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# Potential of Quarry Dust and Cow Dung as stabilisers for Black Cotton soil Eco-blocks for Housing

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**Abstract**
Present concerns for sustainable development have led to a revival of traditional building practices using natural or recycled resources. There is a perception that buildings constructed from such materials are environmentally benign. The use of earth on site as a building material saves manufacturing cost, time, energy, environmental pollution and transportation cost. Due to the atmospheric condition change, blocks made with black cotton soil swell, shrink and crack. This research work reports on the effect of waste material such as quarry dust and cow dung on the strength and stability of soil blocks made with black cotton soil.
Black cotton soil is a soil in which there is a high content of expansive clay known as montmorillonite that forms deep cracks in drier seasons or years owing to extensive swelling and shrinkage. The shrinking and swelling of black cotton soil can significantly damage buildings and roads, leading to extensive subsidence. Accordingly, black cotton soil is never used as a construction material.
The key objective of this research study was to determine the effect of various eco-friendly additives on the structural performance of black cotton soils in Kenya, and hence the potential of stabilized black cotton soil as an eco-block for buildings. Experimental work has delved into basic material properties, as well as strength tests on specimens.
Accordingly, the research work has conducted numerous tests such as atteberg limit, particle density, particle size distribution compaction test and linear shrinkage on material as well as strength test on blocks.
From the results obtained, it is established that the addition of 20% quarry dust to black cotton soil increases the compressive strength of the block from 0.6 to 2.7 MPa, and with further the addition of 6% cement this value increases up to 3 MPa. The addition of Cow dung to black cotton soil reduces the number of cracks and the amount of shrinkage on blocks, and also increases the strength of the blocks from 0.6MPa to 2MPa. It is thus confirmed that the addition of quarry dust and cow-dung have significant positive effects on black cotton soil, rendering them suitable for use sustainable eco-blocks for construction.
**Keywords**: Black cotton soil, quarry dust, cow dung, compressive strength, cracks, shrinkage, eco-blocks, compressed earth blocks, stabilized soil blocks

## 1. Introduction

Silt and clay within a soil sample reacts to moisture, by swelling when water is absorbed, and shrinking when the soil dries out. Such movement can result in surface cracking of walls, pavement and consequently accelerate erosion, which may eventually lead to structural failures. These same phenomena are observed on blocks made with black cotton soil without any stabilizer. Black cotton soil is a unique type of soil in which there is a high content of expansive clay known as montmorillonite that forms deep cracks in drier seasons or years owing to extensive swelling and shrinkage. The shrinking and swelling of black cotton soil can significantly damage buildings and roads, leading to extensive subsidence. Accordingly, black cotton soil is never used as a construction material.

Recently, traditional earth construction technology has undergone considerable developments that enhance the soil's or earth's durability and quality as a construction material for low-cost buildings (Adam and Agib, 2001). The use and adoption of the right stabilization method can improve the compressive strength of blocks and increase its resistance to erosion since stabilizer acts as waterproofing medium and increase the density of soil. Chaibeddra .S and F. Kharchi, (2013) define stabilization as a group of processes, which are applied to a soil in order to improve its characteristics, in particular its mechanical behavior and durability to water. The main objective of soil stabilization is to enhance soil resistance to the erosive effects of the local weather conditions, including variations in temperature; humidity and rainwater as confirmed by Adam and Agid (2001). Stabilized compressed earth block is an innovative advancement of the traditional earth technology and involves adding a little quantity of stabilizer such as cement to earth and making compressed earth blocks. The blocks, if tested and found to be strong enough and durable, may then be used to make walling for eco-housing in line with global sustainable development agenda. The global sustainable development concept emanates from the interrelationship between the social, environmental and economic factors. Accordingly, this research is an innovative work which takes into consideration three key values or aspects: Economic value (cost reduction);

Social value (use of readily available and familiar local material, hence acceptable to African people) and Environmental value (with the objective of conserving the environment).

Extensive research has been undertaken in order to produce quality and acceptable compressed stabilised earth blocks (CSEB) for low cost housing. Paul O. Awoyera and Isaac I. Akinwumi (2014); in their work evaluated the compressive strength of lateritic bricks stabilised with cement, lime and termite-hill. They determined the engineering characteristics and classification of the lateritic soil and the characteristic compressive strength of stabilised bricks as well as the unstabilised bricks were investigated after 7, 14 and 28 days of curing. Each of the three stabilisers were added in varying proportions of 8%, 10% and 12% by weight of the lateritic soil for producing the bricks. They find out that despite the compressive strength increased with increasing proportion of the stabilisers, the compressive strength test conducted after 28 days curing revealed that the cement stabilised bricks developed a rapid increase in strength than the lime stabilised and termite-hill stablised bricks. Baba and all (2013) investigate the suitability of stabilized laterite soils for the production of compressed earth blocks for low-cost housing construction. They took samples for the experiment at two different locations. Sample I was obtained at a borrow pit along Gujba road in Damaturu Yobe state while Sample II was taken at a borrow pit near lake Alau in Borno sate, Nigeria. Their study revealed that the specific gravity, bulk density, moisture content and plasticity index of both samples showed satisfactory performance. They used Different cement stabilization levels of 0%, 2.5%, 5% and 7.5% to prepare the specimens for testing. The maximum compressive strength obtained was 2.48N/mm2 with stabilization level of 7.5% with sample I at 28 days curing. The strength of the specimens increases with increasing cement content with an average value of 0.35N/mm2. They conclude that both the samples exhibit similar characteristics and are all suitable for the production of compressed stabilised soil blocks for walling in low cost sustainable buildings. Obonyo et al (2010) looked at spray testing of compressed bricks from Tanzania in order to counter deterioration due to wind driven erosion. The impacts of using cement, lime, fiber and a commercial stabilising fluid were assessed. Compressed blocks were benchmarked against a standard factory produced bricks. Factory produced bricks hardly eroded whereas the depth of erosion of soil-cement blocks maximum depth of erosion was 40mm. And the inclusion of natural fibre in bricks sharply increases the rate of erosion. Pave (2009) looked at the structural behaviour of Hydraform CSEB by investigating the unit compressive strength, masonry wall compressive strength and flexural resistance of dry stack masonry/reinforced concrete beams. More to the point of durability, Pave looked at three type compressive strength tests, the shoulder test, the centre test and the cube test for block strength evaluation. These tests were carried out during dry, wet and normal humidity conditions. It must be noted that the soil properties used by Pave in the assessment of strength are not presented. From test results Pave found that wet strength is approximately 60% of normal strength and that the shoulder test was an adequate measure of block strength. He also recommended that a minimum strength of 5MPa for testing be maintained.

But due to the high cost and amount of cement used in the process of production, there is need for alternative materials which can help in the reduction of the amount of cement used. Materials such as Fly ash, quarry dust, cow dung have been used to stabilise laterite blocks and also cohesive soils in the case of road construction. The effect of these materials on black cotton soil blocks has not yet been done. The main objective of this work is to determine the effect of quarry dust and cow dung on the strength of black cotton soil blocks (BCSB) as well as their effect on cracking and amount of shrinkage.

## 2. Materials and methods used

Materials used in this study include black cotton soil, cow dung, quarry dust and cement from a local factory. Basic material properties were determined, after which the materials were investigated in line with the key research objective.

### 2.1 *Materials*

#### 2.1.1 Black cotton soil

The term black cotton is derived from the soil's dark or black colour and the fact that it was originally used for growing cotton. Black cotton soil or vertisol has a high content of expansive clay (60%) known as montmorillonite that forms deep cracks in drier seasons or years (Eliud, 2010). Black cotton soil is classed as an expansive soil and is usually poor in engineering properties (Osinubi and al, 2011). In general, black cotton soils are formed in areas where the parent materials are basic rocks such as basalt and phonolites in climates that are seasonally humid or subject to erratic droughts and floods, or to impeded drainage. Depending on the parent material and the climate, they can range from grey or red to the more familiar deep black. As a result of the wetting and drying, massive expansion and contraction of the clay minerals takes place; contraction leads to the formation of the wide and deep cracks that close after rain when the clay minerals swell. Because of its fine grained content, black cotton soil form a coherent mass at suitable moisture content and when dry, those coherent mass become hard and need to be crushed before use.

Figure 2-1: Black cotton soil in natural dry state (Oza J. B. and P.J. Gundaliya, 2013)


Figure 2-2: Black cotton soil in dry (fig 1) and crush (fig 2) form

### 2.1.2 Cow dung

Cow dung is a waste product of animal (bovine). In addition to its use as a fertiliser, Cow dung acts as a repellent to insects such as mosquito. In India, people applied cow dung on the wall and coated it on the floor for it to remain warm in winters and cold in summers. Cow dung used in this work was collected from JKUAT farm (Fig. a), was dry (Figs. b-c) and crushed (Fig. d).

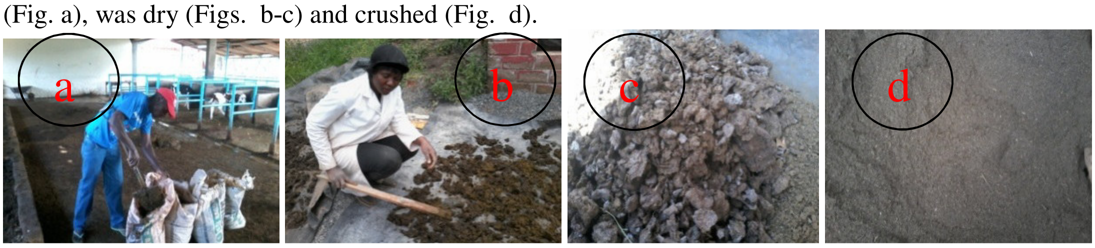


Figure 2-3: Cow dung in wet, dry and crushing form

### 2.1.3 Quarry dust

Quarry dust is a waster product from ballast manufacturing plants. In quarries, there is a large quantity of quarry dust which is a waste material after extraction and processing of rocks to form fine particles. The dust may be used for manufacturing lightweight concrete prefabricated elements. There are two type of quarry dust in Kenya; one from natural aggregate crushing and the other from mechanical stone dressing quarries. In this work dust from one of the mechanical stone dressing plants in Kenya was used.

### 2.1.4 Cement

The cement used was NGUVU of nominal strength 32.5 Mpa as per Kenya standard (KS18-1:2001) from BAMBURI CEMENT (Kenya). **Bamburi Cement Limited** is East Africa's leading Cement producer and is a member of the Lafarge Group - the world's largest building materials group. Bamburi is one of the most technologically advanced yet environmentally responsible cement producers in Africa. **Nguvu CEM IV/B(P) 32,5N** is formulated from Cement Clinker and interground with other constituents, mainly natural Pozzolana, in accordance to the requirements of the following standards adopted from the EN 197 Part 1 - Composition, Specification and Conformity criteria for Common Cements. **Nguvu CEM IV/B(P) 32,5N** is characterized by good early and 28 day strengths and fast setting.

## 2.2 *Testing methods*

The physical properties of black cotton soil were obtained after conducting fundamental soil mechanics testing as BS 1377 (ref: BS 1377, part 2 and 4, 1990) such as moisture content, bulk density, Atteberg limit, linear shrinkage, sieve analysis (wet sieving), particle density and compaction test. The compaction test (ref: BS 1377, part 4, 1990) was done on mixtures of black cotton soil and 20%, 50% and 60% of the selected additive such as quarry dust in order to investigate the effect of quarry dust on dry density of black cotton soils. The optimum moisture content of the mixture which gave the good dry density was used for blocks production.

The different proportion of soil and stabiliser were weight, mixed and water was added a little until the soil mixed reaches the consistency (this quantity of water was not very far from the OMC obtained during the compaction test). The mixture was filled into the mould and compacted. Then the blocks were kept in a curing place and were covered with polyethylene paper to facilitate curing and protection from external agents such as rain. For every mixture, the linear shrinkage was measured to determine the amount shrinkage, and the number of cracks was noted.

The dry compressive strength of the blocks was determined according to BS 1881 part 116, 1983, employing a Universal Testing Machine (UTM). During the compressive test, each block of nominal dimension 290 x 140 x 120 mm was weighed and aligned on the UTM, followed by gradual application of load until failure. Maximum applied load was recorded and used to calculate compressive strength. Table 2.1 presents the composition of the mixtures and sample designation.

Table 2-1: Type of mixture and sample designation

| **Composition of mixture** | **Sample designation** |
|---|---|
| Pure black cotton soil | BCS |
| Black cotton soil + 20% quarry dust | BCS-20QD |
| Black cotton soil + 20% quarry dust + 4% cement | BCS-20QD-4C |
| Black cotton soil +20% quarry dust + 6% cement | BCS-20QD-6C |
| Black cotton soil + 20% quarry dust + 4% lime + 2%cement | BCS-20QD-4L-2C |
| Black cotton soil + 4%lime +2% cement | BCS-4L-2C |
| 4 parts black cotton soil + 1part cow dung | 4BCS-1CD |
| 3 parts black cotton soil + 1 part cow dung | 3BCS-1CD |
| 4 parts black cotton soil + 1part cow dung + 4% cement | 4BCS-1CD-4C |
| 3 parts black cotton soil + 1part cow dung + 4% cement | 3BCS-1CD-4C |

## 3. Results and Discussions

### 3.1 *Basic material properties*

Basic material properties are presented in Table 3.1 and Fig. 3.1. From the table, it is observed that the specific gravity is 1.310g/m3, the dry density 1283.63 kg/m3. In addition the plastic index of black cotton soil is 47% hence this soil needs to be pre-treated with another material in order to have good engineering characteristiques. Indeed, soils with a plasticity index above 20-25 are not suited to cement stabilization using manual presses, due to problems with excessive drying shrinkage, inadequate durability and low compressive strength (Veena and al, 2014). Fig 3.1 give the particle size distribution of black cotton soil as obtained. It is observed that the 89% of the black cotton soil was passing 0.075mm, hence indicating the fine nature of the material. 89.6% of soil sample is presented by fine particle (clay and silt) while 8.47 and 1.93 is presented by sand and gravel respectively. From this result black cotton soil is a clayed soil.

Table 3-1: The Physical properties of black cotton soil

| **Properties** | **values** |
|---|---|
| Moisture content (%) | 28 |
| Liquid limit (%) | 75 |
| Plastic limit (%) | 28 |
| Plastic index (%) | 47 |
| Linear shrinkage (%) | 19 |
| Percentage of fin clay and silt (%) | 89.6 |
| Percentage of sand (%) | 8.47 |
| Percentage of gravel (%) | 1.93 |
| OMC (%) | 25.5 |
| Dry density (kg/m3) | 1283.63 |
| Specific gravity(g/m3) | 1.310 |

 

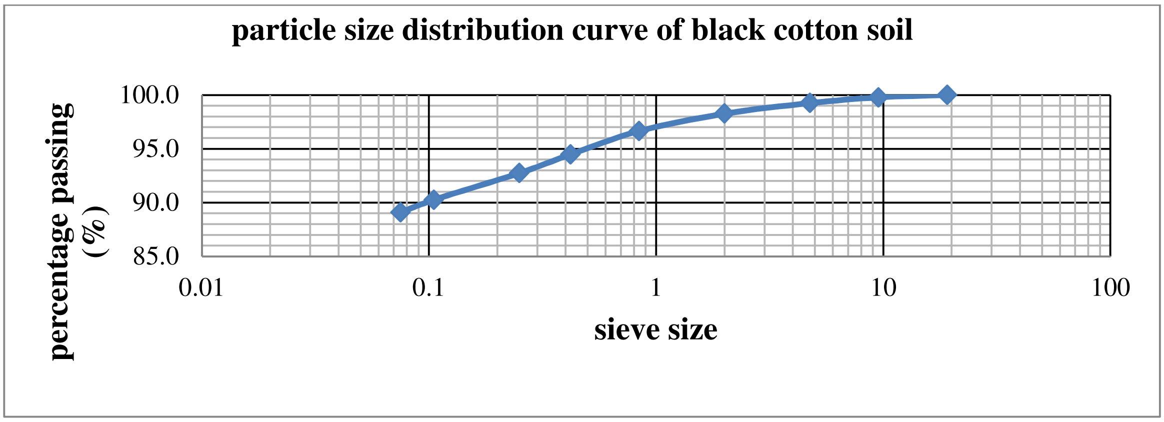


Figure 3-1: Particle size distribution of black cotton soil

### 3.2 *Effect of quarry dust on optimum dry density (ODD) and optimum moisture content (OMC) of RCS*

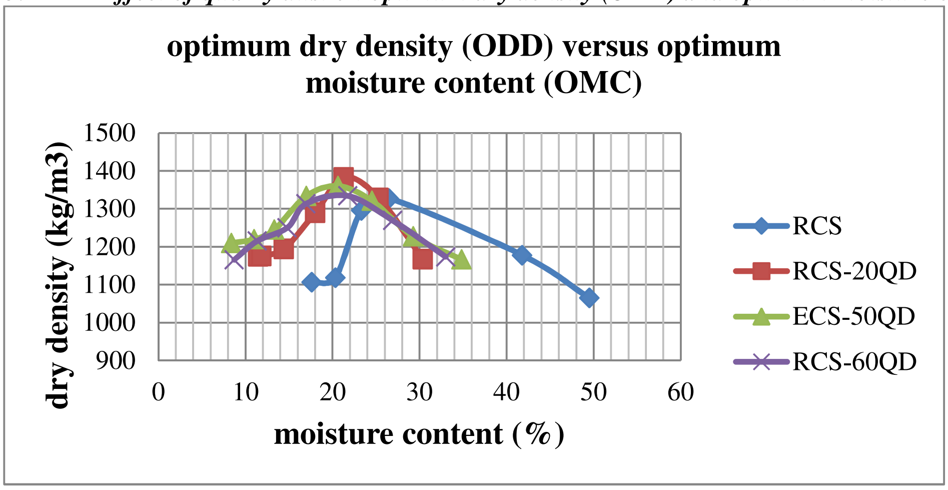


Figure 3-2: Optimum dry density (ODD) versus optimum moisture content (OMC)

From Fig 3-2, it is observed that with addition of quarry dust, the ODD of black cotton soil increase from 1283.63 kg/m$^3$ to 1369.34 kg/m$^3$. The optimum moisture content decreases with increase optimum dry density. The maximum optimum dry density was reached at 20% of quarry dust added on BCS and while from 50% of quarry dust added on BCS, the dry density decrease but still greater than the value obtain for pure soil.

### 3.3 *Effect of quarry dust and cow dung on crack and amount of shrinkage of black cotton soil*

Table 3-2 shows the effect of quarry dust and cow dung on crack and amount of shrinkage of black cotton soil. It is noted that black cotton soil without any type of stabiliser showed many cracks in addition to shrinkage. As quarry dust and cow dung was added, the number of cracks and amount of shrinkage reduced considerably. The potential of quarry dust and cow dung on the reduction of number of cracks and amount of shrinkage is thus clearly demonstrated. This will be improved further by addition of a little quantity of cement.

Table 3-2: effect of quaddy dust and cow dung on crack and shrinkage of black cotton soil

| **Blocks label** | **Number of cracks** | **Linear shrinkage Ls (mm)** | **Images** |
|---|---|---|---|
| BCS | 3 | 33 of large width |  |
| BCS-20QD | 1 | 26 of large width |  |
| 4BCS-1CD | 2 | 8 of large width |  |

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BCS at 7days | BCS-20QD at 28 days | 4BCS-1CD at 28 days

Figure 3-3: Picture representative of different types of blocks at testing ages

## 3.4 *Effect of Additives on compressive strength of blocks*

### *3.4.1 Effect of quarry dust and chemical admixture on black cotton soil*

Compressive strength result for each mixture was determined as an average of three sample blocks for each of the ages. Table 3-3 gives the results obtained from compressive tests on blocks made from the different mixes. The results are further illustrated in Figs3-4.

The compressive strength increases with increase age of curing. As per Kenyan standard, the compressive strength should not be less than 2.5 MPa. The graph above is showing that blocks made with pure black cotton soil were tested only at 7 days due to the crack on blocks which lead to their destruction after that ages and the compressive strength was 0.6 MPa. Meanwhile, with addition of quarry dust, the compressive strength reached 1.9 MPa while with addition of 6% of cement the strength is 2.7MPa acceptable by the Kenyan standard which requires 2.5 MPa.

Table 3-3: effect of quarry dust on compressive strength

| | **BCS** | | | **BCS-20QD** | | | **BCS-20QD-4C** | | | **BCS-20QD-6C** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ages** | **Weight (g)** | **Apply load (kN)** | **Comp. Strength (MPa)** | **Weight (g)** | **Apply load (kN)** | **Comp. Strength (MPa)** | **Weight (g)** | **Apply load (kN)** | **Comp. Strength (MPa)** | **Weight (g)** | **Apply load (kN)** | **Comp. Strength (MPa)** |
| **7** | 8278.5 | 25.82 | 0.65 | 7924.5 | 47.44 | 1.19 | 8269.5 | 59.56 | 1.50 | 8526.5 | 65.01 | 1.64 |
| **14** | - | - | - | 7684.0 | 57.13 | 1.44 | 7884.5 | 68.67 | 1.73 | 8234.5 | 84.84 | 2.31 |
| **28** | - | - | - | 7306.5 | 76.55 | 1.93 | 8075.5 | 89.89 | 2.26 | 8437.5 | 107.58 | 2.71 |

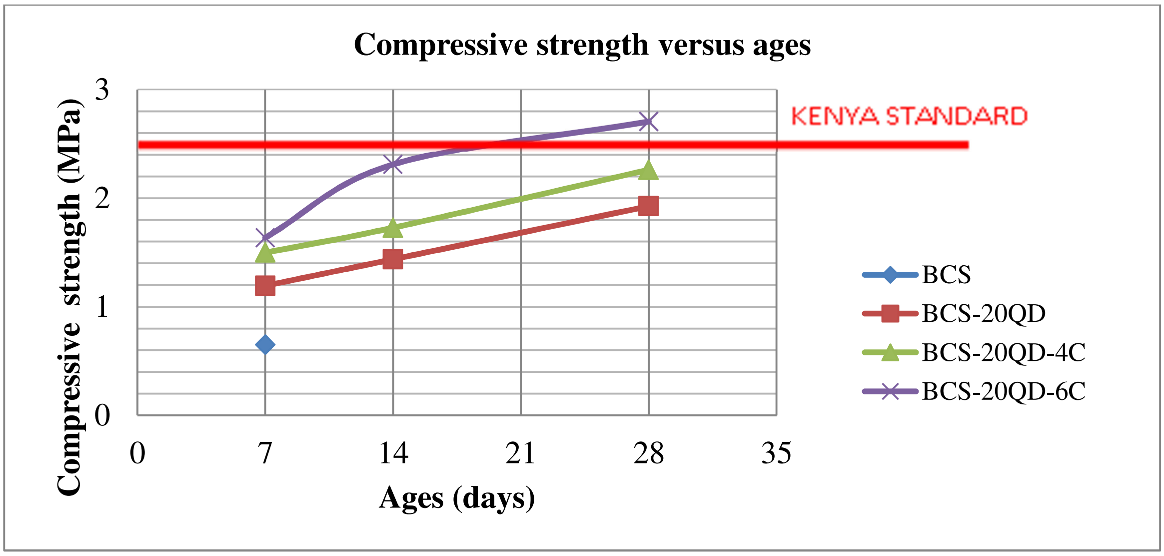


Figure 3-4: Compressive strength versus age

 

### 3.4.2 Effect of cow dung on compressive strength of black cotton soil blocks

Fig3-5 gives the effect of cow dung on compressive strength of black cotton soil blocks. Blocks made with black cotton (BCS) soil only readily crumbled and could only be tested at 7 days and could not reach 28 days. With addition of cow dung, it was possible to get stable blocks of stabilized black cotton soil which could even be tested for 28 days since the number of crack has reduced considerably and this made blocks solid. The compressive strength of blocks stabilised with cow dung are lower than the 2.5 MPa recommended by the Kenya standard even when 4% of cement is added. However, future work should seek optimum amount of cow dung and cement additions that results in strengths higher than the 2.5 MPa  Meanwhile, the mixture cow gung- black cotton soil with a little quantity of cement can be use as plaster when eco housing is concerned since the plaster use in conventional construction consumes a lot of cement.

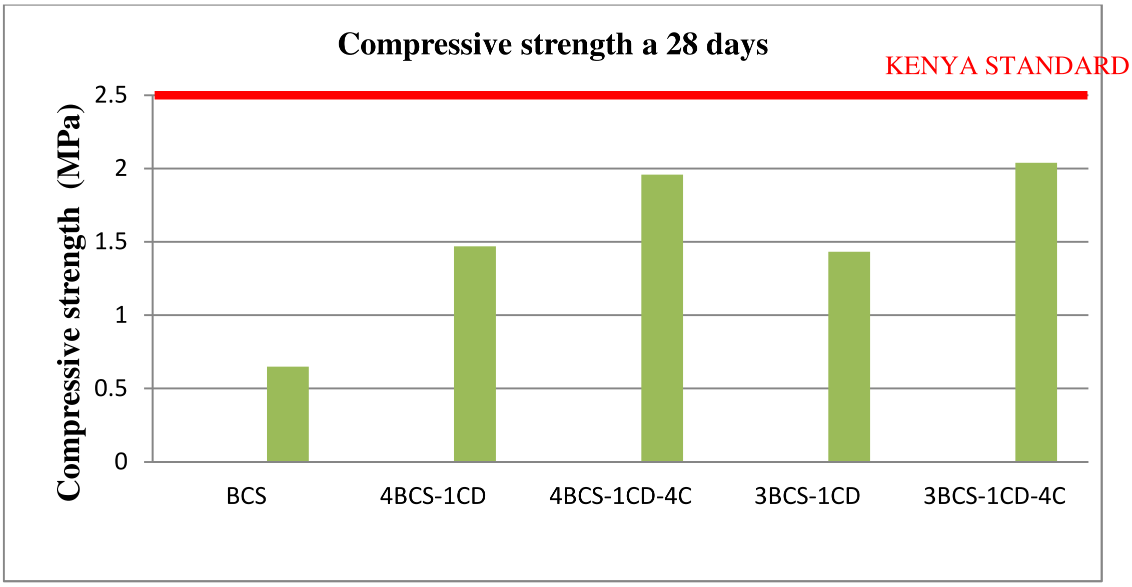


Figure 3-5: Compressive strength a 28 days

**Conclusion**

The key objective of this research study was to determine the effect of various eco-friendly additives on the structural performance of black cotton soils in Kenya, and hence the potential of stabilized black cotton soil as an eco-block for buildings. Results obtained, clearly demonstrate the potential of cow dung stabilized black cotton soil, and and quarry dust stabilized black cotton soil as eco-materials for the manufacture of compressed earth blocks for sustainable construction. More specifically, it is determined that;

a) the addition of 20% quarry dust to black cotton soil increases the compressive strength of the block from 0.6 to 2.7 MPa, and with further the addition of 6% cement this value increases up to 3 MPa.
b) The addition of Cow dung to black cotton soil reduces the number of cracks and the amount of shrinkage on blocks, and also increases the strength of the blocks from 0.6MPa to 2MPa.

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