STRUCTURAL AND THERMAL PERFORMANCES OF RICE HUSK ASH (RHA) BASED SAND CEMENT BLOCK

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Abstract: The sand cement blocks have been used in many countries of the world including Sri Lanka over a long period and it plays a major role in the building and construction industry. However, in order to make the indoor environment of the building as thermally comfortable as well as for achieving high structural performances, it is useful to use an alternative material to make blocks and bricks.

Rice Husk Ash (RHA) is a by-product obtained from the combustion of rice husk which consists of non-crystalline silicon dioxide RHA having pozzolanic properties would reduce the demand of Portland cement whose cost has risen in Sri Lanka. The paper focuses on the study of structural characteristics and thermal performance of Rice Husk Ash (RHA) based sand cement blocks through an experimental investigation.

Strength characteristics of the blocks were investigated by conducting laboratory experiments. Thermal behavior of the block was investigated by comparing the variation of indoor temperatures in two model houses constructed with the sand cement blocks and Rice husk Ash (RHA) based sand cement blocks. It was found that the optimum compressive strength of RHA based cement sand block is achieved at 5% replacement level. The RHA based sand cement block make indoor environment more thermally comfortable than the sand cement block.

1. INTRODUCTION

Different types of bricks and blocks are used in building construction in Sri Lanka and also in other countries. They are generally used for load bearing and non load bearing walls. Structural performances and thermal comfortable are mainly considered when masonry units are used for constructing walls. Blocks should absorb the heat in the day time and slowly releasing it in the night time, to ensure internal temperatures are consistent during the day time and the night time.

Block units absorb water due to their porous nature. The volume of water absorbed is an indication of the pore volume which depends on the interstitial arrangement of the particles of the constituent material at micro level. In using blocks for external wall in humid climate, the density and water resistant ability of the blocks must be considered in order to minimize penetration of moisture or rain water into the interior of the building. Similarly, when block work is to be constructed as canals for drainage, blocks to be used must have a very low value of water absorption coefficient and hence, highly impermeable. Damp penetration weakens the blocks and block work can collapse. [1]

Sri Lanka is a tropical country where warm humid climate conditions prevail and the occurrence of hot discomfort is felt within the built environment during the day time [2]. Many building designers in this region have ignored the climate in their wall construction probably because they adopt same old traditional methods in their house construction. The difference in indoor thermal comfort levels can significantly affect the running cost of the building. The use of fans and air conditioners, which lead to higher electrical consumption, can be reduced with higher indoor thermal comfort rice husk ash blocks comprise of natural sand, water and binder.
This research study has concentrated only the sand cement blocks production. Sand cement blocks containing mixture of sand, cement and water are used extensively in many countries of the world especially in Sri Lanka. As the cost of cement is increasing significantly in these days, this research is carried out to replace the cement with Rice Husk Ash (RHA) by getting a satisfactory strength level and thermally comfortable for sand cement blocks. Since the Sri Lanka is a developing country, the block which is made with RHA is better to use in low cost building construction. Also the open air burning of RHA makes pollution to the environment. It is easy to get RHA for rice producing

countries. Therefore replacing cement with RHA could be economically counterproductive for local sand cement block manufactures at the same time; the unit cost of making block can be reduced. Well graded fine materials of RHA will fill the voids and high compressive strength can be expected than currently using sand cement block as well as with the low water absorption properties.

In practice, the type of ash varies considerably according to the burning technique. The silica in the ash undergoes structural transformations depending on the conditions (time, temperature etc) of combustion. At 550°C – 800°C amorphous ash is formed and at temperatures greater than this, crystalline ash is formed. These types of silica have different properties and it is important to produce ash of the correct specification for the particular end use [3].

Open burning and oven burning can be used for producing the rice husk ash (RHA) and it cannot be suitable temperature for producing rice husk ash in an open burning, also lot of unburnt carbon can be exist in the rice husk ash. Even though, temperature can be controlled in oven burning less amount of rice husk ash can be produced with long time consuming. Hence it also not economical for producing the rice husks ash. Local brick burning place waste lot of amount of rice husk ash than above methods. Temperature can't be controlled and long hour burning is occurred. It may be economical and advantage if they use for manufacturing sand cement block with suitable compressive strength. Therefore this study investigates effect of partially replacing cement with the RHA mainly on the structural and thermal performances in the manufacture of masonry blocks.

2. OBJECTIVES

This research was carried out with the following main objectives;

- To investigate the utilization of locally produced Rice Husk Ash (RHA)
- To investigate an optimum proportion of the Rice Husk Ash (RHA) with satisfactory level of compressive strength.
- To find the Water absorption properties of the RHA based cement-sand block.
- To find the thermal performances of the block.

3. METHODOLOGY

3.1 Materials

For the purpose of this research Rice Husk Ash (RHA) was selected from the Kiln and sieve analysis was carried out so as to determine the particle size distribution. Particle size of 150µm RHA retained (Sample 1), 75µm RHA retained (Sample 2) and 75µm passing (Sample 3) were selected for the study (Figures 3.1 and 3.2).

3.2 Manufacturing of Blocks

First, the RHA was mixed with the cement and then the mortar was prepared as usual. Solid masonry block having the size of 360mm×100mmx170mm were cast with the mix proportion of 1:6 cement-sand by using local block manufacturing machine. The water-cement ratio was controlled to 0.64.

Characteristics of RHA based sand cement blocks having six different RHA contents (5%, 10%, 15%, 20%, 25% and 30%) have been examined so as to investigate RHA used as partial replacement of cement. The RHA based sand cement block was manufactured with Samples 1, 2 and 3 to investigate the compressive strength of blocks (Figure 3.3 and 3.4).

3.3 Compressive Strength

The compressive strength was investigated with the laboratory experiment by using crushing machine as shown in Figure 3.5. Three samples were tested for each replacement level at 28 days and averaged. The strength characteristics of RHA based sand cement blocks were compared with the 0% of RHA content cement sand bock (Control block). The block with replacement level which gives optimum compressive strength was selected for investigation of thermal performance.

3.4 Water Absorption

Water absorption test was carried out to identify and specify the water absorption properties of developed RHA based sand cement block (Figure 3.6). The blocks manufactured with Samples 1and 2 only used to test the water absorption.

Three samples of both sand cement blocks and developed RHA based sand cement blocks were used for water absorption test. First, the blocks were kept in an oven at a temperature of 100-105 °C, for the time period of 24 hours and the dry weights of the blocks were measured. Then the same blocks were immersed in water for the time period of 24 hours and the wet weights were measured. Water absorption of individual sample blocks was determined and the average values were computed.

3.5 Thermal Performances

To ensure the thermal property of RHA, two model houses were constructed, one from sand cement blocks and the other from the blocks manufactured with the Rice Husk Ash (RHA) (Figures 3.7(a) and (b)). All four walls of model houses were constructed with those blocks to explore the thermal properties. The size of the both model houses is 1m x 1m x 1m. For both model houses, cement-corrugated sheets were used for roofing and the floors were cemented. Identical conditions (i.e. Building sizes, roof and floor materials, Building orientation and size and orientation of openings) were provided for both model houses except the wall material. The mortar mix having 1:5 cement: sand was used to construct the walls of the model houses. Opening size is 500 mm x 900mm and the plywood sheets were used for doors.

Temperatures were measured throughout a day (24 Hours) in June to monitor the thermal behavior of both sand cement block and RHA based sand cement block. The weather condition on this particular day was sunny day. Outdoor air temperature, Indoor air temperature, outdoor block surface temperature and Indoor block surface temperature were measured for 15 minutes interval. Air temperature was measured by using a hygrometer and the block surface temperature was measured by using a digital thermometer

4. RESULTS

4.1 Chemical Composition of RHA

The Figure 4.1 shows the chemical composition of rice husk ash which collected from the kiln. The total percentage composition of iron oxide (Fe_2O_3=1.56%), Silicon dioxide (SiO_2=91.75%) and Aluminium Oxide (Al_2O_3=2.07%) was found to be 95.38%.

4.2 Compressive Strength

The average 28 days compressive strength of blocks manufactured with different RHA (Sample 2) replacement level is shown in Table 4.1

The variation of average 28 days compressive strength of blocks with RHA content for blocks manufactured with Sample 2 is shown in Figure 4.2. The optimum compressive strength was obtained at 5% RHA replacement level and it complies with the minimum standard value of 2.8 N/mm^2 according to BS 6073: Part 2: 1981 [4]. And also the variation of compressive strength with % of RHA for Sample 1, Sample 2 and Sample 3 at 28 days is shown in Figure 4.3.

4.3 Water Absorption

The average water absorption of blocks manufactured with different RHA (Sample 2) replacement level is shown in Table 4.2

Table 4.1: *Compressive strength of blocks manufactured with Sample 2*

Block Type (Percentage of RHA)	Average Compressive Strength (N/mm^2)
0% RHA	2.486
5% RHA	**2.928**
10% RHA	1.776
15% RHA	1.933
20% RHA	1.979
25% RHA	1.491
30% RHA	1.323

Table 4.2: *The Water absorption of Blocks*

Type of Blocks (Percentage of RHA)	Average Water Absorption (%)
0% RHA	14.255
5% RHA	**16.583**
10% RHA	17.499
15% RHA	21.788

The results show that the water absorption increases with the percentage of RHA content for blocks developed with Sample 2. But the acceptable value is 12% for masonry blocks according to BS 5628: Part 1: 2005 [5]. And the value obtained is greater than the acceptable value. Also the variation of water absorption with % of RHA for Sample 1and sample 2 is shown in Figure 4.4.

4.4 Thermal Performances

The variation of indoor air temperature with time for both model houses is shown in Figure 4.5. The results clearly show that, the indoor temperature of model house which was constructed with manufactured RHA (at 5% replacement level) based sand cement block is lower than that model house which was constructed with sand cement block for the time period of 9 a.m. to 12 a.m. and in the night time from 1 a.m. to 8 a.m. For the rest of the period of the day, the indoor temperature of model house which was constructed with manufactured RHA (at 5% replacement level) based sand cement block is almost same as the model house which was constructed with sand cement block.

The difference in outdoor surface temperature and indoor surface temperature for both model houses were compared in Figure 4.6. The results show that between 10.30 am to 2.00 pm the (outside- inside) surface temperature is greater for RHA based sand cement block than the sand cement block. And for the remaining time period of the day the fluctuations reduce for both model houses and almost the same temperature was observed.

5. DISCUSSION

5.1 Structural Performances

Compressive strength of RHA based sand cement block increase at 5% RHA (Table 4.1). It is the 17% development of the compressive strength comparing 0% RHA. This may be due to pozzolanic reaction of RHA. Hydration of cement increases the P^H value of the water. Under high P^H value SiO_2 in the mix dissolves. The hydrous silica reacts with Ca^{2+} and produce insoluble compounds (CSH) called secondary cementitous products. With the curing Insoluble compounds produce harden for the mixture. This may contribute to increase the compressive strength of the RHA based sand cement block at 5% RHA content. Further addition of RHA causes decrease in compressive strength.
The chemical reaction involves fixing of $Ca(OH)_2$ in liquid phase from the hydrating cement with the silica in the pozzolana. For lower percentage replacement in such as 5% the silica from the pozzolana is in required amount. This aids the hydration process producing with high compressive strength. For higher replacement level such as 10%, 15%, 20%, 25% and 30%, the amount of Rice Husk Ash in the mix is higher than required to combine with the liberated calcium hydroxide in the course of the hydration. The excess silica substitute part of the cementitious materials and consequently causing a reduction in strength.

However the water absorption results show the considerable water absorbent behavior has to the rice husk ash and also it is expected that the porosity increases with addition of RHA. Also as the RHA collected from the Brick Kiln, it may consist of the burnt clay particle and it would also absorb some amount of water.

5.2 Thermal Performances

The temperature variation shows (Figure 4.5) that the RHA based sand cement blocks have a significant thermal performance than the sand cement block. This shows that for a high thermal mass material, it should have the ability to absorb the heat at day time and release the absorbed heat at night time. Also the results showed that the maximum indoor temperature difference between two model houses is 2 °C and it was experienced at 1.00pm.

At the beginning of the late night, it is seems that the RHA based sand cement blocks started to release the heat, which was stored at day time, assuring the high thermal mass performance. This behaviour causes to maintain an approximately constant temperature, around the optimum, in the indoor environment, while sand cement block maintain a slightly lower temperature at night time and higher temperature in day time compared to the optimum.

6. CONCLUSIONS

The rice husk ash wasted from brick burning place is pozzolonic and therefore is suitable for use in manufacturing masonry blocks. Also the RHA based sand cement blocks can make indoor environments more thermally comfortable than the sand cement blocks with the satisfactory level of strength and the RHA based sand cement block is most suitable for internal wall as it has considerable water absorbent behavior.

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[4] BS 6073-2: 1981 Precast concrete masonry units. Method for specifying precast masonry units

[5] BS 5628-1: 2005 Code of practice for the use of masonry. Structural use of unreinforced masonry

Figure 3.1 Brick Kiln

Figure 3.2 Collected RHA Sample

Figure 3.3 RHA based cement-sand blocks

Figure 3.4 Local block manufacturing machine

Figure 3.5 Compressive Strength Testing

Figure 3.6 Weighing Balance

Figure 3.7(a) Model House

Figure 3.7(b) Model House

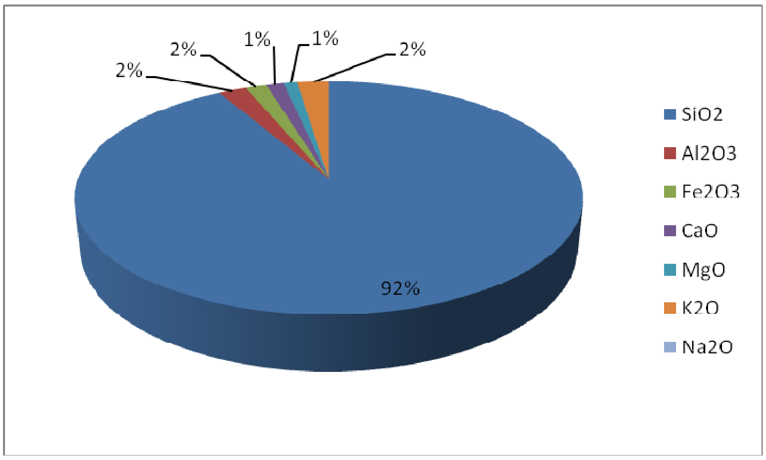

Figure 4.1: The Chemical Composition of RHA

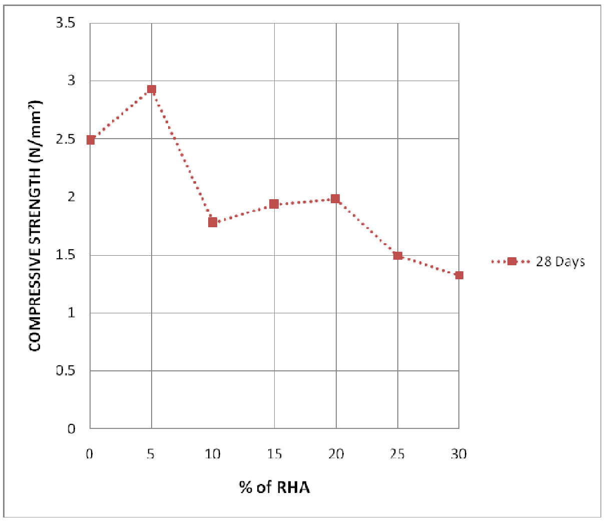

Figure 4.2: The Variation of Compressive Strength with % of RHA (Sample 2) content for with the replacement of cement

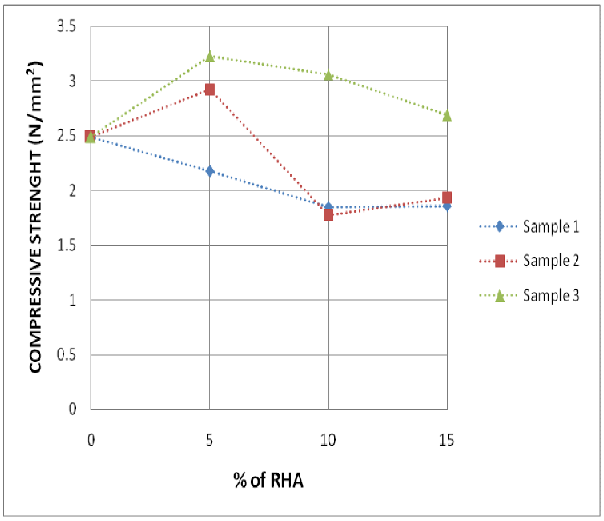

Figure 4.3: The Variation of Compressive Strength with % of RHA for various particle sizes of RHA at 28 days

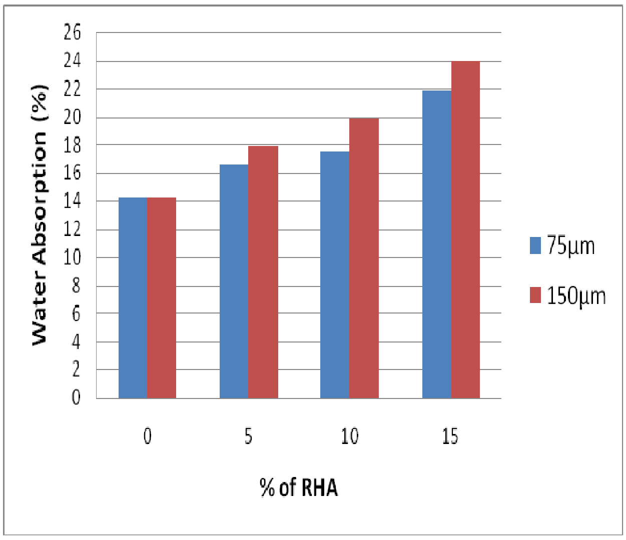

Figure 4.4: The Variation of water Absorption

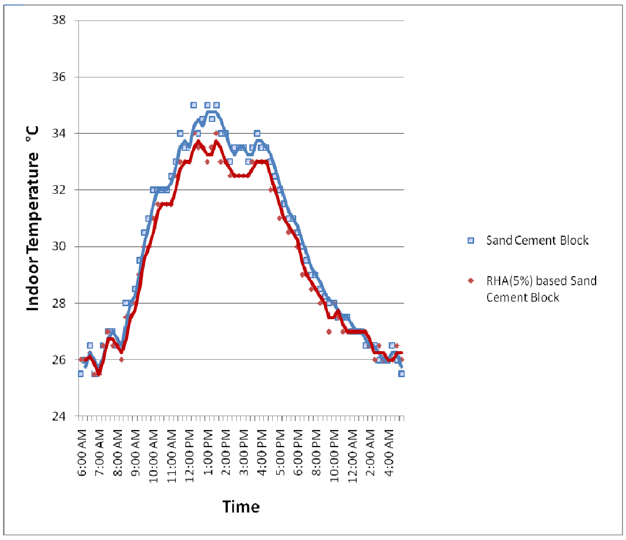

Figure 4.5: The Variation of Indoor Temperature with Time for both Model Houses

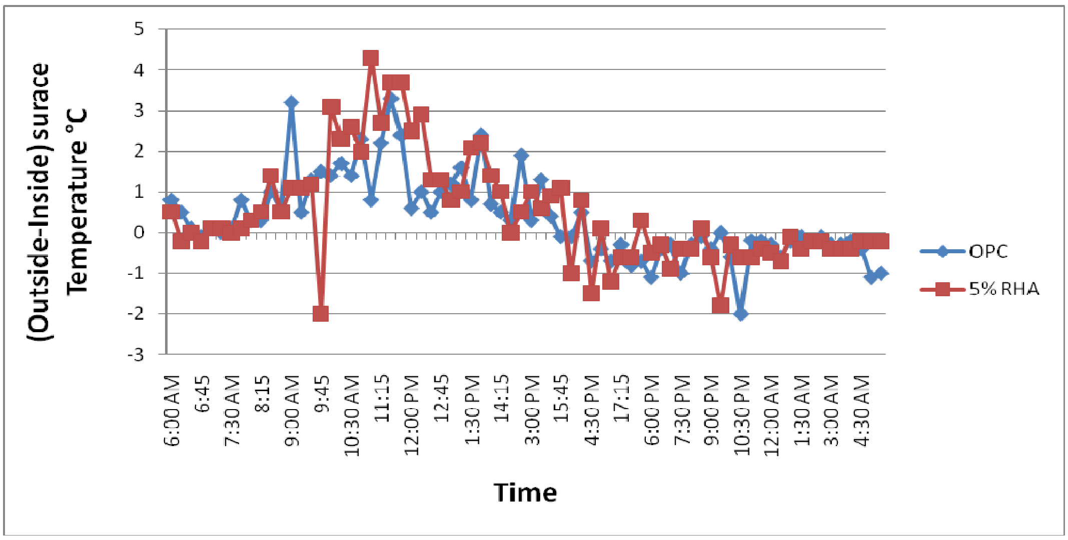

Figure 4.6: The Variation of (Outside-Inside) Surface Temperature with Time for both Model Houses