Properties of Concrete Made With Portland Limestone Cement Partly Replaced by Rice Husk Ash

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ABSTRACT

Research was conducted in Tanzania to investigate the properties of a concrete made by a replacement of 0%, 6%, 12% and 18% with RHA in Portland limestone Cement. What was investigated was the influence of the ash on the workability, strength development and water permeability of the concrete. The water/binder ratio was kept constant. The results obtained indicated that workability of the concrete decreases with an increase in ash content and suggests that there is an optimum replacement content which give maximum concrete strength. Beyond this optimum ash content, the strength of the concrete decreases. It was also found out that the permeability of the concrete decreased with an increase in RHA content and this confirmed earlier findings by some researchers that the introduction of RHA in concrete makes the concrete more durable.

Other benefits of using RHA in concrete are increased resistance to chemical attack, reduced effects of alkali-silica reactivity, reduced shrinkage rates, increased insulation properties of concrete, reduced amount of plasticizers, and reduced potential for efflorescence.
The other obvious advantage of using RHA apart from reduced environmental pollution is the reduction of carbon emission which is associated with the production of Portland cement. Any partial replacement with RHA in Portland cement implies reduced carbon emission which is the cause of global warming and which the world is fighting against.

Keywords: rice husk, rice husk ash, rice husk ash concrete, environmental pollution

INTRODUCTION

Ordinary Portland Cement (OPC) is becoming very expensive nowadays due to increased energy costs. It is becoming unaffordable in developing countries especially to the rural poor who cannot afford even their basic needs. Since the most expensive component of concrete is OPC any partial replacement of it with Rice Husk Ash (RHA) will offer affordability for low cost housing.(1)

Rice husk is the waste material obtained from rice paddy after the extraction of the rice. Nearly a tonne of husk is extracted from every five tones of paddy. In the third world countries this husk is disposed of by dumping or burning and this causes environmental pollution.
Research has, however, shown that the Rice Husk Ash (RHA) is pozzolanic and if it is obtained by burning the husk at controlled temperatures below 700 deg. C the ash will contain amorphous silica (up to 90%) which is highly reactive. The chemical composition of the ash, however, also depends on the type of paddy, crop year, climate, soil and geographical conditions. The ash can be used as a partial replacement of cement in concrete and thus reduce construction costs.

Studies have been carried out in many countries including Tanzania on the use of low cost building blocks (2, 3,4). Studies carried in Kenya showed that it was possible to replace

50% of Portland cement with RHA and the resulting concrete was 25% less expensive (3). Tests done in Indonesia showed that a concrete mix containing 10% cement, 40% RHA and 50% aggregates plus water produced test blocks with an average compressive strength of 12N/mm^2 (4). Comparing these results with normal concrete blocks without RHA which have an average compressive strength of 4.5 to 7N/mm^2 or high strength concrete blocks which have a compressive strength of 10N/mm^2, the use of RHA is surely very effective. Higher strength concrete with RHA can allow for the production of lighter products like hollow blocks which provide lighter walls with reduced quantities of cement and aggregates. Hollow blocks have the added advantage of good insulation properties.

OPC mixed with RHA (RHA cement) shows some enhanced properties. OPC produces an excess of lime during hydration. Adding RHA which is a pozzolan there is a chemical reaction between the RHA and the lime and in the presence of water one gets a stable and a more amorphous hydrate which is stronger, less permeable and more resistant to chemical attack (5). Laboratory research and field experience have shown that environmental circumstances such as high sulphate soils, reactive aggregate, exposure to salt water, de-icing chemicals, freeze- thaw conditions and acids which are deleterious to concrete can be encountered by adding pozzolans such as RHA. The pozzolan acts as filler, a strength and performance enhancing additive.

A comprehensive study undertaken by the Asian Institute of Technology in Bangkok showed that the addition of RHA to OPC speeds up setting times, although the water requirement is greater than in OPC (6). A study on the comparison of compressive strengths of OPC and RHA mortars showed that at 35% replacement, the RHA cement had improved early strength and, due to its higher percentage of silica, the RHA cement also had higher ultimate compressive strengths compared with OPC (7). Highest compressive strength has been obtained when 35% of Portland cement is replaced RHA. With 50% replacement the strength can be considerably reduced (6)

RHA cement exposed to a mixture of 10% hydrochloric acid and 10% sulphuric acid was found to be more resistant to the acids attack than OPC. More recent studies indicate RHA has uses in the manufacture of concrete for the marine environment (8). Replacing 10% cement with RHA one gets improved resistance to chloride penetration. Also improved is capillary suction and accelerated chloride diffusity.

RHA is also used with fly ash in high strength concrete (9,10) and as replacement for silica fume in high strength concrete(1)

EXPERIMENT

Portland limestone cement used

The Portland limestone cement used was of the type CEM II-A-L/32.5R) and was tested according to the European Standard EN 196 and checked for conformity with Tanzania Standard TZS 727-2002 which is equivalent to EN 197. The tests carried out were physical, mechanical and chemical tests. The physical tests were the determination of setting times and soundness according to EN 196: Part 3, fineness according to EN 196: Part 6. The mechanical tests done were the determination of compressive strength according to EN 196: Part 1. The chemical tests were loss on ignition, insoluble residue, chemical contents by XRF analysis according to EN 196: Part 2 and determination of chloride, carbon dioxide and alkali content of the cement according to EN 196: Part 21. The test results are shown on Table 1 and Table 2.

Table 1. Physical and Mechanical Properties of the Portland limestone cement used

Test	Unit	Test results	Requirements according to EN 197-1
Standard Consistence test	%	26	None specified
Initial setting time	min	148	More than 75 minutes
Soundness	mm	1.0	Less than 10 mm
Fineness	cm^2/g	3650	None specified
Early strength (2 days)	MPa	13.6	More than 10 MPa
Standard strength (28 days)	MPa	35.4	Between 32.5 and 52.5 MPa

Table 2. Chemical test results of the Portland limestone cement used

Test	Unit	Test results	Requirements according to EN 197-1
Loss in ignition	%	5.5	≤5.0
Insoluble residue	%	2.3	≤5.0
CaO	%	66.3	None specified
SiO_2	%/	21.1	None specified
CaO/SiO_2	%	3.1	≥2.0
$Al2O_3$	%	4.9	None specified
Fe_2O_3	%	2.7	None specified
MgO	%	1.0	≤5.0
SO_3	%	2.6	≤3.5

From the physical, mechanical and chemical test results it can be seen that limestone cement met all the requirements of the European Standard EN 197-1.

Rice husk ash used

The rice husk was from Kyela, Tanzania. The rice husk was burnt in a furnace at a temperature of 750°C for 2 hours to get the ash. After cooling, the ash was degraded using a Loss Angeles abrasion machine (with 10 spherical balls) for two hours (Plate 2) to obtain a fine ash (Plate 1) whose specific surface was determined to be $133658cm^2/g$. From XRF analysis of the rice husk ash , the composition of the ash was as shown on Table 3. The pycnometer test gave the specific gravity of the ash as $1.99g/cm^3$

Table 3. Chemical composition of the rice husk ash (RHA) from XRF analysis

Compound	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	C	SUM
Percentage (%)	77.31	7.90	3.05	2.30	1.92	<0.007	1.56	1.04	3.40	98.48

Plate 1 shows the Rice husk ash after grinding and Plate 2 shows the Loss Angeles abrasion machine used to grind the RHA.

Plate 1. Rice husk ash after grinding



Plate 2. Los Angeles abrasion machine



Grading curves of the aggregates used to make concrete and concrete mix design

Sand from a river bed and granite aggregates were used to make the concrete used for tests. The grading of the aggregates are shown on Figure 1 and Figure 2. All the relevant aggregates tests such as the presence of deleterious substances, aggregate impact value etc. were performed to ensure that the aggregates complied with Tanzania standards.



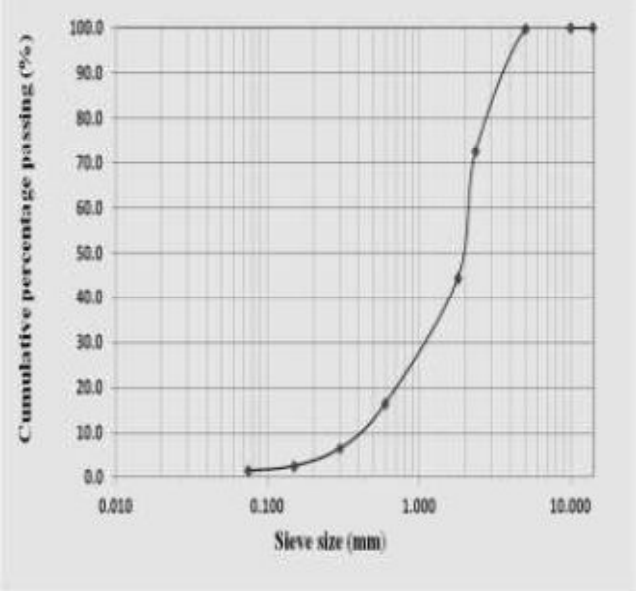


Figure 1. Grading curve of course aggregates

Figure 2. Grading curve of sand

A concrete mix design for grade 30 concrete was made assuming the use of the Portland limestone cement and the mix proportions were found to be cement/water/sand/course aggregates= 1/0.58/1.8/3.6 by weight. Partial replacement of the cement was done using RHA in the following percentages: 0%, 6%, 12% and 18% while keeping the water cement ratio at 0.58

Sump, strength and water permeability tests

The slump test for the fresh concrete showed that as the amount of RHA in a mix increased the workability of the concrete decreases (Figure 3). The variation in strength of concrete with RHA content is shown on Figure 4. Test results for permeability at different concrete ages and for different RHA contents is given on Figure 5.

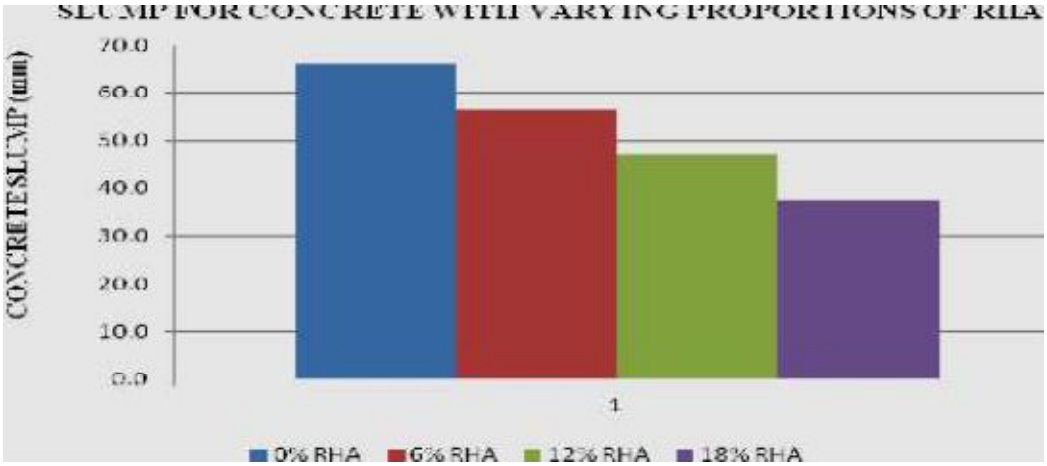


Figure 3. Variation of slump with RHA content

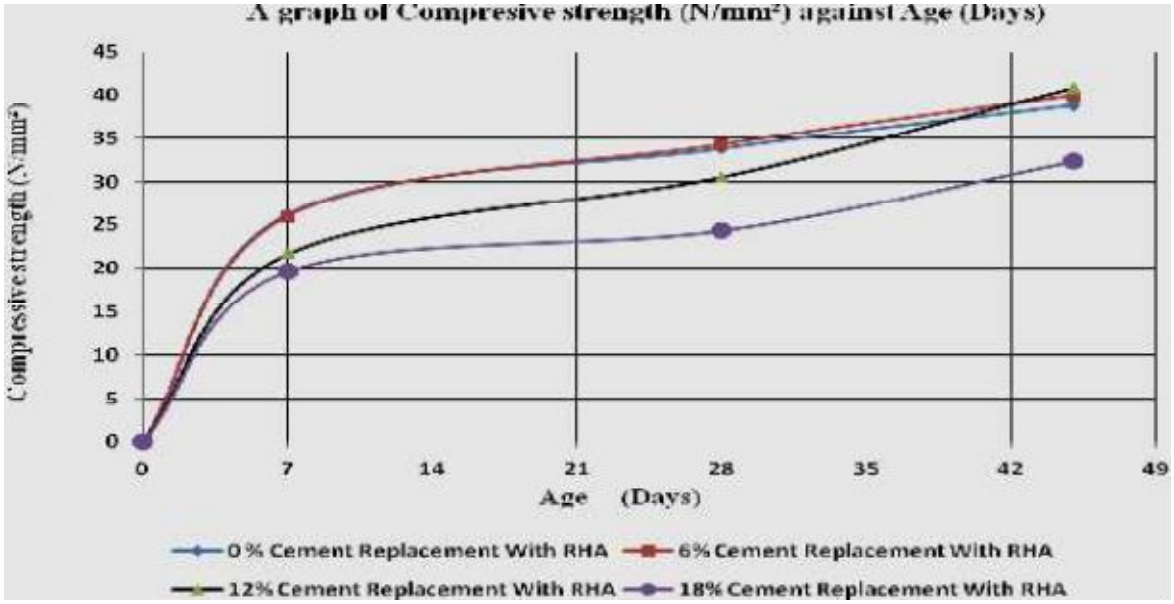


Figure 4. Variation of strength with RHA content

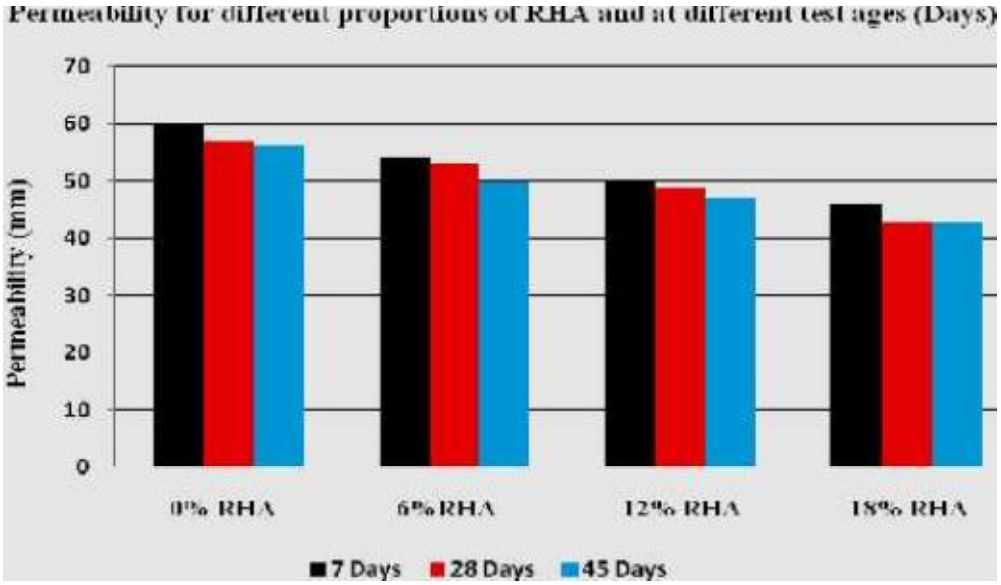


Figure 5. Variation of permeability and concrete age with different RHA different contents

DISCUSSION

The amount of reactive silica contained in the RHA used in this investigation was 77.3% (Table 3) which is less than the maximum of 90% observed in other RHAs in some countries. This is not unexpected since the composition of the ash is known to depend on factors such as type of paddy, crop year, climate, soil and geographical conditions.

The workability of the concrete decreases as the amount of RHA is increased (Figure 3). This is so because of the addition of the finer RHA material which has a higher specific surface than the cement and therefore draws more water from the mix. The higher the specific surface of mix the higher the water requirement to achieve the same workability.

Looking at Figure 4, with 6% RHA replacement, the rate of gain in strength of the concrete was the same as using the limestone cement alone. With 12% RHA replacement the concrete had a higher (or more or less the same) strength at 45 days when compared with using limestone cement alone. The rate of gain of strength shows an upward trend in all replacement ratios (even with 18% RHA replacement) suggesting that the hydration reactions were far from over.
The rate of gain of strength for pozzolans is slower and the normal test age is 90 days.

The permeability of concrete (Figure 5) decreases with an increase in the RHA content in the mix as expected. The smaller sized RHA particles fill the pores in concrete and the reaction of these particles with lime which is released in the hydration of cement produces an amorphous hydrate which is stronger, less permeable and more resistant to chemical attack (5).

CONCLUSIONS

This study has demonstrated that rice husks should not be treated as a waste material which when disposed of by dumping or burning causes environmental pollution. When the husks are burnt at appropriate controlled temperatures they produce RHA which can be used for partial replacement of cement in the construction industry and thus reducing construction costs.

Using RHA in concrete has shown that one gets a stronger and less permeable concrete which due to its low porosity and high strength is more durable.

Other advantages of RHA in concrete are said to be reduced effects of alkali-silica reactivity, reduced shrinkage rates, increased insulation properties of concrete, reduced amount of plasticizers and reduced potential for efflorescence.

Cement production is associated with carbon emission which results in global warming and any partial replacement of cement with RHA is a good contribution towards a better world.

The limitation of the use of RHA lies in the lack of awareness of its potential and the quality of the product itself which may vary from place to place.

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