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Effect of Different Mix Compositions on Compressed Stabilized Earth Block Strength

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Abstract

Climate change and global warming are pressing issues exacerbated by the rapid expansion of the world's population and its housing needs. Traditional construction materials contribute significantly to environmental degradation through the generation of dust, solid waste, hazardous gases, and high energy consumption. In response, this study focuses on exploring environmentally sustainable alternatives, with a particular emphasis on compressed stabilized earth blocks (CSEB). CSEBs are masonry units formed by compacting soil, stabilizers, and water. This research investigates various CSEB compositions incorporating 8% Cement and 15% Ground Granulated Blast Furnace Slag (GGBS), alongside either Sugarcane Bagasse Ash (SBA) or Rice Husk Ash (RHA), conforming to grading zone-II specifications outlined in IS 383. The study evaluates the compressive strength, water absorption, and dry density of CSEBs from eight different mix compositions after 21 days of curing. Results indicate that CSEBs formulated with a mix composition containing 20% SBA or RHA exhibit the most promising performance, meeting the requirements outlined in Indian standards. These findings underscore the potential of CSEBs as an environmentally friendly alternative in construction practices, offering a sustainable solution to mitigate the adverse impacts of traditional building materials on the environment.

Keywords: Compressed stabilized earth block, mix composition, compressive strength, sugar cane, bagasse ash, environmentally friendly

INTRODUCTION

With a history of more than 9,000 years, earthen constructions are among the oldest types of buildings. Even now, a sizable fraction of humanity still resides in huts made of earth. Traditional earthen constructions are primarily non-engineered buildings created with cob, rammed earth, or adobe, as opposed to modern earthen constructions, which are frequently designed employing engineering concepts together with rammed earth and compressed earth blocks. Compressed Stabilized Earth Block (CSEB) is given importance because of its many benefits, including: (i) its use of environmentally friendly natural materials; (ii) its status as a sustainable technology; (iii) its reduction of energy waste in terms of carbon footprint (in consideration of energy consumption by using manufactured products like cement, burnt-bricks, etc., as they require more energy to be spent on their manufacture). The CSEB system encourages locals to participate in a variety of tasks, providing them with the chance to work locally. It also gives self-

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builders the chance to enjoy the satisfaction of erecting the walls of the homes they've always wanted, and it allows them to use the financial savings from the project to pay for their children's education and medical expenses. The production of CSEB is thought to be both economical and energy efficient. Environmentally friendly construction materials are employed. Contributions are provided altogether to keep up a sustainable development. In terms of several scientific and technological characteristics, various researchers have contributed to the development of the technology of compressed stabilized earth block. For the conventional brick production nearly 50% water is used whereas for CSEB blocks only 12–15% water is used. Also, the dimensional stability of CSEB is more than the Conventional brick. In CSEB production different wastes are utilized with that natural resources can be preserved, and pollution can be reduced.

Construction using compressed and stabilized earth blocks (CSEB) has grown quickly in recent years [1]. Compressed New earth masonry units called stabilized earth blocks blend local soil, a stabilizer, and water under pressure. The fundamental component in the creation of blocks at CSEB is soil, which is a resource that is readily abundant practically everywhere in the world. This offers conventional masonry units a sustainable substitute [2]. To provide cohesiveness and improve weather resistance, stabilizers, often Portland cement, are applied with soil. CSEB is not baked or burned to achieve their maximum strength, in contrast to other masonry components. The manufacturing of other masonry components uses a lot of energy, is not environmentally beneficial, and creates waste. According to reports, the construction sector in India alone is accountable for 22% of all greenhouse gas emissions [3]. Depending on the kiln's kind and the fire-fuel utilized in it, a brick kiln emits between 70 and 282 grams of carbon dioxide, 0.001 to 0.29 grams of black carbon, and 0.29 to 5.78 grams of carbon monoxide per kilogram of brick fired [4]. These environmental concerns in their whole are paving the way for the creation of compressed stabilized earth blocks (CSEB). Stabilized earth appears to stand out among environmentally friendly building methods [5]. The soil's composition will determine how much cement must be utilized [6–14]. While clayey soil needs 12–15% cement to stabilize it, silty soil needs 8–12% cement, and sandy soil needs 5–9% cement by volume. Cement level above 15% is unprofitable [3]. Greater cement dosages improve the CSEB's strength due to the increased availability of cementation material to create water-insoluble connections with the silt and sand particles [15]. The development of the C-S-H (calcium silicate hydrate) gel, a hydration product, which results from hydration processes, is primarily responsible for the increase in strength with cement. With additional cement being added, more C-S-H gels are created, which mix the soil particles and provide strength. The early strength of the blocks is a result of the cement's self-hydration products and the binding of sand particles [16]. Nagraj investigate at the contribution of lime to cement in enhancing compressed stabilized earth block durability [6]. Shekhar and Nayak [3] after researching the usage of cement-granulated blast furnace slag (GBFS) as a stabilizer, researchers concluded that CSEBs made by mixing 6% cement and 20% GBFS with lateritic soil can be utilized to build load-bearing walls. A cost-effective way to assure enduring earthen building is to add 4% cement together with 1% straw by weight, according to research that examined the effectiveness of cement, gypsum, lime, and straw as stabilizers [7]. James et al. [8] investigated sugarcane bagasse ash (SBA) and cement in conjunction to create CSEBs, and it was found that 4% cement and 8% SBA met the Indian Standard's requirements for strength. Elahi [9] conducted a study to see how well cement and FA produced satisfactory CSEBs in terms of strength and durability. Akinwumi examined the results of mixing shredded waste plastic into a stabilizing soil to create compressed earth block (CEB) [10, 11]. The microstructure and mechanism of soil blocks with fiber reinforcement and additional agricultural waste fibers are studied earlier [12]. Rammed earth is an optimal sustainable housing option in terms of both environmental sustainability and structural stability, according to research on the environmental effects of building construction [13]. For soil stabilization, utilized lime and rice husk ash generated a significant increase in strength and enhanced other geotechnical characteristics of the stabilized soils [14]. Palanisamy and Kumar [17] focused on replacing river sand used to make unburned bricks with quarry dust and more sandy soil sieved from the site's raw earth supply.

However, technology became more environmentally friendly because of the waste incorporation such as GGBS and SBA, which decreased the weight of the blocks. Industrial trash can also fill up spaces involving dirt granules and tends to make the soil-waste mixture homogeneous, which helps cement hydrate. The soil particles continue to enclose these hydrated materials, considerably improving the soil-cement matrix's ability to connect, this tends to increase the strength of the waste-added blocks [18–25].

This research aims to relate various mix compositions to expected strength for CSEB at 21 days curing in both dry and wet condition. 8 different mix compositions were studied in the present investigation by varying percentage of SBA and RHA ranging from 15 to 30%. The most suitable composition was obtained based on compressive strength and water absorption. Also, with compressed stabilized earth blocks the fast construction of buildings can be done. So, it is very useful in rebuilding houses during natural disasters (Figures 1 and 2).

Figure 1. Soil extraction.

Figure 2. Soil extraction.

METHOD AND MATERIAL

Materials

As seen in Figure 1, the soil for this experiment was gathered from a borrow portion of the Samrudhi Expressway near the bank of the Godavari River, at a depth of 0.40 to 0.80 meters below the surface of the land. Table 1 lists the physical characteristics of the soil used to make CSEB blocks [26, 27].

Table 1. Properties of soil [28].

Properties of Soil	**Grain Size Distribution**			**Atterberg's Limits**			**Optimum Moisture Content**
	Gravel	***Sand***	***Silt & Clay***	***LL***	***PL***	***PI***	
Test result (%)	4.72	21.96	73.32	31	15	16	12

LL- Liquid Limit, PL-Plastic Limit, PI- Plasticity Index

As a stabilizing agent, ordinary Portland cement of grade 53 was utilized. The physical characteristics of cement that were examined in a lab are shown in Table 2.

Table 2. Properties of cement [28].

Description	Fineness of Cement	Standard Consistency	Soundness (Le-Chatelier App.)	Initial Setting Time	Final Setting Time	Compressive Strength	
						@3 days	*@7 days*
Result	2.33%	28.50 %	2.31 mm	115 minutes	385 minutes	30.50 MPa	43.33 MPa

The Sanjivani Sugar Factory in Kopargaon provided the SBA, while one of the brick factory Nagpur provided the RHA and JSW Cement Ltd., Pune provided the GGBS. Table 3 lists the characteristics of soil, SBA, RHA, and GGBS. However, the particle size distribution is comparable to that of soil. It is noticed that the GGBS has very small particles whereas SBA and RHA contain coarser particles.

Table 3. Properties of soil, SBA, RHA and GGBS [28].

S.N.	Properties	Soil	SBA	RHA	GGBS
1	Color	Muddy	Grey	White	White
2	Loose bulk density	1500 kg/m^3	510 kg/m^3	600 kg/m^3	1031 kg/m^3
3	Compact bulk density	1740 kg/m^3	677 kg/m^3	775 kg/m^3	1615 kg/m^3
4	Fineness modulus	2.8	2.16	1.38	0.49
5	Specific gravity	2.52	0.49	1.80	2.90

Mix Composition

The soil sample was dispersed before being sieved to a size that could pass through a 4.75 mm IS sieve. The literature review reveals that 8% of cement results in a good strength for the CSEB block [27] which was proved after taking different trials of cement percentage with soil. Therefore, the amount of cement used in the current study was kept constant at 8% by weight. Similarly, as per previous research, the amount of GGBS is maintain at 15% which gives the CSEB good strength [28]. To study the highest cement-waste reactivity possible, proportion of RHA and SBA were selected in such a way that the combination of soil and RHA or SBA confirming to grading zone -II as per IS 383. The different mixes prepared with different combinations is as shown in Table 4 [29]. Based on numerous tests, the ideal water content needed to cast a good block was determined to be 13% while maintaining the ideal pressure of 17 kg/cm2.

Table 4. Mix composition for making CSEB blocks with SBA and RHA.

		SBA				RHA			
IS Sieve Size, mm	*Grading Zone -II*	*Mix1*	*Mix2*	*Mix3*	*Mix4*	*Mix1*	*Mix2*	*Mix3*	*Mix4*
10	100	100	100	100	100	100	100	100	100
4.75	90--100	86.9	87.36	87.7	93.7	87.34	87.82	88.3	88.78
2.36	75--100	80.6	81.22	81.8	91.7	81.12	81.9	82.6	83.45
1.18	55--90	66.6	67.52	68.4	83.7	67.63	68.88	70.12	71.37
0.600	35--59	48.6	49.80	50.9	71.8	50.84	52.72	54.6	56.48
0.300	30--8	30.5	31.00	31.4	45.2	34.53	36.34	38.15	39.96
0.150	0--10	13.7	13.56	13.4	14.0	15.52	15.96	16.4	16.84
0.075	--	6.18	5.94	5.70	2.59	6.465	6.32	6.175	6.03

Mix 1: 85% Soil + 15 % SBA or RHA, Mix 2: 80% Soil + 20 % SBA or RHA, Mix 3: 75% Soil + 25 % SBA or RHA, Mix4: 70% Soi l+ 30 % SBA or RHA

To create a uniform mixture, dry elements such as soil, GGBS, cement, and RHA or SBA were mixed in a metal tray. The necessary amount of potable water was then sprayed onto this mixture, and it was repeatedly turned over until all the water was added. Making a good intact ball that didn't stick to the hand from early experiments helped determine how much water is needed to get a good quality block. Until every particle is evenly wetted, the process is repeated. The materials were then placed in a mold using a surface area of 190 mm by 90 mm and a depth of 160 mm without being compacted. The mold was then put in a compression machine, and constant pressure of 17 kg/cm^2 was applied, as seen in Figure 3. The specimen's depth was kept at 90mm after 1.5 minutes of applying the necessary pressure. As seen in Figure 4, wet curing was carried out on the specimens after demolding by covering them with plastic sheets and letting them sit at room temperature for 21 days. This technique can stop a moisture loss of 1% to 3% before a test to ensure in the soil stabilization system, there is a pozzolanic reaction.

RESULT AND CONVERSATION

Mix Composition

As grading of particle size plays important role to reduce voids in sample. As per IS 383 grading zone II gives good contribution of materials to achieve optimum strength. So, SBA and RHA will be selected in different proportions as shown in Table 4. Figures 5 and 6 show the grain size distribution of all the mix compositions of SBA and RHA. It is observed that for the Mix 4 grading falls outside the percentage limits of zone II. Figure 7 represents the particle size distribution of Mix 2, both for RHA and SBA which is falling with in the grading zone II. Mix 1 and mix 2 shows good strength as particle size distribution is in grading zone - II. Mix 4 gives less strength than remaining mixes as this mix contains more fines means more voids and hence required more water which ultimately reduced the strength of CSEB blocks.

Figure 3. Hand operated press machine [28].

Figure 4. Curing of blocks.

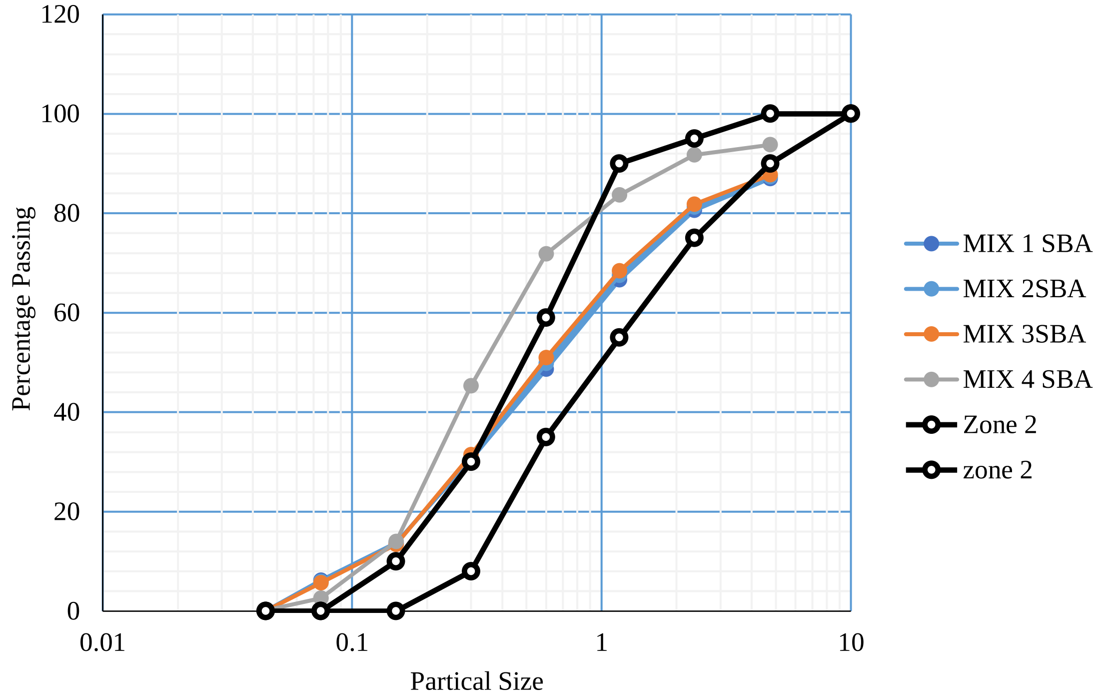

Figure 5. Grain size distribution of different SBA Mix compositions.

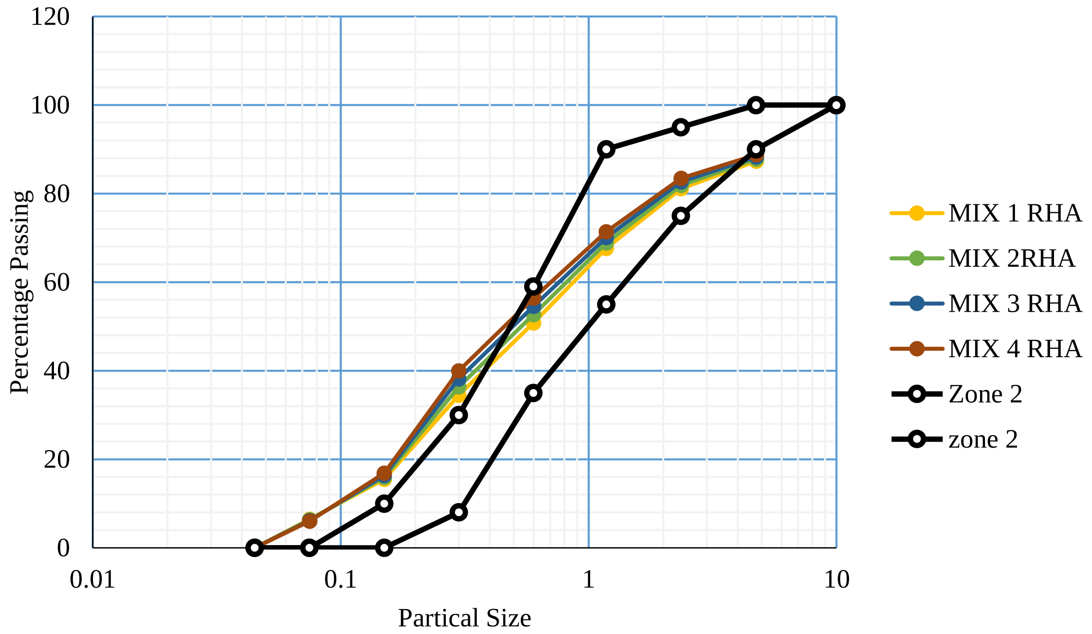

Figure 6. Grain size distribution of different RHA Mix compositions.

Water Absorption and Bulk Density

After 21 days of moist curing, 5 samples of each composition were tested for water absorption comparable to that of standard bricks [23, 24]. Figures 7 and 8 display the performance of CSEB blocks for each of the eight mixes and includes a comparison to locally available bricks. The greatest amount of water that can be absorbed by CSEB blocks using RHA is up to 16%, while using SBA, the maximum amount of water that can be absorbed is up to 16.80%, which is less than the maximum amount of water that can be absorbed by conventional bricks (up to 19.35%). While for mix 4 it is 19.01% for SBA and 18.90% for RHA which is not suitable according to IS requirements for blocks. So, the best suitable results are obtained through Mix 1 and Mix 2 as the water absorption is below 15% [24].

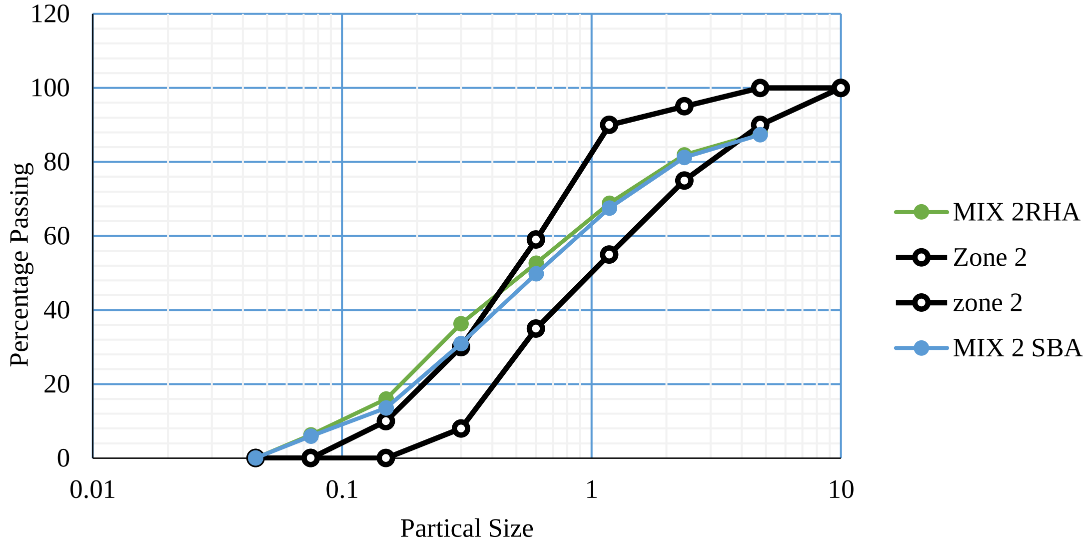

Figure 7. Grain size distribution of Mix 2 SBA and RHA Mix compositions.

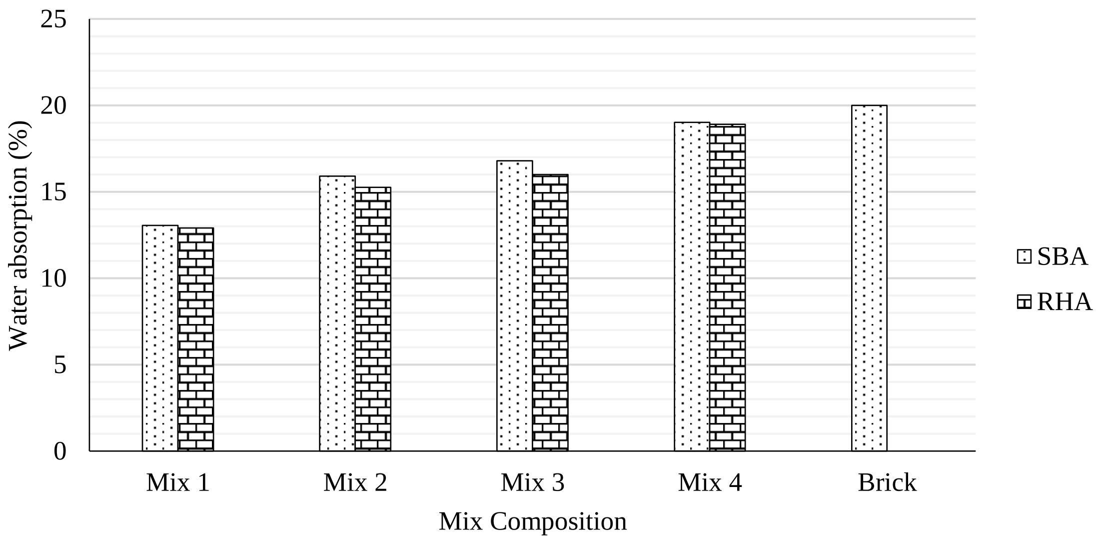

Figure 8. Influence of RHA and SBA added along with soil in CSEB.

The performance of CSEB blocks for each of the eight mixtures is shown in Figure 9, along with a comparison to locally accessible bricks. Most researchers discovered that compressed stabilized earth blocks typically had densities between 1500 and 2000 kg/m^3. In the present investigation, results show density of CESB is in the range of 1400 to 1700 kg/m$^{3.}$ And, if compared with the conventional brick the density of CSEB is nearly same.

Compressive Strength

The most widely used metric for assessing the quality of bricks is the compressive strength. However, it is closely tied to the soil type and stabilizer content. The universal testing device was used to evaluate the blocks' strengths. Figure 10 shows the compressive strength of soil, cement, GGBS, and waste mix

CSEB specimens for various mix compositions. It is noted that the maximum dry compressive strength is achieved with lower percentage of SBA and RHA. But as the percentage of waste increases blocks become light weight but with reduction in strength. For the mix 2 and mix 1 the compressive strength is above 5 N/mm^2 and mix 3 and mix 4 is below 5 N/mm^2.

After determining the results of a water absorption test for moist curing for 21 days, the wet compressive strength of the soil, cement, GGBS, and waste mix CSEB specimens was evaluated. Figure 11 illustrates how the mix composition affects the CSEB's compressive strength while maintaining an 8% cement content and 15% GGBS when wet. The reduction in strength after immersing in water is up to 30%.

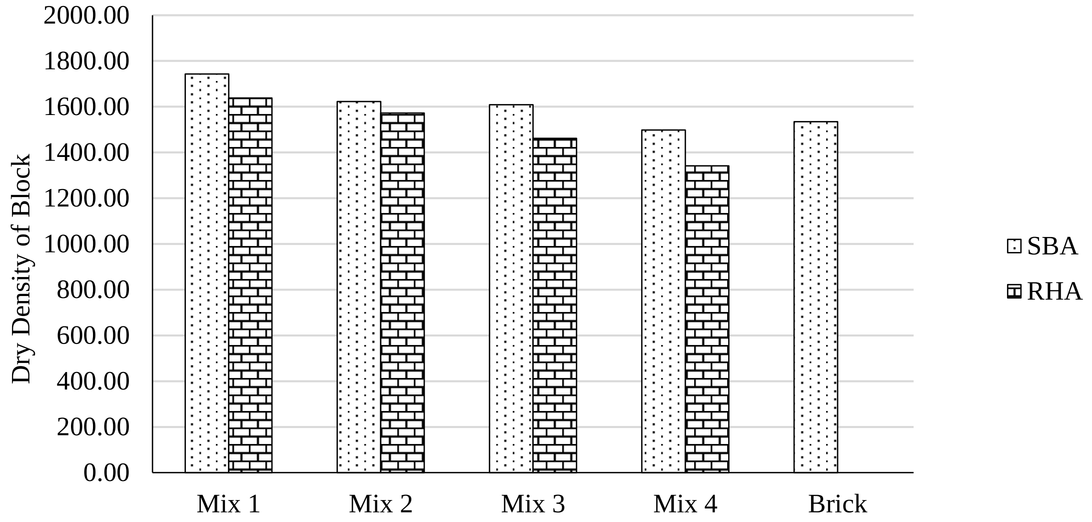

Figure 9. Influence of waste addition on density of CSEB Blocks.

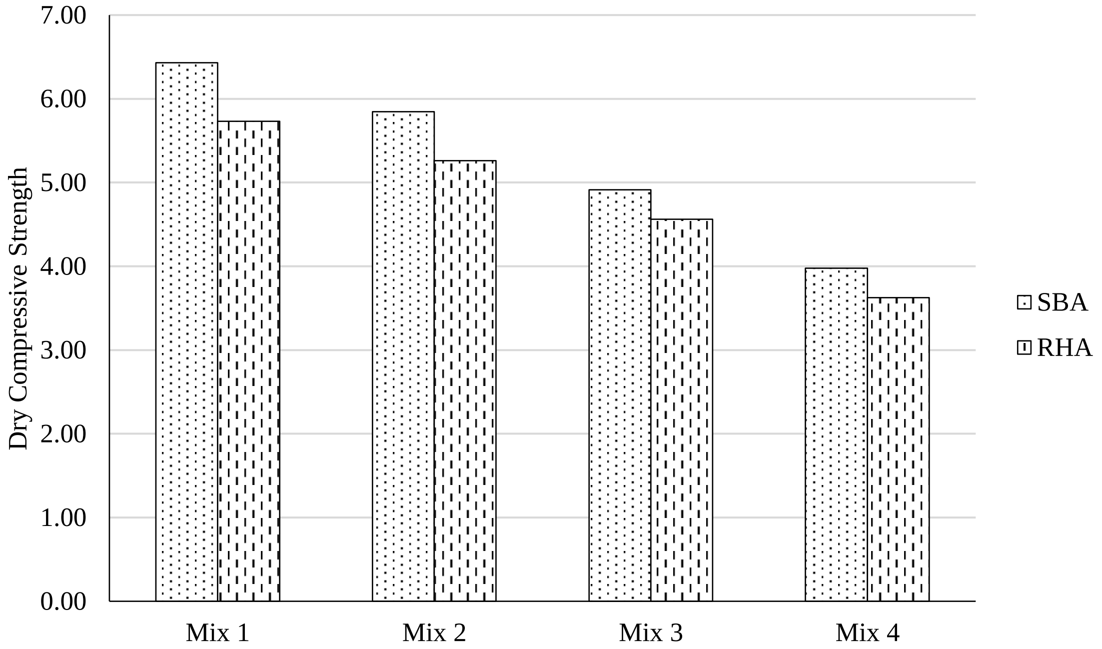

Figure 10. Influence of different mixes on dry compressive strength of CSEB.

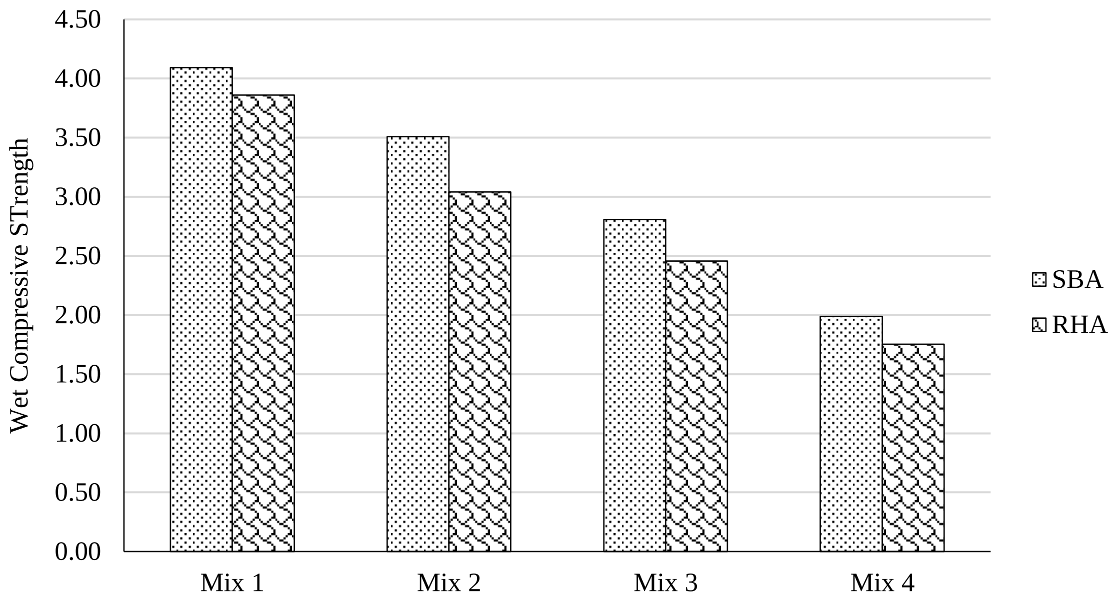

Figure 11. Influence of different mixes on wet compressive strength of CSEB.

CONCLUSION

To produce satisfactory CSEBs with soil, this study was done to determine whether readily accessible sugarcane bagasse ash (SBA) and rice husk ash (RHA), coupled with 8% cement and 15% GGBS, were suitable. The following conclusions are made considering the numerous experiments carried out for this study:

- The results obtained from various mixes coming under in grading zone II shows more suitable and achieved high strength.
- By increasing the ratio of SBA and RHA, the compressed stabilized earth block's capacity to absorb water was decreased. The compressed-stabilized earth block satisfies the Indian Standard's code criteria for earth block manufacture.
- The wet compressive strength specimen is typically 30% weaker than the standard (dry) specimen.
- These CSEB are economic and environmentally friendly as the percentage of CO_2 emission is 95% less than the conventional bricks and the natural resources are also preserved with the use of waste.
- These CSEB also helps to reserve the natural resources as wastes are added and water requirement is just 12% and for bricks water requirement is about 50%.
- Hence it is concluded that among the CSEB mixes considered in this research, the CSEB with a mix composition of 20% SBA or RHA provided the best compressive strength, and the block become lightweight along with less water absorption capacity.

A promising option for an economical eco-friendly building material is the SBA and RHA composite CSEB also as the less time required for construction it comes under smart construction with less pollution.

Limitations of Study

The pressure applied is limited as the machine hand operated good results can be produced with hydraulic compressor.

The study may not have provided sufficient data on the long-term durability and performance of the CSEBs. Future research should involve extended exposure testing to various environmental conditions to assess how these blocks withstand weathering, erosion, and other factors over time. The characteristics of SBA and RHA can vary depending on their sources and production methods. The study might not have explored the potential variability in these waste materials, which could impact the consistency of CSEB properties. The study primarily focused on compressive strength, but other mechanical properties, such as tensile strength, flexural strength, and shear strength, are equally important for assessing the overall performance of CSEBs.

Future Scope of Research

Compressive strength may increase if the compacting force is increased. So further work can be extended for different pressure. Future research should involve extended exposure testing to various environmental conditions to assess how these blocks withstand weathering, erosion, and other factors over time. Further investigations into the quality control of these materials are crucial. Future studies could explore these aspects to provide a comprehensive evaluation.

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