Effect of Partial Replacement of Cement by Rice Husk Ash (RHA) With Special References to Grades M_{45} and M_{50}

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Abstract— **Rice husks also called rice hulls are the shells produced during the dehusking Operation of paddy rice. Research works in past have shown that rice husk bears certain engineering properties by means of which it can be well utilized in production of supplementary cementing materials. In centralized rice milling, huge quantities of rice husk are generated. Each ton of paddy produces about 200 kg of husk. Because of its very low bulk density, rice husk requires large space for storage and hauling. Also due to the very low protein contents, the husk is not suitable as fodder for animals. The high ash and lignin present in the husks render them unsuitable for making cellulose products. Economic disposal of rice husk has proved to be difficult due to its availability in abundance, slow rate of bio-degradation, rough and abrasive surface. So far, it has been a totally waste product of low bulk density. Its dumping storage, handling and transportation' attribute a great problem of disposal for the sake of environmental balance. Due to growing environmental concern and need to conserve energy and resources, efforts have been made to bum the rice husk at controlled temperature and atmosphere and utilize the ash so produced as supplementary cementing material.**

This project work has been taken to make attempt to find out a probable outlet for utilization of this growing agricultural waste dump as part replacement of cement in concrete. This experimental study is carried out to determine optimum utilization of rice- husk ash as partial replacement of cement in high strength concrete of grades M_{45} and M_{50} and to study the resultant effect on workability, air content, temperature effect, and strength properties of high strength concrete.

For this project work, the 'Rice-husk' was collected from Rice Mill, Chandigarh. 120 (One hundred and twenty) cubes of both the grades of concrete were prepared by replacing cement by 0%, 10% 15% and 20% of equal weight of rice husk ash. Compressive strength of the cubes (with and without rice husk ash) at 7, 28, 56 and 90 days is measured and Non -destructive tests (N.D.T.) are also carried out on the cubes.

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I. INTRODUCTION

Recent Developments in Science and technologies have made the manufacture of various new building materials possible through the use of agriculture and industrial waste products. The agro based product in many parts of the world is rise husk. Rice, the staple food in India and other developing countries of the world, is obtained from the paddy cultivation. Paddy mills give rice besides, by – products such as Husk and barn is large quantities. The disposal of bran is not a problem and can be used in manufacturing of edible oil and soaps. Another by product, husk is produced in plenty, being as much as fifth by weight of the paddy milled. Its low bulk density creates problems of storage and hauling, Rice- husk when converted into ash contains highly reactive silica and found to have desirable properties for use as partial replacement of cement in concrete.

Normally, some of the husk is used as an industrial fuel. Because of negligible protein content, rice husk cannot be used as an animal feed. Most of it, is used as fuel, while the rest of it is burnt in open fields.

Recent research studies carried out in India and absorbed that rice husk can be used as a building material along with lime and cement. Raw rice husk contains 20 – 22 % silica in highly reactive form with a cellular structure. Portland cement is primarily a siliceous and calcareous material. When rice is mixed with cement or lime, the highly reactive silica vigorously reacts, resulting in a good binding material.

P.K. Mehta and N. Pitt blended pulverized rice husk with ordinary Portland cement and found the blend to have high compressive strength even at 70 % replacement of cement by rice husk ash. The increase in strength is noticed even at as early as 3 days.

II. REACTIVITY OF RICE HUSK ASH

Rice husk ash is highly reactive pozzolanic material suitable for use in lime pozzolana mixes and for Portland cement replacement. RHA contains high amount of silicon dioxide and its reactivity towards lime depends on combinations of two factors namely

- The non-crystalline Silica content and
- Specific surface area

The non-crystalline phase in RHA obtained from combustion at temperature below 600°C consists primarily of disordered Si-O structure which is the product of decomposition and sintering of opaline or hydrous silica without melting. Occasionally, a small amount of crystalline impurities may be present, including quartz, cristobalite and tridymite. When rice husk ash produced by uncontrolled combustion, the ash is generally crystalline and present poor pozzolanic properties.

However, by burning the rice husks under controlled temperature and atmosphere, a highly reactive RHA can be obtained. Thus, the reactivity of RHA as pozzolanic material depends on the crystalline / amorphous ratio. Evaluation of amount of silica in RHA is determined by analytical method. Shaft Mohammad Lakho carried out studies regarding reactivity of RHA in his thesis work. He studied the parameters necessary for the production of reactive rice husk ash. Various ashes were prepared by changing burning time, burning temperature, supply of air during burning, cooling rate and grinding time. The ashes were blended with lime, mostly in the proportions 30% RHA and 70% lime. Effect of parameters on the reactivity of RHA was evaluated by the degree of its contribution in raising the strength of mortar made with lime -RHA as cementing material.

The main finding of the study were:-

- ➢ Reactivity of RHA is strongly dependent on the condition of supply of air during burning and the cooling rate, in addition to burning temperature, burning time and grinding.
- ➢ Grains of reactive RHA exhibit typical features when observed through a microscope.
- ➢ Reactive RHA can be produced very cheaply and it can be advantageously used together with lime in place of Portland cement for making soil cement blocks.

III. DETERMINATION OF POZZOLANIC REACTIVITY OF RHA

Chemically pure Ca $(OH)_2$, distilled water and Portland cement were used. RHA used in the experiment was burnt in furnace at about 600^0C and ground in ball mill for l hour. The RHA had an average specific surface of 55.l m^2/g. The chemical compositions of RHA is already given in Table 3.3

A glass beaker containing 20 ml of saturated $Ca(OH)_2$ solution at $(40\pm1)^0$C was placed in water bath at the same temperature, then 5.0 g of RHA was added with the solution under continuous stirring. A digital pH meter and an electrical conductivity meter were used to record the variation in pH-value and electrical conductivity of solution with lime.

It was observed that the electrical conductivity of saturated solution at $(40\pm1)^0$C after addition of RHA was changed, which shows the RHA has a very good pozzolanic activity.

IV. PERFORMANCE OF ROLLER COMPACTED CONCRETE.

1. 28 days compressive strength and density were low at low water content, and both increases as water content is increased up to certain value of water content, further increase in water content beyond this value, both strength and density is decreased
2. As RHA is having higher specific surface area than that of Portland cement so, to obtain proper compaction, more water is required than that which is just sufficient for hydration reaction. So water content for maximum density is higher than that of max strength for RHA mixes.
3. Optimum water content based on maximum compressive strength increases with increase 'in RHA content, and similarly, it is based on maximum density and it is increased with increase in RHA content.
4. As RHA is having low specific gravity than that of Portland cement, so the density of RHA Portland cement mixes is reduced.
5. RCC will need less cementitious material than normal concrete for same strength, as water is required to obtain the necessary slump. Due to this, it requires much lower until cost per cubic meter of concrete placed and compared to conventional mass concrete techniques,

Because, high strength concrete is not structurally required in most massive concrete application, a significantly replacement of Portland cement by RHA could be employed to lower the cost of material in finished concrete and lower the heat of hydration.

Utilization of RHA in RCC could promise great economic potential where rice husk is abundant and essentially a waste material. It also helps to conserve energy resources and the environment.

V. OBSERVATIONS AND ANALYSIS 0F M_{50} GRADE CONCRETE MIXES:

1. AT 7 DAYS:

a) Compressive strength test results:

At the age of 7 days, in case of concrete mixes of grade M_{50} (with and without rice husk ash), the average compressive strength results were found to be 51.11 N/mm^2, 49.27 N/mm^2, 48.l8 N/mm^2 and 43.55 N/mm^2 for replacement of' cement by rice husk ash with 0% , 10%, 15% and 20 % respectively.

From the results, it is observed that

1. At the age of 7 days, average compressive strength of rice husk ash concrete decreases as percentage of cement replacement increases. This can be attributed to the delay in the start of pozzolanic action of RHA. Since RHA was obtained by burning rice husk in open field at uncontrolled temperature.
2. Average compressive strength of rice husk ash concrete mixes with 10% and 15 % replacement were found to be higher than 2/3 value of target mean strength i.e. 62.21N/mm^2.
3. Average compressive strength of rice husk ash concrete mix with 20% of cement replacement by rice husk ash is found to be 43.55 N/mm^2, which is slightly lower than 2/3 value of target mean strength.

From 7 day compressive strength results, it can be observed that approximate optimum percentage of cement replacement by rice husk ash is 15%.

(b) UPV test results:

From the results, it is observed that the UPV readings decrease with increase in percentage of rice husk ash and are compatible with decrease in the average compressive strength readings.

(c) Rebound hammer test results:

From the results, it is observed that rebound numbers gradually increase with increase in percentage of rice husk ash in concrete mixes and the age of concrete.

2) AT 28 DAYS

(a) Compressive strength test results:

At the age of 28 days, in case of concrete mixes of grade M50 (with and without rice husk ash) the average compressive strength results were found to be 66.74N/mm^2, 63.11 N/mm^2, 62.80 N/mm^2 and 57.67 N/mm^2 for replacement of cement by rice husk ash by 0% , 10%, 15%, and 20% respectively.

From the results, it is observed that,

1. At the age of 28 days, the average compressive strength of rice husk ash concrete decreases as the percentage of cement replacement increases.
2. Average compressive strength of rice husk ash concrete mix with 10 % and 15% cement replacement are found to be 63.11 N/mm^2 and 62.80 N/mm^2 respectively which are higher than the target mean strength value i.e. 62.21 N/mm^2.
3. Average compressive strength of rice husk ash concrete mix with 20% replacement is found to be 57.67N/mm^2 which is slightly lower than the target mean strength value i.e. 62.21N/mm^2. It is therefore recommended that the approximate optimum replacement of cement by rice husk ash is 15%.

(b) Ultrasonic pulse velocity test results:
From the test results, it is observed that UPV readings decrease with increase in percentage of rice husk ash and increases with the age of concrete for 7 days to 28 days at different percentage replacements.

(c) Rebound hammer test results:
From the results, it is observed the Rebound numbers increase with increase in percentage of rice husk ash and the age of concrete.

3) At 56 DAYS:
(a) At 56 days, in case of concrete mixes of grade M_{50} (with and without rice husk ash), the average compressive strength results were found to be 69.23N/mm^2, 67.64N/mm^2, 65.80N/mm^2 and 59.12 N/mm^2 for replacement of cement by rice husk ash with 0%, 10%, 15% and 20 % respectively.
From results, it is observed that,

1. At 56 days, average compressive strengths of rice husk ash concrete mix with 10% and 15% cement replacement by rice husk ash are found to be 67.64 N/mm^2 and 65.80 N/mm^2 respectively which are higher than the target mean strength i.e. 62.21 N/mm^2.
2. Average compressive strength of rice husk ash concrete mix with 20% cement replacement by rice husk ash is found to be 59.l2 N/mm^2 is lower than the target mean strength. Hence it is recommended that the approximate optimum replacement of cement by rice husk ash is 15 percent.

(b) UPV test results:
It is observed that the UPV reading decreases with increase in percentage of rice husk ash and increase in age of concrete. However it was observed that there was appreciable rise in the values of UPV. This reflects the improvement in the microstructure within the concrete leading to its densification and improved resistance to permeability with the age of RHA concrete.

(c) Rebound hammer test results:
It is observed that the Rebound numbers increase with increase in the percentage of rice husk ash and the age of concrete.

4) AT 90 DAYS

a) Compressive strength test results:
At the age of 90 days, in case of concrete mixes of grade M_{50} (with and without rice husk ash), the average compressive strength results were found to be 71.20N/mm^2,69.79 N/mm^2, 68.00 N/mm^2 and 61.87 N/mm^2 for replacement of cement by rice husk ash with 0% , l0 % 15% and 20% respectively.
From the results it is observed that

1. At 90 days, the average compressive strength of rice husk ash concrete mixes with l0% and 15% are higher than target mean strength i.e. 62.21 N/mm^2
2. The average compressive strength of rice husk ash concrete mix with 20% replacement of cement by rice husk ash is found to be 61.87 N/mm^2 which is slightly lower than the mean strength of the designed concrete.

It is therefore recommended that the approximate optimum replacement of cement by rice husk ash is 15%.

b) Ultrasonic pulse velocity test results:
The values of ultrasonic pulse velocity decrease with increase in percentage of rice husk ash and are compatible with decrease in compressive strength. However, the UPV readings increase with increase in the age of concrete.

c**) Rebound hammer test results**:
The rebound numbers gradually increase with increase in percentage of rice husk ash and the age of concrete.

VI. PRODUCTION OF HIGH STRENGTH CONCRETE

Due to economic and durability considerations, mineral admixtures (RHA, Silica fume, fly-ash, etc) are generally used as a partial replacement of Portland cement in concrete. Highly active pozzolan, RHA is capable of producing high strength in concrete at both early and late ages, especially, when a water- reducing agent has been used to reduce the water requirement.
On the other hand, when RHA is used as a partial replacement for fine aggregates, it is also able to increase the strength of concrete at both early and late ages. The strength gain at early ages is in part due to a slight acceleration in Portland cement hydration; the strength gain at later ages, which can be substantial, is due mostly to the pozzolanic reaction causing pore refinement and replacing the weaker component $Ca(OH)_2$ with the stronger one C-S-H(Calcium silicate hydrate).
If the elimination of large pores and reduction of calcium hydroxide are necessary elements for producing concretes with a high compressive strength, RHA will be most suitable for playing a key role in the production of High - Strength Concrete, irrespective of whether they are used as a cement replacement, fine-aggregate replacement, or both.

Compressive strength of Cement Mortar

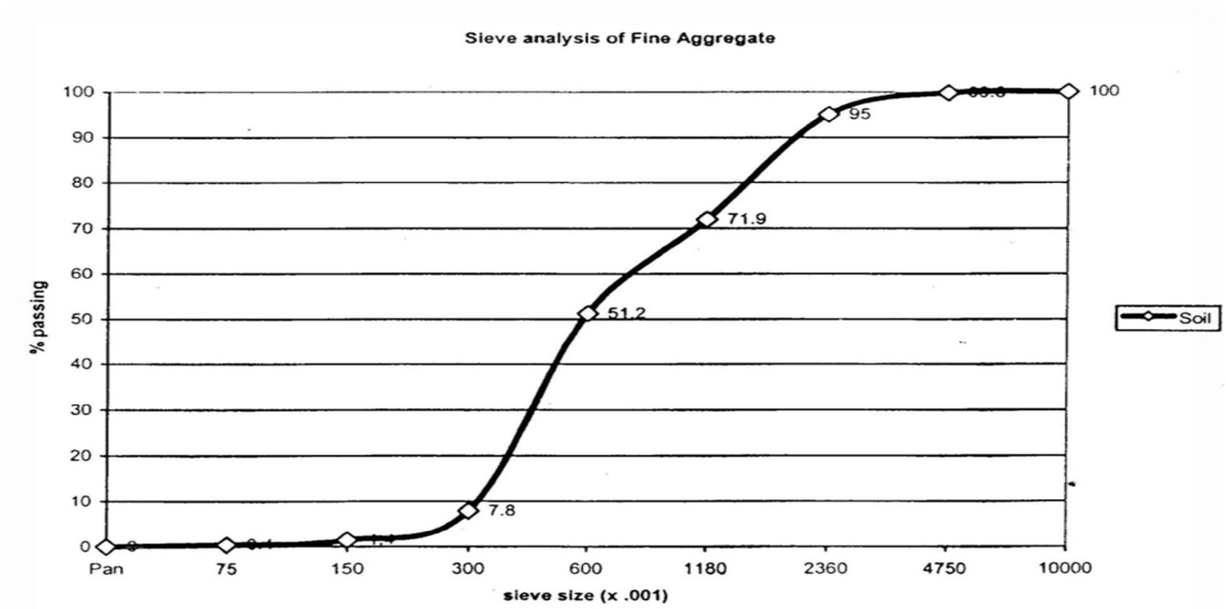
Age of cement cube testing	Cubes no.	Compressive strength(Mpa)	Average Compressive strength(Mpa)
3 days	1 2 3	28.0 27.5 27	27.5

7 days	1 2 3	41.0 42.0 40.0	41.0
28 days	1 2 3	53.0 55.0 54.0	54.0

Sieve Analysis Results of fine Aggregate

Weight of Sample= 1 kg.

IS Sieve size	Weight retained in Kg	Percent weight retained	Cumulative percent weight retained	Percent passing zone	Grading zone
10 mm	0	0	0	100	Conforming to grading zone II of table 4 of IS-383
4.75 mm	0.002	0.2	0.2	98.8	
2.36 mm	0.048	4.8	5	95	
1.18 mm	0.236	23.6	28.6	71.4	
600 µ	0.202	20.2	48.8	51.2	
300 µ	0.434	43.4	92.2	7.8	
150 µ	0.064	6.4	98.6	1.4	
75 µ	0.01	1.0	99.6	0.4	
pan	0.004	0.4	100	0	



Sample Calculation: The compacting factor is determined as the ratio of the weight of partially compacted concrete to the weight of fully compacted concrete.

Considering M45 grade rice husk ash concrete with l0 percent of cement replacement by rice husk ash

$$\text{Compacting Factor} = \frac{\text{Weight of partially compacted concrete}}{\text{Weight of fully compacted concrete}} = \frac{9.98}{12.025} = 0.83$$

CONCLUSION

On the basis of the casting of cubes for 0%, 10%, 15% and 20% replacement of cement by equal weight of RHA, the following conclusions can be drawn.

1. Rice husk obtained from rice mill, located at industrial area, Chandigarh was inspected physically and found suitable for the production of rice husk ash.
2. Rice husk ash which is used in concrete was produced by burning rice husk in open field.
3. Water requirement was more in RHA Concrete than that of the reference concrete, at constant water cement ratio. Water requirement increases with the increasing replacement rate.
4. A super plasticizer “FAIR FLO” was used in the concrete mixes to achieve desired workability.
5. The rice husk ash concrete mix obtained was very much homogeneous and cohesive even at higher level of workability. Addition of rice husk ash in concrete gives a homogeneous and cohesive mix.
6. With increase in percentage of the rice husk ash in concrete, there is decrease in workability of concrete. Loss in the workability is mainly due to the presence of unburnt carbon in rice husk ash, which is hygroscopic in nature. The loss can be also due to the production method of RHA under uncontrolled temperature condition.
7. It is observed that the use of super plasticizer increases the workability more in case of reference concrete, while the increase of workability in case of rice husk ash concrete is slightly less.
8. Mixing of rice husk ash concrete should be done carefully to get uniform concrete.
9. Air content of rice husk ash concrete decreases with increase in the percentage of RHA in concrete. The air content also reduces with higher grades of concrete.
10. The approximate optimum percentage of cement that can be replaced with rice husk ash is 15% for both the grades M_{45} and M_{50}.
11. In case of M45 grade of concrete with 15% of cement replacement by rice husk ash, the actual compressive strength is increased by 0.46% at 28 days, 2.12% at 56 days and 5.15% at 90 days than that of the target mean strength.
12. In case of M50 grade of concrete with 15% of cement replacement by rice husk ash, the actual compressive strength is increased by 0.99% at 28 days, 5.77% at 56 days and 9.31% at 90 days than that of the target mean strength.
13. The Ultra Sonic Pulse Velocity test results show that the values of UPV decrease with increase in percentage of replacement of cement with RHA and increases with the age of concrete In spite of this decrease in UPV values, it has been observed that the values fall in the range of 4.11 to 4.91 km/sec as given in IS: 1331l-Part-I leading to conclusion that the quality of the concrete is excellent.
14. The Rebound hammer test results show that the rebound numbers of RHA concrete mixes increase with increase in the percentage of replacement of cement with RHA. It also increases with the age of concrete. It can thus be inferred that surface hardness of RHA concrete increases ‘with increase in the percentage of replacement of cement with RHA.
15. Temperature test results show that the rebound numbers of RHA concrete mixes increases with increase in percentage of replacement of cement with RHA up to 400°C and tends to decrease at 600°C.
16. Temperature test results show that the compressive strength of RHA mixes increases with increase in temperature up to 400°C and tends to decrease at 600°C.
17. Temperature test results for M_{45} grade concrete, with the 15% replacement of cement with RHA, actual compressive strength is increased by 1.81%, 4% and 1.57% for 200°C, 400°C and 600°C respectively than that of the compressive strength at 28 days.
18. Temperature test results for M_{50} grade concrete, with the 15% replacement of cement with RHA, actual compressive strength increased by 1.34%, 4.57% and 0.96% for 200°C, 400°C and 600°C respectively than that of the compressive strength at 28 days.
19. The other advantages derived by the use of RHA concrete are economy and serviceability. Hence the RHA concrete is the best suited alternative to the conventional concrete. Utilizing the RHA in concrete which is non-bio degradable waste helps to maintain the environmental balance.
20. The Indian concrete industry must recognize and understand the use of RHA in high strength concrete for important civil engineering projects.

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