

Experimental Investigation of the Effect of Fired Clay Brick on Partial Replacement of Rice Husk Ash (RHA) with Brick Clay

Fernando PR*

Eastern University, Chenkalady, Vanthrumoolai, Sri Lanka

Abstract

Clay bricks are more popular in building constructions than the cement/concrete bricks because of eco-friendly and low cost. These bricks have been made from clay, since they found. However, the quality of the bricks can be upgraded by doping with the agricultural natural waste materials. Rice husk (RH), is a most common and hugely abundant wastes that consist of SiO_2 percentage is RHA. In the present study, eight sets of brick were manufactured and each set consists of three bricks. These bricks were doped with RHA of ratio 0 to 30% of the total weight of mixture with a step of 5%. These bricks were allowed to dry for 3 days and fired in the brick kiln, which the traditional method is still used to burn bricks in Sri Lanka. The physical and mechanical properties of the burnt bricks were tested and compared with Sri Lankan Standard Specifications (S.L.S) as well as the British Standard Specifications (B.S.S) and compared with the commercially available brick made purely from clay. The bricks doped with RHA are obviously superior to the commercially available brick in the Eastern region of Sri Lanka. However, the brick doped with 5% RHA has higher compressibility of 3.7 N.mm^{-2} and the water absorption of 15.8% that satisfy the S.L.S and B.S.S.

Keywords: Clay bricks; Rice husk ash; Compressive strength; Water absorption; Eco-friendly

Introduction

A brick is one of the most important building materials that made of clay burnt in a kiln [1-3]. Brick is a mixture of non-metallic inorganic alloy, which are used all over the architectural works. In the middle age, bricks have lost importance and then became more popular again with various styles of architecture.

The importance of locally manufactured bricks has been emphasized in many countries due to their effortless availability and low cost; also, have been upgraded as one of the longest lasting and strongest materials, made from locally available sources. Common building brick is made of a mixture of clay that subjected to several processes, differing per the nature of the material, the method of manufacture and the character of the finished product [1-3]. Burnt brick is normally stronger than sun dried brick [3], but weaker than cement bricks in terms of strength and durability. This drawback in the overall efficiency of the clay brick can be improved by doping with a suitable agricultural waste along with clay in the manufacturing process [4-8]. In this study, the effects of doping in compressive strength and water absorption were analyzed.

Doping materials are used to upgrade the bond in-between the particles, thus the strength of the brick, which is either cementitious or pozzolanic materials. Lime is a traditional Pozzolanic material and wood ash, sawdust ash and fly ash [9-18] are non-traditional pozzolanic materials. Rice husks, sawdust, coal, etc., are the organic materials [6,19-21]. These organic materials control the burning temperature of the bricks, which is of principal importance. The higher burning temperature produces the higher quality yield.

The study was aimed to manufacture clay brick doping with RHA in different ratio, through the crystallization process. The manufactured should brick meets the essential values of compressive strength and water absorption assigned by the Sri Lankan Standard. The manufactured brick also expected to compete with commercial one, which was manufactured under the conditions of the study that is available in the Sri Lankan market.

Experimental Methodology

Materials

Pure clay: Clay was collected from Batticaloa (Eastern Province, Sri Lanka) is shown in Figure 1. Chemical analysis clearly confirms that the major chemical compounds of pure clay are silica, alumina, and ferric oxide, which are tabulated with the previous study by Badr El-Din et al. [9] in Table 1.



Figure 1: Pure Clay from Varpuvettuvan.

*Corresponding author: Dr. Fernando PR, Eastern University, Chenkalady, Vanthrumoolai, Sri Lanka, Tel: +94718497074/+94652228813; E-mail: Plusrf@gmail.com

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| Compounds (%) | SiO ₂ | Fe ₂ O ₃ | Al ₂ O ₃ | CaO | MgO | SO ₃ | Na ₂ O | K ₂ O | TiO ₂ | P ₂ O ₃ | LIO |
|------------------------|------------------|--------------------------------|--------------------------------|------|------|-----------------|-------------------|------------------|------------------|-------------------------------|------|
| Present study | 63.10 | 9.23 | 13.33 | 5.03 | 0.02 | 0.01 | 1.03 | 0.02 | - | - | 8.23 |
| Badr El-Din et al. [9] | 65.20 | 7.36 | 15.26 | 1.01 | 0.83 | 0.08 | 3.12 | 0.62 | 1.92 | 0.15 | 6.01 |

Table 1: Chemical compositions of pure clay collected from Varpuvettuvan.

Rice Husk Ash (RHA): RHA is produced by burning rice husk as shown in Figure 2. However, the physical properties of RHA greatly affects by burning conditions. Therefore, the optimum properties can be obtained by burning at 600°C to 900°C and held for 2 to 3 hours' time [22,23]. After the burning, huge amount of coarse ashes with large particle size were found in the grey-whitish ash, which requires crushing to standardize the particles before manufacturing. The crushing is done by a steel ball milling, which holds of a drum of 10 liters, fixed on a pair of rollers and driven by an electric motor. These steel balls move freely inside. The crushing is continued for 10 to 15 minutes, until the RHA change fully into fine dust. After crushing, the fine dust RHA is ready for brick manufacturing.

Higher percentage of silica can be observed in the RHA that taken from kiln, which is like silica obtained from the control burning system. The loss on ignition (LIO) in the RHA may possibly the existence of free carbon. Table 2 presents the chemical compositions of the RHA in the present study and compared with the previous studies indicate that the RHA is an excellent substitute for brick manufacturing [24,25].

Sample Preparation

In addition to the commercially available brick (Sri Lankan standard size: 20.5 cm × 9.5 cm × 7.5 cm, see Figure 3), eight different sets of brick were made for different weight percentages of rice husk ash as given in Table 3. Traditional brick manufacturing method was employed to mix the raw materials. In this method, materials were measured using weighing balance. In brick preparation, the pure clay was change into a proper plasticity and the workability by mixed with water. Then the prepared clay manually doped with RHA while adding water until proper mixing reached. The raw materials were put in a mould to get green molded bricks. The green bricks were protected by saw dust to keep away from engaging with other newly prepared green bricks. These green bricks were kept to direct air dry under sunlight of temperature around 35°C for one week. Then the green bricks were burned in a brick kiln (see Figure 4) of burning temperature range



Figure 2: Coarse ashes with large particle size were found in the grey-whitish ash obtained after burning at 600°C to 900°C.

| Compounds (%) | SiO ₂ | Fe ₂ O ₃ | Al ₂ O ₃ | CaO | MgO | SO ₃ | Na ₂ O | K ₂ O | TiO ₂ | LIO |
|------------------------|------------------|--------------------------------|--------------------------------|------|------|-----------------|-------------------|------------------|------------------|-------|
| Present study | 87.50 | 0.98 | 1.69 | 1.13 | 1.00 | 0.06 | 0.05 | 1.58 | - | 6.01 |
| Agus [23] | 89.08 | 0.88 | 1.75 | 1.29 | 0.64 | - | 0.85 | 1.38 | - | 2.05 |
| Ghassan et al. [24] | 88.32 | 0.67 | 0.46 | 0.67 | 0.44 | - | - | 2.91 | - | 5.81 |
| Nilantha et al. [25] | 91.75 | 1.56 | 2.07 | 1.3 | 1.0 | - | 0.0 | 2.32 | - | - |
| Badr El-Din et al. [9] | 82.40 | 0.26 | 0.65 | 2.42 | 1.71 | 0.52 | 0.30 | 1.63 | 0.01 | 10.09 |

Table 2: Chemical composition of RHA obtained after burning at 600°C to 900°C in the muffle furnace.



Figure 3: Sri Lankan standard brick size: 20.5 cm × 9.5 cm × 7.5 cm.

| Brick types | Brick Clay (Wt. %) | Rice husk ash (RHA) (Wt. %) |
|-------------------|--------------------|-----------------------------|
| Commercial Bricks | 100 | 00 |
| Type A | 95 | 05 |
| Type B | 90 | 10 |
| Type C | 85 | 15 |
| Type D | 80 | 20 |
| Type E | 75 | 25 |
| Type F | 70 | 30 |
| Type G | 65 | 35 |

Table 3: Eight different sets of brick consist of three bricks in each type prepared in different ratio.

600°C to 850°C, which is the traditional scale manufacturing method of bricks in the Eastern region of Sri Lanka. The burning process was continuously carried out for 2 days and kept about 7 days. The properties of the fired bricks were analyzed.

Analyzes of brick properties

Liquid limit, plastic limit, plasticity index, particle size, Compressive strength and water absorption were analyzed and the results of these properties were compared with the Sri Lankan standard.

Atterberg limit analysis: The liquid limit, plastic limit and plasticity index of the clay were analyzed by Atterberg limit analysis (British standard specification BS1377 (1990)).



Figure 4: Traditional firing method of clay bricks.

Particle size analysis: Particle analysis can be done by different size of sieves, but here this test was not done, because the aim of the research was to disseminate the knowledge to the local markets and improve the self-employment of the local community.

Water absorption analysis: Water absorption property of the fired bricks was analyzed for three bricks in each set. Initially, bricks were kept under the sunlight of temperature of 35°C to 40°C for one day and the dry weights were measured. These bricks were immersed in the water for one day and the wet weight was measured. Water absorption is presented as a percentage was calculated using the below equation, and the average value was calculated for each set of bricks.

$$\text{Water absorption} = \frac{M_2 - M_1}{M_1} \times 100\%$$

Where M_1 - Mass of the dry brick and M_2 - Mass of the wet brick after 24 hours.

Compressive strength analysis: Compressive strength analyses were done using Universal Testing Machine available in the Department of Physics, Eastern University, Sri Lanka. Three bricks from each set were measured and average compressive strength was determined, compared with the Sri Lankan standard.

Results and Discussion

Water absorption analysis

The water absorption as a function of RHA is shown in Figure 5. The water absorption results show a variation in the range between 15.5 and 25%. The curve shows a decreasing behavior when increasing the RHA percentage from 0 to 5%, thereafter the curve shows a sharp increase and level off when $RHA < 10\%$. The change in the behavior depends on the effect of firing temperatures that ensures the completion of the crystallization process and closes the open pores in the sinter, as well as the effect of the soft nature of the RHA particles, which severely decreases the open pores and significantly reduces the water absorption. Further increasing the $RHA > 10\%$, the water absorption increases due to the plastic limit of the clay. This effect indicates that the less recrystallization and less strength of the material. Comparing the Figures, indicate that the compressive strength decreases with water absorption increase.

Compressive strength analysis

Compressive strength of a brick depends on the porosity, pore size, and type of crystallization. It is frequently defined as the failure stress, which measured usually in the bed face of the brick. Figure 6 shows the compressive strength as a function of RHA percentage, which increases

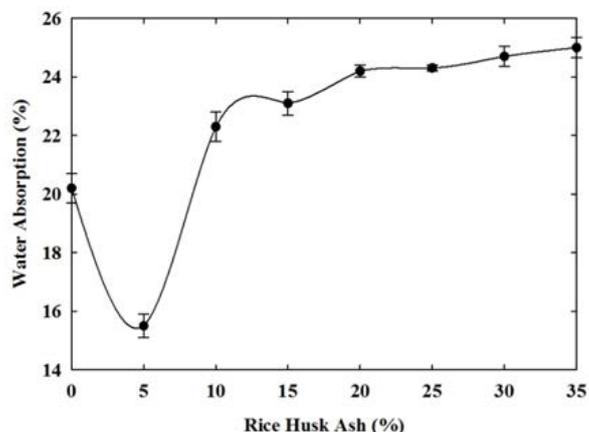


Figure 5: Behavior of water absorption as a function of Rice Husk Ash (%) for different types of clay bricks.

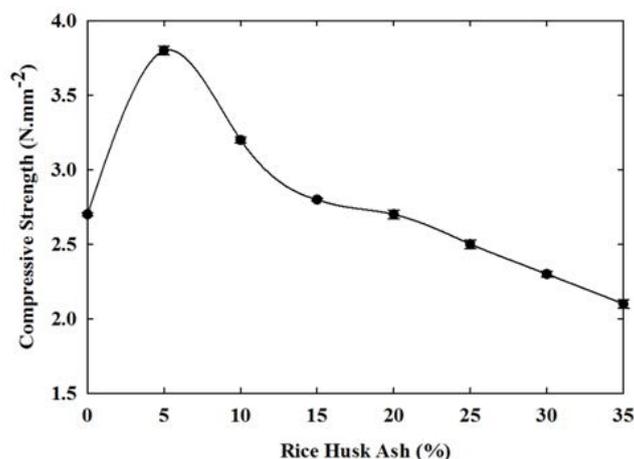


Figure 6: The compressive strength as a function of Rice Husk Ash (%) for different types of clay bricks.

with increasing RHA up to 5%, follows that decreases for $RHA > 5\%$. In the literature, the compressive strength varies between 2.1 to 3.8 $N.mm^{-2}$. The compressive strength of the commercial available clay brick is 2.7 $N.mm^{-2}$. In the present study, the compressive strength of the brick is 3.7 $N.mm^{-2}$.

The impact of terminating temperature on compressive quality might be inferable guarantees the fulfillment of the crystallization procedure, shuts the open pores in the sinter, and, therefore, increments compressive quality of the crystalline aluminosilicate bricks. Recrystallization after dehydroxylation of water pressure, thus different parameters influences the procedure of dehydroxylation may bring about to quality lessening, when $RHA > 5\%$. The dehydroxylation temperature increments with the expansion of water weight. While the impact of the out of shape nature of the RHA particles, which seriously builds the open pores in the sinter on diminishing compressive quality is much noteworthy than that of decreasing silica content. Accordingly, expanding RHA proportion for the most part reductions the open pores in the dirt RHA sinter and, thus, builds the compressive quality. The pliancy variety demonstrates that the water content increment with increment of RHA. Consequently, these variables might be a root for

the lessening of quality, when RHA>5%.

By and large, the compressive quality of the examination mud RHA block sorts is more than adequate contrasted with that of the business clay brick types that accessible in the Sri Lankan advertise.

Conclusions

The conclusions came to in this exploration depended on the analysis are:

1.1 Brick doped with 5% RHA has higher compressibility of 3.7 N.mm⁻² and the water absorption of 15.8% that satisfy the S.L.S and B.S.S.

1.2 The expansions of some agricultural waste materials; which contain high silica substance, for example, rice husk ash can upgrade the physical properties of clay bricks.

1.3 Homemade techniques, such as mixing, moulding and firing were used in this study.

1.4 Compressive strengths were analyzed by the Universal testing machine and the water absorptions were analyzed.

1.5 Clay-RHA block types were contenders with business clay bricks that accessible in the Sri Lankan showcase.

1.6 The ideal clay brick and rice husk fiery remains blend was 5%; by working at the temperatures ordinarily honed in the block industrial facilities and considering the test program executed in this exploration, and restricted on both the tried materials and testing methodology utilized.

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