

# Analysis and Comparative Study on Compressed Stabilized Earth Blocks

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**Abstract :** In the growing concern of awareness regarding sustainable building material and environmental issue, Compressed Stabilized Earth Block (CSEB) gives the view of energy efficient, cost reduction and environmental friendly building materials, overall contribution on the sustainable development. Compressed Stabilized Earth Brick (CSEB) is produced by compressing a mixture of water with three main materials such as Ordinary Portland Cement (OPC), soil, and sand. They represent a very inexpensive and ecological and locally available material. They have good thermal and acoustic characteristics, a good fire resistance and are biodegradable and reversible. Defects or disadvantages of this material are the low mechanical strength compared to other types of building materials, in addition to susceptibility to water. This research provides detailed technical information of Compressed Stabilized Earth Blocks production. These include information on suitable soil types for stabilized earth house construction, amount of stabilizers required, machinery and production process of CSEB. The first part of our work includes a description of different test performed before manufacturing of CSEB. It is followed by detailed overview of process performed production of CSEB. The study is finished by a discussion of the results of tests performed on soil and blocks and an analysis of cost between conventional brick masonry and CSEB block masonry.

**Index Terms :** Environment friendly, masonry, stabilizers, strength, sustainable.

## I. Introduction to Compressed Stabilized Earth Blocks

The process of soil stabilization refers to changing the physical properties of soil by physical or chemical methods in order to improve its strength, durability, or other qualities. The development of earth construction started in the nineteen fifties, with the technology of the Compressed Stabilised Earth Blocks (CSEB): a research program for affordable houses in Colombia. Since then, considerable scientific researches has been carried out by laboratories. The Compressed Stabilised Earth Block (CSEB) Technology offers a cost effective, environmentally sound masonry system. The stabilized compressed earth block has a wide application in construction for walling, roofing, arched openings, corbels etc. Stabilised earth blocks are manufactured by compacting raw material earth mixed with a stabilizer such as cement or lime under a pressure of 20 – 40 kg/cm using manual soil press such as Balram. The soil, raw or stabilized, for a compressed earth block is slightly moistened, poured into a steel press (with or without stabilizer) and then compressed either with a manual or motorized press. The input of soil stabilization has made it possible to build higher with thinner walls, which have a much better compressive strength and water resistance. With cement stabilization, the blocks must be cured for four weeks after manufacturing. After this period of time, they can dry freely and be used like common bricks with a soil cement stabilized mortar. To extend the use of compressed stabilized earth building blocks to all types of housing e.g. low-cost housing in rural and urban areas and middle income housing in urban areas, production techniques need to be further improved so as to achieve better quality and reduce production cost. In order to do this the following points need to be considered carefully:

- Proportions between soil and stabilizer need to be optimized, taking into consideration the specific characteristics of the soil.
- Compaction pressure applied to the moist soil mix needs to be sufficient so as to produce blocks that are dense and strong with regular surfaces and edges.
- Block surfaces need to be smooth so that they have the potential to be used without an additional surface coating or render.

## II. Methodology

### 2.1 Soil Testing

Different test on soil were performed such as sieve analysis, determination of plastic limit, liquid limit and plasticity index of soil was examined and thus evaluating the compressibility of soil which is to be used in the manufacture of compressed stabilized earth blocks.

Sieve analysis test performed on soil:

Table 1 : Sieve Analysis

SIEVE	RETAINED		CUMMULATIVE PERCENTAGE	PASS PERCENTAGE
	RETAINED WEIGHT	RETAINED PERCENTAGE		
4.75	93.45	18.69	18.69	81.31
2.36	43.69	8.74	27.43	72.57
1.18	43.69	8.74	36.17	63.83
0.6	85.56	17.11	53.28	46.72
0.425	51.58	10.32	63.59	36.41
0.3	48.54	9.71	73.30	26.70
0.15	90.41	18.08	91.38	8.62
0.075	27.31	5.46	96.85	3.15
pan	14.56	2.91	99.76	

Plastic limit and liquid limit of soil was determined by the means of Casagrande Apparatus and was found to be: PL = 52% ; LL = 64%

Therefore plasticity index was found to be as :  $PI = LL - PL = 12\%$

The soil was classified as low compressible soil and thus could be used for the production of CSEB(compressed stabilized earth block).

#### A. Procedures for making Compressed Stabilized Earth Blocks

1. Collection of soil sample (try to go for locally available soil)
2. Perform the different tests on soil samples to determine its compressibility.
3. Stabilized the soil with cement or lime.
4. Prepare the sample by mixing different constituents such as sand and Pozzolanic materials in different composition and thus prepare different samples.
5. Compress the mould by hydraulic compressing machine manually.
6. Then dry the samples for 28days , but during drying do not cure the samples as the samples are unburnt and go for strength determination by CTM (compression testing machine) .

#### B. QUANTITY OF MATERIALS NEEDED

Compressed stabilized earth building blocks are usually larger in size than traditional burnt bricks. A typical block size is 290 x 190 x 90mm. Its production will need about 7.5 to 8.5kg of materials depending on the compaction pressure. The exact amount of stabilizer necessary must be established for any particular project. The fraction of cement usually varies between 5% to 8% by weight. Similarly, the optimum water content (OMC) for any particular soil must be determined experimentally. An approximate estimate of about 15% by weight is often assumed. The amount of material required for a typical block press producing 300 blocks per day is shown in table: Material Qty required per day Soil 1.95 tonnes Cement 0.095 tonnes Water 300 litres Total = 2.345 tonnes Table: 5.2 Amount of material required for 300 blocks.

#### C. PROPORTIONING

The selection of a stabilizer will depend upon the soil quality and the project requirements. Cement will be preferable for sandy soils and to achieve quickly a higher strength. Lime will be rather used for very clayey soil.

Table2

Soil for cement stabilization: it is more sandy than clayey	Gravel = 15%	Sand = 50%	Silt = 15%	Clay = 20%
Soil for lime stabilization: it is more clayey than sandy	Gravel = 15%	Sand = 30%	Silt = 20%	Clay = 35%

Table 3

	Minimum	Average	Maximum
Cement stabilization	3 %	5 %	No technical maximum
Lime stabilization	2 %	6 %	10%

NOTE: These low percentages are part of the cost effectiveness of CSEB.

#### D. PRESSING

A pressing machine is loaded with the right amount of the wet mixture of soil, cement and water. There are currently different kinds of presses available on the market both manual and mechanical. The best-known press worldwide is the manual Cinva-Ram, developed in Colombia. There are other types of presses that are similar to the Cinva-Ram and many imitators are available on the market. The advantages of these types of presses are that they are light, manually operated, low-cost, have a simple sturdiness and are easily produced and prepared. The disadvantages are that they only have a single moulding module, are low pressured and have a low output compared to the mechanical presses. The average output is approximately 250-400 blocks per day. The press will compress the mixture, shaping it into a block. Different shapes such as angular or interlocking blocks can be produced by changing the form of the pressing mould. The pressed blocks need to be transported to a storage room, preferably at a close distance to the pressing machine. A pressing machine is loaded with the right amount of the wet mixture of soil, cement and water. There are currently different kinds of presses available on the market both manual and mechanical. The best-known press worldwide is the manual Cinva-Ram, developed in Colombia. There are other types of presses that are similar to the Cinva-Ram and many imitators are available on the market. The advantages of these types of presses are that they are light, manually operated, low-cost, have a simple sturdiness and are easily produced and prepared. The disadvantages are that they only have a single moulding module, are low pressured and have a low output compared to the mechanical presses. The average output is approximately 250-400 blocks per day. The press will compress the mixture, shaping it into a block. Different shapes such as angular or interlocking blocks can be produced by changing the form of the pressing mould. The pressed blocks need to be transported to a storage room, preferably at a close distance to the pressing machine.



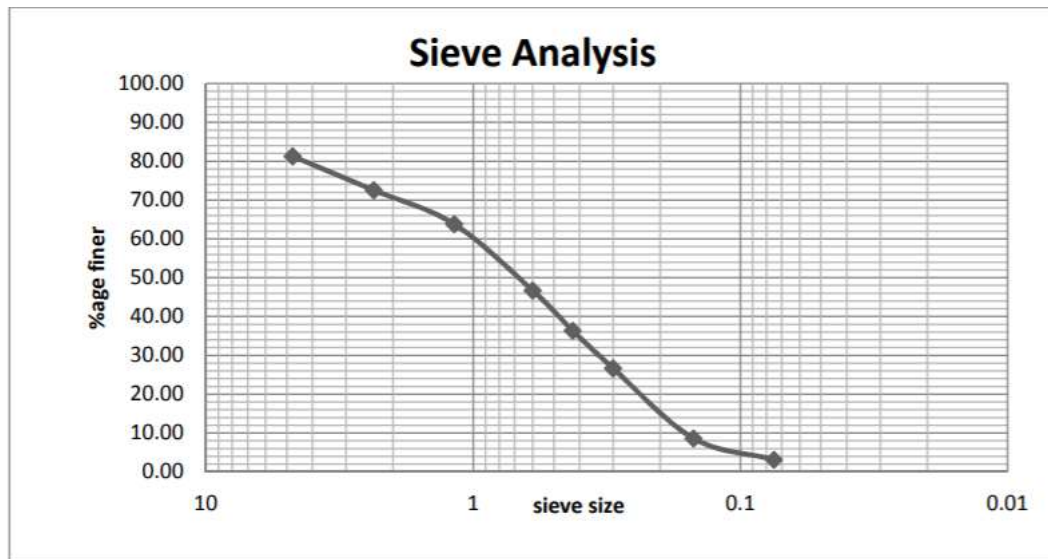
Fig 1: Pressing and Block Ejection

### III. Results

#### *Technical Aspects of Compressed Stabilized Earth Blocks*

##### 3.1 Sieve Analysis

This test was carried out to identify the type of soil whether it is suitable for compressed stabilized earth block or not. A particle size analysis test helps to determine the fraction of soils particle in a given soil sample. To produce a dense and durable block, it is important to that the soil used should be well graded. A dense structure is important for several reasons. A densely packed arrangement will have a higher number of contacting particles, and giving a better load bearing capacity, and the number and size of the inter-particle voids will be reduced, this will reduce the porosity of the soil and hence also its permeability, thereby reducing susceptibility to water penetration.



From the Sieve analysis result, there is 27 % gravel, 46 % sand and 36 % fine soil (silt + clay) in the soil. And from UN recommendation range of particle 00 80.00 90.00 100.00 10 1 0.1 0.01 %age finer sieve size Sieve Analysis distribution suitable for production of compressed stabilized earth block is: 40- 75% sand and 25-60% fine (silt + clay). This implies that the soil which was taken fulfills this requirement so the soil sample is acceptable for Compressed Stabilized Earth Block production. In other words, the soil is considered suitable for Compressed Stabilized Earth Block house construction.

### 3.2 COMPRESSIVE STRENGTH TEST

The compressive strength of stabilized earth blocks (i.e. the amount of pressure they can resist without collapsing) depends upon the soil type, and the type and amount of stabilizer used to form the block. Maximum strengths are obtained by proper mixing of suitable materials and proper soil type. The compressive strength of a block is one of its most important engineering properties. It was established from the literature that the durability of stabilized earth blocks increases with increase in its strength. Based on the three mixture ratios, compressive strength tests were performed based on BS 3921:1985[14] to determine the maximum value of CSEBs. The tests were carried out using 3 samples, and the average value of the samples would be considered accordingly as the final value for compressive strength .It was seen that the compressive strength of CSEB samples became higher as their age increased from 7 to 28 days.

Compressive strength value for Compressed Stabilized Earth Block may be less than  $6\text{N/mm}^2$ . When building are small (e.g. in the case of single storey construction), a compressive strength value from  $3\text{N/mm}^2$  to  $6\text{N/mm}^2$  will be sufficient for building purposes. An experimental test to analyze the effect of different percentage of cement and sand on the compressive strength of the block. Results are as under:

S.no.	Block proportion	Compressive strength ( $\text{N/mm}^2$ )
1	0% cement 0 % sand and soil	1.12
2	4% cement 0 % sand and soil	2.65
3	8% cement 0 % sand and soil	3.60
4	0% cement 10 % sand and soil	1.15
5	4% cement 20 % sand and soil	4.07
6	8% cement 20 % sand and soil	5.34
7	10% cement 20 % sand and soil	6.35

### 3.3 COST ANALYSIS

3.3.1 Estimation and Quantity of material required per cubic meter wall using First Class Bricks and mortar of ratio 1:4

Volume of wall = Base quantity =  $1\text{m}^3$

Dimension of brick with mortar =  $0.2\text{m} \times 0.1\text{m} \times 0.1\text{m} = 0.002 \text{ m}^3$

Number of bricks required =  $1/0.002 = 500 \text{ nos}$

Actual volume of 1 brick =  $0.19\text{m} \times 0.9\text{m} \times 0.9\text{m} = 1.539 \times 10^{-3} \text{ m}^3$

Total volume of required bricks =  $500 \times 1.539 \times 10^{-3} \text{ m}^3 = 0.7695 \text{ m}^3$

Volume of mortar required =  $1 - 0.7695 = 0.2305 \text{ m}^3$

Actual volume of mortar required will be 40% more due to presence of voids in sand =  $0.2305 + 40\% \text{ of } 0.2305 = 0.3227 \text{ m}^3$

Using mortar of ratio 1:4 Quantity of cement required =  $0.3227/5 = 0.06456 \text{ m}^3$

$1 \text{ m}^3 = 30 \text{ bags of cement,}$

therefore  $0.0646 \times 30 = 1.938 \text{ bags say } 2 \text{ bags (or } 100 \text{ kg)}$

Quantity of sand required =  $0.0646 \times 4 = 0.2584 \text{ m}^3$

Table 4 : Cost of Material for Brick Wall

Sr. no.	Item	Quantity	Unit	Rate	Total(Rs)
1	Brick	500	Nos.	6	<b>3000</b>
2	Cement	2	bag	300	<b>600</b>
3	Sand	0.2584	$\text{m}^3$	1000	<b>258.4</b>
				TOTAL=	<b>Rs 3854.4</b>

3.3.2 Estimation and Quantity of material required per cubic meter wall using CSEB blocks and mortar of ratio 1:4

Volume of wall = Base quantity =  $1\text{m}^3$

Dimension of brick with mortar =  $0.3\text{m} \times 0.2\text{m} \times 0.1\text{m} = 0.006 \text{ m}^3$

Number of blocks required =  $1/0.006 = 166.67 \sim 167 \text{ nos.}$

Actual volume of 1 block =  $0.29\text{m} \times 0.19\text{m} \times 0.9\text{m} = 4.959 \times 10^{-3} \text{ m}^3$

Total volume of required blocks =  $167 \times 4.959 \times 10^{-3} \text{ m}^3 = 0.830 \text{ m}^3$

Volume of mortar required =  $1 - 0.828 = 0.172 \text{ m}^3$

Actual volume of mortar required will be 40% more due to presence of voids in sand =  $0.172 + 40\% \text{ of } 0.172 = 0.2408 \text{ m}^3$

Using mortar of ratio 1:4 Quantity of cement required =  $0.2408/5 = 0.04816 \text{ m}^3$   $1 \text{ m}^3 = 30 \text{ bags of cement,}$

therefore  $0.04816 \times 30 = 1.448 \text{ bags say } 1.5 \text{ bags (or } 75 \text{ kg)}$

Quantity of sand required =  $0.04816 \times 4 = 0.1927 \text{ m}^3$

Table 5 : Cost of material for CSEB Wall

Sr. no.	Item	Quantity	Unit	Rate	Total(Rs)
1	Block	167	Nos.	12	<b>2004</b>
2	Cement	1.5	bag	300	<b>450</b>
3	Sand	0.1927	$\text{m}^3$	1000	<b>192.7</b>
				TOTAL=	<b>Rs 2646.7</b>

#### IV. Conclusion

- The high-density compressed and stabilized soil block seems to be a reasonable contender in low-cost building materials.
- It can be firmly presumed that parameters such as particle size and moisture content of the soil can influence the strength of the CSEB. From the particle size of the soil, we can identify the composition of the soil. The composition of the soil can be adjusted until it falls within the ideal curve limit in particle size distribution to produce high strength CSEB.
- The mixture ratio plays a vital role in determining the soil-sand-cement strength. Properties of the soil can be the factor of producing the higher strength CSEBs.

- From the above result we can conclude that 4-8% cement is sufficient for stabilizing the earth block as they give compression strength in the range of 3 – 6 N/mm<sup>2</sup> which is recommended by most of the authorities for producing Compressed Stabilized Earth Blocks.

#### V. Limitations Of CSEB

- Not suitable for high-rise buildings and wide-spans
- Proper soil identification required
- Skilled labour
- Requires quality check at every stage of manufacturing to avoid low-quality products

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