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Research Article

Cement Stabilized Soil Blocks Admixed with Sugarcane Bagasse Ash

Jijo James, P. Kasinatha Pandian, K. Deepika, J. Manikanda Venkatesh, V. Manikandan, and P. Manikumaran

Civil Engineering, Tagore Engineering College, Chennai 600 127, India

Correspondence should be addressed to Jijo James; jijothegreat@gmail.com

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The study involved investigating the performance of ordinary Portland cement (OPC) stabilized soil blocks amended with sugarcane bagasse ash (SBA). Locally available soil was tested for its properties and characterized as clay of medium plasticity. This soil was stabilized using 4% and 10% OPC for manufacture of blocks of size 19 cm × 9 cm × 9 cm. The blocks were admixed with 4%, 6%, and 8% SBA by weight of dry soil during casting, with plain OPC stabilized blocks acting as control. All blocks were cast to one target density and water content followed by moist curing for a period of 28 days. They were then subjected to compressive strength, water absorption, and efflorescence tests in accordance with Bureau of Indian standards (BIS) specifications. The results of the tests indicated that OPC stabilization resulted in blocks that met the specifications of BIS. Addition of SBA increased the compressive strength of the blocks and slightly increased the water absorption but still met the standard requirement of BIS code. It is concluded that addition of SBA to OPC in stabilized block manufacture was capable of producing stabilized blocks at reduced OPC content that met the minimum required standards.

1. Introduction

Soil has been one of the primary components of construction since ancient times, finding applications in a variety of forms like mud plaster, adobe blocks, and rammed earth to name a few. With the development of technology, fired brick came into existence which improved the performance of soil and made them more water resistant and durable. Other forms of soil utilization slowly faded into oblivion due to their inability to resist damage due to water ingress in moist environments. Thus, fired bricks have been the primary building material for construction for a long time. However, in the recent years there has been a shift away from the utilization of fired bricks towards eco-friendly building materials. Utilization of waste based construction materials like flyash bricks has become one of the popular choices. However, in developing countries like India, where there is a need for low cost building materials for housing, earth construction is one of the best alternatives. Housing is one of the basic needs of all human beings, particularly for the economically weaker section and low income groups who cannot easily afford the cost of construction. With the housing requirements in developing countries touching unmanageable proportions, various governments are taking conscious efforts to bridge the gap, especially undertaking housing schemes to ensure housing for the poor. The current housing shortage in India is 6 crore units, which will jump to 11 crore units in 2022 requiring an investment of US$250–260 billion [1]. Due to inadequate resources in developing countries, cost reduction seems to be the best way forward, especially in housing for the economically weaker section. This can be achieved by innovating, manufacturing, and utilizing low cost but durable construction materials from locally available resources. Traditional earth construction techniques such as compressed earth blocks are experiencing a new popularity, taking into account that they constitute green building materials, becoming economically competitive [2]. This is because of the utility of locally available soils in the manufacture of such blocks and lower energy consumption coupled with a comparatively easy manufacturing process that make them an attractive building material. The advantages of compressed earth block construction include easy availability of material, economy,

ease of use, fire resistance, beneficial climatic performance, and low energy consumption whereas its limitations include low durability, low tensile strength, low impact resistance, low abrasion resistance, and low acceptability [3]. One of the major advantages of compressed earth blocks is their low energy consumption. Typical cement stabilized earth blocks require less than 10% of the energy required for manufacture of similar fired clay bricks and concrete masonry units [4]. An earth block or a soil block is a construction or masonry unit of regular dimensions made from soil. It is called a compressed earth block when wet or damp soil is pressed at a high pressure to form the block whereas it is called a compressed stabilized earth block wherein any binder is used for the stabilization of the soil used in the manufacture of the block. A lot of materials have been used for stabilization of soil including cement, lime, flyash, gypsum, and bitumen. Traditionally animal dung, ant hill material, bird droppings, plant extracts, and animal blood have been used for manufacture of compressed stabilized earth blocks whereas chopped straw, grasses, and organic fibres have been used as reinforcement material [3]. Ordinary Portland Cement (OPC) is one of the most common stabilizers used for soil stabilization [5, 6]. However, it is well-known fact that manufacture of OPC contributes to a lot of CO_2 emissions which cannot augur well for a low cost green material. Earlier research in the manufacture of stabilized soil blocks have mostly concentrated on cement and lime stabilization of blocks. Walker [4] studied the strength, durability, and shrinkage characteristics of cement stabilized soil blocks and tried to establish empirical guidelines for cement content required for a wide range of soils. Nagaraj et al. [7] investigated the effect of combination of lime and cement on the long-term durability of compressed stabilized earth blocks. Villamizar et al. [2] investigated coal ash stabilized earth blocks and the effect of addition of cassava peels on their strength and performance. Degirmenci [8] studied the performance of phosphogypsum stabilized adobe blocks and compared its performance with blocks stabilized with natural gypsum. Ajam et al. [9] studied the valorisation of Tunisian phosphogypsum in clay bricks. Bharath et al. [10] probed the performance of stabilized adobe blocks with cement and lime and their combinations. Guettala et al. [11] examined the durability of lime stabilized earth blocks. Guettala et al. [12], in a later study, investigated the performance of stabilized earth concrete in both laboratory and field conditions. Galán-Marín et al. [13] undertook an investigation into compressive and flexural strength of alginate stabilized clay reinforced with sheep's wool, cast in the form of cubes and prisms. Hossain [14] investigated stabilized soil incorporating rice husk ash and cement kiln dust which he concluded as suitable for manufacture of building blocks for low cost houses. Achenza and Fenu [15] explored the potential of stabilized earth blocks using natural polymers like beetroot and tomato residues and reinforced with seaweed fibres. Maskell et al. [16] adopted cement and lime stabilization methods in the manufacture of extruded earth masonry for evaluating their suitability. Ciancio et al. [17] researched the identification of optimum lime content for lime stabilized rammed earth and quick methods for identifying the optimum lime content. Miqueleiz et al. [18] utilized alumina filler waste as replacement for clay in unfired bricks. Vijayaraghavan et al. [19] investigated stabilized mud bricks with cement and combinations of cement with slag and cement with quarry waste. Okafor and Ewa [20] investigated the compressive strength prediction of Obudu earth blocks stabilized with cement kiln dust. Thus, it can be seen that cement has become an indispensable part of manufacture of stabilized earth blocks in most of the cases with lime being another major material. In recent times, there has been utilization of solid wastes in stabilized earth blocks as well but very few have come close to cement in terms of performance. But the utilization of cement can certainly be offset by adopting combinations of cement with other waste materials which has been the thrust area in compressed stabilized earth blocks research in recent times. In this study, an attempt has been made to adopt sugarcane bagasse ash (SBA) as an additive to cement in stabilized earth blocks to improve their performance. Earlier works involving the combinations of lime, cement, and SBA have also been recorded. Alavéz-Ramírez et al. [21] investigated the combination of lime and SBA to improve the durability and mechanical properties of compacted soil blocks. Lima et al. [22] analysed the mechanical properties of cement stabilized compressed earth block masonry with SBA as additive. Onchiri et al. [23] studied the use of SBA as a partial replacement for cement in manufacture of self-interlocking earth blocks. Salim et al. [24] examined the performance of SBA as a standalone stabilizer in the stabilization of compressed earth blocks made from sandy loam soil. Singh and Kumar [25] probed the potential of SBA as a replacement for sand in cement mortar to produce light weight bricks. Madurwar et al. [26] explored the potential of SBA as raw material for brick manufacture with lime and quarry dust. Kulkarni et al. [27] researched the effectiveness of SBA as a replacement for flyash and lime separately in lime-flyash bricks. Khobklang et al. [28] delved into the effect of SBA on the water absorption and compressive strength of cement stabilized lateritic soil-sand interlocking blocks. Greepala and Parichartpreecha [29] compared the performance of flyash, rice husk ash, and SBA as replacement materials on the performance of lateritic soil-cement interlocking blocks. The primary objective of this study is to analyse the performance of cement stabilized earth blocks admixed with SBA in terms of compressive strength, water absorption, and efflorescence.

2. Materials and Methods

The materials adopted in the manufacture of the compressed stabilized earth blocks include the locally available soil, cement, and SBA. The soil adopted in the study was collected from a lake shore in Kolathur village, Kanchipuram district, Tamil Nadu, India. The geotechnical properties of the soil were tested in the laboratory in accordance with the Bureau of Indian Standards (BIS) codes and are tabulated in Table 1.

The cement adopted in the stabilization of the soil for the manufacture of compressed stabilized block is OPC. The typical composition of OPC is given in Table 2.

Table 1: Properties of soil.

Property	Value
Liquid limit [41]	41.8%
Plastic limit [41]	14.5%
Plasticity index	27.3%
Shrinkage limit [42]	10.1%
Maximum dry density [43]	18.5 kN/m^3
Optimum moisture content [43]	11.9%
Unconfined compressive strength [44]	523.4 kPa
BIS classification [45]	CI

Figure 1: Steel moulds adopted for moulding of stabilized blocks.

2.1. Sugarcane Bagasse Ash (SBA). India is one of the largest growers of sugarcane. The major solid wastes generated from the sugar manufacturing process include sugarcane trash, bagasse, press mud, bagasse flyash, and spent wash [30–32]. Bagasse is the fibrous remains of the cane after extraction of sugarcane juice. In many industries, bagasse is used as fuel resulting in the generation of ash called SBA. SBA is one of the wastes of economic importance generated from the sugar industry, as it has lots of potential uses. SBA has been used in the manufacture of low cost adsorbents [30], in ceramics [33], in biomass ash filters [34], in concrete [35, 36], in soil stabilization [37–40], and recently in stabilized earth blocks [21–29]. SBA adopted in the study was obtained from Tiruttani Sugar Mills Pvt. Ltd., Arakkonam district, Tamil Nadu, India. The chemical composition of SBA adopted in the study is given in Table 2.

2.2. Methods. The series of steps involved in going into the investigation involved preparation and characterization of materials, selection of block size and mould fabrication, selection of stabilizer and additive content, casting and curing of blocks, and experimental investigation.

2.2.1. Preparation and Characterization of Materials. The preparation of soil was carried out in accordance with BIS code [47]. OPC was used as available out of the bag obtained from the manufacturer. The SBA obtained from the sugar mill was sieved through 300-micron BIS sieve to enable better reactivity with cement used for stabilization. The soil adopted in the study was tested for its geotechnical properties and classified accordingly. SBA was subjected to X-ray fluorescence test to determine its chemical composition.

2.2.2. Selection of Block Size and Mould Fabrication. BIS code [48] suggests three sizes for cement stabilized soil blocks with dimensions 19 × 9 × 9, 19 × 9 × 4, and 29 × 19 × 9, all dimensions being in cm. The block dimension adopted in this study was 19 cm × 9 cm × 9 cm. Based on the selected block size, two identical steel moulds were fabricated and used for moulding of the blocks. Figure 1 shows the fabricated moulds adopted in the study.

2.2.3. Selection of Stabilizer and Additive Content. There are three types of cement stabilized materials, namely, soil cement, cement bound material, and lean concrete. Soil cement contains less than 5% cement; cement bound material is stronger soil cement but with granular aggregate while lean concrete contains higher cement content than cement bound material [49]. Walker [4] recommends a minimum cement content of 7% and 10% for achieving a characteristic compressive strength of 1 MPa and 2 MPa, respectively. He also states that soils with plasticity index greater than 20–25% are not suitable for cement stabilized soil blocks using manual presses. Adam and Agib [3] recommend cement contents in the range of 5.56% to 8.33% based on the linear shrinkage of the soil. In this study, two trial cement contents were adopted, one in the classification of soil cement while the other in the classification of lean concrete (since no additional granular materials were used in the manufacture of blocks). The SBA contents were adopted on a trial and error basis.

2.2.4. Casting and Curing of Blocks. The methodology adopted in casting of soil blocks was similar to that of preparing unconfined compression cylinders for testing soil specimens, the difference being that the sample was cast in the mould prepared for blocks. The soil blocks were cast to a fixed density of 18.5 kN/m^3 and a moisture content of 12%. The mould was prepared by thoroughly tightening all the bolts and the interior was lubricated with oil for easy removal of the pressed block. The weights of soil, cement, and SBA were carefully measured and mixed in dry conditions thoroughly. The required content of water was measured, added to the mixture, and thoroughly mixed to get an even wet mix. The wet mix was then placed in the mould, and followed by the top plate and a compression test ram was used to press the top plate. The mould was so designed that the top plate cannot be lowered below the fixed dimensions of the block. Completely pressing the entire mix in the mould resulted in achieving more or less uniform density of blocks for testing. After the formation of the block, the mould was opened and the block was removed and was moisture-cured for a period of 28 days by sprinkling of water and covering with plastic gunny bags to prevent loss of moisture. Figure 2 shows the preparation of cement stabilized blocks.

2.2.5. Experimental Investigation. BIS code [48] recommends that a stabilized soil block should meet the compressive strength, water absorption, and weathering resistance requirements. In this investigation, the stabilized soil blocks were subject to compressive strength, water absorption, and

Table 2: Chemical composition of OPC [46] and SBA.

(%) of →	SiO_2	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	Na_2O	P_2O_5	TiO_2	SO_3
OPC	21.45	4.45	63.81	3.07	0.83	2.42	0.20	0.11	0.22	2.46
SBA	35.17	0.281	2.07	5.22	3.75	0.91	0.01	1.03	0.02	0.03

Figure 2: Graphical description of casting and curing of stabilized earth blocks.

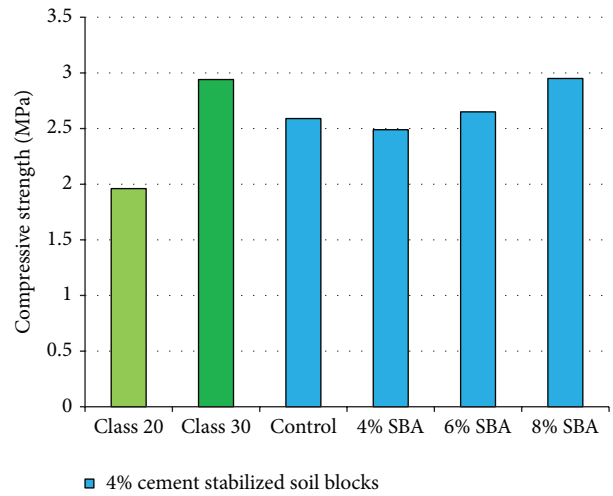

Figure 3: Compressive strength of 4% cement stabilized soil blocks admixed with SBA.

one other test usually performed for burnt bricks, namely, efflorescence test. All the three tests were done in accordance with BIS specifications [50]. Three blocks were tested for each and every combination and the average was taken as the result for the particular combination for a particular test.

3. Results and Discussion

The cement contents of 4% (soil cement) and 10% (lean concrete) were adopted for stabilization of soil blocks. Three SBA contents were randomly adopted as 4%, 6%, and 8%. In an earlier study, Lima et al. [22] had adopted combinations of 6% and 12% cement with 2%, 4%, and 8% SBA. Both the cement contents adopted in that study were above 5% which may be due to the fact that the soil adopted by them was a granular soil, thereby making their block fall in the category of cement bound material. Greepala and Parichartpreecha [29] adopted cement contents in the range of 7.14%–14.28% (calculated from reported mix proportions) and added sand to the soil (1 : 1 mix) before casting of stabilized bocks with SBA. Moreover, Walker [4] states that cement content more than 10% makes it uneconomical but also adds that cement content less than 5% makes the blocks too friable while handling.

3.1. Compressive Strength of Stabilized Blocks. The compression test on the stabilized soil blocks was done in accordance with BIS code specifications. Figure 3 shows the compressive strength of 4% cement stabilized blocks admixed with SBA. According to BIS specification [48] for cement stabilized blocks, there are two classes of blocks, class 20 and class 30 with minimum permissible standard strength of 1.96 MPa (20 kgf/cm^2) and 2.94 MPa (30 kgf/cm^2), respectively. The figure includes the compressive strengths of the two classes of blocks as well for comparison.

It can be seen that addition of SBA results in increase in strength of the stabilized soil block with the exception of 4% addition of SBA wherein there is a marginal decrease. In contrast, Khobklang et al. [28] found that increasing SBA content addition to cement stabilized lateritic soil with sand resulted in a decreasing strength at 28 days of curing. But the same trends were not exhibited at 90 days of curing. The strength of 4% SBA admixed 4% cement stabilized block develops a strength of 2.49 MPa, which is marginally lesser than the strength of control specimen at 2.59 MPa. The strength of the block steadily increases from thereon with increase in SBA content and reaches a maximum of 2.95 MPa for 8% SBA addition. It can be seen that the control specimen and 4% and 6% SBA admixed specimens were comfortably meeting the requirement of class 20 block according to BIS standards. While 8% addition of SBA results in the strength just reaching the strength of class 30 blocks. Hence it can be fairly concluded that 8% addition of SBA results in raising 4% cement stabilized block from class 20 to class 30. Onchiri et al. [23] reported a similar optimal strength of 3.03 MPa with a cement content of 4.8% but at a lower SBA content of 3.2%. However, the soil adopted by them was a red soil with lesser plasticity.

Figure 4 shows the compressive strength of 10% cement stabilized soil blocks admixed with SBA. It can be seen that

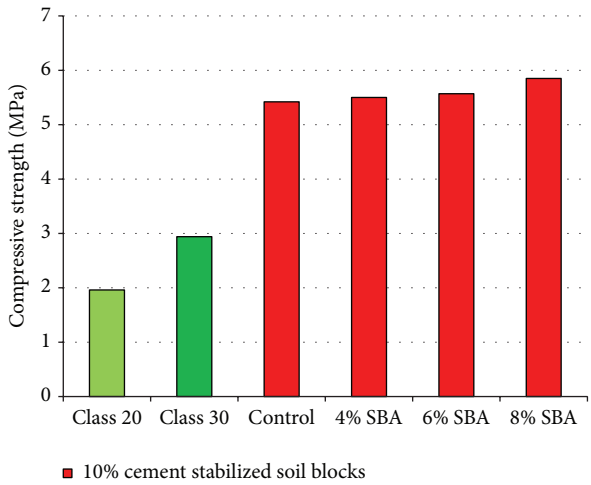

Figure 4: Compressive strength of 10% cement stabilized soil blocks admixed with SBA.

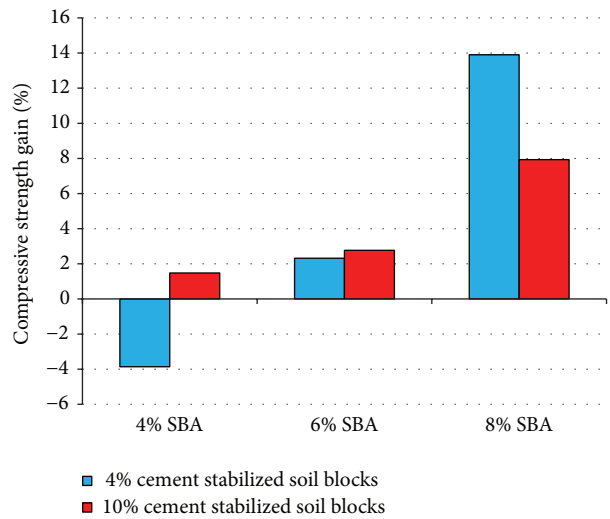

Figure 5: Percentage of compressive strength gain with %SBA.

addition of SBA in the case of 10% cement stabilized blocks results in a steady increase in compressive strength of the stabilized blocks. The compressive strength of 10% cement stabilized block steadily increases from 5.42 MPa to 5.85 MPa for 8% addition of SBA. It is clearly evident that all combinations including the control specimen comfortably meet the strength requirement of class 30 blocks. All the blocks are at least 2.5 MPa stronger than the minimum standard requirement. Khobklang et al. [28] reported strengths of 7.68 MPa and 7.66 MPa at 28 days of curing for two different water/binder ratios adopted in making of their cement stabilized lateritic soil-sand interlocking blocks with SBA. These blocks had a cement to SBA ratio of 15%. The reported strength values are comparatively higher with respect to the present study. However, it needs to be mentioned that the calculated cement contents from the mix proportions were slightly higher than those in the present study. Moreover, sand was used as aggregate along with soil (1 : 1 mix) in manufacture of the blocks. Greepala and Parichartpreecha [29] reported compressive strengths as high as 11.7 MPa for a cement to SBA ratio of 10% for stabilized lateritic soil interlocking blocks with sand.

Figure 5 shows the percentage compressive strength gain of stabilized soil blocks with SBA content. It is clearly revealed that the percentage strength gain is higher due to addition of SBA at lower cement content. For 4% SBA addition to 4% cement stabilized blocks, there is strength loss of 3.86%, whereas on further increasing the SBA content there is strength gain of 2.32% and 13.9% for 4% and 8% SBA addition, respectively. In comparison, the addition of SBA to 10% cement stabilized soil blocks results in steady strength gains of 1.48%, 2.77%, and 7.93% for 4%, 6%, and 8% SBA additions, respectively. Moreover, addition of 8% SBA to 4% cement stabilized blocks raises the block strength to meet the minimum standard requirements of class 30 blocks, whereas 10% cement stabilized block does not require SBA addition to meet the criteria despite SBA addition giving strength benefit. Thus, 8% SBA addition can reduce cement content from 10% to 4% for manufacture of stabilized soil blocks that meets the standards. Considering factor of safety, a slightly higher cement content of 5% can be investigated with varying SBA contents to ensure thorough clearance of standards in future investigations. Salim et al. [24] reported a percentage strength gain as high as 65% for compressed earth block stabilized with 10% SBA alone. The huge difference in percent strength gain in comparison with the present study may be due to the fact that strength of cement stabilized block without SBA is used as control for calculation of percentage strength gain in the present study. In the work done by Salim et al. [24], percentage strength gains are based on strength of unstabilized soil block.

Earlier research adopting combinations of cement and SBA has been reported in the literature. However, two investigations in particular, done by Lima et al. [22] and Greepala and Parichartpreecha [29], were found to be similar to the present study in terms of stabilizer additive combination with enough data for making a comparison. The differences in the investigation done by Lima et al. [22] include a granular soil type, higher cement content, slightly different SBA contents, and slightly denser blocks. The differences in the work done by Greepala and Parichartpreecha [29] include the soil type (lateritic), use of sand as aggregate, varying cement and SBA contents, and slightly lighter blocks. Hence, in order to bring the results to a more comparable level, the authors have reduced the stabilizer content as a ratio between SBA and cement content and have plotted it versus the compressive strength adjusted for differences in unit weights of the blocks. The compressive strengths were adjusted for the target unit weight adopted in the present study which was in between that of values reported in the two works adopted for comparison. However, this comparison still does not account for the difference in soil type since according to Adam and Agib [3], the compressive strength of a stabilized block depends upon soil type, type and amount of stabilizer, and compaction pressure used to form the block. Figure 6 shows the comparison of the present study with

the works carried out by Lima et al. [22] and Greepala and Parichartpreecha [29]. A clear indication of the different levels of compressive strength can be arrived at from the figure. The strength obtained by 6% cement stabilized blocks of Lima et al. [22] develops the least strength; however, the addition of SBA generates a significant gain in strength of the stabilized blocks. Comparing it with the higher cement content in the same study, it can be seen that the addition of SBA does not raise the compressive strength above that of the control specimen. It should be noted that it was mentioned earlier in the percentage strength gain analysis that addition of SBA was more effective at lower cement content in the present study. The compressive strength of 12% cement stabilized blocks of Lima et al. [22] is at a comparable level to that of 4% cement stabilized block of the present study. However, it should be noted that a similar compressive strength is achieved by lower cement content of the present study at a stabilizer content ratio of 1.5, which is correspondingly achieved at a ratio of 0.67 for the higher cement content of Lima et al. [22]. Since there is no data available for higher ratios in work reported by Lima et al. [22], from the trend of the strength curve, the possibility of higher strength at higher ratios cannot be refuted. The 10% cement stabilized blocks in the present study produces higher compressive strengths compared to the combinations mentioned above. The addition of SBA still increases the strength of the stabilized earth blocks although not as high as compared to lower cement content of 4%. The work reported by Greepala and Parichartpreecha [29] develops the highest compressive strength. However, the increasing addition of SBA results in a drastic drop in the compressive strength. Despite the reduced compressive strength, it is still the strongest of all the blocks compared. The reduction in strength may be attributed to the reducing cement content in the mix as Greepala and Parichartpreecha [29] have adopted SBA as a replacement for cement in their study. Nevertheless, it may be possible that higher cement content adopted in the investigation may also be an added reason for reduced effectiveness of SBA. This can be inferred from the steep drop in strength till a stabilizer content ratio of 0.43 corresponding to a cement content of 10%. On further increase in SBA content and corresponding decrease in cement content, the slope of the curve flattens in comparison, indicating SBA to be effective at lower cement content. A complex combination of the two reasons may be responsible for the drastic reduction in strength with increased SBA content. The comparison reveals the effects of difference in soil types and addition of sand as aggregate. It also reinforces the fact that SBA is effective in raising the strength at lower cement content.

3.2. Water Absorption of Stabilized Blocks. The water absorption test in the present study was also done in accordance with BIS specification as in the case of compressive strength test. Figure 7 shows the water absorption of 4% cement stabilized soil blocks. The permissible limit for water absorption according to BIS specification of cement stabilized blocks is 15% which has also been included in the figure for comparison. It is evident from the figure that there is no big difference in the water absorption of the 4% cement stabilized blocks upon addition of SBA. The water absorption of the control specimen increases marginally from 6.59% to 6.89% on addition of 8% SBA, which is only a mere 0.3% increase in water absorption. Another important observation is that all the combinations are well within the permissible limit suggested by BIS code. In fact, water absorption of all combinations is less than half of the permissible limit stipulated in the code. Thus it can be seen that addition of SBA to 4% cement stabilized blocks is beneficial in increasing the compressive strength of the blocks with only a meagre increase in the water absorption levels. Singh and Kumar [25] also reported an increase in water absorption of cement mortar bricks with increasing SBA content. However Lima et al. [22] reported varying water absorption results after 14 days with SBA addition for the two cement contents investigated.

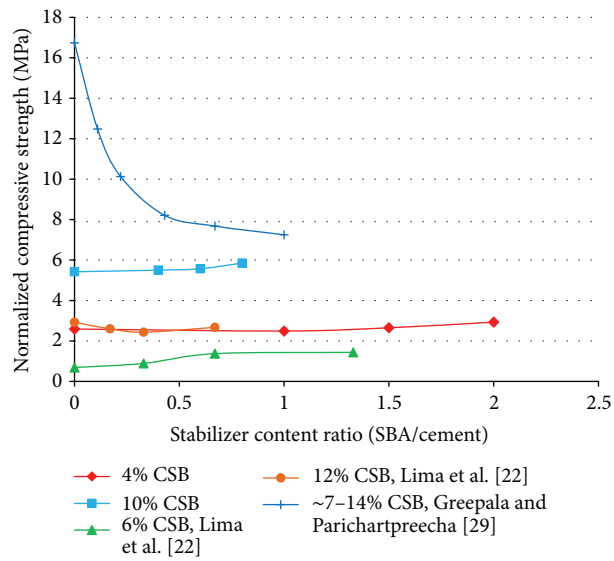

Figure 6: Comparison of compressive strength of present study with earlier works [22, 29].

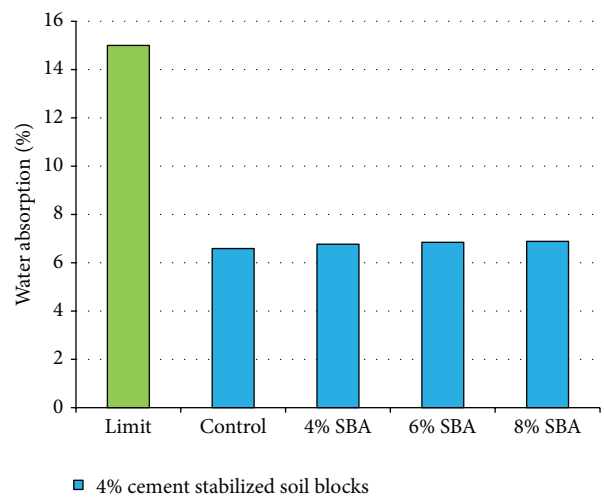

Figure 7: Water absorption levels of 4% cement stabilized blocks admixed with SBA.

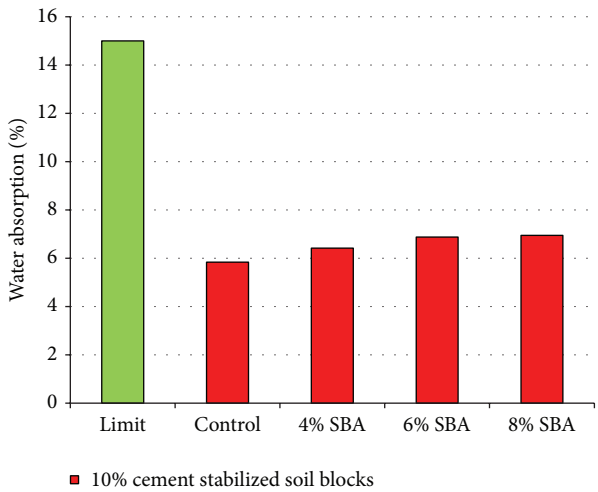

Figure 8: Water absorption levels of 10% cement stabilized blocks admixed with SBA.

Figure 8 shows the water absorption of 10% cement stabilized blocks admixed with SBA. It can be seen that, at higher cement content, the water absorption of the blocks is lesser. As in the case of 4% cement stabilized blocks, the addition of SBA results in increase in the water absorption. However, the increase in water absorption is much higher than the previous case. The water absorption increases from 5.84% for the control specimen to 6.95% for 8% SBA addition, which is an increase by more than 1%. However, all combinations are still below the permissible limits of water absorption, in reality, less than half of the permissible limit of 15%. Greepala and Parichartpreecha [29] also reported increasing water absorption with increasing SBA content, but they were within the 15% limit. Comparing the water absorptions of 4% cement stabilized soil block with 10% cement stabilized soil block, it can be seen that the increase in water absorption is 0.3% and 1.11%, respectively. This again reinforces the interpretation obtained from compressive strength results that addition of SBA is more beneficial at lower cement content when compared to higher cement content. Here again, SBA addition at higher cement content could not control water absorption the same way as it did at lower cement content. A comparison of water absorption test results with Lima et al. [22] and Greepala and Parichartpreecha [29] could not be done because their results reported water absorption after 14 days and 7 days, respectively, whereas in the present case, water absorption results are provided after 24 hours in accordance with BIS specification. The authors felt that normalization would not reflect accurate water absorption at 24 hours as the rate of absorption is usually higher initially and then decreases with progressing time.

3.3. Efflorescence of Stabilized Blocks. The efflorescence test on stabilized soil blocks was conducted in accordance with BIS specification [50]. Table 3 shows the results of efflorescence tests on the stabilized blocks. No efflorescence was detected on any of the combinations.

Table 3: Efflorescence of stabilized blocks.

Cement content (%)	SBA content (%)	Efflorescence
4	0	Nil
4	4	Nil
4	6	Nil
4	8	Nil
10	0	Nil
10	4	Nil
10	6	Nil
10	8	Nil

4. Conclusion

The study involved the utilization of combination of cement and SBA in the manufacture of stabilized soil blocks and gauges its performance with plain cement stabilized blocks as well as the minimum requirements stipulated by BIS code. Based on the results of the experimental investigation carried out, the following points can be concluded.

(i) Cement stabilization of locally available soil can be used in the manufacture of stabilized soil blocks to meet the compressive strength and water absorption norms of BIS specifications. Cement stabilization of soil at 4% cement content meets the specifications of class 20 blocks whereas cement stabilization of soil at 10% cement content meets the specifications of class 30 blocks.

(ii) Addition of SBA to cement in stabilization results in an increased compressive strength of the blocks. However, SBA addition is more effective at lower cement content of 4% producing higher strength gains when compared to higher cement content of 10%.

(iii) Addition of SBA to cement in stabilization results in an increase in the water absorption of the blocks but is still comfortably within the norms stipulated by BIS. However, the addition of SBA produces more water absorption at higher cement content of 10% than lower cement content of 4% for similar SBA contents, again reinforcing the inference that SBA addition is more effective at lower cement content.

(iv) Addition of 8% SBA to 4% cement content increases its compressive strength to meet the strength requirements of class 30 blocks from the original category of class 20 blocks. Thus it can be seen that addition of 8% SBA can result in utilization of just 4% cement for achieving class 30 block specifications. This leads to saving of 6% cement in comparison with the other combination adopted in this study.

(v) The compressive strength of 4% cement with 8% SBA is just enough to meet the class 30 block specifications. Hence, in order to achieve a higher safety margin, slightly higher contents of SBA and cement combinations can be investigated to arrive at optimum

combinations from the point of view of cost and performance.

(vi) The durability aspect of the cement stabilized blocks has not been investigated in this study. Hence, it is recommended that the durability aspect of cement stabilized blocks admixed with SBA should be taken up in future investigations.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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