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Performance of Sand Cement Block Produced With Partial Replacement of Cement by Rice Husk Ash

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Abstract: The sand cement blocks are cement composites and have been widely used in many countries including Sri Lanka. Rice husk ash (RHA) is a waste material with pozzolanic properties. The use of RHA as a substitute of cement is a sustainable application which solves the problem of its disposal by minimizing the environmental pollution. This paper discusses on the performance of a cellular sand cement block containing rice husk ash through an experimental investigation. The burning temperature of the RHA obtained from power plant is 650^oC. Ordinary Portland Cement (OPC) was partially replaced with RHA having different fineness at 5%, 10% and 15% replacement levels to produce sand cement blocks. Particle size of the finer RHA was less than 75 µm. Compressive strength increased up to the 10% cement replacement level only with finer RHA. Replacement percentage beyond the 10% lead to decrease the compressive strength of sand cement block. However, cement replacement with coarser RHA decreased the compressive strength at all the replacement percentages. The density of sand cement block decreased as RHA content increased. Moreover, higher water absorption capacity was observed at higher RHA content.

Keywords: Cement, Compressive strength, Rice husk ash, Sand cement block

1. Introduction

The utilization of rice husk ash as a cement replacement is a new trend in concrete technology as it enhances the properties of concrete and mortar while minimizes the negative environmental impacts. Rice husk is an agro-waste product obtained from the outer covering of rice grains during the milling process. Rice husk contains about 50% cellulose, 25-30% lignin and 15-20% silica (SiO_2) and it constitutes 20% of the 500 million metric tons of rice harvested annually in the word [4].

RHA is used as a partial replacement of cement on structural properties of concrete and mortar, reducing the cost for cement and is produced by the controlled incineration of rice husks to obtain high amount of amorphous silica with low carbon content. Suitable incinerator and grinding method are required for burning and grinding in order to obtain good quality ash [8].More than 90% (in mass) of the RHA which is produced in optimum combustion temperature of 600 ^oC is made up of amorphous silica [7].Generally, the average particle sizeranges from 5 to 10 µm, and the specific surface area ranges from 20 to 50 m^2/g, depend on the conditions of burning and grinding. However, controlled combustion of rice husks produces good quality ash with higher amount of amorphous silica compared to open field burning which results for the higher amount of unburnt carbon in the ash. Amorphous silica reacts with the $Ca(OH)_2$ produced during the hydration of cement by producing secondary type of calcium silicate hydrate gel which leads to higher strength development of mortar and concrete.RHA is an active pozzolan which improves strength because they are smaller than the cement particles and provide a finer pore structure.

Cement blocks are masonry units generally used for the building construction in Sri Lanka. They are used for load bearing and non-load bearing walls. Therefore, structural performances of blocks should be mainly considered for wall types. There is an increasing interest of using sand cement blocks made with RHA as masonry units in building and minor civil engineering constructions since it reduces the cost for cement used in sand cement block production. The use of RHA in sand cement block also decreases the solar heat gain in buildings and improves the thermal comfort [5]. The RHA based sand cement block shows higher water absorption properties compared to block made with 0% RHA. Moreover, density of sand cement block also decreases with amount of RHA.

Therefore this research is aimed at investigating the effect of partially replacing cement with the RHA having different fineness mainly on the compressive strength, density and water absorption of sand cement block.

2. Experimental Programme

2.1 Materials

For the purpose of this research Ordinary Portland cement complying with BS 12 [3] was used. Rice husk ash was obtained from Bio-energy power plant is shown in Figure 1.

Figure 1: As-received RHA

Sieve analysis was carried out to prepare two RHA samples having different fineness. According to Table 1, Particle size less than 75μm was considered as sample U while particle size between 75-150 μm was considered as sample M.

Table 1: Sample notation of RHA

RHA sample type	Particle size
U	< 75 μm
M	75-150 μm

Locally available natural river sand was used as fine aggregate with maximum aggregate size of 5 mm. Pipe borne water, fit for drinking was used for the manufacturing and curing of sand cement blocks.

2.2 Preparation of blocks

The cellular sand cement block samples having the size of 390mm x 100mm x 195mm were produced by using local block manufacturing machine shownin Figure 2.

Figure 2: Local block manufacturing machine

The cement-sand mix proportion of 1:6 was used to prepare the sand cement block samples. Batching was done by volume. Predetermined material quantities were measured by using a weighing balance. Three cement replacement percentages with RHA by weight (i.e., 5%, 10% and 15%) were used. The constant water/binder ratio of 0.7 was used for the manufacturing all sand cement blocks. Hand mixing was employed throughout the process. The sand cement blocks were prepared with RHA sample U and sample M for each replacement percentage. Figure 3 shows the prepared RHA based sand cement blocks.

Figure 3: RHA based sand cement blocks

2.3 Testing methods

2.3.1 Compressive strength

Crushing machine was used to measure the compressive strength of block samples as shown in Figure 4. Two block samples were tested for each replacement percentage at 28 days and average strength was calculated. Compressive strength values of sand cement blocks made with RHA were compared with the compressive strength of control (0% RHA) block.

Figure 4: Compressive strength testing

2.3.2 Water absorption

Water absorption test was carried out to compare the water absorption behaviour of RHA based sandcement blocks with control block sample. Hence, two block samples from each replacement percentage were first kept in an oven for 24 hours at a temperature of 100°C-105°C and dry weights were measured as shown in Figure 5. Then the block samples were immersed in water for 24 hours and wet weights were measured. Water absorption capacity was determined for each block sample and the average values were calculated.

Figure 5: Weighing of oven dried sample

2.3.3 Density

For each replacement level, weights of two block samples were measured separately in their dry state after keeping in the oven for 24 hours at 100°C-105°C. Then densities of each block were calculated and average value was taken. Thereafter variation of density of blocks for each replacement percentage were compared with the control block sample.

3. Results and Discussion

The variation of compressive strength is shown in Figure 6. The optimum compressive strength was obtained at 10% cement replacement level for U series samples.

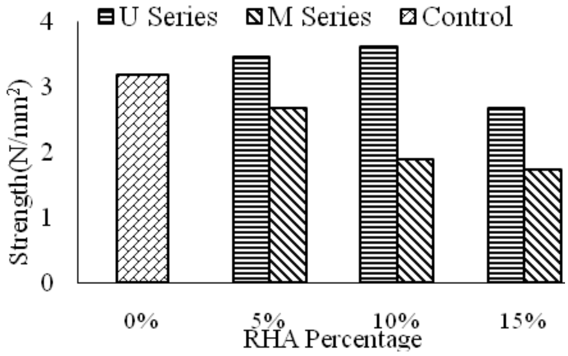

Figure 6: The variation of compressive strength at 28 days

However, 5% replacement level for samples in U series also showed the higher compressive strength than the control sample. These compressive strength values are higher than the specified minimum standard value of 2.8 N/mm^2 according to BS 6073: part 1:1981 [2].It can therefore be concluded that RHA sample U contains higher amorphous silica content than the sample M. Furthermore higher fineness of RHA sample U increases the reactivity of RHA particles resulting the higher compressive strength of blocks in U series.

Water absorption is another focused area of this study. The variation of water absorption is shown in Figure 7.

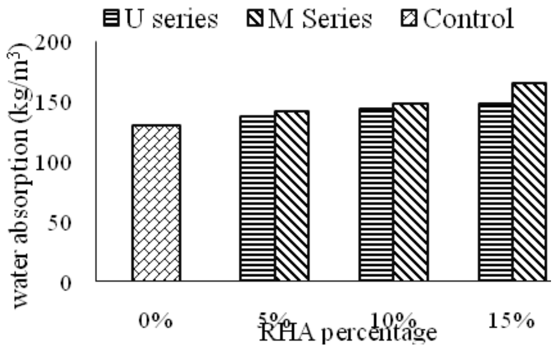

Figure 7: The variation of water absorption

Water absorption increases as the RHA content increases for both U and M samples. However, block made with coarser RHA (sample M) shows the highest water absorption behaviour. All the water absorption capacities are lower than the specified maximum value of 240 kg/m^{3}acccording to SLS: 855[6]. Therefore RHA based block samples show higher durability and resistance to moisture movement.

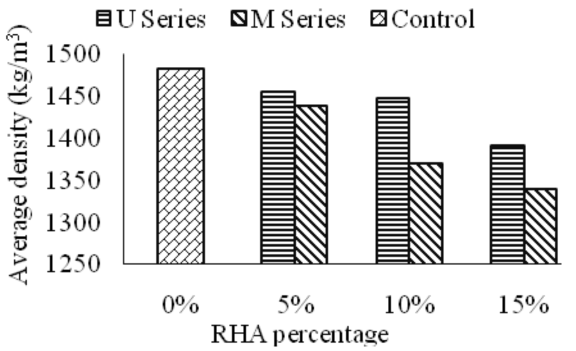

Figure 8: The variation of density

The variation of the density of RHA based sand cement block is shown in Figure 8. Density of RHA based sand cement block decreases as RHA percentage increases. Blocks without RHA show the highest density. This is due to the lower densities of both RHA samples than the density of cement.Lower densities were observed for block samples made with coarser RHA compared to block made with finer (sample U) RHA. It can be concluded that the density of RHA sample U is higher than the density of sample M. However, density values of all block samples are below the BS 2028 [1] minimum limit of 1940 kg/m^3.

4. Conclusions

The rice husk is an agricultural waste material, produced during the rice milling process especially in large scale paddy cultivation areas. The RHA is produced by burning of rice husks and it is identified as a pozzolan. Quality of RHA depends on the burning condition, temperature and grinding methods.

Partial replacement of the ordinary Portland cement with 5% and 10% RHA by mass yields increased strength at 28 days only in the case of block made with RHA having finer particles. Apart from that, 10% is the best percentage to replace the cement with finer RHA in terms of compressive strength.
RHA based sand cement blocks are suitable for external load bearing walls since it has lesser water absorption properties.

Furthermore light weight sand cement blocks can be produced by using this RHA wasted from the power plant. This is an initial approach on sustainable construction.

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