Stabilization of Kipkaren Estate Soil with Sodium Silicate for Making Interlocking Blocks

V. Sugut[1], L. N. Wekesa[2]

[1]*Staff, Department of Civil and Structural Engineering, Moi University, Eldoret, Kenya*
[2]*Student, Department of Civil and Structural Engineering, Moi University, Eldoret, Kenya*

Abstract – *Interlocking soil blocks have gained applicability as alternative construction material in provision of housing in developing countries such as Kenya. It uses native soils which require stabilization to attain required properties. This study investigated the use of Sodium Silicate stabilizer to improve the properties of native soil found in Kipkaren Estate, Kenya for making interlocking blocks in a low-cost housing project that adopted the compressed earth interlocking blocks technology. Another test was done using cement as a stabilizer and further, a blend of the two stabilizers. Characteristic tests were carried out which revealed that the soil was red-loam with slight plasticity. Interlocking blocks specimens were made out of the untreated soil, the Sodium Silicate treated soil at stabilizer dosages of 3%, 6% and 9% proportion by sample weight, the cement treated soil at 3%, 6% and 9% proportion by sample weight and further, out of a blend of 3% cement and 3% Sodium Silicate stabilizer. The blocks specimens were cured and compressive strength test done at days 7, 14, 21 and 28. At 28 days, the untreated sample had 4.17MPa compressive strength while the cement treated sample had 10.43MPa at 9% cement proportion by weight. The 3% Sodium Silicate stabilized sample attained 9.33MPa while the blend of 3% cement and 3% Sodium Silicate samples attained 10.04MPa. It was therefore determined that the blend of 3% cement and 3% Sodium Silicate sample was the most recommended for use since it attained good strengths at low cement proportions and hence cost effective.*

***Key Words*: Interlocking Blocks, Cement, Sodium Silicate, Stabilizer, Compressive Strength**

1. INTRODUCTION

Soil stabilization is a process to improve the physical and engineering properties of soil to obtain some predetermined targets in terms of load bearing capacity, capacity to withstand detrimental effects of the weather, durability etc., **(Faisal A., 2012, [1]).** Over the ages, efforts have been made to improve the native soils for various applications such as road construction, dam embankment, floor and walling in dwelling construction and so on. The technology of soil improvement via stabilization is one of the most practical and cheapest ways of enhancing the strength and durability of native soil. It can also minimize water absorption, water loss, soil erosion and soil settlement. Depending on the stabilization technology applied, soil can be turned from a weak commodity to a very useful resource acceptable as a universal construction material.

Interlocking soil blocks technology has gained adoption in developing countries mostly in form of plain earth compressed material, stabilized earth compressed material and reinforced earth material.

1.1 Objectives

The objectives of this study were as follows:

- To determine the properties of Kipkaren Estate soil under untreated conditions
- To find out the effects of Sodium Silicate in various proportions on properties of the Kipkaren Estate soil.
- To determine the compressive strength of interlocking blocks made from the Kipkaren Estate soil stabilized using cement, Sodium Silicate and a blend.
- To assess suitability of the Sodium Silicate stabilizer in making interlocking soil blocks

2. LITERATURE REVIEW

Yaser Al-Sakkaf et al., 2009, [2], summarized the advantages and disadvantages of earth material in construction as follows:
Advantages:

- It is readily accessible and economical natural material.
- It is easy to work with, requiring unskilled to semi-skilled labour on self-help basis.
- It offers high resistance to fire, as well as high thermal and heat insulation value.
- Earth is recyclable and an environmentally friendly.

Short comings:

- Volume instability
- Low mechanical and strength characteristics
- High maintenance required for exposed surfaces
- Low durability when exposed to atmospheric or ground water and attack by termites and pests.

All the short comings listed above can be adequately solved by stabilization or modification of the earth material using various methods namely **(Amin E. Ramaji, 2012, [3]**):

- Physical : vibration, thermo-electrical, freeze and thaw
- Mechanical: compaction, consolidation, reinforcement

- Chemical additives: conventional agents (cement, lime, bituminous), Enzymes, Polymeric resins

Adriana Erica Amaludin et al., 2019, [4], explored the effects of Sodium Silicate on shear strength characteristics of coastal soils and observed highest increase in strength with a 4% dosage of the stabilizer.
Rute Eires, 2014, [5] studied cement and lime stabilization of earth material for use in stabilized interlocking blocks and observed an improvement in strength and reduction in water absorption and in turn improved durability of the resultant blocks.
Nitin Mane and Rajashekhar, 2017, [6], made an observation that black cotton soil was adequately stabilized using red mud at 30% optimum content and dosed with 2% Sodium Silicate. The Sodium Silicate was able to increase the CBR abut beyond a certain percentage, the CBR values started to drop. The maximum value of CBR so observed was 3.9.
Harender, Akash Batra and Pappu Sharma, 2019, [7], in their work observed a decrease in maximum dry density, an increase in optimum moisture content and an increase in unconfined compressive strength of soil by addition of lime and Sodium Silicate.
Hossein Moayedi et al., 2012, [8], went into the physiochemical changes and mineralogical composition of organic soil improved using Sodium Silicate stabilizer and observed the following:

- The unconfined shear strength of the organic soils improved attributable to the silicate minerals,
- Addition of reactors/accelerators such as Calcium Chloride and Aluminium Sulphates to the system further improved the effect of Sodium Silicate.

3. MATERIALS AND METHODS

The interest of this study was on the native soil in Kipkaren Estate in Kenya where a low-cost housing project was being planned. There were other stabilizers like fly ash, lime and cement which were already being proposed for use in the project. Fly ash was however not readily available while cement was costly in the long run for bulk requirement. Sodium Silicate stabilizer and strengthener was available in the market and was cheap compared to other additives and hence the need for suitability investigation.

The manufacture of the interlocking soil blocks followed a series of processes:

- Soil preparation and characterization,
- Blending and casting,
- Curing and testing

3.1 Soil preparation and characterization

The soil from the Kipkaren Estate study area was excavated from a depth of 300mm below ground level to avoid humus matter.
A sample of the soil was subjected to the following characterization tests which determined the soils to be Red Loam Soil of slight plasticity. The results were as presented in **Table -1.**

Table -1: Properties of the Untreated Soil

SN	Property	Observation
1.	Color	Red-brown
2.	Texture	Fine
3.	Moisture Content	19.48%
4.	Specific gravity	2.63%
5.	Liquid Limit	21.62%
6.	Plastic Limit	17.5%
7.	Plasticity Index	4.12%
8.	Shrinkage limit	6.0%
9.	Maximum Dry Density	1590Kg/m^3
10.	Optimum Water Content	15.11%
11.	pH	6.82

3.2 Blending and Casting

Soil samples prepared and mixed thoroughly with respective additives as demonstrated in **figure -1**.

Figure -1: Soil sample preparation

The first sample was untreated soil and labeled (UT).
The second was a batch of three, treated with cement at 3%, 6% and 9% by weight of the sample and labeled CT3%, CT 6% and CT9% respectively.

The third was a batch of another three, treated with the Sodium Silicate stabilizer at 3%, 6% and 9% by weight and labeled TX3%, TX6% and TX9% respectively.

The fourth was derived from the results of the foregoing tests, and was determined to be a blend of CT3% and TX3% and was labeled CT3%+TX3%.

In each of these cases, specimen blocks were prepared sufficient for carrying out compressive strength test at days 7, 14, 21 and 28. The sample soils were placed in the Block Press Equipment which is operated manually and yielded interlocking blocks as shown in **figure -2**.

Figure -2: Interlocking block on Block Press Equipment

3.3 RESULTS AND DISCUSSION

Specimen blocks were placed on the compression test machine as illustrated in **figure -3**. The results obtained in were compressive loads at crush point as shown by the crushed specimen **figure -4**. The loads were converted and corrected for compression strength presented in **Table -2**:

Table -2: Compressive strength test results (MPa)

S/N	Sample	Compression Strength (MPa)			
		Day 7	Day 14	Day 21	Day 28
1	UT	3.62	3.84	3.57	4.17
2	CT3%	4.39	6.15	8.45	9.22
3	CT6%	4.80	7.13	8.78	9.77
4	CT9%	5.21	7.35	8.56	10.43
5	TX3%	3.90	5.08	7.02	9.33
6	TX6%	3.84	4.44	5.62	6.80
7	TX9%	3.73	4.06	5.65	6.20
8	CT3% + TX3%	4.25	6.45	9.16	10.04

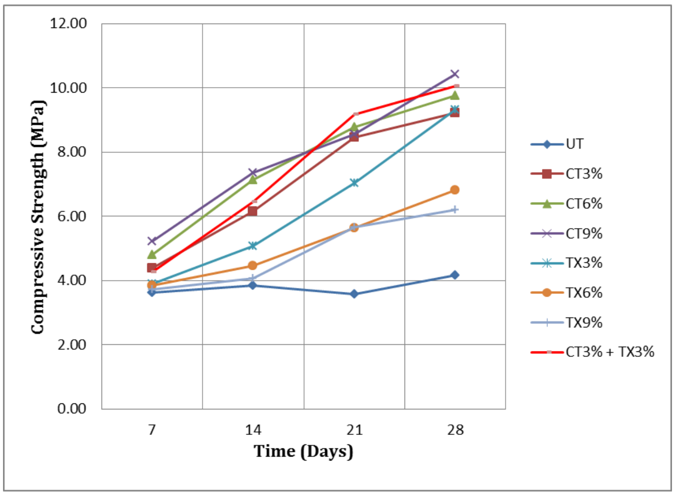

Chart -1: Compressive strength (MPa) against Time (Days)

The results presented in **Table -2** were used to come up with comparative and trend illustration as shown in **Chart -1** and as observed, it is indicated that there was a higher increase in strength capacities for soils treated with cement than those treated with Sodium Silicate between the 7th day and the 28th day as measured.

The highest increase in compressive strength is observed on the soil treated with a blend of cement and the Sodium Silicate stabilizer whereas the untreated soil presents only a marginal increase in strength.

Figure -3: Interlocking block specimen placed on the compressive test machine

Figure -4: Specimen of crushed interlocking blocks form compression test

4. CONCLUSIONS

The following conclusions were drawn from the study:

i) Cement was superior to Sodium Silicate as a soil stabilizer for production of the interlocking blocks attaining a compressive strength of 10.43MPa at 9% proportion by weight, while Sodium Silicate only managed 9.33MPa at 3% proportion by weight.

ii) The most recommended combination was a blend of 3% cement and 3% Sodium Silicate by weight of samples which attained a compressive strength of 10.04Mpa and was at the same time cost effective due to the lower amount of cement being used.

iii) Increase in the amount of the Sodium Silicate lead to a decline in the compressive strength of the blocks.

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