

DEVELOPMENT OF SUSTAINABLE COMPRESSED STABILIZED EARTHEN BLOCKS UTILIZING INDUSTRIAL WASTE FOR ECO FRIENDLY CONSTRUCTION

Jayasurya S^a, Kaviprakash N^a, Madhura S^a, Mohana Krishnan G^a, Vennila A^b

Undergraduate Student, Department of Civil Engineering, Kumaraguru College of Technology, Coimbatore, India^a

Assistant Professor, Department of Civil Engineering, Kumaraguru College of Technology, Coimbatore, India^b

ABSTRACT

The growing loss of natural building materials and building of industrial waste have led to a strong demand for environmentally friendly building materials in the construction industry. This paper explores the manufacture of Compressed Stabilized Earthen Blocks (CSEBs) with the inclusion of industrial byproducts like bagasse ash, foundry sand, and red mud as a partial substitute to the traditional soil. The base matrix was made of locally available red soil that had been stabilized using cement and mix proportions were created, by changing the percentage of waste materials, with the binder content kept constant. The experimental program consisted of the characterization of materials, the preparation of blocks through mechanical compaction, and controlled curing. They were tested on compressive strength, water absorption and density in accordance with the applicable standards. The findings suggest that the addition of industrial waste materials considerably enhances the packing of the particles and helps in the formation of strength owing to the pozzolanic reactions. The optimum mix had a high compressive strength and less water absorption relative to the control mix. The developed blocks are also found to have less cost and environmental impact as compared to the traditional burnt clay bricks. The research establishes that waste-based CSEBs can be used as an environmentally friendly and cost-effective substitute to the current construction processes, especially in low-cost housing construction.

Keywords: CSEB, Bagasse Ash, Foundry Sand, Red Mud, Sustainable Construction, Soil Stabilization.

1.Introduction

The construction industry is among the highest consumers of natural resources and the major contributor to the degradation of the environment due to over extraction of materials and carbon emission. Traditional kiln fired burnt clay bricks need high temperature thus consuming energy and polluting the air. Alternatively, Compressed Stabilized Earthen Blocks (CSEBs) are environmentally friendly since they do not require firing and use of locally sourced materials. Another aspect that promotes sustainability is the use of industrial waste like bagasse ashes, foundry sand, and red mud, which limit the disposal of wastes by landfills and save on the use of natural resources. The advantages of these materials include high silica content and fineness of particles, which are valuable in their bonding and strength development. The current research is aimed at assessing the effectiveness of CSEBs that use waste materials and comparing their characteristics with more traditional masonry units.

2.Materials and Materials Testing

2.1 Materials Used

The materials utilized in this experiment are red soil, cement, bagasse ash, foundry sand, red mud and water. The main substance that works as cohesive is red soil, and cement is used as stabilizer. Bagasse ash helps by giving it pozzolanic properties, foundry sand helps in the packing of particles, and red mud helps in the binding properties.

Table 1 – Physical Properties of Materials

Material	Specific Gravity	Bulk Density (kg/m ³)	Characteristics
Red Soil	2.60	1600	Cohesive, fine
Cement	3.15	1440	Binding agent
Bagasse Ash	2.10	900	Pozzolanic
Foundry Sand	2.50	1500	Fine granular
Red Mud	2.80	1700	Fine, rich in alumina

2.2 Materials Testing

Material testing was done to check the viability of materials in CSEB production. The fineness modulus and specific gravity of foundry sand were 1.7 and 2.6 respectively, which are good values of grading and density. The fineness modulus of red soil was 2.4, specific gravity was 2.65, which was sandy clay loam. The Standard Proctor Test gave an Optimum Moisture Content (OMC) of 12.8% and Maximum Dry Density (MDD) of 1.85 g/cc.

The loss on ignition (LOI) of bagasse ash was also determined and this showed that reactive silica was present and could be used as a pozzolanic material that helps to build strength.

Cement tests revealed a fineness of 6, standard consistency of 31, initial setting time of 140 minutes and final setting time of 270 minutes. The pH of soil was 5.6. These findings validate the fact that the materials can be used to produce stable and strong CSEBs

2.2.1 FOUNDRY SAND

Table 2 – Foundry Sand Test and Result

Test	Result
Grain Fineness Test (Sieve Analysis)	Fineness Modulus = 2.68
Specific Gravity	2.78
Permeability Test	51
Moisture Content	0%
Bulk Density	1.4 g/cm ³ (1400 kg/m ³)
Compressive Strength	0.076 N/mm ²
Water Absorption	3%

2.2.2 BAGASSE ASH

Table 3 – Bagasse Ash Test and Result

Test	Result
Fineness Test	93.2% passing 90 µm sieve
Specific Gravity	2.25
Bulk Density	Loose = 400 kg/m ³ , Compacted = 550 kg/m ³
Loss on Ignition (LOI)	10.5%
Calcium Oxide (CaO) Content	30.84%
pH Test	9.3
Strength Activity Index (SAI)	7 days = 76.7%, 28 days = 80.0%
Frattini Test	Active (point below solubility curve)
Chapelle Test	9286 mg CaO/g

2.2.3 RED MUD

Table 4 – Red Mud Test and Result

Test	Result
Grain Fineness Test (Sieve Analysis)	Fineness Modulus = 2.63
Specific Gravity	2.65
Moisture Content	4.76%
Standard Proctor Test	MDD = 1.68 g/cc, OMC = 11%
pH Meter Test	6.83
Liquid Limit & Plastic Limit	LL = 26%, PL = 26.7%, PI = 0

2.2.4 CEMENT

Table 5 – Cement Test and Result

Test	Result
Fineness Test	3.4% residue on 90 µm sieve
Setting Time Test	Initial = 45 min, Final = 160 min

3. Methodology

3.1 Mix Proportions

Five different mix proportions were developed by varying the percentage of industrial waste materials.

Table 6 – Mix Proportions

Mix ID	Soil (%)	Foundry Sand (%)	Bagasse Ash (%)	Red Mud (%)	Cement (%)
CM	90	0	0	0	10
M1	75	10	3	2	10
M2	70	12	4	4	10
M3	65	15	5	5	10
M4	60	18	6	6	10

3.2 Block Preparation

Compressed Stabilized Earthen Blocks (CSEBs) are prepared in a systematic way to guarantee uniformity and strength. First, the foundry sand, red soil, bagasse ash, red mud and cement are dried and sieved to eliminate impurities. The materials are then combined in dry form as per the desired mix proportion with cement kept at 10% as a stabilizer.

Gradual addition of water is done until the Optimum Moisture Content (12.8%) is reached and the mixture is blended thoroughly to attain uniform and workable consistency. The ready mix is then poured into a 240 × 110 × 105 mm mould and pressed with a mechanical press to enhance density and minimize the number of voids.

Demoulding of the blocks follows the compaction and the blocks are allowed to dry after a period of 24 hours. They are then allowed to dry in 28 days keeping a sufficient amount of moisture to allow proper development of strength. Testing and evaluation of the cured blocks is eventually done.

4. Results and Discussion

4.1 Compressive Strength

The compressive strength of the blocks was tested after 7, 14 and 28 days of curing.

Table 7 – Compressive Strength Results

Trial Mix	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
Trial 1	3.70	5.80	5.98
Trial 2	3.08	3.30	3.65
Trial 3	2.63	3.49	3.86
Trial 4	3.08	3.99	4.06

CSEB blocks showed an increase in compressive strength with time of curing of all the trial mixes, indicating that they were adequately hydrated and bonded. Among the mixes, Trial 1 showed the highest strength with 5.98 MPa at 28 days, followed by Trial 4 (4.06 MPa), Trial 3 (3.86 MPa), and Trial 2 (3.65 MPa). The excellent performance of Trial 1 can be attributed to the optimum proportion of materials, which promoted packing and bonding of particles due to hydration of cement and pozzolanic activity of bagasse ash.

4.2 Water Absorption

Water absorption is a critical parameter affecting durability.

Table 8 – Water Absorption Results

Trial Mix	7 Days (%)	14 Days (%)	28 Days (%)
CM	17.5	15.7	12.1
Trial 1	13.2	11.3	7.56
Trial 2	14.7	12.7	9.76
Trial 3	15.4	13.8	8.94
Trial 4	14.1	12.1	11.09

All mixes had a reduced water absorption with time of curing, which implies enhanced compaction and bonding. Control mix (CM) was the most absorbed and Trial 1 was the least at 28 days with 7.56% followed by Trial 3, Trial 2, and Trial 4.

The decrease in water absorption can be attributed to enhanced particle packing by foundry sand and enhanced bonding by bagasse ash and red mud. Good durability was ensured by all mixes meeting the IS limit of 15%. Trial 1 is the best mix due to the minimum water absorption.

5. Sustainability and Cost Analysis

5.1 Sustainability

The formulated CSEBs have tremendous environmental impacts such as lowering the amount of carbon emission, wasting less of the natural resources, and using industrial wastes as materials. Moreover, the production cost is less than that of conventional bricks since the material and energy needs are minimized.

5.2 Cost Analysis

The cost analysis indicates that Trial 4 is the most cost-effective (₹18.50), then trial 3, trial 1 and trial 2. The reduced cost can be attributed to increased utilization of industrial wastes. Trial 1 however performs better in totality and therefore the optimum mix in terms of price and strength.

Table 9 – Cost Analysis

Parameter	Value (₹)
Trial 1	19.61
Trial 2	20.08
Trial 3	18.86
Trial 4	18.50

Table 10 - Comparison with Conventional Brick.

Parameter	Conventional Brick	CSEB (Optimized)
Energy Consumption	High	Low
Cost	High	Economical
Strength	Moderate	Higher
Environmental Impact	High	Low

6. Conclusion

This paper shows that the recycling of industrial waste materials which include bagasse ash, foundry sand and red mud in the manufacture of Compressed Stabilized Earthen Blocks (CSEBs) greatly enhance their engineering and durability characteristics and encourages sustainable construction processes. The experimental data clearly indicates that the compressive strength increases with the addition of these materials because of the improved packing of particles, the decrease in the number of voids and the development of other cementitious substances as a result of the pozzolanic reactions.

Of the various trial mixes, Trial 1 was the most favorable mix as it had the greatest compressive strength at 28 days of 5.98 MPa and the lowest water absorption at 7.56%, which means that it had high strength and durability. The decreased water absorption relative to the control mix validates the enhanced density and diminished porosity, which are critical in terms of the long-term performance. The research also brings into focus the fact that too much replacement levels can lower the performance marginally, and the need to proportion performance properly is vital.

In terms of the environment, use of industrial byproducts lowers the disposal of landfills, decreases pollution, and saves on the natural resources like land and sand. Moreover, the removal of kiln firing in CSEB manufacture results in great energy savings and carbon emission cut, as compared to traditional burnt clay bricks. Cost wise the developed blocks are economical and the cost of production is competitive and the blocks do not need the use of costly raw materials.

On the whole, the results prove that waste-based CSEBs can be viewed as a viable and sustainable alternative to conventional masonry units. The optimized mix does not only achieve the necessary strength and durability, but also provides environmental and economic benefits. Consequently, the blocks could be successfully implemented in the practice of environmentally-friendly construction, especially in low-price housing, rural development, and ecological infrastructure projects

7. Future Scope

The current research on Compressed Stabilized Earthen Blocks (CSEBs) with industrial wastes can be continued in various ways to improve its effectiveness and usability. Future studies can center on long-term durability research of the material like weathering, freeze-thaw cycles, chemical attacks to determine the performance of CSEBs over varying environmental conditions. More sophisticated tests like microstructural analysis (SEM or XRD) can be conducted to gain a better insight into the bonding mechanism and pozzolanic reactions in the blocks.

The viability of the application of these blocks in practical construction works such as residential and commercial buildings can be carried out via large-scale production and field implementation studies to determine its viability. Also, mix proportions with varying percentages and combinations of industrial waste materials can be optimized to further enhance strength and cost efficiency.

The thermal insulation, acoustics, and fire resistance of CSEBs can also be studied in further research to determine the applicability of CSEBs in modern buildings. It can also be investigated to use alternative stabilizers like lime or geopolymer binders to minimize the use of cement and improve sustainability. In general, the future potential is in enhancing the performance, scaling up production, and advancing the implementation of CSEBs as the sustainable building material of the mainstream.

REFERENCES

- 1.Thennarasan Latha A. et al. (2023) – Studied CSEBs with municipal solid waste incinerator ash, showing improved strength and sustainability.
- 2.Thennarasan Latha A. et al. (2024) – Investigated durability and life cycle analysis of waste-based CSEBs.
- 3.Valenzuela M. et al. (2024) – Reviewed industrial and agro-waste incorporation in CSEBs, highlighting performance improvements.
4. Lopez Rebollo J. et al. (2024) – Studied different stabilizers and their effect on mechanical properties.
5. Bui Quoc Bao et al. (2023) – Developed geopolymer-based compressed blocks using fly ash.
6. Elavarasan S. & Priya (2021) – Experimental study on fly ash-based CSEBs showing improved performance.
7. Sekhar D. C. & Nayak (2018) – Used blast furnace slag to enhance strength and durability.
8. Rivera J. et al. (2020) – Incorporated glass waste and fly ash, improving sustainability and strength.
9. Nagaraj H. B. et al. (2016) – Investigated iron mine spoils in CSEBs and confirmed feasibility.
10. James J. et al. (2016) – Showed pozzolanic benefits of bagasse ash in stabilized blocks.
- 11.Sitton J. D. et al. (2018) – Highlighted importance of mix design and compaction on strength.
- 12.Olumodeji A. O. (2023) – Used rice husk ash in CSEBs and improved durability.
- 13.Ojerinde A. (2020) – Investigated RHA as stabilizer in earth blocks.
- 14.Elahi T. E. et al. (2021) – Studied engineering properties of cement and fly ash stabilized blocks.
- 15.Houben H. & Guillaud (1994) – Provided fundamental concepts and techniques of earth construction.
- 16.Bureau of Indian Standards – IS 1725:1982
Specification for soil-based blocks used in construction.
- 17.Bureau of Indian Standards – IS 2720 (Part Series)
Methods of test for soils (OMC, MDD, moisture content).
- 18.Bureau of Indian Standards – IS 4031
Methods of physical tests for cement.
- 19.Bureau of Indian Standards – IS 383:2016
Specification for aggregates (used for foundry sand testing).
- 20.ASTM International – ASTM C67
Standard test methods for compressive strength and water absorption of bricks.