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Research Article

Performance of Rice Husk Ash and Recycled Coarse Aggregate in Sustainable Concrete: A Review

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Abstract

The increasing demand for construction materials has created a need for sustainable alternatives to conventional cement and natural aggregates. Rice husk ash (RHA) and recycled coarse aggregate (RCA) are two waste-derived materials with significant potential for sustainable concrete production. RHA is obtained from agricultural waste and can act as a supplementary cementitious material, while RCA is produced from construction and demolition waste and can partially replace natural coarse aggregate. This paper presents a concise review of the influence of RHA and RCA on the performance and sustainability of concrete. The reviewed literature indicates that RHA can contribute to strength development and pore refinement when appropriately processed, whereas RCA can reduce the consumption of natural aggregates and divert construction waste from disposal. However, excessive RCA may increase water absorption and reduce mechanical performance, while the properties of RHA are strongly influenced by its processing conditions. The combined use of RHA and RCA therefore requires careful mix design and material quality control. The study concludes that the appropriate combination of these materials can contribute to sustainable concrete and circular construction.

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1. INTRODUCTION

The construction sector consumes large quantities of cement and natural aggregates. Increasing environmental concerns related to cement production, natural-resource depletion and construction waste have encouraged the development of sustainable concrete materials.

Rice husk ash is an agricultural waste-derived material containing significant silica and has been investigated as a supplementary cementitious material. Previous reviews have reported its influence on workability, compressive strength, flexural strength, tensile strength and durability.

Recycled coarse aggregate is obtained mainly from construction and demolition waste. Its use provides an opportunity to reduce the demand for natural aggregates and promote recycling within the construction sector. However, recycled aggregates commonly contain adhered mortar and can exhibit higher porosity and water absorption than natural aggregates.

The combination of RHA and RCA is particularly interesting because the two materials address different waste-management problems. Recent literature reviewing their combined application has identified potential interaction between the pozzolanic action of RHA and the limitations associated with RCA, while also highlighting the need for further long-term and environmental studies.

The objective of this paper is therefore to provide a concise assessment of the potential, performance and limitations of RHA and RCA in sustainable concrete.

2. REVIEW METHODOLOGY

The present study follows a focused literature-review approach. Published research related to RHA, RCA and sustainable concrete was considered using keywords including:

- Rice Husk Ash Concrete
- Recycled Coarse Aggregate Concrete
- Sustainable Concrete
- Green Concrete
- Agricultural Waste Concrete
- Construction and Demolition Waste
- RHA and RCA Concrete

The selected literature was analysed under four major parameters:

1. Mechanical performance
2. Durability
3. Waste utilisation
4. Environmental sustainability

Recent reviews have examined RHA and RCA individually as well as their combined use in sustainable concrete.

3. RICE HUSK ASH IN CONCRETE

Rice husk is an agricultural residue generated during rice processing. Controlled burning and subsequent processing can produce rice husk ash containing silica suitable for cementitious applications.

The performance of RHA depends considerably on burning conditions, grinding, particle size and chemical characteristics. Properly processed RHA can participate in pozzolanic reactions and contribute to refinement of the cementitious matrix.

Previous research reviews indicate that RHA has potential to improve selected mechanical and durability properties while simultaneously reducing agricultural waste-disposal problems.

However, excessive RHA may adversely influence workability because of its fine particle size and high surface area.

Therefore, RHA replacement should be optimised according to the required concrete performance.

4. RECYCLED COARSE AGGREGATE IN CONCRETE

Recycled coarse aggregate is generally produced by crushing and processing waste concrete obtained from construction and demolition activities.

Its principal environmental advantage is the conservation of natural aggregate resources.

However, recycled aggregate differs from natural aggregate because particles may contain adhered old mortar. This can increase water absorption and porosity and can influence the interfacial transition zone in recycled aggregate concrete.

Research reviews have identified recycled aggregate quality, replacement level, water-binder ratio and treatment methods as important factors affecting concrete performance.

Consequently, RCA should be appropriately processed and characterised before incorporation into structural concrete.

5. COMBINED USE OF RHA AND RCA

The combined use of RHA and RCA provides an interesting approach to sustainable concrete.

RCA primarily replaces natural aggregate, whereas RHA can partially replace conventional cementitious material.

Thus, their combined use can address two resource issues simultaneously:

Agricultural Waste → RHA → Partial Cement Replacement

Construction Waste → RCA → Partial Aggregate Replacement

Recent review research has specifically examined this combination and reported that RHA may help compensate for some of the adverse effects associated with the porosity of RCA through its pozzolanic reaction and matrix refinement.

However, the combined system requires careful proportioning because excessive replacement of either component can adversely influence workability and strength.

6. COMPARATIVE ASSESSMENT

Table 1. Comparison of RHA and RCA

Parameter	Rice Husk Ash	Recycled Coarse Aggregate
Waste source	Agricultural waste	Construction & demolition waste
Main application	Partial cementitious replacement	Partial aggregate replacement
Major benefit	Waste utilisation and cement reduction	Natural aggregate conservation
Major challenge	Processing and workability	Water absorption and variability
Strength effect	Depends on replacement and processing	Depends strongly on aggregate quality
Durability	Potentially favourable after proper processing	Requires careful quality control
Sustainability potential	High	High

7. EFFECT ON CONCRETE PERFORMANCE

7.1 Compressive Strength

The effect of RHA and RCA on compressive strength depends on their replacement levels and material characteristics.

Properly processed RHA can contribute to strength through pozzolanic activity and matrix refinement.

In contrast, increasing RCA content may reduce strength in some mixtures because of weaker adhered mortar and the associated interfacial transition zone.

Therefore, optimum replacement rather than maximum replacement is recommended.

7.2 Workability

RHA generally has a high surface area and can increase water demand.

RCA can also influence workability because of its surface characteristics and relatively high water absorption.

Consequently, the combined use of RHA and RCA requires appropriate water management and mix optimisation.

7.3 Durability

Durability is an important consideration for sustainable concrete.

RHA can contribute to pore refinement under suitable conditions, whereas RCA may increase permeability when the recycled aggregate contains substantial adhered mortar.

Recent reviews have highlighted water absorption, permeability, chloride penetration, sulphate attack and other durability indicators as important parameters in recycled aggregate concrete.

8. ENVIRONMENTAL BENEFITS

The combined use of RHA and RCA can provide several environmental benefits:

1. Utilisation of agricultural waste.
2. Recycling of construction and demolition waste.
3. Reduction in natural aggregate consumption.
4. Reduction in conventional cement requirement.
5. Reduction in waste-disposal requirements.
6. Promotion of circular construction practices.
7. Conservation of natural resources.

The environmental benefit, however, should be evaluated considering transportation, processing energy and the complete life cycle of the materials. Research examining environmental and economic aspects has found that the sustainability benefits of alternative materials depend on their production and processing conditions.

9. RESEARCH GAP

The major research gaps identified from the review are:

- limited standardisation of RHA processing;
- variability in recycled aggregate quality;
- limited long-term studies on combined RHA-RCA concrete;
- limited field-scale applications;
- insufficient life-cycle assessment of combined systems; and
- need for optimum mix-design strategies.

Recent literature specifically identifies long-term stability, standardised processing and environmental assessment as important areas for further investigation of RHA-RCA concrete.

10. CONCLUSION

Rice husk ash and recycled coarse aggregate have considerable potential for sustainable concrete production.

RHA provides an effective route for utilising agricultural waste and reducing dependence on conventional cementitious materials. RCA provides an opportunity to recycle construction and demolition waste and conserve natural aggregate resources.

The combined use of RHA and RCA is particularly attractive because it addresses both cementitious-material and aggregate-related resource requirements.

However, the successful application of these materials depends on appropriate processing, material characterisation, replacement level, curing and mix design.

The review concludes that **RHA and RCA can contribute significantly to sustainable concrete when their individual limitations are controlled through appropriate material selection and mixture optimisation**.

Further research should focus on long-term durability, standardised material processing, life-cycle assessment and field-scale validation.

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Akshay Mishra and Alok Pandey are affiliated with the Department of Civil Engineering, Nirwan University, Jaipur, Rajasthan, India. Their academic interests include civil engineering, sustainable construction materials, recycled aggregates, and the application of waste-derived materials in concrete for environmentally sustainable infrastructure development.