PADDY HUSK ASH STABILIZED SOIL BRICKS

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Abstract

Recent trend of using stabilized soil as a construction material necessitates the need to search for alternative binders other than cement, bitumen and chemicals due to their higher costs. Rice husk is produced in millions of tons per year as a waste material in agricultural countries as Sri Lanka. Previous researches have been conducted to identify chemical and physical properties of RHA. Therefore, the use of rice husk ash, which contains pozzolanic amorphous silica component, will considerably reduce the cost of construction. The objective of this research is to investigate the performance of soil bricks stabilized using rice husk ash (RHA) and lime. It will also determine the optimal percentage of lime that can be mixed with rice husk ash in order to gain maximum strength and durability. Totally twenty six number of brick samples were cast to find the compressive strength, density and water absorption. One brick sample was cast without binder (0% RHA, 0% Lime). Other twenty five brick samples were cast by varying binder/ soil mix percentage as well as rice husk ash/ lime mix percentage up to a maximum binder percentage of 25% by weight of dry soil. Five brick samples were tested for water absorption and all the twenty six brick samples were tested for compressive strength and density. Results depicted a considerable increment in compressive strength in bricks stabilized with RHA and lime compared to unstabilized sample. Density and water absorption is lower compared to currently available local bricks. Maximum compressive strength was 4 N/mm^2 at 12.5% lime and 12.5% RHA combination. Economical dosage to stabilize the soil bricks was found to be 10 % lime and 2.5% of RHA combination by which compressive strength of 3.9 N/mm^2 can be achieved. Optimum lime content to stabilize soil blocks was observed to be 10% for most of the RHA combinations.

Key words: Stabilize, Rise Husk Ash, Binder, Pozzolanic

1.0 Introduction

In many developing countries including Sri Lanka, there is a need to probe more into the potentials of soils as a reliable and durable construction material as it is locally available. Soil modification is the addition of a modifier to a soil to improve its strength and durability, such that they become totally suitable for construction beyond their original classification. Over the times, cement and lime are the two main materials used for stabilizing soils. The over dependent on the utilization of industrially manufactured soil improving additives and binders (cement, lime etc), have kept the cost of construction of stabilized bricks financially high. In Sri Lanka, the cost of manufacturing of cement stabilised soil blocks has been gradually increasing owing to the cost of cement. This will persuade manufacturers to produce blocks with low cement content which leads to micro cracks on the walls after construction. It is disappointing to note that most of the country bricks fail to satisfy the strength criterion and have high water absorption. The use of alternative cheaper materials as stabilizers will greatly enhance the production of blocks with the desired properties at low cost. It will also drastically reduce the cost of production and consequently the cost of construction works. Rice Husk Ash is an agro based product which can be used as a substitute of cement without sacrificing the strength and durability.

Paddy is one of the plants that absorbs silica from the soil and assimilates it into its structure during the growth. Rice husk, which is the outer covering of the rice grain is an agricultural by-product generated during the rice milling process with a high concentration of silica, generally more than 80%. It is responsible for approximately 20% of the gross weight of a rice kernel and normally contains 80% of organic and 20% of inorganic substances. The production rate of rice husk ash is about 20% of the dried rice husk.

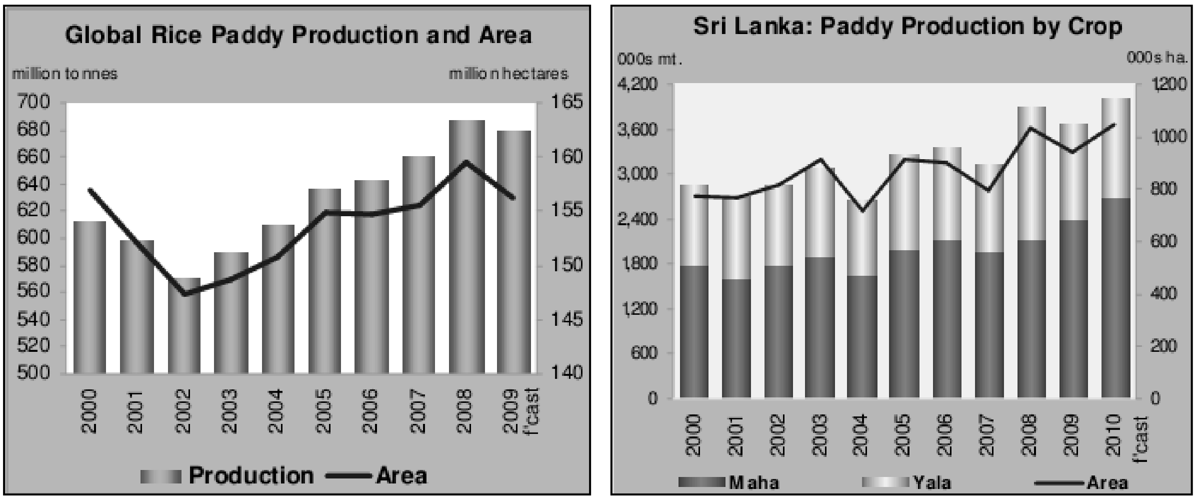

Figure 1: Left: Global Rice Production, Right: Sri Lankan Rice Production (Food and Agriculture Organization of United Nations, 2010, cited in FAO Rice Market Monitor, Volume XIII)

Rice is a heavy staple in the world market and is the second largest amount of any grain produced in the world. Statistics of the world and Sri Lanka itself depict an increase in paddy production over the years. In this scenario, substantial amount of risk husk is generated annually which will impact the environment if not disposed properly. Rice husk has a very low nutritional value and as they take very long time to decompose, they are not appropriate for composting or manure. Apart from being used as primary energy source for parboiling of paddy, burning bricks and clay pots in kilns, massive quantity is burnt in open heap at a temperature ranging from 300 ˚C to 450 ˚C. This process depletes the oxygen quantity in the air and so it is environmentally hazardous. Hence it is a colossal damage to the society, if RHA is produced at a tremendous cost to the nature and not put into productive use. Portland cement by the nature of its chemistry produces large quantities of CO_2 for every tonne of its final product. Therefore, replacing cement in soil stabilization with a secondary cementitious material like RHA will reduce the overall environmental impact of the stabilization process.

The objective of this research is to investigate the performance of soil stabilized bricks produced using rice husk ash and lime.

2.0 Literature Review

2.1 Properties of Rice Husk Ash

Rice Husk Ash is a pozzolan, which contains as much as 80-85% silica which is highly reactive, depending upon the temperature of incineration (Ravande Kishore, Bhikshma V. and Jeevana P,2011). Pozzolanas are defined as siliceous or siliceous and aluminous materials which in themselves possess little or no cementing property, but will in a finely dispersed form in the presence of water chemically react with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties. When water is added to a mixture with pozzolanic material it acts as cement, in some instances providing a stronger bond than cement alone(V.M. Malhotra, P.K. Mehta, 1996 cited in Nick Zemke Emmet Woods, 2009).

The characteristics of the ash are dependent on the components, temperature and time of burning (Hwang, 185 cited in Nick Zemke Emmet Woods, 2009). During the burning process, the carbon content is burnt off and all that remains is the silica content. The silica must be kept at a non-crystalline state in order to produce an ash with high pozzolonic activity. It has been tested and found that the ideal temperature for producing such results is between 600 °C and 700 °C (Nick Zemke Emmet Woods, 2009).

If the rice husk is burnt at too high temperature or for too long the silica content will become a crystalline structure. If the rice husk is burnt at too low temperature or for too short period of time the rice husk ash will contain too large amount of un-burnt carbon. Carbon does not possess pozzolanic properties, thus it does not take part in the strength development process. It acts more or less as filler (Nick Zemke Emmet Woods, 2009).

The typical chemical composition of RHA from various places is given in Table 1 (Mehta 1992, Bui et al 2005, Zhang et al 1996 cited in Suraya Abdul Rashid, Alireza Naji Givi and Farah Nora A. Aziz, 2010).

Table 1: Chemical Composition of RHA from Various Places

Constituent	*SiO_2*	*Al_2O_3*	*Fe_2O_3*	*CaO*	*MgO*	*SO_3*	*Na_2O*	*K_2O*	*Loss on ignition*
Mehta (1992)	*87.2*	*0.15*	*0.16*	*0.55*	*0.35*	*0.24*	*1.12*	*3.68*	*8.55*
Zhang et al (1996)	*87.3*	*0.15*	*0.16*	*0.55*	*0.35*	*0.24*	*1.12*	*3.68*	*8.55*
Bui et al (2005)	*86.98*	*0.84*	*0.73*	*1.40*	*0.57*	*0.11*	*2.46*		*5.14*

Research on the potential of using rice husk ash, reveals that some of its physical properties are responsible for the role that rice husk ash plays in improving the material properties and durability of its composite. Some of these physical properties are larger specific surface area, fine particle size etc. (Safiuddin, 1990, cited in Ogah Sylvester Obam and Amos. Y. Iorliam, 2011) Table 2 shows some physical properties of RHA as published by Narayan (Ogah Sylvester Obam and Amos. Y. Iorliam, 2011)

Table 2: Physical Properties of RHA

Specific Gravity	*2.05 – 2.3*
Bulk Density	*1.86 g/cm^3*
Colour	*Grey*
Odour	*Odourless*
Particle Size	*25 microns - mean*
Appearance	*Very fore*

2.2 Behaviour of RHA

The chemistry of rice husk ash cement involves the chemical reactions of the amorphous silica in the ash with lime to form calcium silicate hydrates. Reactions that take place in the preparation of Rice Husk Ash concrete are given below. Silicon burnt in the presence of oxygen gives silica.

$Si + O_2 \longrightarrow SiO_2$

C_3S (Cement) + $H_2O \longrightarrow CSH + Ca(OH)_2$

The highly reactive silica reacts with Calcium Hydroxide released during the hydration of cement, resulting in the formation of Calcium Silicate Hydrate, which is responsible for strength (Ravande Kishore, Bhikshma V. and Jeevana P, 2011).

$SiO_2 + Ca(OH)_2 \dashrightarrow CSH + SiO_2$

Above reactions are also valid for stabilizing soil with lime and RHA. In that case, Calcium Hydroxide is generated by reacting lime and water instead of hydration of cement.

2.3 Lime-RHA-Soil Blend Reactions

The addition of lime to clayey soils leads to cation exchange and pozzolanic reactions. The cation exchange is the first reaction that takes place immediately and causes the individual clay particles to change from a state of mutual repulsion to mutual attraction typically due to excess Ca^{2+} replacing dissimilar cations from the exchange complex of the soil (Mtallib, M. O. A, 2011).

Some components of natural soils, notably clay minerals, are pozzolanic and the lime-soil pozzolanic reactions results in slow, long term, cementing together of soil particles at their point of interaction. When the lime is added, the pH of the soil is raised, typically to about 12.4 and this highly alkaline environment promotes the dissolution of the clayey particles and the precipitation of hydrous calcium aluminates and silicates that are broadly similar to the reaction products of hydrated cement (Mtallib, M. O. A, 2011). The essence is to replace cement with RHA to get a more economic blend.

The Atterberg limits are significantly altered with lime and rice husk ash combinations. Muntohar (2000) and Mtallib, M.O. A (2011) found out that the liquid limit reduces and plastic limit increases with increasing lime and rice husk ash combinations. This is attributed to the fact that the rice husk ash pozzolanic reaction with the lime form compounds possessing cementitious properties with soil particles. Their results also show decrease in the plasticity index at all lime and rice husk ash contents which makes the stabilized soils better for use as construction materials.

3.0 Methodology

3.1 Materials Used

The soil sample used in this research work was collected, by method of bulk disturbed sampling, from a pit at a depth of 2m at Kalutara area.RHA also was taken from a rice mill at Kalutara and used for the experiments without further incineration. But unburnt carbon particles were removed by sieving and RHA was grinded using an industrial blender to increase the surface area. Quick lime(lime from Dolomite) was used for the experiment.

3.2 Experimental Programme

The tests for this research were conducted in accordance to procedures outlined in BS 1377 (1990).

3.2.1 Sedimentation Jar Test

Straight sided clear glass jar was filled with soil and water. After shaking well, jar was left to settle overnight. The soil was separated out in layers as given below.

Gravel-12mm, sand-32mm, clay-24mm, silt-12mm

Proportions are as follows:

Total: 12 + 32 + 24 +12 = 80mm (equivalent to 100%)

Gravel: 12/80 x 100 = 15%

Sand: 32/80 x 100 = 40%

Clay: 24/80 x 100 = 30%

Silt: 12/80 x 100 = 15%

Figure 2: Sedimentation Jar

3.2.2 Sieve Analysis Test.

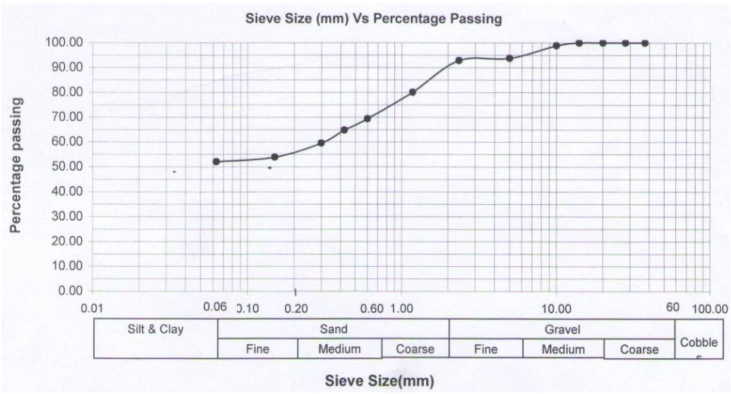

Figure 3: Particle size distribution curve for natural soil sample

3.2.3 Proctor Compaction Test

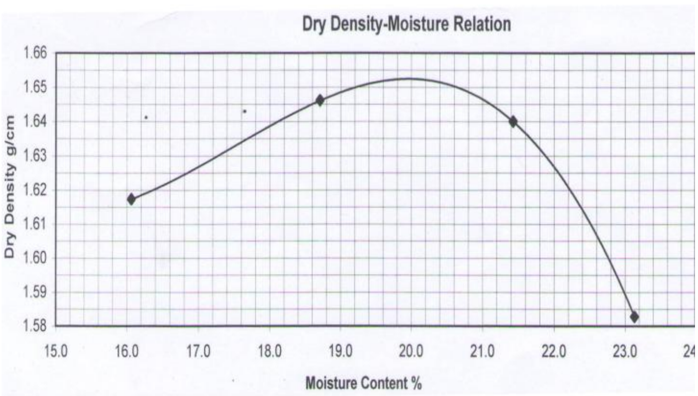

Figure 4: Variation of dry density with moisture content for the soil sample

Maximum Dry Density (g/cm^3) = 1.653

Optimum Moisture Content (%) = 20.0

3.2.4 Mix Proportions of Lime-RHA and Soil

As a starting point to the project, initial mix proportions, were obtained from some previous research work and modified to accommodate local materials. One brick sample was cast without binder (0% RHA, 0% Lime). Other twenty five brick samples were cast by varying binder/ soil mix percentage as well as rice husk ash/ lime mix percentage up to a maximum binder percentage of 25% by weight of dry soil. Since previous researches have shown that influence of water binder ratio on compressive strength is marginal. Thus it was not taken as a controlling factor. Water was added to the mix to have good workability.

Table 3: Mix Proportions of Samples

	GROUP A					*GROUP B*					*GROUP C*				
	A1	*A2*	*A3*	*A4*	*A5*	*B1*	*B2*	*B3*	*B4*	*B5*	*C1*	*C2*	*C3*	*C4*	*C5*
RHA %	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*5*	*5*	*5*	*5*	*5*	*7.5*	*7.5*	*7.5*	*7.5*	*7.5*
Lime%	*2.5*	*5*	*7.5*	*10*	*13*	*2.5*	*5*	*7.5*	*10*	*13*	*2.5*	*5*	*7.5*	*10*	*13*
Number of Brick Samples	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*

	GROUP D					*GROUP E*				
	D1	*D2*	*D3*	*D4*	*D5*	*E1*	*E2*	*E3*	*E4*	*E5*
RHA %	*10*	*10*	*10*	*10*	*10*	*13*	*13*	*13*	*13*	*13*
Lime %	*2.5*	*5*	*7.5*	*10*	*13*	*2.5*	*5*	*7.5*	*10*	*13*
Number of Brick Samples	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*

3.2.5 Production of the Brick Samples

For the purpose of this study, dimensions of soil bricks were taken as 200 x 100 x 100 mm. The quantities of materials obtained from the mix design were measured in each case with the aid of a weighing balance. The rice husk ash and lime were dry mixed thoroughly.

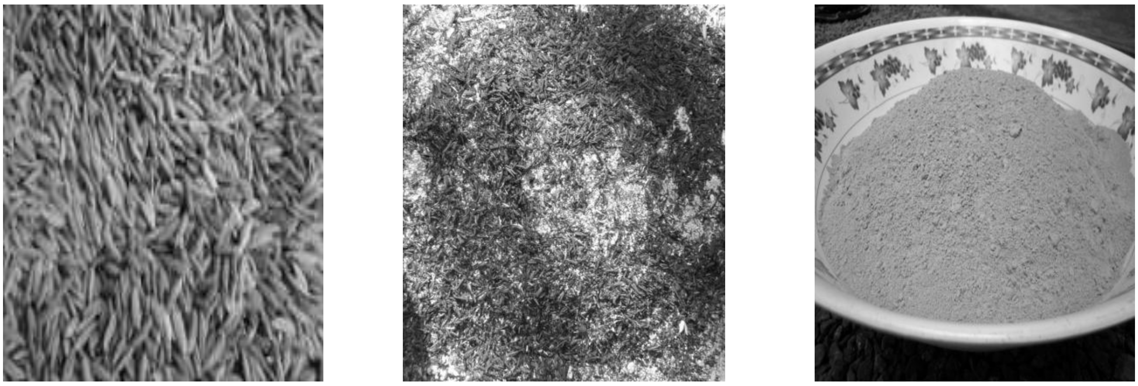

Figure 5: Rice Husk Ash Production Procedure (Left: Rice Husk, Middle: Burned Rice Husk, Right: Rice Husk Ash)

The dry RHA and lime mix then mixed together with soil to obtain a homogeneous mixture. The measured quantity of water was then sprayed on to the mixture. The mixture was further turned with shovels until a mix of the required workability was obtained. The resulting mix was transferred to the steel mould to half the depth. This was tamped uniformly over the cross section of the mould with 25 strokes with a tamping bar. More soil mix was added and tamped until the mould was completely filled to the brim. The content was demoulded in the concrete floor as fresh brick. The brick samples were cured by sprinkling water twice in the morning and evening daily.

3.2.6 Testing of Brick Samples

5 samples of bricks were weighed and soaked in water overnight. Then they were weighed again for the water absorption test. Twenty six brick samples were tested after 37 days to obtain the compressive strength. (It is recommended that the bricks stabilized with lime should be used after at least 37 days)

4.0 Results and Analysis

Table 4: Results of Water Absorption Test

Proportion		*Weight(kg)*		*Water Absorption*
RHA	*Lime*	*Before soaked*	*After soaked in*	
2.5%	*5%*	*3.425*	*3.86*	*12.7%*
5%	*7.5%*	*3.91*	*3.332*	*17.35%*
7.5%	*7.5%*	*3.77*	*3.39*	*11.2%*
10%	*10%*	*3.85*	*3.34*	*15.2%*
12.5%	*12.5%*	*3.75*	*3.27*	*14.67%*

Table 5: Results of Compressive Strength Test

Specimen No	*Sectional Area (mm^2)*	*Volume (mm^3)*	*Weight (g)*	*Unit Weight (kg/m^3)*	*Failure Load (kN)*	*Compressive Strength (N/mm^2)*
A1	20368	2063311	3372	1630	18.8	0.9
A2	20825	2110263	3425	1620	30.8	1.5
A3	20845	2123429	3480	1640	58.2	2.8
A4	20856	2142568	3550	1660	80.8	3.9
A5	20737	2123434	3524	1660	64.9	3.1
B1	20541	2067096	3203	1550	20.6	1.0
B2	20577	2098208	3262	1555	11.7	0.6
B3	20591	2083800	3332	1600	49.1	2.4
B4	20621	2087523	3413	1635	73.6	3.6
B5	20770	2100556	3454	1644	79.3	3.8
C1	20277	2028408	2943	1451	11.7	0.6
C2	20825	2104709	2981	1416	15.8	0.8
C3	20832	2133155	3399	1593	54.5	2.6
C4	20893	2122041	3381	1593	71.9	3.4
C5	21023	2148525	4038	1880	54.5	2.6
D1	20395	2084392	2890	1387	11.7	0.6
D2	20777	2103353	2907	1382	12.1	0.6
D3	21002	2126127	3390	1595	52.0	2.5
D4	20879	2117873	3344	1580	73.4	3.5
D5	20855	2129324	3134	1472	58.0	2.8
E1	20842	2127970	3110	1462	13.3	0.6
E2	20968	2141535	3194	1492	29.2	1.4
E3	21225	2213010	3197	1445	30.5	1.4
E4	21063	2174416	3344	1540	65.8	3.6
E5	21117	2180696	3278	1503	85.3	4.0
F	19602	1919689	3152	1642	16.7	0.9

The compressive strength values obtained for rice husk ash and lime stabilized soil bricks were remarkably higher than the value for unstabilized sample. Peak value of 4 N/mm^2 was observed at 12.5% lime and 12.5% rice husk ash combination. And also it was observed that 3.9 N/mm^2 compressive strength at 2.5% rice husk ash and 10% lime combination and 3.8 N/mm^2 at 5% rice husk ash and 10% lime combination. Also figure 6 depicts that for most of the RHA combinations, maximum compressive strength is achieved at 10% lime content. So 10% lime can be taken as optimum lime content to stabilize soil blocks.

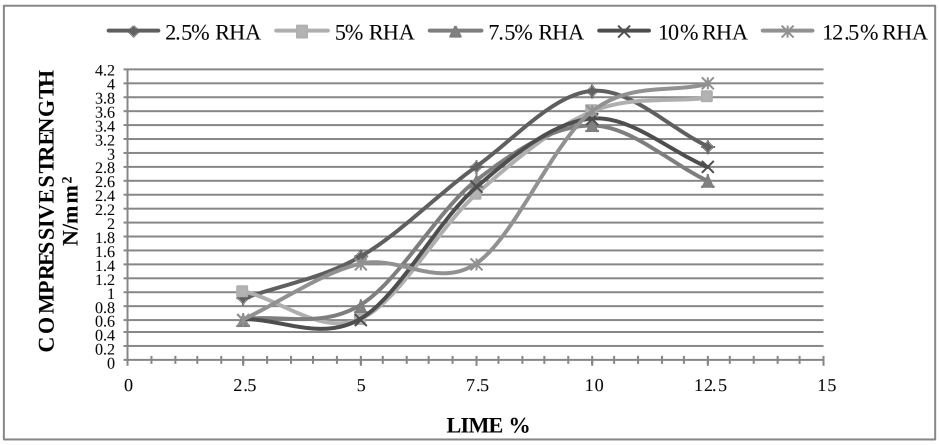

Figure 6: Variation of compressive strength with Lime and RHA percentage

The compaction characteristics of the natural soils were also altered with the addition of lime and RHA. Figure 7 shows that density decreases with increase in rice husk ash percentage.

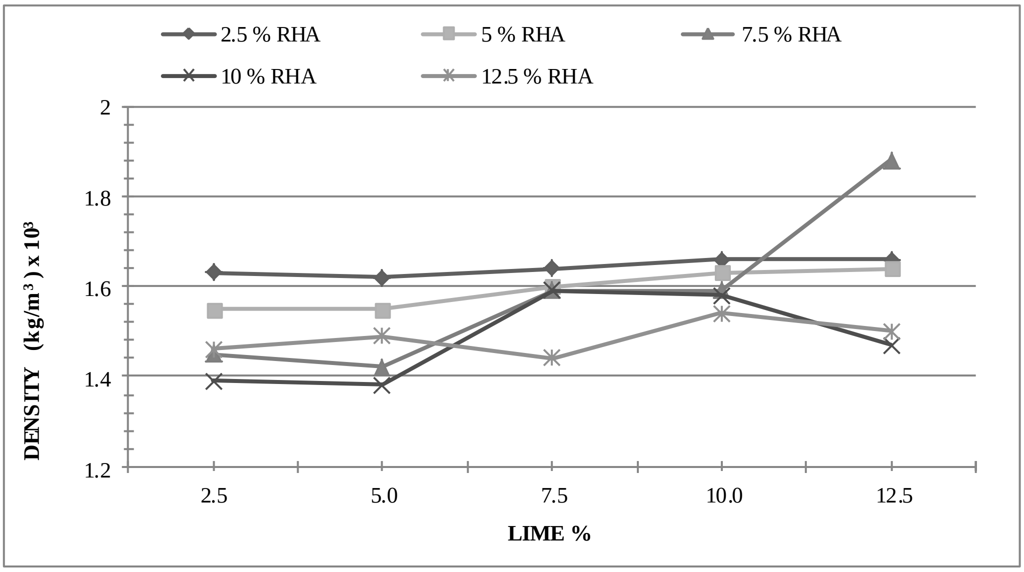

Figure 7: Variation of Density with Lime and RHA percentage

5.0 Conclusion

According to experimental results, the unstabilized brick sample (sample F) exhibits compressive strength value of 0.9 N/mm^2. But when admixed with lime and RHA combinations at varying percentages, considerable improvement can be seen in the compressive strength values. Specifically, the compressive strength was 4 N/mm^2 at 12.5% Lime and 12.5% RHA combination. In general 10 % lime and 2.5% of RHA combination (compressive strength of 3.9 N/mm^2) can be taken as the economical dosage to stabilize the soil bricks.

According to the BS 3921 the compressive strength of a brick should not be less than 5 N/mm^2. However in practice, typical compressive strengths for stabilized soil bricks are less than 4 N/mm^2. Local bricks presently in use have compressive strength within the range of 0.5 N/mm^2 to 1.75N/mm^2 which is much below the standards (Bogahawatta V.T.L). Where the buildings loads are small, in the case of single storey constructions a compressive strength of 1- 4 N/mm^2 is sufficient. Many building authorities around the world recommend values within this range. These stabilized bricks are also suitable to be used for non load bearing partition walls where high compressive strength is not essential.

Density of stabilized soil bricks are not very high (< 1900 kg/m^3) and within the range of normal fired clay bricks density (1300 – 2200 kg/m^3). This may be considered as an advantage, when the bricks have to be transported over long distances.

In comparison with water absorption of different types of clay bricks available in Sri Lanka, lime- rice husk ash stabilized soil bricks exhibit low water absorption value. (< 20 %)

Stabilized blocks can be produced on site itself or nearby area using excavated soil for construction. Thus, it will save the transportation cost and time. Since they can be manufactured by semi skilled labour, local economy will flourish. The use of natural, locally-available waste materials such as rice husk ash directs to sustainable construction. Since energy consumption and air pollution is much less than fired bricks, stabilized blocks can be labelled more eco friendly. If demand of RHA increases, rice mill owners can adopt technologically advanced furnaces to incinerate rice husks at controlled conditions. It will also create a positive impact on the air quality.

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