Rice Husk Ash Concrete - A Resource for High Strength and Durability at Low Cost

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Abstract

Concrete is a ubiquitous construction material, essential for the development of infrastructure worldwide. However, the production of cement, a crucial component of concrete, is an energy-intensive process that contributes significantly to global carbon emissions. To address this challenge, researchers have explored the use of industrial and agricultural waste products as alternative materials in concrete, with the aim of reducing the environmental impact and cost of construction. One such promising material is rice husk ash, a byproduct of the rice milling industry.
Rice husk, an agricultural waste generated in abundance in rice-producing regions, can be converted into a pozzolanic material through controlled burning, resulting in rice husk ash. The use of rice husk ash as a partial replacement for cement in concrete not only provides a sustainable solution for waste management but also offers the potential for high-strength and durable concrete at a lower cost.
Studies have shown that the incorporation of rice husk ash in concrete can enhance various properties, including compressive strength, durability, and workability. One study found that the optimum replacement of cement with rice husk ash was 10%, resulting in concrete with improved mechanical properties. Another investigation demonstrated that replacing up to 15% of cement with rice husk ash can produce concrete with satisfactory strength characteristics.
The pozzolanic nature of rice husk ash allows it to react with the calcium hydroxide released during the hydration of cement, forming additional calcium silicate hydrate gel. This process not only improves the concrete's strength but also enhances its resistance to chemical attack and environmental degradation
Furthermore, the use of rice husk ash in concrete can have a positive impact on the environment by reducing the demand for cement production, which is a significant contributor to global carbon emissions. The replacement of cement with rice husk ash can lead to a decrease in the energy consumption and greenhouse gas emissions associated with cement manufacturing.

Keywords: Rice husk ash, Agricultural waste, Environmental impact

1. Introduction

Finding strong, long-lasting structures at reasonable prices is still a constant problem in the field of construction engineering. Conventional materials like Portland cement, which can be expensive and have a big impact on the environment, are frequently used in traditional construction methods. To overcome these obstacles, engineers and researchers have resorted to using unusual materials in order to develop and enhance building techniques (Bastos et al., 2016). Rice Husk Ash (RHA) is one such substance that has attracted a lot of interest. RHA was once a byproduct of processing rice, but it has since gained notoriety as a useful resource material for improving the performance of concrete. The understanding of RHA's special qualities—especially its high silica concentration, which adds pozzolanic qualities essential for improving concrete's strength, durability, and resistance to different environmental factors—is what is causing this change(Antiohos et al., 2014). The application of RHA in concrete offers a comprehensive strategy to tackle the main issues that construction engineers encounter. Concrete compositions can improve their mechanical qualities as well as their resistance to abrasion, corrosion, and permeability by utilizing their pozzolanic capabilities. Additionally, by recycling agricultural waste, adding RHA to concrete mixes provides a sustainable alternative that lessens environmental effect and dependency on conventional cement ingredients. The purpose of this review study is to examine RHA Concrete's revolutionary potential in the building sector. The study will investigate the varied uses of RHA Concrete in a range of construction scenarios, from large-scale infrastructure projects to residential buildings, by thoroughly analyzing empirical research, experimental analyses, and case studies (Mangabhai et al., 2016). The evaluation will also emphasize the financial benefits of adopting RHA Concrete, such as possible cost savings from lower material usage and better long-term durability. In the end, this review's goal goes beyond simple investigation to promote RHA Concrete's broad use as a standard building material. This study aims to spark a paradigm shift in construction techniques towards more sustainable, efficient structures by highlighting its performance benefits, economic advantages, and environmental sustainability. Additionally, current research and development initiatives are looking at cutting-edge techniques to maximize RHA Concrete's qualities. (Desai, 2008). One notable example of innovation bringing about constructive change is RHA Concrete. Its incorporation into standard building procedures not only promises to produce high-performance structures but also marks a significant advancement in the creation of a built environment that is more robust and environmentally conscientious. Including developments in additive formulas, curing processes, and mixing strategies. These developments seek to expand its use in a variety of construction scenarios and improve its performance qualities even more. As the building sector keeps moving towards more environmentally friendly methods.(Labonnote et al., 2016)

1.1. Rice Husk Ash as a Supplementary Cementitious Material

Rice husk is a byproduct of the rice milling process, and it is estimated that for every ton of rice produced, approximately 200 kg of rice husk is generated (Zareei et al., 2017). Rice husk is typically burned as a low-cost fuel source, but the ash that remains can be used as a supplementary cementitious material in concrete production.

When rice husk is burned under controlled conditions, the resulting ash is highly reactive and can be used as a pozzolanic material, meaning that it reacts with calcium hydroxide (a byproduct of the hydration of Portland cement) to form additional calcium silicate hydrate gel, which is the primary binder in concrete. The chemical composition of rice husk ash, which is high in silica content, makes it a suitable replacement for a portion of the cement used in concrete.(Cordeiro et al., 2008)

Multiple studies have demonstrated that replacing up to 20% of cement with rice husk ash can produce concrete with comparable or even enhanced strength and durability characteristics compared to conventional concrete. (Sivakumar & Ravi Baskar, 2009) The pozzolanic nature of RHA allows it to refine the pore structure of concrete, leading to reduced permeability and improved resistance to various forms of degradation. (Krishna et al., 2016)

1.2. Objective

Rice Husk Ash (RHA) concrete's mechanical performance and suitability for structural applications are assessed using compressive strength testing. The purpose of this testing is to evaluate the efficacy of RHA as a partial substitute for traditional cementitious materials in concrete mixes through thorough experimentation and analysis. The goal is to measure the highest compressive strength achieved and examine the rate of strength development over time by applying controlled compressive loading to RHA concrete specimens. Furthermore, this testing aims to detect any possible differences in compressive strength brought on by varying RHA levels in the concrete mix. The ultimate objective is to offer insightful information about the load-bearing capacity and structural integrity of RHA concrete, enabling well-informed choices to be made throughout the material selection and construction design phases.

2. Literature Review

The use of rice husk ash in concrete has been explored in several studies. One study showed that it is possible to produce high-strength Grade 80 concrete by incorporating rice husk ash, and that the strength and durability properties of this concrete are comparable to those of concrete made with silica fume(Sivakumar & Ravibaskar, 2009). Another study found that the use of rice husk ash as a partial replacement for Portland cement can lead to a reduction in the environmental impact of concrete production, as it can reduce the amount of CO_2 emissions and energy consumption associated with cement manufacturing (Al-Khalaf & Yousif, 1984).

The use of rice husk ash as a cement replacement has also been investigated in other studies. One study found that the replacement of up to 15% of Portland cement with rice husk ash can improve the compressive strength and durability of concrete, while also reducing the overall cost of the concrete. Another study reported that the incorporation of rice husk ash in concrete can lead to a reduction in the environmental problems associated with the disposal of this agricultural waste. (Khan et al., 2011)

3. Methodology

Rice Husk Gathering and Burning: The first step in the process is gathering the plentiful and affordable rice husks, a byproduct of rice mills. After that, these husks are burned at temperatures ranging from 600 to 700°C under carefully monitored circumstances. The husk is converted into silica-rich rice husk ash (RHA) with strong pozzolanic reactivity by this controlled burning process, which is crucial for increasing the strength of concrete.

Rice husk ash: is pulverized into a fine powder after burning, usually with a particle size of 45 microns. In order to increase RHA's surface area and improve its ability to respond within the concrete matrix, this grinding process is essential. Additionally, by filling in micropores, the finer particles increase the finished concrete's density and durability.

Mix Proportioning and Water Adjustment: RHA is added as a partial cement substitute during the mix design phase, usually substituting 10–30% of the cement by weight. Due to RHA's high absorption capacity, the water-to-cement ratio must be carefully regulated to preserve workability and prevent the mixture from drying out too much, which could compromise the strength of the concrete.

Additives for Workability: Superplasticizers are added to the mixture to offset any decrease in workability brought on by the fine RHA particles. Particularly in applications requiring precision molding, these additives enhance flow and facilitate the handling and pouring of concrete.

Curing Procedure: In order to optimize the pozzolanic reaction and improve the concrete's overall strength and durability, proper curing procedures must be followed. The concrete must be kept in a moist environment for at least 28 days.

4. Results and Discussion:

4.1. Compressive strength

After 7, 14, and 28 days of curing, concrete was replaced by rice husk ash based on its compressive strength. The table indicates an increase in compressive strength. This value is significant for all replacement levels as a function of age and blending percentage. It is also possible to employ higher concentrations of RHA without losing strength. All of the rice husk ash-replaced concretes exhibit greater compressive strength than the control concrete after 28 days of curing. The compressive strength of conventional and 5% rice husk ash-replaced concretes was equal after 28 days of curing. Concretes mixed with rice husk ash demonstrated greater compressive strength than control concretes above 5% replacement levels. Comparing rice husk ash to regular OPC concrete, no drop in compressive strength is seen up to a 30% replacement level.

Fig 1: Testing of compressive strength using CTM

Table:1 Compressive strength of rice husk ash replaced concrete after 7, 14 and 28 days of curing

% of Replacement	Average Compressive Strength (N/mm^2)		
	7 DAYS	14 DAYS	28 DAYS
0(OPC)	27.22	33.29	36.45
5	31.32	35.62	36.49
10	30.45	35.97	37.43
15	31.52	35.04	37.38
20	31.64	36.17	37.71
25	33.09	35.27	39.55
30	33.53	35.44	37.80

Table No.2. Compressive Strength of Different Grades of Concrete at 7 Days and 28 Days

Grade of Concrete	Minimum compressive strength N/mm$_2$ at 7 days	Specified characteristic compressive strength (N/mm$_2$) at 28 day
M15	10	17
M20	13.5	23
M25	17	29
M30	20	32
M35	23.5	37
M40	27	44

4.2. Coefficient of water absorption

Finding the coefficient of water absorption is a methodical procedure used to analyses a material's capacity to absorb water, which is an important consideration when evaluating its performance and durability, especially in building materials like concrete. First, in accordance with pertinent standards or specifications, representative samples of the item in question are prepared. This usually entails casting specimens of particular sizes, like cubes or cylinders, for concrete. A precise weighing scale is then used to measure and record each specimen's initial dry weight (W1). This determines the starting weight prior to any water exposure. After preparation, the specimens are submerged in water at a particular temperature for a predefined amount of time, usually at room temperature or in accordance with the testing standard. Depending on the study's criteria or relevant norms, the immersion period may differ. The specimens are taken out of the water after the immersion time, and any extra surface water is carefully wiped away. Before moving on to the following stage, it is imperative to make sure the surface is dry. Each specimen's final weight (W2) following immersion and drying is promptly measured and noted. This action is taken as soon as possible to reduce additional water absorption from the surroundings. The coefficient of water absorption is computed using the data that has been gathered.

Formula: Coefficient of Water Absorption = $((W_2 - W_1) / W_1) \times 100\%$.

This calculation quantifies the amount of water absorbed by the material relative to its initial dry weight. The calculated coefficient of water absorption values provide insights into the material's porosity and susceptibility to water absorption.

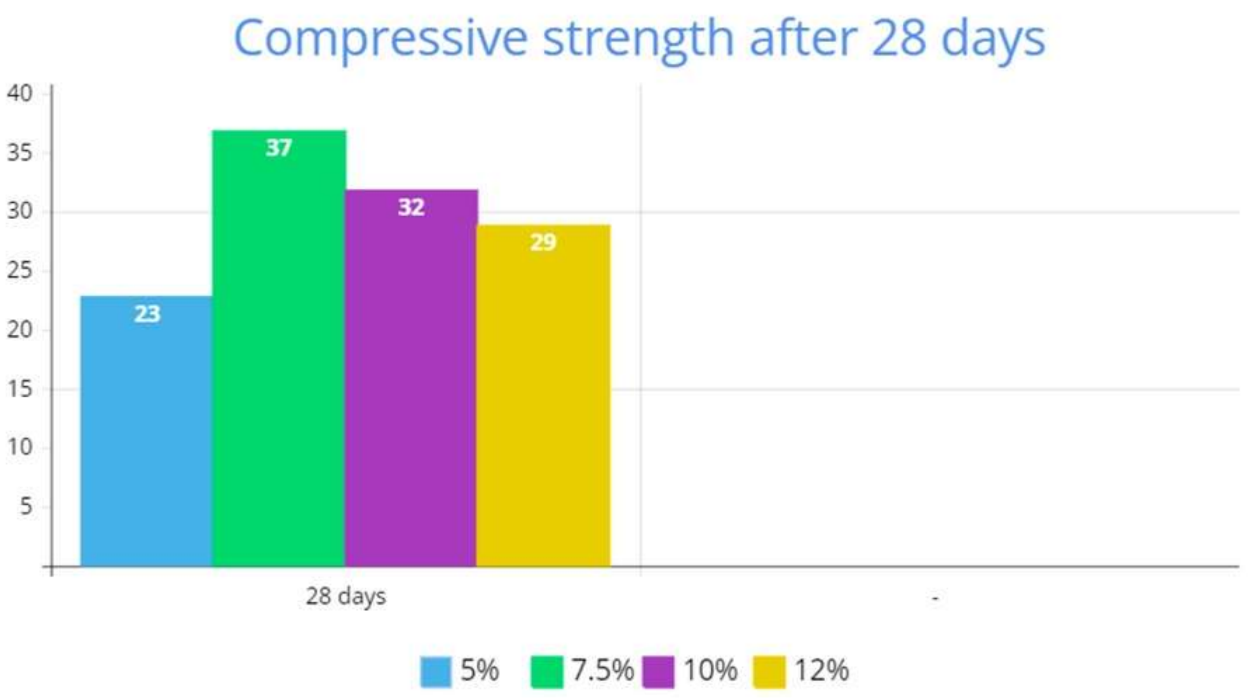

Fig.2: Variation of Compressive strength of rice husk ash replaced concrete after 28 days of curing

Table No. 3 Coefficient of water absorption of rice husk ash replaced concretes

S. No	% of replacement	Coefficient of water absorption (m^2/s)
1	Control (OPC)	3.5571×10^{-10}
2	5	6.7587×10^{-11}
3	10	1.0320×10^{-11}
4	15	1.0644×10^{-11}
5	20	1.2122×10^{-10}
6	25	1.4548×10^{-10}
7	30	1.3030×10^{-10}

5. Conclusion

To sum up, the investigation of Rice Husk Ash (RHA) Concrete offers an engaging story of sustainability and innovation in the field of building engineering. This project's thorough investigation and testing have shown RHA's revolutionary potential as a crucial component in the pursuit of strong, long-lasting buildings at reasonable prices. RHA's special qualities, especially its high silica concentration and pozzolanic qualities, present a viable way to improve concrete formulations. By utilizing these qualities, RHA Concrete overcomes important obstacles in construction engineering and demonstrates exceptional strength, durability, and resistance to environmental influences. Through case studies, experimental analysis, and empirical research, this project has offered thorough insights into the advantages of RHA Concrete's performance and economic feasibility in a range of construction scenarios. RHA Concrete's adaptability and effectiveness have been shown in a variety of projects, from infrastructure to residential buildings, setting the stage for its broad use. This project essentially promotes a paradigm change in construction methods towards resilience, efficiency, and sustainability. By demonstrating RHA Concrete's capacity to produce high-performance structures and encourage environmental responsibility. We can create a future where building engineering flourishes in balance with the environment by working together and taking collective action.

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