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Research Paper

EFFECTS OF STABILIZERS ON COMPRESSIVE STRENGTH OF SOIL BLOCKS: A CASE STUDY USING MANGU SOIL

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This research work investigates and evaluates the effects of Ordinary Portland cement and lime were used as clay stabilizers on the compressive strength of compressed earth blocks with recommendations for the usage of the blocks in the construction industry. The results showed that the addition of sand, lime and cement at various ratios highly improved the compressive strength of the clay blocks made. The highest compressive strength was obtained when 12% cement and 14% lime were added as stabilizers. However the optimum service performance of the blocks in compressive strength was attained at 50% sand with 6% cement and 7% lime added.

Keywords: Clay, Compressed earth blocks, Compressive strength, Mechanical properties, Effects of stabilizers

INTRODUCTION

Earth (clay) is a construction material readily and abundantly available worldwide. A large part of the built heritage is composed of masonry buildings, as brick-mortar masonry has been a traditional construction technique since ancient times and it is still widely used nowadays for new buildings (Sassoni *et al*., 2014). These old earth buildings, associated with the Natives, are gradually disappearing as illustrious sons and daughters of these families are replacing them with modern structures (Egenti *et al*., 2014). In the past, it was a very common construction material used over many years for almost all types of constructions instead of timber, sand and concrete (Silveira *et al*., 2012). Aubert *et al*. (2013), in their study on earth blocks said that researchers have sought to apply procedures developed for other construction materials (concrete, fired bricks, stone, etc.) to earth construction materials. They concluded that

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earth block tested did not have a real compressive strength greater than 45 MPa and the fact that the brick did not break up to this value was due to the specific environment of the unconfined compression test coupled with the specific characteristics of the sample (especially its geometry).

Clay bricks are some of the oldest building materials to be manufactured and used by man after wood. They are still popular as building materials mainly because of their structural properties, easy availability, relatively low cost and easy architectural workability. Traditionally, clay bricks are considered as solid and sustainable materials under normal weather conditions. Where clay deposit are available, bricks can be manufactured locally, which makes them easily available at relatively low cost (Chan, 2011). Earth (clay) is a great heritage to mankind in sustainable clay building technologies around the world as these technologies are adaptable to traditional architectural and cultural practices of different communities. Unburned bricks when used in wet areas require an insulation from rain infiltration because the biggest problem is water effect on brick strength (Abdulrahman, 2009). Clay is the most accessible and cheapest natural construction material for making structural elements for building construction such as clay blocks (fired or unfired). Clay is a cohesive material which can be used as natural binder when sandy particles are added. For making suitable blocks, the properties of clay can be improved by a process called stabilization.

In developing countries such as Kenya, the majority of houses in rural areas are built with laterites (Mbumbia *et al.*, 2000). Despite the obvious limitations of sustainability, acceptability and strength, the use of lateritic earth has continued to increase (Abdulrahman, 2009). Because of the limitations in the use of lateritic earth in construction activities, recent research efforts are directed toward improving the mechanical properties of stabilized earth bricks for the construction of buildings which are low cost and durable (Isik and Tulbentci., 2008). These efforts aim at improving the traditional technologies of using lateritic earth in the construction industry to increase strength, durability and other performance characteristics in addition to lower water absorption. Durability of building materials can be defined as their resistance to functional deterioration over time which is mainly related to the action of water on the walls (Morel and Hamard., 2012).

Stabilization is a set of methods for modifying the properties of the soil to be improved so that it can meet the requirements for the intended use by improvement of physical and mechanical characteristics such as:

a. Increase in strength.

b. Improvement in the resistance against weathering.

c. Reduction in porosity, shrinkage and variation of volume.

d. Improvement in the binding properties between the particles in order to reduce the void ratio and void index.

To meet these durability properties (Reddy, 2012) discuss different methods of soil stabilization and production techniques for soil stabilized blocks. There are various stabilization methods that may be used to improve on each of these durability parameters such as:

a. Chemical stabilization by adding admixtures such as plasticizers and accelerators (Meukam, 2004).

b. Mechanical stabilization by changing the density and compressibility of soil thereby reducing water absorption, permeability

c. Physical stabilization by correcting the granularity and texture of soil (Abdulrahman, 2009) by cement and lime stabilization.

Soil alone is not suitable for making sustainable blocks due to the non-cohesive property of clay (Chan, 2011). Dhandhukia *et al.* (2013), in their study change the physical properties of soil by mixing high clay containing soil with high sand containing soil. The cohesive property is desirable and is required as a natural binder for clay blocks. Romans added sand, natural fibers (straws and dried grass) in clay-water mixtures to improve the workability property and to reduce excessive shrinkage and cracking. Chan (2014) made baked and unbaked bricks with a mixture of clay, cement and fibers (pineapple leaves and oil palm fruit bunches), examined different properties, with a focus on water absorption, compressive strength, density and efflorescence. He observed that specimens with higher density had correspondingly higher strength and water absorption index with cement acting as binder of the composite material. He concluded that the benefits of fiber inclusion are observed in a range of 15% of cement added and the strength is improved with inclusion of fibers on non-baked bricks.

Taallah *et al.* (2014) investigated the mechanical properties and hygroscopicity behavior of compressed earth block and they found that Better result of the dry compressive strength was observed by CEB with 0.05% of fiber content, 8% cement content and compaction pressure of the 10 MPa.

Modern rammed earth is generally stabilized with small quantities of Portland cement in order to improve its strength and durability, however an alternative is to use lime to stabilize the raw soil (Ciancio *et al.*, 20114). Compressive tests are carried out to assess the ability and capability of blocks to withstand compressive loads. It is the most important mechanical test which stimulates the condition of the material in service (Azeez *et al.,* 2011). Generally compressive strength decreases with increasing porosity and while it is also influenced by clay composition and firing. Blocks prepared with optimum quantity of lime along with cement has led to continuous buildup of strength, whereas blocks prepared with cement alone and lesser quantity of lime than optimum quantity have not gained much strength from the time of preparation of the blocks

(Nagaraj *et al.,* 2014). The compressive strength of clay bricks depend on other key parameters for durability such as the percentage of each ingredients, the firing temperature and porosity. The compressive strength of soil can be improved by using a good method of stabilization which will also improve its durability by increasing its resistance. The main categories of binders that can be used to enhance the mechanical properties of earth are Portland cement, lime, bitumen, natural fibers and chemical solutions such as silicates (Elert *et al.,* 2003). Previous studies found that the compressive strength is the most significant property determining the quality of masonry bricks. This depends also on the properties of soil and the binder used. Under wet condition the compressive strength is weaker because of the increased moisture content and hence water absorbed. The compressive strength is highly influenced by many factors such as the type of soil, compacting procedure and the binding materials used (Riza *et al.,* 2011). The iron present in the soil is responsible for low compressive strength in the soil stabilization process and the low compaction levels achieved. Addition of natural fibers improves the compressive strength by reducing cracking due to shrinkage and by increasing cohesion forces. Azeez *et al.* (2011) in his study focusing on the compressive strength of bricks, by mixing clay with cement, showed that the optimum ratios of cement, between 5% and 10%, gave the highest compressive strength. His results showed that with 0% of cement, the compressive strength was 727.91 N; with 4% cement mixed with clay, the compressive strength was 481.03 N and that when 6% cement was mixed with the clay, the highest compressive load at failure was 2,537 N. This meant that cement was an important material in the improvement of the compressive strength of clay bricks.

The aim of this research was to investigate and evaluate the effect of stabilizers on the compressive strength of compressed soil blocks made with clay soil from Mangu in Kenya.

The organization of the manuscript is starting by the material and methods used, results obtained and discussion of results and finish by conclusion and future scope.

MATERIALS AND METHODS

For this study, soil sample 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 and natural fibers.

Clay was initially air dried, broken in powder form and only that passing through 5 mm sieve was used for making the blocks according to the standard (ARS 680:1996). 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 14% as given in Table 1.

Table 1: Variation of Amounts of Stabilizers Added

Cement (%)	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	14%
Lime (%)	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	14%
Sand (%)	50%										

The clay, sand, cement and lime in the various proportions were mixed thoroughly to a homogeneous dry mixture in a pan after which water was added to attain an optimum moisture content previously determined from compaction tests carried out earlier. The wet mixes were filled into the mould of the block making machine in three layers and manually pressed for 30 s after which the blocks were removed from the mould for drying. The blocks were dried during 28 days covered with block polyethylene sheets in a dry cool place protected against rain, direct sun and wind before carrying out the compression tests.

The tests for compressive strength of dried blocks were carried out according to the standard ARS 683: 1996 using a universal compression testing machine as shown in Figure 1 below. The compression loading was applied continuously to failure at a uniform rate of 0.2 MPa/s until complete crushing of the block specimens. A total of 72 specimens of blocks were tested in compression at 28 days.

RESULTS AND DISCUSSION

Table 2 shows the compressive strengths 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).

From Table 2, it is observed that clay blocks made using clay only without any type of stabilizer (CB) had a compressive strength of 2 MPa. This value corresponds to the lower limit of compressive strength acceptable in masonry for unload walls (e.g., boundary wall and internal partition. Clay blocks made with clay using sand as stabilizer (CSB) improved the compressive strength slightly from 2 MPa to 2.3 MPa. These blocks could thus be used for non-load bearing structures.

Figure 1: Compressive Strength Testing in a Universal Testing Machine

Table 2: Compressive strength at 28 days of various clay block compositions with varying percentages of stabilizers

Compressive Strength (MPa) at 28 days												
% Stabilizers / Clay block composition	0%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	14%
Soil (CB)	2.0											
Soil + Sand (CSB)	2.3											
Soil+Sand+Cement (CSCB)		2.4	2.4	2.4	3.1	3.9	4.4	4.6	5.3	5.5	5.7	5.4
Soil+Sand+Lime (CSLB)		2.2	2.1	2.4	2.8	3.1	3.3	4.3	3.5	3.7	2.6	4.4

Figure 2 below shows the plot of compressive strength values of clay blocks made with clay using sand and cement as stabilizers (CSCB) ranging from 2.4 to 5.7 MPa with cement content varying from 3% to 14%. The compressive strengths with cement content between 3 to 7% ranged from 2.4 to 3.9 MPa that is acceptable. These blocks may be used in buildings with non-load bearing walls e.g. boundary walls, in-fills in load bearing structures, single story buildings made of load-bearing structural elements. 8 to 14% cement contents gave higher compressive strength ranging from 4.4 to 5.7 MPa. These strength ranges are good for low rise buildings but it should be borne in mind the increased clay block costs due to increases in cement contents. These blocks can withstand external (live) actions (e.g., in two storey buildings).

Figure 2: Compressive strength of clay blocks made using sand and cement as stabilizers (CSCB)

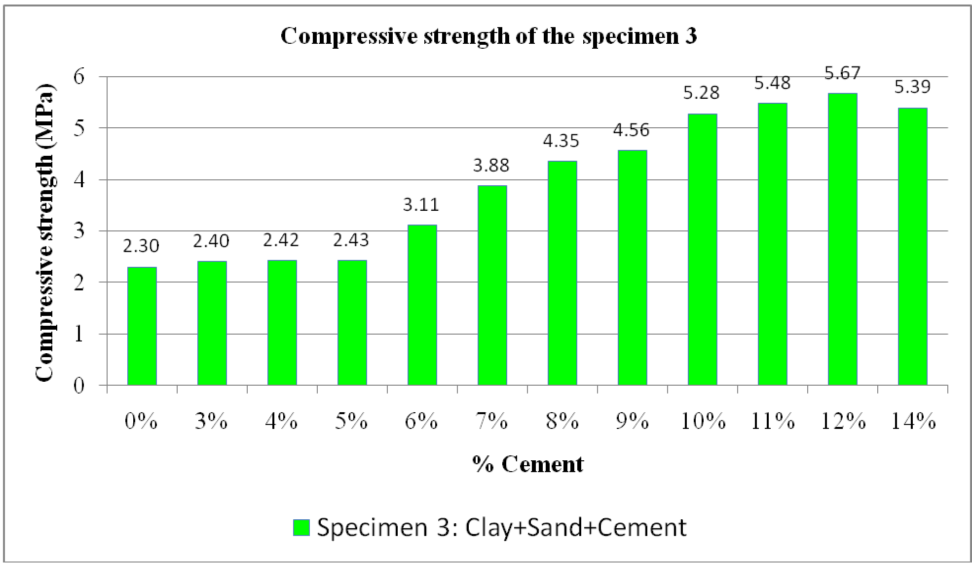


Figure 3 below shows the plot of compressive strength values of clay blocks made with clay using sand and lime as stabilizers (CSLB) as contained in Table 4 ranging from 2.2 to 4.4 MPa with lime content varying from varying from 3% to 14%. The compressive strengths with lime content between 3% to 8% and 10% to 12% ranged from 2.1 to 3.7 MPa which is acceptable. These blocks may be used in blocks in unloaded walls (e.g. boundary wall, in-fills in load bearing structures, single story buildings made of load-bearing structural elements to fairly loaded walls. 9 to 14% lime contents gave higher compressive strength ranging from 4.3 to 4.4 MPa. These strength ranges are good for low rise buildings but it should be borne in mind the increased clay block costs due to increases in cement contents. These blocks can withstand external (live) actions (e.g. in two storey buildings).

Figure 4 below shows a comparison of the compressive strengths of all the four types of

Figure 3: Compressive strength of clay blocks made using sand and lime as stabilizers (CSLB)

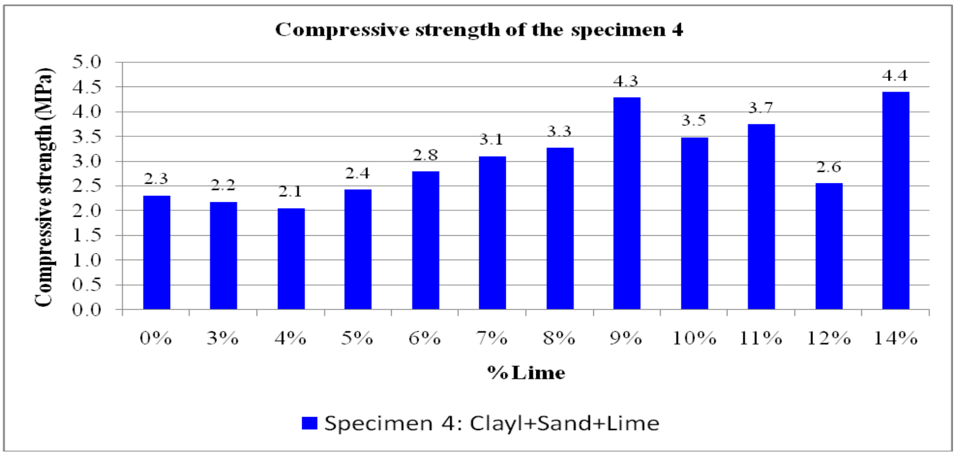
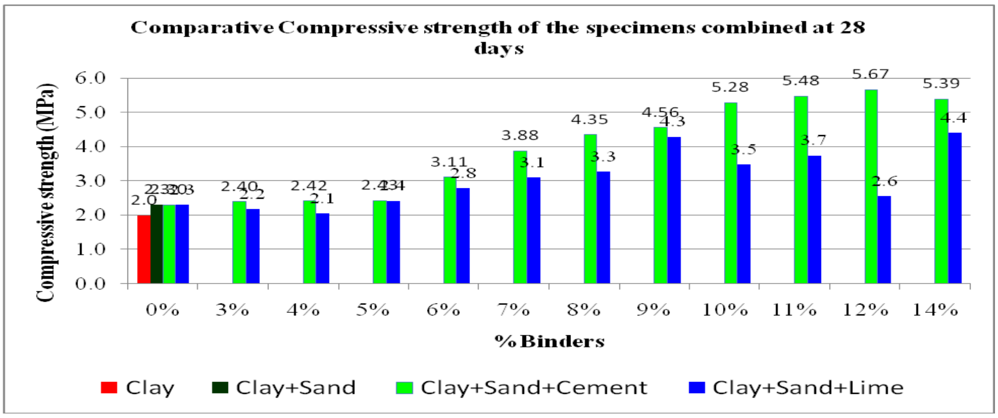


Figure 4: Comparative compressive strength of clay blocks using various combinations of stabilizers



clay blocks, i.e., CB, CSB, CSCB and CSLB as contained in Table 4. From this figure it is observed that in all the cases, the clay blocks using the mixture of cement and sand as stabilizers gave higher compressive strengths than when sand and lime were used. It can be explained by the fact that the compressive strength of cement is higher than the lime one.

CONCLUSION

From the results and discussions above, it may be concluded that:

a. Clay blocks made using clay only without any type of stabilizer (CB) are not recommended for any type of construction works.

b. All other clay blocks made with clay using sand as stabilizer (CSB), using sand and cement as stabilizers (CSCB) and using sand and lime as stabilizers (CSLB) may be used as in-fills in high rise structures and in construction works without very high loads such as single storey buildings.

c. The highest compressive strength with cement as stabilizer is 5.67 MPa at 12% cement content and with lime is 4.40MPa at 14% lime content. However the optimum service performance for the clay blocks subjected to compressive loads was obtained at mixture of sand with 6% to 8% cement and 7% to 9% lime content for common for non-load bearing structures.

d. The best stabilization that gave the best performance in compressive strength was that using mixture of sand and cement as stabilizers.

FUTURE SCOPE

It is recommended that further research work be carried out:

a. Using clays from different locations to ascertain the optimum contents of cement and lime stabilizers.

b. Using other different types of potential stabilizers e.g. sugarcane bagasse ash, fly ash, rice husks ash, etc.

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