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Assessment of the potential of rice husk ash (RHA) as a supplementary material in binary blended cement for road pavement applications

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ABSTRACT

The current study explores the feasibility of using rice husk ash(RHA) as an additive in PPC (Portland Pozzolana Cement) concrete for rigid road pavement. The research investigates the impact of RHA on concrete's strength parameters, specifically tensile, split tensile and compressive strengths. The conventional mix design method is applied for the controlled concrete, serving as baseline for designing mixes with varying percentage of RHA as a replacement for cement. The study examines five replacement levels: 5%, 7.5%, 10%, 12.5%, and 15%. Various curing durations are tested, including 3 days, 7 days, 28 days, and 56 days. The primary focus is to determine the optimal quantity of RHA as a cement replacement through experimental analysis. Key findings reveal that for compressive strength, the optimal replacement level is 10% RHA, while for flexural strength, the optimal replacement level is 5% RHA. These results underscore the potential of RHA to enhance concrete performance in road pavement applications when used judiciously as a partial substitute for cement.

Key words: *Concrete, Rice Husk Ash, Cement, Mix design, Flexural strength, Compressive strength*

Introduction

India, the second-largest global rice producer, faces a substantial byproduct challenge in the form of rice husk, amounting to nearly 22% of the annual 90 million metric tons of rice paddy produced between 2011 and 2022. While the husk serves as a valuable fuel source due to its significant calorific value, contributing to approximately 20 million MT of husk each year, the combustion process generates up to 5 million MT (25% of husk) of rice husk ash (RHA). RHA, primarily composed of silica, finds common usage as tundish powder in steelmaking for insulation. However, the scale of RHA utilization remains uncertain, with a potential dumping issue evident in landfills. This highlights the need for effective strategies to manage and maximize the utilization of RHA, given its valuable composition and potential environmental impact. High demand for natural resources is increased construction activities due to urbanization and the problem of waste disposal lead to spotting the light on the viability of using agro-industrial wastes in the making of concrete. As per Rice Husk Ash market research report, the global production of husked rice is 482 million metric tons. The annual production of RHA reported is 20 mil-

([1]Research Scholar, M.Tech, [2] Professor, [3]Assistant Professor) lion tons. RHA's largest market is the cement industry. The optimum contents of RHA as substitute to cement in view of the strength and durability of the concrete.

In concrete up to 30% RHA can be used without negatively affecting the quality. The compressive strength increases with RHA concentration up to 15% then decreases as RHA levels rice to 30%, yet still remains higher than that of a mix with 100% cement. Beyond 30% RHA, the strength values become lower than that of control mix (Owino and Alex Otieno, 2022). Mechanical property tests indicates reduced plasticity and swelling pressure, with increased unconfined compressive strength (Singh and Chandra, 2023; Ganasen and Krishnaraj, 2023). The compressive strength reaches its maximum at a 15% replacement (Adom-Asamoah, 2013). Concrete pavements are preferred over flexible pavements for road construction (Vadya, 2004).

The suitability of RHA for this application is primarily determined by three key characteristics.

The content of amorphous silica, the amount of unburned carbon, and the particle size (Das *et al.*, 2022; Balakrishnan and Batra, 2021). Fineness and amount of rice husk ash are important factors that can change how well the alkali activated concrete works and how strong it is (Singh, 2022). Additionally, the inclusion of fibers in the matrix demonstrated an improvement in the permeability coefficient (Jagadesh, 2023). Some study identifies the optimal content for RHA blends as 20% and for fly ash as 15%, demonstrating the highest strength among the various mixes a balanced combination of 15% RHA with up to 20% RAP (Reclaimed Asphalt Pavement) emerges as a promising strategy, offering comparable strength and favorable values (Owino and Otieno, 2022).

The proportion of cement that can be replaced with the rice husk ash (RHA) depends on both the desired type of concrete and the specific characteristics of the RHA. Various studies indicate that substituting 25% of cement with RHA can maintain or even improve the compressive strength of concrete compared to using no RHA from day 7 onwards. research has shown that concrete begin to decease when the RHA substitution exceeds 25% particularly when the RHA contains 2% carbon (Varma, Viswanadha, 2011; Getahun *et al.*, 2021). The maximum dry density (MDD) is decreased with an increase of 21.9% in the optimum moisture content (OMC) when RHA is incorporated, which suggests improvement in soil's engineering characteristics but the addition of 9% RHA causes 13.3% reduction in plastic and liquid limit of the soil, although the effect found to be comparatively less pronounced then that achieved with lime. RHA also enhanced compressive and tensile splitting strength ,the moisture related properties like workability, density etc are reduced in case of RAP (reclaimed Asphalt Pavement) a balanced combination of 15%RHA with 20% RAP emerges as promising strategy. This approach advances solid waste management and shows the potential for sustainable concrete construction (Nasiri and Mehran, 2016) in case of alkali activated charcoal the fineness and the amount of RHA are the important factors that can change how well the concrete works or how strong it is. If the RHA has holes in it then it makes the concrete harder to work with (Ghosh *et al.*, 2022; Bouzoubaa and Fournier, 2020).

Materials and Mathedology

This study presents research on the behavior of concrete that has had RHA partially substituted for cement. The first things that were looked into were the PPC, RHA, and aggregates' physical and chemical characteristics. The mixture was mixed to yield concrete that could be used as a control mix for pavement concrete and had a flexural strength of 4.2 MPa.

Cement

Portland pozzolana cement, which complies with IS: 1489 (Part1)-1991, was utilized in the experimental project. Table 1 lists the physical characteristics of the cement as determined by the relevant tests car-

Table 1. Physical properties of procured PPC

Particulars	Test results	Requirements of IS:1489-1991
Specific Gravity	3.15	
Fineness (m^2/kg)	369	300
Normal Consistency	32%	
Setting Time (min)		
Initial	175	30
Final	265	600
Compressive strength (Mpa)		
3 Days	27	16 (minimum)
7 Days	38	22(minimum)
28 Days	56.5	33(minimum)
Drying Shrinkage %	0.06%	0.15 max

ried out in accordance with IS: 269/4831 and the specifications as per IS 1489-1991.

Aggregates

Fine aggregate-fine aggregates and sand was purchased according to the requirement which confirms to the zone 3 as per the specification of IS383:1970.

A. Specific gravity- 2.7
B. Fineness modulus- 2.71
C. Water absorption -0.70%

For the two sands from different sources, the weight of the fine aggregate weighted 1.0 kg. The wet sample was air dried for 24 hours at 105 °C to prevent lumps in the sample.

Coarse Aggregate

Crushed granite with maximum size of 20mm was used as coarse aggregates. The sieve analysis of the combined aggregates meets the specification given in IS383:1970 for graded aggregate

A. Specific gravity -2.64
B. Fineness Modulus -6.816
C. Water absorption-0.4

Water

Due to its active participation in the chemical reaction with cement, water is a crucial component of concrete. Water plays a crucial role in cement gel formation, so its quantity and quality must be carefully considered. Unwanted organic materials or inorganic ingredients in excess of recommended amounts shouldn't be present in mixing water. For this project, clean, drinkable water has been obtained from my workplace to be used for both mixing as well as curing concrete.

Mix Design for M20 Grade Concrete

Design Stipulations

1. Characteristic Compressive Strength required at the end of 28 days: 20 N/mm^2.
2. The maximum size of Aggregate: 20 mm (Angular).
3. Type of Exposure: Moderate.
4. The degree of Workability: 0.90 (compacting factor).
5. Degree of Quality Control: Good

Test Data for Materials

1. Specific Gravity of Cement: 3.15
2. Specific Gravity of Coarse Aggregate: 2.64
3. Specific Gravity of Fine Aggregate: 2.70
4. Assumed slump to be achieved: 50-100 mm

Target Mean Strength of Concrete

The obtained target mean strength for the given grade of concrete = 20 + 4.6 x 1.65 = 27.6 N/mm^2.

Selection of Water Cement Ratio

The free water cement ratio for the obtained target mean strength is 0.50. This is equal to the value prescribed for Moderate conditions in IS 456 -2000.

Selection of Water and Sand Content

From Table 4, of IS:383-2002 for 20 mm nominal maximum size aggregate and sand confirming to grading zone II water content per cubic meter of concrete = 186 kg

sand content as a percentage of total aggregate by absolute volume = 35 percent.

Required water content = 186 + 186x3/100 = 186 +5.58 = 191.61 /m^3.

Determination of Cement Content

Water cement ratio = 0.50
Water = 191.61 /m^3
Cement = 191.61/0.50 = 383 kg/m^3
This content is adequate for mild exposure condition, according to appendix A of IS 456

Determination of Coarse Aggregate and Fine Aggregate

From IS:383 for the specified maximum size of aggregate of 20 mm, the amount of entrapped air in the wet concrete is 2 percent.

0.98 = (191.61 + 383/3.15 + 1/0.33 x fa/2.7) x 1/1000

0.98 = (186 + 372/3.15 + 1/0.77 x ca/2.64) x 1/1000 Fa = 594kg/m^3

Ca= 1356 kg/ m

The Mix Proportion of concrete is shown in Table 2

Table 2. Mix proportion of concrete

Cement	Water	Coarse aggregate	Fine aggregate
383kg	191.61kg	1356kg	594kg
1	0.50	3.54	1.55

Results and Discussion

Below is the list of compressive and flexural strength development for both controlled concrete as well as concrete with RHA at different curing time. The study follows the IS method for controlled concrete.

Compressive Strength

To compare the strength development of Rice Husk Ash (RHA) concrete with Control concrete, compressive strength tests were performed at 3, 7, 28, and 56 days. The results for both Control concrete and RHA concrete are provided in a table. Figure 1 depicts the compressive strength changes for different RHA replacement.

Flexural Strength

It is evident now that strength of concrete in tension (tension and flexural) are not proportionally related although they are closely related. for higher compressive strength concrete shows higher tensile strength but the rate of increase of tensile strength is of decreasing order as concrete ages the strength increases, with a faster increase between 7 to 28 days of curing. After 28 days the strength still goes up, but not as quickly as shown in Fig. 2.

Split tensile strength test

Tensile stress was calculated by using the formula $2P/\pi DL$, where stands for applied load D and L are diameter and length of specimen, respectively the strength of each sample was tested by noticing the failure load. The result shown in Figure 3 indicated that addition of 5% RHA increases the strength by 3.8% however at 10% replacement, there is decrease of 17.5% the highest split tensile strength occurred with a 5% addition of RHA slightly exceeding the strength of the controlled mix .although there is a decrease in strength at 10%. Therefore 5% addition is recommended for strength.

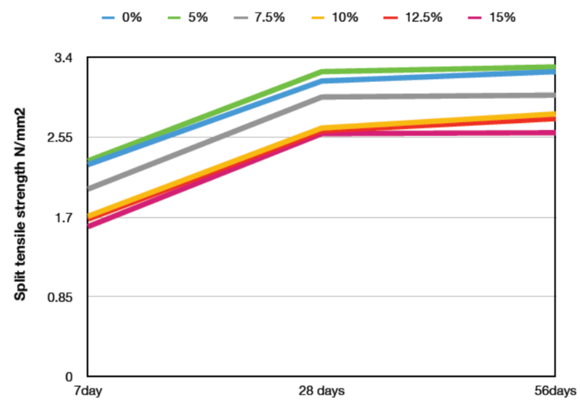


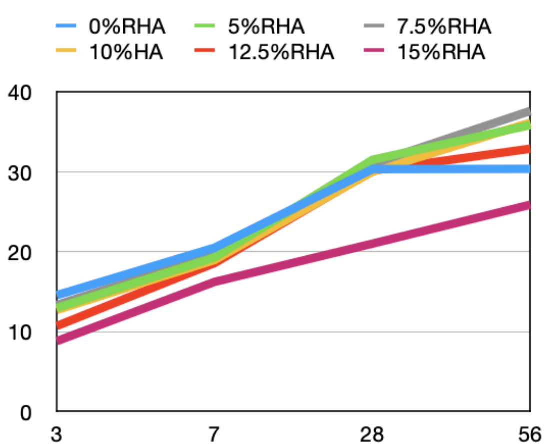
Fig. 3. Split tensile strength of Concrete with different % of RHA at different ages

Slump cone test

The slump test for plain concrete showed a height of 22.5 cm, which was the highest among all the mixes with different percentages of RHA (Rice Husk Ash). The lowest slump occurred in the mix with 5% RHA. Overall, this indicates that the workability of the concrete mix is excellent, suggesting it is reliable and suitable for use in various types of construction projects.

Water Absorption test

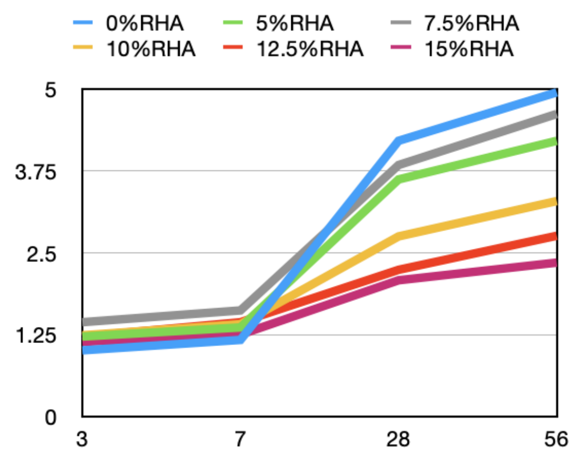
Table 3 shows the water absorption test results ob-



X axis- Age in days

Y axis- Compressive Strength

Fig 1 a. Compressive strength of concrete



X Axis- Age in days

Y axis- Flexural Strength

Fig. 2. Flexural strength of concrete

tained for different replacement percentage of RHA in the concrete mix. Substitution of RHA in concrete tends to reduce the water absorption upto 10% replacement but increases as the percentage replacement increases to 12.5% and 15%.

Table 3. Water absorption test results

Mix	% absorption
0% RHA	0.84
5%RHA	0.71
7.5%RHA	0.65
10%RHA	0.55
12.5 %RHA	1.25
15%RHA	1.9

Conclusion

At all the cement replacement levels of Rice husk ash; there is a gradual increase in compressive strength from 3 days to 7 days. However, there is a significant increase in compressive strength from 7 days to 28 days followed by a gradual increase from 28 days to 56 days. At the initial ages, with the increase in the percentage replacement of Rice husk ash, the flexural strength of Rice husk ash concrete is found to increase gradually till 7.5% replacement. The rate of development of flexural strength is higher at 7 days to 28 days. At the later age between 28 days to 56 days only a marginal increase is observed. There was reduction in split tensile strength for 28 days for every replacement percentage of rice husk content. However it can be enhanced by addition of fibers. Concrete with 7.5% RHA can give better results as longer curing time and can be used in any type of construction.

Conflict of Interest - None

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