THE SUITABILITY OF LIME RICE HUSK ASH CEMENT AS CONSTRUCTION MATERIAL

OBASI, N.L. and ALIMBA,M. U.
Civil Engineering Department,
Enugu State University of Science and Technology, Enugu, Nigeria.

ABSTRACT

Previous studies have demonstrated that rice husk ash cement is unsatisfactory as a construction material particularly for high strength structures due to its structural instability and low strength development. In the present study a comparative analysis of the chemical composition of ordinary Portland cement and the rice husk ash cement indicated that the content of silica, potassium oxide and sodium oxide are greater in rice husk ash cement than in Portland cement while rice husk ash s *deficient in calcium oxide .. However, by gradually increasing the percentage contents of silica, potassium oxide and sodium oxide in the Portland cement to the value*s *found in the rice husk ash a new product, "Artificial Lime Rice Husk Ash" (ALRHA) cement was produced. The new product ALRHA cement compared favourably with the ordinary rice husk ash cement particularly in strength development and degree of stability. It was therefore concluded that high percentage contents of silica, potassium oxide and sodium oxide are responsible for the structural instability and low strength development of the Lime Rice Husk Ash cement. It appears therefore that the successful utilization of the Lime Rice Husk Ash cement when used as a construction material would depend largely on the successful reduction of the high percentage of silica, potassium oxide and sodium oxide to the level present in ordinary Portland cement.*

Key words: Rice Husk; Ash; composition.

NOTATIONS

OPC - Ordinary Portland Cement
ALRHAC - Artificial Lime Rice Husk Ash Cement
LRHAC - Lime Rice Husk Ash Cement
CaO - Calcia
$A1_20_3$ - Alumina
Fe_20_3 - Ferric Oxide
FeO - Ferrous Oxide
SiO_2 - Silica
MgO - Magnesia
SO_3- Sulphur III Oxide
K_2O - Potassium Oxide
Na_2O- Sodium Oxide
S- Sulphur

1.0 INTRODUCTION

Agricultural residues including rice husk are composed of organic constituents such as cellulose, lignin, fiber and small amount of protein and fat. In addition, they contain some minerals which include silica, aluminum, iron plus oxides of trace elements introduced into the soil through fertilizer applications. The residue itself cannot be used as a cement replacement and it is the ash obtained from pyroprocessing the residue that is of interest. The two factors that require consideration in the pyroprocessing are the ash content and its chemical constituents that is important because it indicates the amount of residue that needs to be burnt. Silica is generally the major chemical constituent of the ash, which is propitious because with suitable conditions of pyroprocessing it can react with lime to produce cementitious Calcium Silicate hydrates. Cook [1] reported that for every 1000kg of rice husks burnt, 200kg of ash are produced.

In the conversion of rice husk to ash the combustion process removes the organic matter and leaves a silica ash residue. However, such thermal treatment of the silica in the husk results in structural transformations that influence both the pozzolanic activity of the ash and its grindability. Mehta [2] states that totally amorphous silica can be produced by maintaining the combustion temperature either below 500^{o}C under oxidizing conditions for prolonged periods or up to 680^{o}C. On the other hand, it has been showed that if the duration time of combustion was less than one hour, a combustion temperature of 900°C could be used with the ash still remaining amorphous and the grinding of the ash of amorphous silica to a suitable particle size lasting for about 30minutes.

Cook [1] reported that utilization of agricultural residues in housing and construction industries has been investigated for many years with only limited commercial success. Rice husks are residues produced from rice mills in significant quantities on a global basis. Beagle [3] cited two German patents as forerunners in describing the use of rice husks in concrete production as early as 1924. Further work in this area was by McDaniel [4] in the United States of America. Similarly, Hough et al [5] investigated the incorporation of lime in the rice husk ash as a replacement of Portland cement. However the proceedings from UNIDO Conference [6] in 1979 recommended that the use of the rice husk ash cement would be mainly for mortar and plaster/rendering applications.

The improvement in the use of the ash resulting from burning rice husk as a cementitions binder in conjunction with lime is currently receiving attention worldwide. It would appear to offer the attractive prospect of providing low cost alternative cement by using a readily conventional binder particularly as Portland cement is generally expensive in most developing countries.

Cement as a building material has remained a central pivot of shelter and infrastructural development all over the world. Construction industries depend so much on cement for its developmental activities such that the demand is always on the increase. It has been shown that some cement plants in most developing countries have either broken down due to lack of regular maintenance resulting from old age or are currently operating below their design capacities. For instance, in Nigeria the national demand for cement from 1986 to 1996 ranged from 4.0 to 7.8 million tones per year while local production over the same' period ranged between 2.3 to 3.5 million tones per year Bello, [7]. The production profile of the Nigerian Cement Industries as shown in Table 1 indicates that only 36% of their installation capacities are currently being utilized. Cook [8] reported that over eight million tones of rice husk is available each year during the processing of rice. Some are used as fuel while the greatest portion is dumped as a waste by-product constituting environmental problems to the society. The basic research and development work in the area of rice husk ash cement technology has been undertaken by a variety of Institutions and individuals principally in the Indian sub-continent. The current potential uses of this material include production of building blocks, mortar for rendering and low strength concrete. [9]

However, the products of this material

exhibited high degree of instability and low strength development and the primary objective of this study is to examine the potentials inherent in rice husk ash of predetermined proportions to give a by-product that has self-cementing characteristics similar to ordinary Portland cement. It could be noted from the report of the Bureau of Agricultural Economics [10] shown in Table 1.1 that the largest quantity of rice produced come from the developing countries and the utilization of rice husks to produce Portland cement replacement should be very attractive in these countries due to the availability of the raw materials.

Table 1.1: Chemical Composition of Cement Types

Type of Cement	Composition								
	CaO	A_2O_3	Fe_2O_3	FeO_3	SiO_3	MgO	SO_3	S	Total
Portland Cement	64.1	5.5	3.0	-	20.0	1.4	2.1	-	98.1
High Alumina	37.7	38.5	12.7	3.9	5.3	0.1	0.1	-	98.3
Portland Blast	59.0	8.1	1.0	0.5	22.8	3.5	l.7	0.5	97.1
Eiesn Portland	59.4	8.5	0.8	1.7	23.5	3.3	2.0	0.5	99.7
Mochofen	53.2	11.0	0.5	1.3	26.5	3.0	1.6	1.0	98.1
Slaz (Cold Process)	49.0	12.8	-	1.3	27.4	2.8	1.0	1.0	95.3
Super Sulphated	45.0	13.1	1.0	0.9	25.2	3.5	7.0	1.0	96.7

Source: Lea [11].

2.0 MATERIALS AND METHODS

2.1 Materials

Materials utilized for this study include ordinary Portland cement from Niger Cem PLc Nkalagu, Rice Husk from Abakaliki Rice Mill, Calcium Oxide from Niger Gas Plc Emene, Aggregates, Water, Potassium Oxide, Sodium Oxide and Silica.

2.2 Production Of Lime Rice Husk Ash Cement (LRHAC)

In this study, three samples of rice husk were prepared for open air burning and oven burning. The samples for oven burning were at controlled temperatures of 400°C and 600^{o}C respectively. The ash residue obtained from the burnt rice husk samples was analyzed chemically according to Lea [11]. A combination of lime and Ash in a weight ratio of 2:1 [11] was ground by ball milling for some hours producing a pozzolanic reaction to form a cementitious material called Lime Rice Husk Ash Cement (LRHAC).

Preparation of Artificial Lime Rice Husk Ash Cement (ALRHAC)

The preparation of Artificial Lime Rice Husk Ash Cement was achieved by weighing out three equal samples of Ordinary Portland cement and gradually adding to each sample progressively sodium oxide, potassium oxide and silica in the percentage order of 34%, 67% and 100% respectively. The samples with varying percentages of the excess compounds are code- named Cycles I, II and III respectively and the calculated percentage by weight of the various compounds added. The cycle III sample is however assumed to be chemically equivalent to the natural lime Rice Husk Ash Cement and is called the Artificial Lime Rice Husk Ash Cement "ALRHAC".

2.4 Experimental Quality Control Tests

Each of the Cycle samples produced as Artificial Lime Rice Husk Ash Cement was used to produce fresh concrete and mortar whose quality was assessed by conducting some quality control tests like the fineness, soundness, setting time and compressive strength. The sample products from Ordinary Portland cement and natural Lime Rice Husk Ash Cement were used as control.

2.4.1 Fineness

The fineness of the samples of the Artificial Lime Rice Husk ash cement as well as that of cement were determined by oven-drying and then passing the samples through different sieves. The samples retained in sieves 72BS and 170BS are shown in Table 3.4.

2.4.2 Setting Time

The initial and final setting times of the samples produced were determined in the laboratory with the Vicat apparatus. The paste of standard consistency was prepared using about 650g of each sample with water content of 26% by weight and was thoroughly mixed with the trowel. The quantity of water required to bring the cement slurry to a paste of tandard consistency was determined by using the 10mm plunger attachment on the Vicat apparatus while the initial and finial setting times were determined according to B.S 4550 on all samples using the 1mm and 5mm diameter needles.

2.4.3 Soundness:

Le Chatlier's Mould was placed on a small glass plate and filled with each of the cement paste of standard consistency. The pastes were leveled up and covered with another glass plate and the whole assembly immersed in water at room temperature of about 28°C for 24 hours. The gap between the indicators of the mould was measured and the whole assembly was immersed in the water bath and heated to the boiling point temperature of 100°C for one hour thirty minutes after which the moulds were removed from the water bath and allowed to cool for hours. The vertical gap in space between the indicators of the mould and the sample were re-measured after cooling and the values earlier recorded were subtracted from the current values.

2.4.4 Compressive Strength Test

Construction materials such as cement, fine and coarse aggregates were each weighed out in the proportion of 1:2:4 and water content of about 60% by weight was added and thoroughly mixed to form concrete. Some steel cube moulds were properly cleaned, oiled and sampled concrete filled in two layers and each layer was compacted manually by using a 1.8kg tamping bar. Each layer received 25 blows and the surface of the concrete was trowelled level with the top of the mould. The test specimen in their moulds were stored in a vibration free environment under room temperature of about 28°C and covered with moist sack for 24 hours to allow setting and hardening of the concrete. The concrete samples were clearly identified with dates and marks to differentiate the cubes prepared with the various types of cement. The concrete samples were demoulded and cured by immersion in water at room temperature of 28°C until the period of tests. The samples were tested after three, seven, twenty one and twenty eight days on surface dry condition immediately they were removed from the curing tank. The corresponding compressive strength results determined by using the compression machine in accordance with BS 1881.

3.0 RESULTS AND DISCUSSIONS

The study consisted of X-raying the approximate chemical compositions of ordinary Portland cement [11] and Rice Husk Ash presented in Tables 3.1 and 3.2. A comparative review of the chemical compositions of these cement types revealed that Rice husk ash obtained at burning temperature of 600°C has Silica, potassium oxide and sodium oxide in excess by 20%, 3.2% and 0.12% respectively when compared with ordinary Portland cement. However, it was also observed that its content of Calciurn oxide was deficient by 60%.

The results of the investigation show that fineness tests on the various materials conducted yielded values that compared closely particularly for Lime Rice Husk Ash Cement (LRHAC) and Cycle 3 cement with a percentage difference of 3.5% for 170 BS mesh and 4.8% for 72 BS mesh (Table 3.3). Similarly, the fineness values for LRHAC and OPC differ by 12% for 170 BS mesh and 4.8% for 72 BS mesh while Cycle III cement and OPC differ by 9.4% for 170 mesh only. The results obtained from various cement types conformed within the limits exhibited by Ordinary Portland Cement in line with the specification of the British Standard, but the test results for the Cycle ill and LRHAC indicate high degree of resemblance in the chemical composition while results ofLRHAC and OPC when compared with the results of Cycle III and OPC further indicate that LRHAC has a close resemblance in chemical composition with the Cycle III cement type.

<u>Table 3.1</u>: Chemical Composition of Rice Husk Ash for open air and oven burning.

Compound Composition	Open Air Burning	Oven Burning (400°C)	Oven Burning (600°C)
Silica ($Si0_2$)	89.15	86.56	85.51
Calcia (CaO)	2.10	2.97	1.25
Magnesia (MgO)	1.32	2.14	2.50
FerricOxide(Fe_2O_3)	0.18	0.63	0.92
Alumina (Al_2O_3)	4.32	3.65	0.75
SodiumOxide(Na_2O)	0.05	0.10	0.12
PotassiumOxide(K_2O)	1.48	2.70	3.16
Others	1.40	1.25	5.80

<u>Table 3.2</u>: Typical chemical analysis of rice husk ash

Constituents	Percentage by weight (i)	Percentage by weight (ii)
$Si0_2$	92.15	85.5
A_IO_3	0.41	0.75
Fe_2O_3	0.21	0.92
CaO	0.41	1.25
MgO	0.45	2.50
Na_2O	0.08	0.12
K_2O	2.31	3.16

***Sources:** (i) Cook [1]; (ii) Result from this study*

<u>Table 3.3:</u> Calculated Percentage Weights of Compounds

Cycles	Percentage additions	$Si0_2$ (kg)	Na_20 (kg)	K_20 (kg)
I	33%	10.92	0.28	0.10
II	67%	21.84	0.57	0.20
III	100%	32.76	0.85	0.30

Table 3.4: **Fineness And Setting Time Result**

Sample Type	72BS Sieve (%)	170 BS Sieve (%)	Initial Setting		Final Setting	
			Minutes	Hours	Minutes	Hours
Portland Cement	0.20	5.8%	80	1.33	110	1.83
Lime Rice Husk Ash	0.21	6.6%	93	1.55	232	3.87
Cycle I Cement	0.20	5.95%	90	1.50	180	3.00
Cycle II Cement	0.21	6.2%	94	1.57	208	3.47
Cycle III Cement	0.20	6.4%	94	1.58	240	4.00

The consistency tests conducted on the materials show that the initial and final setting time values for LRHAC and Cycle III cement differ only by 1% and 3.4% respectively which is insignificant as can be seen in Table 3.4. Similarly, the setting time values for Cycle III cement and OPC differ by 17.5% and 118% respectively which show that there is some differences in the chemical composition of the materials. Equally, the setting time values for LRHAC and Cycle III cement compared closely with each other, though the values recorded for all cement types were within the limits of the ten hours specified by the British Standard (BS4550). Das and Mohau [12] obtained setting time values of 75 minutes for initial setting and 500 minutes for final setting on similar materials tested in Nepal with the Vicat apparatus. However, the Indian Standard recommended an initial setting time of 120 minutes and [mal setting time of 1440 minutes.

Table 3.5: Soundness Test Results

	Portland Cement		LRHAC		Cycle I		Cycle II		Cycle III	
Sample No	1	2	1	2	1	2	1	2	1	2
Gap After	20.5	24.5	22.5	26.5	10.0	19.5	14.0	24.0	20.0	24.5
Gap Before	19.7	23.7	22.0	26.0	9.50	18.5	13.4	23.4	20.0	24.0
Expansion/Contraction	0.80	0.80	0.50	0.50	0.50	1.0	0.60	0.60	0.50	0.50
Average Expansion/ Contraction	0.80min		0.50mm		0.75mm		0.60mm		0.50mm	

Soundness tests indicate the rate of volume change of concrete after setting and Table 3.5 shows the results of the soundness tests conducted on the materials. The results equally show that the expansion recorded for LRHAC was 0.5mm which corresponds with the value exhibited by Cycle III brand of cement. The expansion results of Cycle III cement and LRHAC differ from that of OPC by 37.5% showing appreciable difference in chemical composition. Generally, the expansion test result for Ordinary Portland Cement ranges between 0.50mm and 1.00mm as specified by the British Standard (BS4550) indicating that all cement types used in this study would not undergo significant changes in volume during pre and post construction periods. This implies that there was no traces of free or uncombined Lime, Magnesia and Calcium Sulphate in all the brands of cement under study. Expansion in Le Chatelier's mould according to Das and Mohau [12] was 2.5mm while Cook [1] reported that the Le Chatelier's expansion test carried out on similar material in Nepal was 0.5mm which is the same with the result of the present study. The quality of cement usually used for construction depends primarily on its mechanical strength in the set and hardened states. The mechanical test therefore plays a vital role in determining the quality of concrete with respect to minimum strength that must be attained under any given condition. The compressive strength results obtained for all brands of cement as show that compressive strength values for LRHAC and Cycle III brand of cement for periods 3, 7, 21 and 28 days differ in percentage value ranges of 18.9%, 10.7% 2.2% and zero% respectively showing that the difference in values tends to zero with time. Also the strength results of LRHAC and OPC from 3 to 28 days differ in the ranges of 92%, 87.8%, 81.5% and 80.4% which are similar to those of Cycle ill cement and Ordinary Portland cement. It could be seen that the compressive strength values for LRHAC and Cycle III brand of cement compared closely indicating that Cycle III brand of cement is an approximate representation of LRHAC. The compressive strength results obtained by Das et al [12] on rice husk ash cement in Nepal were 2.0,2.7 and 4.9 Mpa for periods of 3, 7 and 28 days respectively. The plot of compressive strength results against time presented in Figure 3.1 show the pattern of compressive strength development of various brands of cement used in this study. It was observed that the compressive strength of Ordinary Portland Cement decreased progressively with increase in the proportion of excess compounds as shown by the various brands of cement. The rate of strength development was faster in all samples within the first week. Each brand of cement shows a unique trend of strength increase with time and the values attained at the third week seemed to be the optimum values since the strength profiles ran asymptotically to the time axis. The slopes of the strength curves show that the Portland cement has a higher rate of strength development than Lime Rice Husk Ash Cement.

CONCLUSIONS

The various types of cement used in this study showed indications of good fineness, soundness, consistency and uniformity when used for concrete production. The new product Cycle III cement (ALRHAC) compared favourably with the Lime Rice Rusk Ash Cement (LRHAC) particularly in strength development and degree of stability. It can be concluded that the excess values of silica, potassium oxide and sodium oxide are principally responsible for the low strength development and structural instability exhibited by Lime Rice Husk Ash Cement as construction material. It appears therefore that the effective utilization of the LRHAC as construction material would depend largely on the successful reduction of the excess compounds to the values contained in Ordinary Portland Cement. This would ensure the effective disposal and utilization of the agricultural waste improvement in the rural economy and generation of employment for the rural dwellers. In addition the utilization of Lime Rice Husk Ash Cement could result in considerable savings in construction costs thereby encouraging infrastructural development particularly in the rural areas. There are limited application of rice husk ash cement in reinforced concrete work. However, Sulaiman, et al [13] have reported the construction of low cost houses using lime rice ash mixes in reinforced concrete lintels and roof beams.

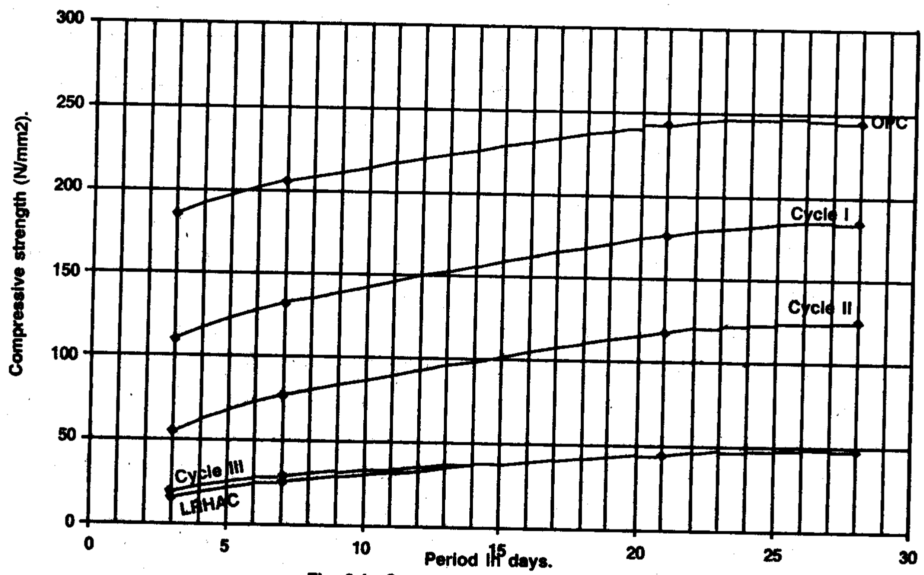

Fig. 3.1: *Compressive strength results for various samples.*

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