
Effect of Sand on the Properties of Compressed Soil-Cement Stabilized Blocks

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Abstract: With the growing concern of awareness regarding sustainable building materials and environmental issues, a number of people have resorted to using soil-cement stabilized blocks (SCSBs) as an alternative for burnt bricks. However, these stabilized blocks are also known for their high-water absorption capacity during wet seasons which affects their strength and durability. The study conducted involved a series of physical properties tests of soil (particlesize distribution analysis and Plasticity Index test); mechanical property tests (compressive strength test and water absorption test), which were undertaken in accordance with the ASTM standard. It compared the compressive strengths and water absorption capacity among SCSBs with a sand blend at different proportions of mixture (10%, 20% and 30%) and those without sand, maintaining the quantity of cement constant at 5%. The results indicated that the compressed stabilized earth blocks using silty clay soil blended with sand and with 5% cement were stronger compared to those without sand. However, the water absorption capacity of the blocks (both with and without sand), revealed no significant difference except for the blocks with 20% of sand which proved to have the lowest water absorption capacity (15%). The SCSBs of 10% addition of sand proved to be the strongest with compressive strength of 2 Mpa. The study concluded that 10% blend of sand could be adopted in block manufacturing for sustainable low-cost housing construction. Having known the strength of these blocks, the users can go ahead and use them in low cost housing construction projects.

Keywords: Compressive Strength, Stabilized, Earth Blocks, Sand, Water Absorption

1. Introduction

There is an urban housing crisis in most of the developing countries which is largely attributed to the rapid urbanization [1]. In order to provide sustainable housing, most people in low income communities prefer to build low cost housing with locally available materials.

The impediments to solving the housing problem are scarcity and high cost of building materials. Ideally, low-cost housing must rely on raw materials that are in easy accessibility locally. Furthermore, such materials must be abundantly available and be renewable in nature. Due to these and other various reasons, the investigation of alternative materials for the construction of low cost housing has been the focus of many studies in many developing countries.

In Uganda, burnt clay/soil bricks have dominated the

market and have raised concern about environmental issues. In Kumi District in particular, the cost of burnt clay bricks is high due to inadequate and high cost of energy from firewood used for burning bricks which has resulted into rampant cutting of trees in the past years. A number of people have resorted to using unfired soil-cement stabilized blocks as the alternative for burnt bricks. The main advantage of manufacturing unfired bricks is that it requires lesser energy than fired bricks, and hence the release of carbon dioxide into the atmosphere is 80% less than fired bricks [2, 3].

One of the drawbacks in using earth alone as a material for construction is its durability which is strongly related to its compressive strength [4]. Sand has been used in the mix for manufacturing SCSBs. In literature, however, the optimum amount of sand required in improving properties of SCSBs is scanty. The purpose of this study, therefore, was to blend soil-cement mixture with appropriate proportions of sand to improve durability and strength properties of these blocks.

2. Literature Review

2.1. Compressed Stabilized Earth Blocks

Stabilization is a process of mixing admixtures with soil to improve its volume stability, strength, permeability and durability [5]. Stabilization is considered to be an important step in the manufacture of CSEBs, and is aimed at improving the performance of soil as a construction material. Compressed earth blocks are the most important modern building materials which have enough production flexibility to let them be integrated into both formal and informal sectors of structural activities [6].

The technology of traditional earth construction has undergone considerable developments, and enhanced earth's durability and quality as a construction material for low-cost building [7]. The compressed earth block is the modern descendent of the molded earth block. The earth compressed blocks became widely used around the world in the last 30 years or more, not only in third world countries, but also in developed countries like USA, France, Canada, and Austria. The performance of the stabilized compressed earth block was comparable with others in terms of their strength characteristics. Meanwhile, the reduction of transportation time, cost and attendant pollution can also make earth blocks more environmentally friendly than other materials.

The durability and strength of the structures using CSEB, both stabilized CEB and unstabilized CEB are appropriate for buildings and meet the US Building Code Standard for compression and modulus for rupture tests. The fact is that the durability of a CSEB building will allow it to last for centuries as evidenced by the ancient earthen structures which still stand today in many parts of the world. CSEB have proven to be water proof, fireproof, bug proof, and bulletproof. These structures can be built to resist earthquake damage in seismic zones. By utilizing clay and sand, CSEB would be an incredible building material.

Good production could be performed by increasing compressive strength and using improved curing [8]. A lot of research work has been done in the development of local and stabilized soil bricks [9, 10]. National and international standards have also been developed for these procedures such as New Zealand standard 1998 and Standards Australia handbook 2002 [11, 12]. The test methods of earth walls vary from country to country because of the varied weather conditions. They are also not based on the evaluation of field performance [13]. A number of guidelines and publications that explain various aspects of earth wall construction and testing have been produced as well [14].

2.2. Water Absorption and Moisture Content

Water absorption is a function of clay and cement content and usually related with the strength and durability of earth bricks and therefore it is important to determine the rate of water absorption of earth bricks. Research indicates that water absorption rate decreases with increasing age of earth bricks [3]. High rate of water absorption of a specimen may

cause swelling of stabilized clay fraction which results in losing strength with time. As observed by Walker, water absorption, as well as porosity, increases with clay content and decreasing cement content. [15]. In a study by Guetalla and others, they tried to reduce the water uptake by adding a hydrophobic material, in this case was polymethylhydrogen-siloxane and combined with slag + fly ash which is highly absorbent and the result showed that the water uptake with the addition of 0.5% siloxane was less than a quarter of the water uptake of fly ash-slag without additive [9].

Sand content in the mixes apparently can reduce water absorption and weight loss even though does not affect the compressive strength significantly. Moisture contents affect strength development and durability of the material and have a significant influence on the long-term performance of stabilized soil material, especially, has an effect on bonding with mortars at the time of construction. When the brick is dry, water is rapidly sucked out of the mortar preventing good adhesion and proper hydration of the cement and when the brick is very wet the mortar tends to float on the surface without gaining proper adhesion.

Types of compaction affect the optimum water content in the stabilized mixes. Dynamic compaction can reduce the optimum water content from 12% to 10% with about 50% increase in compressive strength. It is stated that the optimum water content ranges between 10 to 13% for static compaction, as for vibro-static compaction slightly increases compressive strength with the same water content for low compressive load [10]. Research indicates that soil-lime mixes require higher optimum moisture content than soil-cement mixes [9].

2.3. Durability

Durability is the measure of the ability of the block to endure or sustain its distinctive characteristics of strength, dimensional stability and resistance to weathering under conditions of use for the duration of the service lifetime of the structure. Earth blocks have to be durable and water proof to exclude any undesirable influences of the environment such as rain, winds, rising damp or other severe weather conditions of exposure. The main purpose of stabilization is to prevent water attacks and this can be achieved by using a durable material with limited loss in mechanical strength in a wet state. From several experiments, durability is associated with the stabilizer content, clay content and compacting stress. Basically, durable stabilized clay building material can be achieved as long as they are not saturated. The problems arise when the materials are subjected to the long-term saturation and exposed to various climatic conditions. It was observed that rain drop can release the kinetic energy that impacted the brick and causing material falling from the surface of wall panels [16]. He stated that wet/oven dry ratio of 33% may be a suitable criterion for evaluating the durability of cement stabilized earth specimen. As observed [3], combination of bricks made of clay, cement, lime and Ground Granulated Blast Furnace (GGBS) subjected up to 100 cycles 24 hours repeated of freezing and thawing showed

satisfaction result where only having maximum 1.9% weight loss at the end of the 100th cycles. The examination after the test showed no damage occurrence of any type. Nevertheless, in general, clay material still has potential to damage from rising damp, freeze/thaw cycles and surface erosion caused by wind-driven rain as clay mineral tend to disrupt the cement action.

2.4. Density

Commonly, most researchers have established that the densities of compressed stabilized earth bricks are within the range of 1500 to 2000 kg /m³. Density of the compressed earth brick is consistently related to its compressive strength and compaction force applied during production. The dry density is largely a function of the constituent material's characteristics, moisture content during pressing and the degree of compactive load applied. Types of compaction applied such as dynamic, static and vibro will also affect the density. The density of brick can be determined through standard procedure such as ASTM C 140 and BS 1924-2 and others.

2.5. Shrinkage

Drying shrinkage of the bricks is primarily governed by the plasticity index and cement content. Water-loss also contributes to the shrinkage of the clay fraction. For low clay mineral content (index plasticity below 20%), drying shrinkage showed steady increase with the increase of clay content, but for plasticity index beyond 25% – 30% drying shrinkage increased rapidly as the clay content also increased. Soil with plasticity index <20 is good for cement stabilization with cement content 10%, and commonly used drying shrinkage limit is from 0.008% to 0.10%. Sand as part of the mix, seems to have significant influence in shrinkage although sand content does not affect significantly the compressive strength [9]. It was reported that shrinkage increases rapidly during the first 4 days for cement stabilized earth bricks and the addition of sand reduces the shrinkage as sand particles oppose the shrinkage movement [10]. It was also observed that the addition of cement content reduced the shrinkage until 44% for 10% cement content added. BSI 6073 and Australian Standards 2733 can be used to measure the drying shrinkage.

3. Research Methodology

3.1. Experimental Set up

This research study was conducted at the Uganda National Roads Authority's laboratories located in Kyambogo in Uganda for the sieve analysis of the soil, preparation of the sample mixtures, making of the blocks, curing of the blocks and testing of the blocks after 28 days of curing for the compressive strength and water absorption capacity. The blocks for water absorption capacity test were measured and fully immersed in water for two (2) hours and results

recorded in table 4. The laboratories provide testing, monitoring and quality control for construction materials such as bitumen, concrete, aggregates, soil as base course and embankments as part of quality assurance for any project for obtaining reliable data.

3.2. Research Instruments of the Study

The instruments used in this study were: the sieve pan set for sieving analysis of the soil, block mould, weighing scales, pans, PI apparatus, trays, polythene sheeting, water containers for immersion and ACV machine. Soil for the CSEB samples were sieved and then used in each desired mixture. On the other hand, to determine the compressive strength and water absorption capacity of the block samples, treatment/curing procedures were conducted and compressive strength and water absorption capacity tests were also done by ACV machine and weighing respectively. Durability of the blocks was consequently determined after compressive strength and water absorption capacity.

3.3. Research Study Procedure

3.3.1. Collection of Materials

Soil and sand were available in the local area and the soil in particular was picked from Kyambogo University Campus area. Pozzolana cement was bought from Banda, a local market located in Kampala. The sieve pan and other laboratory materials used were from the UNRA Kyambogo Laboratory.

3.3.2. Soil Selection and Preparation

The sample soil for block production was made free from topsoil, usually found up to 1m below ground surface. The soil was sun dried and then sieved through an aperture size No. 14 passed and retained sieve No. 20 according to BS Standard Testing Sieve. The sand used was clean lake sand.

3.3.3. Proportioning of the Samples

The deigned mixture was properly prepared through the set-ups needed for the purpose of this study. Mix proportions were determined and used as indicated in Table 1. It presents the quantity of specimen design mixtures of the CSEB with sand and CSEB without sand. The production process involved two set-ups and the process was proportioned by weight. The first set-up was for the CSEB without sand samples which consisted of two specimens while the other set-up was for the CSEB with sand with the same specimen samples. Cement content remained constant (all with 5% cement) in varied proportions of the soil, sand, and water mixture to determine the compressive strength of the blocks. The blocks test specimens were produced, cured under plastic sheeting with adequate sprinkling of water daily for 28 days after which the manufactured CSEB through recommended procedures were tested for compressive strength and water absorption capacity, the parameters which were of interest in this study.

Table 1. Quantity of Specimen Design Mixtures.

Block Sample	Specimen	Proportion	Cement (%)	Sand (%)	Soil Sample (%)	Total Sample (%)
Compressed Stabilized Earth Block (CSEB) without sand	1	1:19	5	-	95	100
Compressed Stabilized Earth Block (CSEB) blended with sand	A	1:2:17	5	10	85	100
	B	1:4:15	5	20	75	100
	C	1:6:13	5	30	65	100

4. Results and Discussion

Before considering the test for compressive strength of the CSEB, there was a need of discussing the type of soil that was used in this study. Understanding the type of soil used in this study was a big influencing factor in the possibility of producing alternative walling material. Identification of the soil type, grain size, liquid limit, plastic limit, and plasticity index of the soil are presented in table 2.

4.1. Particle Size Distribution and Plasticity Index Tests

The results of the soil properties such as the grain size analysis, liquid limit, and plastic limit are presented in Table 2. Thus, according to the test results, it was established that the type of soil sample used was “Silty Clay Soil” and from observation, the soil had a plasticity index of 21 which means that there is a gradual increase in drying shrinkage with increasing clay content.

4.2. Compressive Strength Test

Table 3 shows the compressive test results of the compressed stabilized earth block samples. The set-up

contains two samples for each category that were cured for 28 days before testing on February 22, 2017.

Furthermore, all samples had the ratios of components in accordance to the designed mixture presented earlier in Table 1. From the test results, sample 2, block 2 indicated the highest compressive strength (44.8 KN or 2.0 Mpa) followed by sample 2 block 1 (42.7 KN or 1.9 Mpa). This compressive strength was obtained from CSEB with 10% blend of sand as indicated in figure 1. It was observed that after this optimum percentage of sand content, any further increase in sand was not in any way beneficial in the strength gain of the blocks. Otherwise, all the test results of the three samples with a blend of sand of different percentages (10%, 20%, and 30%) achieved total average compressive strength greater than that of CSEB without blend of sand.

The results in table 3 indicate that better compaction (from density figures) resulted in better compressive strength. The compressive strengths range of 1.3 Mpa - 1.9 Mpa are strong enough for even double storeyed building as it would be for 14 Mpa of burnt clay bricks. The researcher due to financial constraints, preferred to use two samples each, however, three or more could have been more sufficient to provide more reliable results.

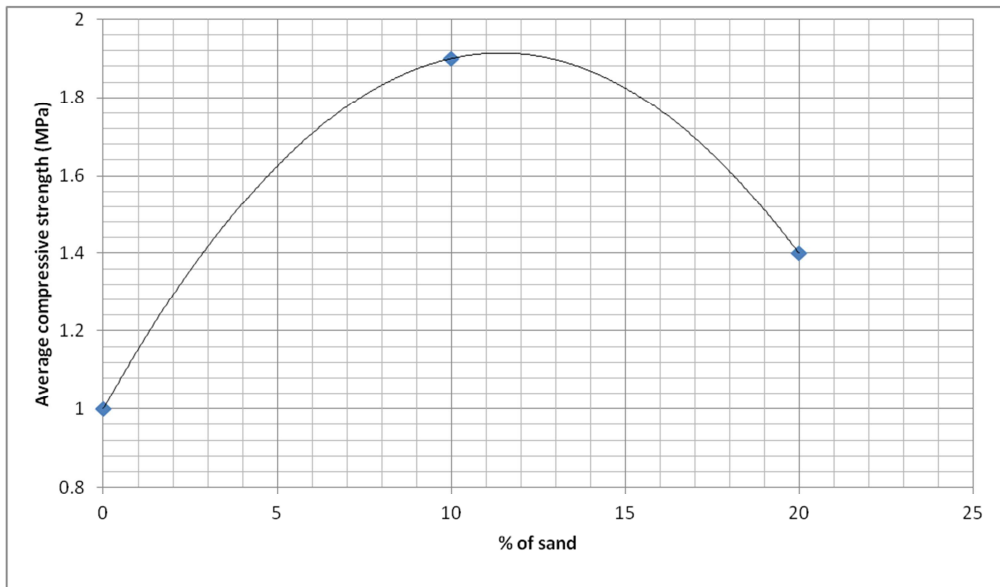


Figure 1. Average Compressive Strength Vs. %age of sand.

Table 2. Summary of Particle Size Distribution and plasticity index Tests.

Trial pit no.	% passing the given standard sieves																	
	75 mm	63 mm	50 mm	37.5 mm	28 mm	20 mm	14 mm	10 mm	6.3 mm	5.0 mm	2.0 mm	1.18 mm	0.600 mm	0.425 mm	0.300 mm	0.212 mm	0.150 mm	0.075 mm
TP 1	100	100	100	100	100	100	100	100	100	100	99	97	95	93	89	86	82	78

Table 2. Continue.

Trial pit no.	GM	PM	PP	LL	PL	PI	LS	AASHTO Classification		
				%	%	%	%	Class	GI	
TP 1	0.3	1960	1643	44	23	21	10	A-7-6	(7)	Silty CLAY Soils

Table 3. Compressive Strength Test.

Block no.	Percentage of sand added	Block dimensions (mm x mm x mm)	Densities of block samples(g)	Test load (KN)	Age of blocks(days)	Block strength (Mpa)	Average strength
1	0	90x255x140	6240	22.4	28	1.0	1.0
2		90x255x140	6150	21.8	28	0.9	
2	10	90x255x140	6257	42.7	28	1.9	1.9
2		90x255x140	6610	44.8	28	2.0	
3	20	90x255x140	6720	34.9	28	1.5	1.4
2		90x255x140	6565	30.1	28	1.3	
4	30	90x255x140	6097	28.3	28	1.2	1.3
2		90x255x140	6309	30.8	28	1.3	

4.3. Water Absorption Capacity Test

Table 4 and Figure 2 indicate the water absorption capacity test results of the compressed stabilized earth block samples. The set-up contained two samples for each category that were cured for 28 days before testing on February 22nd 2017. The samples were weighed when dry and then fully immersed in water for 120 minutes (2 hours). The sample blocks were weighed again and the results are presented in table 4. The samples did not appear to have significant differences generally in water absorption capacity although

CSEB with 20% of sand appeared to exhibit the lowest.

After the above test, the researcher re-immersed all the sample blocks into the water to determine whether the blocks would be able to sustain being in water without disintegrating/breaking for 24 hours. However, after 12 hours samples without the sand were found broken into pieces but those with sand were removed after 36 hours intact or without breaking at all. This, therefore, shows that addition of sand to CSEB improves the resistance of the blocks to water or and erosion destruction and subsequently improves on the durability of the blocks.

Table 4. Water Absorption Capacity Test.

Block Category	Percentage of sand added							
	Neat		10%		20%		30%	
	1	2	1	2	1	2	1	2
Mass of dry block after oven drying (g)	6340	6166	5979	6614	6824	6572	6379	6087
Mass of wet block after soaking (g)	7390	7244	7064	7681	7826	7590	7479	7183
Mass of water (g)	1051	1077	1085	1067	1002	1018	1100	1095
Water content (%)	17	17	18	16	15	15	17	18
Average water content (%)	17		17		15		17.5	

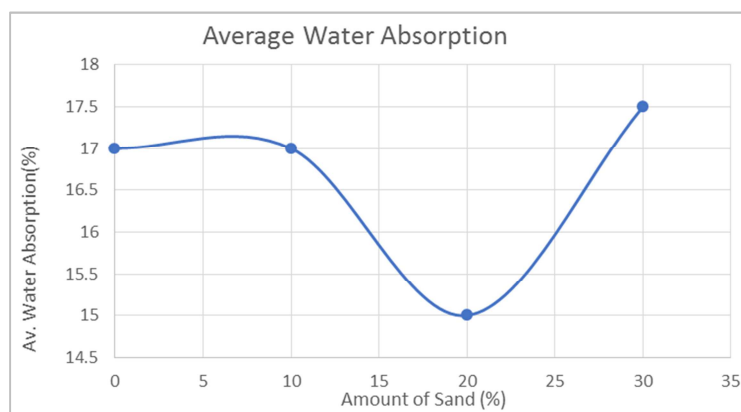


Figure 2. Average water absorption capacity Vs. %age of sand.

5. Conclusions and Recommendations

5.1. Conclusions

Based on the findings of this study, the research has drawn the following conclusions:

The results in testing revealed that the compressive strengths of compressed stabilized earth blocks using silty clay soil and sand with cement were higher compared to those without sand. However, the water absorption capacity of the blocks (both those with sand and those without sand), indicated no significant difference as revealed by the results

except for the blocks with 20% of sand which proved to have the lowest (15%) water absorption capacity. It is concluded that compressive strength of the CSEB depends on the compaction applied on the block during production. The higher the compaction applied, the higher the compressive strength as revealed by results from table 3.

The investigation of this study revealed that many different factors were responsible for ensuring a good bond between the soil particles, sand and cement mixed within it. These requirements not only affect the components of the mixture used, how it is prepared, delivered into its final state, but also curing and environmental conditions of the finished product. The study concluded that 10% sand blending produces CSEB with optimum strength recommended for construction.

5.2. Recommendations

The study absolutely attained its objectives. However, to improve this research for better results, the research team recommends the following suggestions:

- i. There must be an estimated force during the compaction that should be applied in CSEB production. The present study used manual press and it is advisable to manipulate machine in order to define accurate load of compaction and also to make things work easier and faster in producing CSEB.
- ii. The mould should properly be filled to maintain uniform size of the blocks and for proper compaction.
- iii. Further research on different types of soil is very important due to availability and diversity of the soil types.
- iv. A more detailed account of the interaction between cement and clay and why too much clay in the mixture is detrimental to the effectiveness of the cement is another topic for further investigation.

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