Partial Replacement of Cement with Rice Husk Ash and its Pozzolanic Activity: A review

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***Abstract* - Rice husk ash (RHA) is a supplementary cementitious material (SCM) and precise study has been done so as to be incorporated in cement concrete as a partial replacement of cement. This paper reviews the insertion of Rice husk ash (RHA) in ordinary Portland cement in cement concrete by some certain amount and its pozzolanic activity due to which innovation and advancement can be seen in physical, mechanical, and structural properties of the concrete. Rice husk ash gives two effects in the mortar or cement concrete i.e., filler effect and pozzolanic effect. This study reviews the pozzolanic contribution of RHA towards cementitious system. The percentage replacement of the rice husk concrete used in the earlier studies were taken as arbitrarily like 5%, 10%, 20% so on to observe and calculate the total effect of the rice husk ash. Previous studies gave clear cut result about the better performance of rice husk ash concrete than conventional concrete. The hydration reaction which occurs due to cement and the additional pozzolanic reaction of RHA with the hydrated products generated earlier innovates and advances the various properties of rice husk ash concrete.**

***Index Terms* - Rice husk ash, C-S-H gel, Supplementary cementitious material, Compressive strength**

1.INTRODUCTION

Rice grain is the outer grain of the rice which is Agro-industrial by-product generated from the Rice milling industries in many parts of the world [1]. Researchers are putting efforts towards finding the materials that have capability to replace the ingredients of the concrete to some extent, since cement is the primary raw material of the concrete mix and Manufacturing of cement results into emission of the huge amount of CO_2 which is very hazardous for environment [2, 3, 4]. Thus, rice husk ash was introduced into the concrete world. When rice husk achieves the limit of full combustion, it produces about RHA equal to 20 to 25% by weight [5, 6]. The raw rice husk is consisting of mainly cellulose 40%, lignin 30% and silica 20%. when combustion occurs the raw rice husk ash loses the lignin matrix leaving away only a porous silica structure [7]. Hence RHA contains very good volume of silica [8, 9]. Since rice husk ash is a highly pozzolanic material [10] and thus it can be used as the partial replacement of the cement in the cement concrete. By using the rice husk ash, we can minimize the cost of the construction, and can make the useful use of agricultural waste. High profile research is going on the mechanical and structural properties of the concrete in which RHA is used with or without other additional materials.

2. LITERATURE REVIEW

It was found by the Mehta and Pirtz [11] that RHA has found very good results in decreasing the temperature of mass concrete higher than that of concrete which has been made from ordinary Portland cement (OPC). It was found by Mahmud et al. [12] that RHA-used concrete mainly have better strength than OPC, also shrinkage is low and higher durability was found than OPC concrete. Zerbino et al. [13] concluded that the concrete which is made with the help of ground RHA (up to 25%) gives very good improvement in the mechanical properties concrete. It was also seen that if we make the use of the fibres in the rice husk ash concrete the mechanical strength of the concrete increases and intern the voids and the permeability of the concrete decreases thus adding up to the durability of the concrete.

The increase in the fineness of the increases the reactivity of the rice husk ash. Ismail and Waliuddin concluded that there can be influence on the activation of the pozzolanic properties of RHA due to the fineness of RHA [14]. Good results also obtained by the Chopra by grinding RHA of crystalline form [15]. But Mehta suggested that high degree grinding of amorphous RHA should be avoided as pozzolanic activity may be derived from the internal surface area of the particles [11]. Also, it was stated by Zain et al. Partial grinding of crystalline RHA for 30 mins in Los Angeles machine undergoing, Combustion of 10mm and 20mm diameter steed rod produces good quality RHA [16]. But they suggested that grinding should be done for 60 min or more to reach the value of standard fineness. Thus, the RHA which has been burned and grinded under restrained combustion can be utilized as pozzolanic material in cement and concrete.

Thus, inserting RHA in concrete innovates and advances the various properties of the concrete like strength, durability, reduction towards the hazardous impact on the environment. The silica (Sio_2) which is present in the RHA after combustion reacts with the hydration product of the cement Ca $(OH)_2$ to form a secondary product which is termed as Calcium–Silicate–Hydrated (C–S–H) gel [17-19]. Indeed C-S-H gel is responsible for the hardening and various other properties of the concrete or mortar. Calcium hydroxide is the byproduct of the siliceous compounds which are present in the cement in the form of tri-calcium silicate (C3S) and di-calcium silicate (C2S) and in case of ordinary Portland cement only specific amount of C3S and C2S is present which produces specific amount Ca $(OH)_2$ thus only specific amount of RHA will react with Ca $(OH)_2$ which will result into the formation of C-S-H gel.

3. MATERIALS AND PROPERTIES

3.1 Cement

Ordinary Portland cement can be used in the manufacture of rice husk ash concrete of grade 43 and 53 subjected to standards of IS: 12269-2013 of specific gravity 3.15[20].

3.2. Fine aggregates

Fine aggregates subjected to the standards of IS: 383: 1970 for graded aggregates are used:

a. Specific gravity =2.62
b. Fineness Modulus = 2.58

3.3 Coarse Aggregates

Crushed Granites of different sizes are used in the manufacture RHA concreted subjected to the references of IS 383: 1970 for graded aggregates:

a. Specific gravity (S.G) =2.64
b. Fineness Modulus = 6.816

3.4 Rice husk ash

Rice husk ash having the following properties which are mentioned in the table 1 can be used:

Physical State	It must be Solid–Non-Hazardous
Appearance	It should be Very fine powder
Particle Size	Mean size of the particles can be taken as 25 microns
Color	Grey
Odour	Odourless
Specific Gravity	2.3

Table 1[21]

3.5 Super plasticizers

Super plasticizers are the materials which make it possible to form of concrete of high workability with low water cement ratio. Rahul Batra has used Conplast SP430G8 admixture which is manufactured by the "FOSCROC Chemicals". Which is basically a Sulphonated Naphthalene Polymer and is a brown liquid instantaneously dispersible in the water [21]. The parameters of super plasticizer which are considered while making RHA concrete should be as:

1. Specific gravity: As per standards should be 1.265-1.280 at temperature of 270 Celsius.
2. Chloride content: The presence of chloride should be less than 0.05%
3. Air entrainment: There should be possibility of less than 1% air entrainment.

3.6 Water

This is one of the main ingredients of the concrete mix. It is because of the water chemical reaction takes place in concrete mix. Thus, quality and the quantity of the water should be of main concern. The water is responsible for the many properties of the concrete like workability, strength, and other structural properties. It should that more use of the water gives more workability but reduces the strength of the concrete as already stated in Abraham's Law. Researchers also suggest that the water which is used for concreting should have ph. value ranging from 6 to 8 and it should be free from organic matter. Also, the water to be used for the concreting should have minimum hardness as the carbonates and bi carbonates effect the setting time of the concrete mix, even the higher concentration of salts may result in the decrement of the strength of the concrete.

3.7 Mixing

The mixing of the concrete is done by hand mixing or in laboratory batch mixer and on the large scale it can be done with the help of Machine mixers, but during mixing it should be ensured that there should no loss of water and other materials. During and after the mixing chemical actions inside the concrete mix start playing their role.

3.8 Hydration of Portland cement

The chemical reaction that takes place in between ordinary Portland cement and water is termed as hydration of the cement. During hydration of the cement series of chemical reactions of anhydrous calcium silicates (C3S and C2S) and aluminates (C3A and C4AF) takes place with water to form hydrated products [22]. Out of them only C3S and C2S are responsible for the formation of the calcium hydroxide Ca $(OH)_2$. The chemical Reaction of Tricalcium silicate and di calcium are given in fig 1.

$$2(3CaO.SiO_2) + 6H_2O \rightarrow 3CaO.2SiO_2.3H_2O + 3\,Ca(OH)_2 \qquad (1)$$

$$2[3*(40+16)+\{28+(16*2)\}] \qquad 3*\{40+2*(16+1)\}$$

$$=456gm \qquad =222gm$$

$$2(2CaO.SiO_2) + 4H_2O \rightarrow 3CaO.2SiO_2.3H_2O + Ca(OH)_2 \qquad (2)$$

$$2[2*(40+16)+\{28+(16*2)\}] \qquad \{40+2*(16+1)\}$$

$$=344gm \qquad =74gm$$

Fig 1

It was reported by the Newman and Choo That Ca/Si ratio in C–S–H gel (produced either from C3S or C2S) should be approximately 1.7 and the chemical formula of C–S–H gel is $C_{1.7}SH_3$ [i. e, $(CaO)_{1.7}SiO_2.(H2O)_3$] [22]. Thus, clearly it can be seen that there is extra amount of calcium in the system after the hydration of C3S and C2S which are precipitated in the form of (Ca $(OH)_2$. From reactions 1 and 2 we can easily calculate the amount of the (Ca $(OH)_2$ produced by knowing the amount of C3S and C2S.

3.9 Chemical action between Ca $(OH)_2$ and SiO_2

Amorphous rice ash contains 20% of the silica. For the first time it was reported by the James and Rao that the hydrated product (Ca $(OH)_2$ reacts with the SiO_2 which is present in the rice husk ash and results into the formation of the C-S-H gel [23]. Because of the reaction between SiO_2 and calcium hydroxide ($Ca(OH)_2$) the probability rate of the formation of the C-S-H gel in RHA concrete was also discussed by the many researchers. At the end it was confirmed by the Yu et al that it is amorphous silica which reacts with the calcium hydroxide to form one kind of C-S-H gel [19]. The chemical reaction in presence of the water follows the pattern given below:

$$2SiO_2 + 3Ca(OH)_2 + H_2O \rightarrow 2Ca_{1.5}SiO_{3.5}\cdot 2H_2O \qquad (3)$$

$$2*(28+16*2) \quad 3*\{40+2*(16+1)\}$$

$$=120gm \qquad =222gm$$

From the reaction it can be seen clearly that 120 gm silica (SiO_2) reacts with 222 gm $Ca(OH)_2$ and gives the secondary C–S–H gel.

4. METHODOLOGY

4.1 Slump test

Slump test is being done on plain concrete and RHA used concrete to evaluate the workability as per IS: 1199- 1959[24].

4.2 Water absorption test

With 0, 5,10 and 15% replacement of RHA water absorption tests were done for concrete specimen (Cylindrical) as per IS: 1124-1974 [25]. Oved dried specimens (24 hours at 100 ± 5 °C) and weight of it (Wd) were taken and the specimen were submerged in the water for 24 hrs. At room temperature, after these specimens were removed from the water and were wiped out with the help of the cloth so as to create dry surface condition and weight taken (Wssd) and the water absorption capacity was determined with the help of the following formula:

Water absorption (%) =Wssd −Wd/Wd× 100

4.3 Compressive Strength Test

Specimens of 100 mm diameter and 200 mm height were prepared to go under compressive strength test after 7,14 and 28 days of curing subjected to the standards of IS: 516-1959 [26, 29].

4.4 Flexural strength test

To determine the flexural strength of the plain concrete and the RHA used concrete beam specimens of the size 150 mm × 150 mm × 700 mm were prepared, and test was done according to IS:516-1959 [26].

4.5 Split Tensile Strength tests

150 mm diameter and 300 mm length of cylindrical specimen taken to determine split tensile strength under compression testing machine. It was then left for hardening for 24 hrs., And then followed by casting and curing process for 28 days then was tested as per IS: 5816-1999 [27, 29]

5. RESULTS AND DISCUSSIONS

5.1 Slump Value

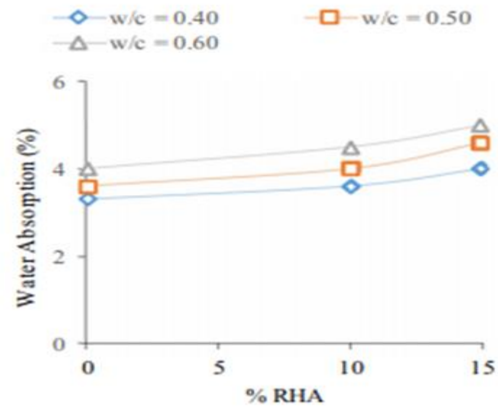
It is because of the addition of the RHA into the concrete the cohesiveness of the concrete mix increases due to which stiffness of the concrete mix increases. Slump test results which were obtained by Ayesha Siddika in her experimental clearly shows the lower value of the slump [28, 29]. It was seen that the slump decreases with increase in RHA content.

5.2 Water absorption capacity

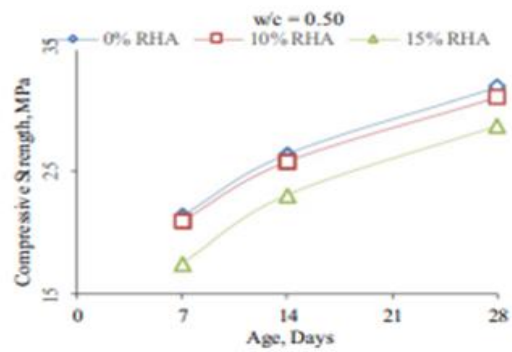
Since RHA concrete is more porous the plain concrete. Hence with increase in the water cement ratio porosity also increases. Hence RHA concrete possesses more water absorption capacity than plain concrete. The variation ranges from 10 to 28% [28] as shown in graph 1.

5.3 Compressive strength

It was seen that as we increase the percentage of the RHA in concrete the strength of the concrete starts decreasing. Concrete with zero percentage of RHA has maximum strength while the optimum content of the RHA is 10% with respect to the compressive strength. It was seen with increase in the content of RHA from 10% to 15% there is about average 10 to 12% decrease in the compressive strength of the concrete. The reason behind the decrease in the strength of the concrete due to use of RHA is mainly because of the decrease in the density and increase in the porosity of the concrete. If the water cement ratio is high in RHA concrete, there will be also decrease in the strength of the concrete as porosity will increase. After 28 days it was seen that the variation of compressive strength with respect to the plain concrete is very less thus it can be used as supplementary cementitious materials as far as strength and the workability is concerned.The strength variation can be seen with the help of graph 2, graph 3 and graph 4 [28].



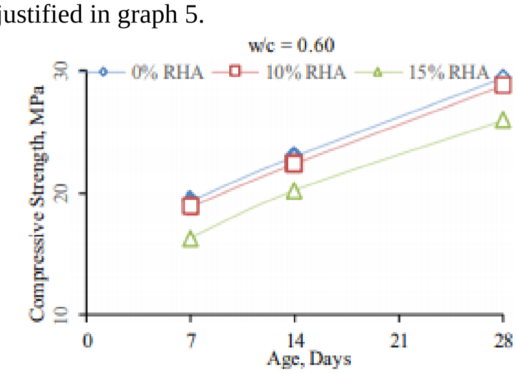
Graph 1 Water absorption
[Source: Ayesha Siddika et al (2018)]



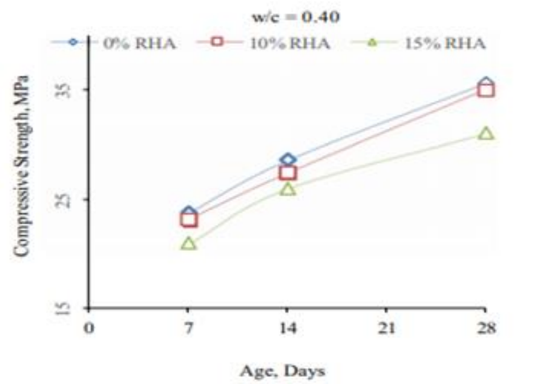
Graph 2 Compressive strength with w/c ratio 0.50
[Source: Ayesha Siddika et al (2018)]

4.4. Split tensile strength

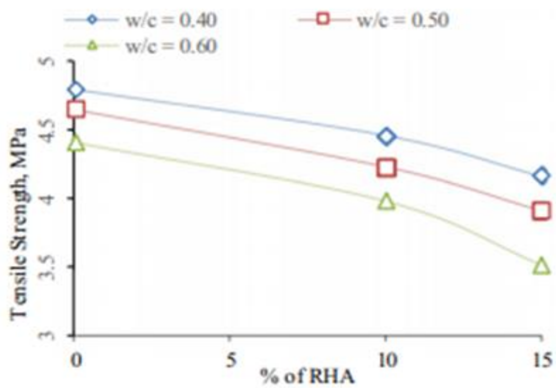
It was seen that low water cement ratio and 10% replacement of the RHA criteria is suitable as far as tensile strength is concerned. These results are justified in graph 5.



Graph 4 Compressive strength with w/c ratio 0.60
[Source: Ayesha Siddika et al (2018)]



Graph 3 Compressive strength with w/c ratio 0.40
[Source: Ayesha Siddika et al (2018)]



Graph 5 Variation in the tensile strength
[Source: Ayesha Siddika et al (2018)]

6. CONCLUSIONS

Rice husk ash is waste material which can be used as the supplementary cementitious material it reduces the negative impact on the environment emitting less CO_2. As far as workability, tensile strength and compressive strength is concerned the amount of cement which is replicable with RHA is 10%. The water absorption capacity of the RHA concrete is more than that of plain concrete. Use of RHA with high percentage and with high water cement ratio lowers the strength of the concrete. The RHA concrete can be used for various general applications in day-to-day life. RHA is economical that of the plain concrete.

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