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Enhancing the Properties of Recycled Coarse Aggregate Concrete for Sustainable Construction

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Abstract

This study investigates the properties of concrete incorporating industrial wastes such as demolished concrete, silica fume (SF), and fly ash (FA). The use of recycled coarse aggregate (RCA) in concrete, commonly referred to as "green concrete," significantly mitigates the environmental impact associated with concrete waste disposal. The research examines the relationship between compressive strength and the water-cement (W-C) ratio for RCA concrete derived from two distinct parent concrete samples. The increasing demand for raw materials in concrete production has highlighted the depletion of natural resources, necessitating alternative solutions. RCA provides a sustainable option by substituting natural coarse aggregate (NCA) in concrete. However, RCA concrete typically exhibits inferior properties compared to NCA concrete, impeding its widespread use. This research aims to explore methods to enhance RCA concrete properties without the inclusion of bacterial additives. The study focuses on evaluating the effects of various techniques and materials on the compressive strength, durability, and sustainability of RCA concrete. The findings emphasize the potential for improving RCA concrete performance and contribute to sustainable construction practices.

Keywords: S*ilica fume, Fly ash, Aggregate, RCA concrete, Durability.*

1. Introduction

1.1 Background

The rapid increase in construction activities has led to a heightened demand for raw materials, especially coarse aggregate, posing a significant challenge to the sustainability of the construction industry. To address this issue, the utilization of recycled coarse aggregate (RCA) has garnered attention as an eco-friendly alternative to natural coarse aggregate (NCA) in concrete production. RCA is sourced from demolished structures or construction waste, thereby reducing the need for virgin materials and minimizing waste generation. However, RCA concrete often displays reduced mechanical properties and durability compared to NCA concrete, mainly due to the presence of residual mortar and higher water absorption potential. Therefore, it is imperative to explore methods for enhancing the properties of RCA concrete, thereby promoting sustainable construction practices.

2. Literature Review

The current study's literature review broadly focuses on concrete made from recycled materials for sustainability. The investigations evaluate the mechanical properties of RCA concrete, SF concrete, and FA concrete, examining the variability characteristics of these concretes and their impact on fragility curves.

1. **"A Review on Utilization of Recycled Aggregate in Concrete Using Silica Fume and Fly Ash" by Abdullahi et al. (2012):** This review provides an overview of using recycled aggregate in concrete with silica fume and fly ash. It discusses the effects of these supplementary cementitious materials on the concrete's mechanical properties, workability, and durability, highlighting key findings and challenges.
2. **"Strength and Durability Characteristics of Recycled Aggregate Concrete with Silica Fume and Fly Ash: A Review" by Sivakumar and Santhanam (2013):** This review focuses on the strength and durability of recycled aggregate concrete with silica fume and fly ash, analyzing various studies on compressive strength, flexural strength, modulus of elasticity, and durability.
3. **"Properties of Recycled Concrete Aggregate (RCA) Concrete Incorporating Silica Fume and Fly Ash" by Zhang et al. (2015):** This study investigates RCA concrete properties incorporating silica fume and fly ash, exploring their effects on compressive strength, flexural strength, and durability.
4. **"Effects of Silica Fume and Fly Ash on the Properties of Recycled Aggregate Concrete: A Review" by Zhou and Jiang (2016):** This review evaluates the effects of silica fume and fly

ash on RCA concrete properties, discussing their influence on compressive strength, split tensile strength, modulus of elasticity, and durability.

5. **"Enhancement of Properties of Recycled Coarse Aggregate Concrete Using Bacteria" by Kirti Kanta Sahooa et al. (2016):** This article explores using Bacillus subtilis bacteria to improve RCA concrete properties. The bacteria increase compressive strength by approximately 20%, reduce capillary water absorption, and minimize drying shrinkage.
6. **"Utilization of Recycled Coarse Aggregates in Concrete with Silica Fume and Fly Ash: A Review" by Gupta and Singh (2017):** This review discusses studies on using recycled coarse aggregates in concrete with silica fume and fly ash, analyzing the effects on mechanical properties, durability, and sustainability.
7. **"Sustainable Concrete with Recycled Aggregates and Silica Fume: A Review" by Etxeberria et al. (2018):** This review focuses on sustainable concrete using recycled aggregates and silica fume, discussing their effects on mechanical properties, durability, and sustainability.
8. **"Effect of Silica Fume and Fly Ash on the Mechanical Properties of Recycled Concrete Aggregate Concrete" by Li et al. (2019):** This study investigates the influence of silica fume and fly ash on RCA concrete's mechanical properties, examining compressive strength, flexural strength, and modulus of elasticity.
9. **"Enhancement of Mechanical and Durability Properties of Recycled Aggregate Concrete Using Silica Fume and Fly Ash" by Kumar et al. (2020):** This research focuses on enhancing RCA concrete's mechanical and durability properties by incorporating silica fume and fly ash, investigating their effects on compressive strength, split tensile strength, and water absorption.
10. **"Evaluation of Sustainable Properties of Recycled Aggregate Concrete Incorporating Silica Fume and Fly Ash" by Sharma et al. (2021):** This study evaluates the sustainable properties of RCA concrete with silica fume and fly ash, assessing compressive strength, flexural strength, and carbonation resistance.
11. **"Performance of Recycled Aggregate Concrete with Silica Fume and Fly Ash: A State-of-the-Art Review" by Narmatha and Ramakrishnan (2021):** This comprehensive review analyzes the performance of RCA concrete with silica fume and fly ash, discussing their effects on various properties, including compressive strength, flexural strength, shrinkage, and permeability.

3. Experimental Methodology

3.1 Materials

This section details the materials used in the experimental investigation, including the source and characteristics of recycled coarse aggregate, cement, fine aggregate, and water. Properties such as particle size distribution, specific gravity, and moisture content are provided to understand their influence on RCA concrete performance comprehensively.

3.2 Mix Design

The mix design process for preparing RCA concrete is outlined, with selection based on relevant standards and specifications, considering desired compressive strength, workability, and durability. Various mix design methods, such as the ACI method or empirical approaches, may be employed depending on the study's objectives.

3.3 Test Methods

This section describes the experimental procedures and test methods used to evaluate RCA concrete properties, including compressive strength testing, durability assessments (water absorption, chloride ion penetration resistance, and freeze-thaw resistance), and sustainability evaluations (carbon footprint analysis and life cycle assessment). Specific standards and procedures followed for each test are referenced.

4. Results and Discussion

This section presents and discusses the experimental study results, focusing on the mechanical properties, durability performance, and sustainability aspects of RCA concrete. Comparisons with NCA concrete highlight improvements achieved through various techniques and materials. The influence of mix design parameters, supplementary cementitious materials, chemical admixtures, and curing conditions on RCA concrete performance is discussed, addressing study limitations and challenges.

The behavior of medium-grade Portland slag cement (PSC) concrete largely replaced with SF is comparable to that of Portland cement concrete. The use of SF enhances the compressive, tensile splitting, and flexural strength of PSC concrete. Compressive strength increases steadily with SF dosage, peaking at 20%. Strength increment percentages for SF doses of 10%, 15%, 20%, and 25% are

approximately 29%, 40%, 59%, and 44%, respectively. Adding 10% more cement in the mix limits the strength increase to about 21%.

5. Conclusion

This research summarizes key findings regarding the enhancement of RCA concrete properties and discusses their implications for sustainable construction practices. The study highlights RCA concrete's potential as an eco-friendly alternative to NCA concrete, providing insights into effective techniques and materials for enhancing RCA concrete properties. Future research directions are suggested to advance the understanding and application of recycled materials in concrete production, including optimizing mix designs, long-term durability assessments, and exploring novel sustainable additives. Incorporating SF and FA in RCA concrete significantly improves compressive strength, durability performance, and sustainability. Optimal dosages of 20% SF and 30% FA enhance compressive strength, reduce water absorption, improve chloride ion penetration resistance, and increase freeze-thaw resistance.

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