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UTILIZATION OF RICE HUSK ASH IN CONCRETE AS A PARTIAL REPLACEMENT OF CEMENT

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ABSTRACT

High cost of construction materials and the need for providing a sustainable growth in the construction field has prompted this work to search for alternative materials feasible for use in construction. For this objective, the use of agricultural by-products and industrial waste products comes to mind to replace Portland cement partially of which you will agree that they will be of great advantage. These industrial wastes and agricultural by-products such as Fly Ash, Rice Husk Ash, Silica Fume, Calcined Clay Puzzolana (Surkhi), and Ground Blast Furnace Slag can be used to replaced cement because of their pozzolanic behavior, which otherwise requires large tract of lands for dumping. In the present investigation, Rice Husk Ash has been used as an admixture to cement in concrete and its properties has been studied. An attempt was also done to examine the strength and workability parameters of concrete. In the use of rice husk ash as partial cement replacement, concrete grade of M15 and M20 were used and four different replacement levels namely 5%, 10%, 15% and 20% are selected and studied with respect to the replacement method.

KEYWORDS: Fly Ash, Rice Husk Ash, Silica Fume, Calcined Clay Puzzolana (Surkhi).

INTRODUCTION

Infrastructure development works, cement is the most widely consumable material. It is considered as a durable material in construction. Concrete as a major source of a nation's infrastructure due to its economic progress and strength, and indeed to the superiority of life. Portland cement production takes over 5% of global CO_2 emissions, and reduce the limitations of cement (OPC), it can be partially replaced with green materials which have pozzolanic characteristics. Number of green materials has been studied for the replacement of cement partially like fly ash, ground nut shell ash, etc. which have been successful. The present paper focuses on the replacement of cement partially with Rice Husk Ash (RHA). Production of rice is seen in Northern Part of Nigeria and a few States in Southern part of Nigeria but India is known to be one of the leading producers of Rice. Globally rice paddy of about 600 million tons is being produced, accounting for an annual production of 120 million tons Rice Husk. Rice husk produced during the processing of the rice is either burnt or dumped as waste material. Rice husk ash contains 90%-95% of reactive silica. It is estimated that the world rice harvest is about 588 million tons per year. Extensive research has been carried out on the use of amorphous silica in the manufacture of concrete. Most of these studies have been performed in order to find the effectiveness of Rice Hush Ash (RHA) as a pozzolan by concentrating on the amount of ash present in the mix and on the enhanced characteristics resulting from its use.The influence of particle size effect on the strength of rice husk ash mixed with gap-graded Portland cement concrete was discussed by Ravande Kishore et.al[1] that characteristics of high strength rice husk ash concrete, Bui et.al.[2] found that replacement of the cement partially up to 20% RHA by mass results in enhanced early-age compressive strength in the gap-graded binder mixtures. Analysis on optimum level of replacement for strength and durability properties of concrete was discussed by Ganesan et.al[3], Gemma Rodrı´guez de Sensale[4], Hwang Chao-Lung et.al.[5] They found that increase in the replacement of cement by RHA in concrete decreases the concrete workability by a slump of 27% and compaction factor of 9%. The optimum replacement level of Rice Husk Ash is found to be 10% for both M20 and M30 grades of concrete. Tashima, M.M et.al[6] discussed about the possibility of adding Rice Husk Ash (RHA) to the concrete and Rama Rao, G.V. et.al[7] discussed about the high strength concrete with RHA as mineral admixture. Carbon neutral off-White Rice Husk Ash as a replacement for white cement partially was discussed by Rossella, M.Ferraro et.al[8] They observed that due to the presence of high amorphous silica and large specific surface area, OWRHA is an efficient pozzolanic material which can also be used as a supplementary cementing material. Percentage of OPC, upto 15% by weight, can be replaced with OWRHA without causing any undesirable effect on the strength properties. Reactivity of rice husk ash was discussed by James J et.al[9] and observed that addition of RHA to the cement reduces the formation of Ca(OH)2 and protects the concrete from efflorescence, sulphate attack and chloride attack. An alternative to cement for rural housing was discussed by Deepa Nair G. et.al[10] where they presented that about 90-95% of reactive silica was present in the RHA which was responsible for the pozzalanic behaviour of the rice husk ash. Minimization of environmental problems using rice-husk ash in concrete was discussed by Rawaid Khan et.al[11] and they concluded that concrete mixture containing 25% RHA as a replacement of OPC resulted in same strength as the concrete containing 100% OPC.The effect of silica fume on carbon nanotubes based cement composite was carried out by K.M.Mini et.al.

2.0 METHODOLOGY

The present investigation focuses on assessment of the suitability of Rice husk ash, a cementitious material by conducting various physical and chemical analysis and hence to understand the influence of RHA on concrete properties (fresh state and hardened state). It was also proposed to determine the optimum level for replacement of RHA to attain maximum compressive strength and to understand the application of RHA in concrete.

2.1 Materials Used For The Research

❖ Ordinary Portland Cement (OPC): OPC of 42 Grade was used to conduct the experimental work to control the specimenes. The chemical analysis of the cement was performed to get the composition and the results are presented in Table 1.

Table 1: Chemical composition of cement.

Chemical Composition	Concentration
Lime saturation	0.9
Alumina modulus	1.23
Insoluble residue (%)	0.25
Magnesia	1
Sulphuric anhydride (SO_3) (%)	1.5
Loss on ignition (%)	0.8
Alkali	-
Chloride (%)	0.002
Humidity (%)	65±5

- ❖ Fine aggregate: Fine aggregate (sharp sand) free from nearby river having 2.61 of specific gravity and size below 4.75 mm were used.
- ❖ Coarse aggregate: Coarse aggregate commonly known as crushed aggregates were also brought from nearby river having 2.65 of specific gravity and nominal maximum size of 20 mm were used.

- Water: Water (palatable liquid) accessible within the campus laboratory was utilized for the mixing and curing of concrete in cylinders.
- Rice Husk Ash: Rice Husk was brought from vicinity of a nearby rice farm with a rice processing unit on the farm, Rice Husk (RH) was burnt in a closed drum (uncontrolled burning) at range 700 ^{0}C for two (2) hours to enhance the good quality rice husk ash. RHA was obtained after passing through 300µm standard sieve used for experimental study. Figure 1 show the rice husks and rice husk ashes from sticky, red and brown rice respectively.

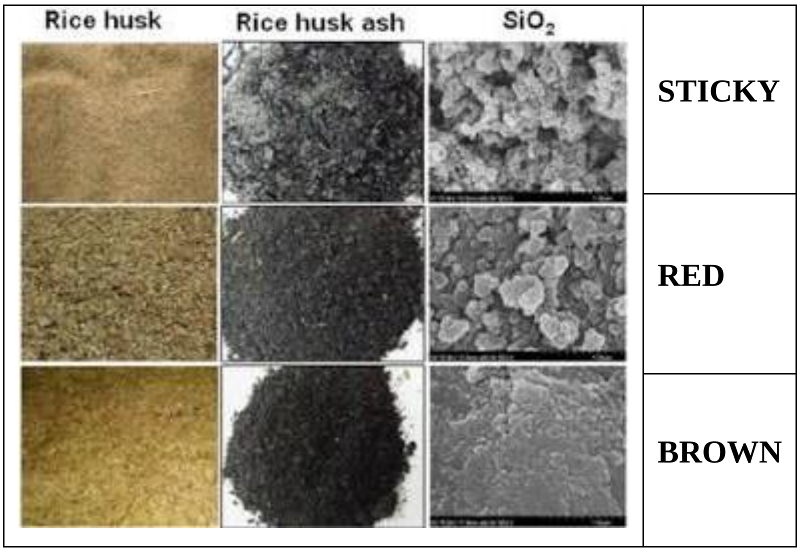

Fig 1: Samples of Rice husks, Rice husk ashes and their silicate.

To examine the suitability of rice husk ash as a replacement for cement, the various chemical and physical properties were carried out. These properties of RHA were compared with standard cement properties for assessing the correctness of RHA as a supplementary cementitious material.

Chemical analysis of Rice Husk Ash (RHA) sample was done. Two samples of Rice Husk Ash were taken for analysis and the one which contained more silica was selected for the experimental investigation. Table 3 reports the results of chemical analysis of sample 1 and sample 2, hence sample 1 was used.

Table 2: The composition of the riee husk organic compound.

Content, % wt			
C	**H**	**O**	**N**
39.8 - 41.1	5.7 -6.1	0.5 -0.6	36.6 - 37.4

Table 3: Chemical Analysis of rice husk ash.

Content, % wt								
Samples	**Sio_2**	**Al_2o_3**	**Fe_2o_3**	**Cao**	**Mgo**	**K_2o**	**Na_2o**	**P_2o_5**
1	93.4	0.05	0.06	0.31	0.35	1.4	0.1	0.8
2	79.84	0.14	1.16	0.55	0.19	2.90	0.08	-

Various properties of rice husk ash like specific gravity, bulk density, fineness and pH level were determined and compared with that of the cement as shown in Table 4

Table 4: Comparison of Physical Properties of RHA and Cement.

Property	**Rice Husk Ash**	**Cement**
Specific Gravity	1.95	3.15
Bulk density	530 kg/m3	1440 kg/m3
Fineness	13%	2%

In Table 4 Specific gravity of Rice Husk Ash was very less when compared to the specific gravity of cement while bulk density of Rice Husk Ash was also less than that of the cement. Because of low bulk density the volume occupied for a given mass was more and hence the RHA fills the pores in concrete making it impermeable. The fineness expressed as the percentage of sample retained after passing through 90µ sieve was 13% where as the standard fineness of cement is 2% and hence the fineness of RHA was under acceptable limits. So, it can be used as supplementary cementitious material.

Table 5: pH value of Riee Husk Ash.

pH after stirring	7.35
pH after 1 day	7.23
pH after 5 days	6.93
pH after 20 days	6.48
pH after 30 days	6.31

It was noted that as the number of days increases, pH of Rice Husk Ash decreases. This shows that the alkalinity was decreasing and hence it can be inferred that the addition of Rice Husk Ash does not make the concrete alkaline in nature.

2.2 Casting of specimen

For the experimental analysis total 32 concrete specimens were casted (refer table 6). The size of each specimen was taken as 150 mm diameter and 300 mm length cylindrical in shape. Concrete mixes were prepared as per grades given in the table 6, then, concrete cylinders were kept for the curing purpose as shown in figure2, for the period of 7, 14 and 28 days. While preparing the concrete cylinders, the slump test was also checked for the each grade for NSC and after replacing the RHA in concrete. Afterward, cement is replaced by RHA as per percentage given in the table 6 and same shall be cured for the mentioned period of time. For the each grade of concrete the pair of cylinders were casted to check the average results. After the completion of the required curing period every specimen was checked for the compressive strength in the compressive strength machine as shown in fig 3. After the necessary investigations, tested samples will be placed outside of the laboratory as shown in figure 4.

Table 6: Quantity of specimens.

% of RHA	Mix Proportions	
	M20(1:1½:3)	M15 (1:2:4)
0	2 x 2 = 4	2 x 2 = 4
5	2 x 2 = 4	2 x 2 = 4
10	2 x 2 = 4	2 x 2 = 4
20	2 x 2 = 4	2 x 2 = 4
Sub Total	16	16
Total Specimens	32	

Fig. 2: Specimen in curing tank.

Fig. 3: Specimen testing for compressive strength.

Fig. 4: Specimen after Testing.

3.0 RESULTS AND DISCUSSION

3.1 Fresh concrete properties

Workability of concrete assesses the behaviour of fresh concrete from mixing upto compaction. The terms mix-ability, transportability, mouldability and compactability collectively represent workability. Various tests were performed to measure workability of concrete and the effects of RHA on workability properties of concrete were studied.

The workability values in terms of Slump (mm), Vee –Bee Degrees (sec.) and compaction factor for varying RHA percentage of concrete mix at a temperature of 320 C are given in Table 7.

Table 7: Fresh concrete with varying % of RHA.

% of RHA	Slum Values (mm)	Vee-Bee Degrees	Compaction Factor
0	66	3	0.885
5	56	6	0.869
10	35	9	0.785
15	13	12	0.664
20	7	20	0.604

The results of slump test to assess the workability of fresh concrete indicates that incorporation of RHA in concrete leads to a decrease in slump value , which depends on the RHA content. This reduction in slump was due to the absorption of some quantity of mixing water by RHA particles. Because of the large surface area of RHA, more water molecules were attracted towards the surface of these particles. Thus, the quantity of the free water available for the concrete mix which helps in improving the fluidity of the mixture was decreased and there was an increase in the viscosity of the concrete mix. This in turn reduces the workability of the concrete and the effect was the same for other two tests also.

3.2 Compressive strength

At varying percentage of RHA, Compressive strength got improved from a period of 7 days to 28 days. The percentage increment of RHA is seen table 8. The table indicates that the 28 days strength increases from 26.2 MPa to 29.8 MPa with incorporation of 10% RHA. This 13.74% enhancement of compressive strength of concrete with RHA was attributed to the increase in pozzolanic action when RHA was added in concrete. However, for other variations in RHA, there was a reduction in compressive strength of concrete after a curing period of 28 days. When the percentage replacement of Rice husk ash was increased, the compressive strength of Rice husk ash concrete was also found to increase slowly, up to nearly 10% replacement and then decreased which is indicated in figure 5.

Table 8: Compressive strength of RHA concrete for M20 (1: 1½: 3).

OPC % replacement with RHA	Compressive Strength (N/mm2)			Avg. Compressive Strength (N/mm2)		
	7days	14 days	28 days	7days	14 days	28 days
0	15.1	19.3	27.2	14.7	18.6	26,9
	14.3	17.9	26.6			
5	14.7	18.0	26.9	14.1	18.1	26.2
	13.5	18.2	25.5			
10	15.5	20.1	29.6	15.9	19.8	29.8
	16.3	19.5	30.0			
15	12.8	16.5	17.3	12.5	16.2	17.2
	12.2	15.9	17.1			
20	11.5	12.8	16.9	11.2	12.7	16.5
	10.9	12.6	16.1			

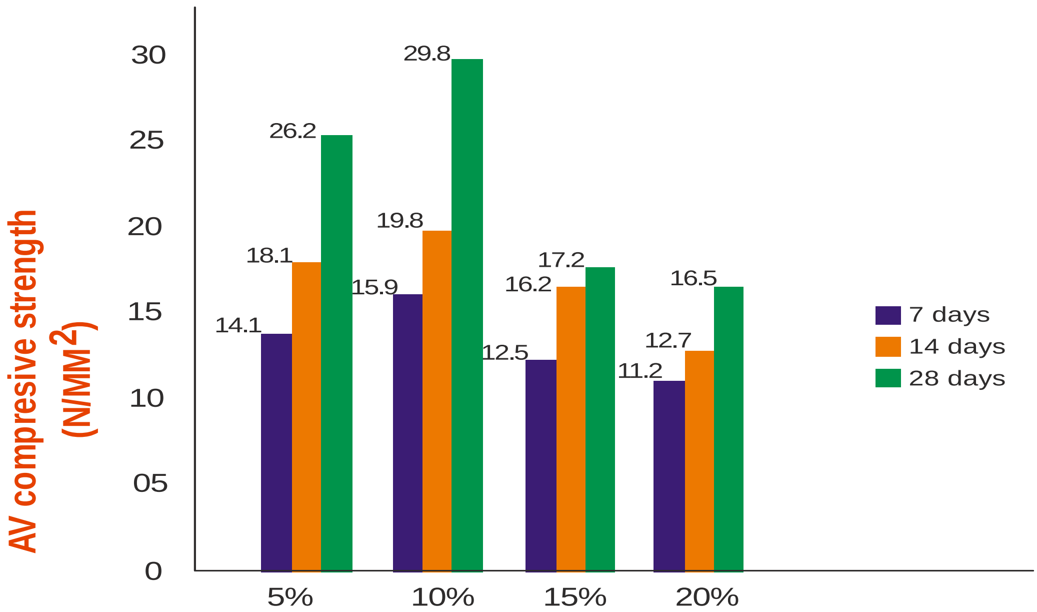

Figure 5: Average compressive strength of concrete grade M20 containing different percentage of RHA at different curing periods.

3.3 Split tensile strength

Fig.6 shows the variation of split tensile strength with respect to the percentage of RHA. Table 9 reports the split tensile strength percentage variation with respect to 0% RHA for different RHA replacements. Increase in the split tensile strength of concrete can be seen from 2.20 MPa to 2.58 MPa as the percentage of RHA increases from zero to 10%. The enhancement of split tensile strength may be due to the strengthening of Interfacial Transition

Zone (ITZ) by the silica content present in RHA. The individual ingredients of concrete such as cement, fine and coarse aggregate have a higher tensile strength when tested independently. However, when they are mixed to form concrete, the tensile strength was found to be lesser when compared to the individual strength. This may be due to the fact that even though ITZ is one of the weakest link in concrete, the existence of silica content in RHA makes a stronger and denser ITZ when compared to the normal concrete as it helps in reducing the voids present in ITZ, but with 15% and 20% RHA the strength was found to be decreasing. When the percentage replacement of Rice husk ash was increased, the split tensile strength of Rice husk ash concrete was also found to be increasing slowly, up to nearly 10% replacement and then it decreased. Graph between split tensile strength and curing period for varying percentage of RHA is shown in figure 6.

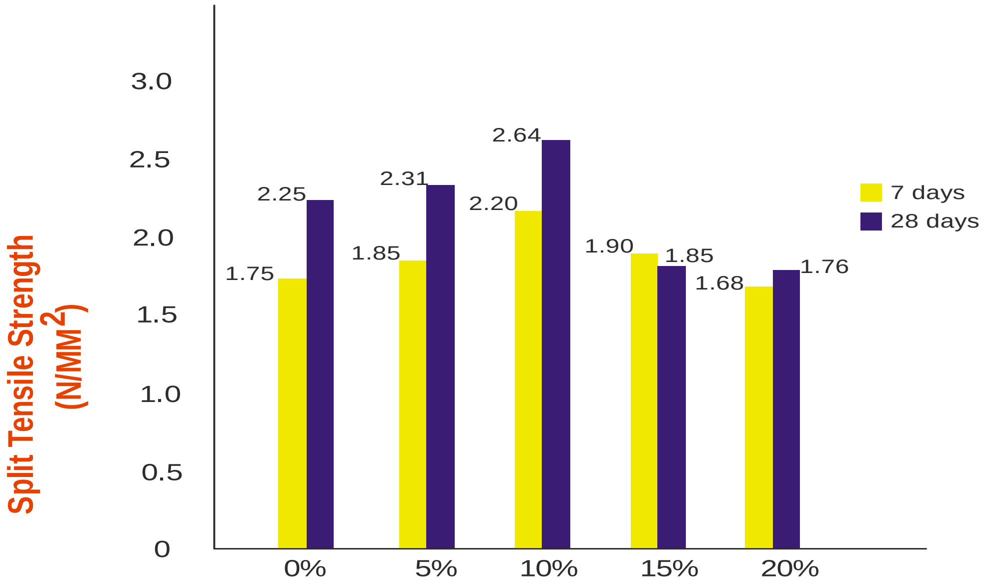

Fig 6: Variation in Split Tensile strength for varying percentages of RHA.

Table 9: Split tensile strength percentage variation with respect to different RHA replacements.

OPC % replacement with RHA	Split tensile strength for 7 days in N/mm^2	Split tensile strength for 28 days in N/mm^2	Split tensile strength percentage change from 0% RHA of 28 days
0%	1.75	2.25	-
5%	1.85	2.37	5.33%
10%	2.20	2.58	14.67%
15%	1.90	2.15	-4.44%
20%	1.68	1.95	-13.33%

4. CONCLUSION

This research was successfully carried out, to the establishment of RHA as an alternative cement replacement material in concrete. After the detailed investigation the following conclusions have been drawn.

- RHA in concrete gives the higher compressive strength as compared to the normal strength concrete, hence optimal results were found at the 10% replacement of cement with RHA.
- The usage of RHA in concrete is not only a waste-minimizing technique; also it saves the amount of cement.
- The replacement of cement with RHA increases the workability of fresh concrete; therefore the use of super-plasticizer is not essential.
- The usage of Rice husk ash in concrete as a replacement for cement can decrease the emission of green-house gases to a larger extent which automatically increases the possibility for gaining more number of carbon credits
- It is recommended that future research should be performed to assess the use of RHA in concrete for several properties of concrete for example modulus of elasticity, flexure test, drying shrinkage etc.

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