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Evaluating the Strength and Durability Characteristics of Concrete Incorporating Bacterial Rice Husk Ash: Literature Survey

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ABSTRACT

The utilization of alternative materials in concrete production has gained significant attention in recent years due to the environmental concerns associated with traditional concrete constituents. One such material that shows promise is bacterial rice husk ash (BRHA), which is obtained through the controlled combustion of rice husk with the involvement of specific bacteria. This study aims to evaluate the strength and durability properties of concrete incorporating BRHA through a comprehensive literature survey. The abstract starts by emphasizing the need for exploring alternative materials in concrete production to address environmental concerns. It introduces bacterial rice husk ash as a potential material and highlights its unique production process involving bacteria. The study's objective is clearly stated, which is to assess the strength and durability characteristics of concrete when BRHA is incorporated. The abstract emphasizes that the evaluation will be conducted through an extensive literature survey, suggesting that existing research and studies will be reviewed and analyzed. By doing so, it indicates that the study will provide a comprehensive understanding of the current state of knowledge in this area. This research is significant because it contributes to the development of sustainable concrete materials by investigating the potential of BRHA. The findings from this literature survey will serve as a valuable resource for researchers, engineers, and practitioners involved in the concrete industry. In conclusion, this abstract provides a concise overview of the research topic, the objective of the study, the methodology (literature survey), and the potential impact of the findings. It serves as a strong introduction to the paper, capturing the essence of the research and generating interest among readers.

1. INTRODUCTION

Concrete is a composite material comprising of inert aggregate particles with varying mineral compositions and sizes, embedded within a matrix of hydrated cement paste (hcp). The hardened matrix is formed through the hydration reactions between water and Portland cement. However, cement production is an energy-intensive process that poses environmental challenges. On a global scale, around 1.5 billion tons of cement are utilized annually, contributing to approximately one ton of CO2 emissions per ton of cement produced, accounting for 7% of global CO2 emissions (Mehta and Monteiro, 2014). In addition to the fundamental components of Portland cement, water, and aggregates, modern concrete formulations often incorporate

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supplementary ingredients. These may include:

- ✓ Chemical admixtures.
- ✓ Pozzolanic materials like fly ash, silica fumes, or blast furnace slag.
- ✓ Discontinuous fibers made of materials such as steel, glass, or natural, synthetic

The inclusion of these additional components aims to enhance specific properties of the concrete, such as workability, durability, and strength. By exploring alternative materials and techniques, the concrete industry strives to reduce the environmental impact associated with traditional concrete production while maintaining or improving the overall performance of the material.

2. METHODS TO IMPROVE DURABILITY

The American Concrete Institute, in ACI 116R, provides a definition of concrete durability as its capacity to withstand various forms of weathering, chemical deterioration, abrasion, and other service-related conditions. It also highlights that durability refers to concrete's inherent ability to maintain its original properties over a specific period.

- ➢ Chemical Approaches: One method involves the application of epoxy coating, which creates a barrier between steel reinforcement and water/oxygen, reducing corrosion. Additionally, the use of penetrating sealers such as siloxane can be beneficial, as they react with the siliceous components of cement and aggregates.
- ➢ Advancements in Self-Healing Bacterial Concrete (Biological Method): A groundbreaking technique for repairing damaged structural elements involves the utilization of selective bacterial plugging. This process harnesses the metabolic activities of bacteria to induce the precipitation of calcium carbonate, specifically calcite, effectively sealing cracks and fissures. This biomineralization approach offers a viable solution for remediation in construction materials.
- ➢ Physical Strategies: Physical methods include incorporating pozzolans like silica fume and fly ash into concrete mixes, which enhance impermeability and improve durability. Moreover, the inclusion of supplementary cementing materials can enhance sulfate resistance, further bolstering the chemical durability of concrete.

3. SUPPLEMENTARY CEMENTITIOUS MATERIALS

At its core, concrete consists of a simple mixture comprising portland cement, sand, coarse aggregate, and water. Portland cement serves as the primary cementitious material in concrete. In modern concrete formulations, supplementary cementitious materials are commonly incorporated, comprising a portion of the overall cementitious content. These materials are typically derived from byproducts of other processes or natural sources. They may undergo further processing before being utilized in concrete applications. Among these materials, certain ones are known as pozzolans. On their own, pozzolans lack inherent cementitious properties. However, when combined with portland cement, they undergo a reaction that results in the formation of cementitious compounds (ACI 116, 2000).

4. RICE HUSK ASH

Rice is a vital staple food for more than half of the world's population, making it the second most extensively cultivated crop after wheat in terms of cultivation area and production. According to the Food and Agriculture Organization of the United Nations (FAO), global rice production has experienced a consistent increase, growing from approximately 150 million tonnes of paddy rice in 1960 to surpassing 740 million tonnes in 2013. Table 1 presents a breakdown of paddy production across continents, with Asia being the dominant region, contributing to over 90% of the world's paddy production.

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Continents	Paddy Production(million tonnes)
Asia	671
North America	8.6
South America	24.5
Europe	3.89
Africa	28.7
Oceania	11.7

Table 1.1: Global rice paddy production in 2013 (F.A.O., 2013)

5. LITERATURE REVIEW

Several research studies have focused on the strength and durability characteristics of concrete incorporating bacterial rice husk ash. The following provides an overview of various studies conducted in these areas.

Ganesan et al (2008) The objective of the study was to determine the optimal replacement level of rice husk ash (RHA) in concrete to improve its permeability properties. Eight different concrete mixes were prepared, including a control mix, with varying proportions of RHA ranging from 5% to 35% by weight of cement. A water-to-binder ratio of 0.53 was maintained for all mixes. Cylindrical specimens measuring 100 mm in diameter and 50 mm in height were cast from each mix for chloride penetration tests. The tests were conducted at both 28 and 90 days of curing. The results indicate that the total coulombs charge passing through the RHA-blended concrete specimens consistently decreased as the RHA content increased up to 30%. However, at a 35% RHA content, there was a slight increase in the total charge passed value, although it still remained lower than that of the control concrete. This trend was observed for both the 28 and 90-day cured specimens. The inclusion of RHA as a partial replacement for ordinary Portland cement (OPC) led to a significant reduction in chloride permeability, particularly at the 30% RHA replacement level. In fact, the total charge passed for the 30% RHA blended concrete exhibited a substantial reduction of more than 70% compared to the control concrete, for both the 28 and 90-day cured samples.

Myunck et al. (2008). The researchers investigated the impact of bacterial carbonate precipitation on the durability of mortar specimens with varying levels of porosity. They observed that the deposition of calcium carbonate crystals on the surface of the specimens led to a significant reduction in water absorption, ranging from 65% to 90%, depending on the porosity of the samples. Additionally, the treated specimens exhibited improved resistance against freezing and thawing. The findings from the biodeposition treatment were comparable to those achieved through conventional surface treatments. Based on their observations, the researchers concluded that surface treatments play a crucial role in safeguarding construction materials against the penetration of water and other harmful substances. They also reported on the effects of bacterial calcite precipitation on various parameters influencing the durability of both concrete and mortar.

Givi et al (2010) The researchers examined the enhancement of concrete's compressive strength through the partial substitution of cement with rice husk ash derived from agro-waste. Two types of rice husk ash were utilized, one consisting of ultra-fine particles with an average particle size of 5 µm and the other with a particle size of 95 µm. Four different replacement levels of 5%, 10%, 15%, and 20% by weight were investigated. The findings revealed that the incorporation of rice husk ash in the range of 5% to 15% and 20% for the 95 µm and 5 µm ash respectively resulted in concrete with improved strength. Specifically, the compressive strength of the concrete increased when cement was partially replaced with the respective rice husk ash percentages. Overall, the study demonstrates the potential of using rice husk ash as a partial replacement for cement in concrete, leading to enhanced compressive strength.

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Habeeb and Mahmud (2010) The researchers conducted a study focusing on the compressive properties of concrete with varying levels of rice husk ash (RHA) replacement, ranging from 0% to 20% of the cement content. The results indicated that the inclusion of RHA led to a significant improvement in strength, particularly at a replacement level of 10%, where the strength increased by 30.8% compared to the control mix. Furthermore, the study found that up to 20% of the cement could be successfully replaced with RHA without negatively impacting the strength of the concrete. In terms of the RHA particle size, finer RHA concrete exhibited higher strength than concrete with coarser RHA at the age of 28 days. Comparing the percentage increments of RHA concretes to the control OPC mix, at a replacement level of 10%, the strength increments were found to be 22.2%, 26.7%, and 30.8% for 5%, 10%, and 15% RHA replacement, respectively. Overall, the findings suggest that incorporating RHA in concrete can significantly enhance its compressive strength, especially at optimal replacement levels, while maintaining comparable strength at early ages and demonstrating the superiority of finer RHA particles at later stages of curing.

Khassaf et al. (2014) The researchers investigated the impact of rice husk ash (RHA) on the slump of concrete, with a constant water-cement ratio of 0.58. The cement content was replaced with RHA at proportions of 10%, 20%, and 30% by mass. The results revealed that as the percentage of RHA replacement increased, the value of slump decreased. Specifically, the slump measurements were recorded as 70 mm, 55 mm, 45 mm, and 15 mm for 0%, 10%, 20%, and 30% replacement of cement by mass, respectively. In summary, the findings demonstrated that the presence of RHA in the concrete mixture led to a reduction in slump, indicating a decrease in the workability of the concrete with an increasing amount of RHA.

Sanusi et al. (2014) The researchers conducted an assessment of the water absorption properties of binary concrete containing 10% rice husk ash (RHA) after 28, 56, and 90 days of curing. The results showed that the binary concrete exhibited lower water absorption compared to the control concrete at all time intervals. Specifically, the water absorption percentages for the binary concrete were measured as 5.76%, 4.98%, and 4.2% at 28, 56, and 90 days respectively. In contrast, the control concrete displayed water absorption percentages of 5.96%, 5.26%, and 4.56% at the same respective time intervals. These findings indicate that the inclusion of RHA as a replacement material led to a reduction in the water absorption percentage of the concrete. The binary concrete consistently exhibited lower water absorption values compared to the control concrete, suggesting an improved resistance to water permeability.

Bang et al. (2014) The compressive properties of concrete were examined at two different time intervals, specifically 7 and 28 days. Among the various concentrations tested, the highest improvement was observed in the cubes treated with a concentration of 5x109 cells for a duration of 7 days. However, when the incubation period was extended to 28 days, the increase in compressive strength for all the treated cubes was found to be relatively small compared to the 7-day period.

Narde et al. (2018) In this research, attempts were made to examine the suitability of replacing cement with rice husk ash and fly ash, and natural sand with various percentages of quarry sand in M25 grade concrete. The characteristics evaluated included compressive strength, acid attack resistance over a period of 30 days, 60 days, 90 days, and 120 days, carbonation effects, and microstructural analysis through XRF Analysis. The controlled mix, which consisted of 100% natural sand and 100% cement, was compared with critical mixes that incorporated 22.5% fly ash, 7.5% rice husk ash, and 30% quarry sand as replacements for cement and natural sand, respectively. The durability of the mixes was examined. The inclusion of rice husk ash and fly ash in the concrete was found to enhance its resistance to sulfuric acid and hydrochloric acid attack. This improvement can be attributed to the reduced presence of calcium hydroxide, which is more susceptible to acid attack. The utilization of fly ash and rice husk ash as partial replacements for ordinary Portland cement was found to be more effective in reducing acid

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attack. Overall, the study demonstrated the potential benefits of incorporating rice husk ash, fly ash, and quarry sand in concrete, leading to improved durability and resistance to acid attacks.

Sam et al. (2020) This paper reviewed the existing research on the utilization of fly ash and rice husk ash as partial replacements for concrete, focusing on their chemical composition and their impact on the compressive strength of concrete. To analyze the chemical compounds present in fly ash and rice husk ash, various charts, tables, and figures were employed. The findings revealed that the percentage of minor compounds such as Sodium oxide (Na2O), Titanium oxide (TiO2), and Phosphorus pentoxide (P2O5) varied depending on the initial processing of coal or rice husk. In some cases, these compounds were found to be very low or not even detected in the final product. The data regarding the compressive strength of concrete with incremental additions of fly ash (0%, 10%, 20%, 30%, 40%, 50%) and rice husk ash (0%, 5%, 7.5%, 10%, 12.5%, 15%) were analyzed over a minimum duration of 7 days and a maximum duration of 28 days. The results indicated that the optimal percentage of partial replacement for achieving strong compressive strength in concrete was determined to be 30% for fly ash and 7.5% for rice husk ash. These percentages were found to yield the best combination of materials for enhancing the compressive strength of the concrete specimens. Overall, the study provided insights into the chemical composition of fly ash and rice husk ash and determined the optimal replacement percentages for achieving desirable compressive strength in concrete.

Adinna et al. (2020) In this study, rice husk was subjected to calcination within a temperature range of 500°C to 600°C. The resulting grey ash was finely ground to a powder that passed through a BS sieve with a size of 0.075mm. This rice husk ash was then incorporated into concrete mixes at different percentages relative to the cement content. Simultaneously, a proprietary admixture called Water Seal was used to prepare similar concrete cubes, with varying percentages of 0%, 2%, 4%, 7%, 10%, and 12%, serving as substitutes for rice husk ash. The control group contained zero percent admixture. During water absorption experiments, it was observed that the cumulative weights of water absorbed by the concrete cubes reached a constant value after 6 to 7 days of water immersion, regardless of whether they contained rice husk ash or the proprietary water repellent admixture. The amount of water absorbed decreased as the percentage of admixture increased for both types of additives. For instance, after 7 days of water immersion, concrete cubes containing 2% dosage of rice husk ash absorbed 0.19kg of water, while those containing Water Seal absorbed 0.25kg. In contrast, the control cubes absorbed 0.75kg of water. These findings indicate that the incorporation of rice husk ash or the proprietary Water Seal admixture in the concrete led to a reduction in water absorption compared to the control group. The percentage of water absorbed decreased with higher admixture content, suggesting the effectiveness of both additives in improving the water repellency of the concrete.

Bixapathiet al. (2021) In the previous study, rice husk ash was utilized as a substitute for Ordinary Portland Cement (OPC) in M20 grade concrete. Rice husk ash, an agricultural byproduct, was selected as a potential alternative material. Concrete specimens were cast to evaluate the workability, strength, and durability of the concrete. Various proportions of rice husk ash (0%, 5%, 10%, 15%, 20%, and 25%) were used to replace OPC, and the effects on workability, strength, and durability were investigated. The concrete specimens were subjected to curing periods of 7 days, 14 days, and 28 days, and their compressive, split tensile, and flexural strengths were measured. Based on the experimental results, it was observed that the highest values of compressive, split tensile, and flexural strengths were obtained when the concrete contained 15% rice husk ash. However, as the proportion of rice husk ash increased from 0% to 25%, the percentage loss of strength and weight also increased, indicating a potential decrease in the overall performance of the M20 grade concrete. Therefore, the study highlighted that while the inclusion of rice husk ash at a certain proportion (15%) could enhance the strength properties of the concrete, higher percentages of ash replacement (above 15%) may lead to a reduction in strength and weight-bearing capacity.

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Suja et al. (2022) Various supplementary materials, including silica fume, Ground Granulated Blast Furnace Slag (GGBS), fly ash, and rice husk ash, have been used as cement replacements in the past. Rice husk ash, a waste product obtained from the combustion of rice husks, has been utilized as an additive in various materials such as refractory bricks and lightweight concrete. The ash obtained from the burning process consists of approximately 90% silica and 5% alumina. It possesses desirable properties such as high porosity, lightweight nature, and a large specific surface area. With its composition of 90% amorphous silica and 5% alumina, rice husk ash exhibits highly pozzolanic characteristics. Its use in concrete contributes to improved durability while offering economic and environmentally friendly benefits. Additionally, the inclusion of fibers in concrete extends the duration before initial cracking occurs and reduces initial shrinkage. The objective of the project was to incorporate 0.75% steel fibers and 0.25% polypropylene fibers while replacing cement with rice husk ash at varying percentages up to 30% with increments of 5%. The aim was to investigate the effects of these additions on the properties of the concrete.

Manubothulaet al. (2022) In this study, a combination of cement, sand, lime, fly ash, rice husk ash, aluminum powder, water, and superplasticizer was used as materials for producing aerated blocks. Rice husk ash, which is an eco-friendly waste material from rice mills, was included as an additional ingredient in the mixture. Fly ash, another environmentally acceptable substance commonly used with cement, was also incorporated. The resulting lightweight concrete had a density of 1600 kg/m3. The influence of rice husk ash on concrete was examined through compressive testing. Cube specimens were subjected to compressive strength testing after a 28-day period of underwater curing. The proportions of aluminum powder were varied at 0.05%, 0.1%, and 0.15%, while the variations of rice husk ash (RHA) were set at 5% and 10%. The water-to-cement ratio remained constant at 0.5, as did the cement-to-sand ratio of 1:2. A total of eighteen blocks were cured underwater for 28 days. It was observed that the concrete block containing 5% rice husk ash and 0.05% aluminum powder exhibited higher strength compared to the other concrete blocks.

Ayyanaret al. (2023) The properties of concrete were investigated by partially replacing cement with rice husk ash and bagasse ash, at a rate of approximately 30%. Various tests were conducted to assess the compressive strength, split tensile strength, flexural strength, and durability properties, including resistance to acid attack and sulphate attack. Among the different percentages of cement replacement with rice husk ash and bagasse ash, the results of the strength tests indicated that the optimal proportion was approximately 70% cement, 20% rice husk ash, and 10% bagasse ash (Cement: RHA: BA). This composition, with a 30% replacement of cement, was found to produce high-performance concrete and contribute to sustainable construction. The cement content in the concrete was substituted with bagasse ash and rice husk ash at varying percentages of 5%, 10%, 15%, 20%, 25%, and 30%. The obtained optimum proportion was advantageous in improving the mechanical strength and durability properties of the concrete. To enhance the workability of the concrete with the replacement materials, Conplast 340 Superplasticizer was utilized in this project.

6. SUMMARY

This paper presents a comprehensive review of existing literature on the use of bacterial rice husk ash (RHA) in concrete to enhance its strength and durability properties. The aim of the study is to evaluate the effectiveness of incorporating bacterial RHA as a supplementary material in concrete production. The literature survey covers a wide range of research articles, conference papers, and technical reports related to the topic. It explores the various aspects of concrete performance, such as compressive strength, tensile strength, flexural strength, and durability properties like resistance to chloride penetration, carbonation, and sulfate attack. The findings from the literature indicate that the addition of bacterial RHA in concrete has a positive impact on its strength characteristics. It enhances the compressive, tensile, and flexural strengths of

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concrete, leading to improved structural performance. Moreover, the inclusion of bacterial RHA contributes to the durability of concrete by reducing chloride penetration, carbonation, and sulfate attack, thereby extending the service life of concrete structures. The review also highlights the mechanisms through which bacterial RHA interacts with cementitious materials, including its pozzolanic activity and chemical reactions that enhance the strength and durability properties of concrete. Overall, the literature survey provides valuable insights into the use of bacterial RHA as a supplementary material in concrete production, demonstrating its potential to enhance both the strength and durability characteristics of concrete. The findings presented in this paper serve as a basis for future research and development in the field of sustainable and durable concrete materials.

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