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PERFORMANCE EVALUATION OF CONCRETE INCORPORATING RICE HUSK ASH AS A SUPPLEMENTARY MATERIAL

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ABSTRACT

The study examined the effects on concrete qualities of substituting rice husk ash (RHA) for ordinary Portland cement (OPC) at various percentages: 0%, 5%, 10%, 15%, and 20%. The compressive strength, cracking strength, and rate of water absorption were measured at 7, 14, 28, and 56 days after curing in the laboratory studies. According to the findings, the concrete's durability was enhanced due to an increase in compressive and tensile strength as well as a decrease in water absorption. The RHA primarily accomplished its goals by increasing the concentration of calcium silicate hydrate (C-S-H) gel through the pozzolan-cement reaction and by filling smaller gaps with the additional particles, resulting in a more compact structure. Due to dilution, concrete exhibits less strength and retains more water when the cement percentage is dropped by more than 10%. This is because, when the cement percentage declines, concrete fails to hydrate correctly and the pozzolanic reaction cannot take place as it should. The tires lasted longer, performed as expected, and were still environmentally friendly because they were created with 10% RHA and agricultural waste.

Keywords: Rice Husk Ash, Partial Cement Replacement, Compressive Strength, Split Tensile Strength, Water Absorption, Pozzolanic Reaction, Durability, Sustainable Construction.

1. INTRODUCTION

Ordinary Portland cement (OPC), a major ingredient in concrete, is responsible for 8% of the world's CO2 emissions, making ORK the most widely used construction material but also the leading cause of serious environmental problems. This motivation has prompted research and engineering to examine sustainable choices and other cementations materials (SCMs) that can replace ordinary portland cement (OPC) in concrete mixtures. One promising choice for concrete mixtures is using rice husk ash (RHA), since it is made from the ash left over after rice milling and crop processing. Because of its high silica, RHA is a great pozzolan that, when

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mixed correctly into concrete, can help strengthen and improve the durability of concrete. Using RHA helps remedy the environmental effects of making cement and assists in handling excess agricultural waste while growing the circular economy in the construction industry.

Variations in compressive, tensile and water absorption strengths as a function of RHA concentration allow for an examination of the material's performance in concrete. Chemical reactions between RHA's reactive silica and the calcium hydroxide made by hydration Portland cement increase the concentration of C-S-H, which in turn increases the strength and filling capacity of the concrete. Moreover, the very small particle size of RHA, which acts as a micro-filler, decreases porosity and increases durability due to the reduction of penetrable water into the concrete. Note that excessive cement replacement with RHA could negatively impact strength development because there is reduced cementitious material. Therefore, it is critical to optimize the use of RHA. This study will evaluate performance of concrete containing various amounts of RHA to understand the optimum dosage in terms of the benefits of RHA and minimizing negative effects related to the structural and durability performance.

2. LITERATURE REVIEW

Bahri et al. (2019) assessed the resilience and longevity of a novel kind of high-performance concrete reinforced with rice husk ash (RHA). Reducing chloride entrance into HSHPC and increasing compressive strength and elastic modulus were among the effects of RHA, according to a study published in the IOP Conference Series: Materials Science and Engineering. Through pore refinement and the creation of calcium silicate hydrate (C-S-H) gel, they discovered that RHA has high pozzolanic capabilities, which would enhance the strength and durability of construction materials.

Dharmaraj et al. (2023) looked into the possibility of using ash from rice husks to create HPC. Materials Today: Proceedings published their findings, which highlight the fact that RHA may greatly improve concrete's resistance to compression and split tensile stress. The study demonstrated that by substituting a portion of the cement with RHA, the concrete's bonds were enhanced, leading to stronger and more sustainable concrete with reduced cement requirements.

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In its discussion of greener alternatives to traditional concrete additives, the research highlighted RHA.

Faried et al. (2021) concentrated on how nano rice husk ash (NRHA), at different degrees of burning, can influence ultra-high-performance concrete (UHPC). Their study, published in Construction and Building Materials, showed NRHA could enhance of UHPC mechanical performance and microstructure density. They concluded NRHA was beneficial for UHPC, especially if it was monitored during combustion. Their study described increased compressive strength, with reduced porosity, and enhanced indicators of durability, such as chloride ion and sulfate attack resistance. The findings linked the UHPC improvement features to the nanoscale particle size and pozzolanic reactivity of NRHA.

Hasan et al. (2022) studied the incorporation of rice husk ash (RHA) as an SCM in sustainable high strength concrete. In a study published in Materials, the authors found that the addition of RHA allowed compressive strength to improve, and water absorption and durability to decrease. The authors highlighted the ability to mitigate the carbon footprint from cement-based construction by partially replacing OPC with rice husk ash for greater sustainability without compromising structural performance.

Hu, He, and Zhang (2020) studied the sustainable applications of rice husk ash in cement-based materials focusing on both environmental impact and performance enhancement. Their study published in the Journal of Cleaner Production involved a detailed life-cycle assessment and performance evaluation. The research established that RHA considerably decreased the environmental impact of cement production and decreased mechanical strength, permeability, and long-term durability. The authors noted that RHA both improved properties of concrete and advanced sustainable construction.

3. RESEARCH METHOLODY

This research utilizes an experimental methodology to examine the effects of varying RHA content (0-20%) on concrete's mechanical and durability properties through standardized laboratory tests. Data were analyzed to determine the best RHA amount to improve strength and reduce water absorption.

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3.1. Research Design:

The purpose of this experiment was to analyze the effects of partially substituting rice husk ash (RHA) for standard Portland cement in concrete, specifically looking at its mechanical and durability qualities. The effects of RHA replacement levels on compressive strength, split tensile strength, and water absorption were studied in studies involving0%, 5%, 10%, 15%, and 20% RHA. In order to determine the optimal level of RHA for this investigation, a control mix was utilized, which included no RHA.

3.2. Data Collection:

Primary data were collected by laboratory testing of concrete specimens made using different amounts of RHA, after curing periods of 7, 14, 28, and 56 days, as regards the property being evaluated. All testing regimens were conducted under Indian Standard (IS) specifications to ensure accurate, reliable, and reproducible data obtained.

3.3. Materials and Mix Design:

The ingredients were OPC, RHA powder, natural river sand from Zone II, coarse aggregate (maximum size 20mm), and drinkable water. Concrete mix designs were created using RHA in place of OPC at weight percentages of0%,5%,10%,15%, and 20%. In order to isolate the influence of RHA, the cementitious material water-to-cementitious material ratios were maintained constant for all mixtures. The mix ratios were based on standard design processes.

3.4. Mixing, Casting, and Curing:

To get the desired consistency, the concrete elements were mechanically mixed with great care. After that, the new concrete was slump tested to make sure it was workable. For compressive strength, specimens were sorted into 150 mm cubes, for split tensile strength, they were placed in 150 mm × 300 mm cylinders, and for water absorption, they were placed in discs. The specimens were cured and demolded for 24 hours before being placed in a water tank at room temperature until testing age.

3.5. Testing Procedures:

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The compressive strength tests were carried out at 7, 14, 28 and 56 days with a compression testing machine conforming to IS 516. The split tensile strength was obtained at 28 days following IS 5816. Water absorption was determined at the end of 28 days of curing with the procedure outlined in IS 1199. All tests were completed with three specimens per mix, and the average values were recorded for discussion and analysis.

3.6. Data Analysis Techniques:

The test data was summarized using tables and figures. We compared control mixes to RHA mixes to determine trends and differences in performance. These improvements in strength & durability were due to both pozzolanic activity and the filler effect of RHA. When interpreting the results, we focused on defining the amount of RHA that offered the best combination of strength and long-term durability.

4. DATA ANALYSIS AND INTERPRETATION

In Table 1 and Figure 1, the compressive strength values of concrete mixes with varying percentages of RHA as a partial replacement of cement were summarised at 7, 14, 28, and 56 days after curing, in comparison to the control mix (0% RHA). Despite significant heterogeneity among the data points for each mix, the results showed that compressive strength increased consistently with ageing during the curing durations. In terms of compressive strength, 10% RHA in concrete has the best value across all curing ages; mixtures with 5% and 15% RHA are quite close; and mixes with 20% RHA have the lowest value.

Table 1: Compressive Strength of Concrete with Varying RHA Content

RHA Replacement (%)	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)	56 Days (MPa)
0% (Control)	24.8	31.5	37.2	40.3
5%	26.1	33.0	39.4	42.8
10%	27.0	34.7	41.8	45.2
15%	25.2	32.3	38.5	42.1
20%	22.8	29.5	34.7	38.0

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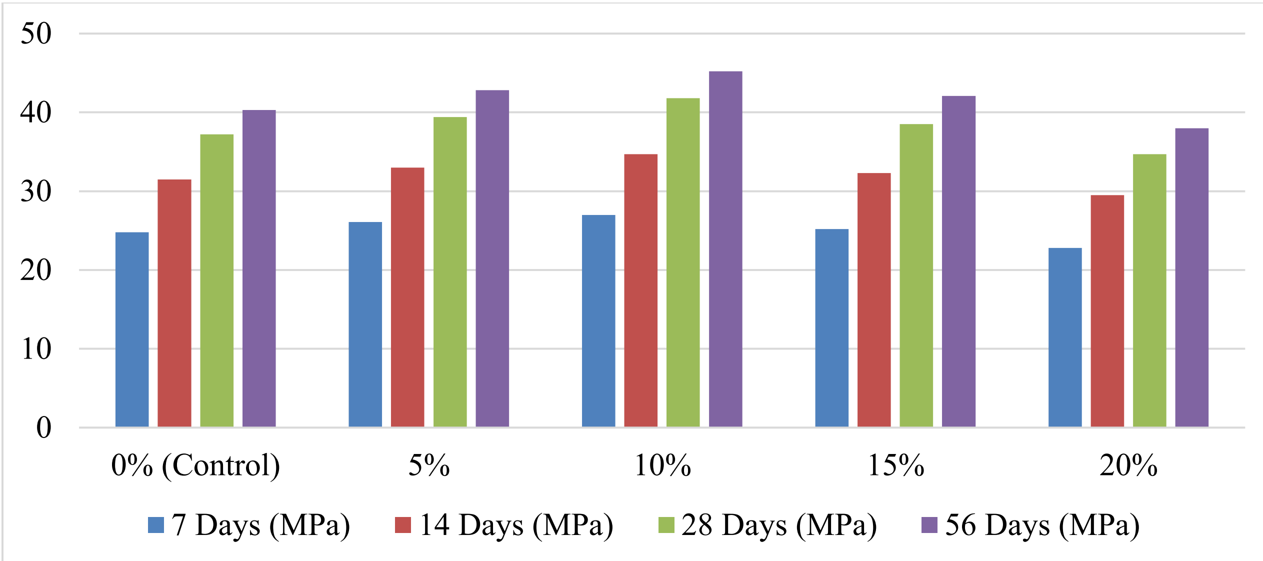

Figure 1: Graphical Representation of Compressive Strength of Concrete with Varying RHA Content

The results show that up to a 10% acceptable dose, replacing cement with RHA boosts the compressive strength of concrete. The formation of extra calcium silicate hydrate (C-S-H) gel, which aids in improving strength, is a result of a pozzolanic interaction with calcium hydroxide in the cement matrix. In addition, the densities and micro gaps might be filled by RHA because to its tiny particle size. However, when the dose exceeds 10%, a dilution effect is observed, leading to a decrease in compressive strength. It is possible that there was a dilution of the amount cement that had to be available to complete development of strength, due to too large an amount of RHA. Therefore, RHA was found to be an optimum dosage of 10 per cent which did not compromise with the compressive characteristics of the concrete and improved compressive performance.

Table 2 and Figure 2 show the variation in the split tensile strength of concrete at 28-days curing ages at the different replacement levels of rice husk ash (RHA) which are 0% (control), 5%, 10%, 15% and 20%. The control mix produced a tensile strength of 3.02 MPa. A gradual increase in tensile strength was found with the 5% (3.20 MPa) and 10% (3.38 MPa) RHA replacements. The strength begins to lose strength after this point at the 15% (3.10 MPa) replacement and at the 20% it was the lowest at 2.85 MPa.

Table 2: Split Tensile Strength at 28 Days

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RHA Replacement (%)	Split Tensile Strength (MPa)
0% (Control)	3.02
5%	3.20
10%	3.38
15%	3.10
20%	2.85

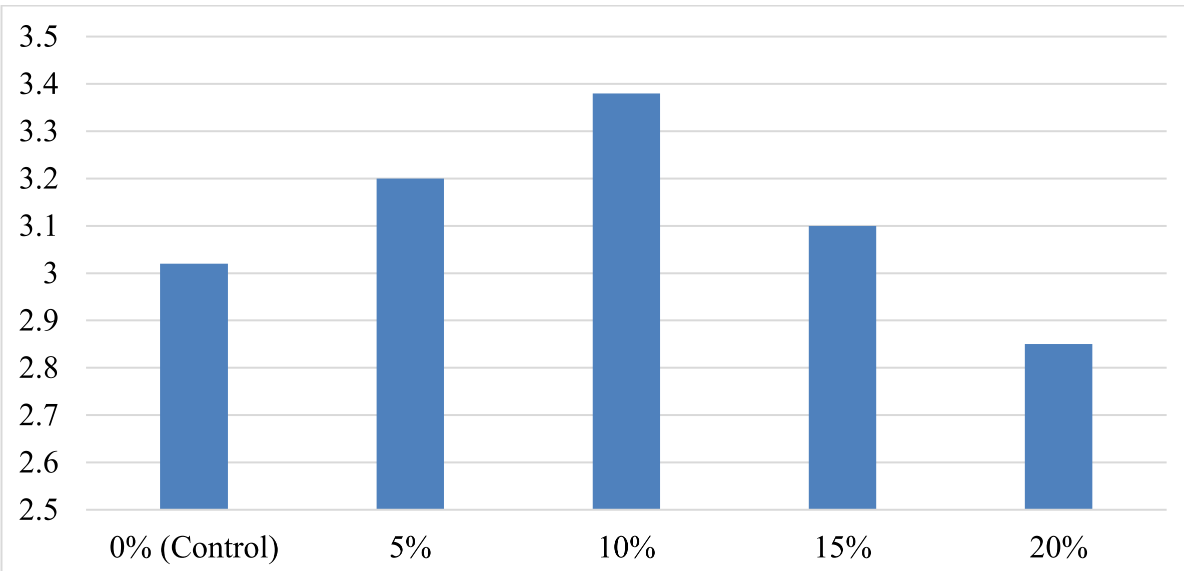

Figure 2: Graphical Representation ofSplit Tensile Strength at 28 Days

According to the results, tensile strength of concrete is increased when RHA is added to the mix at a rate of 10%. This indicates that the enhancement of bonding and matrix properties is brought about by pozzolanic activity and filler particles such fine RHA. At 10% RHA, concrete demonstrates not only the best cementitious content but also the advantages of RHA, as seen by its highest tensile strength. If the tensile strength drops below 10% RHA, it might be because there are less strong hydration products available for matrix formation due to the lower cement concentration. In conclusion, RHA up to 10% is beneficial, but above this point, it probably starts to damage tensile strength.

The water absorption percentages of concrete specimens that have been partially replaced with rice husk ash (RHA) may be found in Table 3 and Figure 3, respectively. The control mix with zero percent RHA absorbed the most water volume (5.4%). Reactive hydroxylamine (RHA)

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reduces water absorption to 4.8% at 5% RHA and to 4.3% volume at 10% RHA replacement. Following this, there is a progressive rise in water absorption, reaching 4.6% volume at 15% RHA and 5.0% volume at 20% replacement.

Table 3: Water Absorption Percentage

RHA Replacement (%)	Water Absorption (%)
0% (Control)	5.4
5%	4.8
10%	4.3
15%	4.6
20%	5.0

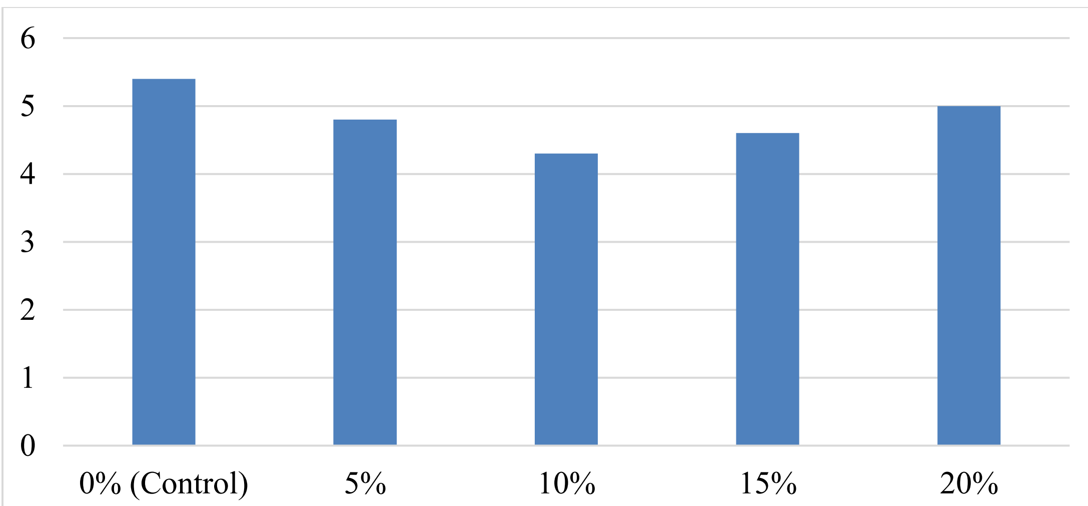

Figure 3: Graphical Representation ofWater Absorption Percentage

The study shows that adding up to 10% RHA provides a good improvement in resistance to water absorption, a critical indicator of durability. The enhanced water absorption resistance can be attributed to both the micro-filling effects of smaller-sized RHA particles and the pozzolanic reaction creating a denser concrete matrix through reduction of pore connectivity. Beyond 10% we see a progressive increase in absorption rates, likely due to the reduction of cement content not providing adequate availability of hydration products resulting in a poorer pore structure. The overall totality of the data suggests that while up to 20% RHA can create improved permeability

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and durability characteristics, 10% RHA results in the best trade off in terms of reducing permeability while maintaining structural integrity and durability in the long-run.

5. CONCLUSION

According to the study, using up to 10% RHA instead of regular Portland cement in concrete improves its mechanical and durability factors. With the lowest porosity (a measure of water absorption) during all curing times, the concrete specimens exhibited the best compressive and split tensile strengths, indicating superior structural performance and durability with this degree of RHA replacement. Because more calcium silicate hydrate (C-S-H) gel was generated and more C-S-H was present in the concrete matrix as a result of the pozzolanic reaction between the RHA and calcium hydroxide, this is mostly to blame. RHA provides fine particle fillers for micro voids generated in concrete to decrease porosity and improve density, leading to reduced water permeability. However, above 10% RHA content, the concrete showed reductions in strengths and increases in water absorption, likely due to the dilution effect where too much RHA was included and consequently reduced the amount of available cement for the hydration reaction and thus weakened the concrete matrix. In conclusion, the research demonstrates that an RHA replacement of 10% is the optimal dosage of RHA in concrete, which provides a balance of better strengths and durability properties without compromising the cementitious properties of the concrete mix, which is both sustainable and effective for partial cement replacement.

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