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RESEARCH ARTICLE OPEN ACCESS

Partial Replacement of Cement with Eggshell Powder in Concrete

Haider Hateem Noorani[1], Farzan Majid Lone[2], Muzamil Hussain[3], Suhail Mushtaq Itoo[4], Lone Omar Hassan[5], Dr. Ghulam Mohi ud din R.[6]

[1,2,3,4,5] B. TECH Student Sem 8th, Civil Engineering, SSM College Of Engineering, Pattan Baramulla, J&K, India 193121
[6] Associate Professor, Civil Engineering, SSM College Of Engineering, Pattan Baramulla, J&K-India 193121

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Abstract:

This research paper investigates the feasibility of using eggshell powder as a partial replacement for cement in concrete. The study aims to explore the mechanical properties of concrete when eggshell powder is incorporated, thereby promoting sustainable construction practices by utilizing waste materials. The experimental results indicate that the inclusion of eggshell powder can enhance certain properties of concrete while reducing the environmental impact associated with cement production.

Keywords — **Eggshell powder, Cement, Compressive Strength, Sample Weight.**

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I. INTRODUCTION

Concrete is one of the most widely used construction materials globally, known for its strength, durability, and versatility. It is primarily composed of cement, water, aggregates (fine and coarse), and various additives. The production of Ordinary Portland Cement (OPC), a key ingredient in concrete, is associated with significant environmental concerns, including high carbon dioxide emissions and the depletion of natural resources. As the demand for sustainable construction practices increases, researchers and engineers are exploring alternative materials that can reduce the environmental impact of concrete production.

One such alternative is eggshell powder, which is derived from the waste generated in the poultry industry. Eggshells are primarily composed of calcium carbonate (approximately 95%), along with small amounts of other minerals. The disposal of eggshells poses a challenge, as they contribute to landfill waste. However, when processed into a fine powder, eggshells can serve as a valuable additive in concrete mixtures. The incorporation of eggshell powder not only promotes waste recycling but also enhances the properties of concrete.

This study focuses on the partial replacement of cement with eggshell powder in M20 grade concrete. The primary aim is to investigate the effects of varying percentages of eggshell powder on the mechanical properties of concrete, including density, workability, compressive strength, and water absorption. By utilizing eggshell powder as a sustainable alternative to traditional cement, this research seeks to contribute to the development of eco-friendly

construction materials while addressing the challenges associated with cement production. The findings of this study may provide insights into the feasibility of incorporating eggshell powder in concrete, ultimately promoting sustainable construction practices and reducing environmental impact.

Advantages of Eggshell Powder in Concrete:

- Sustainable Material
- High Calcium Content
- Improved Compressive Strength
- Economic Benefits
- Reduction in Carbon Footprint

Disadvantages of Eggshell Powder in Concrete:

- Decreased Strength Beyond Optimal Levels
- Processing Requirements
- Potential for Organic Contaminants
- Limited Research on Long-Term Performance

II. OBJECTIVES

- To investigate the feasibility of using eggshell powder as a partial replacement for cement in concrete mixtures.
- To determine the optimal percentage of eggshell powder that enhances the mechanical properties of concrete, specifically compressive strength and workability.
- To evaluate the effects of eggshell powder on the density and water absorption characteristics of concrete.
- To conduct a comparative analysis of the performance of conventional concrete versus concrete with varying percentages of eggshell powder.
- To provide recommendations for the practical application of eggshell powder in the construction industry based on experimental findings.

III. SCOPE

- Investigate the properties and characteristics of eggshell powder as a sustainable alternative to cement in concrete production.
- Conduct a series of laboratory tests to evaluate the mechanical properties of concrete, including compressive strength, flexural strength, and workability, with varying percentages of eggshell powder.
- Formulate and optimize concrete mix designs that incorporate eggshell powder, ensuring proper proportioning and consistency.
- Compare the performance of conventional concrete with that of concrete containing eggshell powder to identify improvements or limitations.
- Explore the feasibility of integrating eggshell powder into existing concrete production processes and its implications for the construction industry.

IV. MATERIALS & TESTS

- Cement:
  - o Type: Ordinary Portland Cement (OPC)
  - o Test: Fineness, Consistency, Setting Time, and Compressive Strength as per IS 12269:2013
  - o Setting time was found to be:

  Initial: 28 Minutes

  Final: 8 Hours
- Fine Aggregates:
  - o Type: Sand
  - o Test: Sieve Analysis, Specific Gravity, Water Absorption, and Fineness Modulus as per IS 383:2016

  Fine Aggregate Zone: Zone 2
- Coarse Aggregates:
  - o Type: Gravel or Crushed Stone

o Test: Sieve Analysis, Specific Gravity, Water Absorption, and Aggregate Impact Value as per IS 383:2016

Aggregates used are of the range 10mm – 20mm

- Eggshell Powder:

o Type: Processed waste material

o Test: Particle Size Distribution, Chemical Composition, and Compressive Strength of concrete with varying percentages as per IS 456:2000

- Water:

o Type: Clean and potable water

o Test: Potability and pH level as per IS 456:2000

- Mixing and Casting Equipment:

o Equipment: Concrete mixer, cube moulds, and curing tanks

o Test: Ensure compliance with mixing standards and curing practices as per IS 456:2000

V. EXPERIMENTAL WORK

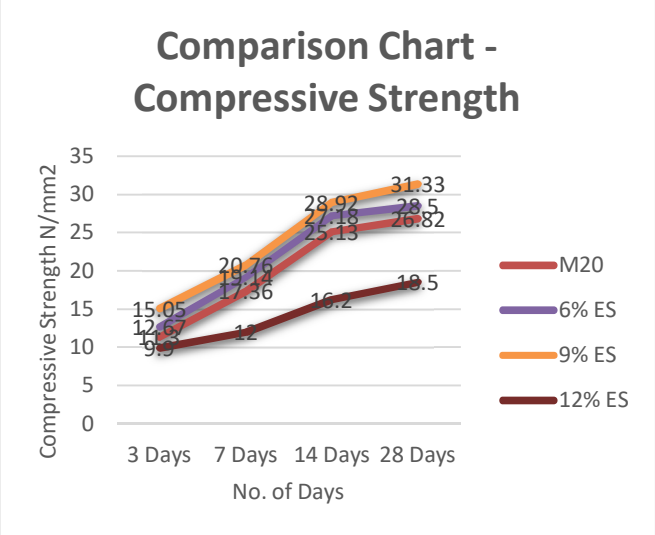
- **Material Preparation:**
  - Collected and processed eggshells by cleaning, drying, and grinding into a fine powder.
- **Mix Design:**
  - M20 concrete used.
  - Developed concrete mix designs with varying percentages of eggshell powder (0%, 6%, 9% and 12%) as a partial replacement for cement.
- **Batching:**
  - Accurately measured and batched all materials (cement, aggregates, eggshell powder, and water) according to the designed mix proportions.
- **Mixing:**
  - Mixed the materials in a concrete mixer to achieve a uniform consistency, ensuring thorough incorporation of eggshell powder.
- **Casting:**
  - Cast concrete samples in 150mm cube moulds, filling in three layers and compacting each layer with a tamping rod.
- **Curing:**
  - Cured the concrete cubes in clean water for 3, 7, 14 and 28 days to ensure proper hydration and strength development.
- **Testing:**
  - Conducted compressive strength tests on the cured cubes at 3, 7, 14 and 28 days using a compression testing machine.
  - Performed workability tests using the Slump Test to assess the consistency of the concrete mixes.
- **Data Analysis:**
  - Analysed the test results to evaluate the effects of eggshell powder on the mechanical properties of concrete, including compressive strength and workability.

VI. RESULTS & DISCUSSION:

Comparison between compressive strength of M20 and different percentages of Eggshell:

Grade / Days	Compressive Strength (N/mm²)			
	M20	6% ES	9% ES	12% ES
3 Days	11.3	12.67	15.05	9.9

7 Days	17.36	19.14	20.76	12
14 Days	25.13	27.18	28.92	16.2
28 Days	26.82	28.5	31.33	18.5



❖ The chart shows that the compressive strength of concrete increases with the increase in the eggshell powder quantity but up to 9% only. The ESP quantity above this results in massive decrease in the compressive strength.

VII. CONCLUSION:

- The research successfully demonstrated the feasibility of using eggshell powder as a partial replacement for cement in concrete, contributing to sustainable construction practices.

- Incorporating up to 5% eggshell powder in concrete mixes resulted in enhanced compressive strength, comparable to that of conventional concrete without any replacement.

- The study highlighted the importance of optimizing the percentage of eggshell powder, as higher replacement levels led to a decline in compressive strength due to dilution of cement content and potential bonding issues.

- Workability tests indicated that the addition of eggshell powder affected the consistency of the concrete, necessitating careful adjustments in the water-cement ratio to maintain desired workability.

- The use of eggshell powder not only promotes waste recycling by repurposing a common agricultural by-product but also reduces the carbon footprint associated with cement production.

- The findings underscore the potential of eggshell powder as an eco-friendly alternative in concrete production, encouraging further exploration of industrial by-products in construction materials.

- Future research should focus on the long-term durability and performance of concrete containing eggshell powder, as well as its application in various environmental conditions.

- Overall, this study provides a foundation for advancing sustainable construction technologies and practices, aligning with the growing demand for environmentally responsible building materials.

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- **IS 1489 (Part 1): 1991** – "Portland Pozzolana Cement": This standard defines the requirements for Portland Pozzolana Cement (PPC), which is a type of cement incorporating supplementary materials. Eggshell powder, with its pozzolanic properties, can be used in a similar manner as fly ash or other pozzolanic materials.
- **IS 383:2016** – "Specification for Coarse and Fine Aggregates from Natural Sources for Concrete": Though primarily about aggregates, this standard can also inform your mix design when using eggshell powder as part of the binder.
- **IS 10262:2019** – "Concrete Mix Proportioning Guidelines": This document provides detailed guidance on mix design, which is essential when substituting materials like cement with eggshell powder.
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