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Malaysian Rice Husk Ash – Improving the Durability and Corrosion Resistance of Concrete: Pre-review

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Abstract

The objective of this paper is to presents and study a pre-review of Malaysian rice ash ask as a partial cement replacement in different percentage, grinding time and performance corrosion of RHA blended concrete. The increasing demand for producing durable construction materials is the outcome of the fast polluting environment. Supplementary cementitious materials prove to be effective to meet most of the requirements of durable concrete. Rice husk ash is found to be greater to other supplementary materials like silica fume and fly ash. Due to its high pozzolanic activity, both strength and durability of concrete are enriched. Addition of rice husk ash to Portland cement not only improves the early strength of concrete, but also forms a calcium silicate hydrate gel around the cement particles which is highly dense and less porous. This may increase the strength of concrete against cracking. Previously, investigation on the corrosion performance of rice husk ash blended concrete is very limited. Further researches are ongoing or have started recently by the authors to study the performance of RHA and corrosion of concrete mixes. Various tests were carried out to evaluate durability of concrete made with 10, 20, 30 and 40% replacements of RHA by weight of cement. Nevertheless, the results of compressive strength, absorption test and chloride penetration from previous investigation were presents in this study.

Keywords: Rice Hush Ash; Corrosion; Compressive Strength; Absorption and Chloride Penetration

1. Introduction

Blending of reactive rice husk ash in cement has become a common recommendation almost in all the international building codes. Owing to its technological and economical advantages, it has gained its importance. It is learnt that, in order to produce RHA, a specific set of temperature and duration of burning has to be maintained. However, the form of silica obtained after combustion of RHA depends on the temperature and duration of combustion of rice husk.

Studies by Chandrasekar et al. [1] have shown that the physical and chemical properties of ash are dependent on the soil chemistry, paddy variety, and climatic conditions. Other studies have been

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made by Maeda et al. [2] and Muthadhi et al. [3] also shown that differences may also due to fertilisers applied during rice cultivation.

The chemical compositions of RHA from various locations are presented in Table 1 which shows that the variation in chemical composition, especially silica content, is not high (in the range of 85% to 95%). All the other constituents of RHA, except potassium and magnesium, are available in a very small range, i.e., less than 1%.

TABLE 1: COMPARISON OF CHEMICAL PROPERTIES OF RHA FROM VARIOUS LOCATIONS [3]

Weight, %			
Constituents	Malaysia	Brazil	Netherlands
SiO_2	93.1	92.9	86.9
Al_2O_3	0.21	0.18	0.84
Fe_2O_3	0.21	0.43	0.73
CaO	0.41	1.03	1.4
K_2O	2.31	0.72	2.46
MgO	1.59	0.35	0.57
Na_2O	*	0.02	0.11
SO_3	*	0.1	*
LOI	2.36	*	5.14
Note:* not reported			

The present day construction industry is under tremendous compulsion of producing not only strong, but also durable building materials to cater to the increasing needs, devastating forces, and fast polluting environment. Blended cements, though not altogether a new concept, are in the forefront of durable building materials.

2. Rice husk combustion

Rice-husk is an agricultural by-product material. It constitutes about 20% of the weight of rice. It contains about 50% cellulose, 25–30% lignin, and 15–20% of silica. When rice-husk is burnt rice-husk ash (RHA) is generated. On burning, cellulose and lignin are removed leaving behind silica ash.

The controlled temperature and environment of burning yields better quality of rice-husk ash as its particle size and specific surface area are dependent on burning condition. For every 1000 kg of paddy milled, about 200 kg (20%) of husk is produced, and when this husk is burnt in the boilers, about 50 kg (25%) of RHA is generated. Completely burnt rice-husk is grey to white in color, while partially burnt rice-husk ash is blackish.

Research on producing rice husk ash (RHA) that can be used in concrete is not new. In 1973, Mehta [4, 5] investigated the effect of pyroprocessing on the pozzolanic reactivity of RHA. Based on his work, Pitt [6] developed a fluidized bed furnace for the controlled combustion of rice husk. It was found that when the temperature of burning and the residency time inside the furnace are controlled, highly pozzolanic RHA could be produced.

Since then, many attempts have been made to produce and use pozzolanic RHA in several countries including, among others, China, Japan, India, Guyana, Malaysia, Senegal, Taiwan, and the UK (Yu et al. [7], Yamamoto et al. [8], Boateng and Skeete [9], Singh et al. [10], Mahmud et al. [11], Cisse and Laquerbe [12], Cook et al. [13], Hwang and Wu [14], Zhang and Malhotra [15] and Bouzoubaa and Fournier [16].

Mehta [17] suggested that essentially amorphous silica can be produced by maintaining the combustion temperature below 500°C under oxidizing conditions for prolonged periods or up to 680°C with a hold time less than 1 min. However, Yeoh et al. [18] report that RHA can remain in the amorphous form at combustion temperatures of up to 900°C if the combustion time is less than 1 hour, while crystalline silica is produced at 1000°C with combustion time greater than 5 min.

Using X-ray diffraction, Chopra et al. [19] observed that at burning temperatures up to 700°C, the silica was in an amorphous form. The effect of different burning temperatures and the chemical composition of rice husk (Taiwan RHA) were studied by Hwang and Wu [20]. It was observed that at 400°C, polysaccharides begin to depolymerize. Above 400°C, dehydration of sugar units occurs. At 700°C, the sugar units decompose. At temperatures above 700°C, unsaturated products react together and form a highly reactive carbonic residue. The X-ray data and chemical analyses of RHA produced under different burning conditions given by Hwang and Wu [20] show that the higher the burning temperature, the greater the percentage of silica in the ash. K, S, Ca, Mg as well as several other components were found to be volatile.

3. Properties of RHA

RHA is a very fine material. The average particle size of rice-husk ash ranges from 5 to 10µm. Physical properties values as reported by few authors are given in Table 2.

Rice husk ash is very rich in silica content. Silica content in RHA is generally more than 80-85%. Chemical composition of RHA as reported by few authors is given in Table 3. For RHA to be used as pozzolan in cement and concrete, it should satisfy requirements for chemical composition of pozzolans as per ASTM C618. The combined proportion of silicon dioxide (SiO_2), aluminium oxide ($A1_2O_3$) and iron oxide (Fe_2O_3) in the ash should be not be less than 70%, and LOI should not exceed 12% as stipulated in ASTM requirement.

TABLE 2: PHYSICAL PROPERTIES OF RHA

Property	Value			
	Mehta et al. [4]	Zhang et al. [21]	Feng et al. [22]	Bui et al. [23]
Mean particle size (µm)	-	-	7.4	5.0
Specific gravity	2.06	2.06	2.10	2.10
Fineness: Passing 45 µm (%)	99	99	-	-

TABLE 3: CHEMICAL COMPOSITION OF RHA

Constituents	Percentage		
	Mehta et al. [4]	Zhang et al. [21]	Bui et al. [23]
Silica (SiO_2)	87.2	87.3	86.98
Alumina (Al_2O_3)	0.15	0.15	0.84
Iron Oxide (Fe_2O_3)	0.16	0.16	0.73
Calcium Oxide (CaO)	0.55	0.55	1.40
Magnesium Oxide (MgO)	0.35	0.35	0.57
Sodium Oxide (Na_2O)	1.12	1.12	0.11
Potassium Oxide (K_2O)	3.68	3.68	2.46
Sulfur Oxide (SO_3)	0.24	0.24	-
LOI	8.55	8.55	5.14

Malaysian rice husk as illustrate in Figure 1, was then incinerated in an Furnace Gas rate of $10^{o}C$ per minute up to $700^{o}C$, maintained at this temperature for 6 hours, and then allowed to cool down to room temperature as show in Figure 2.

(a) (b)

Figure 1. (a) Raw rice husk (b) Rice Hush Ash (RHA)

4. Rice husk ash in concrete

Ikpong and Okpala [21] studied the variation in strength of medium workability concrete with the incorporation of RHA. Cement was partially replaced with 0, 20, 25 and 30% of RHA. 28-days designed strength of concretes was 20, 25, 30 and 40 N/mm^2. The compressive strength continued to increase with age for each of the mixes. The control mix (0% RHA) attained a higher strength than the OPC/RHA mixes at all age. At the age of 28 days all the OPC/RHA concretes, except the designed mix of 40 N/mm^2, had attained their 28-day design strengths. For the designed mix of 40 N/mm^2, the mix having 30% RHA content reached 98.5% of its design strength, while the one having 40% RHA content reached 86.5%.

However, Zhang and Malhotra [15] investigated the influence of 10% RHA inclusion as partial replacement of cement on the compressive strength of concrete and compared it with the compressive strength of concrete containing 10% silica fume (SF). Water-to-cementitious material ratio was maintained at 0.40. At 28 days, the RHA concrete had a compressive strength of 38.6 MPa compared with 36.4 MPa for the control concrete and 44.4 MPa for SF concrete. At 180 days, RHA concrete exhibited compressive strength of 48.3MPa compared with 44.2 MPa for the control concrete and 50.2MPa for SF concrete. On the other hand,

Wada et al. [22] demonstrated that RHA mortar and concrete exhibited higher compressive strength than the control mortar and concrete. They have further reported excellent strength development at the early stages even without steam curing for RHA mortar and concrete.

Saraswathy and Song [23] investigated the effect of partial replacement of cement with rice husk ash (RHA) on the porosity and water absorption of concrete. Cement was replaced with 0, 5, 10, 15, 20, 25, and 30% RHA. Proportion of control (without RHA) mix was 1:1.5:3 with w/c ratio of 0.53. Porosity and water absorption test was carried out as per ASTM C642-97. They concluded that: (i) porosity values decreased with the increase in RHA content because small RHA particles improved the particle packing density of the blended cement, leading to a reduced volume of larger pores; and (ii coefficient of water absorption for rice husk ash replaced concrete at all replacement levels was found to be less when compared to control concrete.

Studies by Zhang and Malhotra [15] investigated the chloride-ion penetration resistance of concretes made with 10% RHA and 10% silica fume (SF). Details of the concrete mixture along with the chloride-ion penetration test conducted as per ASTM C1202 are given in Table 4. It can be seen from these results that use of RHA and SF has drastically reduced the chloride-ion penetration at both the age. These values were less than 1000. As per ASTM C1202, when charge passed through concrete is less than 1000 coulombs, the concrete has very high resistance to chloride-ion penetration.

TABLE 4: TEST RESULTS OF RESISTANCE OF CONCRETE TO CHLORIDE-ION PENETERATION, [15].

Mix No.	Type of Concrete	Strength (MPa)	Chloride-ion (Coulombs)	
			28 days	90 days
CO-D	Control	36.5	3175	1875
R10-D	10% RHA	45.5	875	525
SF10-D	10% SF	42.8	410	360

5. Ongoing studies by the authors

The authors of this paper are conducting research to study performance of concrete incorporating rice husk ash as a supplementary cementing material. However, the effect of chloride penetration containing RHA on blended concrete also will investigate on this study. The RHA was achieving from Agrilectric Power Plant in Nibong Tebal, Pulau Pinang, Malaysia. Rice husk ash was accomplished from burning in Furnace Gas with the maximum temperature of 700^{o}C for six hours. Ground RHA will obtain using ball mill grinding with varying time. Nevertheless, the XRF, XRD and SEM analysis will perform on Portland cement and RHA.

The experimental work includes testing of chloride ion permeability and properties of harden concrete containing RHA. The concrete mixes containing 10%, 20%, 30% and 40% of RHA as a substitute for cement and water/binder ratios of 0.40, 0.45 and 0.50. This experimental work is still ongoing, and is expected to be completed by the end of August 2011.

6. Experimental program by the authors

6.1. *Harden Concrete Characteristics*

Test on harden concrete can be classified into mechanical test to destruction and non destruction test and thus make possible a study of the change in properties with time. The compressive strength test, density, porosity and water absorption will be selected in this study.

6.2. *Rapid Chloride Permeability Test*

Corrosion is mainly caused by the ingress of chloride ions into concrete annulling the original passivity present. The RCPT has been developed as a quick test able to measure the rate of transport of chloride ions in concrete. RCPT is based on the principle that negatively charged chloride ions are attracted to a positive electrode and consists of measuring the total charge passed through a sample over the six hours test duration when a direct current (D.C.) potential difference of 60 V is applied across the end of the samples. RCPT involves two steps: Sample preparation including conditioning, saturation and setting up the test and monitoring the amount of electrical current passing through the sample during six hours test duration as described in ASTM C1202 [24]. Figure 3 represents the RCPT setup.

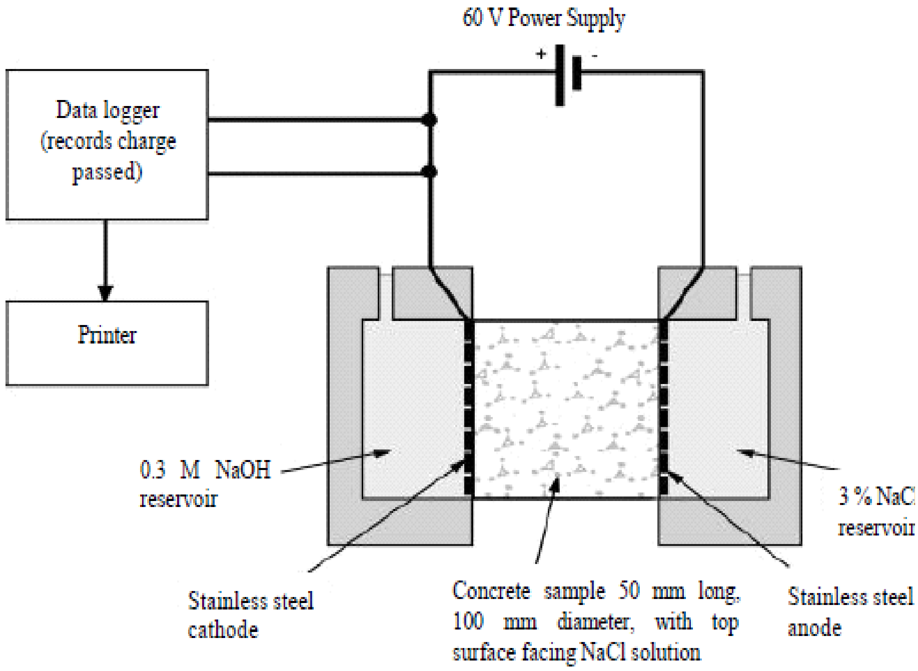

Figure 3: Rapid Chloride Permeability Test, ASTM C1202 [24]

6.3. *Rapid Migration Test*

According to Tang et al. [25] and Tong et al. [26], the specimens of 100 mm diameter and 50 mm height will be condition and test for the chloride ion diffusion coefficient using the modified rapid migration test (MRMT) at the age of 28 days. The solutions employ in migration tests will be 3% NaCl (in limewater) in the cathode side and limewater in the anode side. Apply voltage of 30 V dc at 8 h will employ. The typical chloride migration test illustrate in Figure 4.

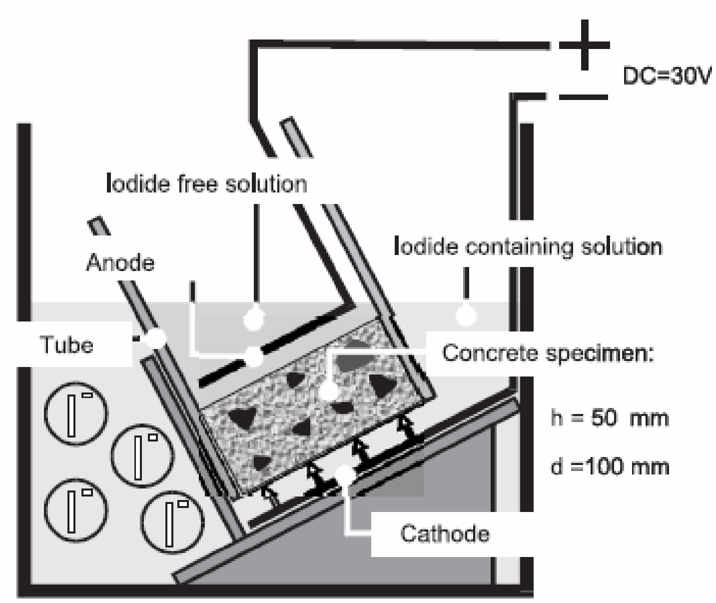

Figure 4: Typical chloride migration cell, Tang et al. [28] and Tong et al. [26]

7. Summary

Different of rice husk ash at 0%, 10%, 20%, 30% and 40% replacement levels will be evaluate to determine the optimum of RHA in concrete mixes. The optimum grinding time of RHA also will be evaluated. Conversely, properties of harden concrete, the rapid chloride ion penetration test; rapid migration test will use to monitor the chloride solution of concrete and strengths. However, the current test methods and standards for sulfate attack will use for this issue.

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