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Performance of Compressed Stabilised Earth Blocks with Rice Husk Ash

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Authors' contributions

Author PA managed the literature searches, designed the experimental work, analysed the results and prepared the manuscript. Authors KJ, CMS, VV and EP assisted in carrying out the experimental works. All authors read and approved the final manuscript.

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ABSTRACT

This study investigated the feasibility of using Rice Husk Ash (RHA) as a partial replacement of cement in the stabilization of clay soil for the production of compressed earth blocks. Varying levels of percentage replacement of cement with rice husk ash in range of 0%, 2.5%, 5%, 7.5%, 10% and 12.5% was used. From the compressive strength test results, compressive strengths of 2.07 MPa, 1.64 MPa, 1.74 MPa, 1.90 MPa and 1.50 MPa were obtained for blocks admixed with 2.5%, 5%, 7.5%, 10% and 12.5% respectively. Water absorption was found to increase steadily with increase in percent of rice husk ash and value is 8.55% for the block with 12.5% RHA. Unit weight of blocks decreased with increase in percent of rice husk ash.

Keywords: Compressive strength; water absorption; blocks; rice husk ash; unit weight.

1. INTRODUCTION

Utilization of waste based construction materials likes fly ash bricks has become one of the popular choice. 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. Traditional earth construction techniques such as compressed

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earth blocks are experiencing a new popularity, taking into account that they constitute green building material. The advantages of compressed earth blocks construction include easy availability of material, economy, ease of use, fire resistance, low abrasion resistance, low energy consumption and low acceptability. Typical cement stabilized earth blocks require less than 5% of energy required for manufacture of similar fired clay bricks and concrete masonry units.

A soil block is a masonry unit of regular dimension made from soil. It is called a compressed soil block when wet or damp soil is pressed at a high pressure to form the block whereas it is called compressed stabilized soil block wherein any binder is used for the stabilization of soil including cement, lime, fly ash, etc. Stabilization of soil improves its strength.

OPC is one of the most common stabilizers used for soil stabilisation. In recent times, there has been utilisation of soild wastes in stabilized soil 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 combination of cement with other waste material 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 rice husk ash (RHA) as an additive to cement in stabilized earth blocks to improve their performance. The primary objective of this study is to analyze the performance of cement stabilized earth block admixed with RHA of size 19 cm x 9 cm x 9 cm in terms of compressive strength, water absorption, unit weight and efflorescence.

Cost comparison between cement stabilized soil block and cement stabilized soil blocks with rice husk ash. This will lead to reduction in the amount of cement required for stabilization and provision of more durable low-cost compressed soil blocks for masonry works accompanied with waste management.

2. LITERATURE REVIEW

Alabi et al. [1] conducted a study on use of RHA stabilized lateritic soil as sub-base in road construction. They concluded that the compaction characteristics of the natural lateritic soils were altered with the addition of RHA. Treatment with RHA showed a general decrease in the MDD and increase in OMC with increase in the RHA content. The Optimum RHA content was found at 2.5% for CBR tests for both soaked and unsoaked which indicate an improvement in the treated soil compared with the CBR of the natural soil. The UCS values were at their peak at 2.5% RHA. They recommended based on the study, up to 2.5% Rice Husk Ash (RHA) content can be recommended as suitable material for treatment of lateritic soil to improve its geotechnical properties (in places where they are abundant) before using it as subbase materials in road construction. It is also recommended that Rice Husk Ash (RHA) intended for use for field stabilization be burnt between the temperature of 600ºC and 700ºC.

Roy [2] conducted a study on soil stabilization using RHA and cement. She found out that soil can be stabilized by treatment with RHA and a small percentage of cement. It shows a general decrease in the MDD and increase in OMC with increase in the RHA content. There is also an improvement in the unsoaked CBR (106% at 5% RHA content) compared with the CBR of the natural soil. And also the UCS value isat its peak at 5% RHA (90.6% improved).For maximum improvement in strength, soil stabilization using 5% RHA content with 6% cement is recommended as optimum amount for practical purposes.

Baskaran et al.,[3] investigated the characteristics of paddy husk ash-lime stabilized soil bricks. They found out that the unstabilized brick sample exhibits compressive strength value of 0.9 N/mm2. But when admixed with lime and RHA combinations at varying percentages, considerable improvement can be seen in the compressive strength values. Specifically, the compressive strength was 4 N/mm2 at 12.2.5% Lime and 12.2.5% RHA combination. In general 5% lime and 2.5% of RHA combination (compressive strength of 3.9 N/mm^2) can be taken as the economical dosage to stabilize the soil bricks. Density of stabilized soil bricks are not very high (< 1900 kg/m^3) and within the range of normal fired clay bricks density (1300 – 2200 kg/m^3). This may be considered as an advantage, when the brick shave to be transported over long distances. In comparison with water absorption of different types of clay bricks available in Sri Lanka, lime- rice husk ash stabilized soil bricks exhibit low water absorption value.

Takhelmayum et al. [4] conducted an experimental study on the properties of cement concrete using rise husk ash. They conducted that there was a significant improvement in compressive strength of the concrete with rice husk ash content of 5% & 12.5 for M20 grade at different ages that is 7 days and 28 days. The study shows that the early strength of RHA concrete was found to be less and the strengthwith age. There is significant reduction of work ability in fresh concrete with increase amount of RHA content in cement. Due to the lower density of RHA concrete the self-weight of the structure gets reduced which results in overall savings. The addition of RHA for the concrete decreases the water absorption of concrete. The use of RHA in civil construction works will reduce environmental pollution, improve the quality of concrete and reduce its cost of production as well as solving the problem of agro waste management.

Shatat [5] compared the hydration behavior and mechanical properties of blended cement containing various amount of rice husk ash in presence of metakastolin. The main conclusion of this study could be summarized as follows: At the early ages of hydration rice husk ash acts as filler whereas at later ages it acts as pozzolana. Increasing rice husk ash content make a dilution effect, require higher water demands and forms a layer of rice husk ash particles around anhydrous cement grains which delays the hydration ofcement. Accordingly it is recommended to use the pozzolanic cement mix containing 75 wt% OPC, 20-15 wt% MK and 5-10 wt% RHA, respectively instead of OPC and control cement for general construction purpose. In addition, the utilization of RHA in construction purposes solves the problem of the disposal those keeping the environment free from pollution.

The potential and efficiency of using rice husk ash (RHA) to add up or partially replace Portland cement in deep cement mixing technique was examined by Jongpradist et al [6]. A series of unconfined compression tests on cement-RHA-stabilized clay are conducted to investigate the influence of RHA on the mixture properties. Special attention is paid to its efficiency for increasing the strength by partial cement replacement to obtain high-strength soil cement, and it is compared with fly ash. Test results indicate that up to 35% of RHA could be advantageously added up to enhance the strength if the cement content in the mixture is larger than 10%. The RHA enhances the strength of cement-admixed clay by larger than 100% at 28 days. For curing time of 14 and 28 days, the RHA exhibits higher efficiency on Portland cement replacement when the cement and overall cementitious contents are not less than 20 and 35%, respectively. The optimum condition for high-strength mixture is achieved when RHA is added to the 20% cement content mixture. When compared with fly ash of similar grain size, the efficiency of RHA is higher when the content to be added is greater than 15%. This indicates the suitability of RHA for use in high-strength soil-cement.

Ronoh [7] investigated the characteristics of earth blocks stabilized with RHA and cement. They found out that stabilization of soil with cement and RHA is a feasible construction technology because the compressive strength of stabilized blocks is higher than the strength of unstabilized blocks. However, when RHA is used as a partial replacement of cement, the optimum combination of cement and RHA is 2.5% and 7.5%, respectively. Nevertheless, it should be realized that stabilized blocks are generally not resistant to wetting and should be used in situations where there is minimum wetting. Use of RHA can reduce the cost of producing stabilized blocks by as much as 73%.

Various studies reported that the Cement-RHA treatment on different soil is effective method to reduce the cost of production of blocks and improve the strength properties of different soil blocks. Hence in this study, effect of locally available clay is to be treated with cement and rice husk ash and to be checked before utilizing as an eco friendly building construction material.

3. MATERIALS USED

The materials adopted in the manufacture of the compressed stabilized earth blocks include the locally available soil, sand, cement, and rice husk ash.

3.1 Soil

The soil used in this study was excavated from a construction site in Chennai, Tamilnadu. Thesoil was sundried to bring down the moisture content to12.5% and it was then powdered to a size less than 4.75 mm using mallet.

The geotechnical properties of the soil were tested in the laboratory in accordance with the Bureau of Indian Standards (BIS) codes. The engineering and index properties such as specific gravity, Atterberg's limits, compaction characteristics etc. of the particular soil selected for this study were determined in the laboratory. The soil used for the study is shown in Fig. 1 and its properties are given in Table 1.

Fig. 1. Soil used in the study

Table 1. Properties of soil

Property of soil	Value
Specific gravity	2.54
Soil classification	CH
Liquid limit (%)	60
Plastic limit (%)	21
Plasticity index (%)	39
Maximum dry density (g/cc)	1.79
Optimum moisture content (%)	12.5%
Natural water content (%)	22.5%

Fig. 2. Cement

Table 2. Chemical properties of cement

Chemical	OPC
SiO_2	21.45
Al_2O_3	4.45
CaO	63.81
Fe_2O_3	3.07
K_2O	0.83
MgO	2.42
Na_2O	0.20
P_2O_5	0.11
TiO_2	0.22
SO_3	2.46

3.2 Cement

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

3.3 Rice Husk Ash (RHA)

Rice Husk Ash is a pozzolan, which contains as much as 80-82.5% silica which is highly reactive, depending upon the temperature of incineration [8]. Pozzolanas are defined as siliceous or siliceous and aluminous materials which in themselves possess little or no cementing property, but will in a finely dispersed form in the presence of water chemically react with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties. RHA is collected from rice mills in Chennai, where RHA is produced through open fire burning of rice husks.

When water is added to a mixture with pozzolanic material it acts as cement, in some instances providing a stronger bond than cement alone [9]. If the rice husk is burnt at too high temperature or for too long the silica content will become a crystalline structure. If the rice husk is burnt at too low temperature or for too short period of time the rice husk ash will contain too large amount of un-burnt carbon. Physical properties of rice husk ash used in this study is given in Table 3.

Table 3. Physical properties of RHA

Specific Gravity	2.05 – 2.3
Bulk Density	1.86 g/cc
Colour	Grey
Odour	Odourless
Particle Size	25 microns – mean
Appearance	Very fine

RHA was taken from a rice mill at Chennai (Fig. 3), in Tamilnadu and used for the experiments without further incineration. The ash was sieved through 0.6 mm sieve to remove unburnt carbon particles and finally sieved through150 μm sieve to get the fine ash used.

3.4 Fine Aggregate

Aggregates, made of geological resources like sand, stones, and gravel are used in almost all types of construction. Aggregate can be used in its natural shape or can be crushed into smaller pieces. The average size of the used aggregates was 2.5 mm. The aggregates used in this research were sourced from the best locations on Avadi in Chennai which is shown in Fig. 4.

Fig. 3. Rice Husk Ash

Fig. 4. Fine aggregate

Fig. 5. Mixing process

Fig. 6. Steel Moulds

Fig. 7. Finished bricks

3.5 Water

Drinkable tap water devoid of contaminants was used in this study.

3.6 Preparation of Soil Bricks

The soil and rice husk ash were thoroughly mixed with spade and compacted manually (Fig. 5). The RHA obtained from the rice mill was sieved through 300-micron BIS sieve to enable better reactivity with cement used for stabilization. With five different batches (2.5%, 5%, 7.5%, 10% and 12.5%.), 45 soil blocks with nominal dimensions 19 cm x 9 cm x 9 cm were produced from each batch for compressive strength, water absorption and efflorescence tests. The mould used and finished bricks are shown in Figs. 6 and 7 respectively.

4. RESULTS AND DISCUSSION

4.1 Proctor Compaction Test

The blocks were prepared with maximum dry density and optimum moisture content obtained from the standard compaction test. Hence it is essential to determine the maximum dry density and optimum moisture content before the preparation of blocks. It was proved that with the addition of RHA, the dry density decreases with the increment of moisture content [1,2,7]. RHA has relatively low specific gravity compared to the soil and Portland cement and acts as filler in the soil voids.

The Maximum Dry Density (MDD) of soil decreases with increasing RHA content probably due to an initial simultaneous flocculation and agglomeration of clay particles caused by cation exchange (Table 4). A lower MDD for soil with stabilizer indicates that the compaction energy is less than in the natural state of the soil. Increased Optimum Moisture Content (OMC) with an increase in RHA content as seen in Table 4 was probably due to the agglomeration of clay particles in the presence of the stabilizer, forming lumps and larger voids.

The compaction test was conducted in two set, the first set with cement content of 0%, 5% or 12% by the weight of the soil. Fig. 8 depicts the variation in dry density with moisture content for three different cement content in soil. The other set was done with addition of different percentage of RHA (12.5%, 2.5%, 5%, 7.5% and 10% by the weight of the soil) and shown in Fig. 9. Table 4 shows the values of maximum dry density and optimum moisture content for cement stabilized soil admixed with RHA.

Table 4. MDD and OMC variation

Sl. No	Cement content (%)	RHA content (%)	MDD (g/cc)	OMC (%)
1	34	0	1.790	12.50
2	32.2	2.5	1.651	15.65
3	30.8	5	1.609	20.44
4	29.8	7.5	1.482	21.42
5	27.8	10	1.462	28.55
6	25.8	12.5	1.444	30.13

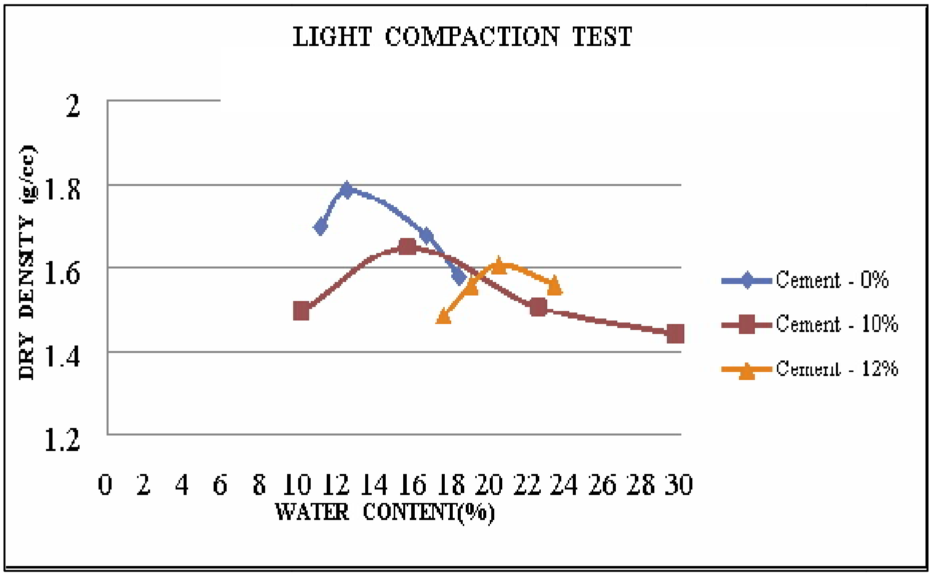

Fig. 8. Effect of variation in cement content on dry density

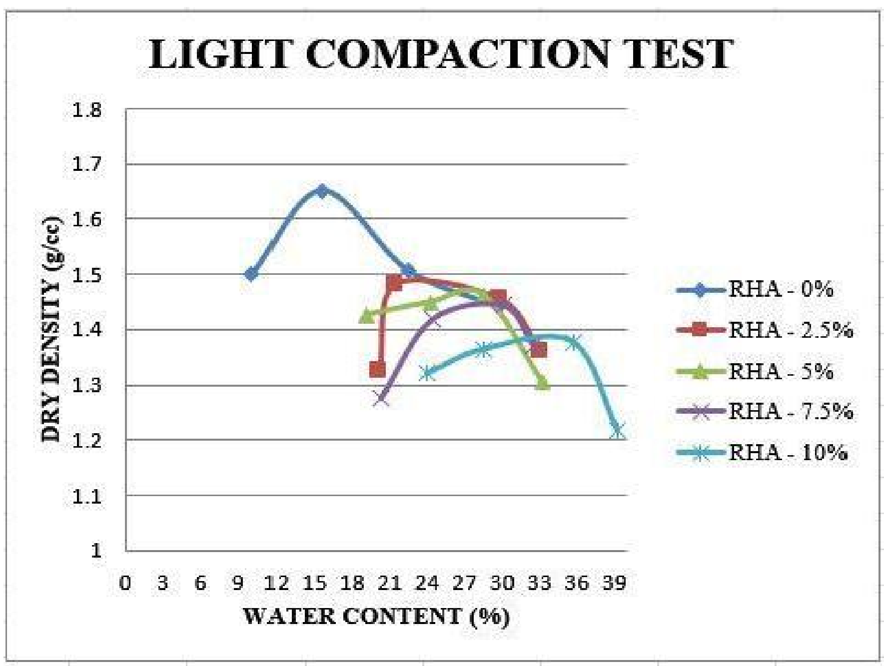

Fig. 9. Effect of increasing RHA on dry density

4.2 Compressive Strength Test

The compression test on the stabilized soil blocks was done in accordance with as per IS: 3495 (Part 1)-1992 specifications [11]. The results of the test are shown in the Fig. 10. Compressive strength decreases with increase in percent of rice husk ash. It is seen the block with 2.5% of RHA had the highest compressive strength of 2.07 N/mm^2. It is higher than that of blocks with 5%, 7.5%, 10% and 12.5% by 26%, 19%, 8% and 38% respectively. The decrease in compressive strength may be attributed to higher surface area of rice hisk ash [1].

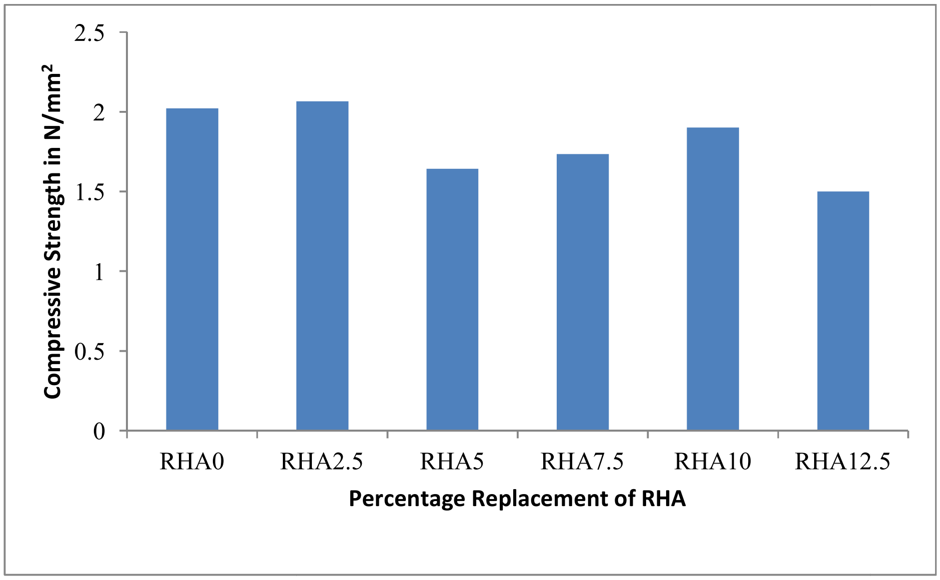

Fig. 10. Compressive strength

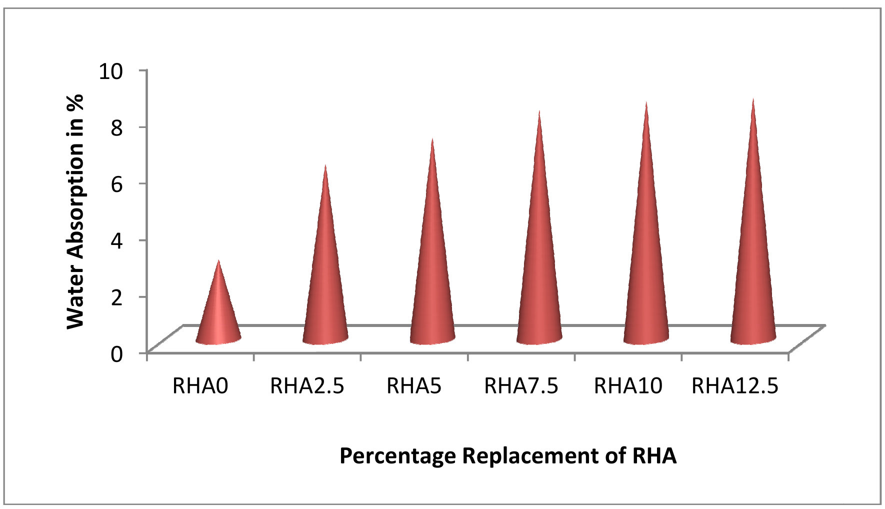

Fig. 11. Water absorption

4.3 Water Absorption

Water absoprtion test was carried out as per IS: 3495 (Part 2)-1992 specifications [11]. As seen in Fig. 11, water absorption steadily increases with increase in percentage of rice husk ash. Values of water absorption of blocks with 2.5%, 5%, 7.5%, 10% and 12.5% rice husk ash are higher than that of block wihout rice husk by 2.2%, 2.5%, 2.9%, 2.9% and 3% respectively. It is mainly due to porous microstructure of rice husk ash as reported by Singh [10].

4.4 Efflioresence Test

The efflorescence test on stabilized soil blocks was conducted in accordance IS: 3495 (Part3)-1992 specifications [11]. No efflorescence was detected on any of the specimens.

4.5 Weight

Weight of the blocks are determined as shown in Fig. 12 and it was found out that by increasing the RHA content weight is decreasing. It may be due to the lower specific gravity of RHA.

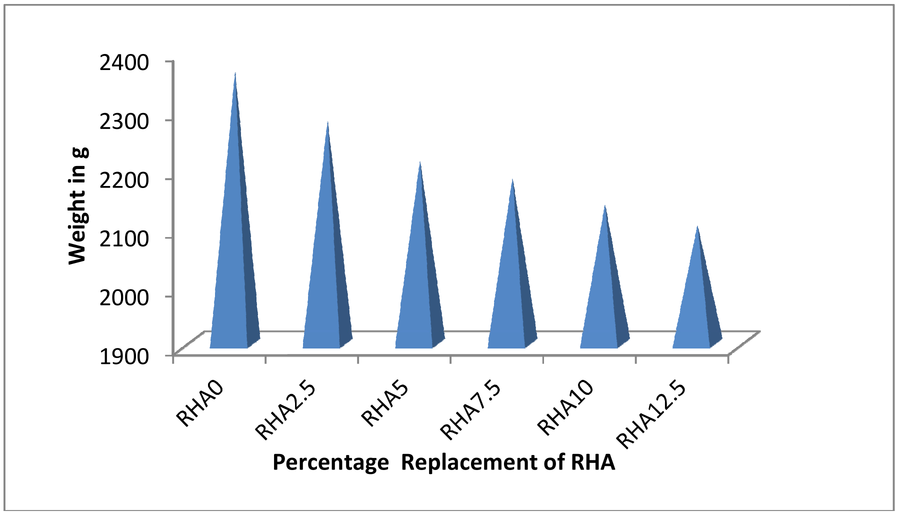

Fig. 12. Weight of blocks

5. CONCLUSION

The study involved the utilization of combination of cement and RHA in the manufacture of stabilized soil blocks and gauges its performance with respect to plain cement stabilized blocks. Based on the results of the experimental investigation carried out, the following points can be concluded:

1. By the addition of RHA the MDD decreases and the OMC increases than the cement stabilized soil.
2. Addition of RHA to cement in stabilization results in a decreased compressive strength of the blocks than cement stabilized blocks hence we realized that it cannot be used as load bearing masonry.
3. Addition of RHA to cement in stabilization results in an increase in the water absorption of the blocks hence we realized that it is not resistant to wetting.
4. By the efflorescence test it is found that in general conditions it also have no efflorescence.
5. Unit weight of the block decreases with increasing the of RHA content. Hence we can say that by the addition of RHA the weight of the blocks are reducing and its make easily handling.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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