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GREEN AND SUSTAINABLE CONCRETE-THE POTENTIAL UTILIZATION OF RICE HUSK

Deepak Kumar Yadav[1], Prof. Kapil Soni[2]
[1]Scholar M.Tech (Structure) Department of Civil Engineering, RNTU, Bhopal (M.P).
[2]Guide &HOD , Department of Civil Engineering, RNTU, Bhopal (M.P).

ABSTRACT: Concrete which is widely used material in the construction industry, has a carbon footprint. Approximately 10% of global Carbon Dioxide (CO 2) gas is emitted during the production of cement which is vital ingredient of concrete. The increase in production of cement affects global warming and climate change. Therefore, many have attempts have been made to develop green and sustainable concrete by utilizing different waste materials. With the utilization of waste materials as cement replacement, the CO_2 gas emissions can be reduced as well as resolve the environmental These artificial pozzolonic materials have played an important role in the production of concrete that gives high performance. During the late 20th century, use of mineral admixtures to enhance properties of cement and concrete has been increased in industries. The objective of the dissertation is to identify the optimum percentage of RHA and fly-ash as partial replacement of cement in M-35 grade of concrete. Also other parameters like slump, initial & final setting time, & compressive strength on 7th, 14th & 28th days of curing after casting were observed to study the behavior of blended concrete to compare the results with the quality controlled cement concrete of M-35 grade. These observations are taken on different percentages of RHA and flyash to determine an optimum replacement that can be made without compromising the strength of the concrete of desired strength.

KEY WORDS: Rice husk ash (RHA), Flyash, Replacement of cement, Super- Plasticizer, Sustainability, Pozzolonic Material, Compressive strength, Workability and Durability.

I. INTRODUCTION

The price of the building materials has reached an alarming rate of increase in the recent past. This has necessitated government, private and individuals to go for research of locally available materials to partially or fully replace the conventional materials [12]. The increasing demand for cement and concrete is met by the partial replacement of cement [16]. The whole concept of this idea is to ensure that an average working class citizen of India will be able to own a house. Concrete being a composite material eccentrically composed of a binder [12]. Now, Concrete is not just made up of aggregate, portland cement and water. Often but not always it has to incorporate at least one of the additional ingredients such as admixture or cementitious material to enhance its strength and durability [16]. Within which are embedded particles or fragments of relative inert filler in Portland cement concrete. The binder is a mixture of Portland cement. The filler may be any of a wide variety of natural or artificial. Fine and coarse aggregate; and in some instances an admixture. Concrete is presently one of the most essential materials that have been used in the civil engineering construction works. When concrete is reinforced with steel, it has got a higher capacity for carrying loads. Concrete being a heterogeneous mix of several ingredients, the quality of the constituent material and their respective proportions in the concrete, determine its strength and other properties. [12]

A vast majority of the cement used in construction work as the Portland cement. Portland cement is manufactured by mixing naturally occurring substances containing calcium carbonate with substances containing alumina, silica and iron oxide. [12]

ASTM C618-05 [19] defined pozzolana as siliceous or siliceous and aluminous materials which in themselves have little or no cementitious properties but when finely divided and in moisture presence, at ordinary temperature causes hydration of Portland cement to liberates calcium hydroxide that possesses cementitous properties.

II. METHODOLOGY

MATERIAL & METHODS

CEMENT

Portland Pozzolona Cement (PPC) is being used for a number of applications like housing, commercial complexes, roads, wells, canals, dams etc. which establishes Jaypee Cement (PPC) as the preferred choice of the discerning customer. It is particularly well suited for the tropical climatic conditions of India.

Cement used in the experimental work is PORTLAND POZZOLONA CEMENT (PPC) conforming to IS: 1489 (Part1)-1991 [18]. The physical properties of the cement obtained on conducting appropriate tests as per IS: 269/4831 and the requirements as per IS 1489-1991 [18] are given in Table 3.

Table.3. Chemical Properties of Procured PPC

Particulars	Test Result	Requirements of IS:1489-1991
Insoluble Residue (% by mass)	24.5	27 max
Magnesia (% by mass)	2.1	6 max
Sulphuric Anhydride	1.55	3.0 max
Loss of Ignition	1.8	5.0 max
Chloride (%by mass)	0.011	0.1 max

RICE ASH HUSK (RHA):
Rice husk Ash used in the present experimental study was obtained from Bhargav krisi farm Jijajipur Vidisha. The ground ash was taken for chemical and physical tests to check on its performance as a pozzolanic material.

Chemical Tests on RHA
Chemical tests were carried out at pollution control board of Bhopal on various samples of ground ash. The aim was to confirm the elemental oxide contents in the ash, especially the silica. The amount of silica present is a criterion for good pozzolana. Representative sample sizes were digested using combination of mineral acids and then filtered. The filtrates were set aside for determination of various elements. The following methods were employed:

Gravimetric method
This was used for determination of SiO_2
The residue from the filter paper was heat a temperature of about 900^{o}C, cooled and weighed.
A drop of sulphuric acid was added to the resulting material followed by treatment with hydrofluoric acid (HF) in order to expel SiO present. After fuming off the sulphuric acid and
2
drying the residue present, followed by cooling, the weight of this residue was determined. The difference between the weight of the ash and the weight of the residue represent the
weight of SiO , which was then expressed as a percentage of original ash samples.
2
Atomic Absorption Spectroscopy method
This was used for determination of Al_2O_3, CaO, Fe_2O_3, MgO

Loss on Ignition (LOI)
This was used to determine the organic content in the ash. A representative known weight of sample was ignited in a furnace to a constant weight. The loss on ignition expressed as a percentage of the original sample represents organic content.
Physical Tests on RHA

The physical tests were carried out at the Department of Civil Engineering Laboratory in accordance with the Indian. Standard using various mixes of Portland pozzolana Cement (PPC) and Rice Husk Ash (RHA). The following tests were carried out:-
Compressive Strength
The compressive strength of RHA cement was determined using 150mm concrete cubes. The cement component was made by replacing 8, 10, 12, 14 and 16% of pozzolana Portland cement (PPC) for one set of sample cubes. Also standard mortar cubes and concrete cubes without RHA were cast for comparison. For mortar cubes 1 part of cement was mixed with 3 parts of sand. For concrete cubes a ratio of 1:1.6:2.907 for cement: sand: aggregate by weight was used. About 45 mortar cubes and 45 concrete cubes were made with standard sand and well-graded aggregates as shown in Fig.7, mixed by a mechanical mixer and compacted by means of standard vibration machine. The cubes were cured and crushed for compressive strength for each mix at different curing periods. Compressive strength results of mortar PPC/RHA in N/mm^2

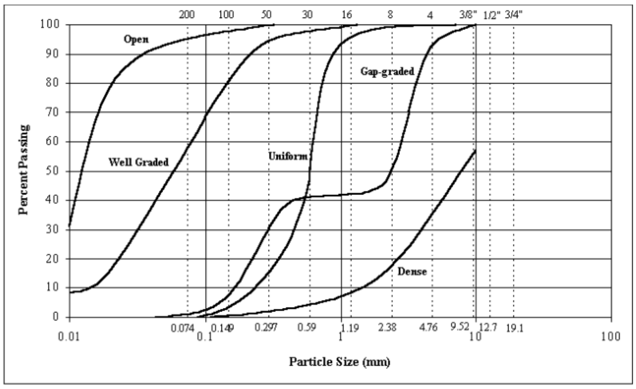

Fig.7. Gradation Curve for Aggregates

TEST ON CONCRETE SPECIMEN (As per IS:516-1959) [59]
The testing machine has reliable type of sufficient capacity for the tests and capable of applying the load at the specified rate. The permissible error shall be not greater than ±2 percent of the maximum load. The testing machine shall be equipped with two steel bearing platens with hardened faces. One of the platens shall be fitted with a ball seating in the form of a portion of a sphere, the center of which coincide platen shall be plain rigid bearing block. The bearing faces of the platens shall be at least as large as, and preferably larger than the nominal size of the specimen to which the load is applied. The bearing surface of the both platens, when new, shall not depart from a plane by more than 0.01mm at any point, and they shall be maintained with a permissible variation limit of 0.02mm. The movable portion of the spherically seated compression platen shall be held on the spherical seat, but the design shall be such that the bearing face can rotated freely and tilted through small angles in any direction.

Fig.11. Compressive Testing Machine

Procedure:
Specimens stored in water shall be tested immediately on removal from the water and while they are still in the wet condition, surface water and grit shall be wiped off the specimens and any projecting fins removed. Specimens when received dry shall be kept in
water for 24 hours before they are taken for testing. The dimensions of the specimens to the nearest 0.2mm and their weight shall be noted before testing.

Placing the specimen in the testing machine:
The bearing surfaces of the testing machine shall be wiped clean and any loose sand or other material removed from the surface of the specimen which is to be in contact with the compression platens. In the case of cubes, the specimen shall be placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast, that is, not to the top and bottom. The axis of the specimen shall be carefully aligned with the center of thrust of the spherically seated platen. No packing shall be used between the faces of the test specimen and the steel platen of the testing machine. As the spherically seated block is brought to bear on the specimen, the movable portion shall be rotated gently by hand so that uniform seating may be obtained. The load shall be applied without shock and increased continuously at a rate of approximately 140 $kg/cm^2/min$ until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load applied at failure to the specimen shall be recorded and the appearance of the concrete and any unusual features in the type of failure shall be noted.

Calculation:
The measured compressive strength of the specimen shall be calculated by dividing the maximum load applied at failure to the specimen during the test by the cross sectional area, calculated from the mean dimensions of the section and shall be expressed to the nearest kg per sq cm. average of three values shall be taken as the representative of the batch provided the individual variation is not more than ±15 percent of the average. Otherwise repeat tests shall be made.

III. RESULT ANALYSIS

STRENGTH CHARACTERISTICS OF CONCRETE:
Most concrete structures are designed assuming that concrete processes sufficient compressive strength but not the tensile strength. The compressive strength is the main criterion for the purpose of structural design. To study the strength development of rice husk ash (RHA) concrete in comparison to control concrete.
Compressive strength tests were conducted at the ages of 7, 14, 28 days. The tests results are reported in table for control concrete are in table for RHA concrete respectively.

Control concrete (CC):
Effect of Age on Compressive Strength:
It is always found that the compressive strength continuously increased with curing time. It is revealed from the literatures that cement contribute to highest strength. Maximum strength was obtained after 28 days of curing. Formation of calcium-silicate-hydrate, calcium-aluminate-hydrate and calcium alumino ferri hydrate from the pozzolanic reactions provide high strength.

Table 14 gives the test results of control concrete. The 28 days strength obtained for M35 grade control concrete is 40.44 MPa. The strength results reported in table.15 are presented in the form of graphical variation (Fig. No. 15), where in the compressive strength is plotted against the curing period.

Table.15. Compressive Strength of Control Concrete in N/mm^2

Grade of concrete	7 days	14 days	28 days
M35	30.67	32.44	40.44

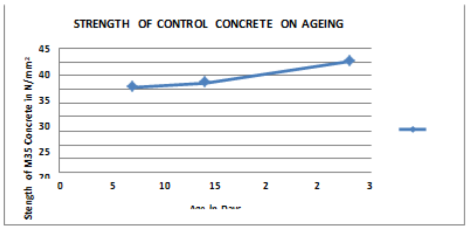

Fig.18. Strength of Control Concrete at Different Ages

The strength achieved at different ages namely 7, 14, 28 days for control concrete are also presented in the bar chart in Fig. No. 16. From the figure, and it is clear that as the age advances, the strength of control concrete increases. The cementitious material is characterized by high pH volume of pastes prepared from them, low solubility of their hydrations and very well developed specific surface and micro porosity [56]. The basic products of hydration are the C-S-H (calcium silicate hydrate) phases, calcite and hydro garnets. Application of such binders guarantees mechanical strength of obtained products. The strength increases with increase in curing time because after 28 days the hydration reaction has completed resulting in blockage of pores and densifying the structure. It is known that compressive strength is dependent on the quality of pore structure of the cement based materials [8]. This is assumed to the result of physical changes induced by the normal " hydration process" despite the "false set" mechanism (i.e. participation of salts such as gypsum that impart adequate strength)[22] From the literature also it was found that cement content and curing are the most imported factor, with the water-cement ratio being less imported. The influence of water/cement ratio is to be secondary compared to the constituents of matrix [55, 52]. Carbonation also plays an important role in increasing the strength. Carbonation of portalindite is given by
$Ca(OH)_2 + CO_2$ ---------- $CaCO_3 + H_2O$
The volume changes accompanying this reaction can help to fill pore spaces, densify the structure and improve the structural integrity. Carbonation accelerates C_3S hydration and results in improving mechanical and chemical properties. Presence of $Ca(OH)_2$ increases $CaCO_3$ formation both through providing nucleation sites for precipitation and as a consequence of undergoing carbonation itself. Compaction also plays an important role in increasing the compressive strength as it decreases the porosity.[28, 51, 31, 30]

Presences of high alkalis also accelerate the hydration of cementitious materials resulting in development of higher strength [46]. Hence with increase in the cement content and increasing curing time resulted in maximum strength.

Strength achieved by M35 grade control concrete at different ages as a ration of strength at 28 days is reported in table 14 From the table, it can be seen that 7 days strength is found to be 0.74 times that of 28 days strength, for 14 days, the strength is found to be 0.81 times that of 28 days strength.

Table.16. M35 Grade Concrete at Different Ages as a Ratio of Strength at 28 days

Concrete grade	7 days	14 days	28 days
M35	0.74	0.81	1.0

Fig.19. Strength of Concrete at Different time

Rice husk ash (RHA) concrete:

Effect of Age on Compressive Strength of Concrete:

Figure 18 and figure19 represents the variation of compressive strength with age for M35 grade RHA concrete. In each figure, variation of compressive strength with age is depicted separately for each replacement level of RHA considered namely 8%, 10%, 12%, 14%, and 16%. Along with the variation shown for each replacement, for comparison similar variations is also shown for control concrete i.e., for 0% replacement.

In each of these variations, it can be clearly seen that, as the age advances, the compressive strength also increases. The highest strength obtained at a particular age for different replacement levels with RHA is reported in table.17 for the ages of 7 days, 14 days, 28 days respectively.

Table.17. Highest Compressive Strength obtained at Different time

Sample ID	Curing Time (Days)	Length	Width	Thickness	Volume(cu. mm)	Compressive Load	Area (sq.)mm	Compressive Strength(N/mm2)
CC (0% RHA)	7 Days	150mm	150mm	150mm	3375000	69	22500	30.67
	14Days	150mm	150mm	150mm	3375000	72.9	22500	32.44
	28Days	150mm	150mm	150mm	3375000	90.99	22500	40.44
CC1 (8%RHA)	7 Days	150mm	150mm	150mm	3375000	52	22500	23.11
	14Days	150mm	150mm	150mm	3375000	61.49	22500	27.33
	28Days	150mm	150mm	150mm	3375000	83.99	22500	37.33
CC2 (10%RHA)	7 Days	150mm	150mm	150mm	3375000	58	22500	28.78
	14Days	150mm	150mm	150mm	3375000	63.99	22500	28.44
	28Days	150mm	150mm	150mm	3375000	87.99	22500	39.11
CC3 (12%RHA)	7 Days	150mm	150mm	150mm	3375000	56.99	22500	25.33
	14Days	150mm	150mm	150mm	3375000	63.49	22500	28.22
	28Days	150mm	150mm	150mm	3375000	85	22500	37.78
CC4 (14%RHA)	7 Days	150mm	150mm	150mm	3375000	44	22500	19.5
	14Days	150mm	150mm	150mm	3375000	47.99	22500	21.33
	28Days	150mm	150mm	150mm	3375000	58.99	22500	26.22
CC5 (16%RHA)	7 Days	150mm	150mm	150mm	3375000	40.9	22500	18.22
	14Days	150mm	150mm	150mm	3375000	45	22500	20
	28Days	150mm	150mm	150mm	3375000	56.9	22500	25.33

In this study, RHA was used as pozzolanic material in combination with cement. pozzolans contain significant amount of silicates. From results it is found that the compressive strength of the products involving RHA for the different curing period was higher than the compressive strength of the products without RHA for same curing periods. Maximum strength for the compositions i.e. CC1, CC2, CC3, CC4, CC5 was obtained after
28 days curing. Even after 7 days of curing the strength was obtained near to that of
conventional concrete. The main factor responsible for improvement in compressive strength is the chemical hydration [37,38]. Since RHA is latently hydraulic and undergoes hydration reactions in the presence of water and calcium hydroxide, this secondary pozzolanic reaction yields a denser microstructure because the $Ca(OH)_2$ is consumed and CSH paste is formed [53, 11]. Another factor which leads to an increase in strength development is due to heterogeneous nucleation. This process enhances the chemical activation of the hydration of cement. Thus, increasing the amount of the mineral admixture and refining its particle size will promote heterogeneous nucleation due to availability of sites [25, 36]. Compressive strength gain of composite has been attributed to the hydration and porosity [34]. Availability of more pore water for the hydration reaction also increases the compressive strength. Initially, the granulated RHA in contact with water react very fast and the hydration ceases because of the formation of a thin layer of silica rich gel over the surface. In the presence of an activator (cement), the structure of the gel is broken down and products similar to the one obtained hydration of pozzolana portland cement are formed [17].

The value of compressive strength increases via active generation and submission of aluminate hydrates. Other imported factor which helps in increasing the strength development is formation of alunimo-ferrite-tricalciumsulfate and alunimo-ferrite-monocalciumsulfate. The hardened structure filled the mocropores thereby densifying the structure, formation of calcium-silicate-hydrate, calcium alumonate-hydrate reaction provide strength. RHA contains SiO_2, Al_2O_3 and Fe_2O_3 which undergoes upon addition of water to generate phases similar to those found in cement based systems [24].

From the table no. 17 it is revealed that minimum compressive strength of 18.22 N/mm2 was found with 16% RHA and 84 % cement after 7 days of curing. Further decreased in concentration of the RHA with cement the compressive strength increased. The increase in strength may be due to the contribution of pozzolanic activity of RHA. This showed that the chemical constituents present in the RHA are important components, which significantly contributed to attain strength of 25.78 N/mm2. After 14 days of curing the compressive strength of RHA product was determined to assess the strength. The composition with 16% RHA showed the minimum strength of 20 N/mm2 while maximum strength of 28.44 N/mm2 was obtained with quantity of RHA (10%). The compressive strength after 28 days of curing was found to be maximum when compared with the strength of the products obtained after 7 days and 14 days curing. From the results it is revealed that the maximum strength of 39.11 N/mm2 was obtained with 10% RHA. After 28 days of curing the hydration reaction is completed resulting in composition of the product and thereby increasing the strength. The varying trends of strength of the RHA product after curing 7, 14, 28 days are shown in Fig. No. 18.

Percentage increase in strength with respect to control concrete strength (i.e 0% replacement) at 7 days, 14 days, 28 days are calculated and presented in table 17 to 19.

Table.18. Change in Strength of Concrete at 7 days w.r.t.
% Replacement of RHA

Percentage Replacement	Increase or Decrease in Strength
0-8%	-32.71
0-10%	-18.96
0-12%	-21.08
0-14%	-56.79
0-16%	-68.33

Table.19. Change in Strength of Concrete at 14 days w.r.t.
% Replacement of RHA

Percentage Replacement	Increase or Decrease in Strength
0-8%	-18.69
0-10%	-14.06
0-12%	-14.95
0-14%	-52.08
0-16%	-62.20

Table.20. Change in Strength of Concrete at 28 days w.r.t.
% Replacement of RHA

Percentage Replacement	Increase or Decrease in Strength
0-8%	-8.33
0-10%	-3.40
0-12%	-7.04
0-14%	-54.23
0-16%	-59.65

From table no.20 the change in strength for M35 grade RHA concrete is presented separately and the following observations are made, the maximum increase in the compressive strength of RHA concrete i.e., 37.52% has occurred at 28 days with 10 % replacement, whereas the compressive strength of RHA concrete is found to be decreased by 9.05% at 7 days with 14% RHA replacement. It can be clearly observed that at the age of 28 days, there is gradual increase in the compressive strength of RHA concrete for all the replacement levels with respect to control concrete.
Strength development of concrete for different percentage replacements with RHA is presented in table 18 to 20. In each table, by what percentage the compressive strength increases with respect to previous age is reported.

Table.21. % Increase in Compressive Strength of M 35 Grade RHA Concrete w.r.t. time

CRL	% Increase Between 7-days to 14 days	% Increase Between 14-days to 28 days
0%	57.71	24.66
8%	18.26	36.58
10%	10.32	37.52
12%	11.41	33.87
14%	9.05	22.93
16%	9.76	26.65

From the above table it can be clearly seen that, the strength is higher for control concrete (i.e. 0% replacement) for initial period up to between 7-14 days up to 10% replacement with Rice husk ash, and for 12% replacement with RHA, the strength is approximate same when compared to that of control concrete. The rate of strength development between 14-28 days is maximum when cement is replaced with 10% RHA. Thus from the above table it is clear that the rate of strength development is maximum up to the age of 28 days at all the replacement levels with RHA.

Effect of percentage replacement of cement with Rice husk ash (RHA) on compressive strength of concrete:
Figure no.19 represents the variation of compressive strength with percentage Replacement of RHA for M35 grade concrete.
Comparison between different replacements is made possible if the water cement ration is common. For better pictorial representation, the variations in 7-14 days and 14-28 days are also represented in the form of bar charts in the figure 19 From the result it is found that compressive strength increased with curing time. It found that the maximum strength was obtained with 10% RHA replacement with cement. It is revealed from literature that cement in combination with 10% RHA contribute highest strength. Formation of calcium alumino-silicate hydrate is mainly responsible for the strength and low swell of the treated RHA, as well as heavy metal immobilization. The increased strength is attributed to the increased amount of pozzolanic product formation due to increased amount of alumina and silica [44]. Cement and cement silicate mixture are all effective in chemically stabilizing metal wastes [3]. High specific surface area of calcium silicate hydrate, aluminum iron silicate, calcium aluminium oxide hydrates, entrapped heavy metal ions and stabilized them chemically. RHA improves the microstructure and durability of the hardened concrete. The physical effect of the RHA particles increases the composites density and micro structural homogeneity by filling the micro pores thereby densifying the structure which in turn yields an increase strength and decrease the porosity [54].

IV. CONCLUSION

The results of the study show that there are good prospects of using RHA as pozzolana in combination with PPC in the construction industry.
The RHA used in this study is a pozzolanic material; it is rich in silica (76.3%). The loss of ignition was relatively high (14.6%). Increasing RHA, fineness increases and increasing its reactivity.
Increase in the amount of RHA in the mix resulted in dry and unworkable mixture unless Sp is added. The inclusion of Sp in RHA concrete while maintaining the water cement ratio increased the slump and improved the cohesiveness of the concrete.
The compressive strength of the blended concrete with 10% RHA obtained 39.11 N/mm^2 could be valuably replaced by RHA after 28 days curing. The compressive strength increases with curing time.
The physical effect of the RHA particles increases the composites density and micro structural homogeneity by filling the micro pores thereby densifying the structure which in turn yields increase strength and decrease the porosity. Hence RHA improves the microstructure and durability of the hardened concrete.
From the study conducted, it was clearly observed that RHA

has a pozzolanic properties that has the potential to be used as partial cement replacement material and can contribute to the sustainability of the construction material.

Recommendation for future work

- Other levels of replacement with Rice husk ash can be researched.
- Some tests relating to durability aspects such as permeability against water, chloride ions penetration resistance, resistance to corrosion of steel reinforcement, resistance against sulphate attack durability in marine environment etc. with Rice husk ash and Silica fume need investigation.
- The study may further be extended to know the suitability of concrete for pumping purpose, as present day Ready Mix Concrete (RMC) technology is involved where pumping of concrete is necessary to be done on large heights.
- Rice husk ash concrete can be used as a structural material, but it is necessary to investigate the behavior of reinforced Rice husk ash concrete under flexure, shear, torsion and compression.
- Further the experiments can also be performed for wheat husk ash.

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