377-1990: Part 2. For Atterberg limits, the soil was sieved through 425μm sieve and the soil passing this sieve was oven dried before conducting the test. The tests were carried out on the soil alone and soils with different proportion of cement.

2.3. Compaction Tests

Standard Proctor compaction test, according to BS 1377–1990: Part 4 was applied to determine the maximum dry density (MDD) and the optimum moisture content (OMC) of the soils. The soil mixtures, with and without additives, were thoroughly mixed with various moisture contents before compaction. The first series of compaction tests were aimed at determining the compaction properties of the unstabilized soils. Secondly, tests were carried out to determine the proctor compaction properties of the clay upon stabilization with varying amounts of cement and rice husk ash (RHA).

2.4. Block Production and Compressive Strength Test

Batching of materials was done by weight according to the mix proportions for cement and rice husk ash as shown in Table 1.

Table 1: Mix proportions for cement and rice husk ash

Batch	Cement (%)	RHA (%)
1	8	0
2	7	2.5
3	6	5
4	5	7.5
5	4	10
6	3	12.5
7	2	15
8	1	17.5
9	0	20

Dry materials (clay soil, Rice Husk Ash and cement) were mixed first until uniform mixture was produced, then water was added and mixing continued until a homogeneous mix was obtained. The mixed sample was then placed in the CINVA-Ram press machine and manually pressed to produce the blocks which were extruded immediately. They were cured in a shade while covered with polythene bag. Twelve replicates of the blocks were produced for each mix where three blocks were tested after 7, 14 and 28 days, respectively. The average compressive strength of three blocks was determined in accordance to BS EN 772-1 (2003).

2.5. Water Absorption Tests

The dry blocks were weighed using an electronic weighing machine and the weight recorded as (Wd). The blocks were then immersed in water for 24 hours with only 5 mm of a block inserted in water. They were then removed and weighed again, (Ww).

Fig. 1. Water absorption test of the blocks

3. Results and Discussion

3.1. Determination of Soil Classification

The soil consisted of 12.82% gravel, 7.92% sand and 79.26% fines. The range of particle distribution suitable for building of earth block is: 0 – 40% gravel, 25 - 80% sand and 18 - 55% fines (silts and clays) [11]. This implies that the Juja soil used in the study does not meet the minimum requirements for earth block production. In other words, the soil considered requires an improvement or stabilization for it to be utilized in block production.

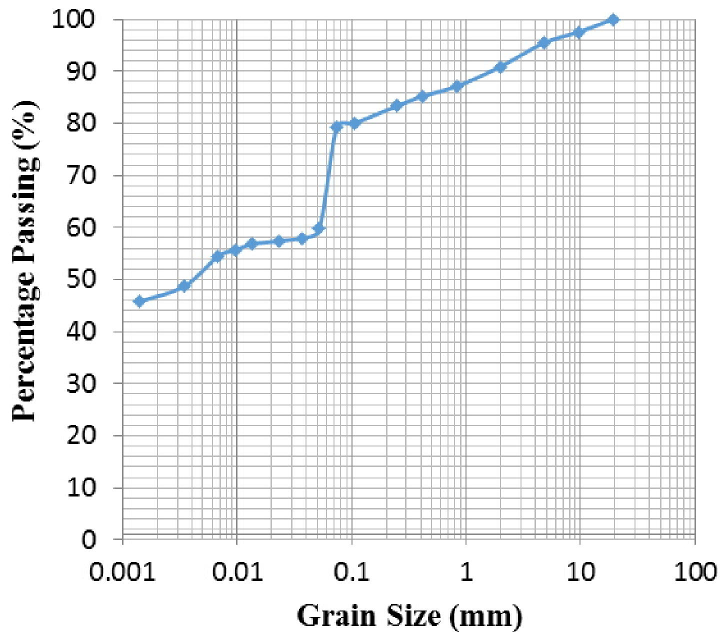

Fig. 2. Particle size distribution of the soil sample

3.2. Effects of Stabilizers on the Compaction Characteristics

The maximum dry density (MDD) and optimum moisture content (OMC) for neat soil were 1382 kg/m3 and 15.8%, respectively (Table 2). Addition of cement and RHA tended reduce the MDD and increase the OMC as shown in Figure 3 and Figure 4.

Table 2: Physical properties of the soil (neat soil)

S. No.	Description	Measured Values
1	Specific gravity	2.55
2	Liquid limit (%)	90.25
3	Plastic limit (%)	32.44
4	Shrinkage limit (%)	16.14
5	Plasticity Index (%)	57.81
6	Maximum Dry density (Kg/m^3)	1382
7	Optimum Moisture content (%)	15.8
8	Compressive strength	0.8 MPa
9	Colour	Dark Grey

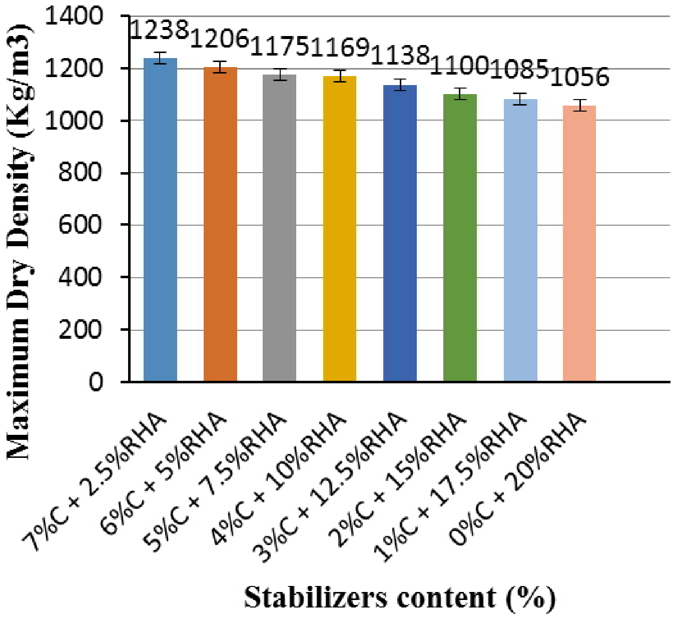

Fig. 3. Effects of cement and RHA content on the MDD of soil

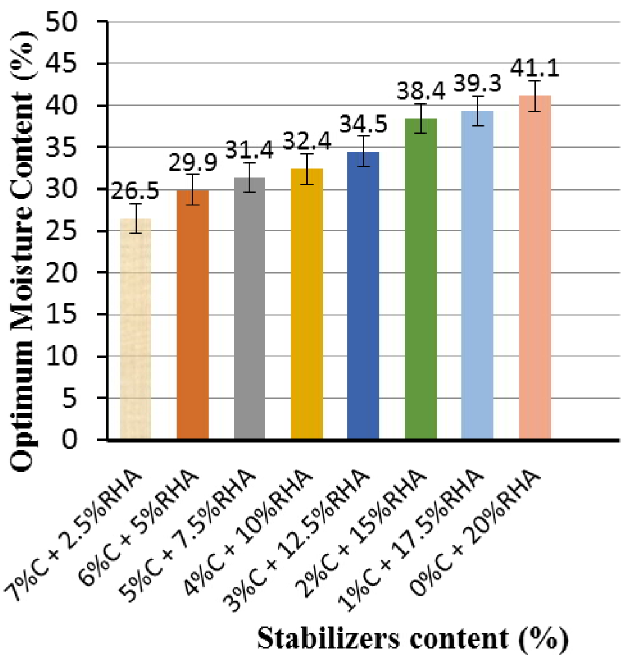

Fig. 4. Effects of cement and RHA content on the OMC of soil

RHA has relatively low specific gravity [12] compared to the soil and Portland cement and acts as filler in the soil voids. The MDD of soil decreases with increasing RHA content probably due to an initial simultaneous flocculation and agglomeration of clay particles caused by cation exchange [13]. A lower MDD for soil with stabilizer indicates that the compaction energy is less than in the natural state of the soil.

Increased OMC with an increase in RHA content was probably due to the agglomeration of clay particles in the presence of the stabilizer, forming lumps and larger voids [14]. The stabilization process requires water for hydration to take place and for the reaction between the pozolanic substances (RHA/cement) and soil to take place. According to Wikipedia accessed on August 19, 2015, the pozolanic reaction is as follows:

$Ca(OH)_2 + H4SiO_4 \rightarrow Ca2+ + H_2SiO_4^{2-} + 2\ H_2O \rightarrow CaH_2SiO_4 \cdot 2\ H_2O$

In the presence of aluminate ($Al(OH)_4-$), calcium aluminate hydrates, such as C_4AH_{13}, C_3AH_6, are formed.

3.3. Compressive Strength Analysis for Cement and RHA Stabilized Blocks

The compressive strength of blocks prepared using neat soil was 0.8 MPa. Addition of 7% cement and 2.5% RHA resulted in increased compressive strength of about 2.8 MPa as shown in Figure 5. However, increased replacement of cement with RHA resulted in reduced compressive strength. Nevertheless the strength of blocks stabilized with 20% RHA (1.5 MPa) without any cement was still higher than the strength of blocks made from neat soil. The Kenya Standard Specification (1993) specifies that at 28 days, the dry compressive strength of Compressed Earth Blocks must be greater than 2.5 MPa. Therefore at most, 7.5% RHA should be combined with a minimum of 5% cement to achieve the minimum strength for stabilized blocks as shown in Figure 4.

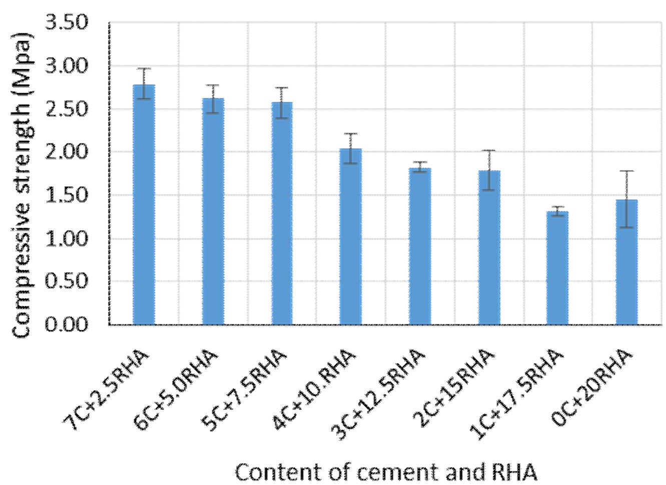

Fig. 5. Effects of cement and RHA content on the 28th day compressive strength

To achieve the minimum required strength, blocks should be cured for at least 28 days (Figure 6). RHA stabilized blocks hydration takes a long time thus low early strength and higher strength at 28 days. The 7, 14 and 28 day compressive strength for 5% cement and 7.5% RHA stabilized soil blocks were 0.89 MPa, 1.04 MPa and 2.58 MPa respectively.

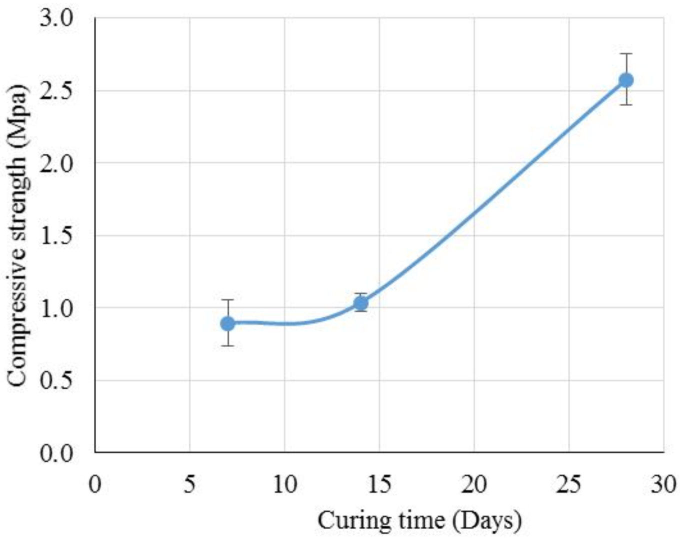

Fig. 6. Effects of curing time on the compressive strength (MPa) – Case of 5% Cement and 7.5% RHA

3.4. Water Absorption Tests

All stabilized blocks raptured after some time as shown in Table 3. The blocks stabilized with 8% cement had a longer time to start of breaking down of 6hrs 20 minutes and the blocks with 0% cement + 20% RHA broken in 30 minutes. Clearly, excess moisture negatively affects the strength of stabilized soil blocks. Therefore, such blocks are only useful where there is no possibility of excessive wetting. It is concluded that this technology is best used in the construction of internal walls where excessive wetting is not a concern.

Table 3: Water absorption test results

Mix Proportion	**Average time to start disintegrating**	**Average time to block rupture**
8%C + 0%RHA	6hrs 20min	12 hrs
7%C + 2.5%RHA	5hrs	8hrs
5%C + 7.5%RHA	3hrs 20min	5hrs 50min
4%C + 10%RHA	2hrs	5hrs 40min
2%C + 15%RHA	50min	3hrs 20min
0%C + 20%RHA	10min	2hrs

3.5. Cost Analysis

The cost of blocks made from 5% cement with 7.5% RHA was KES 20.50 compared to a cost of KES 28 for blocks made using cement alone. Therefore, the cost of using cement in combination with RHA was nearly 30% less than the cost of blocks made using blocks made from soil that is stabilized with cement alone as shown in Table 4.

Table 4: Costs incurred in earth blocks production

Description	**8% cement**	**5% cement + 7.5% RHA**
Cost of 50kg of cement	700	700
Cost of acquiring 50kg of RHA	–	500
Cost block production	1000	1000
Total expenditure (KES)	1700	2200
No. of blocks produced with 50kg of cement	63	110
Cost of one block produced (KES)	28	20.50

4. Conclusions

From this study it may be concluded that stabilization of soil with cement and RHA is a feasible construction technology because the compressive strength of stabilized blocks is higher than the strength of un-stabilized blocks. However, when RHA is used as a partial replacement of cement, the optimum combination of cement and RHA is 5% and 7.5%, respectively. Nevertheless it should be realized that stabilized blocks are generally not resistant to wetting and should be used in situations where there is minimum wetting. Use of RHA can reduce the cost of producing stabilized blocks by as much as 30%.

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