COMPRESIVE STRENGTH, DENSITY AND WATER ABSORPATION OF CLAY BRICKS WITH PARTIAL REPLACEMENT OF LIME AND RICE HUSK ASH

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ABSTRACT

Rice Husk Ash (RHA) is the one of the most common agricultural wastes in Sri Lanka, which comprises higher percentage of silica. This silica can be obtained by burning the rice husk at high temperature; will significantly reduce the cost of production. The objective of this research is to investigate the physical properties of RHA and lime added clay bricks. The maximum strength and durability of the clay bricks will be determining by the percentage addition of lime with RHA. Eight different series of brick samples, which contains three units each, were manufactured to measure the compressive strength, density and water absorption. Each series consists seven brick samples of RHA ratio from 0 to 14 % and the lime ratio from 0 to 15% of the total weight of mixture. These brick were fired in the traditional brick kiln. Water absorption, compressive strength and density of the manufactured bricks were then analyzed and estimated according to Sri Lankan Standards (SLS) and compared with the commercially available brick made entirely from clay. Each analysis was performed for three brick samples in each series. Experimental evidence reveals a remarkable increment in the physical properties. However, the density and water absorption are lower than the market bricks. Maximum compressive strength was 4.9 N.mm^{-2} at 12.5% lime and 12.5% RHA combination. Physical properties of the new bricks are obviously higher than the bricks available in the local markets.

1. INTRODUCTION

Clay brick is primary ancient construction materials. Physical properties of these bricks have been increased by using natural agricultural wastes. The rice husk ash (RHA) is one of the agro waste materials that can be used to improve the quality of the clay bricks for present use.

Previous studies confirmed that RHA which has good pozzolanicity is the one that undergone controlled combustion with certain temperature. To yield amorphous silica, various researchers have had suggested different temperature ranging from the 500 °C to 700 °C [1, 2, 3-7]. However, the RHA resulted from uncontrolled burning temperature in the rice milling combustion is in crystallite form which the consequences have poor pozzolanicity.

The RHA is responsible for; (i) increase flexural strength, compressive strength, durability and resistance to chemical attack, (ii) enhance the workability and (iii) reduce the thermal conductivity, permeability, effects of alkali-silica reactivity, shrinkage due to particle packing and potential for efflorescence due to reduced calcium hydroxide [8].

This research aims to upgrade the physical properties of clay bricks with natural agricultural waste during production. These waste materials contain chemicals such as cementitious or pozzolanic increases the strength by forming bonds between the particles. Lime is one of the Pozzolanic materials. Organic matters such as wood ash, sawdust ash and fly ash are known as non-traditional pozzolanic materials [3-14]. These non-traditional materials high temperature during firing the bricks provides higher quality to the finished product.

2. INVESTIGATIONS

Present research is planned to product brick with the mixture of RHA and lime with various ratios. New product must satisfy the required values of physical properties assigned by the Sri Lankan Standard (SLS). The new product should compete with market product, which is product under the same condition of our study, that is available in the Sri Lankan market.

3. EXPERIMENTAL METHODOLOGY
3.1. MATERIALS
3.1.1. BRICK CLAY:

The brick clay for this research was collected from Batticaloa in the Eastern Province of Sri Lanka. The chemical analysis was carried out for the collected samples, which clearly confirms that the major chemical compositions of the clay are silica, alumina, and ferric oxide, are given in Table 1. The chemical properties of brick clay were studied by many researches, and the properties could be differing place to place as indicated in Table 1. Table 2 shows some of the common physical properties of the clay brick could be change place to place in a small percentage.

Table 1: The chemical analysis of brick clay

Chemical Composition (%)	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	TiO_2	P_2O_3	LIO
Present study	63.10	9.23	10.63	5.03	0.02	0.01	1.03	0.02	-	-	8.23
Badr El-Din *et al.* [4]	65.20	7.36	15.26	1.01	0.83	0.08	3.12	0.62	1.92	0.15	6.01
Fetra Venny *et al.* [22]	59.20	5.81	27.9	0.24	0.38	-	0.27	1.80	1.01	-	-

Table 2: The physical properties of brick clay [24]

Physical Property	Values
Liquid limit	23 %
Plastic limit	12 %
Plasticity index	12 %
Optimum moisture content (OMC)	12.50 %
Maximum dry density (MDD)	1850 kg/m^3
Natural moisture content	22 %
Specific gravity	2.69
Soil bearing capacity	49 KN/ m^3

3.1.2. RICE HUSK ASH:

RHA is obtained by burning rice husk. Therefore, the most favorable physical properties can be gained by firing in the temperature range 500 °C to 900°C and duration between 2 to 3 hours [11, 13, 15, 16]. After burning, the grey-whitish ash should be removing or crush to remove the ashes with large particle before the brick production. Previous research reported indicates that the amorphous RHA is suitable for pozzolanic activity rather than the crystalline [8]. It can be observed that the RHA taken from kiln contains higher amount of silica, which is similar to silica obtained from the control burning system. The present and previous studies of chemical analysis are reported in Table 3. These properties could be varied for different varieties of paddy.

Ball milling technique is applied to crush the grey-whitish ash that has a 5 liters' drum with a pair of rollers, which operates by an electric motor. The steel balls, which are inside the drum, are free to move independently. The crushing process should be done for 30 minutes, until the ash and the large particles in the grey-whitish ash, convert into fine dust. This fine dust grey-whitish ash can be used for brick production. Some physical properties from previous study are tabulated in Table 4 [17], which is play a major role in the improvement of material properties and durability of its composite. For example, particle size, specific surface area etc.

Table 3: The chemical analysis of rice husk ash produced by utilizing the muffle furnace

Chemical Composition (%)	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	TiO_2	LIO
Present study	87.50	0.98	0.69	1.13	1.05	0.06	0.05	1.58	-	4.55
Badr El-Din et al.[4]	82.40	0.26	0.65	2.42	1.71	0.52	0.30	1.63	0.01	10.09
Agus [17]	89.08	0.88	1.75	1.29	0.64	-	0.85	1.38	-	2.05
Ghassan et al. [18]	88.32	0.67	0.46	0.67	0.44	-	-	2.91	-	5.81
Nilantha et al. [19]	91.75	1.56	2.07	1.30	1.00	-	0.0	2.32	-	-
Mehta [20]	87.20	0.16	0.15	0.55	0.35	0.24	1.12	3.68	-	8.55

Table 4: The physical properties of rice husk ash[17, 23*].

Physical Property	Values
Specific Gravity	2.05-2.3
Specific Surface	1573.45 kg/ m^2
Bulk Density	1.86 /cm^3
	* 0.96 - 1.60 g/cm^3
Particle size	25 μm (mean value)
Moisture content*	8 – 9 %
Hardness*	5 – 6 Mohr's scale
Colour	Gray

3.1.3. LIME:

Hydrated lime was used as an additional binder, available in the local market in the Batticaloa district. Chemical composition of the lime was analyzed using XRF is tabulated in Table 5. The Ca^{2+} would react with silicate in RHA and forms "Tobermorite gel", which would increase the strength of the block. Physical properties; specific surface, specific gravity and particle size are shown in Table 6.

Table 5: The chemical analysis of the lime.

Chem. composition(%)	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	MnO	H_2O	P_2O_5	LIO
Present study	1.00	0.09	0.15	94.01	0.05	0.05	0.01	0.01	0.02	0.01	0.00	4.6
Agus Setyo M. [21]	0.00	0.08	0.13	59.03	0.25	0.02	0.05	0.03	0.04	0.04	0.00	40.33
Fetra Venny et al. [22]	1.45	0.43	0.92	92.70	3.68	0.57	-	-	-	-	-	-

Table 6: The physical properties of lime [22].

Physical Property	Values
Specific Gravity	2.28
Specific Surface	3956.30 kg/m^2
Particle size	6.52 µm (cumulative value)

3.2 SAMPLE PREPARATION

In addition to the commercially available brick (Sri Lankan standard size: 22 cm × 10.5 cm × 6.5 cm) [25], Eight different series of bricks were made with different weight percentages of clay, RHA and lime as given in Table 7. Traditional mixing method was applied to mix the clay, RHA and lime. In brick casting, initially the clay was mixed with water and prepared into a suitable correct plasticity and the workability. Thoroughly mixed RHA-lime was added to the prepared clay while adding water until proper mixing reached. The raw materials were placed in the mold to get the green molded bricks. The organized clay bricks have been covered by way of saw dirt to keep away from enticing with different newly prepared clay bricks and also to prevent lack of moisture. These inexperienced clay bricks were subjected to direct air dry underneath daylight of temperature around 35°C for one week. Then the clay bricks were burned in a brick kiln of burning temperature range 600°C to 850°C, which is the commercial scale manufacturing procedure of fired clay bricks within the Eastern location of Sri Lanka. The burning method was continuously finished for two days and kept approximately one week. Properties of the fired bricks have been analyzed.

Table 7: The mixing percentage of brick clay, rice husk ash and lime.

Brick Series	Brick Clay (wt. %)	RHA (wt. %)	Lime (wt. %)
Commercial Brick	100	00	00
Series A	100	00	2.5
			5.0
			7.5
			10.0
			12.5
			15.0
SeriesB	98	02	00
			2.5
			5.0
			7.5
			10.0
			12.5
			15.0
SeriesC	96	04	00
			2.5
			5.0
			7.5
			10.0
			12.5
			15.0
SeriesD	94	06	00

			2.5
			5.0
			7.5
			10.0
			12.5
			15.0
Series E	92	08	00
			2.5
			5.0
			7.5
			10.0
			12.5
			15.0
Series F	90	10	00
			2.5
			5.0
			7.5
			10.0
			12.5
			15.0
Series G	88	12	00
			2.5
			5.0
			7.5
			10.0
			12.5
			15.0
Series H	86	14	00
			2.5
			5.0
			7.5
			10.0
			12.5
			15.0

3.3 ANALYSIS OF BRICKS

The compressive strength, density and water absorption properties of the new bricks were analyzed according to Sri Lankan and British standards.

3.3.1 PARTICLE SIZE ANALYSIS

Particle analysis can be achieved by specific size of sieves, but here this take a look at changed into not achieved, due to the fact the intention of the studies become to disseminate the knowledge to the neighbourhood markets and enhance the self-employment of the local community.

3.3.2 DENSITY ANALYSIS

Density is described because the ratio among the dry mass and the quantity of the clay brick, quantifying the quantity of clay found in the quantity. It is evident from the definition; higher price is the denser

brick and obviously superior its mechanical and durability properties. Literature shows that the typical cost of the plain density of the everyday fired clay brick range from 1200 to 2200 kg.m^{-3} [26]. To decide the average densities, mass, length, width and the height of the brick were measured the usage of mechanical stability and Vernier calliper of sensitivity 0.1 g and 0.01 mm respectively. In each series, 3 bricks were recorded and average densities had been calculated the use of equation (1).

$$\rho = m \,/\, V \tag{1}$$

3.3.2 WATER ABSORPATION ANALYSIS

Water absorption analysis was accomplished to decide the water absorption belongings of the fired clay bricks. Three bricks from every percent of RHA addition had been analyzed. Initially, the bricks had been kept underneath the sunlight of temperature of 35 °C to 40 °C for one day and the dry weight of the bricks have been measured. These bricks had been immersed within the water for sooner or later and the moist weight of every brick was measured. Water absorption is provided as a percent changed into calculated the use of equation (2) and the average cost turned into calculated for each bricks.

$$\text{Water absorption} = \frac{M_w - M_d}{M_d} \times 100\% \tag{2}$$

Where M_d is the mass of the dry brick and M_w is the mass of the wet brick after 24 hours.

3.3.3 COMPRESSIVE STRENGTH ANALYSIS

Compressive strength analyses have   been done using Universal Testing Machine to be had within the Department of Physics, Eastern University, Sri Lanka. The testing manner changed into performed in step with the Sri Lankan Standards 855: Part 1: 1989 [27], which is just like ASTM C67-05 [28]. Initially, the brick surfaces had been smoothening to get clean parallel surfaces to form a great floor   contacts among the brick and the two urgent discs fitted inside the machine. The compressive power of bricks changed into measured with the help of a strain gauge of sensitivity 2 kg.cm^{-2} connected to the Universal Testing Machine. The maximum pressure applied (F) to simply destroy the brick (or force at failure), width (W), and length (l) of the block had been recorded. Three bricks from each set were measured and the common compressive power turned into decided the usage of equation (3) and as compared with the Sri Lankan standards.

$$\text{Compresive Strength} = \frac{F}{W \times l} \tag{3}$$

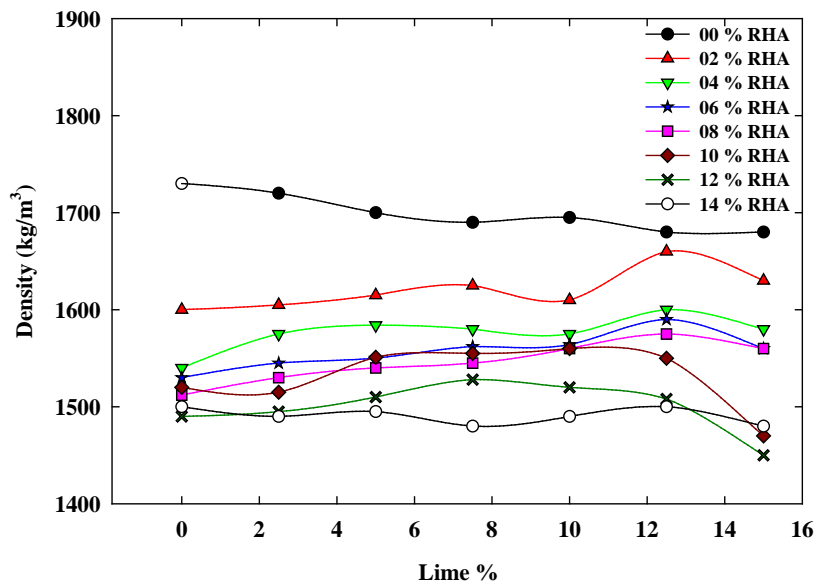## 4   RESULTS AND DISCUSSION

4.1 DENSITY

Figure 1: The change in density as a function of rice husk ash (%) and lime (%)

The density of the clay bricks will increase with increasing the rice husk ash and lime percent as much as 12 % RHA and display a drop in 14 % RHA. However, evaluating with the economic brick the RHA doped bricks show a considerably huge change. The decreasing conduct with increasing lime > 14 % be attributed to coating of the clay by using the lime and RHA that result to huge debris with larger voids and much less density or the burning temperature [29, 30]. According to Kiyohiko *et al.* [30] the density increases with increasing temperature to the positive limit. Moreover, Kiyohiko *et al.* [30] states that the density of the clay brick boom from 1800 kg.m^{-3} to 2200 kg.m^{-3} at the same time as increasing baking   temperature from 900°C to 1100°C respectively, that's decreasing shape from 2200 kg.m^{-3} to 2000 kg.m^{-3} whilst increasing the baking temperature from 1100°C to 1200°C. The impact could rely upon the form of the chemical and physical conduct of the clay material.

Not only that this effect is unlike related to ordinary clay brick due to the integration of RHA and lime. The formation of the pores might be ascribed to the presence of unstable organic compounds within the RHA and lime that burnt off in the course of the firing process. However, the reduction in density is a beneficial final results that revealed the ability use of the fired clay bricks as light-weight constructing materials. As in keeping with BS 3921:1982, the minimum density of the regular fired clay brick is 1300 to 2200 kg.m^{-3} [31,32]. Therefore, all of the bricks are appropriate for constructing construction, but the bricks include 12 % and 14 % RHA can be advocated for construction.

4.2 WATER ABSORPATION

Water absorption is one of the indicator to check the first-class of the bricks. Figure 2 shows that the water absorption will increase with increasing the RHA percentage, however decreases with increasing the lime percentage. The maximum water absorption is in the variety of ≈ 17 to 18 % for 14 % RHA, but the lowest is inside the range of ≈ 15.5 to 13% for 00% RHA. This behaviour shows that the RHA plays a prime role in clay-RHA-lime mixture. According to the results, all the bricks lie between the recommended fee of 20% as consistent with the Sri Lankan Standards SLS 39 [25] and 12% as in line with the British Standard BS 3921

[33]. The variation depends on porosity which is relying on impact of firing temperatures that guarantees the completion of the crystallization manner and closes the open pores in the sinter, in addition to the effect of the smooth nature of the RHA and lime particles, which severely decreases the open pores and appreciably reduces the water absorption.
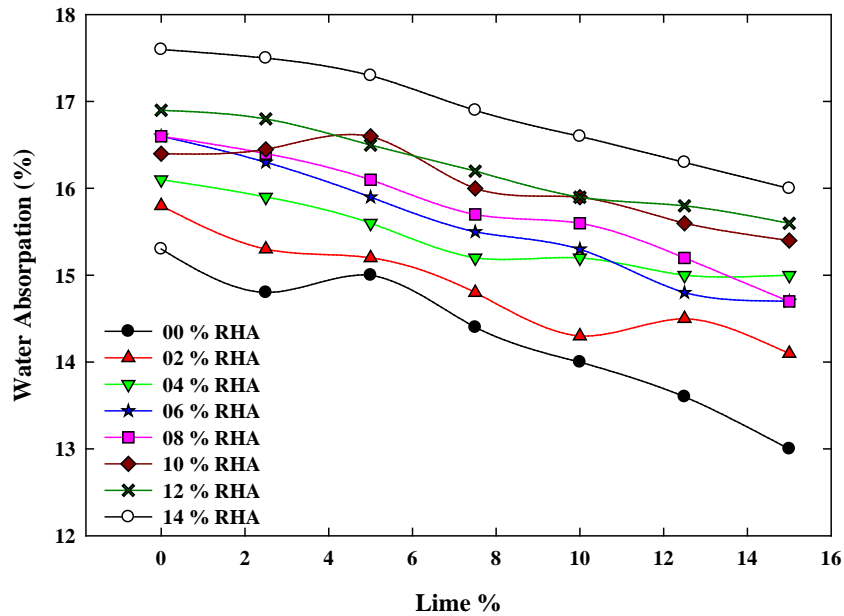

Figure 2: The change in water absorption as a function of rice husk ash (%) and lime (%)
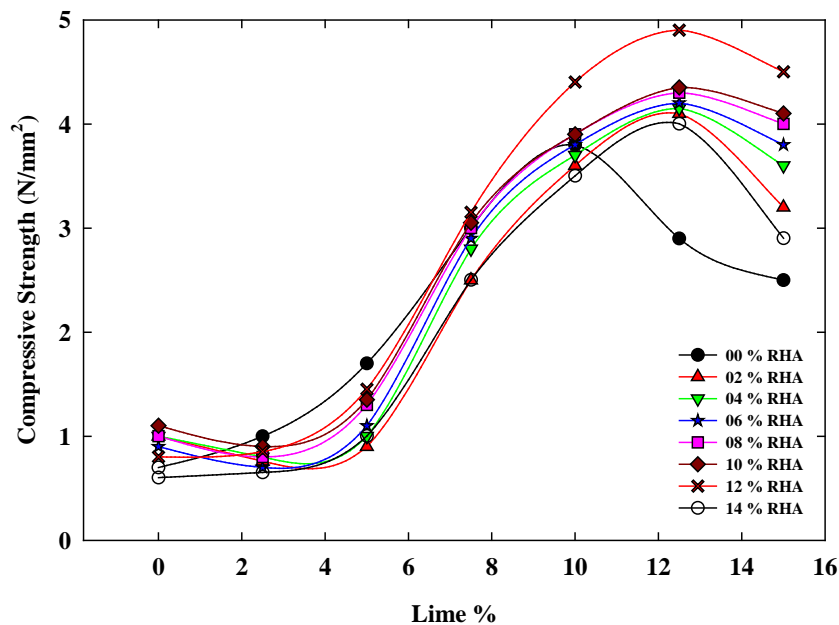
4.3 COMPRESSIVE STRENGTH ANALYSIS

Figure 3: The change in compressive strength as a function of rice husk ash (%) and lime (%)

Compressive strength is an critical parameter use to determine the durability of the clay brick. This sturdiness can be destroyed by means of the factors of porosity, pore size, and type of crystallization. This is defined via the strain failure regular to the mattress face of the brick. The compressive electricity as a characteristic of rice husk ash (%) and lime (%) are shown in Figure 3. The compressive power of the market clay brick is

0.8 N.mm^{-2}. The compressive electricity will increase with increasing the RHA % as much as 12 % and shows a decreasing trend. Although, the power increases with increasing the lime % up to 12.5 % and then decreases. However, the most yield is obtained at 12.5 % of lime for 12 % RHA is ready 4.9 N.mm^{-2}. Considering the 12.5 % of lime addition, the electricity varies from 2.8 to 4.8 N.mm^{-2}. According to the British Standards BS 3921 the electricity must be better than 5 N.mm^{-2}, but in exercise the electricity of the locally available clay brick is within the range 0.5 to 1.75 N.mm^{-2} which may be very lower than the standards [33]. Therefore, the 12.5 % of lime   and   12   %   RHA comprise bricks can   be advocated for production purpose.

The effect of firing temperature on compressive energy may be attributable ensures the of entirety of the crystallization method, closes the open pores inside the sinter, and, consequently, increases compressive electricity of the crystalline alum in silicate brick. Recrystallization after dihydroxylation of water molecules, as a result different parameters influences the procedure of dihydroxylation may cause to energy reduction,   while RHA > 12 %. The dihydroxylation temperature will increase with the growth of water pressure. While the impact of the flabby nature of the RHA particles, which severely increases the open pores in the sinter on reducing compressive strength is much giant than that of lowering silica content. As a result, increasing RHA ratio generally decreases the open pores in the clay-RHA sinter and, consequently, will increase the compressive energy. The plasticity variation shows that the water content increase with growth of RHA.

Conclusion

The conclusions reached in this studies were based totally at the experimental evaluation are;
1. The addition of some agricultural waste materials; which contain high silica content; consisting of rice husk ash can enhance the physical houses of clay brick.
2. Clay-RHA-lime bricks are competitors with neighborhood bricks available within the Sri Lankan market.
3. The ideal lime and rice husk ash aggregate is 12.5 % and 12 % respectively in addition to the density and the water absorption is enjoyable the standards. Therefore, the lime 12.5 % : RHA 12% n be endorsed for construction purpose.

Acknowledgment

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