Investigation of Mechanical Behaviour of Concrete on Partial Replacement of Cement by Rice Husk Ash

[1]Vipul Kumar, [2]Paresh Biswal (Guide)

[1]PG Scholar, [2]Assistant Professor
Department of Civil Engineering
GIET University, Gunupur, Odisha, India

Abstract: **Cement is widely noted to be the most expensive constituent of concrete. The entire construction industry is in search of a suitable and effective waste product that would considerably minimize the use of cements and ultimately reduce the construction cost. Rice husk ash (RHA) which has the pozzolanic properties is a way forward. This research study was therefore, experimentally carried out to determine the optimal amount of Ordinary Portland Cement (OPC) to be partially replaced with Rice Husk Ash (RHA) in concrete production. The rice husk ash was collected from Tilda Uganda limited and burnt at Uganda Clays Limited. Ordinary Portland cement (OPC) was replaced with Rice hush Ash (RHA) by weight at 0%, 5%, 10%, 15%, 20% and 25% with a mix design of 1:1.84:2.44. Chemical characterization tests were carried out on the rice husk ash to determine the major oxides of silica, alumina and iron. Physical tests carried out were slump test on fresh concrete and Compressive Strength test , flexural and splitting tensile strength tests on hardened concrete at different ages of 7, 14 and 28 days of curing. The results on chemical characterization tests revealed that the sum of the percentage of the three major oxides (SiO2,Fe2O3 and Al2O3) were greater than the set standard result (70%) while for the physical tests the slump test results decreased as the percentage replacement of Ordinary Portland cement (OPC) with Rice hush Ash (RHA) increased, which indicated less workable concrete. The compressive strength, flexural and splitting tensile strength tests of the hardened concrete also decreased with increasing Ordinary Portland cement (OPC) replacement with Rice Hush Ash (RHA).**

***Keywords*: Compressive strength, flexural strength, steel fibers, Rice husk ash (RHA)**

I. INTRODUCTION

Concrete is the most widely used man-made construction material and is second only to water as the most utilized substance on the planet (Gambhir, 2005). It is obtained by mixing cement, water, course aggregate and fine aggregate (and sometimes admixtures) in required proportions. The mixture when placed in forms and allowed to cure hardens into a rock- like mass known as concrete (Telford, 1989). There are numerous high rise structures all over the world most of which are constructed out of concrete, and many still to be constructed (Farny & William, 1994).

The major component of concrete being cement(Ordinary Portland cement) which acts as a binder is increasingly getting expensive due to its increasing costs of manufacturing and selling on the market hence making concrete very expensive. People most of whom lie below the poverty line in Uganda cannot afford this high cost material hence opting for inadequate mixed proportions of cement with other concrete materials during construction and ending up not building durable and decent houses.

Due to the above increasing cost of the conventional building material (Ordinary Portland cement), there is need for affordable building materials so as to provide adequate housing for the increasing population in Uganda.

One such alternative building material is the abundant paddy rice husk ash. This ash is produced by burning rice husks that are readily available at Tilda Uganda limited located in Kibimba. Tilda Uganda limited harvests about 1000 tonnes of paddy rice in a month of which the content of husk in paddy is 22% making it 220 tonnes of husks.

II. LITERATURE REVIEW

Concrete is one of the most widely used construction materials in the world (Kosmatka H, 1988). It is a durable and high strength material that has a low permeability. Both fresh and hardened states of concrete must fulfill their intended purpose of use.

Consistency and cohesiveness are the two most important properties when concrete is in its fresh state, as they must facilitate compaction and transportation without segregation (Moral & Tasdemir, 1996).When in the hardened state, it is imperative that the compressive strength of concrete lies within the required limits. The compressive strength affects density, impermeability, tensile strength and chemical resistance.

Concrete is a material formed by mixing cement, aggregate (gravel and sand), water, with or without the incorporation of admixtures and additions (Tsivilis, 2000).

Concrete when fresh, is a liquid paste that can be moulded into any desired shape and yet develops strength to carry different loadings, when matured. This unique characteristic advantage of concrete made it to be the more preferred choice for application in the construction industry.

The cement component as a constituent of concrete is the main binder in translating the liquid paste into a rigid strong concrete. Therefore cement is a vital component and acts as a bonding material within concrete (final monolithic product) (Cui & Tang, 2007).

Concrete, a composite consisting of aggregates enclosed in a matrix of cement paste including possible pozzolanas, has two major components – cement paste and aggregates. The strength of concrete depends upon the strength of these components, their deformation properties, and the adhesion between the paste and aggregate surface (Thomas, 1989).

Alkalis in cement (typically calcium hydroxide and sodium and potassium oxide can react with aggregates containing reactive silica carbonate mineral constituents. In cured cement, these reactions produce different types of expansion that can cause concrete deterioration through internal cracking, surface cracking, and /or aggregate pop out.

III. MATERIALS USED

Cement

Ordinary Portland Cement (OPC) was used in this research study. It was obtained from Seroma cement outlet located at Plot 20 – 22 Entebbe road in Kampala Uganda. This cement is a product manufactured by Tororo Cement factory and it is classified as CEM 1 42.5N (EN 197-1:2005).

Aggregates

The aggregates used in the study were lake sand as the fine aggregates and crushed coarse aggregates obtained from Kasenyi landing site and Muyenga quarry respectively. The fine aggregates used had a maximum size of 5 mm. Crushed coarse aggregates obtained from Muyenga quarry had a maximum size of 20mm (BS 1881: Part 108: 1983).

Rice Husk Ash

Rice husk ash is a by-product of burning rice husks under controlled temperatures so as to acquire the necessary chemical components. The rice husks were obtained from Tilda Uganda limited located on Kampala – Malaba highway in eastern Uganda.

They were then burnt in a blast furnace at temperatures between 500 0 c to 700 0 c at Uganda Clays Limited located on Entebbe road, Kajjansi in Kampala. This temperature was determined using a beam radiator instrument.

The burnt ash was then ground in a mortar and pestle to acquire finer particles which were sieved through a 75 micron sieve in order to remove any impurity and larger size particles (BS 812- 103.1:1985).

Chemical characterization tests on rice husk ash sample were carried out, where three analytical techniques were applied. These included Instrumental Ultra Violet, Titration and Gravimetric analysis techniques. The instrumental technique applied is Ultra-violet Spectrophotometer 20D+ to determine Iron (Fe) content. Titration and gravimetric analysis techniques were applied to determine calcium oxide and magnesium oxide, and, loss on ignition (LOI) and moisture content (MC) (ASTM committee C01; chemical analysis of cement).

Water

Water plays a major role in concrete mixing in that it starts the reaction between the ordinary Portland cement, rice husk ash and the aggregates.

It also helps in the hydration of the mixture. In this research, the water used was that of National Water and Sewerage Cooperation which is safe drinking water as specified in the standard (EN 1008, 1997).

IV. RESULTS & DISCUSSIONS

Grading results for fine aggregates:

The fine aggregates to be used require being well graded and therefore the sieve analysis or grading was carried out. For the fine aggregates to show that they are well graded, they need to fit well within the envelope. Therefore this was achieved as shown in Figure 1 for the fine aggregates used in this research study.

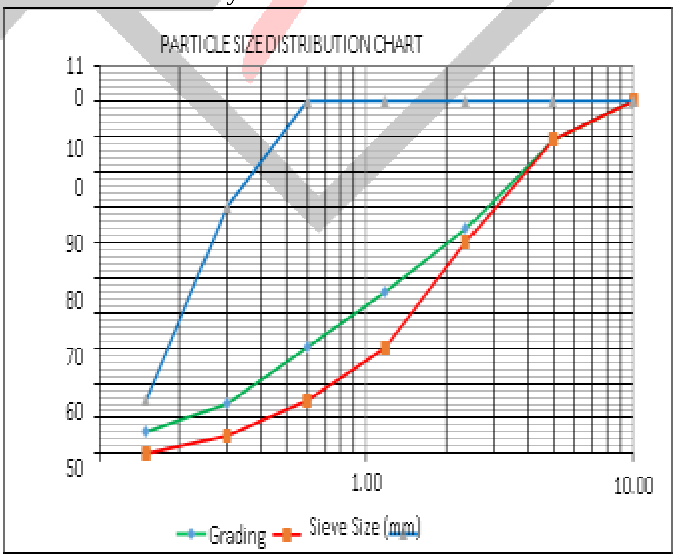

Fig 1: Particle size distribution for fine aggregates

Grading results for coarse aggregates:

The coarse aggregates to be used need to be well graded and therefore the sieve analysis or grading was performed according to (BS 812: Part 103.1:1985). The coarse aggregates were well graded since they fit well within the envelope as shown in Figure 2 below.

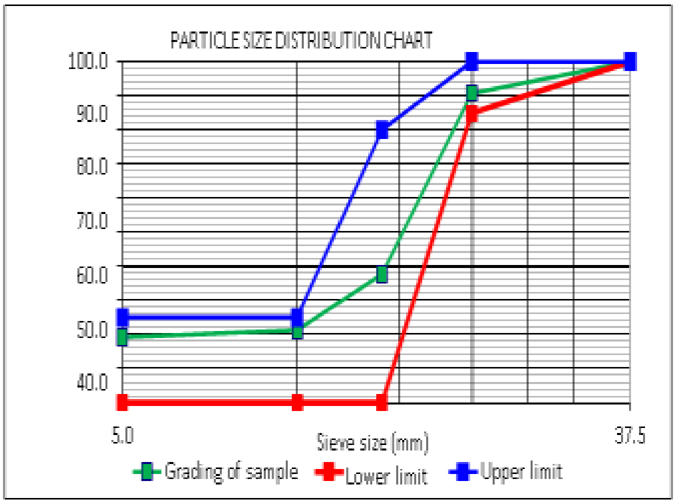

Fig 2: Particle size distribution for coarse aggregates

Slump Test:

The slump test was carried out in accordance to BS 1881: Part 102:1983 on fresh concrete made by varying the RHA content by a 5% increment while reducing the OPC content, and formulating the mixes accordingly (Jayanti, et al., 2013). This was done so as to determine the workability of fresh concrete for each mix. Results of these tests are presented in below.

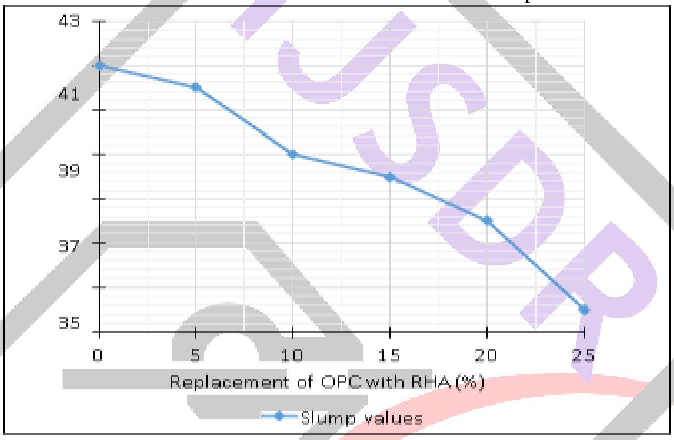

Fig 3: Slump values for the different percentage replacements of OPC with RHA

Compressive strength test results:

The compressive strength of the concrete was determined by crushing three 150 mm squared size cubes at ages 7, 14 and 28 days for each mix. The test was carried out according to B.S.1881 part 116:1983 using a compressive testing machine with a constant loading rate. The compressive strength results are shown below Table 1.

Table 1: Compressive strength test results

	Compressive strength (N/mm^2)		
% replacement ofOPC with RHA	7 days	14 days	28 days
0%	32.30	37.04	48.61
5%	31.26	35.70	45.93
10%	28.74	32.44	41.04
15%	25.33	29.93	35.41
20%	17.33	23.85	28.89
25%	10.37	15.40	21.48

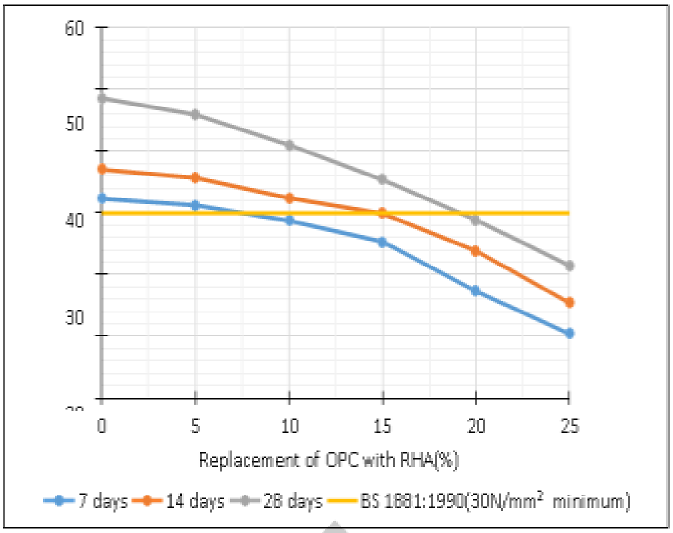

Fig 4: Compressive strength for the different percentage replacements of OPC with RHA

Flexural strength test results:

From the Table and Figure below, the variation of flexural strength is similar to that of compressive strength where by the flexural strength decreased with increased percentage replacement of OPC with RHA. The flexural strength was noted to increase with increasing curing days for all the mixes. The flexural strength from 0% to 15% replacement of OPC with RHA respectively were seen to have met the required minimum standard of 4.5 N/mm2 at 28 days as compared to the 20% and 25% replacements. Also the 5% to 15% replacements of OPC with RHA provide the empirical evidence of using RHA as a partial replacement of OPC with RHA in construction (EN 12390-5- 2009). Therefore, for percentages from 5% to 15% concrete can be used in construction to construct concrete blinding.

Table 2: Flexural strength test results

	Flexural Strength (N/mm^2)		
% replacement ofOPC with RHA	7 days	14 days	28 days
0%	5.22	6.79	9.00
5%	4.15	5.71	7.01
10%	3.40	4.40	5.92
15%	2.58	3.69	4.92
20%	1.98	2.57	3.64
25%	1.20	2.00	2.69

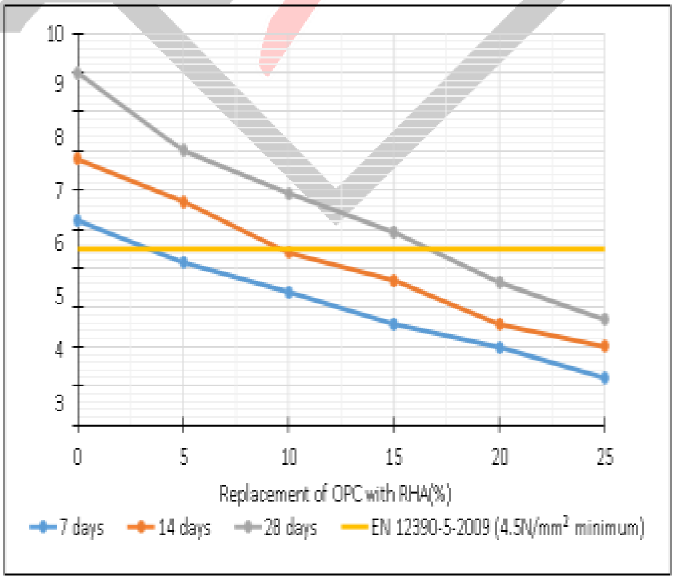

Fig 5: Flexural strength for the different percentage replacements of OPC with RHA

Split tensile strength test results:

From the Table and Figure below, the splitting tensile strength test results show a similar trend to the compressive strength of concrete cubes shown in Figure 4.4 above. The splitting tensile strength decreased with an increase in the percentage replacement of

OPC with RHA in concrete production. The 0% to 10% replacements of OPC with RHA respectively were seen to meet the required minimum standard of 2.9 N/mm2 at 28 days compared to 15%, 20% and 25% replacements (EN 1992-1-1:2004). Therefore the replacement of OPC with RHA in concrete production can be conducted from 0% to 10% to achieve the required splitting tensile strength of concrete.

Table 3: Split tensile strength test results

	Splitting Tensile Strength (N/mm^2)		
% replacement ofOPC with RHA	7 days	14 days	28 days
0%	3.64	4.00	4.99
5%	2.74	3.00	3.99
10%	2.33	2.63	3.02
15%	2.10	2.42	2.71
20%	1.26	1.61	1.98
25%	1.09	1.28	1.49

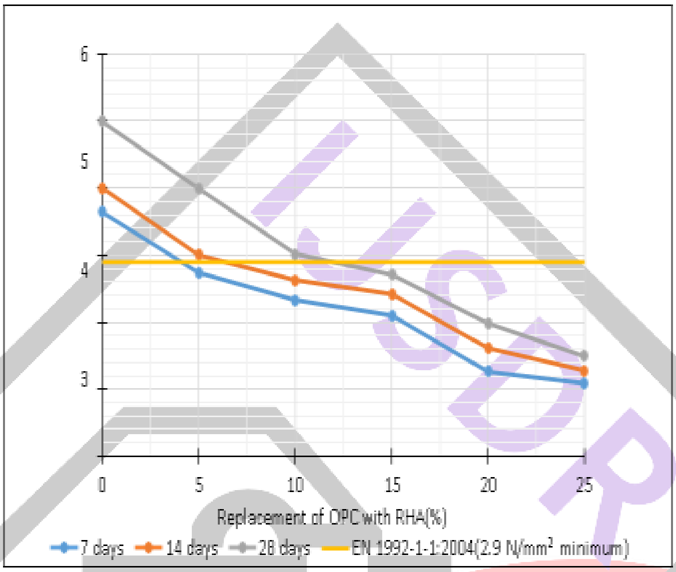

Fig 6: Splitting tensile strength for the different percentage replacements of OPC with RHA

V. CONCLUSIONS

From the study carried out, the following conclusions can be made;

1. The chemical characterization tests on RHA showed that the three important and major oxides of Silica (SiO2), Iron (Fe2O3,) and Alumina (Al2O3) content was 79.08% by weight. This sum is greater than 70% which is the minimum requirement by (ASTM C618, 1993) hence meeting the specifications. This showed that RHA had significant chemical properties that facilitate its use as a pozzolana.
2. The slump test results indicated that the workability of fresh concrete decreased with the increasing percentage of RHA in concrete. The concrete became less workable/stiff as the RHA percentage increased and that could therefore be solved by incorporating admixtures within the concrete.
3. The optimum addition of RHA as partial replacement for OPC for better performance was 5% and 10% since the hardened concrete met all the minimum requirements for compressive (30N/mm2), flexural (4.5N/mm2) and splitting tensile strength (2.9N/mm2) at 28 days.
4. Therefore in conclusion, it was clearly shown from the study conducted that RHA is a pozzolanic material which has the potential to be used as partial OPC replacement and can contribute to the sustainability of the construction material.

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