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EFFECT OF RICE HUSK ASH ON STRUCTURAL AND THERMAL PROPERTIES OF CLAY ROOF TILES

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Abstract: Utilization of waste matter in building construction is becoming more popular in the world mostly because it not only gives alternative for construction material but also gives a solution for waste management while reducing environmental pollution. Among many waste materials, Rice Husk Ash (RHA), a waste from clay products manufacturing process has no proper usage in many countries including in Sri Lanka.

Objective of this study is to investigate the effect of waste RHA collected from a brick kiln on structural and thermal properties of clay roof tiles.

Roof tile specimens with different RHA percentages (0%, 5%, 10%, 15% and 20%) were manufactured in industrial scale. Structural properties of clay roof tile such as transverse breaking load, bulk density and water absorption were determined. In addition, thermal behaviour of roof tiles was examined. Furthermore, the physical and chemical properties of RHA and clay were also determined in order to find the reasons for characteristic behaviour of RHA added clay roof tiles.

For 10% RHA replacement, transverse breaking load can be increased by 47.24%. Bulk density is reduced with the percentage of RHA added, which is a favourable property for roof tiles as a roofing material. RHA increases water absorption property. However, addition of RHA up to 15% is acceptable, as it satisfies the limits specified in standards.

Heat transmitted through the roof clay tile is reduced with increasing RHA percentage. Hence, cooler environment can be built under RHA added roof tiles than under conventional roof tiles.

It was found that the brick kiln RHA contains high amount of SiO_2 content of 84.14% and that may be the most probable reason for the strength gain property of RHA added roof tiles.

Keywords: Clay; Rice Husk Ash; Roof tiles; Structural properties; Thermal properties

1. Introduction

Rice is the staple food in many countries, resulting to produce a large amount of rice husk. Rice husks are often used as a fuel in brick manufacturing industry, as a result, a considerable amount of rice husk ash (RHA) accumulates in the environment, without having a proper usage. Rice husk ash, a waste of brick kiln, is unusually high in silica which is around 90%, highly porous and light weight, with a large external surface area.

There are a number of previous studies that have been carried out to investigate the enhancement of properties of construction materials like high strength concrete, normal concrete, masonry blocks and bricks with the addition of RHA. For example, Gupta and Wayal [1] has observed that the optimal replacement percentage of RHA in concrete found to be varied from 10% to 20%. Perera *et al.* [2] has investigated the behaviour of RHA added clay bricks and has concluded that optimum RHA replacement ratio is 4% to enhance the clay brick properties. However, according to Kazmi *et al.* [3], 5% is the best proportion for RHA replacement in clay bricks [4]. When RHA is added to masonry blocks, the compressive strength of RHA based cement sand blocks has increased with the addition of lime and 5% of RHA addition has provided the optimum value [4]. However the effect of RHA on structural and thermal properties of clay roof tiles have not been investigated.

Nowadays, asbestos sheet roof covering is becoming more popular among people mostly because of easiness in handling, fast assembling, cost effectiveness and high strength when compared to wood and clay tiles. However, the World Health Organization has found that use of asbestos as roofing material, cause lung cancer, cancer of the larynx and ovary, mesothelioma, and asbestosis (fibrosis of the lungs). Due to these reasons, many countries have already banned the use of asbestoses. Sri Lanka is also going to ban manufacturing and importing of asbestos roofing materials by 2018 [5]. Clay roof tiles can be a better alternative to asbestos roofing, considering several advantages of roof tiles over asbestos roofing: health favourability, better appearance, thermal absorption. However, main disadvantage of clay roof tile over asbestos is lesser strength and durability properties. Construction cost of clay tiles can also be minimized by using RHA as a component. Use of RHA for roof tile manufacturing prevents environmental pollution that caused by open dumping of rice husk ash as well. Although many other researches are based on specimen cast within the laboratory, this study will be investigating the performance of roof tiles prepared in industrial scale kiln. Therefore, findings would be more practicable and hence, they will contribute to introduce a new trend of producing clay roof tiles. And it would be helpful to uplift the clay tile industry.

The main objectives of this study is to investigate the effect of waste rice husk ash (RHA) collected from a brick kiln on properties (transverse breaking load, bulk density, water absorption and thermal properties) of clay roof tiles.

2. Materials and Methodology

2.1 Materials

2.1.1 Raw materials

The clay for the study was collected from Bangadeniya and Pannala areas, located in Puttlam District, North Western Province of Sri Lanka. The Rice husk ash was collected from an industrial brick kiln at Akurugoda area in Southern Province.

2.1.2 Preparation of Roof Tile Specimens

In the mixture, three types of clay; namely, 'Kiri Mati' (clay), 'Goda Mati' (very clayey sand) and 'Kalawam Mati' (mix of above two types) were mixed in 1:1:2 ratio with required amount of water to make the mixture to mould the tile specimens. The amount of water added to the mixture depends on the weather condition. Separate clay samples were prepared by mixing different RHA contents (i.e., 0%, 5%, 10%, 15% and 20%) according to weight. The roof tile specimens in this study were cast in a roof tile factory at Waikkal, in Puttlam District, following the same method of manufacturing roof tiles in industrial level.

2.2 Laboratory Experiments

2.2.1 Raw Materials

2.2.1.1 Sieve Analysis

Sieve analysis for RHA was conducted as specified in [6]. Wet sieve analysis was conducted for clay in accordance with [7].

2.2.1.2 Specific gravity and Atterberg's Limits

Specific gravity test for both RHA and clay was performed as mentioned in [8] using Equation 1.

$$Gs = B/(P+B-Ps) \quad \textbf{(1)}$$

Where,

Gs is specific gravity, B is weight of the sample (i.e., either clay or RHA), P is the weight of pycnometer and Ps is the weight of pycnometer and the mixture.

Atterberg's limit tests for clay samples mixed with RHA (of 0%, 5%, 10%, 15% and 20%) were carried out as specified in [9].

2.2.1.3 Chemical Analysis

XRF (X-Ray Fluoresce) test for RHA sample was performed according to the process described in [10].

2.2.2 Tile Specimens

2.2.2.1Transverse Breaking Load

According to Bureau of Indian standards [11], two parallel self-aligning cylindrical steel bearers, with the bearing surface rounded to 40 mm diameter were placed on the universal testing machine. The tile specimens were supported evenly flatwise on the bearers set with a span of 25 cm and resting on the bottom surface. The load was applied through a third steel bearer of similar shape placed midway between and parallel to the supports which was kept on the tile as shown in Figure 1. The length of all the bearers was exceeded the maximum width of the tile under test. The load was applied downwards perpendicular to the span, at a uniform rate of 450 N/min.

Figure 1 : Arrangement of specimen for transverse test

2.2.2.2 Bulk Density

Dry weight of a specimen was measured after keeping it in an oven at a temperature of 1100C. Volume of a specimen was obtained by calculating the overflowed water content when one roof tile (which was kept under water for 24 hours) was immersed into a totally filled water bucket. Bulk density was calculated by dividing the dry mass by its volume.

2.2.2.3 Water Absorption

The samples were kept in an oven at a temperature of 110°C for 24 hours. The mass of each tile specimen was weighed (Dry mass (W_d)). They were then completely immersed in a bowl of water for 24 hours (until no bubble was observed.). This procedure was repeated for the remaining tiles. Excess water was removed from the samples by wiping the sample using tissue papers and the wet mass (W_w) was also weighed. The amount of water absorbed (W_a) by the roof tile was subsequently calculated as in Equation 2 according to [12].

$$Wa = \frac{Ww - Wd}{Wd} x100\% \qquad (2)$$

Thermal Properties

Experimental set-up to investigate thermal properties was developed as found in a previous study by Halwatura and Jayasinghe [13].

Roof tile specimens were covered with insulating material (rig foam) in all sides except the top and the bottom sides. Space between the tile and the rig foam was filled with saw dust to avoid heat transferring from other sides except the top side. A 4 feet- type "K" thermo couple was placed at the bottom surfaces of the middle of the tile. (Figure 2). The apparatus was kept in a little higher elevation on a wooden frame under which air flow was allowed. This was done for sample specimens of 0%, 5%, 10%, 15% and 20% of RHA. They were kept in the sun and temperature readings were taken at 30 min intervals from 8.00 am to 6.00 pm on a sunny day in August. Readings were taken from a digital thermometer; Model 307.

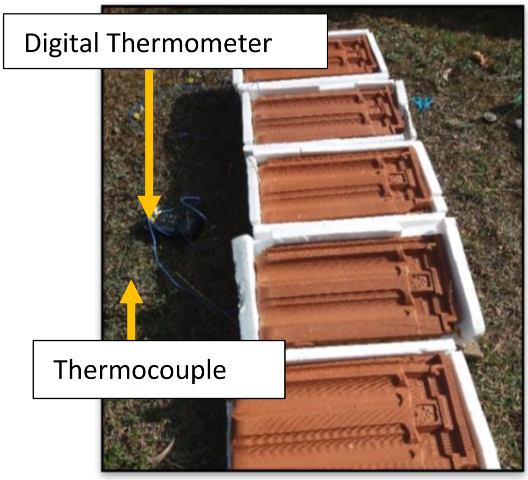

Figure 2 : Testing thermal properties

3 Results and Discussion

3.1 Raw Materials

3.1.1 Particle size distribution of RHA

Particle size distribution of RHA obtained by sieve analysis is shown in Figure 3. It can be seen that the percentage of passing through 250μm sieve is 62.34%. Fineness modulus is

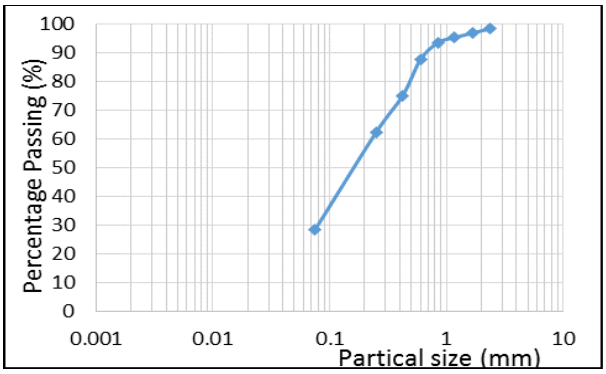

Figure 3 : Particle size distribution of RHA

1.62, implying major portion of RHA sample is fine and hence they can move easily through clay particles when mixing.

3.1.2 Particle size distribution of Clay

Figure 4 shows the particle size distribution of clay mixture (as described in section 2.1.2) that used to manufacture tile specimens. It can be observed that more than 85% of particles passes through 75µm sieve, showing that majority is silt and clay. Sand percentage is very small. Fineness modulus of this clay is 0.23.

Due to the presence of high amount of micro particles, the interaction of clay particles with RHA particles would be more effective.

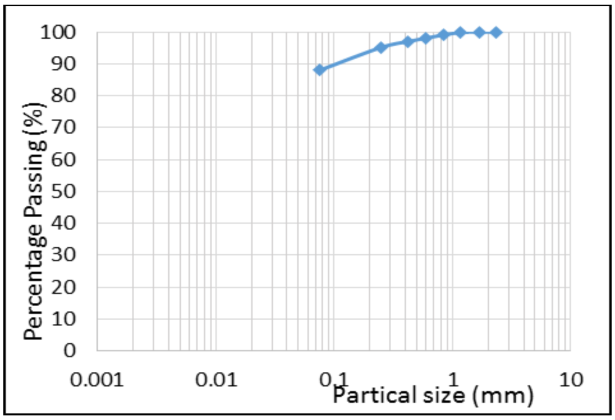

Figure 4 : Particle size Distribution of Clay

3.1.3 Specific Gravity

Specific gravity of RHA was 2.07 whereas that of clay was 2.47. The specific gravity of RHA that have burnt under controlled temperature was found to be 2.05 and 2.11 by Reddy *et al.* [14] and Sultana *et al.* [15] respectively. Kazmi *et al.* [3] has showed that specific gravity of RHA taken from an industrial brick kiln was 2.11. Hence it is clear that specific gravity of RHA is similar for these two methods of burning. As the specific gravity of RHA is lesser than that of roof tile clay, addition of RHA to roof tiles would help to produce lighter roof tiles.

3.1.4 Atterberg's Limits

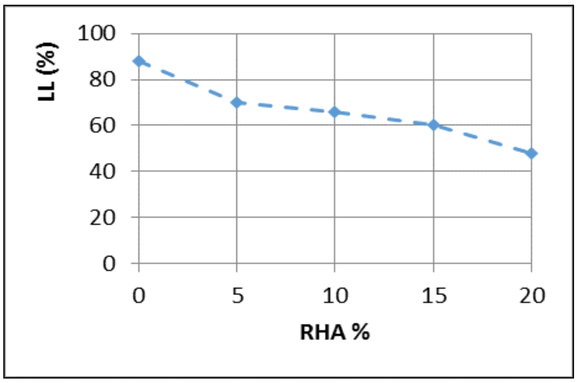

Figure 5 : Variation of Liquid Limit with RHA %

Liquid limit of this clay soil (without adding RHA) is 88% and it decreases with the addition of RHA to clay (Figure 5). Kazmi et al. [3] has observed the reduction of liquid limit when RHA content increases in the soil. According to Ling and Weng [16], when liquid limit decreases, shrinkage also decreases. Shrinkage reduction is favourable for roof tiles.

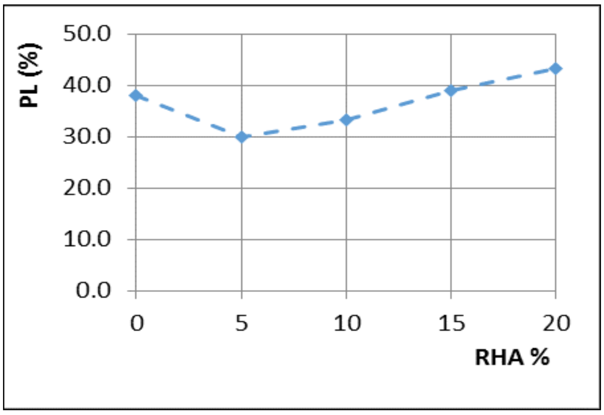

Figure 6 : Variation in Plastic limit with RHA %

Variations of plastic limit with RHA % is shown in Figures 6. Clay with 5% RHA shows the minimum plastic limit which is 30%.

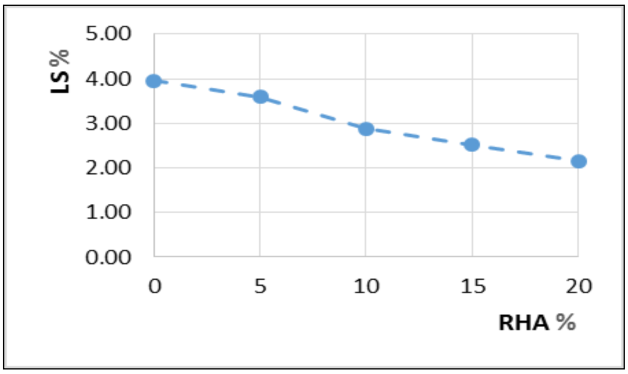

Figure 7 : Variation in Linear Shrinkage with RHA %

A decreasing trend in linear shrinkage was observed with increasing percentage of RHA. (Figure 7). It decreases from 3.96% to 2.16%. Sultana *et al.* [15] has also found the same behaviour of linear shrinkage when RHA is added to clay. This reduction of linear shrinkage is due to presence of more amorphous silica in RHA as explained by Kumar *et al.* [17]. This is favourable for roof tiles hence it will be helpful to eliminate cracks, warping and many other defects which reduce their durability.

3.1.5 Chemical Analysis of RHA

Table 1 : Chemical composition of RHA

Component	Percentage (%)
SiO_2	84.14
Al_2O_3	4.08
Fe_2O_3	1.15
CaO	0.97
MgO	0.44
SO_3	0.05
K_2O	1.34
Na_2O	1.69
LOI	6.13

SiO_2 is the major component in RHA which is 84.14% of total weight (Table 1). This high amount of SiO_2 is found to be the main reason for strength gain property of RHA added building materials [3]. It has been reported SiO_2 percentage in brick kiln RHA as 77.21 % by Kazmi *et al.* [3].

3.2 Tile Specimens

3.2.1 Transverse Breaking Load

Transverse breaking load of tiles is increasing with RHA content up to 10% RHA replacement (Figure 8). It increases with RHA percentage up to 10% replacement. High amount of SiO_2 presented in RHA would be the reason for this strength gain. Nevertheless, large amount of RHA addition is not desired as it makes bond between RHA and clay particles weak. Maximum breaking load was recorded as 1149.54 N for 10% RHA replacement which is an increment of load of 47.24%. The requirement for breaking load of Class A type roof tile is 900N [11] which is satisfied by 5%, 10% and 15% RHA replaced tiles. However this test needs further studies.

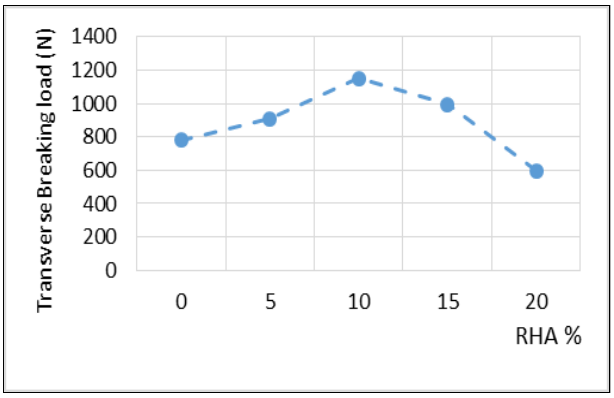

Figure 8 : Variation in Transverse Breaking Load with RHA %

3.2.2 Bulk Density

When increasing the RHA percentage, bulk density of the roof tile decreases slightly (Figure 9). 10%, 15% and 20% RHA replacements give 3.04%, 6.16% and 7.77% density reductions, respectively. This is due to the lesser specific gravity of RHA when compared to clay as discussed in preceding section. Hence, higher the RHA percentage in the tile, lesser the weight of the tile. This will ultimately result cost reduction in building construction starting from the foundation due to the lesser weight of the roof.

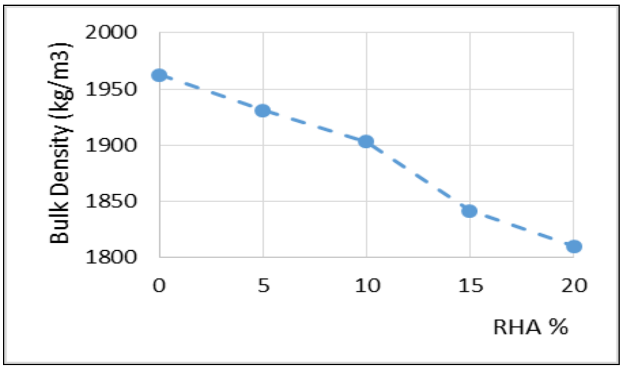

Figure 9 : Variation in Bulk density with RHA

3.2.3 Water Absorption

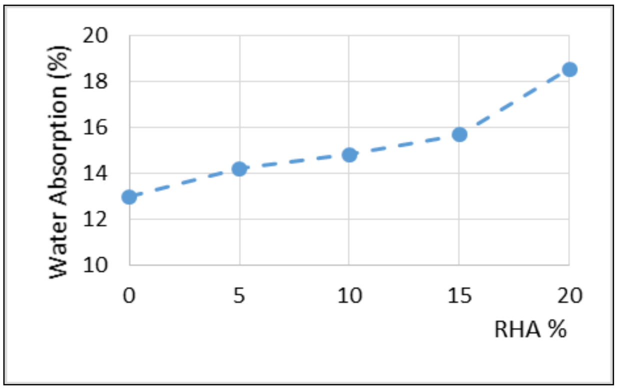

Figure 10 : Variation in Water Absorption with different RHA %

3.2.4 Thermal Properties

Figure 10 shows water absorption of tiles for each percentage of RHA. Water absorption increases when RHA content is higher. Water absorption of conventional roof tile (0% RHA) remains as 12.98% whereas that in 15 % and 20% RHA tile has reached to a value of 15.68% and 18.55%, respectively. However, when water absorption is higher, more water remains in the tile causing the growth of small plants and moss on the roof which reduces the durability and aesthetic appearance. Sultana et al. [15] also found the increment of water absorption when RHA replacement with clay is increased. According to Bureau of Indian Standards [11], the maximum value for water absorption of clay roof tiles is 18%. Hence, addition of RHA up to 15%, is acceptable considering water absorption.

Variation of temperature of the beneath of the tile specimen throughout a sunny day are presented in Figure 11. In most of cases, the tile having the highest (20%) and lowest (0%) RHA content were having the lowest and highest temperatures respectively. There is a trend of reducing the inside temperature when the RHA percentage in

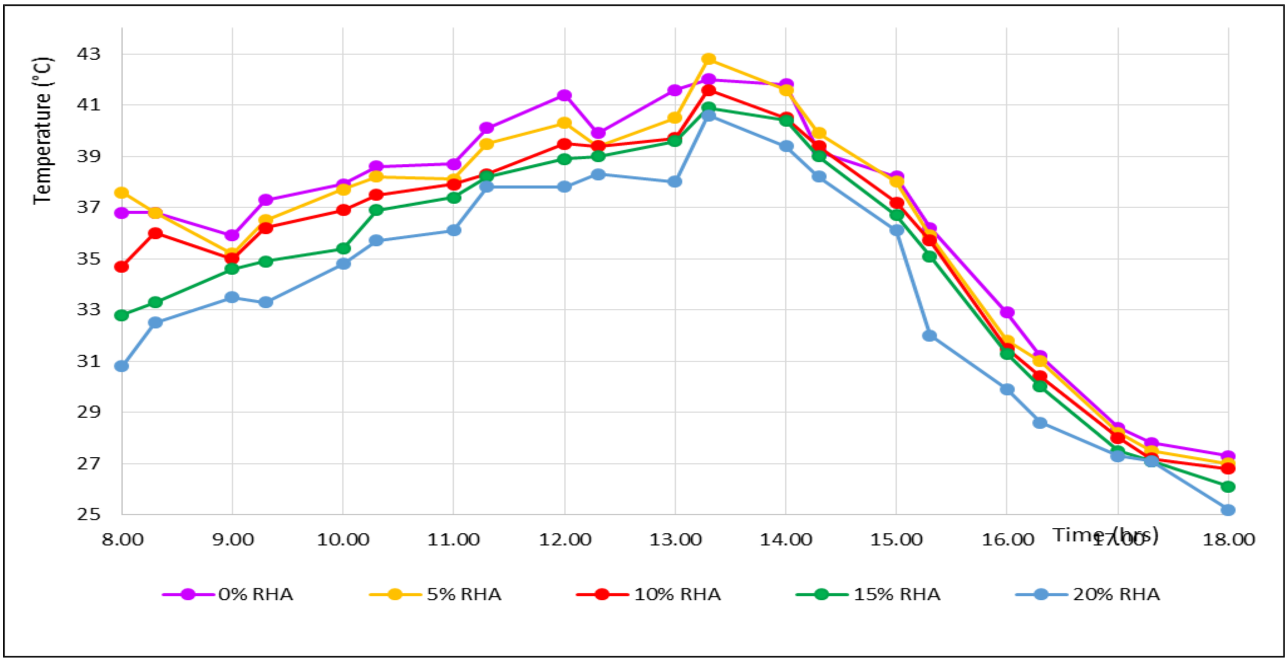

Figure 11 : Variation of inside temperature

the roof tile increases. This reduction of thermal conductivity may be due to the improved porous nature of the roof tile with the addition of RHA. Therefore, by having RHA added clay tiles in the roof, inside environment can be made further cooler.

4 Conclusions

The rice husk ash (RHA) that is produced as a waste material from the clay brick production process in Sri Lanka contains high amount of silica and found to be suitable to use to enhance the properties of clay roof tiles.

10% replacement of RHA shows 47.24% increment of transverse breaking load. RHA addition reduces bulk density and thermal conductivity.

Reduction of linear shrinkage indicates the reduction of the risk of defects of roof tiles such as cracking and warping. However, RHA increases water absorption of roof tiles.

As a whole, use of RHA in the production of roof tiles helps to enhance the structural and thermal properties. This also provides a solution for environmental damage caused by open dumping of RHA as waste.

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