EFFECT OF RICE HUSK ASH AS ADDITIVES IN LIME MORTAR

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Abstract- This paper describes an investigation of the effect of using rice husk ash, in combination with lime and cement, as well as the production of low cost masonry units. The mass of binder was maintained (RHA mortar) or partially replaced by Rice husk ash (RHA) in weight percentages of 5%, 10%, 15%, 20% and 30%. The mortar samples were exposed to the same curing conditions, and afterwards tested at different ages, up to 28 days. The results of compressive strength are 3.10 MPa, 3.05 MPa, 3.32 MPa, 3.27 MPa, 8.48 MPa, and 5.69 MPa respectively. The partial substitution of lime by rice husk ash as agricultural waste can be useful to adjust the mortars characteristics for different types of supports and applications sites. Based on laboratory test performed, the addition of 20% rice husk ash is maximum composition to enhance strength and durability of lime mortar. The high silica content in RHA may also bond aggregate with each other. This may provide an opportunity for rice husk ash to be promoted widely in the world related to the enhancement in lime mortar for the construction and conservation of historic buildings.

Keywords- Lime Mortar, Rice husk Ash, Strength, Durability, Waste Material

I. INTRODUCTION

In recent decades, the use of certain types of mortar and ordinary Portland cement caused the damages to historic brick and stonework becomes main concern of specialists involved in the conservation and repair of historic buildings. How to build our homes, both in terms of design and choice of materials, has always been a problem for humanity and global environment. Concern about the harmful environmental impact of global cement manufacture has prompted extensive research into the search for and development of more sustainable binders for construction. Then, it is known that the production of each ton of Portland cement releases almost one ton of carbon dioxide into the atmosphere. Worldwide, the cement industry alone is estimated to be responsible for about 7% of all CO2 generated. The production of Portland cement is also very energy intensive.

Nowadays, it is common knowledge that the Portland Cement (PC) used in mortars for conservation and repair of old buildings was generally a wrong choice, being responsible for several problems in the repaired area, where it is frequently associated with the origin of the pathology and global effect. The challenges listed above are more a result of the fact that Portland cement is not particularly environmentally friendly. Bearing this in mind, facing the degradation of the housing stock and the global construction crisis, maintenance of buildings arises as both a work and study opportunity, promoting the development of new and compatible mortars based on lime for the repair of old masonries.

Today, lots of lime mortars which were used in ancient sites are still working. For instance, Organic – Inorganic lime mortars were widely used in many ancient buildings due to their good performance in some fields (such as caking property, water repellency, weather-ability, etc.), hydraulic mortar prepared by lime with ash, clay and brick powder, and reinforced mortar prepared by lime with straw and fiber. As a result there has been a resurgence of interest in building limes, which when produced at a large enough scale with the same production efficiencies as cement and in some cases do demand less energy and emit less carbon dioxide in manufacture.

The use of pozzolanic materials in construction dates back to thousands years ago. Pozzolans are defined as materials rich in silica and/or alumina in amorphous form, with high specific surface that have the property of reacting with calcium hydroxide, in the presence of water, forming hydraulic products. Rice-husk ash (RHA), is one of the agricultural wastes and pozzolanic. Rice husks constitute about 20% of the volume of rice produced annually in the world, which is approximately 80 million tones.

It can be used as a partial replacement of cement in lime mortar. Due to rich in silica content (approximately 85% of silica content), it can be produced from rice husk using appropriate combustion technique for use in concrete as a supplementary cementitious material. Although some rice husks are used for animal feed, fire making, litter material, marking concrete, board production, and as silicon carbide whiskers to reinforce ceramic cutting tools, most of this agricultural by-product is disposed of, and its accumulation is a serious environmental problem.

There is a growing demand for fine amorphous silica in the production of special cement and concrete

mixes with high performance, high strength and low permeability concrete. Rice husk ash having a very small particle size of 25 microns, so that it can fills the interstices in between the cement and the aggregates. Research on the use of agricultural waste as additives in mortar production is relatively new. More research on long term durability of this kind of lime mortar would give more confidence to the construction industry in using them for their more sensitive project.

The aim of this paper is to examine the effect of rice husk ash as additives filler for making lime mortar in experimental and practical environments. Mutual recognition of this material and it usage in mortar by both civil engineers and agricultural engineers, would pave the way for other potential uses of agricultural wastes in the construction industry, as well as certain other industries. It will also lead to a more environmentally sustainable industry.

II. EXPERIMENTAL STUDY

2.1 Materials

2.1.1 Lime Putty

The ratio used is 2:3 which 2 parts of sand and 3 parts of binder. Lime Putty used as a binder in lime based mortar for this research. Lime putty was stored in the container which filled with water to keep the moisture of the putty. The amount of lime putty for each cube bar mould is 500 gram while for the prism bar mould is 1000 gram for each mould.

2.1.2 Sand

Sand occurred in granular materials composed by divided rocks and mineral particles. Sand is mineral which contains silica (silicon dioxide, SiO2) caused it resistant to weathering. According to ISO 14688, sand was grades as fine, medium and coarse with ranges 0.063 mm to 0.2 mm to 0.63 mm to 2.0 mm. in the United States, five sub-categories based on size of the sand which are very fine sand (1/16 – 1/8 mm diameter), fine sand (1/8 mm – ¼ mm), medium sand (1/4 mm – ½ mm), coarse sand (1/2 mm – 1 mm) and very coarse sand (1mm – 2mm).

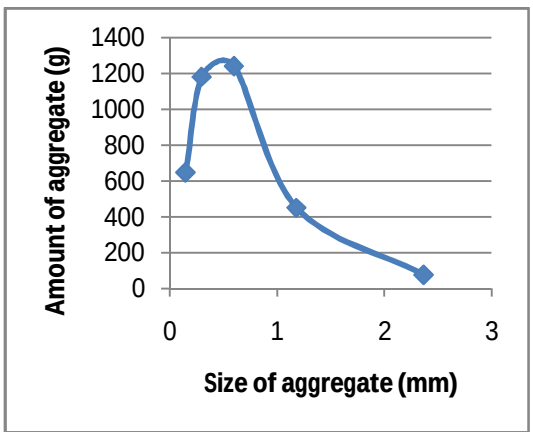


Figure 1. The amount of fine aggregate used

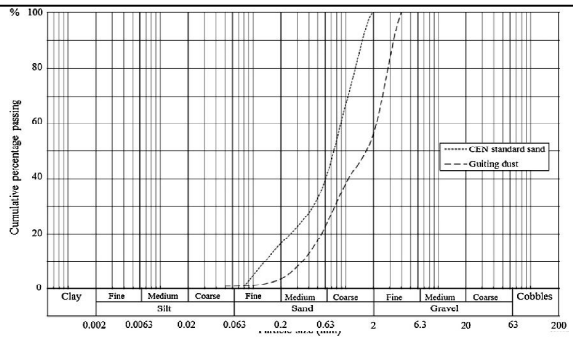


Figure 2. Graph of particle size distribution

Two fine aggregates were examined in this investigation. All except one of the mortars were prepared with Guiting dust, limestone fines from Guiting Quarry, in Gloucestershire. The particle size distribution (PSD) of this fine aggregate was determined in accordance with BS 933-1:2012 and is shown in Fig. 2. One mortar was also prepared using CEN standard sand as a point of reference, when considering the resulting mortar strengths. The PSD of the CEN standard sand, in accordance with BS EN 196, is also shown for comparison. After grading and sieving analysis, it was considered to use fine aggregate as mention in Fig. 1 above.

2.1.3 Portland Cement

The amount of Portland cement that used in this study is 20 % of total amount of sand. The used of Portland cement to ensure the lime based mortar hardened faster compared lime based mortar without adding cement because of time constrain. Cement reacted faster with presence of water and air. Additional Portland cement needed to increase the strength of lime mortar because of time constrain. In this research, the amount of Portland cement for each cube bar mould is 140 gram while for prism bar mould is 300 gram.

2.1.4 Rice Husk Ash (RHA)

RHA is one of pozzolanic material that been used for gauging the lime based mortar to increased the strength of lime mortar. RHA as the pozzolanic material was added after mixing lime putty with sand and Portland cement. The amount of this study is 5%,10%, 15%, 20% and 30% of the total amount of sand. The main display of rice husk ash is grey and the particle size of RHA is finer. This rice husk ash was supplied from Senggora tile factory located at Bachok, Kelantan with the detail of product shown in table 1 below.

Table 1. Properties of RHA

Chemical Composition (%)	RHA
SiO_2	86.98
Al_2O_3	0.73
Fe_2O_3	0.84
CaO	1.40
MgO	0.57

SO_3	0.11
Na_2O	2.46
K_2O	-
LOI	5.14
Physical Properties of RHA	
Median particle size (μm)	7.15
Specific gravity	2.1
Blaine Fineness (m^2/kg)	350

2.2 Sample preparation

2.2.1 Mould

The size of cubic mould is 50 mm x 50 mm x 50 mm and consists of 3 gang mould. While for prism mould, the size is 160mm x 40mm x 40mm and consists of 3 gang mould. The mould made from steel to decrease the reaction of the mixture with the surface of the mould.

2.2.2 Flow table

The flow table provides an efficient means of determining the flow of hydraulic lime mortars. Using the flow mould provided, a specific volume of material is mould on the table. The diameter of the mould is 10mm. the mould is removed and the table subjected to a specific number of ½ in (12.7mm) drops using the crank handle. The samples tamped 15 times according to BS standards. The increase in average diameter of the sample indicates the flow. The workability of the mixture was tested through the flow table test. It can be determined by the spread area after the mixture being tamped 15 times.

Table 2. The result of flow table test

Type of mortar	Last reading (mm)	Flow table reading (mm)	Additional Water (ml)
Lime Mortar (without any additives)	12.33	2.33	-
Lime Mortar added with 5% of RHA	11.87	1.87	-
Lime Mortar added with 10% of RHA	11.95	1.95	-
Lime Mortar added with 15% of RHA	11.82	1.82	-
Lime Mortar added with 20% of RHA	11.05	1.05	-
Lime Mortar added with 30% of RHA	11.46	1.46	1000

Based on the table 2 above, the range of flow table reading between the samples is quite large which 1.05 mm to 2.33mm. Lime mortar without any additives has high workability compare to other samples. The flow table reading of lime mortar without additive is 2.33mm. Meanwhile, the lowest workability is lime mortar with 20% of rice husk ash and the flow table reading for this mixture is 1.05mm. Lime mortar with 10% of rice husk ash and lime mortar with 30% of rice husk ash have average reading is 1.95 mm and 1.46mm respectively.

The workability of the samples have affected by the presence of water in the mixture. High workability means much water in the mixture caused the mixtures is not rigid and high moisture. High moisture caused the percentage of crack occurred is higher than the mixture that have lower moisture.

2.2.3 Bench mounted mixer

It is used for mixing cement and mortar pastes. The heavy duty mixer has 3 operating speeds, lever to adjust the height of the 5 qt (4.73 L) bowl and a planetary mixing action to ensure through and complete mixing. Supplied completed with a stainless steel bowl, flat beater and a wire whip. The power of this mixer is 325 W and the voltage is 220 – 240V. The frequency for this mixer is 50 – 60 Hz. The product dimension for this mixer is 41.1 cm x 26.4 cm x 33.8 cm and the bowl dimension is 49 cm x 38.9 cm x 31 cm.

Table 3. Mix proportion of lime mortar

Sample	Sand (gram)	Lime Putty (gram)	Portland Cement (gram)	Rice Husk Ash (gram)
Lime Mortar (without any additives)	700	500	140	0
Lime Mortar added with 5% of RHA	700	500	140	35
Lime Mortar added with 10% of RHA	700	500	140	70
Lime Mortar added with 15% of RHA	1000	750	165	138
Lime Mortar added with 20% of RHA	1500	1000	300	260
Lime Mortar added with 30% of RHA	1500	1000	140	342

2.2.4 Casting and Compacting

Lime based mortar was casting half of the bar mould first and needed to tamp 15 times for cube bar mould and 25 times for prism bar mould according to British standard. Tamping process is important to compact the lime based mortar and to ensure there was no air in the mixture. Then the moisture was filled in the bar mould and tamped for the second time. After casting completed, the mixture will be exposed for harden about 3 days.

III. RESULT AND DISCUSSION

3.1 Compressive strength

Table 4. The result of compression test

The result of Compression Test for Lime Mortar withoutAdditive			
Lime Mortar Without Additive	Maximum Load (kN)	Surface Area (mm2)	Stress at maximum Load (MPa)
Sample 1	7.208	2502.98	2.889
Sample 2	8.148	2495.00	3.266
Sample 3	7.825	2499.99	3.136
Average			3.097

It will determine the characteristics of materials under crushing loads. Compressive stress are calculated and plotted as a stress-displacement diagram which is used to determine load at maximum load. After curing process for 28 days, each of the samples undergoes the compression test to determine the maximum load of lime based mortar with additives. Compression test were carried out At Faculty Engineering Laboratory. The speed of the compression machine is 25 mm/min with 50% humidity. Based on the table 4, the range of maximum load of all samples of lime mortar without additives is narrow which is 7.208 kN to 8.148 kN with different value of surface area of the cubes. Meanwhile, for the samples of lime mortar with 20% of rice husk ash, the range maximum load is between 20.580 kN to 21.830 kN. It shows that each cube exhibits almost the same strength and workability. The highest stress at maximum load is 8.732 MPa of lime mortar with 20% of RHA.

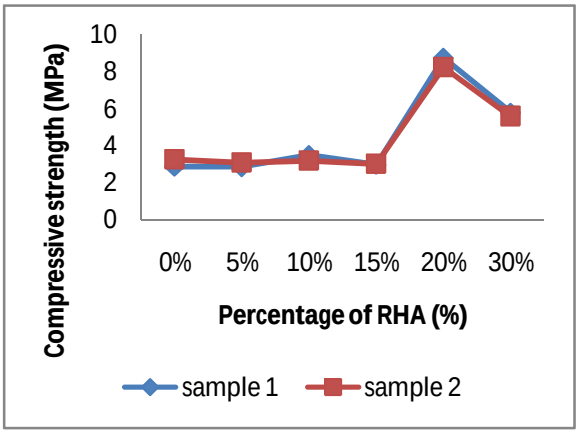


Figure 3. The compressive strength of lime mortar

The strength of lime based mortar with RHA as the additive increasing compare to lime based mortar without additives. This indicates that RHA is one of pozzolanic materials due to increasing strength of lime mortar. The mixture produces filler effect due to its fine particle size. This may allowed the RHA particles to increase the reaction with $Ca(OH)_2$ to give more calcium silicate hydrate (C-S-H) resulted in higher compressive strength. During the reaction of hydrate of lime mortar will generated calcium hydroxide and the addition of RHA will fix the calcium hidroxyde to increase the strength of the lime mortar. Hydration processed lead to the strength improvement of lime mortar.

The pozzolanic activity of RHA produces more amount of CSH which improving the compressive strength of the lime based mortar. As shown in fig.3, Lime mortar with pozzolanic material shows higher value of compressive strength due to increased reactivity of RHA, the compressive strength decrease which is lower than lime mortar that added with 20% of RHA. Thus, 20% of RHA seems to be the optimal limit for this research.

3.2 Flexural strength

Flexural strength is defined as the maximum stress in the outermost fiber which calculated at the surface of the specimen or tension side. The flexural test determined materials behavior subjected to simple beam loading. Flexural strength test was performed on the day 28th in the laboratory of concrete and material, Faculty Engineering, University of Malaya. Maximum stress and maximum load at yield are calculated for increments of load. Results are plotted in a stress-displacement diagram. For flexural test of lime based mortar in prism form. The speed used was 25 mm/min with 29^{o}C temperature and 50 % of humidity.

Table 5. The result of flexural strength, compressive strength and modulus of elasticity

Mortar	Fs(MPa)	Cs(MPa)	E (MPa)
0% RHA	0.91	3.10	4094
5% RHA	2.24	3.05	4142
10%RHA	3.19	3.32	5181
15%RHA	3.27	3.27	5457
20%RHA	4.57	8.48	12,786

The results show that the addition of RHA to lime based mortar exhibited an increase in the flexural strength and the higher strength was due to the finer RHA mixture. Increasing pozzolanic reaction and the packing ability of the RHA fine particles determined the strength of lime based mortar.

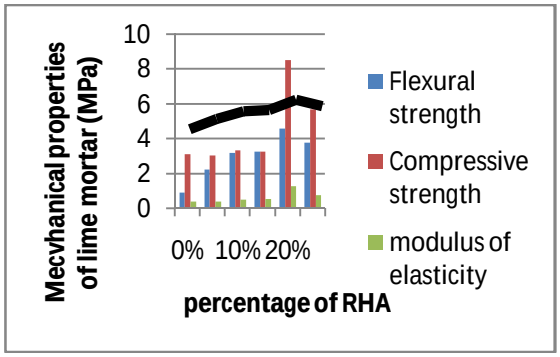


Figure 4. The mechanical properties of lime mortar

Based on the description of fig.4, it is clearly shows the flexural strength test specimens with RHA had a positive effect on flexural strength higher than the specimen without additives RHA. 20% RHA recorded the highest bending stress of 4.57 MPa, compared with other specimens in this experiment. This indicates an increasing number of RHA in lime mortar mix, partially the flexural strength of lime mortar. This is because rice husk ash becomes binder to other substances in lime mortar and it caused the specimen to be strong and resistant to bending load.

CONCLUSION

Additional of pozzolanic admixtures affect the strength and durability of lime mortar and have a big

impact on the construction industry. It is also very important implications for the work of caring, maintenance and conservation of old and historic buildings using appropriate lime mortar. Lime mortar then past and present is significantly different from all aspects. The mortars described in this study presented interesting results in terms of water action behavior and mechanical strength that fact found explanation in the analysis of their microstructure. The partial substitution of lime by rice husk ash as agricultural waste can be useful to adjust the mortars characteristics for different types of supports and applications sites. Nowadays, some additives are coal fly ash (PFA), brick powder, POFA, RHA and others. Those additives can improve the strength and durability of lime mortar. Based on laboratory test performed, the addition of 20% rice husk ash is maximum composition to enhance strength and durability of lime mortar.

The high silica content in RHA may also bond aggregate with each other. This may provide an opportunity for rice husk ash to be promoted widely in the world related to the enhancement in lime mortar for the construction and conservation of historic buildings. It is also readily available and cheap in the supply of rice market in Malaysia. The use of lime mortar should be diversified in order to maximize it. Therefore, further research should be done on the properties of lime available at the present. Mix design of OPC lime mortar cement should be right and proper.

It requires in ensure the strength of the maximum compression and bending to pozzolan lime mortar can be promoted further in advance of the construction industry. Furthermore, the use of RHA provides an opportunity for high-value production and trade of rice in Malaysia. The problems that appear in connection with rice husk ash can also be addressed extensively.

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