KANKAR LIME AS AN ALTERNATE STABILIZER FOR COMPRESSED EARTH BLOCKS

Abdul Mueed Iqbal[1], Arif Khan[1], Umar Javed[1], Sabahat Arif[1].
[1]Department of Architectural Engineering & Design, UET, Lahore, Pakistan.
Corresponding Author: ae.mueed@gmail.com

***ABSTRACT**: Traditionally Compressed Earth Blocks are stabilized with Portland Cement or Fat Lime. Cement imparts good strength but lacks the sustainability. Fat lime is a sustainable material and suits to soil but lacks in terms of strength. Kankar lime is another material which has close properties to cement and fat lime besides more sustainable than cement. Kankar is abundantly available under the beds of rivers and saline soil in Pakistan. It has been extensively used as mortar in subcontinent before the advent of cement. It is a local material and does not involve complex industrial processes for its manufacture. It is a hydraulic lime and is expected to exhibit certain properties like cement that the fat lime does not possess. This research investigates engineering properties of Compressed Earth Blocks prepared with Cement, Fat lime and a mixture of Fat Lime with Kankar Lime through experimental studies. After comparative analysis of engineering properties of all blocks the research concludes that Kankar Lime can be used as a good stabilizer for Compressed Earth Blocks and its engineering properties can be achieved between those stabilized with cement and Fat lime.*

Keywords: Cement, Kankar Lime, Red Lime, Fat lime, Compressed Earth Blocks, Compressive Strength, Water Absorption.

1. INTRODUCTION

Among traditional building materials the Stabilized Compressed Earth Blocks have some advantages over the other materials for low cost construction. Major part of the material, i.e. soil is locally available and the manufacturing process of blocks is simple. Compressed Earth Blocks (CEBs) have good thermal and acoustic properties. Generally the energy required to make cement stabilized compressed earth blocks is less than 10% of that required for preparation of concrete blocks or burnt bricks. [1]

Historically sun dried earth brick or adobe was the main masonry unit for construction of ordinary housing in plain areas. It is generally considered that construction with adobe is very vulnerable to the catastrophe and destruction [2]. Under current building regulations the adobe construction does not fall under the category of permanent construction [3] as most of the soil's originally lack dimensional stability, strength and durability requirements of building construction [1] which can be achieved by increasing the density of soil [4] subject to keeping all other parameters constant. Blocks with greater density are easy to handle, have better surface hardness and have relatively higher compressive strength [3]. The concept of compressing the earth blocks to increase their density evolved nearly in the middle of twentieth century which also led to the development of compression machines to ease the densification of soil blocks.

The Compressed Earth Blocks (CEBs) are normally stabilized by some reasonable material to gain better strength. The natural properties and composition of soil determine the type of stabilizer to be used. The Ordinary Portland Cement (OPC) yields the best results as a stabilizer for sandy soils , whereas it does not provide appreciable results with silty and clayey soil. Fat lime as a stabilizer gives best results with the clayey soils [5]. Sandy soil cannot be stabilized with fat lime due to coarser particle size while silty soils may or may not be stabilized with fat lime [4].

Cement is associated with the use of a lot of energy and emission of CO_2 during its whole lifecycle from extraction of its raw materials to the production, transportation, construction, demolition and final disposal. Life cycle assessment of various materials reveals that the relative primary energy demand for the production of cement to other building materials is 11.7%, while that of lime is only 3% that makes cement less sustainable than Lime [6]. Apart from being a sustainable material, Fat Lime is not comparable to cement for stabilization of CEBs. Kankar lime had been used extensively as binding material in masonry mortar since centuries, therefore; it is expected that it may have stabilizing properties for soil. It also remained an economical material due to its local availability. It is still an economical material as kankar lime is cheaper than white/fat lime in sub-continent [4]. According to various factories near Lahore, Pakistan (May, 2015), dealing with kankar lime in nodular and powder form, the cost of kankar lime is almost half of that of white lime and cement.

The focus of this research is to analyze the engineering properties of Compressed Earth Blocks (CEBs) stabilized with Kankar Lime and to compare them with those stabilized with Cement and White Lime Cream. For this purpose an experimental study was designed and performed. Three types of Compressed Earth Blocks (CEBs) samples were prepared using three different stabilizers; one with cement, second with White Lime Cream and the third with combination of Kankar Lime and white lime cream. In all samples of Cement Stabilized Compressed Earth Blocks (CSCEB) the quantity of cement was kept as 10% as beyond this limit the production of blocks become un-economical [5]. Whereas, in LSCEB the quantity of White Lime Cream was maintained at 20% as at this limit it gets reasonable stabilizing properties [7]. KSCEB are produced by replacing 10% of White Lime Cream in LSCEB with 10% Kankar Lime. Kankar lime is a semi hydraulic material, but exhibits good pozzolanic properties when used with Fat Lime [4]. Samples were tested in lab for various engineering properties such as Compressive Strength, Dry Density, Water Absorption and Porosity. Results were analyzed and properties of Kankar Lime stabilized blocks were studied in comparison to other stabilizers used for block production to find out whether it can be used as alternate to traditional stabilizers meeting the requirements of standards and codes established by various organizations such as New Mexico Earthen Building Materials Code [8] and the standards established by Auroville Earth Institute [9] and CRATerre EAG & CDI [10].

2. MATERIALS AND METHODS

2.1. Materials

The raw materials for the production of stabilized CEBs' test samples include Soil, Cement, White Lime Cream and Kankar Lime. Soil was taken from the site near the laboratory, Bestway Cement [11] brand from open market, Fat Lime from Pind Dadin Khan (Jhelum) [12] and Kankar Lime from Kasur (Lahore) [13].

2.1.1. Soil

Soil sample was extracted at 3 feet depth from the earth surface. The extracted soil was dried, pulverized and then screened through ASTM sieve #4. In this research the composition of soil was kept as it was extracted. Classification of soil was determined by sieve analysis and hydrometer test. AASHTO Standard Compaction Test was performed to approximately estimate the quantity of water required for block production. Fig. 1 & fig. 2 show the classification of soil used in this work. The soil classification determines that the soil is predominantly silt and the optimum moisture content for that soil is 15.73%. The quantity of water required for block making depends upon two factors that are; hydration of stabilizers and Compaction of soil. It has remained a debate for researchers to determine the quantity of water for block making but up till now it could not be defined [5]. In this research, the quantity of water was added on the basis of visual observation at the mixing stage. The total amount of water in all the samples remained very near to the optimum moisture content for compaction of soil.

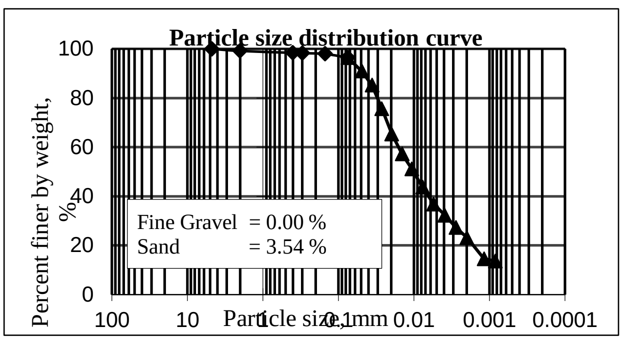

Figure 1: Results of Sieve analysis and Hydrometer test.

2.1.2. Cement

Cement used for this research was ordinary Portland cement (Bestway Cement) and no preparation was required. According to the tests performed in lab the initial setting time of the cement was 1 hr. 55 minutes and the final setting time was 3 hrs. 15 minutes.

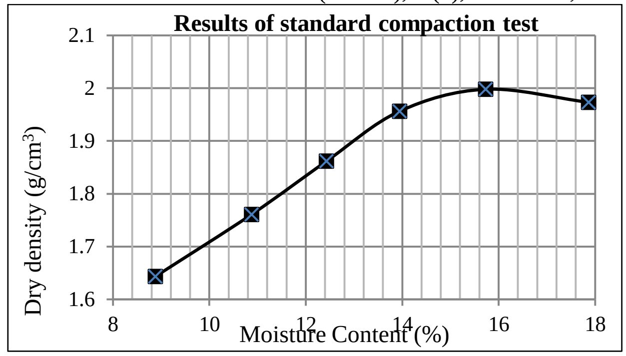

Figure 3: Results of Standard Compaction Test.

2.1.3. White Lime Cream

It was slaked in lab for 24 hours according to ASTM C5-03 [14], impurities were filtered out on "*malmal"* (a cotton cloth with loose weaving) and was allowed to mature for 3 months to make Lime Cream. The pH of Lime Cream was tested to be in the range of 11.6 to 12.3.

2.1.4. Kankar Lime

Kankar Lime also known as Red Lime was obtained in finely ground form which was previously gone through calcination and grinding process.

2.2. Procedure for CEB Production

Initially, the batching of prepared raw materials was done by weight. Table 1 shows the mix proportion of raw materials for each type of block sample. In case of CSCEB dry quantities of cement and soil were measured and were mixed manually as dry materials. Then water was added and mixed thoroughly. For LSCEB and KSCEB the white lime cream was measured wet while the soil and Kankar lime were measured as dry. The dry materials were mixed together then wet materials were added and the required amount of water was also added and mixed.

Table 1: Mix proportions for blocks

Block Type	Soil	Stabilizer		
		Cement	White Lime Cream	Kankar Lime
CSCEB	90%	10%	-	-
LSCEB	80%	-	20%	-
KSCEB	80%	-	10%	10%

The mix awaiting compression was saved in polythene bags to avoid loss of moisture. The quantity of mix required for the production of one block was weighed and filled in mould and rammed. The compression was done within 15 minutes after mixing so that the binders may not set and harden before compression. The blocks were compressed in a hydraulic

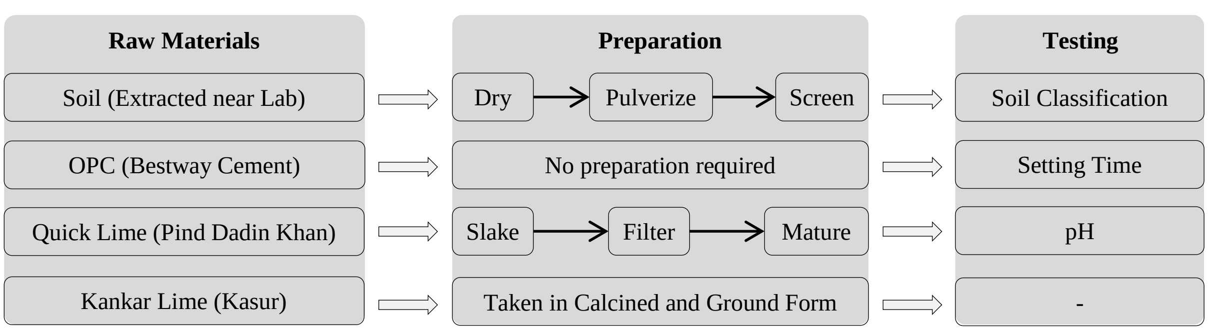

Figure 2: Schematic diagram for preparation of raw materials for test samples.

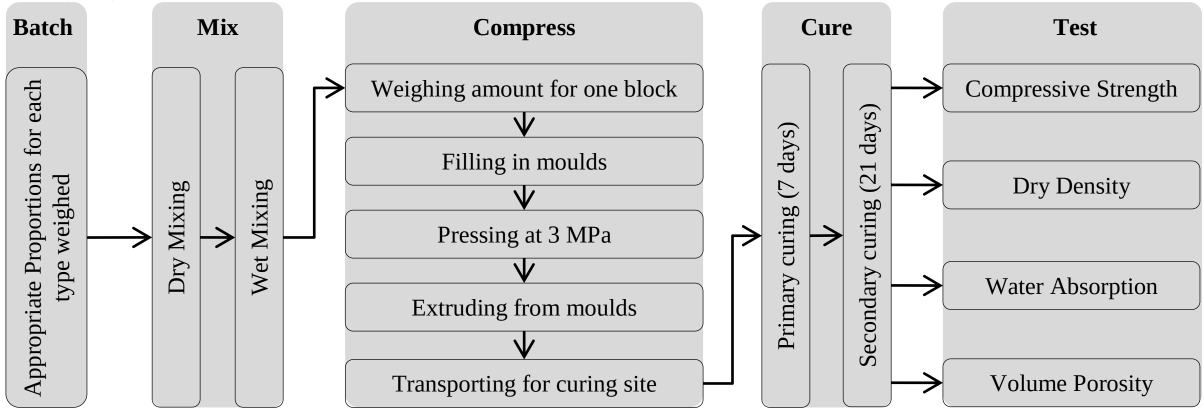

Figure 4: Schematic diagram for Production and Testing of CEB Samples.

compression machine at 3 MPa pressure. This was done by attaching a specially designed assembly with universal testing machine (Kai Wei Universal Testing Machine). The samples were extruded from the mould after pressing and then carefully transported for curing.

There are two phases of curing for compressed earth blocks as determined by Kerali; the first being primary curing (3-5 days, maximum 7 days) and secondary curing (upto 28 days for Cement and 56 days for Lime) [5]. The primary curing was done for 7 days by wrapping in polythene sheets. Polythene sheets ensure nearly 100% relative humidity [15]. In secondary curing all the blocks were un-wrapped and kept under shade for next 21 days. After the age of 28 days the blocks were tested for various engineering properties.

2.3. Testing of Samples

2.3.1. Compressive strength

After 28 days curing the blocks were dried in oven at 105ºC for 24 hours and these were allowed to cool down for three hours before testing. The dry weights of the samples were measured and dry density was obtained. The test was performed on three samples from each mix using Kai Wei Universal Testing Machine (maximum loading capacity 2000 KN). The size of blocks for compressive strength testing was kept 290×140×95 mm. This proportion of block size was determined according to New Mexico Earthen Building Materials Code (NMAC 2009), section 14.7.4.11C. According to NMAC 2009, the minimum length of the block should be twice its width and the block should be tested on its bed face as laid in the construction. The strain rate was kept such that to attain the loading rate as 220 KN/min (500 psi/min described by NMAC 2009) [8].

2.3.2. Water absorption and Volume Porosity

The size of blocks for water absorption testing was smaller than those used for compression strength testing. The size of the block for this test was kept as 100×100×65 mm. After 28 days curing the blocks were dried in oven at 105ºC for 24 hours and these were allowed to cool down for three hours and dry mass was noted as W_D. Then the blocks were immersed fully in water for 24 hours and the wet weights were measured as W_W. The water absorption (W.A) and volume porosity (V.P) of the blocks was determined as:

$$W.A\,(\%) = \frac{(W_W - W_D)}{W_D}\,X\,100 \qquad \& \qquad V.P = \frac{W.A \times \rho}{\rho_W}$$

where: ρ = Block dry density & ρ_w = Density of Water.

Total water absorption was determined according to ASTM C 642-97 [16]. The test was performed on three samples of each type and the average water absorption and volume porosity was reported.

3. RESULTS AND DISCUSSION

3.1.1. Compressive strength

Compressive strength of kankar lime stabilized compressed earth blocks (KSCEB) is 1076 psi which is more than average strength of class-A CEB described by Auroville Earth institute, India. This value of compressive strength is 3.6, 3.1 and 3.7 times the minimum described by NMAC 2009 (300 psi), CRATerre-EAG (348 psi) and Auroville (290 psi) respectively. From the compressive strength values, it can be concluded that kankar lime can be used as a good stabilizer. It is also evident from fig. 5 that the compressive strength of KSCEB lays between that of CSCEB and LSCEB.

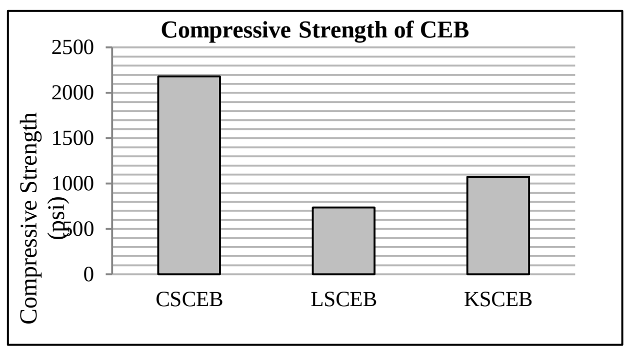

Figure 5: Compressive strength of CSCEB, LSCEB and KSCEB.

3.1.2. Dry density

The dry density of KSCEB is 114.78 lb/ft^3 and it is more than the minimum density recommended by CRATerre-EAG (106.18 lb/ft^3). This is very close to the density of CSCEB and a little more than LSCEB as shown in Fig. 6. This shows that kankar lime with the mentioned proportions as a stabilizer can help the compression equal to the ordinary Portland cement.

3.1.3. Water absorption and Volume porosity

The water absorption of CSCEB, LSCEB and KSCEB is 17.99%, 19.90% and 17.78% respectively as shown in fig. 7. All the values are within the maximum desired limit i.e. 20%

as defined by Auroville Earth Institute [9]. The total volume porosity of CSCEB, LSCEB and KSCEB is 33.1%, 34.4% and 32.9% respectively. The value of volume porosity also depicts that KSCEB are compressed equal to CSCEB i.e. the kankar lime did not cause any problem in compression.

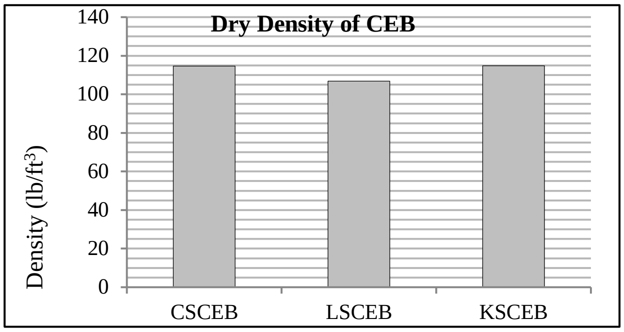

Figure 6: Dry density of CSCEB, LSCEB and KSCEB.

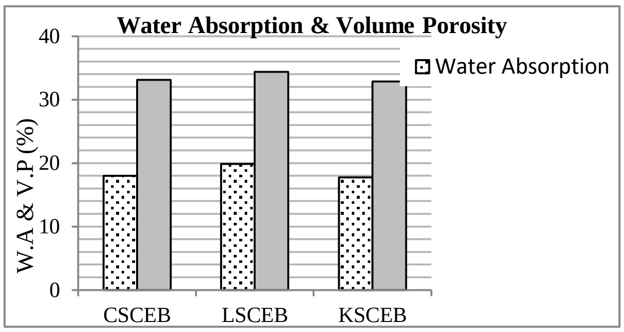

Figure 7: Water Absorption & Volume Porosity of CSCEB, LSCEB and KSCEB.

4. CONCLUSIONS

- Kankar lime can be used as alternate stabilizer in silty soil for production of Compressed Earth Blocks with engineering properties in desirable range and minimum cost as compared to other traditional stabilizers.
- The compressive strength of Kankar Stabilized Compressed Earth Blocks (KSCEB) is found to be 1076 psi which is almost half of Cement Stabilized Compressed Earth Blocks (CSCEB) and 1.5 times greater than Lime Stabilized Compressed Earth Blocks (LSCEB). According to established standards for CEB, the KSCEB falls above Class-A Blocks.
- Water absorption value of KSCEB is slightly less than CSCEB and 2% less than LSCEB. Volume Porosity of KSCEB is also a little less than CSCEB and 1.5% less than LSCEB. Therefore the durability of the KSCEB is equally good as that of CSCEB and better than LSCEB.

5. RECOMMENDATIONS

During the Mughal period and even before that the kankar lime was the most popular material in building construction. Pakistan is rich in terms of kankar lime reservoirs but its use is limited to repair of heritage buildings. The revival of kankar lime in construction of buildings is strongly recommended as it is more economical and environment friendly as compared to cement.

It is also recommended that further studies may be carried out to investigate Kankar Lime as stabilizer in sandy and clayey soils.

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REFERENCES AND NOTES

[1] Walker PJ. “Strength, Durability and Shrinkage Characteristics of Cement Stabilised Soil Blocks”, *Cement & Concrete Composites*, **17**, 301-310, (1995).

[2] Grünthal G (ed.), Musson R, Schwarz J, Stucchi M. “European Macroseismic Scale 1998”, *Cahiers du Centre Européen de Geodynamique et de Seismologie*, **15**, Luxembourg, (1998).

[3] Gooding DE, Thomas TH. “The potential of Cement-Stabilized building blocks as an urban building material in developing countries”, *Developing Technology Unit* **44**, (1995).

[4] Chandra S. “History of architecture and ancient building materials in India”, *Tech Books International*. **Vol. 2**, (2003).

[5] Kerali AG. “Durability of compressed and cement-stabilised building blocks”, Ph.D. Thesis, *University of Warwick*, *School of Engineering*, (2001).

[6] Bribián I, Capilla A, Usón A. “Life cycle assessment of building materials: Comparative analysis of energy and environmental impacts and evaluation of the eco-efficiency improvement potential”, *Building and Environment*, **46**, 1133-1140, (2011).

[7] Iqbal, AM. “Development of Compressed Earth Blocks Utilizing Waste Paper Pulp”, M.Sc. Thesis (unpublished), *Department of Architectural Engineering and Design, University of Engineering and Technology*, *Lahore*, *Pakistan*, (2015).

[8] “New Mexico Earthen Building Materials Code (NMAC)”, *Construction Industries Division of the Regulation and Licensing Department, Mexico*, (2009)

[9] “Compressed Stabilised Earth Block” *Auroville Earth Institute*, Available online: http://www.earth-auroville.com/maintenance/uploaded_pics/4-cseb-en.pdf; (Accessed: 2014, June 22)

[10] Houben H, Rigassi V, Gamier P. “Compressed Earth Blocks: Production Equipment”, *CRA-Terre-EAG and Centre for Development of Industry, France* (1996).

[11] Bestway Cement Limited is a popular manufacturer of Portland cement in Pakistan.

[12] Pind Dadan Khan is tehsil of Jhelum district, located on the bank of River Jhelum, about 28 kilometres East from the M2 motorway. It is rich in mineral resources, including Rock Salt, Brine, Gypsum, Coal, Bentonite, Silica Sand, Fireclay, Limestone and Marble

[13] Kasur is located near Lahore and is rich in reservoirs of Kankar.

[15] "Standard Specifications for Quicklime for Structural Purposes", *American Society for Testing Materials*. **ASTM C5-03,** USA, (2004).

[16] Rigassi V. "Compressed earth blocks: manual of production", *Deutsches Zentrum für Entwicklungstechnologien - GATE in: Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH in coordination with BASIN*, **Volume I**, (1985).

[17] "Standard Test Method for Density, Absorption, and Voids in Hardened Concrete", *American Society for Testing Materials,* **ASTM C 642-97**, USA (2004).