Sustainable Carbon-Absorbing Concrete: A Review of MgO and Rice Husk Ash with Emphasis on RCC Beam Behaviour

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***Abstract*—The growing demand for infrastructure, combined with increasing environmental concerns, has intensified the need for sustainable alternatives in the construction industry. Conventional concrete, while essential for modern development, is associated with high carbon dioxide (CO_2) emissions due to cement production. In this context, carbon-absorbing concrete has emerged as an innovative approach to mitigate environmental impact by incorporating materials capable of reducing and sequestering CO_2. This review paper explores the potential of Magnesium Oxide (MgO) and Rice Husk Ash (RHA) in developing such sustainable concrete systems.**

MgO contributes to carbon sequestration through its carbonation reaction, forming stable magnesium carbonates that enable long-term CO_2 storage within the concrete matrix. RHA, an agricultural waste product with high silica content, acts as a pozzolanic material that enhances the microstructure, reduces porosity, and lowers cement demand.

The study concludes that MgO–RHA blended concrete presents a promising pathway toward low-carbon and partially carbon-sequestering construction materials. Furthermore, it identifies key research gaps, including the need for long-term performance evaluation and standardized methodologies, and outlines future directions to advance the implementation of sustainable concrete technologies in structural engineering practice.

***Index Terms*—Carbon absorption concrete, Magnesium Oxide, Rice Husk Ash, nesquehonite, Carbonation, Sustainable concrete, CO_2 sequestration, RCC beam.**

I. INTRODUCTION

The construction industry is a major contributor to global carbon dioxide (CO_2) emissions, largely due to the extensive use of cement in concrete production. With the rapid growth of infrastructure and urbanization, reducing the environmental impact of concrete has become a critical priority. This has led to increased research on sustainable materials and technologies aimed at lowering the carbon footprint of construction without compromising structural performance.

Carbon-absorbing concrete has emerged as a promising solution in this regard, as it not only reduces emissions but also enables the sequestration of CO_2 within the concrete matrix. This approach represents a shift toward developing materials that actively contribute to environmental mitigation, supporting the transition to low-carbon and sustainable infrastructure.

Among the materials explored, Magnesium Oxide (MgO) and Rice Husk Ash (RHA) have gained significant attention due to their complementary roles. MgO facilitates CO_2 sequestration through carbonation, forming stable magnesium carbonates, while RHA, a silica-rich agricultural by-product, acts as a supplementary cementitious material that reduces cement usage and enhances microstructural properties through pozzolanic reactions. The combined use of MgO and RHA offers both environmental and performance advantages.

Reinforced concrete (RCC) beams provide a reliable basis for assessing performance, particularly in terms of load–deflection response, crack behaviour, stiffness, and load-carrying capacity. Understanding these aspects is crucial for the adoption of sustainable concrete in structural applications.

This paper presents a focused review of MgO–RHA based carbon-absorbing concrete, with emphasis on its mechanical properties, durability, and performance in RCC beams. The study synthesizes existing research to highlight current advancements, identify gaps, and outline future directions for the development of sustainable concrete technologies.

II. LITERATURE REVIEW

1) Zhang et al. (2024) investigated reactive Magnesium Oxide (MgO)-based concrete under carbonation curing and reported that strength development is primarily governed by CO_2 absorption rather than conventional hydration. The formation of stable magnesium carbonates significantly enhances matrix densification, reduces porosity, and improves durability. The study establishes MgO as a promising carbon-sequestering binder capable of contributing to sustainable concrete development.

2) Mo and Panesar (2017) examined the effect of carbonation on MgO concrete and observed a substantial increase in compressive strength due to CO_2 curing. Their findings indicated that carbonation accelerates strength gain and refines the microstructure, demonstrating that MgO-based systems can achieve performance comparable to conventional cement while offering environmental benefits.

3) Li et al. (2017) explored the hydration and carbonation mechanisms of MgO cementitious materials and reported that the formation of dense carbonate phases significantly enhances structural integrity. The combined effect of hydration and carbonation leads to reduced permeability and improved resistance to environmental degradation, thereby enhancing durability.

4) Unluer and Al-Tabbaa (2019) evaluated MgO composites in terms of strength development, carbonation potential, and corrosion resistance. The study showed that MgO-based concrete can sequester measurable amounts of CO_2 while maintaining mechanical properties similar to Ordinary Portland Cement (OPC). Additionally, improved resistance to reinforcement corrosion was observed due to reduced permeability, contributing to longer service life.

5) Ruan and Unluer (2021) provided a comprehensive analysis of carbonation curing in MgO systems, identifying key influencing parameters such as CO_2 concentration, curing duration, and environmental conditions. The study concluded that optimized carbonation curing significantly enhances both mechanical and durability properties, reinforcing the potential of MgO as a sustainable construction material.

6) Ganesan et al. (2008) investigated the use of Rice Husk Ash (RHA) as a supplementary cementitious material and reported significant improvements in compressive, tensile, and flexural strength. The high silica content of RHA contributes to strong pozzolanic activity, resulting in the formation of additional calcium silicate hydrate (C–S–H) and a refined microstructure.

7) Zain et al. (2011) evaluated the durability characteristics of RHA-blended concrete and found that the incorporation of RHA significantly reduces permeability and enhances resistance to carbonation and chloride ingress. This leads to improved long-term durability and structural performance while reducing cement consumption.

8) Shi et al. (2024) reviewed carbonation testing methods for concrete, emphasizing the importance of accelerated carbonation techniques in evaluating durability performance. The study also highlighted the relationship between carbonation depth and reinforcement corrosion, which is critical for assessing the long-term behaviour of reinforced concrete structures.

9) Kumar et al. (2023) examined the structural behaviour of sustainable concrete materials in reinforced concrete (RCC) beams and reported that alternative binders can achieve comparable load–deflection response, crack propagation

patterns, and ultimate load-carrying capacity. This confirms the feasibility of using low-carbon materials in structural applications.

10) Habert et al. (2020) analysed the environmental impact of cement production and highlighted that the cement industry is a major contributor to global CO_2 emissions due to calcination and fuel combustion processes. The study emphasized the urgent need for alternative binders such as MgO and supplementary materials like RHA to reduce the carbon footprint of concrete.

11) Lothenbach et al. (2011) investigated blended cement systems and reported that the incorporation of supplementary materials significantly improves durability and reduces environmental impact. The study provides a strong foundation for understanding the benefits of combining multiple sustainable materials in cementitious systems.

12) Recent studies (2022–2024) on MgO–pozzolan blended systems indicate that the integration of MgO with silica-rich materials enhances both carbonation efficiency and mechanical performance. The pozzolanic reaction improves matrix densification, while MgO contributes to CO_2 sequestration, demonstrating a synergistic effect that is highly beneficial for sustainable concrete development.

III. LITERATURE SUMMARY

From the literature review, it is understood that reducing CO_2 emissions in concrete can be effectively achieved by incorporating sustainable materials such as Magnesium Oxide (MgO) and Rice Husk Ash (RHA). MgO contributes to carbon absorption through carbonation, while RHA improves strength and durability due to its pozzolanic nature. These materials not only reduce cement consumption but also enhance the overall performance of concrete.

Based on these findings, the present study is focused on M30 grade concrete, where partial replacement of cement is carried out using MgO and RHA. To evaluate the practical structural behaviour, two reinforced concrete beams are considered one conventional beam and one replacement beam incorporating MgO and RHA.

The literature suggests that such sustainable replacements can maintain comparable structural performance in terms of load–deflection behaviour, crack development, and load-carrying capacity. Therefore, this study aims to further investigate the combined effect of MgO and RHA in RCC beams and assess their suitability as carbon-absorbing and structurally efficient concrete materials.

IV. CONCLUSION

As that through the literature study the designed to examine the behaviour of M30 grade concrete when partially replaced with Rice Husk Ash [RHA] derived by from Rice Husk waste and Industrial grade of Magnesium Oxide [MgO] is used as an additive for the carbon absorption in concrete.

Therefore, this study adopted a uniform 10% replacement level of Rice Husk Ash [RHA] for all modified mixes and percentage of Magnesium Oxide (MgO) is varied with different mix proportion. Four concrete mixes were prepared:

- M0 – Conventional Concrete
- M1 – 10% RHA+ 4% MgO

All mixes were designed as per IS 10262:2019. Dry mixing was carried out for cement, aggregates, and RHA and MgO for the respective percentage of replacement and additive percentage of materials for mix proportions before the addition of water to ensure the uniform mixture of all replacement and additives materials. The water–cement ratio of 0.45 was kept constant for all batches. Workability was measured using the slump cone test to investigate any reduction caused by the hydrophobic nature of rubber particles.

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