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Effect of Rice Husk Ash (RHA) on structural properties of fired clay bricks

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Abstract: In Sri Lanka, some amount of rice husk has been used as a fuel to fire bricks. However, rice husk ash (RHA) produced from the brick firing process has not yet been utilized effectively. Objective of this study is to utilize the rice husk ash wasted from the brick kiln to enhance structural properties of fired clay bricks.
Rice husk ash was collected from the brick kiln, located in Embilipitiya area, while the clay was collected from Dankotuwa area, where a brick manufacturing has been well established. Sieve analysis was performed for the collected RHA to identify the particle size distribution. The clay was mixed manually with different percentage of RHA: 0%, 2%, 4%, 6%, 8% and 10%. Atterberg limit of the mixture was investigated in order to identify suitability of the mixture for brick production. Bricks having a size of 195mm x 95mm x 50mm were cast manually and kept for drying. All the bricks were fired in a brick kiln. The burning temperature was within the range of 600 ^oC to 850 ^oC. Compressive strength and water absorption of fired bricks were investigated.
All percentages of addition of RHA improve the mixture for brick manufacturing. The optimum compressive strength of 3.55 N/mm^2 was found at 4% of addition of RHA. It was found that 32.7% improvement in the compressive strength of the bricks with 4% RHA addition compared to the control bricks (i.e., fired clay bricks with 0% of RHA), implying that RHA wasted from the brick kiln can be effectively used to improve the structural properties of the fired clay bricks.

Keywords: Rice Husk Ash (RHA), burnt clay bricks, compressive strength, water absorption, silicon aluminium ratio

1. Introduction

At present the generation of solid waste is enormously high. Hence large amount of environment impacts occur. Most of the solid waste has appreciable properties. Therefore waste materials can be used for various purposes as building materials. The major quantities of wastes generated from agricultural sources are rice husk, sugarcane bagasse, jute fibre, coconut husk, cotton stalk, etc. (Raut, et al. [1]).

Sri Lankans have been engaged in agricultural tasks since ancient time. Sri Lankan farmers produce large amount of rice, as a result, large amount of rice husk is disposed as waste. Rice husk ash (RHA) is obtained from burning of Rice husk. The husk is a by-product of the rice-milling industry. By weight, 10 % of the rice grain is rice husk. On burning the rice husk about 20 % becomes RHA. (Agus [2])

In Sri Lanka, rice husk is often used as a fuel. For example, in Embilipitiya area the handmade brick producers used rice husk to fire clay bricks and the resulting RHA is open dumped. The use of rice husk on energy production is a good practice. However, the wasting of RHA, which has high percentage of silica, is not appreciable. In some areas of Sri Lanka, the Rice husk is open burning. This practice causes a lot of environmental issues.
Izwan et al. [3] concluded that the risk husk ash burnt in a controlled manner with high temperature have high percentage of SiO_2 .According to the investigation of the De Silva and Uduweriya [4], ideal temperature for producing RHA with high pozzalonic activities is control buring at 600 ^oC for

2-3 hrs. In addition, they found that in the brick kiln, where the rice husks were burnt, the temperature varies from 600°C to 850°C. Chemical composition of RHA that are available in different countries has been investigated in previous studies (Agus [2], Ghassan et al. [5]. and Nilantha et al [6]) Nilantha et al. [6] have investigated the properties of the Sri Lankan RHA, which was collected from brick kiln. Agus [2] and Ghassan et al. [5] have investigated the properties of RHA obtained from control burning process. Chemical composition of RHA reported in above mentioned studies are compared in Table 1. It can be observed that the RHA collected from brick burning process contains high amount of SiO_2; similar to SiO_2 in RHA obtained from control burning process.

The fired clay bricks are very popular among public due to its low cost and thermal performance. The demand for the graded clay bricks is comparatively high. As mention in the Sri Lankan standards for handmade fired clay bricks the average compressive strength of bricks should be more than 2.8 N/mm^2 and the water absorption should be less than 28%. At present, bricks produced in most of the areas, was not able to reach these standards: the compressive strength and water absorption properties have a considerable deviation. However, if the brick has low compressive strength properties it directly influences on propagation of cracks. The wall should be capable of withstand humid weather conditions; if the walls have less water résistance, the water will penetrate into the building. When constructing a wall, burnt brick should be immersed in water to absorb water, otherwise the water, which is in the mortar will be absorbed by the blocks and then the mortar will not be properly strengthen. Hence the water absorption should be balanced. Major properties (i.e., compressive strength and water absorption) of the bricks should be satisfied in order to use bricks for constructing buildings.

To improve properties of the bricks, chemical behaviour of clay materials plays a major role. De Silva and Crenstil [7] have investigated the chemical behaviour of clay materials under different ratio of SiO_2/Al_2O_3 and found that the proper SiO_2/Al_2O_3 can improve the strength characteristics of clay. Adding RHA which contains high amount of silica to clay can be used as a method to increase the silicon/aluminium ratio.

Table 1: Chemical Compositions Rice Husk Ash

	Nilantha et al. [6]	Ghassan et al. [5]	Agus [2]
SiO_2	91.75	88.32	89.08
Al_2O_3	2.07	0.46	1.75
Fe_2O_3	1.56	0.67	0.88
CaO	1.3	0.67	1.29
MgO	1	0.44	0.64
Na_2O	0	-	0.85
K_2O	2.32	2.91	1.38
Loss in ignition	-	5.81	2.05

When constructing buildings the bricks play a key role by satisfying major properties such as compressive strength and water absorption.In addition, the properties of the material that used in burnt clay brick production should have liquid limit, plastic limit and plasticity index of 38.09%, 20.21%, and 17.78%, respectively (Lin et al.[9]), in order to mold a brick.

Objectives of the present study are,

- to investigate the effect of the Rice Husk Ash on compressive strength and water absorption of fired clay bricks in industrial scale brick manufacturing process.
- to investigate optimum mix proportion of RHA that can be used to manufactured fired clay bricks.

2. Methodology

Methodology includes selection of materials, manufacturing of fired brick with RHA in industrial scale and conducting experiments in the laboratory.

2.1 Materials

Clay: The clay for this study is collected from Dankotuwa (located in Puttlam District, North Western Province). It was collected from a pit about 1m deep near the bank of the river (Maa Oya, Sri-Lanka). The pit was dug and excavated with the aid of an excavator.

Rice Husk Ash: The rice husk ash was collected from the output of the brick kiln (Figure 1), located in Embilipitiya.

Figure 1: RHA collected from brick kiln

2.2 Manufacturing of Bricks

Different amount of rice husk were mixed with clay according to different weight percentages: 0% (control sample), 2%, 4%, 6%, 8% and 10%. The rice husk ash was used as silica (SiO_2) containing additive. The handmade bricks of dimensions 195mm x 95mm x 50mm were prepared using the moulds under local brick production workmanships. The materials were measured using weighing balance. The clay bricks were dried under the warm weather condition prevailing in dry zone in Sri Lanka. The clay bricks were fired in a brick kiln, which is the industrial scale manufacturing process of fired bricks in Sri Lanka.

When preparing the clay for the brick casting, first the collected clay was mixed with water and prepared it to a suitable with correct plasticity and the workability. This prepared clay was weighed and approximately 2.5kg clay samples were prepared. Then RHA was mixed with clay as weights shown in Table 2.

Table 2: RHA Sampling

Weight of RHA (g)	Percentage of RHA (%)
50	2
100	4
150	6
200	8
250	10

The RHA was mixed with clay manually while adding water until proper mixing reached The mix was placed in the mould and the clay brick was prepared. The prepared clay bricks were covered by saw dust to avoid engaging with other newly prepared clay bricks. The prepared clay bricks were kept one week for the drying. When the required drying condition of the clay bricks was achieved they were placed in the kiln for the burning process. The burning was done for two days continuously and kept about one week. Fired clay bricks were transported to the laboratories after two weeks and subjected to require experiments. Figure 2 shows the prepared clay bricks (a) before burning (b)after burning.

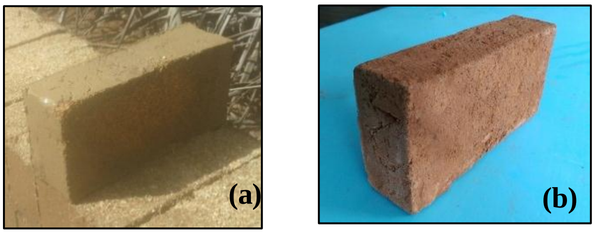

Figure 2: Manufactured Clay Bricks
(a) Before burning (b) After burning

2.3 Laboratory Experiments

Laboratory experiments were conducted to measure the probable property variation. The Atterberg test and the hydrometer analysis test were conducted to determine the suitability of the clay for brick manufacturing. The compressive strength test and water absorption test were conducted to measure the property variation due to addition of RHA.

2.3.1 Atterberg limit test

Atterberg limit test was performed to determine the liquid limit, plastic limit and plasticity index of the soil that was used to cast clay bricks and also the test was performed for clay soil with relevant mix proportions (0, 2, 4, 6, 8, and 10% RHA contents). Atterberg limit test was conducted in accordance with the British standard specification BS1377 (1990).

2.3.2 Sieve analysis for the RHA

The RHA was dried and large broken brick particles were removed. The weights of the sample and the weight of each sieve were measured. The set of sieves (2.36mm, 1.70mm, 1.18mm, 0.85mm, 0.60mm, 0.425mm, 0.25mm and 0.075mm)were arranged as the largest mesh opening was at the top and the smallest was at the bottom. The pan was attached at the bottom of the stake of sieves. The sample of RHA was poured on the top sieve and the cover plate was added to avoid dust and loss of particles while shaking. The stacks of sieves were placed on the mechanical shaker and horizontal shaking was applied for a time of 10 minutes. Then the weight of the sieve with remaining RHA was measured and the percentage of soil passing was determined.

2.3.3 Wet Sieve Analysis

The clay samples collected from Dankotuwa was subjected to the wet sieve analysis. The collected clay samples were put into a 1000ml measuring cylinder and water and sodium hexa sulphate were added and mixed thoughrouly. The cylinder was kept for 24 hours without any disturbance. The sample was mixed again and passed through the 0.075mm sieve. The remaining on the sieve was washed from water until the entire fine particles passed. The retained particles on the sieve and the pan were collected to the weighed pans separately. Then the samples were oven dried for 24 hours and the dry weights were measured. The retaining on the 0.075mm sieve was analysed using general method of sieve analysis descried in a preceding section.

2.3.4 Compressive Strength

The compressive strength was investigated by using the compressive strength machine available in the Construction and Building Materials laboratory. Six bricks from each level of RHA addition were tested (Figure 3) and average compressive strength was calculated. The strength characteristics were compared with the brick standards.

Figure 3: Testing of Bricks using Concrete Crushing Machine

2.3.5 Water Absorption

Water absorption test was performed to determine the water absorption property of the rice husk ash mixed fired clay bricks. Three bricks from each level of RHA addition were selected and the water absorption test was performed. First the samples were kept under the temperature of 100-105 ^{o}C for a period of 24 hours and the dry weight of the samples was measured. The same bricks that were dried in an oven were immersed in the water for a period of 24 hours and the wet weight of each brick was measured. Water absorption is defined as the ratio of the reduction of weight to dry weight of the brick and presented as a percentage. An average value of water absorption was calculated for each proportion of additive added bricks.

3. Results and Discussion

3.1 Suitability of the clay for brick production

Figure 4 shows the variation of the liquid limit with each RHA proportions. The addition of RHA up to 4% lead to decrease the liquid limit to a value of 37.2% and after that the liquid limit is gradually increased up to 40.1% with further addition of RHA. Reducing the liquid limit lead to less shrinkage and when it increases the dry strength permeability and the shrinkage are increasing (Lin and Weng [8]). Lin and Weng [8] have found a liquid limit of 38.09% as the clay soil. In the current study, 4% addition of RHA resulted a mixture with the liquid limit to be 37.2% and is a similar value compared with the findings of the Lin and Weng [8].

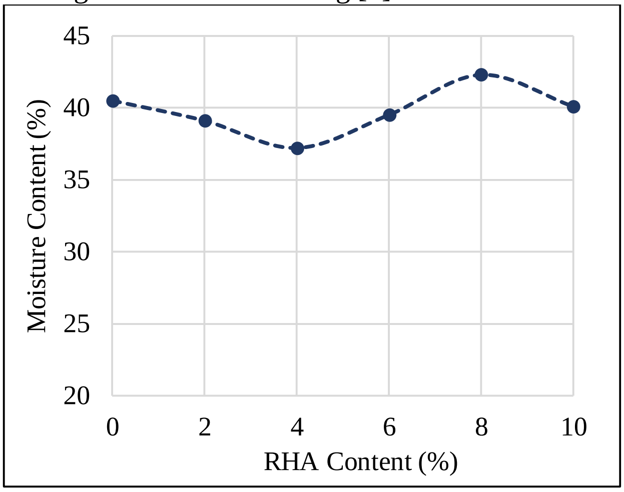

Figure 4: Liquid limit variation with RHA content

3.2 Particle size distribution of RHA

Particle size distribution of the RHA is presented in Figure 5. It can be observed that (250□m) sieve passing RHA particle percentage is 58.15%, indicating that the collected RHA samples consist with more fine particles. When the RHA particles are much finer the particles move much easier between clay particles. Consequently, the achievable degree of mixing of RHA to clay is significantly high and the expected reaction between clay and RHA at high temperature may have much efficiency.

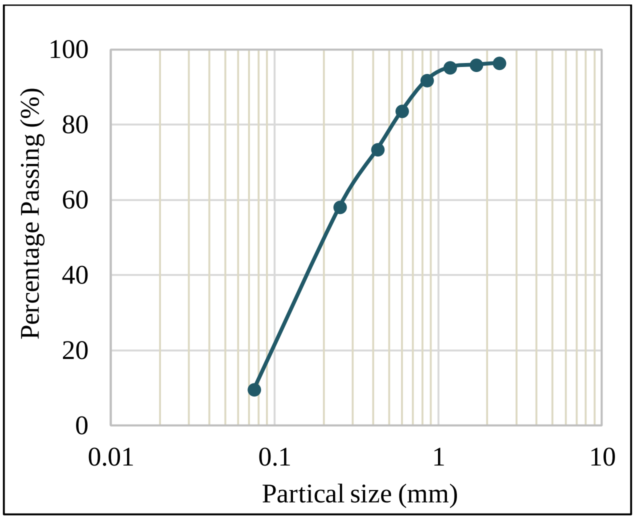

Figure 5: Particle Size Distribution Curve of RHA Sample

3.3 Particle size distribution of clay

Particle size distribution of the Dankotuwa clay is presented in Figure 6. It can be observed that the percentage of silt and clay (less than 0.□□□m) is more than 95% and the sand percentage is about 4%. It seems that Dankotuwa clay has high amount of micro particles which will contribute efficiently to the effective interaction with RHA particles.

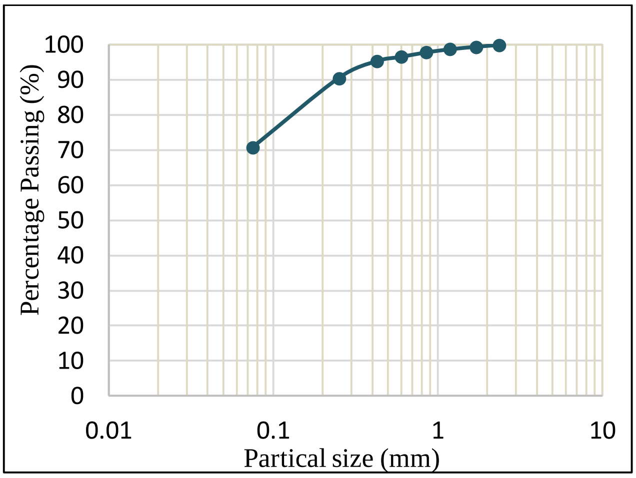

Figure 6: Particle Size Distribution Curve of Clay Sample

3.4 Compressive Strength

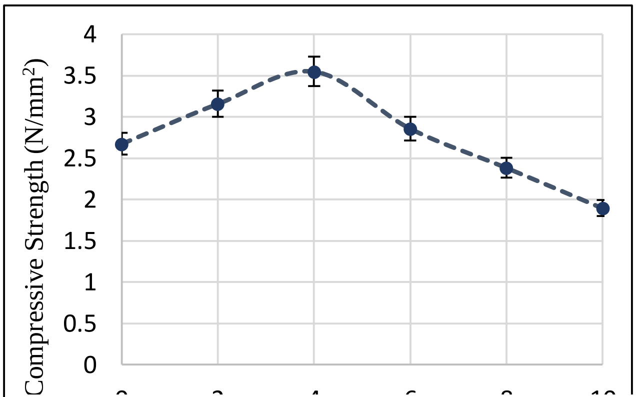

Figure 7: Compressive Strength variation of fired Clay Brick with different RHA content

The optimum compressive strength was found as $3.55N/mm^2$ at the 4% addition of RHA (32.7% improvement) (Figure 7). Compressive strength of 2.675 and $1.813N/mm^2$ were found at 0% and 10 % RHA respectively. When heating clay bricks a chemical recrystallization occurs. Amount of SiO_2 affects the strength gaining in the latest stage and also efficiency of the reaction and the amount of recrystallized material developed decide the latest strength (De Silva and Crenstil [7]). The strength increase up to 4% addition of the RHA can be explained through the amount of available RHA affects the latest stage strength gaining.

The recrystallization after dehydroxylation of water molecules, hence other parameters affect the process of dehydroxylation may cause to strength reduction after 4% addition of the RHA. The increase of water pressure increases the dehydroxylation temperature (De Silva [7]). Plasticity limit variation 19.3-33.7 indicates that the addition of RHA increase the amount of water content in the clay. Hence these conditions may cause the strength reduction after 4% addition of the RHA.

3.5 Water Absorption

It was found that until 0% to 4% addition of RHA, the water absorption does not have much variation, although it decreases (Figure 8). The addition of the RHA to 2% to 4% produce a good stable structure and it is explained that under the availability of the silica, later strength can be achieved hence the pores of the clay brick reduced and the water absorption reduced due to the activeness of better recrystallization. According to the plastic limits the increase of the water content increase with the addition of the RHA content. Hence the peak reaction temperature increase and it may occur a reduction in stable structure development or recrystallization. The increase of water absorption capacity indicates that the less recrystallization and less strength. According to Figures 7 and 8, it is indicated that when the water absorption increases the compressive strength decreases. Also this relationship defines that there may be an effect on water absorption to strength gain of fired clay bricks as explained in a preceding section

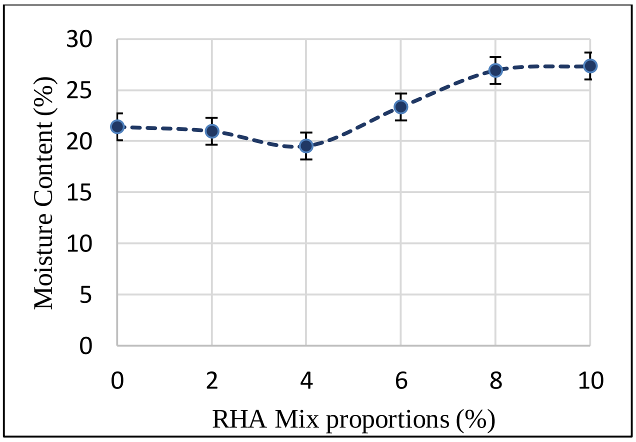

Figure 8: Water absorption variation of fired clay brick with different RHA content

4. Conclusions

The Rice Husk Ash (RHA) wasted from the brick kiln contains high amount of silica and can be used as SiO_2 provider for clay materials to increase SiO_2/Al_2O_3 ratio. The water absorption and compressive strength characteristics showed a great improvement with 4% RHA addition. The compressive strength of the fired clay brick was optimized with a value of $3.55N/mm^2$ which is greater than Sri Lankan standards. At this level of RHA addition, brick strength had an improvement of 32.7% (compared with 0% RHA addition) indicates that bricks are suitable for load bearing walls. At 4% RHA addition, the lowest water absorption was obtained with a value of 19.51%. A waste of RHA from a brick firing process can be utilised as an additive for manufacturing of the fired clay bricks which increase the strength characteristics. Utilization of RHA for clay brick manufacturing prevents environmental pollution caused by open dumping of rice husk and this will contribute to use the rice plant with a maximum efficiency.

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