

Experimental Study of Stabilised Soil Blocks Using Cement and Lime

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Abstract— India is a developing country and in various developing countries like India economical construction along with economical construction material plays a vital role in the development of country. Waste material in construction can play tremendous role to make it economical and durable due to some of its specific properties relevant to construction materials. This dissertation shows comparative and experimental study on utilization of cement and lime in soil blocks in a very small quantity. Soil samples are taken from various selected places randomly. In this project cement and lime are added in soil by weight of soil in the various proportions of possible combinations. Compressive strength test is performed on soil blocks and their result is being evaluated and compared.

Keywords: Cement, Lime, Soil, Soil Blocks, Soil Stabilization, Bricks and Compressive Strength

I. INTRODUCTION

The history of civilization is same as that to the history of masonry. Man's first civilization, which was started about 6000 years ago, was evident from the remains of the masonry heritage found during excavations. During those early days, masonry buildings used to be constructed from any available material at hand. The Mesopotamians used bricks that were made from alluvial soil deposits of the nearby River Euphrates and Tigris to build their cities nearby two rivers. Where civilization existed in the region of mountains or rocky outcrops, stones were used for masonry work. The Egyptian pyramid that exists near the rocky borders of the Nile valley are best examples of such stone masonry. In the Eastern civilization, reminder of historical masonry is the reputed Great Wall of China, which can be considered as one of the seven construction wonders in the world. The prevision for good quality of housing is considered as an important responsibility for well-being of people in any country. For this purpose building materials on the basis of natural resources are often used. Some of the best examples are the use of clay for making bricks, and river sand for making cement stabilised sand blocks. The commercial application of these resources often leads to various different environmental problems. If clay mines are not filled up properly, they will collect water and allow mosquitoes to breed. Extensive amount of sand mining can lower the river- beds and will allow salt-water intrusion inland. Therefore, the development of many alternative brick materials as possible will be of great benefit to minimize the impact on the environment. Earth material may be used for construction of walls in many ways. But, there are few undesirable properties such as lesser strength when mixed with water, soil erosion due to wind or pouring rain and poor dimensional stability. These drawbacks should be eliminated significantly by stabilization of the soil with a chemical agent like cement. Cement stabilized soil is generally used for brick blocks with proper compaction that may be achieved either with manual hydraulically operated machines.

A. Why Use Earth for Building?

Various benefits which are offered by earth construction materials are generally underutilized in the developed countries where the earth is used as a low-embodied material is often the case. Historical claims that, earth was the most widely known and used building material in construction industry and probably was the most important of all building materials. According to Middendorf, he recorded cases for the use of earth bricks dated back to Mesopotamia around 8000 BC. Recent reports have indicated that, nearly half of the world's population is still living in earth material used buildings. Of all urban housing units worldwide there are nearly 25 % which does not conform to building regulations while 18 % are considered to be the non-permanent structures. Earth for the building purpose is available everywhere and exists in various different compositions. It is most widely used in developing countries like India to provide houses to the greatest number of people with the least cost demand. However, it should be noted that earth buildings are not a phenomenon only of the developing or under developed countries, but also in developed countries. It is very important to ensure that the materials that are used for construction purpose meets all the specification in every respect. This means that all relevant properties should be checked properly before start of construction.

There are many benefits of buildings with earth. For example, earthen made structures are completely recyclable, so sun-dried bricks can be return to the earth without polluting the soil. Using earth for such eco-friendly buildings will be a strong synonym in the future of mankind. In addition, energy requirement to produce stabilised soil block is only 5 (kWh)/cubic meter, where as it is about 1000 (kWh)/cubic meter for fired brick and 400- 500 (kWh)/ cubic meter for concrete.

B. Energy Requirement to Produce Different Building Materials

Building materials	Unit	Energy (kWh)
Cement	Sack	50
Concrete	Cubic meter	400 - 500
Fired brick	Cubic meter	1000
SSB's	Cubic meter	5

C. Aim of the Dissertation

The main of this dissertation is to safe guard the environment by utilizing earthen material, to provide an economical construction material to construction industry and enhance the properties of the bricks and also to make it durable and low cost. To make brick work economical and least time consuming. The advantage of using soil blocks in wall construction is to make it eco-friendly and reduces the pollution in the environment.

D. Objective of the Dissertation

The main objective of this dissertation is thus to provide detailed technical information on the production of compressed stabilised earth blocks which includes information about suitable soil types, local stabilisers, production of compressed stabilised earth blocks, quality of the blocks, and its economical value. It also comes up with optimum cement and lime content of stabilised soil blocks for low cost housing and also to make comparative study with conventional clay bricks.

II. MATERIAL AND METHODS

This chapter deals with material used in this project and also method adopted for this project. Properties of material which is used in this project is described along with methodology, chapter start with material used and goes on to the Moulding process, which is done as per IS 456:2000, then mixing, casting, compaction and curing details is given.

A. Selection of Material

1) Cement

Properties of Cement

S. NO	Property	Value
1	Fineness	3.82%
2	Initial Setting Time	41 min
3	Final Setting Time	197 min
4	Specific Gravity	3.14
5	Soundness	2 mm
6	Compressive Strength	7 Days – 24.56 MPa
		28 Days – 37.84 MPa

2) Water

Consolidating water with a cementitious material a structural bond is developed by the procedure of hydration. The concrete glue ties the total together, fills voids inside of it, and makes it workable. A lower water-to-bond proportion yields more grounded, tougher cement, while more water gives workable cement with a higher droop. Tainted water used to make cement can bring about issues when setting or in creating untimely disappointment of the structure. Hydration includes various responses, frequently happening in the meantime. As the responses continue, the results of the concrete hydration handle slowly bond together the individual sand and rock particles and different segments of the solid to shape a strong mass. Water used for concrete should be free from hazardous amount of oils, acids, alkalis, salts, sugar, organic materials or other matter. Water which is used in this project is confirming to the specification of IS 456: 2000.

3) Soil

Physical properties of soil

S. NO	Physical properties	Values
1	Specific gravity	2.61
2	Natural moisture content	14.87%
3	Optimum moisture content	19%
4	Maximum dry density	1610kg/m3
5	Silt content	16.25
6	Clay content	13.75
7	Sand content	70%
8	Linear shrinkage	7.14%

9	Liquid limit	31.91%
10	Plastic limit	25.75%
11	Plasticity index	6.16%

4) Soil Classification

- a) Residual soils
- b) Transported or deposited soils

5) Soil Classification by particle size distribution

- a) Gravels
- b) Sands
- c) Silts
- d) Clays

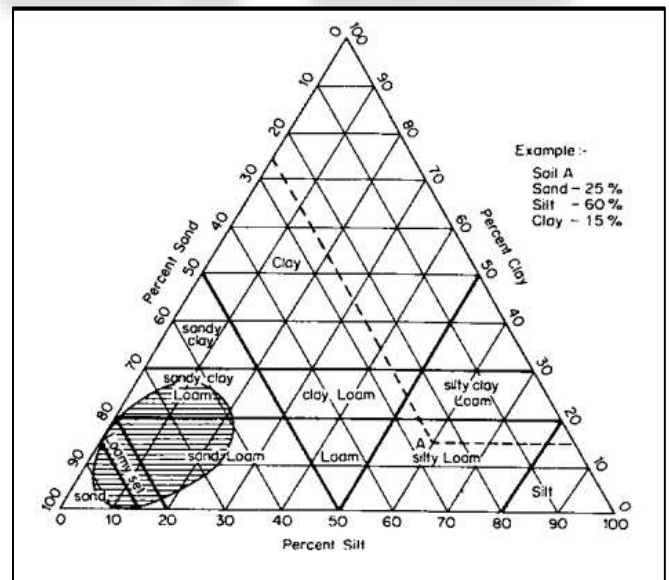
6) Soil Classification by plasticity (Fine content)

- a) Cohesive soil
- b) Cohesionless Soil
- c) Exploitation

B. Available Criteria for Soil Suitability

Selecting a suitable type of earth can take place in the field using parameters, which are the fruit of experience acquired in the course of operational practice. If any doubt persists, laboratory identification tests should be carried out. It is not an exhaustive review but rather included as indication of the variation between authors and as a warning that such criteria should be used as a guide in initial soil selection rather than as a rigid set of rules. Some of the criteria based only on particle size while others use criteria based solely on the Atterburg limits (plasticity index). In general it would be wise to consider both.

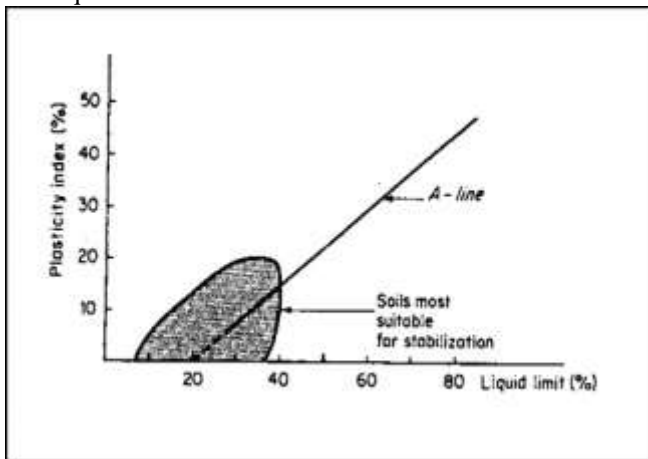
- 1) Triangular chart for particle size classification of soils: If the granular composition of soil falls within the limits of the recommended shaded area of Fig. 3.3, the soil is usually considered as suitable for stabilised soil block production. Shaded area indicates soil most suitable for soil stabilisation.



Triangular chart for particle size classification

- 2) Atterburg limit criteria for soil stabilisation: If plasticity of the soil fall preferably within the limits of the recommended shaded area of the plasticity chart as shown in Fig. 3.4 below, the soil is considered suitable for soil cement block production. From Fig 3.4 is applicable only to the fraction of soil finer than 0.4 mm,

roughly between the limits; Plasticity index 0- 22 %, liquid limit 7-40%.



C. Tests for Soils

1) Field Tests

Field tests are for preliminary site surveying to identify if the soils are most likely suitable and so restrict the number of soils to be more rigorously assessed by laboratory tests or trial production. The tests will provide a rough idea of a soil's grading and plasticity and also indicate whether a soil contains significant organic matter (reject outright), a majority of gravel, a majority of sand or a majority of fines. They may also be able to distinguish whether silt or clay is a more significant fraction of the fines. They are generally fairly easy to perform and often require little or no experimental equipment, making them very simple to implement. Simple field tests which are performed to get an indication of the composition of the soil sample includes: smell test, nibble test, touch test, sedimentation test, adhesion test, washing test, linear shrinkage test, dry strength test, water retention test, consistency test and cohesion test. However field tests are frequently reported, without acknowledging the reliance they place on the operator's senses. Interpretation of the results is a skilled operation. Consider for example the dry strength test, the prepared soil sample is crushed between the fingers and the ease of crushing is taken as a measure of the soil's clay content. For a novice operator the ease of crushing the soil and comparing the clay content is difficult but a skilled operator may compare the ease of crushing with that of soils he/ she has previously tested and hence arrives at a more precise conclusion. Tests that rely on personal judgment are open to differing interpretation between operators and depend on the operator's skill for their accuracy. Training and experience of field tests may provide a fact, quite accurate determination of the soil's characteristics. All of the test results observed (both the good and the bad), plus the location and depth of the soil samples in question should be recorded in case it is later necessary to use a soil for blending which on preliminary examination had been rejected.

2) Laboratory Tests

The laboratory tests establish numerical values for certain soil parameters, primarily the percentage distribution of the different sizes of soil particles present and the plasticity limits. These values are subsequently used to determine the best available soil or domination of soils. All of these tests

rely on accurate weighing and or some form of laboratory equipment scales with a resolution higher than one thousandth of the chosen sample weights is desirable. There are four main types of tests: The sieving test, sedimentation test, Atterburg limit test and compaction test. The sieving tests separate the different size fractions of the soil in to discrete parts thereby indicating the soil's particle grading. The silt and clay fraction are too small to particle grading. The silt and clay fractions are too small to be easily separated by sieving and as such are normally reported as a combined fraction [11]. The larger particles may be separated in to a number of size fractions, depending on the number of sieve sizes available, according to the EBCS and ASTM particle classification boundaries. A full laboratory analysis would give the percentage by weight of each of these size bands. The sedimentation tests if correctly conducted have the ability to separate the larger sand and gravel size fraction from the combined fines fraction and under favorable circumstance to further distinguish the combined fraction in to separate silt and clay fraction. However the simplest test, the glass-jar sedimentation test, is usually included under fieldtests because visual discrimination of the silt/ clay boundary may not be possible. In this case the test can only be used to give an idea of the general relative proportions of sand and fines. In its coarsest form the glass- jar sedimentation test provides no more information than a sieving test and although less accurate, it does not require any mass measurement. Further, although the sedimentation time is long the operator time required to conduct the test is less than that for a sieving test. The Atterburg or plasticity tests define the soil's liquid limit, plastic limit and plasticity. The Atterburg limits allow the soils plasticity characteristics to be related to the criteria given in section 3.4 above. The shrinkage test is a test of the soil's contraction on drying and gives a combined measure of the soil's particle grading, plasticity and clay type. It gives an overall idea of the soils behavior and suitability for stabilisation. The degree of contraction may be thought of as a measure of the expansive force, which the soil stabiliser will have to withstand when a manufactured block is exposed to water. The degree of contraction is then taken as a measure of the quantity of stabiliser required. The shrinkage test may be used as a straightforward method of determining a soil's suitability for use where more complex testing is not possible or not justified for small- scale production. However it must be remembered that this test gives no direct information on the soil's constituent parts and as such will not allow easy soil modification. It was empirically designed for used with the CINVA RAM, a low- pressure (2MPa) manual- 3. Conceptual Review Department of Civil Engineering 43 compaction-moulding machine developed by VITA. It was intended to gauge the amount of stabiliser needed for a given soil compacted with this machine. It is quite suitable for small- scale production if soil modification is not considered cost effective but it must be used in conjunction with tests on trial blocks. It must be remembered from the above discussion of soil suitability that the compaction pressure used to compact the block does affect the soil requirements. The shrinkage test was empirically calibrated for the CINVA-RAM (2MPa) and is not directly applicable to a machine operating at a separate compacting pressure. In general if the machine compacts to a higher pressure then the cement

content may be decreased for a given soil shrinkage or alternatively the range of acceptable soil shrinkage values may be increased. If the results from these are to be of use, a great deal of time and precautions must be taken. This point is seldom brought to notice. These tests appear simple to carry out and they produce numerical values, which are relatively easy to interpret, but they are not proofed and will produce misleading results if not carefully performed. The sedimentation tests in particular are very delicate, requiring time and practice to be perfect. In general soil tests are subject to two accuracy limitations: experimental care and measurement resolution.

3) Soil stabilisation

There are several methods of soil stabilisation widely used to improve construction quality. Some of the major stabilisation techniques are described below.

4) Mechanical stabilization

Mechanical stabilisation involves tamping or compacting the soil by using a heavy weight to bring about a reduction in the air void volume, thus leading to an increase in the density of the soil. The main effects of compaction on the soil are to increase its strength and reduce its permeability. The degree of compaction possible, however, is affected greatly by the type of soil used, the moisture content during compaction and the compression effort applied. Best results can be obtained by mixing the correct proportions of sand and clay in a soil. More recent developments for roads and embankment construction have led to compacting soil with vibrating rollers and tampers. Tampers and block-making presses are also used for the purpose of single storey constructions. The major drawback of mechanically compressed stabilised earth blocks is their lack of durability especially in places of moderate to high rainfall. Manual stabilisation or compaction methods vary from foot treading to hand tamping equipment, with compacting pressures varying between 0.05 to about 4MPa. Mechanical equipment may achieve compacting pressures of several thousand MPa.

5) Cement stabilization

Cement as a stabilising material is well researched and understood and its properties are clearly defined. From different types of cement, Portland cement is readily available in most urban areas, and usually available in semi-urban areas, as it is one of the major components for any building construction. Earlier studies have shown that cement is a suitable stabiliser for use with soil in the production of compressed stabilised soil Block. Cement is mainly composed of Lime (CaO) and Silica (SiO₂), which react with each other and the other components in the mix when water is added. This reaction forms combinations of Tri-calcium silicate and Di-calcium silicate referred to as C3S and C2S in the cement literature. The chemical reaction eventually generates a matrix of interlocking crystals that cover any inert filler (i.e. aggregates) and provide a high compressive strength and stability. Cement is usually mixed with an aggregate to form concrete. The aggregate is usually inert filler that makes up the bulk of the material, and the cement coats the aggregate in the gaps. The concrete industry has recognized that the achieved strength of concrete is highly dependent on the quantity of voids present in the mixture before curing. The presence of 5% air voids will reduce the strength of a concrete mix by about 30% and even 2% voids

can result in a drop of strength of more than 10% compared to a sample with 0% voids present [20]. To aid the particle intimacy, different aggregate grades are mixed together giving a spectrum of particle sizes that reduces the quantity of air voids in the material. Cement is considered a good stabiliser for granular soils but unsatisfactory for clays. Generally cement can be used with any soil type but with clays it is uneconomical the reason being that more cement is required. The range of cement content needed for good stabilisation is between 3% and 18% by weight according to soil type. Findings have shown that there is a relationship among linear shrinkage and cement content needed for stabilisations. It is seen that the cement to soil ratio ranges between 5.56% and 8.33% for measured shrinkage variations of between 15mm to 60mm.

6) Lime stabilization

One major alternative binder to cement is lime. By adding lime to the soil for stabilisation, four basic reactions are believed to occur: Cation exchange, flocculation and agglomeration, carbonation, and pozzolanic reactions. The pozzolanic reaction is believed to be the most important and it occurs between lime and certain clay minerals to form a variety of cementitious compounds, which bind the soil particles together. Lime can also reduce the degree to which the clay absorbs water and so can make the soil less sensitive to changes in moisture content and better its workability. Lime is a suitable stabiliser for clay soils. Lime is cheaply and easily available than Portland cement in Ethiopia and is produced locally in traditional kilns. However, some improvements still need to be made in its production and processing. It is estimated that up to 40% of cement used in building construction in masonry mortars could be saved through the use of lime and other lime associated binders. The advantages that lime has over Portland cement are that it requires less fuel to manufacture and requires relatively simple equipment to make. It is therefore more suitable for village scale production and use. When lime is used as a stabiliser instead of cement, the quantity of stabiliser required has been increased. However, research at the United Kingdom Building Research Establishment shows that such increment is not necessary if a sufficiently high compacting effort is applied on a high clay content soil. The reduction in the volume of air voids brings the lime and soil particles into closer contact and the stabilising reactions can take place more easily. Tests show that wet compressive strengths of between 3MPa and 3.5MPa may be achieved with compacting efforts in the range of 8 - 14MPa

7) Mix Proportion

Providing detailed technical and economic information on the production of compressed stabilised earth blocks by assessing the potential of local materials i.e. types of cement and soil is the purpose of this investigation. Thus one types of cement from manufacturers, and a soil sample from Bhopal nearby area are selected and prepared. To this effect the following test programs, are followed. The mix proportions are made based on literature recommendations. A total weight of soil taken is 5 kg and mixed with stabilizers in different proportions.

Block Name	Quantity of stabilizers/ ingredient			
	% Clay	% OPC	% Lime	% Water
CSEB1	100	10	10	25%
CSEB2	100	15	5	25%
CSEB3	100	10	5	25%
CSEB4	100	5	5	25%
CSEB5	100	10	0	25%
CSEB6	100	15	0	25%

Table 4: Stabilizer proportions

Block Name	Quantity of stabilizers/ ingredient		
	Clay (kg)	OPC (kg)	Lime (kg)
CSEB1	5	0.50	0.50
CSEB2	5	0.75	0.25
CSEB3	5	0.50	0.25
CSEB4	5	0.25	0.25
CSEB5	5	0.50	0
CSEB6	5	0.75	0

Table 5: Stabilizer content

8) Specimen Preparation

Since the preparation of specimens was considered to be one of the most important stages in the execution of the experiments, extra care had been taken with the soil, cement mix, moisture content, compression, curing, and sizing of the samples.

The high levels of accuracy, reliability and consistency demanded by the experiments be maintained throughout the testing regimes, and for all the different types of tests conducted. Specimen preparation describes the raw materials used, the mix proportions, addition of moisture, the compression method used, the curing regime, and the dimensions of the samples.

Literature indicates that an ideal soil would have an optimum raw materials composition of: sand 75%, fines (silt and clay) 25% of the fines, at least not less than 10% has to be clay. The actual mix then used consisted of: Sand 70%, Silt 16.25% and Clay 13.75%.

A shrinkage test and a simplified sedimentation test were used to confirm the limits for the different constituents. Blocks of average dimension 220*220*115 mm were subsequently made in this manner for the proportion shown in table 3.

The constituent parts of the mixed soil preparations were weighed separately using an accurate and sensitive electronic weighing machine which was accurate to $\pm 0.05g$. a mechanical mixer had to be used to improve on the degree of mix.

To produce the blocks, a pre-installed M7 E380 machine designed on the quasi-static compression principal was used for the entire samples. Before filling the mould for each compression, the mould lining was lightly oiled with used engine oil. The soil was carefully poured into the mould, all pre-weighed, packed and sealed in light transparent plastic bags. After each pouring, the soil was leveled in the mould. The use of the M7 E380 machine was based on the operational manual of the machine.

The blocks were compressed by the pumping act of the side pump up to 10 MPa. The hydraulic pressure was released using the flow valve screw causing the hand pump to become slack. The mould cover (Top ram) was then moved upwards to expose the green block, which was, then

demoulded. The green blocks were then carefully removed and put over base plates, and immediately placed in plastic bags and left to cure in the shade. The dimensions and the weights of the green blocks were recorded.

Curing of the blocks consisted of two distinct phases described herein as primary and secondary phases. The curing time, temperature, duration, and moisture conditions were of particular interest to the experiment. The purpose of primary curing is to ensure that moisture is retained in the block and not lost rapidly. This was done for a period of five days. Laboratory dry conditions were used with curing temperatures of 22-24 °C. After five days, the blocks were noticeably lighter in color than when demoulded. Each of the blocks were marked using permanent ink markers in each case to clearly show the percentage cement content, moulding pressure, date and time of production, and an identification number. This decision to mark individual blocks was to be found very useful later on. In order to enable the blocks to further achieve strength, secondary curing was allowed to continue for a further fifty-one days. The clearly marked blocks were placed side by side and covered with a large polythene sheet. This was done to slow down evaporation and to protect the blocks from external interference. The blocks were then left to dry in this manner under laboratory air conditions.

9) Tests on blocks

Different tests and experiments, all of which have direct bearing with the investigation of the effects of stabilisation and moulding pressure on the strength and performance of blocks, were selected and conducted. The tests include the wet and dry compressive strength tests and the water absorption test. Although the wet and dry compressive strength tests and the water absorption tests are both now standard performance tests quite largely described and used for stabilised soils, they were at first developed for concrete blocks and fired bricks.

10) Compressive strength test

The compressive strength of the blocks is however their most important property. The compressive strength values give an overall picture of the quality of the block and are an indication of the hardness of the hydrated cement paste that binds the different particles together. The main aim of the compressive strength tests was to conclude the wet compressive strength values of the blocks. It is the value of wet compressive strength which is normally lower than the dry compressive strength. This is usually used in the structural design of buildings. The compressive strength test done is a standard test on the basis of ASTM standards, Volume 04.08, Soil and Rock, 1996.

After the 7, 14 and 28 days curing period, the blocks of average dimension 22×22×11.5cm is measured and weighed. The main compression equipment used was the Concrete Testing Machine with a maximum load of 100KN.

Each block sample of dimension 22×22×11cm was soaked for 24 hours or overnight in ordinary tap water. They were then removed and kept aside for 30 minutes to let the extra surface water to drip off. The samples were then carefully placed within the set marking pins of the compression-testing machine.

The crushing load was then continuously applied without shock to the sample at a rate of 3.5 MPa per minute

till failure and in this way the maximum crushing load was obtained for each sample. The wet compressive strength was then calculated in each case from the ratio of the maximum load and the cross sectional area of the block in N/mm².

11) Water absorption test

The aim of the water absorption test was to determine the percentage moisture absorption capacity of the block samples. Block samples were weighed in the laboratory dry condition (W_d) and, immersed in water for 24 hours, removed and weighed again (W_w). An accurate electronic weighing machine was used in case, to an accuracy of 0.05g. The percentage moisture absorption by weight was calculated from the formula:

$$M_c = \frac{W_w - W_d}{W_d} \times 100 (\%)$$

Where: M_c = percentage moisture absorption (%) W_w= mass of wetted sample (g)

W_d = mass of dry sample (g)

Through the water absorption test, it should be possible to determine the ability and extent to which blocks can absorb moisture. Knowledge of the water absorption levels of blocks could serve as useful criteria for setting limits and for investigating possible ways of reducing the same in order to improve on the durability of blocks.

The apparatus consisted of an accurate weighing balance, a stop watch and a water trough with a capacity to hold up to 2 fully immersed blocks. The entire test took two days to complete mainly due to the overnight soaking of the block samples in water. This test helps to investigate the effect of water absorption of stabilised soil blocks during the rainy season. The recommended maximum water absorption value of blocks is from 15% to the maximum value of 20%

III. EXPERIMENTS AND RESULTS

A. General

Tests and experiments on blocks are vital to measure the block properties upon which durability is dependent. These properties are strength, water absorption and to monitor the blocks performance in conditions that simulate the cause of

the deterioration. The tests will need experimental results and data from which general and localized trends can be identified and from which comparisons can be made with theoretical predictions or other available data. The tests also would give an opportunity with which the validity of currently held beliefs could be tested and any agreements or departures from the norm found. It is expressed early that translating the experimental data into information to facilitate the potential improvement of production and the performance of blocks would be the broad objective of this thesis.

B. Compressive Strength

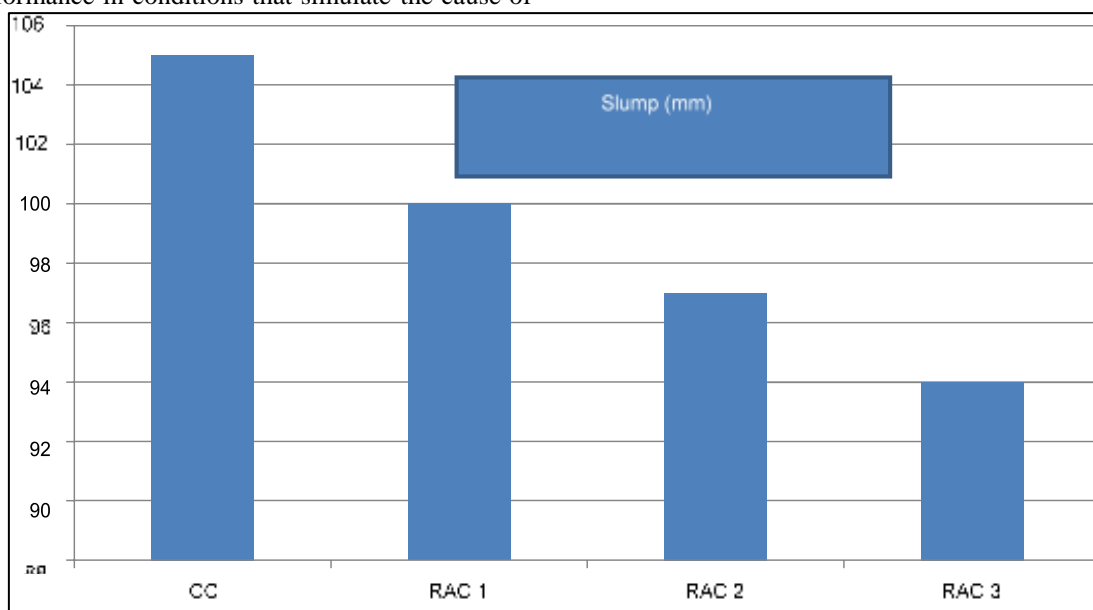
There are several manufacturing variables that could affect the performance of blocks. These include soil type, cement content, compaction pressure, moisture content, and curing method. In the experiments conducted it was concluded that of these multiple variables, only the cement content shall be varied while all the other parameters would remain fixed. The reason for this decision and approach was based on the fact that it was the stabiliser content. This, according to the literature on stabilised soils played a vital role for the improvement in strength, dimensional stability and durability of blocks.

C. Effects of Cement and Lime Content on the Compressive Strength of Soil Blocks

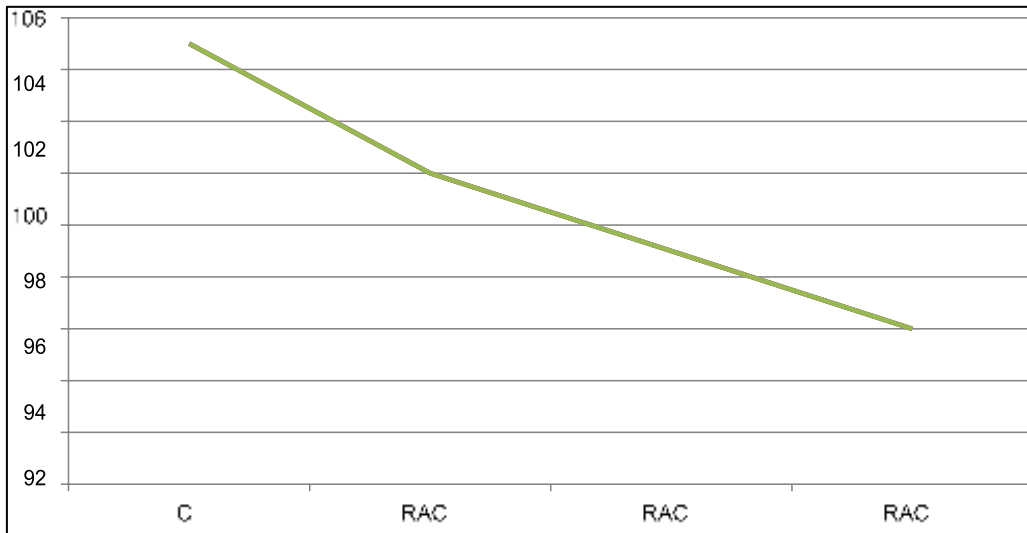
The 7th, 14th, 28th and 56th days mean compressive strength values of compressed soil blocks stabilised with ordinary Portland cement and all the raw data's of cube compressive strength test results are presented in a tabulated form in Appendix 3 and in a graphical form below

S. No.	Percentage Recycled Aggregate	Mix Name	Slump (mm)
1	0%	CC	105
2	10%	RAC1	100
3	20%	RAC2	97
4	30%	RAC3	94

Table 6: Workability of Recycled aggregate Concrete



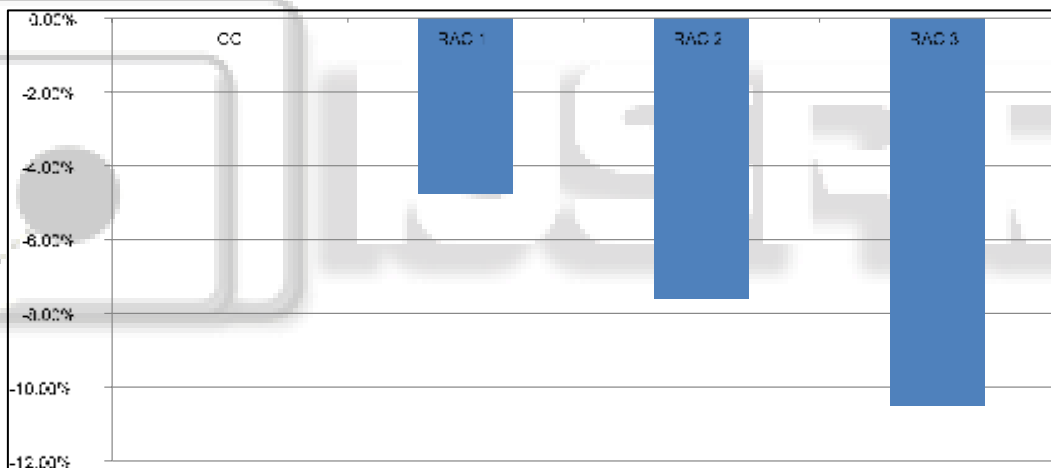
Graph 1: Workability of Recycled Aggregate Concrete (Bar Graph)



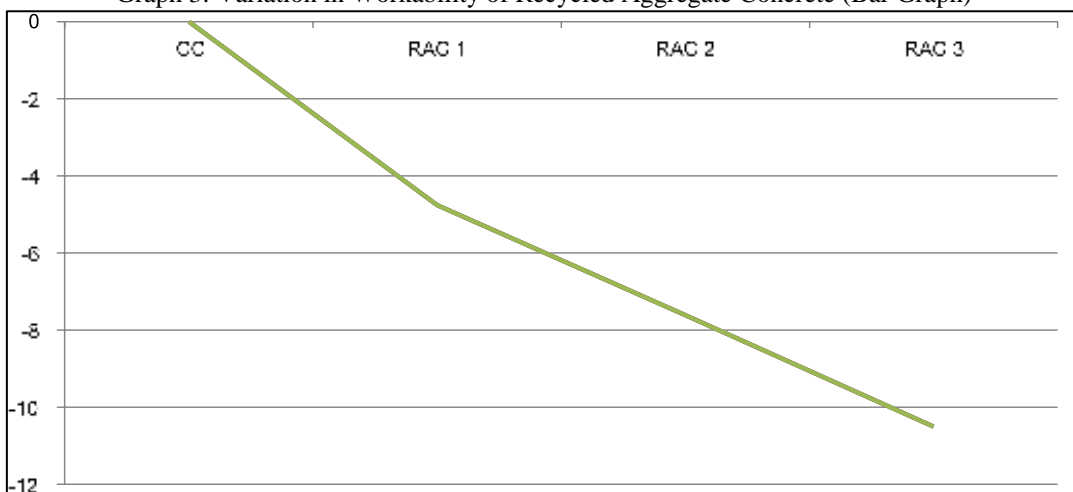
Graph 2: Workability of Recycled Aggregate Concrete (Line Graph)

S. No.	Percentage RCA	Mix Name	Variations in Workability (%)
1	00%	CC	0
2	10%	RAC 1	-4.76
3	20%	RAC 2	-7.61
4	30%	RAC 3	-10.5

Table 7: Variation in Workability of Recycled Aggregate Concrete



Graph 3: Variation in Workability of Recycled Aggregate Concrete (Bar Graph)



Graph 4: Variation in Workability of Recycled Aggregate Concrete (Line Graph)

IV. CONCLUSION AND FUTURE SCOPE

- From this study it is concluded that all the mixes which are used in this study are useable as per requirements at different levels of construction.
- The highest compressive strength of 3.85 N/mm² was achieved with CSSB1 at curing of 28 days.
- All the samples exhibit similar characteristics and are all suitable for the production of compressed stabilised soil blocks for walling in low cost sustainable buildings.
- A proper substitute for clay bricks is achieved for low cost housing and can be suggested for construction purpose.
- As these bricks can be prepared even at site which may reduce the transportation time, cost, also will help in reducing pollution which makes CEB more environmentally friendly than other materials.
- The maximum strength obtained at 28 day strength for all samples are within the minimum strength requirement recommended for the construction of low-rise buildings.

V. FUTURE SCOPE

- There is also a scope of using fly ash with lime and cement which can be taken into consideration.
- Use of foundry sand and RHA can also be studied and results can be analysed for best possible options.

REFERENCES

- [1] Qasrawi H.Y., Asi I.A., Wahhab H.I.A., "Proportioning Roller Compacted Concrete Pavements mixes under hot weather conditions for a specified tensile strength", *Cement and Concrete Research*, 2005, 267-276
- [2] Atis C.D., "Strength Properties of high-volume fly ash roller compacted and workable concrete, and influence of curing condition", *Cement and Concrete Research*, 2005, 1112-1121
- [3] Abdel-Halim M.A.H., Al-Omari M.A., Iskender M.M., "Rehabilitation of the spillway of Sama El-Serhan dam in Jordan, using roller compacted concrete", *Engineering Structures*, 1999, 497-506
- [4] . Koçak, E.S., "A Suitable Roller Compacted Concrete for Kahramanmaraş- Suçatı Dam", METU Civil Engineering Department, January 1998
- [5] . Sun W., Liu J., Qin H., Zhang Y., Jin Z., Qian M., "Fatigue Performance and Equations of Roller Compacted Concrete with Fly Ash", *Cement and Concrete Research* Vol. 28, No. 2, pp.309-315, 1998
- [6] S.Pavan, S. Krishna Rao, "Effect of Fly ash on Strength Characteristics of Roller Compacted Concrete Pavement", *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)* Volume 11, Issue 6 Ver. II (Nov- Dec. 2014).
- [7] S.Krishna Rao et al , "Evaluation of Properties of Roller Compacted Concrete Pavement (RCCP)" *IJEAR* Vol. 4, Issue Spl-2, Jan - June 2014.
- [8] Harris Angelakopoulos, Kypros Pilakoutas, Panos Papastergiou "Fibrous roller- compacted concrete with recycled materials – feasibility study" *magazine of concrete research* 2015, 67, 801 – 811.
- [9] Cao C, Sun W, Qin H (2000). The analysis on strength and fly ash effect of roller- compacted concrete with high volume fly ash. *Cement and concrete research*, 30(1): 71-75.
- [10] Mardani-Aghabaglou A, Ramyar K (2013). Mechanical properties of high-volume fly ash roller compacted concrete designed by maximum density method. *Construction and Building Materials*, 38, 356-364.
- [11] Pavan S, Rao SK (2014). Effect of Fly ash on Strength Characteristics of Roller Compacted Concrete Pavement. *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)* Volume 11, Issue 6 Ver. II (Nov-Dec.2014), PP 04-08.
- [12] Yerramala A, Babu KG (2011). Transport properties of high volume fly ash roller compacted concrete. *Cement and Concrete Composites*, 33(10): 1057-1062.
- [13] Rao et al. Strength and Compaction Characteristics of Fly Ash Roller Compacted Concrete *International Journal of Scientific Research in Knowledge*, 3(10), pp. 0260- 269, 2015
- [14] Hisham Qasrawi, 2013 The use of steel slag aggregate to enhance the mechanical properties of recycled aggregate concrete and retain the environment pp 298-304