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Performance Evaluation of Laterite Stabilized Blocks for Rural Housing

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ABSTRACT: India, the country of large population facing serious problem of housing particularly for poor who make most of the total population. It is today's need to develop and use local building materials to contribute to the solution of building material crisis. The study involved in investigating the performance of cement stabilized laterite scrap blocks admixed with sugarcane bagasse ash (SBA) and paddy husk ash (PHA). Locally available laterite stone scrap was tested for compressive strength, water absorption, and weathering loss properties. The mix ratio adapted for the manufacturing of laterite stone scrap stabilized block was 1:5.25 (cement: laterite stone scrap) by weight. This laterite scrap was stabilized using 16 % cement for manufacture of blocks of size 23 × 15 × 10 cm. Laterite stone scrap stabilized blocks were prepared by replacing cement with 2 %, 4 %, 6 % and 8 % by SBA and PHA. The laterite stone scrap blocks admixed with 16 % cement were considered as control. All blocks were cast followed by moist curing for a period of 28 days. They were then subjected to compressive strength (IS 3495 (Part 1): 1992), water absorption (IS 3495 (Part 2): 1992), and weathering tests (IS 1725: 1982) in accordance with Indian standards specifications for soil based in general building construction. The results of the tests indicated that the compressive strength of the blocks decreases from 3.92 N/mm² to 0.87 N/mm² i.e. 77.80 % with addition of SBA to replace the cement content from 2 % to 8 % by weight. The compressive strength of blocks decreases from 5.35 N/mm² to 1.18 N/mm² i.e. 77.94 % with addition of PHA used to replace the cement content from 2 % to 8 % by weight. The water absorption of the blocks increases from 14.09 % to 19.92 % with addition of SBA used to replace the cement content from 2 % to 8 % by weight. The water absorption of blocks increases from 11.24 % to 17.90 % with addition of PHA used to replace the cement content from 2 % to 8 % by weight. The average loss of weight in weathering test for all the treatment was in the range of 0.04 % to 1.28 %. The results showed that laterite stone scrap stabilized blocks prepared with 84 % laterite stone scrap, 14 % cement, 2 % SBA and blocks prepared with 84 % laterite stone scrap, 14 % cement, 2 % PHA met the standard requirement of BIS code. It is concluded that laterite stone scrap stabilized blocks with 2 % replacement of cement by SBA and laterite stone scrap stabilized blocks with 2 % replacement of cement by PHA were capable of producing stabilized blocks at reduced cement content that met the minimum required standards. Laterite stone scrap stabilized blocks have a great potential in future for low and medium cost rural housing construction and contribute on sustainable development.

KEYWORDS: Laterite stone scrap, Compressed stabilized blocks, Sugarcane bagasse ash, Paddy husk ash.

I. INTRODUCTION

India, the country of large population facing serious problem of housing. Particularly for poor who contributes most of the total population. It is today's need to develop and use local building materials to contribute to the solution of building material crisis. Utilization of waste-based construction materials like fly ash 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. Low cost 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. Governments are taking conscious efforts to bridge the gap, especially undertaking housing schemes such as 'Pradhan Mantri Awas Yojana (PMAY)' to ensure housing for all by 2022 for low income group and Maharashtra Housing and Area Development Authority (MHADA) Housing scheme. 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 [7].



Due to inadequate resources of construction material in developing countries, cost reduction is the best way in housing for the economically weaker section. This can be achieved by innovative manufacturing and utilizing low cost but durable construction materials from locally available resources. Compressed earth blocks are experiencing a new popularity, considering that they constitute green building materials, becoming economically competitive. This is because of the 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.

In Konkan region of Maharashtra and some parts of Southern India, laterite stones are traditionally used for construction of buildings and other works. The demand for laterite stone is increasing with the development in construction activities. The cost of such natural laterite stones is also increasing. It also enhances environmental deterioration due to over exploitation. Since good quality of clay suitable for bricks is not available for making of bricks, laterite stones of size $300 \times 200 \times 150$ mm are generally used for construction. The compressive strength of laterite stone varies from 2.5 N/mm^2 to 4.0 N/mm^2 depending upon quality of rock [14]. The texture of laterite stone being porous, it requires more quantity of cement plaster to get uniform levelled plaster. Moreover, laterite stone of thickness 100 mm lead to possibility of breakage during dressing operation and transportation. Dressing of laterite stone is costly operation. The cost of stone masonry is more than conventional brick masonry because it requires skilled labour.

An earth block is a masonry unit of regular dimensions made from soil. When wet or damp soil is pressed at a high pressure to form the block, it is called a compressed earth block. Whereas if any binder such as cement, lime, fly ash, bitumen, or gypsum is used for the stabilization of the soil used in the manufacture of the block, it is called a compressed stabilized earth block. Soil stabilization is the process of improving the soil strength by adding different types of additives. Soil stabilization achieved by mechanically mixing the natural soil and stabilizing material together into a homogenous mixture or by adding stabilizing material to an undisturbed soil deposit and obtaining interaction by letting it permeate through soil voids [4]. Compressed stabilized earth block is a better alternative to burnt clay bricks. These blocks can be produced in a decentralised fashion employing simple manually operated or semi-mechanized presses utilising local soil. Also, these blocks are economical and consume less thermal energy during production.

Compressed stabilized earth blocks offered numbers of advantages. It increases the utilization of local material and reduces the transportation cost. Also, generates local economy rather than spending for import materials, makes quality housing available to more people. Faster and easier production method resulted in less skilled labour required, good strength, insulation and thermal properties, less carbon emission and embodied energy in the production phase. There is huge difference in production of compressed stabilized earth blocks and clay bricks in terms of energy consumption and carbon emission during the production process. On an average, cement stabilised earth blocks consumed less than 10 % of the input energy as used to manufacture similar burnt clay bricks [13].

Compressed stabilized earth blocks create minimum waste and easily dispose off, also does not cause direct environmental pollution during the whole life cycle. Compressed stabilized earth blocks also absorb atmospheric moisture which resulted create healthy environment inside a building for its occupant. The earth used is generally subsoil, thus the topsoil can be used for agriculture. Building with local materials can employ local people and is more sustainable in crisis. Compressed stabilized earth blocks give the view of energy efficient, cost reduction and environmentally friendly building materials and overall contribution on the sustainable development. Compressed stabilized earth blocks are ultimately greener, comparable in strength, durability and low in thermal conductivity. Compressed stabilized earth bricks have a great potential in the future for low to medium cost rural housing construction and contribute on sustainable development.

There are several laterite stone quarries in Konkan region. During excavation of laterite stone, around 25 % – 30 % lateritic stone scrap is generated. It is estimated that about 2.83 m^3 of the laterite stone scrap is generated during excavation of about 11.33 m^3 of the laterite stone [6]. This laterite stone scrap creates problem in quarries and needs removal for further excavation. To add value to this waste material, it is felt necessary to manufacture the blocks using different constituents that are suitable for the construction.

Sugarcane production in India is over 300 million tonnes per year [8]. After the extraction of all economical juice from sugarcane, about 40 to 45 per cent fibrous residue was obtained known as bagasse. Bagasse is often used as a primary fuel source for sugar mills. Bagasse reused in industry as fuel in boilers for heat generation leaving behind 8 to 10 per cent ash as waste, known as sugarcane bagasse ash (SCBA). Sugar-mill generates about 10 million tonnes of sugarcane bagasse ash as a waste material. Sugarcane bagasse consists of approximately 50 % of cellulose, 25 % of hemicellulose, and 25 % of lignin [16]. The residue after combustion presents a chemical composition dominated by



silicon dioxide. The SCBA contains high amounts of un-burnt matter, silicon, aluminium, and calcium oxides [15]. The dumping of these industrial wastes in open land poses a serious threat to the society by polluting the air and waste bodies. Thus, sugarcane bagasse ash is one of the good waste materials to produce high quality compressed stabilized earth blocks.

India is a major rice producing country. Rice milling generates a by-product known as the husk. Rice husk are the protective covering of rice grains which are separated from grains during milling. During milling of paddy, about 78 % of weight is received as rice, broken rice, and rest 22 % of the weight of paddy is received as the husk. Some husk is utilized as fuel in the rice mills to generate steam for the parboiling process. Other applications of rice husk are as insulators, lithium battery anodes, waste water adsorbents and fertilizer-soil amendment. This husk contains about 75 per cent organic volatile matter and the balance 25 per cent of the residual weight of the husk is converted into ash during the firing process, is known as rice husk ash. This rice husk ash, in turn, contains around 85 % - 90 % amorphous silica [16].

The most prominent waste materials for the construction are laterite stone scrap, sugarcane bagasse ash, paddy husk ash and materials from construction demolition. This waste utilization is to support sustainable development by promoting rational use of natural resource and pollution free environment. One effective way to reduce the environment impacts is to use these waste materials such as sugarcane bagasse ash and paddy husk ash a partial replacement of cement in making of compressed stabilized earth blocks. This have the potential to reduce cost, conserve energy and minimize waste emission. Due to rapid growth in construction activity, the available sources required for cement production are getting exhausted and also, good quality construction materials must be transported from long distance, which adds to the cost of construction. Therefore, it is necessary to replace cement by an alternate material partially, without compromising the quality of compressed stabilized earth blocks. On the other hand, materials waste such as sugarcane bagasse ash, rice husk ash is difficult to dispose of which in return is environmental hazard. The partial replacement of cement with agricultural waste, such as the sugarcane bagasse ash and paddy husk ash contribute to useful disposal of the waste materials, and reduced consumption of cement, thus lowering adverse effects on the environment.

The engineering properties of laterite stone scrap may need to be improved to make them suitable for construction. So, the laterite stone scrap blocks can be used in the construction of rural housing. It is therefore necessary to develop and conduct different tests to study the various engineering properties of compressed stabilized blocks produced from laterite stone scrap, sugarcane bagasse ash, rice husk ash. With this background study entitled "Development of laterite quarry scrap stabilized blocks for rural housing in Konkan" undertaken

II. RELATED WORK

Utilization of paddy husk ash and sugarcane bagasse ash for partial replacement of cement in building materials

Paya et al. (2002) studied on sugarcane bagasse ash (SCBA) and its properties for reusing in concrete production. The sugarcane bagasse ash was chemically, physically, mineralogically characterized and evaluated. Some parameters were determined such as carbon content, presence of crystalline material, granulometric distribution, morphology of particles, and reactivity towards lime pozzolanic activity had been carried out. It showed that sugarcane bagasse ash from factories had inorganic carbon content higher than 15 %. The morphology of the particles, granulometry, and the carbon content of sugarcane bagasse ash affected negatively on the properties of fresh mortar and concrete. Sugarcane bagasse ash showed a high pozzolanic reactivity despite the high carbon content and crystallinity. It was observed that there was increase in the strength of concrete when used as hydraulic binder.

Thirumalai and Palanisamy (2015) conducted a study to see the effect on the bagasse ash (SCBA) and rice husk ash (RHA) as cement replacement in self-compacting concrete (SCC). The bagasse ash and rice husk ash were added as a partial replacement for cement. There were trial mixes prepared with the varying water cement ratio, replacement percentage, quantity of super plasticizer and viscosity modifying agent and tested. The results obtained were showed that the grade M25 Self Compacting Concrete produced with a partial replacement of Portland Pozzolana Cement (PPC) by Bagasse Ash or Rice Husk Ash, or with an up to 8 per cent combination of the two, without reducing workability requirements.

Tolmatti et al. (2018) worked on the feasibility of using the fly ash (FA), rice husk ash (RHA) and sugarcane bagasse ash (SCBA) waste in concrete production as a partial replacement of cement. The cement was replaced by rice husk ash, in the range of 0 %, 10 %, 20 % and 30 % by weight. The concrete mix produced, tested and compared concrete mixture of M20, M25 and M30 in terms of compressive strengths with the conventional concrete. The evaluated test results for mechanical properties for compressive strengths at 7, 14, 28, 56 and 90 days respectively and tensile and flexural strengths at 28 days. The results showed that at 20 % to 30 % replacement of cement the decreased



rate of strengths in flexural strengths and compressive strength than the rate of change at 10 % to 20 %. It was revealed that for all concrete mixture of M20, M25 and M30 the compressive strength and durability values increased with the age of concrete specimen from 56 to 90 days.

Properties of compressed stabilised earth blocks

Reddy (1994) studied on pressed soil-cement block technology. It was suggested that soils contain predominantly no expansive clay minerals with 60 % to 70 % sand, and less than 15 % clay size fractions were ideally suited for soil-cement block production. It was suggested that the area of the block restricted to less than 45,000 mm², in view of the limited energy supplied by persons involved in compaction operations. It was concluded that soil-cement blocks were energy efficient compared to conventional materials burnt bricks. It was observed that soil cement block consumed only 25 to 30 per cent of energy used to produce burnt bricks. Riza *et al.* (2010) emphasizes on the advantages of using CSEB for better living. It promotes healthier building material and cost reducing in production and also in service cost. The full scale production of compressed stabilized earth bricks has demonstrated that this kind of building material have a great potential in the future for low to medium cost housing construction and contribute on sustainable development.

Jain *et al.* (2011) worked on the engineering properties of laterite stone scrap blocks. Compressive strength, toughness index and water absorption capacity of the laterite stone scrap blocks were determined. Paddy husk ash, saw dust and processed fly ash were used as other constituents and added to the laterite stone scrap in the range of 3 to 9 %, 3 to 9 % and 20 to 30 % respectively. The cement was used as binding material and added in the range of 8 to 16 %. It was observed that the block prepared from laterite stone scrap 85 %, cement 12 % and paddy husk ash 3 % where in conformation with Bureau of Indian standards for Rural Housing. Veena *et al.* (2014) worked on the experimental investigation on cement stabilised laterite soil blocks. Materials such as fly ash and quarry dust were used to reduce the usage of cement and soil contents respectively, in about 10 % to 30 % of materials were replaced to prepare block. It was observed that the 28th day compressive strength of block with 20 % - 30 % cement replacement by fly ash was 7.65 N/mm² and 7.99 N/mm² respectively. Also, with replacement of laterite soil with quarry dust from 10 % - 20 % the 28th day compressive strength of block 9.81 N/mm² and 11.26 N/mm² observed respectively.

Jijo *et al.* (2016) investigated on the effect of cement stabilized soil blocks admixed with sugarcane bagasse ash (SBA). Cement stabilized soil blocks were prepared by 4 % and 10 % OPC. 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. It was observed that the water absorption of the control specimen increases marginally from 6.59 % to 6.89 % on addition of 8 % SBA. For 10 % cement stabilized blocks the water absorption of the blocks was lesser. It was concluded that for 4 % cement stabilized blocks, the addition of SBA results in increase in the water absorption. The water absorption increase observed from 5.84 % for the control specimen to 6.95 % for 8 % SBA addition. There was no efflorescence was detected on any of the combinations. Moses *et al.* (2020) studied on the feasibility of laterite soil for manufacturing compressed stabilised earth block. It was observed the variation of compressive strength (N/sq.mm) of compressed stabilised earth block during curing period of 3rd, 7th, 14th, 21st and 28th days for cement addition of 0 %, 2.5 %, 5.0 %, and 7.5 %. It was concluded that higher percentage of OPC optimized, for improving the compressive strength of the laterite soil to use for making CSEB.

III. METHODOLOGY

Materials used for the development of laterite stone scrap blocks

Laterite stone scrap. The laterite stone scrap was collected from quarries of laterite stone located nearby Dapoli, Dist. Ratnagiri (MS). The laterite stone scrap was used after passing through IS sieve no. 4 of size 4.75 mm [12].

Cement. Cement is building material which act as a binding agent in stabilized block. It is used as a binding material which bind laterite stone scrap. Ordinary Portland cement (OPC) 53 Grade cement procured from local market of Dapoli, Dist. Ratnagiri (MS).

Water. Water is an important ingredient in block making process as it actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel and soil stable. Tap water was used for experimental study.

Sugarcane Bagasse Ash (SBA). Completely burnt SBA adapted in the study was obtained from Diamond Sugar Mills Pvt. Ltd. Vijaynagar, Tal. Karad, Dist. Satara (MS). Sugarcane Bagasse ash was used after passing through IS sieve no. 30 of size 600 µm for experimental study [5].

Paddy Husk Ash (PHA). Paddy husk was collected from Rice mill, Murud, Tal. Dapoli, Dist. Ratnagiri. It was burnt in a closed drum for the use of experimental study. Paddy husk ash was used after passing through IS sieve no. 30 of size 600 µm for experimental study [5].

Process of Manufacturing of laterite stone scrap stabilized blocks

In the production process of laterite stone scrap stabilized blocks using manually operated machines three distinct operation steps are as follows:

Mixture preparation

The adapted mix ratio for the manufacturing of laterite stone scrap stabilized block was used 1: 5.25 (cement: laterite stone scrap) by weight for all mixes [6]. Where T₁₀ is the fired clay brick collected from local market having dimensions 215 × 145 × 95 mm for comparative study with developed laterite stone scrap blocks. Laterite stone scrap is sieved through IS sieve 4.75 mm to remove bigger clay lumps, gravel etc. Sieved laterite stone scrap is spread into a thin layer on level ground and then the cement is spread on top and mixed thoroughly using a spade. Totally 10 types of treatments undertaken in the study are given in Table 1.

Table1. Combination of treatments

Treatment no.	Combinations	Laterite stone scrap (%)	Cement (%)	Sugarcane bagasse ash (%)	Paddy husk ash (%)
T ₁	CLS	84	16	-	-
T ₂	CB ₁ LS	84	14	2	-
T ₃	CB ₂ LS	84	12	4	-
T ₄	CB ₃ LS	84	10	6	-
T ₅	CB ₄ LS	84	8	8	-
T ₆	CP ₁ LS	84	14	-	2
T ₇	CP ₂ LS	84	12	-	4
T ₈	CP ₃ LS	84	10	-	6
T ₉	CP ₄ LS	84	8	-	8
T ₁₀	CLB	-	-	-	-

The weights of soil, cement, and SBA or RHA 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 wetted laterite stone scrap cement mixture is pressed into a block using the machine. Mixture preparation has been carried out in batches such that the wetted laterite stone scrap cement mixture converted into blocks within 40 minutes. This is mainly to avoid setting of the cement before pressing into a block. Generally, Laterite stone scrap sufficient for 30 blocks is processed in each batch.

Block pressing

The processed laterite stone scrap is compacted into a block using a machine. The wet mix was then placed in the vibrating mould and followed by the top plate manually compressed to finish top surface of the block. 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 uniform density of blocks for testing. The blocks are formed by application of force to a loose laterite stone scrap, water and fine aggregate mix in a vibrating mould that determines final blocks specific dimensions. The machine used for this study produces blocks with standard dimensions of 230 x 150 x 100 mm [11].

The area of the block restricted to less than 45,000 mm², in view of the limited energy supplied by operator involved in pressing of top plate. Compaction bigger soil blocks in manually operated presses cause production of poor-quality blocks, because of low densities due to inadequate compaction. The machine is kept in operation for 2-3 minutes for better compaction of blocks.

Stacking and curing

After the formation of the block, the block was removed from the mould. The fresh block was stored for curing under polythene sheet. The blocks were moistened daily after each 12 hrs. After the first 7 days of curing blocks were stacked up to 4 layers and kept it in a shaded area and was cured for a period of 28 days by sprinkling of water and covering with plastic sheet to prevent loss of moisture. Out of the 10 blocks prepared for each laterite stone scrap mix, three (3) blocks were used for compressive strength, three (3) for water absorption tests and three (3) for weathering test.



All the three tests were done in accordance with Indian Standard specifications. Three blocks were tested for each combination and the average were taken as result for the combination for a particular test.

Testing of Laterite Stone Scrap Stabilized Blocks

Density of laterite stone scrap stabilized blocks

To find out density of laterite stone scrap stabilized blocks, three random blocks selected from the samples and dried to constant mass in a hot air oven heated to approximately 105 to 110°C. After cooling the blocks to room temperature, the dimensions of each block were measured in centimetres and the overall volume computed in cubic centimetres. The blocks are then weighed in kilograms.

The density is calculated by using following formula as given in IS 2185 (Part 1): 2005:

$$\text{Density} = \frac{\text{Mass of block, in kg}}{\text{Volume of specimen, in cm}^3} \times 10^6 \text{ kg/m}^3 \quad \dots(1)$$

Compression strength test

The surface unevenness in the bed faces of blocks was removed to provide two smooth and parallel faces. Specimens were immersed in water at room temperature for 24 hours. Then the specimens were removed and drained surplus moisture at room temperature. The frog and all voids are filled with cement mortar. The cement mortar was prepared with cement and clean coarse sand of grade 3 mm. The blocks are then stored under the damp jute bags for 24 hours followed by immersion in clean water for 72 hrs.

To find out compressive strength of laterite stone scrap stabilized blocks, the blocks were wiped thoroughly before placing it on the wooden platform of the compression testing machine. The specimen placed with flat faces horizontal, and mortar filled face facing upwards between two plywood sheets each of 3 mm thickness and carefully centred between plates of the testing machine. The plywood was placed on the samples to distribute load evenly. Load applied axially at a uniform rate of 14 N/mm² per minute till failure occurred and noted the maximum load at failure. Crushing strength per unit area is calculated by dividing the maximum load at which the sample crushes or fails with the bearing area of specimen.

The compressive strength is calculated by using following formula as given in IS 3495 (Part 1): 1992:

$$\begin{aligned} \text{Compressive strength (N/mm}^2\text{)} \\ = \frac{\text{Maximum load at failure in N(kgf)}}{\text{Average area of the bed faces in mm}^2\text{(cm}^2\text{)}} \quad \dots (2) \end{aligned}$$

Water absorption test

The specimen blocks were dried in a hot air oven at a temperature of 105 to 115 °C for 24 hrs, till it attains substantially constant mass. The specimens cooled to room temperature and its initial weight (M_1) was noted.

Completely dried specimen blocks were immersed in clean water at a temperature of 27 ± 2 °C for 24 hours. The specimen blocks were removed and wiped traces of water with a damp cloth and final weight (M_2) was noted. The weighing was completed within 3 minutes after the specimen has been removed from water.

Water absorption, per cent by mass, after 24-hour immersion in cold water is calculated using the following formula given in IS 3495 (Part 2): 1992:

$$\begin{aligned} \text{Percentage absorption by weight after 24 hrs.} \\ = \left(\frac{M_2 - M_1}{M_1} \right) \times 100 \quad \dots (3) \end{aligned}$$

Where,

M_1 = Wt. of dry sample, g

M_2 = Wt. of sample after immersed in distilled water for 24 hrs. g

Weathering test

To determine the weathering effect on laterite stone scrap blocks, the shower of diameter 10 cm with 36 holes of 2 mm diameter was used. A device pump was provided to create a constant pressure of 1.5 ± 0.2 kgf/cm² for this test.

The specimen blocks to be tested was mounted such that only one face was exposed to shower and discharged water find an exit without wetting the other faces or getting collected such that blocks get immersed. These showers were placed at 18 cm from the block and are arranged by the side, such that the complete face gets exposed. The period of exposure was limited to 2 hours and then the exposed surfaces were examined. The tests are carried out on three (3) blocks of each combination as given in IS 1725: 1982.

Statistical analysis

The statistical analysis of developed laterite stone scrap stabilized blocks was carried out by the RBD (Randomized Block Design) analysis at 5 % level of significance. The data of four (4) tests of ten (10) treatments were arranged and analysed by the method of RBD statistical analysis.

IV. EXPERIMENTAL RESULTS

Density of laterite stone scrap stabilized blocks

The average densities of laterite stone scrap stabilized blocks T_1, T_2, \dots, T_{10} were found to be 1855.84 $\text{kg/m}^3, 1704.41 \text{ kg/m}^3, \dots, 1520.01 \text{ kg/m}^3$ respectively. It is observed that the minimum and maximum densities were 1520.01 kg/m^3 and 1872.34 kg/m^3 of treatments T_{10} and T_6 respectively. It is revealed from Fig.1 that treatment blocks from T_2 to T_5 when sugarcane bagasse ash used to replace the cement content from 2 to 8 % by weight the density of the blocks decreases from 1704.41 kg/m^3 to 1542.35 kg/m^3 by 9.5 %. Similarly, from treatments T_6 to T_9 when paddy husk ash used to replace the cement content from 2 to 8 % by weight the density of blocks decreases from 1872.34 kg/m^3 to 1540.78 kg/m^3 by 17.7 %. Also, it is revealed from Fig.1 that density of laterite stone scrap stabilized blocks admixed with paddy husk ash shows higher densities as compared to density of laterite stone scrap stabilized blocks admixed with sugarcane bagasse ash.

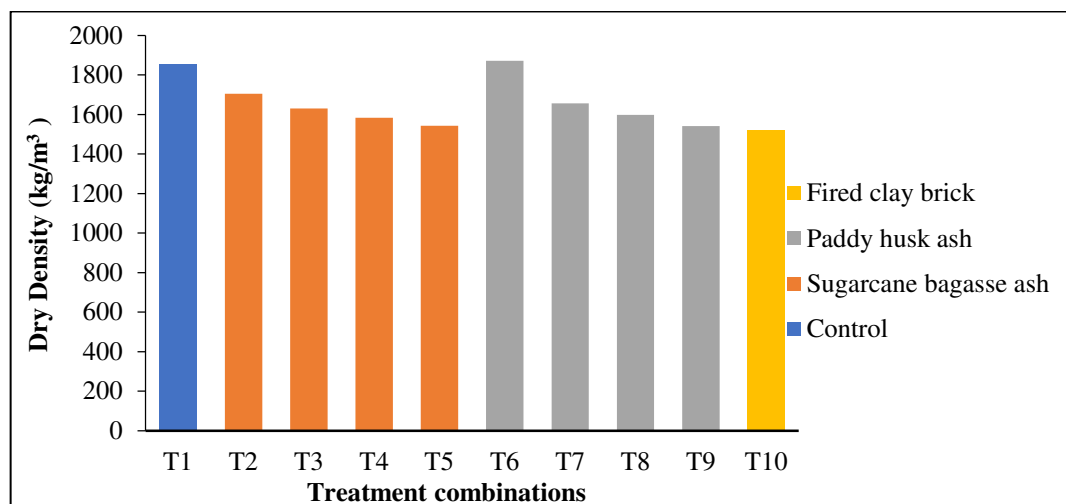


Fig. 1 Effect of Ash content on dry density of laterite stone scrap stabilized block

Compressive strength of laterite stone scrap stabilized blocks

The compression strength for all the treatment laterite stone scrap stabilized blocks were in the range of 0.87 N/mm^2 to 5.53 N/mm^2 . The minimum compressive strength was of T_5 blocks. The maximum compressive strength was of T_1 blocks. The second highest compression strength was 5.35 N/mm^2 of T_6 blocks. It is revealed that with decrease in cement and increase in sugarcane bagasse ash the compressive strength of laterite stone scrap block decreases. Similarly, with decrease in cement and increase in paddy husk ash, the compressive strength of laterite stone scrap block decreases.

Fig. 2 shows that from treatment T_2 to T_5 when sugarcane bagasse ash used to replace the cement content from 2 to 8 % by weight the compressive strength of the blocks decreases from 3.92 N/mm^2 to 0.87 N/mm^2 by 77.80 %. Similarly, from treatment T_6 to T_9 when paddy husk ash used to replace the cement content from 2 to 8 % by weight, the compression strength of blocks decreases from 5.35 N/mm^2 to 1.18 N/mm^2 by 77.94 %.

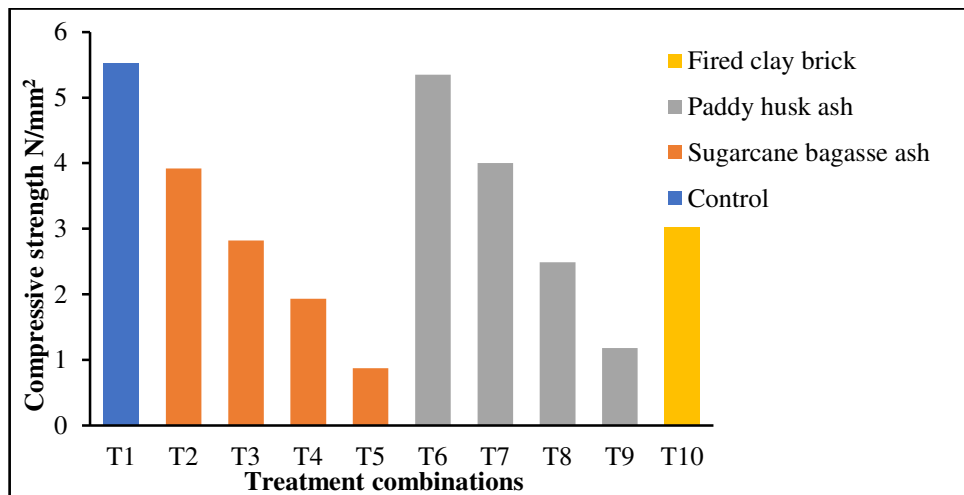


Fig. 2 Effect of Ash content on compressive strength of laterite stone scrap stabilized block

Also, it is revealed from Fig. 2 that, the compressive strength of laterite stone scrap stabilized blocks admixed with paddy husk ash shows higher compressive strength as compared to compressive strength of laterite stone scrap stabilized blocks admixed with sugarcane bagasse ash.

As per Anonymous (1992a) the minimum compressive strength is specified as not less than 1.96 N/mm² for Class 20 and 2.94 N/mm² for Class 30. The T₁, T₂, T₃, T₆, T₇, T₈ and T₁₀ blocks have compressive strength 5.53 N/mm², 3.92 N/mm², 2.82 N/mm², 5.35 N/mm², 4.0 N/mm², 2.49 N/mm² and 3.02 N/mm² respectively. T₁, T₂, T₆, T₇ and T₁₀ blocks have compressive strength 5.53 N/mm², 3.92 N/mm², 5.35 N/mm², 4.0 N/mm² and 3.02 N/mm² respectively. Thus, treatment blocks T₁, T₂, T₃, T₆, T₇, T₈ and T₁₀ for Class 20, treatment blocks T₁, T₂, T₆, T₇ and T₁₀ made from constituents meet the specification of Class 30 blocks, are recommended for rural housing from compressive strength criteria.

Water absorption of laterite stone scrap blocks

The water absorption for all the treatment of laterite stone scrap blocks were in the range of 10.37 % to 30.53 %. The minimum water absorption was of T₁ block. The maximum water absorption was of T₁₀ block. The second lowest water absorption was 11.24 % of T₆ blocks. It is revealed that with decrease in cement and increase in sugarcane bagasse ash, the average water absorption of laterite stone scrap block increases. Similarly, with decrease in cement and increase in paddy husk ash, the average water absorption of laterite stone scrap block increases. Specific gravity of sugarcane bagasse ash and paddy husk ash is less than cement. Replacement of cement by sugarcane bagasse ash and paddy husk ash cause lower density and more pore space within the block which causes increase in water absorption.

Fig. 3 shows that from treatment T₂ to T₅ when sugarcane bagasse ash used to replace the cement content from 2 % to 8 % by weight the water absorption of the blocks increases from 14.09 % to 19.92 %. When paddy husk ash used to replace the cement content from 2 % to 8 % by weight in treatment T₆ to T₉ the water absorption of blocks increases from 11.24 % to 17.90 %.

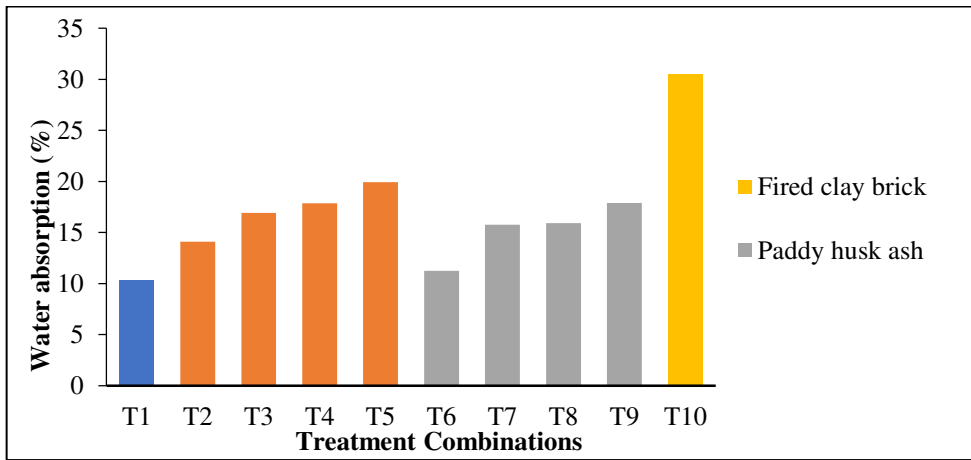


Fig. 3 Effect of Ash content on water absorption of laterite stone scrap stabilized block

Also, it is revealed from Fig. 3, that water absorption of laterite stone scrap stabilized blocks admixed with paddy husk ash shows lower water absorption as compared to water absorption of laterite stone scrap stabilized blocks admixed with sugarcane bagasse ash. Sugarcane bagasse ash and paddy husk ash have higher specific gravity and more porous as compared to cement, so with replacement of cement by SBA and PHA from 2 % to 8 % water absorption increases. As per Anonymous (1992b) an average water absorption shall not be more than 15 per cent by weight. T₁, T₂ and T₆ blocks have 10.37 %, 14.09 % and 11.24 % average water absorption. Thus, the blocks T₁, T₂ and T₆ made from constituents meet the specification of average water absorption are recommended for rural housing from average water absorption criteria.

Weathering test of laterite stone scrap blocks

The average loss of weight for all the treatment of laterite stone scrap blocks were in the range of 0.04 % to 1.28 %. The minimum weight loss was of T₆ block. The maximum weight loss was of T₉ block.

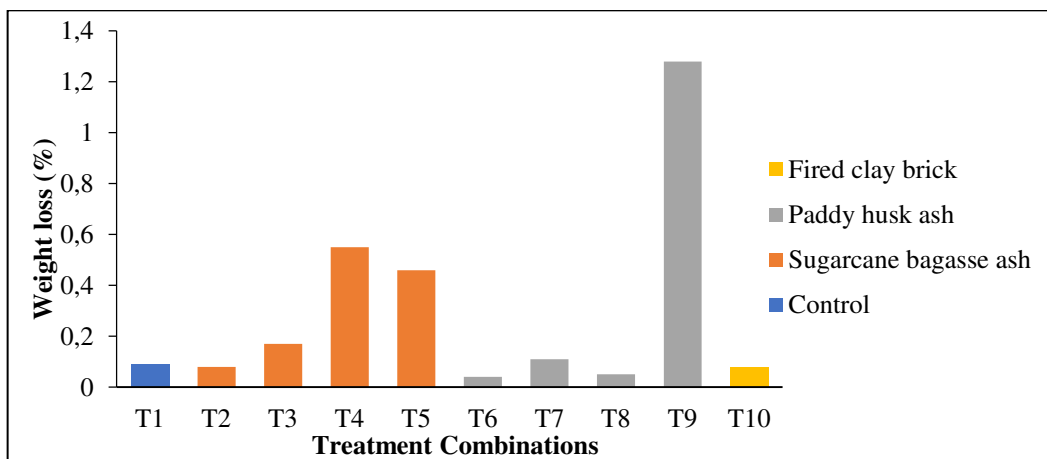


Fig. 4 Effect of Ash content on weight loss of laterite stone scrap stabilized block

Fig. 4 shows that from treatment T₂ to T₅ when sugarcane bagasse ash used to replace the cement content from 2 to 8 % by weight the maximum weight loss of the blocks increases from 0.08 to 0.46 %. In treatment from T₆ to T₉ when paddy husk ash used to replace the cement content from 2 to 8 % by weight the maximum weight loss of blocks increases from 0.04 to 1.28 %. Initially with increase in paddy husk ash weight loss increase slightly and at last weight loss increases rapidly as compared to the sugarcane bagasse ash. It was revealed from Fig. 4 that with increase in ash content average weight loss of laterite stone scrap stabilized blocks increases.

As per Anonymous (1982), the maximum loss of weight shall not exceed 5 per cent. It is reveals that all the treatment blocks T₁, T₂, ..., T₁₀ blocks shows average weight loss 0.09, 0.08, ..., 1.28 % respectively. T₁, T₂, ..., T₁₀

blocks made from the constituents meet the standard specification for weathering test. Thus, all T_1, T_2, \dots, T_{10} blocks are recommended for rural housing from weathering test criteria.

Comparative performance of laterite stone scrap stabilized blocks of prepared under of different treatments

The comparative results of density, compression strength, water absorption and weathering of laterite stone scrap stabilized blocks are given in Table 4.

Table 2 Density, Compression strength, water absorption and weight loss of different treatments

Treatment	Density (kg/m ³)	Compression strength test (N/mm ²)	Water absorption test (%)	Weathering test (%)
T₁	1855.84	5.53	10.37	0.09
T₂	1704.41	3.92	14.09	0.08
T ₃	1631.21	2.82	16.91	0.17
T ₄	1584.04	1.93	17.87	0.55
T ₅	1542.35	0.87	19.92	0.46
T₆	1872.34	5.35	11.24	0.04
T ₇	1656.30	4.00	15.75	0.11
T ₈	1598.79	2.49	15.92	0.05
T ₉	1540.78	1.18	17.90	1.28
T ₁₀	1520.01	3.02	30.53	0.08

Table 3 Cost of Production of different material contribution

Treatments	Laterite stone scrap (%)	Cement (%)	Sugarcane bagasse ash (%)	Paddy husk ash (%)	Cost, (Rs./Block)
T ₁	84	16	-	-	9.01
T ₂	84	14	2	-	7.96
T ₃	84	12	4	-	7.26
T ₄	84	10	6	-	6.67
T ₅	84	8	8	-	6.12
T ₆	84	14	-	2	8.75
T ₇	84	12	-	4	7.68
T ₈	84	10	-	6	7.21
T ₉	84	8	-	8	6.75
T ₁₀	-	-	-	-	12.00

Note: Laterite stone scrap = Rs. 0.10/kg; cement = Rs. 6.00/kg; sugarcane bagasse ash = Rs. 2/kg; Paddy husk ash = 3.5/kg; Manufacturing cost = Rs. 2/block (Jain *et al.*, 2011)

Table 4 Comparative performance laterite stone scrap stabilized blocks of different treatments based on Indian standards

Sr. No.	Test	BIS requirements	Treatment specimen satisfying requirements
1.	Compression strength	For class 20 not less than 1.96 N/mm ²	T₁, T₂, T₃, T₆, T₇, T₈, T₁₀
		For class 30 not less than 2.94 N/mm ²	T₁, T₂, T₆, T₇, T₁₀
2.	Water absorption	Not greater than 15 % by weight	T₁, T₂, T₆
3.	Weathering test	Not greater than 5 % by weight	T₁, T₂, T₃, T₄, T₅, T₆, T₇, T₈, T₉, T₁₀

From Table 4 it is revealed that treatment T₁, T₂ and T₆ blocks satisfying all the physical requirements of Indian standards. It is revealed from Table 3 that T₁ (Rs. 9.01) have higher production cost than T₂ (Rs. 7.96) and T₆ (Rs. 8.75). Also, Table 3 revealed that T₂ and T₆ are economical as compared to T₁₀ (Rs. 12.00) i.e. fired clay brick



collected from local market. Thus, T2 and T6 laterite stone scrap stabilized blocks were recommended for low and medium cost rural housing construction and contribute on sustainable development in Konkan.

V. CONCLUSION

The following conclusions drawn from the study

1. The compressive strength of the laterite stone scrap stabilized blocks decreased by 77.80 % and by 77.94 % with cement replacement by sugarcane bagasse ash and paddy husk ash respectively from 2 % to 8 % by weight.
2. Compressive strength of laterite stone scrap stabilized blocks admixed with paddy husk ash showed higher compressive strength (i.e. 35.58 %) as compared to compressive strength of laterite stone scrap stabilized blocks admixed with sugarcane bagasse ash.
3. The water absorption of the laterite stone scrap stabilized blocks increased from 14.09 % to 19.92 % and 11.24 to 17.90 % with cement replacement by sugarcane bagasse ash and paddy husk ash from 2 % to 8 % by weight respectively.
4. Water absorption of laterite stone scrap stabilized blocks admixed with paddy husk ash showed lower water absorption (i.e. 1.98 %) as compared to water absorption of laterite stone scrap stabilized blocks admixed with sugarcane bagasse ash.
5. The weathering loss of the laterite stone scrap stabilized blocks increased from 0.08 % to 0.46 % and 0.04 % to 1.28 % with cement replacement by sugarcane bagasse ash and paddy husk ash from 2 % to 8 % by weight respectively. Thus, weathering of laterite stone scrap stabilized blocks increases with increase in ash content.
6. Locally available laterite stone scrap can be cement stabilized using 84 % laterite stone scrap, 14 % cement and 2 % sugarcane bagasse ash or 2 % paddy husk ash to meet the Indian standard specifications for soil based blocks used in general building construction.

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