A performance assessment on Compressed Stabilized Earth Block (CSEB) using geo – polymeric binders

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Abstract. The development of the country mainly depends on Rural Development. About 55% of rural peoples still live in earth building. According to the US Green Building Council, the building sector accounts for 39% of the global emission of CO2. If new technologies were not adopted means the emission could be doubled by the year 2050 according to United Nation Environment Program (UNEP). New technology is required to sustain the environment and earth materials. In India, One of the recently developing technology is Compressed Stabilized Earth Block (CSEB). This CSEB technology replaces the usage of conventional burnt clay bricks. In this Context, The earth materials are not widely used in CSEB because it includes the vital part of industrial wastes. The characteristics of CSEB with Granulated Blast Furnace Slag (GGBFS), Fly Ash of class-F and coir fiber are to be investigated. Nowadays, the controlling, management and disposal of waste materials are a difficult task. The Flyash-F is an industrial waste material that is obtained from a thermal power plant and it contains a low amount of CaO. GGBFS is also an industrial waste obtained from the quenching molten iron slag in steel industries. About 20-25% of dry volume soil is replaced by a combination of Flyash and GGBS with the addition of a geopolymer solution. Both the waste materials bring the CSE-Block as eco-friendly to the environment and cost-effective. Besides, The CSEB exhibits high strength, low creep, very minimum water absorption and good erosion resistance. In this paper, we are experimentally investigating the compressive strength and water absorption nature of CSEB with varying ratios of binders and Geo-Polymeric solution.

1. Introduction
Mud based technology was an ancient technology and it was started during the ninetieth century. A Compressed Stabilized Earth Block also is known as stabilized Earth block. It was stabilized by a different stabilizing agent such as Fly ash, Ground Granulated Blast Furnace Slag (GGBFS) and Geo-Polymeric solution such as Sodium hydroxide and Sodium silicate (Na2SiO3) as Activating Alkaline Solution (AAS). CSEB technology developed for environmentally friendly and cost-effective construction.

The Flyash class-f pulverized from the bituminous coal. At present, NLC (Neyveli Lignite Co-operation) produces 200 million tons of Flyash per year. GGBFS in-organic waste material from steel industries. The effect of Efflorescence was reduced when GGBFS was using about 50-60% and it protects against chloride and sulfate attack. The Geo-polymeric solution was In this project, The combination of Flyash and GGBS will increase the compressive strength of CSEB and decrease the water absorption of the
Block. The optimum percentage of GGBS (20%) gives the maximum increment in the CBR value. Red soil sample and 15% Flyash and 25% GGBFS give compressive strength was 14.83 MPa at 28 days. The water binder ratio was 0.52 (T.V. Preethi May 2014). Experimental investigations about Flyash, GGBS, Silica fume and Kadapa slab powder. 75% flyash+22%GGBS+3% silica fume with 8M gives excellent compressive strength about 10.3MPa at 28 days and water absorption was 6.7%. 75% flyash+22%GGBS+3%kadappa slab powder gives the rate of water absorption was 6.6% (Sunandana Reddy Mar-Apr 2018).

In this experiment an attempt was made to produce a new innovative and cost effective building material to achieve high strength of CSE- Block by using industrial waste material. The optimum dosage of GGBFS and Fly Ash was obtained. The experimental investigations on the effect of altering important variables such as coir fiber, GGBFS and fly ash content on stabilized earth blocks was done. In addition the compressive strength of CSEB with different curing methods was also performed. The result shows that the developed technology was able to produce high strength, innovative and cost effective building material.

2. Materials & Methodology

The methodology includes the theoretical principles and analysis of the body associated with a branch of knowledge.

2.1. Red soil

Red soil was procured locally from Dindigul. The red soil is rich in iron content and it is the key factor for enhancing the strength in the block. The engineering properties are determined using the standard tests as per I.S codes.

| Parameters          | Values |
|---------------------|--------|
| Gravel              | 10%    |
| Sand                | 15%    |
| Silt                | 36%    |
| Clay                | 39%    |
| Liquid limit, LL    | 15.65% |
| The plastic limit, PL | 7.5%   |
| Plasticity index, PI| 8.15%  |
| Optimum Moisture    | 15%    |
| Maximum Dry density ($p_{\text{max}}$) | 2.33 g/cm$^3$ |
| Maximum Bulk density ($p_{\text{bulk}}$) | 2.03 g/cm$^3$ |
| Specific gravity, G | 2.23   |
2.2. Flyash – F
Flyash class-F is obtained by a coal-based thermal power station procured from Tuticorin. Specific Gravity of Flyash was 2.78. The Flyash material sieved to ensure the material free from lumps. The Specific gravity test conducted by as per IS 1727-1967.

![Figure 1. Flyash-F](image1)

2.3 Ground Granulated Blast Furnace Slag (GGBFS)
GGBFS contains 30-50% of lime content. So, the combination of Flyash and GGBFS increases the strength of the block. GGBFS was procured from Madurai. Specific Gravity of GGBFS was 3. The test was done as per Indian standards IS 1727-1967.

![Figure 2. GGBFS](image2)

2.4. Coir Fiber
The coir fiber was procured from the local market at free of cost. The fibers are cut into 3 to 4cm. The coir fiber was treated before the block making. It was soaked in a NaOH solution for 2 hours and it was dried 70°C in the oven for about 5hrs.

![Image 3](image3)
2.5. Alkaline solution
The Alkaline solution also is known as the Geo-Polymer solution. The NaOH solution prepared with a concentration of 8M & 10M. The molecular weight of NaOH was 40. The mass of NaOH solids was measured as 255 grams per kg of NaOH solution for 8M concentration. The solution was prepared at normal room temperature. When the solution mixed, both solution starts to react (polymerization) and it liberates a large amount of heat so it is recommended to leave it for about 24 hours thus the alkaline solution gets ready as a binding agent.

2.6. Mix proportions
The CSE-Block mix proportion is investigated with two different Molarity 8M & 10M. The binder ratio (NaOH: Na₂SiO₃) was 1:2. Average Weight of one block was 6 Kg. actually; 0.6 kg of the alkaline solution is required for the making of one block. The results are discussed on Table 3.1 & 3.2. The soil percentage is taken as base constant (75%) and molarity of Geo-Polymer solution fixed as 8M in the main mix proportion based on experimental investigation.

| Mix ID  | Red soil (%) | Flyash –F (%) | GGBFS (%) | Coir fiber (%) |
|---------|--------------|---------------|-----------|---------------|
| M1      | 75(8M)       | 12            | 12        | 1             |
| M2      | 75(10M)      | 12            | 12        | 1             |
| M3      | 75(8M)       | 12.5          | 12.5      | -             |
| M4      | 80(8M)       | 10            | 10        | -             |
| M5      | 85(8M)       | 7.5           | 7.5       | -             |

Table 2.2. Trial mix proportions
Mix ID | Red soil (%) | Flyash-F (%) | GGBFS (%)  
---|---|---|---
CSEB-1 | 75 | 5 | 20  
CSEB-2 | 75 | 10 | 15  
CSEB-3 | 75 | 15 | 10  
CSEB-4 | 75 | 20 | 5  
CM | 75 | - | 25  

2.7. Casting & Curing Of CSEB
The stabilized mud block was made by using the HYDRO FORM machine. The blocks were made with a Geo polymer solution at various proportions. The size of a block is 210 x 115 x 115 mm. Initially, the dry mix was done by adding GGBS & Flyash with soil and then the alkaline solution was added and allowed to mix with help of hydraulic rotating drum.

Figure 5. HYDRO FORM machine

The block should be taken gently and they should be kept on a smooth and flat surface at 24hours for the Resting period of block. Curing was carried out with different curing methods such as oven and ambient curing. CSE-Blocks placed on the oven at 60°C for 24hrs. Water curing doesn’t require for Geo-Polymer blocks.

Figure 6. Oven Curing

3. Result and discussions
3.1. Compression test: (IS3945:1992)
Compressive strength is the ability of structure or material to carry the loads on its surface without any crack or deflection. Compressive strength of CSE-Block depends on many factors such as water-binder ratio, the molarity of an alkaline solution, quality of GGBFS & Flyash-F material, quality, etc... The area of the block was 224.2cm². The compression test was conducted on the 3rd, 14th, 28th day of curing. The wet and dry compressive strength of CSE-Block in both oven and ambient curing was tested at the end of 28 days.

Table 3.1. Compression value at 14th day of curing

| S.no | Sample ID | Average Compressive Strength (MPa) |
|------|-----------|----------------------------------|
| 1    | M1        | 9.56                             |
| 2    | M2        | 8.49                             |
| 3    | M3        | 16.03                            |
| 4    | M4        | 7                                 |
| 5    | M5        | 8.7                              |

Table 3.2. Compression value at 28th day of curing

| Sample ID | Dry Compressive Strength (MPa) | wet Compressive Strength (MPa) |
|-----------|-------------------------------|--------------------------------|
|           | Ambient Curing | Oven Curing |                     |
| CSEB- 1   | 23.72            | 26.7        | 14.95               |
| CSEB- 2   | 23.82            | 24.71       | 11.37               |
| CSEB- 3   | 12.09            | 13.72       | 8.50                |
| CSEB- 4   | 13.53            | 17.12       | 10.82               |
| CM        | 24.62            | 28.0        | 16.44               |
Figure 7. Compression test

Figure 8. Compressive strength at 14th day of curing

Figure 9. Dry Compressive strength at 28th day of curing
3.2. Water absorption test: (IS 3495:1992(part-II))

Water absorption of CSE-Block is an important factor in classifying its durability. Generally, First class bricks having a high water absorption of about 20%. Stabilized mud block is less than 13% as per Indian standards.

![Figure 11. Water absorption test](image)

**Table 3.3. Water Absorption Test**

| Mix ID  | Dry Weight (Kg) | Wet Weight (Kg) | Water Absorption (%) | Permissible limit |
|---------|-----------------|-----------------|----------------------|-------------------|
| CSEB-1  | 5.734           | 5.9             | 2.81                 |                   |
| CSEB-2  | 5.562           | 5.73            | 3.02                 |                   |
| CSEB-3  | 5.435           | 5.74            | 5.31                 |                   |
| CSEB-4  | 5.73            | 6.02            | 5.06                 |                   |
| CM      | 5.862           | 6.1             | 4.06                 |                   |
| M1      | 5.56            | 5.93            | 6.65                 |                   |
| M2      | 5.74            | 6.07            | 5.75                 |                   |
Water absorption can be measured by dry weight and wet weight of the specimen. It was expressed in a percentage of the mass of the sample. The minimum water absorption rate was 2.81%. The mix proportion of CSEB-1 gives better results.

3.3. UPV Test: (Is 13311:1992 Part-1)

An ultrasonic pulse velocity (UPV) test is an in-situ, non-destructive test to check the quality of concrete and mud blocks. In this test, the strength and quality of mud block are assessed by measuring the velocity of an ultrasonic pulse passing through a mud CSE-blocks. Higher velocities indicate good quality and continuity of the material, while slower velocities may indicate block with many cracks or voids. The test procedure is done according to the standard code specification of IS1331 (part1):1992.

| S.no | Mix ID  | Receiving point | Pulse Velocity (L/T) in Km/s |
|------|---------|-----------------|-----------------------------|
| 1    | CSEB-1  | 2HZ             | 4.32                        |
| 2    | CSEB-2  | 2HZ             | 3.03                        |
| 3    | CSEB-3  | 2HZ             | 3.9                         |
| 4    | CSEB-4  | 2HZ             | 3.78                        |
| 5    | CM      | 2HZ             | 4.32                        |
3.4. Scanning Electron Microscopy (SEM) analysis
It provides high-resolution imaging useful for evaluating various materials for surface fractures, flaws, contaminants. It gives results about the physical and chemical properties of the sample. It helps to identify the chemical composition of the sample.

Table 3.5. Chemical composition of Flyash-F

| Element | Normalized Concentration[wt.-%] |
|---------|---------------------------------|
| Ca      | 11.39                           |
| O       | 46.24                           |
| Si      | 23.52                           |
| Al      | 7.71                            |
| Fe      | 9.54                            |
| C       | 1.09                            |
| Mg      | 0.51                            |

Figure 12. UPV Test

Figure 13. Microscopic view Flyash
Table 3.6. Chemical composition of GGBFS

| Element | Normalized Concentration[wt.%] |
|---------|-------------------------------|
| Ca      | 11.18                         |
| O       | 39.85                         |
| Si      | 34.41                         |
| Al      | 7.92                          |
| Mg      | 2.54                          |
| C       | 0.21                          |
| S       | 0.64                          |

Figure 14. Microscopic view GGBFS

4. Conclusion
From the study of CSEB with Geo-Polymeric binders. The conclusion is based on the experimental study on compressive strength and water absorption of CSE-blocks. We concluded the following points:

- The Optimum Percentage of soil is taken as 75% of the results from the trial mix proportion. Because increment in the percentage of soil leads to achieving unsatisfied results.
- The strength of block decreases when the molarity of the solution increases.
- The strength of the block increases when the flyash content increases in the range of 5-10% gradually. But when the fly ash content increases more than 10%, the block strength reduces up to 10MPa.
- The CSE-Block made of proportion was 75% of red soil+20% of GGBFS +5% of Flyash. It gives better geometrical properties and yield better compressive strength on different curing methods. The stress was 26.7 MPa at 28 days (oven curing) and 23.72 MPa at 28 days (Ambient curing). The rate of water absorption was 2.87%.
- The Proportion of 75% of red soil+5% of GGBFS +20% of Flyash. The compressive strength was 17.12 MPa at 28 days (oven curing) and 13.53 MPa at 28 days (Ambient curing). The rate of water absorption was 5.06%.
- If Flyash content increases the rate of absorption of the block also increases.
- The ultrasonic pulse value range between 3 to 4.7 as an average. It indicates good internal
quality and flawless composition of CSE-B block.

Reference

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