



Compressive Strength of Stabilised Soil Blocks (SSBs) Produced in Eldoret Municipality of Uasin Gishu County, Kenya

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ABSTRACT

The availability of varying soil types in most parts of Kenya suggests that, SSBs technology can be feasible in most parts of the country. However, despite this overwhelming and glaring evidence of existing untapped resource, tests in alternative low cost housing material such as SSB Technology has not been carried out extensively especially in Uasin Gishu County. The main objective of this study was to determine the compressive strength of SSBs produced from the research area. Soil samples were obtained from 5 development zones namely Kimumu, Langas, King'ong'o, Munyaka and Rehema estates which are considered as low income settlement areas within the municipality. The findings from compressive strength of SSBs differed significantly ($\chi^2 = 506$, $df=4$ $p=0.00$) for all cement: soil ratio groups. Strength of SSBs increases linearly with the increase in cement ratio. A ratio of 6% cement gives structurally sound blocks in Eldoret.

Key words: Compressive Strength, Stabilized Soil Blocks (SSBs), Eldoret Municipality, Uasin Gishu County, Kenya

INTRODUCTION

The 1999 population and Housing censuses in Kenya, puts the population of Uasin Gishu County at 665,000 persons with an annual growth rate of 3.5% per annum. The population was projected to be 690,037 persons in 2002 and is expected to grow to 1.4 million people by the year 2022. In terms of urban settlements, Eldoret town is the principle urban centre in the County with an estimated population of 216,356 (Word Bank, 2004). Eldoret town exerts a lot of influence as far as urbanization in Uasin Gishu District is concerned. It accounts for about 22.25% of the total population in the County. The overall poverty in Uasin Gishu is estimated at 42.22%, poverty gap (depth of poverty) at 12.4% and severity of poverty at 5.04 % (Word Bank, 2004)

Housing as an economic sector is a key component of the economy. Housing investment typically comprise 10%-30% of gross capital formation in developing countries (Republic of Kenya (2002). As an asset, housing is even more important make up from 20%-50% of reproducible wealth in most countries (Republic of Kenya (2002; World Bank, 1993). In Kenya, the output from construction industry is estimated at ksh 3.2 billion per year, with labour force associated with construction standing at slightly below Kenya shillings half a billion. About 80% of this is directly related to the building industry (World Bank, 1993). Building materials constitute 30-50% depending on the type of building construction. Globally the annual value of the construction industry is of the order of 1.5 trillion dollars constituting about 8% of GDP and about 60% of fixed capital formation. It is one of the most relevant forces of the world economy representing 7% of total employment (G.O.K., 1995). In Kenya the construction industry is a key indicator and driver of economic activity and wealth creation The construction sector involves the construction of a wide range of public and private sector facilities including but not limited to Buildings- Residential buildings and estates, slum redevelopment, hospitals, schools and other educational facilities, hotels and touristic



facilities, factories, shops and other commercial and industrial facilities. Thus the output of the construction industry has a profound impact on livelihoods hence the need for development.

Low cost housing strategies in Kenya is of considerable significance to economic growth and provision of decent and affordable shelter to low-income earners. SSBs technology if given the attention it needs can be a boast to the Government of Kenya's plan of developing at least 150,000 housing units per year given the current worrying poverty rates in Kenya and Africa as a whole. The housing problem will have been solved.

LITERATURE REVIEW

Critical review of soil as building material

The utilization of soil as building material is one of the oldest and most common methods used by a large percentage of the developing countries. It has several advantages to offer as building material (Katerega, 1973). It is the most readily available and cheap material found everywhere. It's easy to work with, requires less, encourages, and facilitates unskilled individuals and group participation on house construction on self-help basis (United Nations Industrial Development Organization, 1987). It offers a very high resistance to fire destruction and provides a comfortable build living environment due to its high thermal and heat insulation value

Importance of soil as a building material

Soil have a high resistance to fire destruction, which is a desirable quality of a good house. Its high heat/thermal insulation value enables it keeps the inside of a house cool when the outside is hot and vice versa creating comfortable living environment. It is a good noise absorbent material a quality that is highly valued in House design and planning. It is cheaper than most alternative walling materials because of Low cost for excavation and transportation or no cost on building sites. It is readily available at most building sites, easy to work with using simple tools and fewer skills. It also encourages and facilitates self-help and community participation in house building. Soil is available in large quantities in most regions. Has Low energy input in processing and handling requires only 1% of the energy needed to manufacture and process same quantity of cement concrete. It is environmentally appropriate, (Frenchan, 1982; Moriarty, 1973).

Technical Challenges facing soil as construction material

However, despite all these good qualities soil offers in construction, the materials have remained unpopular in so many countries. Most people are vaguely aware of the poor qualities of soil as a building material. Their inner fears, hesitation, and doubts towards soil as building material for permanent houses and other buildings reflect this (Katerega, 1973). Among the outstanding weaknesses of the soil as a building material includes low load bearing capacity, low resistance to moisture destructive effect resulting in crumbling of its products leading to structural failure when exposed to moisture, low binding strength for its particles, which contributes to its low compressive strength, high moisture absorption ratio, high shrinkage/swelling ratio resulting in major structural cracks of its products when exposed to different weather conditions.

These weaknesses puts soil at a disadvantage as compared to conventional materials such as concrete, burnt bricks, and dressed stones. It should be noted that a lot of research was carried out to arrive at an acceptable strength in concrete among other materials. The same



experimental research ought to be extended to soil to improve its qualities. In fact, the good qualities of soil outnumber its weaknesses and by extension outweigh them (Ngowi, 1997).

Method of improving the qualities of soil

There are basically three methods of improving soil performance for construction purposes includes Application of protective measures, Application of high compaction compressive pressure, and Application of stabilisers to soil (Katerega, 1973). the choice of either of which is determined by type of soil being considered for construction, the intended use and required improvement, The climatic conditions of area where products are to be used, The desired quality to be attained for the end products, The alternative stabilisers available for improving the soil and the available equipment to be used during the improvement process.

Application of protective measures

Since soil has a low resistance to moisture destruction, it is necessary to protect soil against moisture exposure by either constructing thick walls and dome shaped roofs supplemented by rendering the external surfaces with less permeable materials. This is good for dry and hot climates. For the case of wet humid areas, the protection is best done by provision of very deep overhangs over buildings supplemented by short walls rendered with water proof materials externally and by raising the ground floor slab of buildings to over 200mm above ground level. A splash apron is at times constructed sloping away from the base of external walls to protect the house against splashes and floods.

Application of high compaction and compressive pressure

Soil products are known to perform better under high compaction pressures during production. This includes ramming and compacting of moist soil for floor slab and walls, production of unstabilised soil blocks using machines such as “Cinva-ram” and “Brepak” block presses. The extra compaction pressure during production stage is used in binding the soil particles more to increase on the compression strength of the blocks when kept dry. When soil is stabilised before compaction, the performance is far better in quality and stronger than unstabilised compacted soil blocks (Walker, 1995).

Application of stabilisers to soil

This is the most efficient and effective method that gives a more direct quality improvement of soil products for construction (Walker, 1995). A combination of stabilisation and compaction yields the desired qualities for most soils. Experiments have revealed that different stabilisers assist in reducing or even eliminating different soil weaknesses (Katerega, 1973).

Soil stabilisation

On average every kind of soil can be made a better building material with addition of correct stabilisers. Stabilisers cement particles of soil together make the block or wall stronger. Stabilisers improves water absorption rates of soil hence reduces shrinkage and swelling. The most common stabilisers includes Lime, Portland cement, Bitumen and asphalt cutbacks, Pozzolana e.g. fly ash, rice husk ash, Natural fibres straw, Commercial soil stabilisers (for roads), Sodium silicates (water glass), Resins and Molasses (Stulz, 1983). It is always necessary to carry out a research to establish the most suitable stabilisers.

Soil selection criteria for stabilisation with Cinva – ram

Wide ranges of soils are suitable for stabilization with this machine. In qualitative terms, soils for this purpose must be readily friable upon drying and easy to compact. The soils should be sufficiently cohesive to allow handling of the blocks immediately after, mounding. The



compacted stabilized soil should also be able to dry without harmful shrinkage. Three of these requirements (friability, compactability, drying shrinkage) put an upper limit to the suitable content of fines in the soil; while the requirements for ease of handling (Compatibility) sets a lower limit for the desirable clay and silt content (Cook, 1983; Hammond, 1972; UNCHS, 1989). suggested that suitable soils should have a content of fines between 12% and 65%, a liquid limit ranging from 30% to 40%, and plasticity index of 12% to 20%.

Effectiveness of stabilisers in different soil types

Experiments have shown that not all soil types are suitable for stabilisation. There are soils, which are structurally too poor for construction purposes and any attempts to reduce their weaknesses, tend to give unsatisfactory and cost ineffective results. These are soils with high clay content, over 30% by volume (Katerega, 1973). Such soils tend to have very high shrinkage/ swelling ratios, over 18%, which results in major cracks of their products at different moisture contents. They require very high proportions of stabiliser contents, over 15% by volume or a combination of more than one stabiliser to reduce their weaknesses. They at times produce unpredictable results due to some chemical reactions of clay with some mineral stabilisers e.g. Cement and Lime. Black cotton soil is one such kind of soil and is common in most parts of Nairobi (Katerega, 1973). However, the majority of other soil types are structurally sound for stabilisation

Optimum contents of soil stabiliser for different soil types.

The optimum/ economic mix ratios of stabiliser with different soil types have to be determined through experiments to give the required qualities and strength. In Kenya, the building by laws currently require among other things a building block to have a minimum bearing capacity of 3N/mm^2 for single storey building construction purposes (G.O.K, (1989). Experiments indicate that once a 140mm thick block attains the bearing capacity, it tends to satisfy most if not all the requirements expected of external walls (Katerega, 1973). 3N/mm^2 is therefore being taken as the basis for experimental work by HRDU/BRE in improving soil products for use in building works.

Stabilisation with lime

Lime is one of the best stabilisers of clay. It reacts with clay to form a binder. Among the soils, which work well with lime, includes; gravely clay, sandy clay, silty clay, clayey gravel, and clayey sands. Lime stabilisation has been acknowledged as effective and cost effective method of improving the strength and other engineering properties especially of clayey soils. An addition of 1-2% of lime is utilised in modifying the soil; increasing its pH, improving its workability and reducing its plasticity (Herrin & Mitchel, 1996). A Base Exchange reaction occurs with calcium cat ions of the lime replacing the weaker metallic ions such as sodium and hydrogen on the surface of clay particles (Whitlow, 2001). Because the bond between clay particles is dependent to large extent on the charge and size of ions, clay particles with calcium ions coalesce together. As this reaction takes place, the soil becomes more friable and also gets flocculated (Herrin & Mitchel, 1996).

Further addition of lime is utilised in achieving strength gain of lime soil mix with time. Beneficial effects of addition of lime are attributed to different types of interaction that take place between the lime and clay minerals (Herrin & Mitchel, 1996; IRC, 1973; Ladd *et al.*, 1960). They are Aggregation of clay particles, Cat ion exchange involving replacement of sodium, hydrogen, and potassium ions by calcium, Reaction of lime and carbon dioxide from atmosphere to form calcium carbonate and thereby effecting cementation of soil particles



together and Cementation action due to formation of calcium silicate hydrate and calcium aluminate's hydrate and this reaction continues quite for some time.

Experiments from laboratories and field have revealed that effectiveness of lime stabilisation depends largely on the degree of pulverization/ fitness of soil particles to be treated, the moisture content added to lime soil mix, the density attained and the time elapsed between mixing and compaction of the mix. Other factors such as soil type and purity of lime have a strong bearing on the success of the technique (Davidson et al., 1965; Mahotra *et al.*, 1982; Michell, & Hooper, 1961), Lime as a stabiliser can be used with nearly any soil having plasticity index greater than or about 10-12. It improves the stability and penetration resistance of soil under wet conditions (Moriarty, 1973).

The amount of lime used varies generally from 6% to 14%. Lime can be combined with cement as stabilisers. Usually, the reaction between clay and lime is slower than between clay and cement. Lime stabilised soil blocks must be kept moist for at least seven days (14 days if possible), and then kept in a shade for 7 more days. At least one to two months of curing is necessary depending on prevailing weather? It takes lime-stabilised blocks about six times as long to get full strength as it does cement soil blocks (Moriarty, 1973).

Stabilisation with Portland cement

Portland cement as used in concrete is also one of the best soil stabilisers. Cement can be used with any soil with plasticity index from 0 to 12 (Walker, 1995; Stulz, 1983). Usually the cement content ranges from 6% to 10% with sandy soil 3% may be sufficient. It is advisable to use as little cement as possible to reduce the cost. Cement can be blended with lime for stabilisation. It is known to improve the compressive strength of soil remarkably. It also enhances resistance of soil against water penetration. Cement reduces swelling and shrinkage of the soil. However, it does not mix easily with soil. It should therefore be mixed thoroughly with dry soil before introducing water. The soil cement blocks must be kept wet for at least seven days. The longer the soil cement blocks are kept wet the harder and stronger it becomes (Stulz, 1983).

Cement-lime stabilization

A blend of cement lime for stabilisation gives a better combination both in terms of strength and cost. Usually equal parts of lime and cement are used. Lime must be added first because it makes soil easier to work with (Moriarty, 1973). Water is then added and covered for one to two days. After two days, the soil is mixed again and lumps broken. Add cement and water to bring soil to its correct water content. After thorough mixing, the mixture is feed to the mould and compacted immediately before it hardens.

Soil type in the research area

The type of soils prevailing in Uasin Gishu County has been influenced by altitude, rainfall, temperatures and the underlying geology (G.O.K, 2001). Two major soils types cover the research area namely the Ferralic cambisols and Ferralic chromic acrosols (FAO / UNESCO, 1974). These soils are dark red to dusk red, with clay to loamy texture and weak to moderate sub-angular blocky structure (G.O.K, 2001). Ferrali chromic acrisols are deep soils with high moisture storage capacity and are dark-to-dark red in colour (G.O.K, 2001).

Sample site selection five development zones, which were densely inhabited by middle and low-income earners namely; Kimumu, Langas, King'ong'o, Munyaka and Rehema estate were



randomly selected and Soil samples from these development zones were taken for stabilisation.

Soil sampling procedure

Samples from foundation level were extracted at depths ranging from 0 to 1.2 meters below the natural ground surface and used for SSBs production.

SSBs production procedure

After thorough mixing of cement and soil the mixture was compacted dynamically using a Cinva-ram block press machine of size 290 x 140 x 120mm. The entire process was carried out as follows: -

Soil extraction and Batching

This involved removal of topsoil by digging and excavation of sub soil. Soil excavated from foundation trenches were considered suitable to suffice for production of stabilised soil blocks for low cost domestic houses, excavated subsoil was sieved through a 6mm sieve. Sieving was necessary as it facilitates uniform distribution of cement (the binder) on the soil particles during mixing. A batching box measuring 15x15x15cm was used to establish the amount of soil / cement in the corresponding amount of cement added on top. The ratios of stabilisers used were 0% (control), 3%, 6%, 9% and 12% cement. 2% lime was used in all cases to take care of base reactions except for the case of control as suggested in the literature review (Herrin & Mitchel, 1996; Whitlow, 2001).

Mixing, Moulding and Curing

The soil and cement were first dry mixed thoroughly until a uniform colour was achieved. Water was then added slowly using a watering can. The right amount of water was judged by squeezing the mixture. When no more water could come between the fingers and mixture could not stick to the hands, it was considered ready for moulding.

The inside of the Cinva-ram block press was first polished with an oily rug, then filled with the mix and compressed manually. The specimens were removed from the mould after compaction and stored under shade with air circulation and moist cured at approximately 100% relative humidity. The blocks were then moist cured for a minimum of 7 days by sprinkling water on the blocks every morning using a watering can for seven days. During the seven days the blocks were kept under shade. On the second day, the blocks were turn over so as to lie on the edge side. On the third day the blocks were again turned over so that they lie on the hidden side. No attempt was made to control the temperatures of curing but the ambient temperature varied between 21°C and 27° C. Temperatures were not considered to have significant effect for cement stabilization.

Strength test on Stabilised blocks

Compressive strength tests and specific gravity tests were performed on 7 days and 28 days old blocks in the laboratory and analysis of the results done. To achieve this, Chi-square was used as the general framework for evaluation. This method was considered suitable because it compares the means of the various ratio groups for (seven-days and twenty-eight day blocks). The level of significance was taken at $\alpha = 0.05$

RESULTS AND DISCUSSION

Compressive strength of SSBs



The compressive strength of SSBs differed significantly ($\chi^2 = 506$, $df = 4$, $p = 0.00$) for all cement: soil ratio groups. The Average strength gained by 7days and 28days SSBs were as shown in table 1.

Table 1: Average Strength gained for different ratios

Compressive Strength (N/mm ²)					
Cement: soil ratio	Control	1:33	1:17	1:12	1:8
Seven days	1.96	2.09	2.42	2.56	2.70
Twenty eight days	2.22	2.78	3.23	3.41	3.60

Standard error of means ranges from 0.01 to 0.05. In both cases the compressive strength of the blocks increased linearly with increase in cement ratio used.

This information was represented graphically as shown in figures 1.

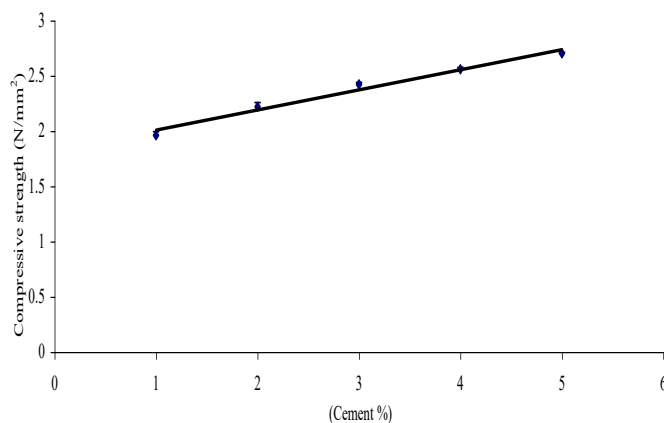


Figure 1: Seven and Twenty-eight days of compressive strength

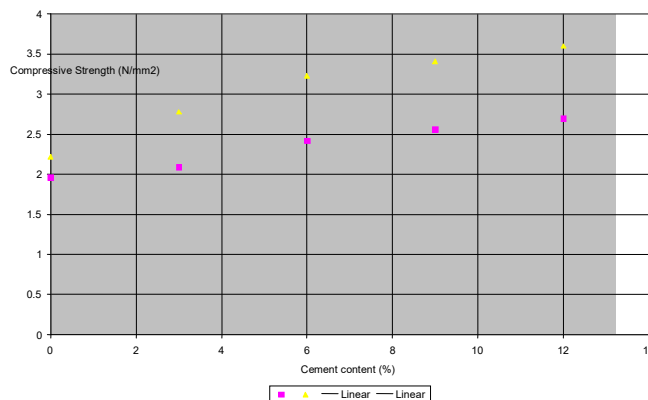


Figure 2: Seven and Twenty-eight day Compressive strength



It was noted that for 28-day compression, resulted to higher compression strength of the Stabilised Soil Blocks as compared to 7-day compression.

DISCUSSION

Compressive strength of SSBs

Comprehensive strength is a very important factor that is usually considered when selecting materials for construction purposes. Materials used in construction of walls should have sufficient comprehensive strength to withstand the loads imposed on it. The recommended bearing capacity of walling materials varies from one country to another because each country has its own bye laws and codes of practice that regulates building standards in construction industry. In Kenya, the byelaws recommend a bearing capacity (compressive strength) of 3N/mm^2 as the minimum required strength for building materials.

Stabilised soil blocks generally have varying strengths depending on the type and ratio of stabilisers used. The Higher the ratio of stabilisers, the better is the strength of SSBs when other factors are kept constant. Curing period, exposure to element of weather and specific gravity usually affects the strength gained by stabilised blocks considerably. If curing conditions are good, strength varies linearly with cement/lime content. Poor curing conditions will give non-uniform strength gain even with increased cement/lime content.

The findings revealed that there is a difference between strength gained by seven-day and twenty-eight day blocks as illustrated in Fig 1. The graphs are similar to those of previous soil-cement studies and indeed those from concrete studies. This is confirmed by earlier studies (Moriarty, 1973). The small variation in compressive strength of blocks within the same soil/cement ratio group was attributed to variation in degree of curing. This is because the blocks that were exposed to adequate curing developed desirable strength.

The general ability of the builder to make soil blocks was not evaluated because the researcher closely monitored the blocks for this research. Hence variation in strength would be expected when “lay” men produced the blocks. It was observed that the only important parameters, which could be controlled under building site conditions, were maximum lump size, curing conditions, and cement/lime content. Other parameters such as temperature and moisture content are expected to vary from place to place and time to time.

CONCLUSION

Strength of SSBs produced in Eldoret Municipality of Uasin Gishu County increases linearly with the increase in cement ratio. A ratio of 6% cement gives structurally sound blocks in Eldoret. However, any variation in water content, and mode of curing, affects strength development of blocks negatively. To achieve quality blocks, proper mixing and batching ought to be carried out.

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