# EFFECTS OF STABILIZERS ON WATER ABSORPTION OF COMPRESSED EARTH BLOCKS MADE FROM MANGU SOIL

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***ABSTRACT***

*This work characterizes, classify and improve the physical properties of the natural material from Mangu with stabilizers to be qualified as good soil for the production of good earth blocks with low water absorption coefficient. Results of the test carried out showed that the natural soil used was clayey soil with medium plasticity. The addition of 50% sand, has highly improved the soil grading properties. The ratios with optimal performances are 50% sand added with 6 to 8% cement and from 8 to 9% added with. Stabilizers have highly improved the hydrological properties of blocks specimen for using capillary environment.*

***Keywords:*** *Clay, Compressed Earth Block, Plasticity, Effect of Stabilizer, Water Absorption.*

## I. INTRODUCTION

Water absorption is the main cause of the deterioration of Earth bricks. The high absorption of water contributes to a rapid deterioration of this type of brick [1]. The amount of water absorption depends to the type of soil used and is related with the compressive strength and durability of the materials. The increase of the moisture content reduces the strength which is more related to the porosity of the material. [2] revealed in their study that the decrease of the compressive strength with the increase of the water content is the same for almost all the bricks and also that with the moisture content in a range from 1 to 6% the strength decreased approximately up to 50%. [3] revealed that water absorption is an indication of the porosity earth blocks and that water absorption and porosity greatly depend on the ambient temperature. [4] in his study focused on physical and mechanical properties of wastes Recycling in Fired Clay Bricks, indicated that the using of fly slag in high amount increase the density and the strength but decrease the water absorption index which has been defend by [5] Showing in his study that good bricks can be produced with an addition of organic–inorganic wastes or marble residue mixed with clay soils. They investigated the change occurred in the water absorption and porosity with waste addition at each temperature. Their results shown that porosity and the water absorption increased with the addition of residues. They observed decrease in open porosity and water absorption when the temperature increased from 950 to 1050°C. This increased the compressive strength by reducing the porosity content. According to [6], moisture contents affect the strength development and durability of the material. The stabilization of clay bricks with cement, lime, cement-lime and cement-resin, show the lowest water absorption. When the brick is dry, water

is rapidly sucked out of the mortar preventing good adhesion and proper hydration of the cement. Water absorption can be reduced by adding hydrophobic materials.
The durability of brick is mainly affected by the water absorption. The basic principle of the stabilization is to prevent water attacks to obtain a durable material. According to [7], using unburned bricks in wet area require an insulation of the wall from rain infiltration because the biggest problem in the unburned blocks is the water effect on the brick strength. [6], revealed that wet/oven dry ratio of 33% may be a suitable criterion for evaluating the durability of cement brick. Clay brick material is durable when it is not saturated. The problems of durability arise when the brick material is exposed to the saturation and wet conditions. The deterioration of bricks occur rapidly with the high value of the water absorption [1]. Many people choose earth construction for their low cost and low embodied energy therefore; there is a need to improve durability. To increase durability, for example, the problem of rain penetration in buildings must be solved. The durability of bricks can be improved by improving the compressive strength, reducing the absorption of water of the material by good stabilization method [7].
Water content is also affected by the type of compaction. The dynamic compaction can reduce water content from 12% to 10% with increasing of the compressing strength up to 50%. In a range of 10 to 13% of water content, compaction by vibration slightly increase the compressive strength. The international standard to determine water content can be presented such as ASTM D 558, Australian Standards 1289, BS 1924-2 (1990), BS EN 1745, ASTM C 140 BS EN 771-2 and Australian Standards 2733.
The goal of this study is to characterize and make proposals in order to improve the natural soil from Mangu through soil mechanic tests and for the production good soil blocks with high resistance to water capable to withstand in wet area.

# II. MATERIAL AND METHOD

## 2.1 Materials

For this study, soil samples were collected from Mangu village while the stabilizers used were sand from a local quarry in Juja, all in sub-county of Thika, Kenya, ordinary Portland cement of class 35, hydrated lime.

## 2.2.Method

### 2.2.1. Soil mechanic tests

Standard soil classification tests were carried out according to the British Standards BS 1377-2: 1990 [8]. The moisture content has been determined using the oven dry method. The particle density was determined using the pyknometer method. The bulk density has been determined on undisturbed samples. The particle size distribution of soil has been determined using wet sieving analysis method. The dry density, void ratio, porosity and saturation ratio were determined by computing the existing relationships between bulk density, moisture and particle density initially determined. The cone penetrometer method and roll method were respectively used to determine the liquid and plastic limit.

### 2.2.2. Making of blocks

The clay was initially air dried, broken in powder form and only that passing through 5mm sieve was used for making the blocks according to the standard (ARS 680:1996) [9]. Clay samples were mixed with 50% sand, varying ratios of binders (cement or lime) and water. The ratios of stabilizers (cement and lime) were added in different percentages ranging from 3% to 12%

### 2.2.3. Testing procedure for water absorption

The test was carried out according to the ARS 683: 1996. The specimens of blocks were preventively dried at in open air at 25±2°C for 28 days. In this test, the blocks were partially immersed on 5mm height in a metal tray of size (190x100x20) cm; the 5mm was kept constant during the test. And the all the precautions were taken to keep the 5mm of immersion constant during the test. The bottom face of each block were put on the level guides in wood placed into the metal tray in their position of normal using, distilled water at 20°C was put in the pan to immerse the blocks on 5mm depth for the blocks to absorb that water by capillarity absorption. The water level was kept constant during the test up to the saturation of the blocks. The mass of wet blocks $M_i$ was recorded after 10 minutes.

**Figure 1:** Illustration of Water Absorption test by Capillarity of specimens

# III. RESULTS

The geotechnical parameters of the natural material used are summarized respectively in tables 1, 2 and 3 below.

**Table 1:** State parameters of clay used

| **Samples source** | **Moisture content (%)** | **Particle density (g/m$^3$)** | **Bulk density (g/m$^3$)** | **Dry density (g/m$^3$)** | **Porosity (%)** | **Void ratio (%)** | **Saturation ratio (%)** |
|---|---|---|---|---|---|---|---|
| Mangu | 18 | 2.28 | 1.33 | 1.14 | 42 | 1.10 | 38.80 |

**Table 2**: Grading particles of soils samples used

| **Samples sources** | Dmax | **%passing through sieve** | | | |
|---|---|---|---|---|---|
| | | Clay (0.0001-0.002) mm | Silt (0.002-0.075) mm | Sand (0.075–2) mm | Gravel (2 – 60) mm |
| **Mangu** | 20mm | 45% | 37% | 12% | 6% |

**Table 3:** Consistence Limit of natural material used

| Samples sources | Liquid limit $W_L$ (%) | Plastic limit $W_P$ (%) | Plasticiy index $I_P$ (%) |
|---|---|---|---|
| Mangu | 50.0 | 26.0 | 24 |

From table 2, the studied soil has natural moisture content of 18% and a saturation ratio of 38.80%. The specific gravity and bulk density are respectively 2.28 and 1.33. The dry density, the void ratio and the porosity are respectively 1.14, 1.10 and 42%.

Table 2 shows that the highest diameter of the material used is of 20 mm. The passing through sieves of 0.002, 0.075 mm, 2mm and 20 mm are respectively of 45%, 16%12% and 6%.

The table 3 shows that the values of $W_L$ and $W_P$ of the studied soil are respectively 50% and 26% with plasticity index of 24%.

From tables 2 and 3, the particles passing through 75µm sieve is >35%. The soil is then classified as clayey soil with medium plasticity.

Table 4, shows the water absorption of soil blocks at 28 days of:

a. clay blocks made using clay only without any type of stabilizer (CB)
b. clay blocks made with clay using sand as stabilizer (CSB)
c. clay blocks made with clay using sand and cement as stabilizers (CSCB)
d. clay blocks made with clay using sand and lime as stabilizers (CSLB)

**Table 4:** Water absorption by capillarity at 28 days of various clay block compositions with varying percentages of stabilizers

| **% Stabilizers / Clay block composition** | **0%** | **3%** | **4%** | **5%** | **6%** | **7%** | **8%** | **9%** | **10%** | **11%** | **12%** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Soil (CB) | 11.3 | | | | | | | | | | |
| Soil + Sand (CSB) | 17.8 | | | | | | | | | | |
| Soil+Sand+Cement (CSCB) | | 5.99 | 10.58 | 7.48 | 3.52 | 4.04 | 5.63 | 3.99 | 3.99 | 5.35 | 6.7 |
| Soil+Sand+Lime (CSLB) | | 2.87 | 2.36 | 2.69 | 3.01 | 17.12 | 7.89 | 6.05 | 8.20 | 10.53 | 0.59 |

The trends of water absorption of clay block composition are showed in bar charts in figures 2 and 3 below.

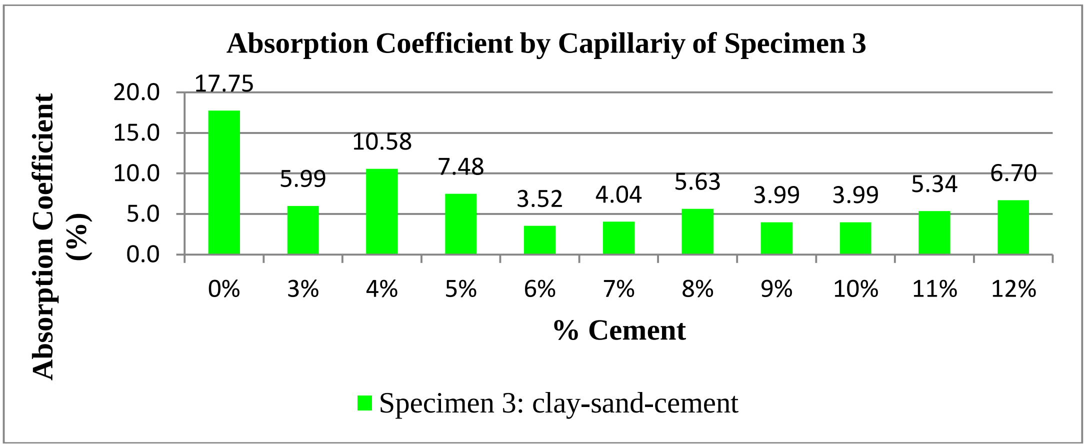


**Figure 2:** Bar Chart of Capillarity absorption for Specimen 3 (Clay +Sand +Cement)

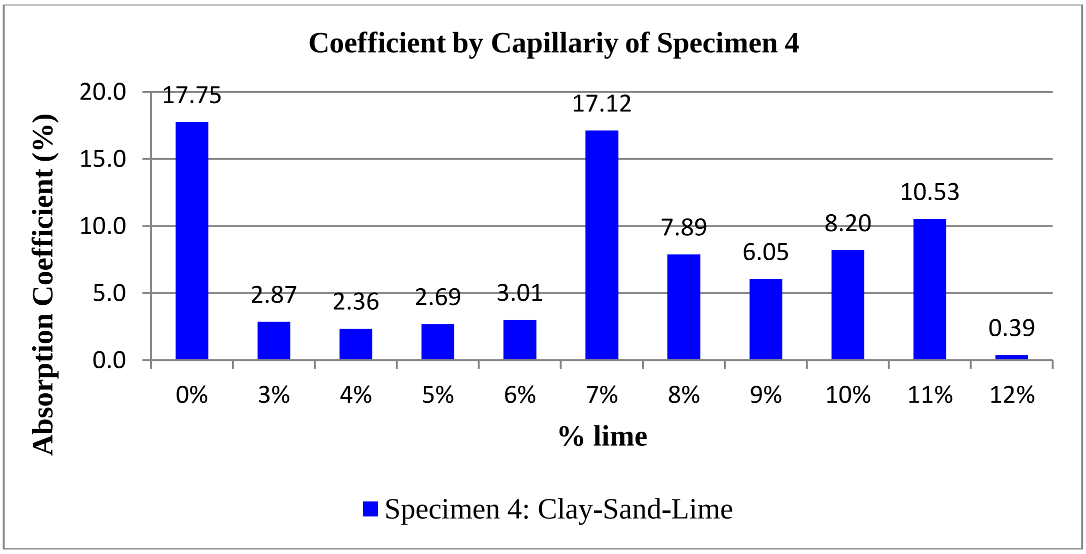


**Figure 3:** Bar Chart of Capillarity absorption for Specimen 4 (Clay +Sand +Lime)

From table 4 and figures 2 and 3, it is observed that the values of the water absorption by capillarity of blocks made are respectively:

i. 11.3% for pure soil blocks (CB)
ii. 17.8% for stabilized with the sand (CSB)

iii. 10.85 to 3.99% for the blocks stabilized with sand and cement (CSCB) and
iv. 17.12 to 2.87% for blocks stabilized with sand and lime (CSLB.

## IV. DISCUSSION

Being clayey soil, to be qualified as a good soil for making compressed soil blocks, there is a real need to improve the granularity of natural soil used. To do so, sand has good properties of reducing shrinkage and cracking. From table 2, the addition of sand from 3 to 50% has highly improved the grading properties of the clay. 50% sand has been used for making the blocks because it shrinks less than all the others mixing.

For block made from clay without any addition of stabilizer (CB), capillary absorption in water is 11.3% which is within *of* the recommended values (0-15) % by the standard (ARS: 1996), [9], those blocks can be used in a capillary environment provide with protection against water damage like used for unload-bearing structure for walls covered or protected with cement mortar against water damage.

For blocks made from the mixture of clay-sand (CSB), the absorption coefficient is 17.8% which is out of the recommended values by the standard because of sandy particles effects. CSSBs for this specimen are not suitable for a capillary environment therefore can be used only in a dry environment with no risk of being wet.

For blocks made from mixture of clay-sand-cement (CSCB), at (3, 5, 8, and 11) % cement, the capillary absorption varies between 5.35% and 10% due to the reaction effect between sand and clayey soil with cement. These values are acceptable for a capillary environment for structural elements capable to withstand to important loads (e.g. blocks make for lateral walls exposed to rain like for bathroom walls being splashed). With addition of (6-12) % cement, the absorption coefficient varies between 0.05 and 3.99% due to the high amount of cement which act with sandy particles. These values are highly recommended for a capillary environment (e.g. external wall unprotected from capillary rise, internal wall unprotected from water leaking through the roof).

For blocks made from the mixture of clay-sand- lime (CSLB), at 7% lime gives absorption coefficient of 17.12%, which is out of recommended value by the ARS [9]. Then are not suitable for capillary environments; therefore they are only recommended for a dry environment with no risk of being wet. With 8 and 11% lime, the capillary absorption of water are between 6.05% and 12.91% due to the high amount of lime and sand that with clay soil. These values are acceptable for a capillary environment in relation with values recommended by the standard in table 5-2 and recommended for works (e.g. blocks make for lateral walls exposed to rain like for bathroom walls being splashed). With (3-6 and 12) % limes the capillary absorption coefficients vary between 0.59 and 3.01% due to the presence of lime. These values highly are recommended for a capillary environment for exposed and uncovered walls (e.g. external wall unprotected from capillary rise, internal wall unprotected from water leaking through the roof).

## V. CONCLUSION

From the results and discussion above, it is concluded that with respect to Mangu soils:

i. The addition of 50% sand highly improved the soils for acceptance in making good compressed building blocks.
ii. Blocks made with clay only (CB) are suitable for use in wet areas but not where the environment is continuously wet.
iii. Blocks made from the mixture of clay and sand (CSB) are not suitable for use in wet environments and are therefore recommended for use in dry environments.
iv. Blocks made with mixture of clay, sand and lime (CSLB),with the exception of addition of 7%lime content, are suitable for use in wet environments but their amount of stabilizer (lime) used will depend of the severity of wet exposure conditions..
v. The mixture of clay and sand only from the studied sites should not be used to make building blocks unless binders (cement, lime) are added to reduce water absorption to acceptable levels.
vi. Only All the stabilizers used are recommendable for multipurpose according to the field of use in the recommendations.

vii. The more the binders (cement and lime) are added as stabilizers, the low is the absorption of water but for economic reasons the mixture with the high amounts of binders may not be economically viable.

viii. To be sustainable and economical soil block making using soil from the research sites studied, it is recommended that optimum mixratiosof45%sand and 6% binders (cement or lime) be used with the soils for compressed block making.

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