Effect of lime on characteristics of Rice Husk Ash (RHA) based masonry blocks

Abstract

Rice husk, which is one of the major agro-waste material in Sri Lanka, is produced Rice Husk Ash (RHA) by burning as fuel in brick kiln. Mixture of sand, cement and water are extensively used to manufacture masonry blocks in Sri Lanka, although the cost of cement is high. Because of having highly pozzolanic constituents of RHA, it can be used as a material instead of cement to produce cement sand masonry blocks.

It was frequently reported that compressive strength of RHA based blocks increase at 5% RHA usage and further addition of RHA caused decrease in compressive strength. This decrease may be caused by lack of Ca^{2+} in cement to react with SiO_2 available in RHA to produce insoluble compounds. In this study, an attempt was made to increase utilization of RHA amount by adding Ca^{2+}.

Solid masonry blocks having the size of 360mm x100mm x 170mm were cast with the mix proportion of 1:6 Cement-Sand. Blocks were cast in two series. In the first series, RHA was used as addition with respect to cement weight. In this series of study, four different RHA contents (0%, 5%, 10%, and 15%) were used with constant lime content (10%). In the second series, with the well proved data for the addition of Ca^{2+} increases the utilization of RHA amount and compressive strength of blocks, RHA was used as partial replacement. In this series of study, RHA based cement sand blocks were produced with four different RHA contents (5%, 10%, 15% and 20%) and with constant lime content (10%).The blocks were tested for 7, 14 and 28 Day compressive strength.

When RHA used as addition, the optimum 28 Day compressive strength of blocks was found as 4.937 N/mm^2 for 10% RHA. It was 76% strength development comparing with the minimum standard value of 2.8 N/mm^2. These blocks can be used well in load bearing walls. When RHA used as partial replacement, 28 Day compressive strength of blocks was found as3.467N/mm^2 for 10% RHA. The RHA replacement for cement will help to reduce the unit cost of the sand cement block while improving sustainability.

Keywords: Rice Husk Ash (RHA), pozzolanic constituents, cement masonry blocks, compressive strength, sustainability

1. Introduction

Various types of structures are being constructed all over the world by using bricks and blocks. Among these structures, blocks are very popular in building construction in many countries including Sri Lanka. Various kinds of blocks available in construction sites include solid blocks, hollow blocks, soil bricks and sand-cement blocks. Solid blocks are very popular in constructing buildings. They are generally used for load bearing and non load bearing walls in building construction. Structural performances are mainly considered when all types of structures are constructed. For load bearing walls high structural performance is essential. In order to have high structural performances, it is very important to use innovative material to make masonry blocks. Mixture of sand, cement and water are extensively used to make masonry blocks in Sri Lanka although the cost of cement is high.

Attempts have been made by previous researchers to investigate properties of different materials that can be used as civil engineering construction material. Rice Husk Ash has been attracted for several studies, because of having highly pozzolanic constituents that can be used as a partial replacement material with cement to produce cement sand masonry blocks (Alireza et al. 2010, Oyekan and Kamiyo 2008, Ghassan and Hilmi 2010 and Jiffry et al. 2010).

Sri Lanka is a country where its main occupancy is agriculture since in ancient time. As a result of agriculture, producing rice is being increased. Rice milling industry generates a lot of rice husk during milling of paddy which comes from the fields. During milling of paddy about 72 % of weight is received as rice, 5%-8% of broken rice and bran. About 20%-22 % of the weight of paddy is received as husk (Muthadhi and Kothandaraman 2010). This husk is used as fuel in the rice mills to generate steam for the parboiling process. This husk contains about 75 % organic volatile matter and the balance 25 % of the weight of this husk is converted into ash during the firing process, is known as Rice Husk Ash (RHA) (Agus 2002). In Sri Lanka, Rice Husk Ash (RHA) is produced by burning as fuel in brick kiln, where the inside temperature is about 500^0C.

Rice Husk available in different countries has been studied by different researchers in their previous studies (Alireza et al. 2010, Jiffry et al. 2010, Oyekan and Kamiyo 2008).Chemical composition of RHA for different studies are compared in Table 1.

Table 1: Chemical composition of RHA (Wt. %)

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	Loss in ignition
Jiffry et al. 2010	*91.75*	*2.07*	*1.56*	*1.3*	*1.00*	*0*	*2.32*	-
Ghassan et al.2010	*88.32*	*0.46*	*0.67*	*0.67*	*0.44*	-	*2.91*	*5.81*
Agus 2002	*89.08*	*1.75*	*0.78*	*1.29*	*0.64*	*0.85*	*1.38*	*2.05*

Generally, a similar chemical composition of RHA could be observed. It contains around 85 % - 90 % amorphous silica (i.e. SiO_2). In the conversion of rice husks to ash, the combustion process removes the organic matter and leaves the silica rich residue. Rice husks are approximately cellulose (40%-45%), lignin (25%-30%), ash (15%-20%) and moisture (8%-15%) (Agus 2002). To reduce the amount of waste materials, rice husks are incinerated by controlled combustion to remove the lignin and cellulose, leaving behind an ash composed mostly of silica (retaining 25% of the mass of rice husks) (Agus 2002).

During the controlled burning process, the carbon content is burnt off and all that remains is the silica content. If RHA was burnt in an uncontrolled manner they will be less reactive (Oyekan and Kamiyo 2008). The silica must be kept at a non-crystalline state in order to produce an ash with high pozzalonic activity. It has been tested and found that the ideal temperature for producing such results is between 500 °C and 700 °C (Ghassan and Hilmi 2010). Rice Husk burning as fuel in brick kiln, could be considered as control burning as the burning process usually occurred at about 500^0C and the produced RHA shows chemical compositions similar to the composition published in literature

By adding pozzolanic material to mortar or concrete mix, the pozzolanic reaction will only start when $Ca(OH)_2$ is released. Generated $Ca(OH)_2$ are dissolved in the water and generate Ca^{2+} and OH^- ions. The p^H value of the mixture increased because of the hydration of cement. The Ca^{2+} and OH^- react with SiO_2 and Al_2O_3 by producing secondary cementations product called “Tobermorite gel”(C-S-H) and Calcium aluminate hydrate(C-A-H) that give strength to the cement paste .Previous researches have revealed that Ca^{2+} in the cement reacts with the silica in the RHA in the presence of moisture(Oyekan and Kamiyo 2008). Tobermorite particles are responsible for the cementing properties as well as important Engineering properties such as compressive strength.

In previous studies it was found that 28 Day compressive srength has developed at 5% of RHA replacement compared to 0% RHA (Oyekan and Kamiyo 2008 and Jiffry et al. 2010). It can be expected that in the presence of moisture, the Ca^{2+} in the cement reacts with the silica in the RHA and produce torbemorite gel which will be responsible for the strength gain of the paste.The increase of quantity of RHA decreases the compressive strength of the cement sand blocks (Oyekan and Kamiyo 2008 and Jiffry et al. 2010). This may be due to lack of Ca^{2+} in the cement to react with the Silicate which is supplied from RHA. Therefore, Ca^{2+} should be added to the mixture to produce secondary cementitious product, which gives harden properties to the blocks.

It was hypothesized that increasing of the Ca^{2+}in the mixture, would affect on quantity of RHA that can be effectively used in the mixture. By adding hydrated lime, amount of Ca^{2+} can be increased. The amount of Ca^{2+} (added to the mixture) and silica (available in RHA) are satisfied to form “Tobermorite gel” which gives the strength of the cement block.

2. Methodology

Methodology includes selection of materials, manufacturing of blocks and laboratory experiments.

2.1 Materials

Rice Husk Ash

Rice Husk Ash (RHA) was supplied from a brick kiln (Figure 1) functioning at Karapitiya, Galle. In this kiln, rice husk was burnt at elevated temperature and only rice husk was used as the fuel for the brick burning. The RHA collected from the kiln is free from any debris and consists with particles in different sizes (Figure 2).The particle size of the RHA used in the study was between 75 µm and 150 µm. RHA was sieved through 150µm sieve pan and collected the retaining portion of the sieve pan sized 75µm. The sieved RHA, that was prepared for block manufacturing is shown in Figure 3.

Figure 1: Brick kiln

Figure 2: RHA used in the study

Figure 3: Sieved RHA

Sand: The clean, sharp river sand was used in the study. The sand was free of clay, loam, dirt and any organic or chemical matter. The sand passing through 4.75mm zone of British Standard test sieves as described in Sri Lanka Standard 855: 1989 was used.

Cement: The cement used in the study was Ordinary Portland Cement (OPC) as described in Sri Lanka Standard 855: 1989.

Water: Fresh, colourless, odourless and tasteless potable water was used. Water was free from organic matter of any type as described in Sri Lanka Standard 855: 1989.

Lime: Hydrated lime available in the market (Figure 4) was used.

Figure 4: hydrated lime bag

Figure 5: measuring lime

2.2 Manufacturing of blocks

With the different RHA amounts and constant lime amount, the RHA based cement sand blocks were manufactured in two series. In the first series, similar to the previous study (Jiffry et al. 2010), RHA was used as addition with respect to cement weight. Four different RHA contents (i.e., 0%, 5%, 10%, and 15%) with constant lime amount (10%) were used to manufacture the RHA based cement sand blocks. In the second series, RHA was used as partial replacement with respect to the cement weight. In this series, four different RHA contents (i.e., 5%, 10%, 15%and 20%) with constant lime amount (10%) were used to manufacture the RHA based cement sand blocks.

Solid masonry blocks having the size of 360mm x 100mm x 170mm were cast with the mix proportion of 1:6 Cement: Sand by using local block manufacturing machine. Predetermined material quantities were measured by using weighing balance (Figure 5). In order to prepare mortar, the cement and RHA were thoroughly mixed and then the mixture was turned over number of time with the sand until an even colour and consistency were attained (Figure 6). Measured hydrated lime was added to the water, in which the volume has already been measured. The water was well mixed to prepare uniform solvent (Figure 7). The solution was filtered through a well cleaned piece of cloth. Then the solution was added to the mixture (Figure 8). The mixture was further turned with shovel until achieving a mix of the required workability. The water cement ratio was maintained as 0.7.

Figure 6: mixing cement sand and RHA

Figure 7: added lime to water and mixed well

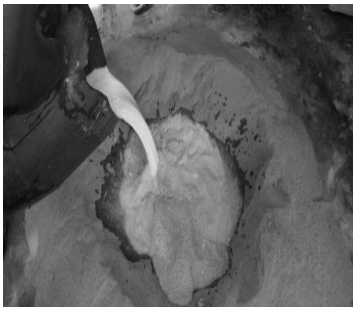

Figure 8: adding lime water solvent to mixture

The mortar was transferred to the steel mould to full depth (i.e., 170mm) of the mould in the block manufacturing machine (Figure 9) and vibro-compaction was given to the mould for a period of 10 seconds in order to have a proper compaction. After the first compaction the mortar was reduced by 20% of the height of the mould. Then additional amount of mortar was added to the mould and excess mortar was removed to get smooth surface. Vibro-compaction was given to the mould for another 10 seconds, so as to get further compaction. After removal of the block from the machine mould (Figure 10), they were left on the ground.

Figure 9: filled the mould with mortar

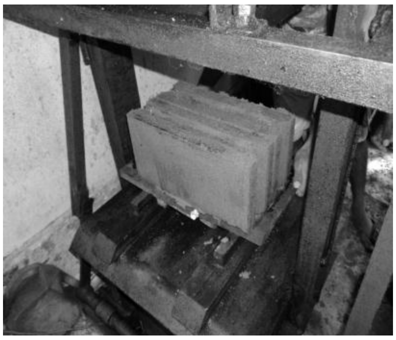

Figure 10: manufactured blocks

Curing of the blocks

After 24 hours from the manufacturing, curing was started and continued until testing day. Curing process was identified as the most important part of the maintenance of the blocks because strength gained by the blocks depends up on the curing of the blocks. Blocks were cured by spraying water on to the blocks by using a bucket twice a day.

2.3 Laboratory Experiment

Compressive strength

The compressive strength was investigated with the laboratory experiment by using a crushing machine available in the Construction and Materials Laboratory (Figure 11). Three samples were tested for each addition and replacement level at 7, 14 and 28 day age. Average compressive strength at each age was determined by averaging three corresponding strength measurements. The strength characteristics of RHA based cement sand blocks were compared with the minimum standard compressive strength value of sand cement block at 28 Day (i.e., $2.8 N/mm^2$) according to BS 6073: Part 2: 1981.

Figure 11: crushing machine

3. Results

3.1 Compressive strength

The average compressive strength of RHA based cement sand blocks with addition of different percentage of RHA and addition of constant amount of lime (10% of cement weight) is shown in Table2.

Table 2: Average compressive strength of blocks (RHA used as addition)

Sample Identification	*RHA contents*	*Lime contents*	*Average compressive strength(N/mm²)*		
			7 Day	*14 Day*	*28 Day*
Sample 1	*0%*	*10%*	*1.636*	*2.376*	*2.967*
Sample 2	*5%*	*10%*	*2.760*	*3.653*	*4.217*
Sample 3	*10%*	*10%*	*2.876*	*3.921*	*4.937*
Sample 4	*15%*	*10%*	*1.826*	*2.966*	*3.667*

It can be seen from Table 2 that the average compressive strength at 28 Day is greatest for Sample 3, in which blocks were produced with 10% RHA and 10 % lime. However, 28 Day average compressive strength decreases with further addition of RHA (i.e., 15 %). This variation was observed with 7, 14 and 28 Day average compressive strength and can be clearly seen in Figure 12.

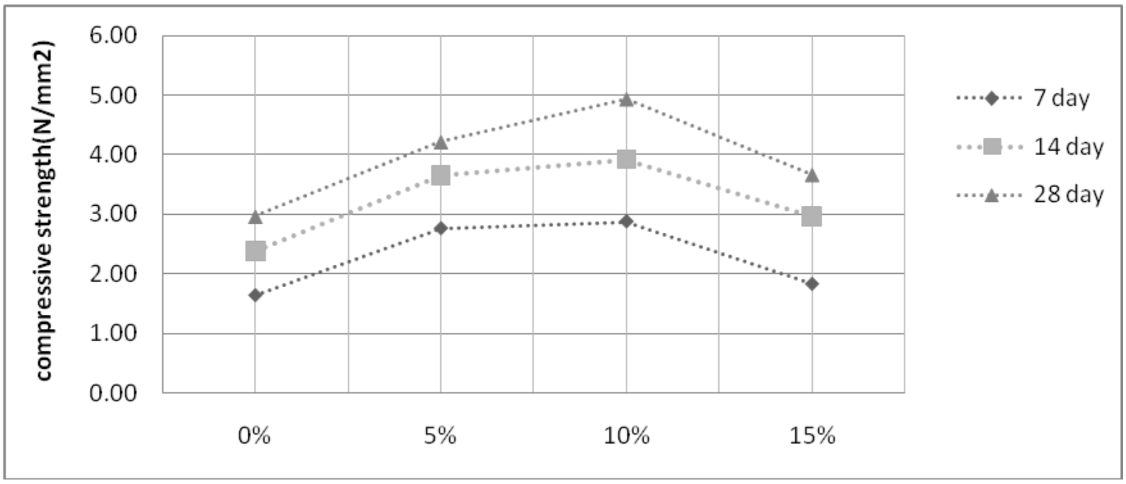

Figure 12: Variation of average compressive strength with the level of % of RHA- addition

Table 3 shows the average compressive strength of RHA based cement sand blocks with replacement of different percentage of RHA and addition of constant amount of lime (10% of cement weight).

Table 3: Average compressive strength of blocks (RHA used as replacement)

Sample Identification	*RHA contents*	*Lime contents*	*Average compressive strength(N/mm²)*		
			7 Day	*14 Day*	*28 Day*
Sample 1	*0%*	*10%*	*1.636*	*2.376*	*2.967*
Sample 2	*5%*	*10%*	*1.701*	*2.517*	*3.180*
Sample 3	*10%*	*10%*	*1.794*	*2.930*	*3.467*
Sample 4	*15%*	*10%*	*1.680*	*2.456*	*2.914*
Sample 5	*20%*	*10%*	*1.587*	*2.031*	*2.723*

It can be seen from Table 03 that the optimum average compressive strength was obtained at 10% of RHA level, in which blocks were produced with 10% RHA and 10% lime. However, 28 Day average compressive strength decreases with further addition of RHA (i.e., 15% and 20%).

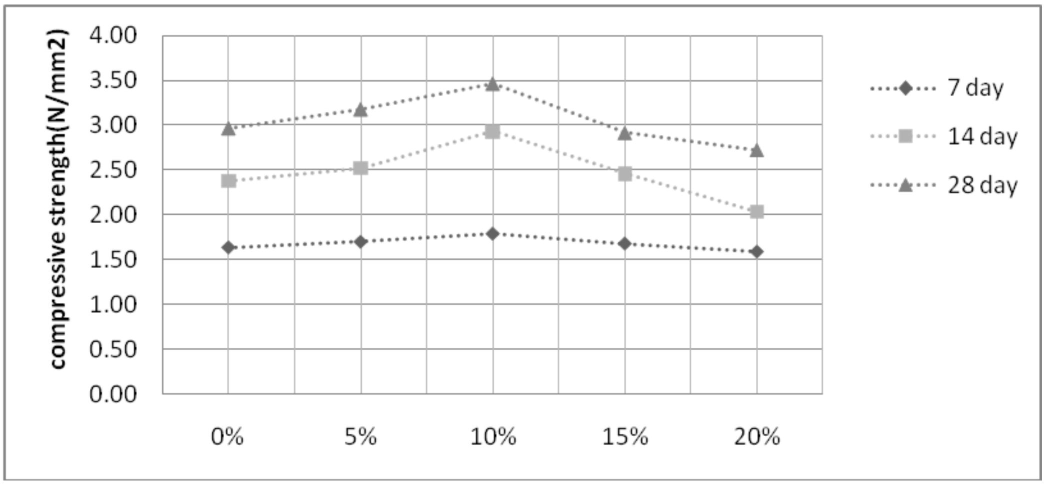

Figure 13: Variation of average compressive strength with the level of % of RHA- replacement

The compressive strength test results show clearly that the replacement of RHA for cement was satisfied the minimum standard value of 2.8N/mm^2 according to BS 6073: Part 2: 1981.The average compressive strength values were satisfied up to 15% RHA level.

4. Discussion

The compressive strength of the Rice Husk Ash (RHA) based cement- sand blocks obtained in the current study were compared with a previous study published by Jiffry et al. 2010 (Figure 14).

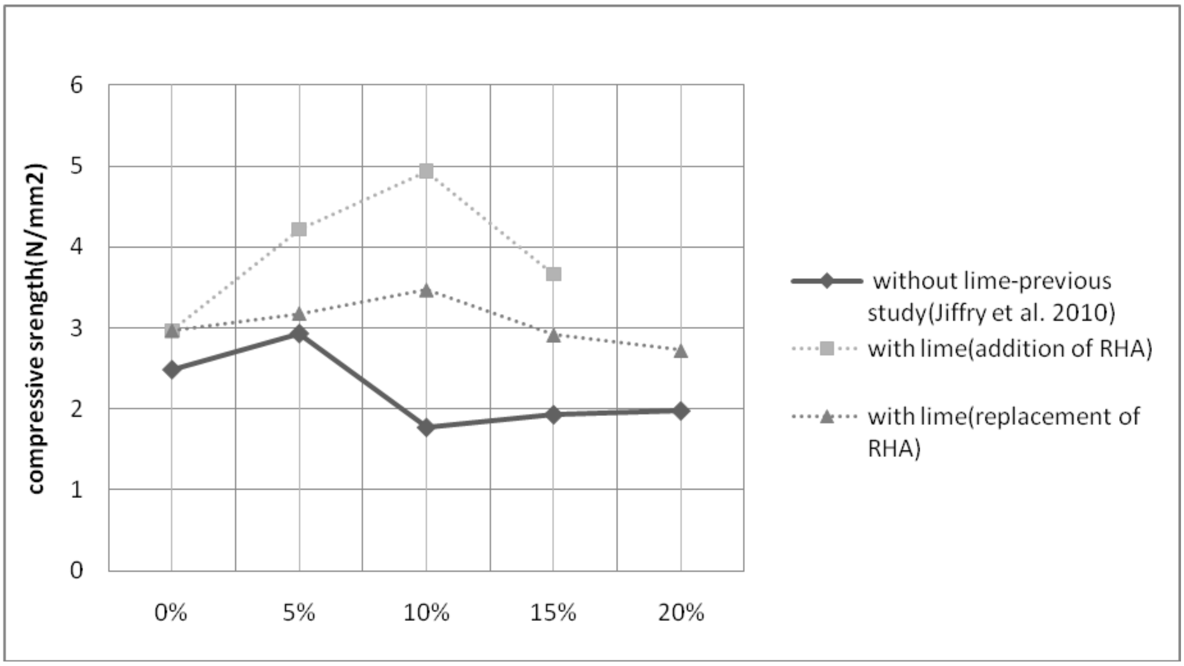

Figure14: Comparison of 28 Day average compressive strength with RHA percentages

It can be seen in Figure 14, that with the addition of lime the compressive strength of RHA based cement sand blocks increases. In a previous study it was found that, compressive strength of RHA based cement-sand blocks increased at 5% RHA(Jiffry et al. 2010).It is the 5% development of the compressive strength comparing with minimum standard compressive strength value of sand cement block at 28 Day (2.8N/mm^2) (BS 6073: Part 2: 1981). This occurs due to pozzolanic reaction of RHA. Hydration of cement increases the P^H value of water. SiO_2 and Al_2O_3 in the mixture dissolve due to increase of p^H value. The hydrous Silica and Alumina react with the Ca^{2+} and produce insoluble compounds (CSH, CAH) called secondary cementitious products. With the curing insoluble compounds produce harden for the mixture. This may contribute to increase the compressive strength of RHA based sand cement block at 5% RHA content. The addition of RHA causes decrease in compressive strength, since there might be a lack of Ca^{2+} for the continuation of reaction.

In the current study, with the addition of Ca^{2+} by using lime for the manufacturing of RHA based block higher compressive strength has been achieved and also the optimum percentage of utilization of RHA has increased up to 10%. It is the 76% development of the compressive strength comparing with minimum standard compressive strength value of sand cement block at 28 Day (i.e., 2.8N/mm^2) (BS 6073: Part 2: 1981). At the 15% of RHA, the compressive strength has been achieved higher value comparing with the standard value. It is the 31% development of the compressive strength comparing with standard value (i.e., 2.8N/mm^2) (BS 6073: Part 2: 1981). This was attributed to continuation of pozzolanic reaction of RHA with the presence of Ca^{2+}. The Ca^{2+} available in lime might contribute to increase the both compressive strength and amount of utilization of RHA. Increased Ca^{2+} reacts with more SiO_2 available in the RHA, and increases the development of secondary cementitious products, which contributes to harden the cement paste.

The curing time also affects on the compressive strength of blocks. The lime cementing process is a much slower reaction, which requires considerably longer time than the hydration of cement. The lime cementing process occurs well in hydrous environment. Therefore, the continuation of curing process continues the gain of compressive strength. In addition, the curing temperature accelerates the chemical reactions and solubility of the silicates thus increases the rate of strength gain. Moreover higher P^H accelerates formation of secondary cementitious products.

In the second step, the RHA material was used as partial replacement for cement with constant lime amount. The average 28 Day compressive strength of all samples (5%, 10%, 15%and 20% of RHA) were satisfied the minimum standard compressive strength value of sand cement block at 28 Day (2.8N/mm^2) (BS 6073: Part 2: 1981).By replacing 20% of RHA instead of cement with adding of 10% lime, can save about Rs.1.35 from a block. Detail calculation has been discussed in Pushpakumara et al. (2011).

The Rise Husk Ash from brick kiln has good amount of passing 150 µm tests sieve particles. So the RHA for manufacturing of blocks can be found easily. The RHA is a waste, which can be effectively used in block manufacturing and prevent the environmental pollution by RHA. The cement cost is increasing; therefore alternative solutions for reducing the usage of cement are essential. The RHA with lime gives good cementitious product and have excellent strength gain. The cost for lime and RHA is lesser than the cost of the same amount of cement.

5. Conclusions

The Rice Husk Ash (RHA) wasted from brick kiln is highly pozzolanic and found as suitable to use in manufacturing masonry blocks. Addition of Ca^{2+} resulted to increase the utilization of RHA amount and increased the compressive strength compared to adding of RHA without lime. The addition of RHA, blocks have good compressive strength and can use for load bearing walls well. The replacement of RHA also shows higher compressive strength compared to standard. These blocks save the cost, help to utilize the rice husk ash waste and prevent the environmental pollution caused by open dumping of rice husk ash.

Acknowledgement

The authors wish to express their special thanks to Faculty of Engineering, University of Ruhuna for providing necessary funds and help for carrying out the research work presented in this paper.

References

Agus Setyo Muntohar (2002) “Utilization of Uncontrolled Burnt Rice Husk Ash in Soil Improvement”, *DIMENSI TEKNIK SIPIL VOL.4, NO.2 September 2002:pp.100-105*

Alireza Naji Givi, Suraya Abdul Rashid, Farah Nora A. Aziz, Mohamad Amran Mohd Salleh(2010)“Contribution of Rice Husk Ash to the Properties of Mortar and Concrete: A review”, *Journal of American Science 2010;6(3):pp.157-165*

A.Muthadhi, and S.Kothandaraman(2010)“Optimum production conditions for reactive Rice Husk Ash ”,*Materials and Structures(2010)43:pp.1303-1315*

BS 6073-Part 2: 1981 Precast concrete masonry units. Method for specifying precast masonry units.

Ghassan Abood Habeeb, Hilmi Bin Mahmud (2010) “Study on Properties of Rice Husk Ash and Its Use as Cement Replacement Material”, *Materials Research 2010*; 13(2): *pp185-190*

G.L.Oyekan and O.M. Kamiyo(2008)“Effect of Nigerian Rice Husk Ash on some Engineering properties of Sandcrete Blocks and Concrete.” *Research Journal of Applied Sciences2008; 3 (5):pp.*345-351,

Jiffry I., Nilantha B.G.P., Kumara Y.S. and Subhashi G.H.M.J. (2010) “Use of Rice Husk Ash (RHA) for manufacturing of masonry blocks.” , *Proceeding of The 104th Annual Sessions of the Institution of Engineers, Sri Lanka (IESL).October 2010.*

Sri Lanka Standard 855: 1989, Specification for cement blocks

Pushpakumara B.H.J., Kapukotuwa S.B.K.D.K. and Samarasignhe B.G.C.M (2011) “Effect of lime on characteristics of Rice Husk Ash (RHA) based masonry blocks” *Undergraduate research report, Faculty of Engineering, University of Ruhuna.*