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Development and Performance Evaluation of Sustainable Concrete Specimens Using Coconut Shell Charcoal Powder and Rice Husk Ash

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ABSTRACT:

This study explores the development of sustainable concrete blocks incorporating coconut shell charcoal powder (CSCP) and rice husk ash (RHA) as partial replacements for cement and fine aggregates. The research aims to enhance the environmental sustainability of concrete while ensuring its suitability for non-structural applications. CSCP improves thermal insulation and reduces density, while RHA, with its pozzolanic properties, contributes to strength and durability. Experimental investigations, including compressive strength and water absorption tests, reveal that the optimized mix provides satisfactory performance for non-load-bearing applications such as partition walls, pavements, and other secondary construction elements. While these blocks may not be suitable for structural applications, they offer a cost-effective and eco-friendly alternative to conventional concrete, reducing cement consumption and promoting waste utilization. This research contributes to the advancement of sustainable building materials and supports environmentally responsible construction practices.

Keywords: Sustainable concrete, coconut shell charcoal powder (CSCP), rice husk ash (RHA), non-structural applications, eco-friendly construction, thermal insulation, pozzolanic materials, waste utilization, compressive strength, sustainable building materials.

1.Intoduction:

The increasing demand for sustainable construction materials has driven research into the use of agricultural and industrial waste in concrete production. Conventional concrete relies heavily on cement and natural aggregates, contributing to high carbon emissions and resource depletion. To mitigate these environmental concerns, alternative materials such as coconut shell charcoal powder (CSCP) and rice husk ash (RHA) have been explored for their potential in reducing cement dependency while enhancing specific properties of concrete.

CSCP, a by-product of coconut shell pyrolysis, is known for its lightweight nature and thermal insulation properties, making it a potential substitute for fine aggregates. Meanwhile, RHA, a pozzolanic material rich in silica, improves strength and durability through secondary hydration reactions. While previous studies have focused on the use of these materials in conventional concrete applications, limited research has examined their combined effects on concrete performance.This study aims to evaluate the feasibility of using CSCP and RHA in concrete specimens by analyzing their compressive strength, water absorption, and density characteristics. The findings will help determine their suitability for non-structural applications such as partition walls, paving, and lightweight concrete elements, ultimately contributing to the development of more sustainable and eco-friendly building materials.

2. Literature Review

The use of alternative materials in concrete has gained significant attention due to increasing environmental concerns and the need for sustainable construction practices. Several studies have explored the incorporation of agricultural and industrial waste in concrete to enhance its properties while reducing dependency on conventional materials. This section reviews relevant research on the use of coconut shell charcoal powder (CSCP) and rice husk ash (RHA) in concrete.

2.1 Coconut Shell Charcoal Powder (CSCP) in Concrete

CSCP, derived from coconut shells, is a lightweight material that improves thermal insulation and reduces concrete density. Studies indicate that CSCP can partially replace fine aggregates, but excessive replacement may lead to reduced compressive strength due to increased porosity.

2.2 Rice Husk Ash (RHA) in Concrete

RHA, a pozzolanic material rich in silica, enhances compressive strength and durability when used as a partial cement replacement. It improves water resistance but may increase water demand**,** affecting workability.

2.3 Combined Effect of CSCP and RHA

Research suggests that using CSCP as a fine aggregate replacement and RHA as a cement substitute can create a balance between lightweight properties and strength improvement. However, an optimal mix proportion is necessary to maximize benefits.

2.4 Suitability for Non-Structural Applications

CSCP and RHA concrete is best suited for non-load-bearing applications such as partition walls and paving blocks. Studies confirm that these materials reduce construction costs and environmental impact while maintaining acceptable performance.

This study builds on existing research by evaluating the **mechanical and durability properties** of concrete specimens incorporating CSCP and RHA, contributing to **sustainable building materials**.

3. Materials And Methodology

This section describes the materials used, mix proportions, specimen preparation, and testing methods to evaluate the performance of **coconut shell charcoal powder (CSCP) and rice husk ash (RHA) in concrete specimens using Portland Pozzolana Cement (PPC).**

3.1 Materials Used

- **Portland Pozzolana Cement (PPC):** Used as the primary binder due to its improved durability, reduced carbon footprint, and better long-term strength development.
- **Fine Aggregates:** Natural river sand was used as the primary fine aggregate.
- **Coconut Shell Charcoal Powder (CSCP):** A lightweight material obtained from processed coconut shells, used as a partial replacement for fine aggregates.
- **Rice Husk Ash (RHA):** A pozzolanic material rich in silica, used as a partial replacement for cement to enhance durability.
- **Water:** Clean potable water was used for mixing and curing.

3.2 Mix Proportions

Concrete mixes were designed by replacing:

- CSCP at 5%, 10%, and 15% of PPC
- RHA at 5%, 10%, and 15% of PPC.

Mix ID	Cement (kg/cube)	RHA (kg/cube)	CSCP (kg/cube)	Fine Aggregate (kg/cube)	Course Aggregate (kg/cube)	Water (kg/cube)
M1 (5% RHA + 5% CSCP)	1.22	0.07	0.07	2.09	4.05	0.61
M2 (10% RHA + 10% CSCP)	1.15	0.12	0.12	2.09	4.05	0.61
M3 (15% RHA + 15% CSCP)	1.08	0.17	0.17	2.09	4.05	0.61

3.3 Casting and Curing of Specimens

- Concrete cubes (150mm × 150mm × 150mm) were cast for testing.
- The specimens were cured in water for 7, 14, and 28 days before testing.

3.4 Testing Methods

The following tests were conducted to evaluate the mechanical and durability performance of the concrete:

- Compressive Strength Test**:** To determine the load-bearing capacity of the specimens.
- Water Absorption Test: To assess permeability and durability.

4. Results and Discussion

This section presents the experimental findings for **water absorption and compressive strength** of cube specimens incorporating **Rice Husk Ash (RHA) and Coconut Shell Charcoal Powder (CSCP) as partial cement replacements** in M20-grade concrete.

4.1 Water Absorption Test

Water absorption was measured after 24 hours of immersion. The results indicate an increasing trend with higher RHA and CSCP replacement due to their porous nature.

Mix ID	Water Absorption in %
M1 (5% RHA + 5% CSCP)	3.7%
M2 (10% RHA + 10% CSCP)	4.4%
M3 (15% RHA + 15% CSCP)	5%

Observation:

- **Increased porosity** due to RHA and CSCP results in higher water absorption.
- **M1 (5% RHA + 5% CSCP)** shows the lowest water absorption, making it the most durable mix.
- **M2 (10% RHA + 10% CSCP)** has moderate absorption but remains within acceptable limits.
- **M3 (15% RHA + 15% CSCP)** has the highest absorption, which may affect long-term durability.

4.2 Compressive Strength Test

Cube specimens (150mm × 150mm × 150mm) were tested using a Compression Testing Machine (CTM) at 7, 14, and 28 days. The results indicate a decrease in strength with increased RHA and CSCP replacement, and none of the mixes achieved the target strength for M20 concrete.

Mix ID	7 Days	14 Days	28 Days	Suitability
M1 (5% RHA + 5% CSCP)	13	16	18	Non-structural works
M2 (10% RHA + 10% CSCP)	10	13	17	Non-structural works
M3 (15% RHA + 15% CSCP)	8	11	14	Non-structural works

Observation:

As per (IS 456:2000) Minimum 28-Day Strength (MPa)

8 - 12 MPa can be used for Non-structural, flooring, PCC,

16 - 18 MPa can be used for General structural work

21+ MPa can be used for Heavy structural applications

- M1 (5% RHA + 5% CSCP) achieves 18 MPa at 28 days, which is slightly lower than 20 Mpa but still **structurally usable**.
- M2 (10% RHA + 10% CSCP) shows a moderate reduction 16 MPa at 28 days, making it suitable for **medium-strength or non structural applications.**
- M3 (15% RHA + 15% CSCP) has the lowest strength 14 MPa at 28 days, indicating a significant reduction, making it best for **non-structural applications.**

5.Conclusion

This study assessed the feasibility of using Rice Husk Ash (RHA) and Coconut Shell Charcoal Powder (CSCP) as partial cement replacements in M20 concrete. The experimental results indicate:

- Strength Reduction: Partial replacement of cement led to 6-30% strength reduction, making the mixes unsuitable for structural applications.

- Non-Structural Suitability: The developed mixes are suitable for non-load-bearing applications such as pavements, flooring, and partition walls.
- Water Absorption: Increased replacement levels resulted in higher water absorption, affecting durability.
- Sustainability: Utilizing RHA and CSCP promotes eco-friendly construction by reducing cement usage and carbon footprint.
- Future research should focus on optimizing mix design and enhancing durability properties for wider applications.