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Research Paper

EXPERIMENTAL INVESTIGATION ON CEMENT STABILIZED SOIL BLOCKS

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Homelessness in India has been a problem for centuries. Our Indian government's planning report says about 78 million people are homeless in India, despite the country's growing global economic stature. This study finds a way to produce a sustainable product for the development of our society. One of the applications of soil cement is SSB; in this study laterite soil is used to fabricate the stabilized soil blocks. The mix proportions are calculated and the blocks have been casted and cured for 28 days. Materials such as Fly Ash and Quarry Dust are also used to reduce the usage of cement and soil contents in various proportions were examined to arrive a cost effective and sustainable bricks. About 10% to 30% of materials are replaced to Prepared Block. The size of block is maintained as 20 cm x 10 cm x 10 cm. The Compressive Strength Test, Water Absorption Test and Block Density Test are carried out to determine the behavior of soil with cement and water. The cost of production and energy audit by the soil blocks has been analyzed. The obtained results are compared with the current codal provision and the national building code of India and found that the developed laterite bricks are commercially competitive with improved strength.

Keywords: Laterite Soil, Fly Ash, Quarry Dust

INTRODUCTION

The construction industry is making rapid strides all around the globe. New materials and new construction techniques are coming up in order to reduce the cost of construction and also to deliver the finished product as soon as possible to the customers. In the current scenario, utilization of profuse material to manufacture sustainable product using a high Stabilized Soil Block is also a one among those products, which is widely used for the construction of walls, pillars, buildings and so on.

One of the applications of soil cement is SSB; laterite soil is used to fabricate the soil blocks with the help of cement as a stabilizing

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agent. Soil Stabilized Blocks can be an efficient material for low cost housing product. There has been lots of research going on to determine the compressive strength of these blocks. Also to develop a high quality, without populating the environment with more sustainable, durable and strength blocks for building construction. Materials such as Fly Ash and Quarry Dust are also used to reduce the usage of cement and soil contents in various proportions were examined to arrive a cost effective and sustainable bricks cement stabilized soil blocks with a view to make available the existing experiences in this field to those who produce or plan to manufacture blocks so as to improve production techniques and quality of output. This includes information on suitable soil types, local stabilizers, production of cement stabilized soil blocks, quality of the blocks, and their economical value. It also comes up with optimum cement content of stabilized soil blocks for low cost housing. The objectives of this work are threefold. Firstly, to investigate the main constituent materials and the block production process, secondly to examine the main block properties and their performance, and thirdly to make recommendations for improved specification, testing and protection of cement stabilized soil block for the duration of their service lifetime.

Cement-stabilized building blocks is used as a generic name to cover a wide range of building materials. A cement-stabilized building block is defined here as one formed from a loose mixture of soil and/or sand and/or aggregate, cement and water (a damp mix), which is compacted to form a dense block before the cement hydrates. After hydration the stabilized block should demonstrate higher compressive strength, dimensional stability on wetting and improved durability compared to a block produced in the same manner, but without the addition of cement. This definition includes a range from hand-tamped soil blocks containing only enough cement to enhance their dry strength (but not to achieve any long term wet strength) to close-tolerance high-density concrete blocks, mechanically mass produced and suitable for multi-storey construction without a render. The spectrum of cement-stabilized building blocks has been split traditionally into two distinct fractions, sandcrete and soil-cement. Although the terms “soil-cement” and sandcrete/ sand cement/ concrete have very different images in the public minds of the developing countries, there is no clear boundary between them. Good soil-cement may be stronger than poor concrete and use “soil” no different in particle size distribution from the so called “sand” used in sandcrete. Provided that the mixtures are “damp” rather than liquid, then there is no practical reason to discriminate between soil and sand cement, the production process being the same (Gurcharan singh, 1979).

Walker *et.al.* (1995) has done a study on Strength durability and shrinkage characteristics of cement stabilized soil blocks. In this study, to assess the influence of soil characteristics and cement content on the physical properties of stabilized soil blocks. The test results shows that the saturated strength and durability of cement stabilized soil blocks are improved by increased cement content and impaired by clay content and the most ideal soils for cement soil block production have a plasticity index between 5

and 15 above 20-25 are not suited to cement stabilization using manual presses, due to problems with excessive drying shrinkage, inadequate durability and low compressive strength (Walker, 1995).

Kabiraj *et al*. (2012) has done a experimental investigation and feasibility study on stabilized compacted earth block using local resources. In this study is carried out mainly to find out a suitable mix proportion to blend locally available materials such as soil, sand, clay, grits, jute, etc., with cement for making compacted earth block for construction of affordable residential building and the results were studied (Kabiraj and Mandal, 2012)

Venkatarama and Richardson (2007) has done a experimental study on Optimum soil grading for the soil-cement blocks, The paper deals with an experimental study on the influence of soil grading on the characteristics of soil-cement blocks and shear-bond strength of soil-cement block masonry triplets. Influence of clay content of the soil-cement block on strength, absorption and durability characteristics, and interfacial mortar-block bond strength has been examined (Venkatarama Reddy and Richardson Lal Rao, 2007).

Bahar *et al*. (2004) has done an investigation is carried out by earth construction suffers from shrinkage cracking, low strength and lack of durability. Experimental study to investigates a stabilized soil by either mechanical means such as compaction and vibration and/or chemical stabilization by cement. Soil used was characterized by its grading curve and chemical composition. Compaction was either applied statically or dynamically by a drop weight method. A mixture of sand and cement was also tried. The effect of each method of stabilization on shrinkage, compressive strength, splitting tensile strength and water resistance are briefly reported. The experimental results showed that the best method of stabilization of the soil investigated, which gives a good compressive strength and a better durability at a reasonable cost, could be a combination of a mechanical compaction and chemical stabilization by cement or sand and cement up to a certain level (Bahar *et al.,* 2004).

Peter walker and Trevor Stace (1997) has done a study on Properties of some cement stabilized compressed earth blocks and mortars. This paper investigated in to the effect of soil properties and cement content on physical characteristics of compressed earth blocks and soil mortars are presented. A series of test blocks were fabricated using a range of composite soils, stabilized with 5% and 10% cement, and compacted with a manual press. Result for saturated compressive strength, drying shrinkage, wetting/drying durability, and water absorption testing are presented in this paper (Peter Walker and Trevor Stace, 1996)

From the above literature read, it is understood that the inorganic soil is suitable for soil cement. The Soil containing higher silt and clay fraction are suitable for soil cement construction. The Sandy soils with 5% cement give adequate strength and protection against weathering. For soil blocks liquid limit should be <40% and plasticity index should be in the range of (2.5-22). The Cement soil block production have a plasticity index between 5

and 15. The Soils with a plasticity index above 20-25 are not suited to cement stabilization using manual presses, due to problems with excessive drying shrinkage, inadequate durability and low compressive strength. The Strength increase with increase in the density of the soil blocks. The Durability of the soil blocks increases with increase in cement content and dry density. The Soil containing 70%of sand and 20% of clay give best result. The Optimum strength is reached when the clay content is about in the range of 14-16% and 4-8% of cement content.

MATERIALS USED

The soil used in this work was laterite soil was brought from Thiruvallur district, which is about 18.7 km to the west of Chennai. The laterite soil conforming to the requirements of IS 1498-1970. The cement used in this work was Ordinary Portland Cement of grade 53 conforming to the requirements of IS 1489:1991. The super plasticizer used in this work was cera plast 400. The fly ash used for this work was conforming to the requirements of IS 3812-1981 and quarry dust also used in this work.

SOIL TESTING AND CHARACTERIZATION

In soil test result shows that the according to Indian standard classification system, the soil sample is coarse grained and the soil is named as GW-GM&SW-SM. Mostly the soil is slightly sand or well graded sand. In this soil maximum dry density is 1.65 g/cm^3 and optimum moisture content has 10%. Soil has specific gravity of 2.67 and 6.6% of water content. The soil specimen has angle of internal friction of 30º and cohesion of 0.05 kg/cm^2. The relative density of soil has 67.17%, the codal specification of soil sample is dense. The liquid limit is 33.2%, plastic limit is 29.16% and the shrinkage limit is 25.42%. In codal specification the casagrande's plasticity chart shows the soil is classified as in organic slit of medium plasticity. In permeability test, according to USBR classification soil is pervious as co-efficient of permeability obtained is greater than mm/s. As the soil properties were in good correlation with the IS Specifications.

CEMENT TESTING AND CHARACTERIZATION

In the test result shows according to Indian standard classification system, cement has 2.96667% of Fineness. The particular cement has Percentage of water for standard consistency of 29. The particular cement has Initial setting time of 200 min and Final setting time of 4 h 10 min. And the particular cement has Compressive strength of cement at 3 days, 7 days and 28th days has16.22 N/mm^2, 19.86 N/mm^2 and 30.85 N/mm^2. As the cement properties were in good correlation with the IS Specifications.

MIX DESIGN

Adopted Mix Ratio

The adopted mix ratio for the manufacturing of soil block is 1:7 for the all mixes. Totally 5 types of mix is proposed. 13 Casting done and 137 bricks are casted.

Totally 5 types of mix is proposed they are:

a. Mix 1-Cement:Laterite Soil (CS)

b. Mix 2-Cement:Laterite Soil:Super Plasticizer (CSS)

c. Mix 3- Cement:Fly Ash:Laterite Soil (CFS)

d. Mix 4-Cement:Laterite Soil:Quarry Dust (CQS).

e. Mix 5-Cement:Fly Ash::Laterite Soil:Quarry Dust (CFQS).

Fly Ash is used in the 3rd mix for the replacement of cement in the range of 20, 25 and 30% of the cement content.

Cement: Fly Ash: Laterite Soil (20%) – CFS1, Cement:Fly Ash: Laterite Soil (25%) – CFS2, Cement:Fly Ash: Laterite Soil (30%) – CFS3.

Quarry dust is used in the 4th mix for the replacement of soil in the range of 10,15 and 20% of the soil content. Cement: Quarry Dust: Laterite Soil (10%) – CQS1, Cement: Quarry Dust: Laterite Soil (15%) – CQS2, Cement: Quarry Dust: Laterite Soil (20%) – CQS3.

Similarly Fly Ash and Quarry Dust is used in the 5th mix for replacement of cement and soil in the range of 10, 15 and 20% of the soil and cement content. Cement: Fly Ash:: Laterite Soil: Quarry Dust (10%) – CFQS1, Cement: Fly Ash: Laterite Soil: Quarry Dust (15%) – CFQS2, Cement: Fly Ash:: Laterite Soil: Quarry Dust (20%) – CFQS3.

The first mix is done by two method, one was done manually and other was done in vibratory compaction. They were respectively denoted as CSM and CSV. Cement:Laterite Soil (Manually) – CSM, Cement: Laterite Soil (Vibratory) – CSV.

The next mix was Cement: Fly Ash: Laterite Soil (30%) it was also done with manually and vibratory. They were respectively denoted as CFSM and CFSV. Cement: Fly Ash:Laterite Soil (Manually) – CFS3M, Cement: Fly Ash: Laterite Soil (Vibratory) – CFS3V.

Both the mixes were observed, compared and the interpretation of results based on their compressive strength.

MANUFACTURING AND EXPERIMENTAL PROGRAM

The following equipment has been used to manufacture the soil blocks they are, Brick mould, Trowel, Batching container, Mixing machine, Table vibrator, Trolley, Oil, Weighing machine, curing tank and Oven.

Casting Procedure

The materials required for making the mix are taken and are weighed. After the weighed materials are placed inside the mixing machine and are mixed. Then the materials are uniformly mixed, water is then added to the mix. After the mix is placed inside the batching container and the Oil is applied on the sides of the brick mould and the mix is applied in 3 layers to the mould. After Vibrations are provided to each layer with the help of vibratory machine and the surface is finally leveled. After demoulding is carried out on the next day and the brick is weighed. For drying the brick is kept under atmospheric conditions for one day and brick is weighed after this. The brick is kept in the curing tank.

After 7 days, compressive strength test need to be carried out. After 28 days, compressive strength test need to be carried out. The Block density and Water absorption test is carried out after 28th day. And the brick is firstly weighed and kept for oven drying at 100°C. After 24 h, it is weighed and water absorption test is thus done. Stabilized Soil

Figure 1: Stabilised Soil Block

Figure 2: 7th Day Compressive Strength Test

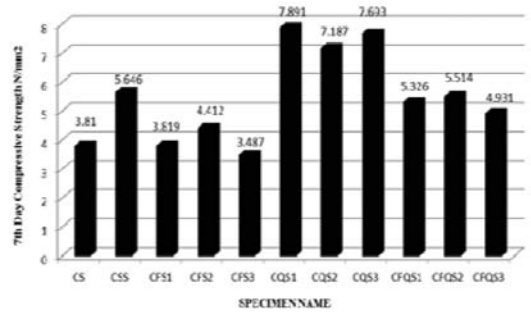


Figure 3: 28th Day Compressive Strength Test

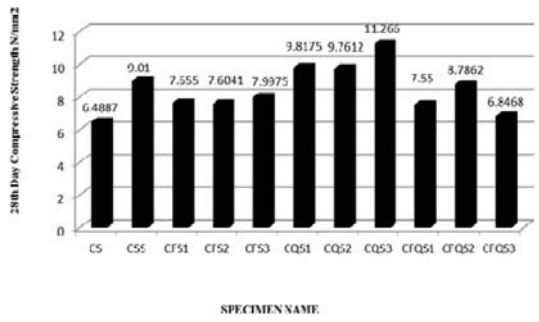


Figure 4: Variation in Block

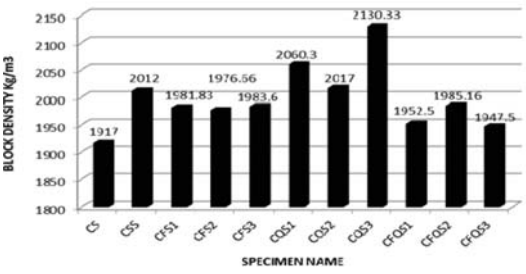
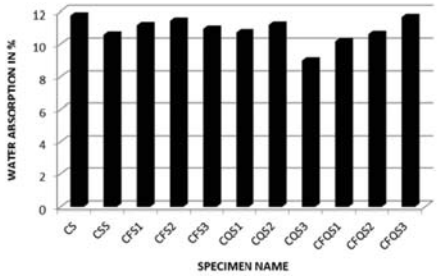


Figure 5: Variation In Percentage Of Water Absorption Density



Block, 7th, 28th, block density and water absorption are shown in below Figures 1, 2, 3, 4 and 5.

RESULTS AND DISCUSSION

The Observation made during the 7th, 28th, block density and water absorption test are tabulated in Tables 1 to 3.

Table 1: 7th Day Compressive Strength Test

Specimen Name	7th Day Compressive Strength N/mm²
CS	3.810
CSS	5.646
CFS1	3.819
CFS2	4.412
CFS3	3.487
CQS1	7.891
CQS2	7.187
CQS3	7.693
CFQS1	5.326
CFQS2	5.514
CFQS3	4.931

Table 2: 28th Day Compressive Strength Test	
Specimen Name	**7th Day Compressive Strength N/mm²**
CS	6.4887
CSS	9.0100
CFS1	7.6550
CFS2	7.6041
CFS3	7.9975
CQS1	9.8175
CQS2	9.7612
CQS3	11.266
CFQS1	7.5500
CFQS2	8.7862
CFQS3	6.8468

Results shows that stabilization of soil block using Ordinary Portland Cement fulfills a number of objectives that are necessary to achieves lasting structure from locally available soil. Some of these are having better mechanical characteristics (leading to better compressive strength), better cohesion between particles (reducing porosity which reduces changes in volume due to moisture fluctuations). CQS3 Mix ratio has attained more strength after the 28th day compressive strength test. In all mixes when increase in density of the block leads to decrease in water absorbing capacity of the block. Similarly when increase in density of the blocks has results in increase in compressive strength of the soil block. There is no disintegration of soils from block at water curing period and also there is no resemblance of crumble behavior due to repeated drying and wetting of soil blocks.

Table 3: 28th Day Block Density and Water Absorption Test				
SN	**Wet Weightkg**	**Dry Weightkg**	**Block Densitykg/m³**	**Waterabsorption%**
CS	4.285	3.834	1917.00	11.77
CSS	4.450	4.024	2012.16	10.58
CFS1	4.406	3.963	1981.83	11.17
CFS2	4.404	3.953	1976.66	11.45
CFS3	4.401	3.967	1983.60	10.95
CQS1	4.571	4.120	2060.30	10.73
CQS2	4.485	4.034	2017.00	11.20
CQS3	4.640	4.260	2130.33	8.968
CFQS1	4.301	3.905	1952.50	10.17
CFQS2	4.392	3.970	1985.16	10.62
CFQS3	4.350	3.895	1947.50	11.68
Note: SN=Specimen Name				

As per IS:2185 (Part 1)-1979 Indian Standard Specification for Concrete Masonry Units Density of block should not be less than 1800 kg/m^3, the minimum average compressive strength of units have to be 5 N/mm^2 and the minimum strength of individual units 3.2 N/mm^2. The minimum compressive strength at 28 days being the average of 8 units. Water absorption should not be more than 10%. All the Soil blocks experimented in this project have satisfied the above specifications and hence this can be used for construction purposes.

Study the cost details of required materials in PWD Tamil Nadu Schedule rates 2012 can be used to take the price details of required materials. Performing cost analysis of all the materials, it was found that about 90% cost was more for cement. It was found that cost of the CQS3 brick had more but the 28th days compressive strength is high. When fly ash was added to the mix, it had less cost. When super plasticizers were added to the mix, compared to other mixes, it gives better strength but the cost proved to be high.

CONCLUSION

The following conclusions are drawn from the study:

1. Extensive soil test have been carried out and the characteristics of the soil was found. The type of soil used in this is classified as GW-GM&SM-SW. The soil is silty sand or well graded sand. The codal specifications given soil specimen has a uniformity coefficient of 657.14%, which indicates that the soil is non-uniform. In the soil the sand is 51.35% and gravel is 48.65%.
2. Cement test have been carried out and the characteristics of the cement was found. In the test result shows according to Indian standard classification system, cement has 2.96667% of Fineness. The particular cement has Percentage of water for standard consistency of 29. The particular cement has Initial setting time of 200 min and Final setting time of 4 h 10 min. And the particular cement has Compressive strength of cement at 3 days , 7 days and 28 days has16.22 N/mm^2, 19.86 N/mm^2 and 30.85N/mm^2. As the cement properties were in good correlation with the IS Specifications
3. CQS3 Mix ratio has attained more strength after the 28th day compressive strength test.
4. In all mixes when increase in density of the block leads to decrease in water absorbing capacity of the block.
5. Similarly when increase in density of the blocks has results in increase in compressive strength of the soil block.
6. There is no disintegration of soils from block at water curing period and also there is no resemblance of crumble behavior due to repeated drying and wetting of soil blocks.
7. Higher the water content, better is the compressive strength of the super plasticizer used in the mix.
8. Though CQS is having low water content, it gives the maximum Compressive strength.

9. Compared with the other mixes, CFS and CFQS gives lower strength.
10. Increase in water content has lead in to breakage of corner and edges of soil blocks.
11. Machine compaction can be neglected in the production of stabilized soil blocks.
12. According to Indian Standard Concrete Masonry Units IS: 2185 (part1)-1979 minimum strength of individual units is 3.2 N/mm^2. When the bricks were tested for compressive strength, all bricks had strength more than 3.2 N/mm^2.
13. As per IS:2185 (Part 1)-1979 Indian Standard Specification for Concrete Masonry Units Density of block should not be less than 1800 kg/m^3, the minimum average compressive strength of units have to be 5 N/mm^2 and the minimum strength of individual units 3.2 N/mm^2. The minimum compressive strength at 28 days being the average of 8 units. Water absorption should not be more than 10%. All the Soil blocks experimented in this project have satisfied the above specifications and hence this can be used for construction purposes.
14. Performing cost analysis of all the materials, it was found that about 90% cost was more for cement.

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