**ANALYTICAL STUDY ON STRENGTH IN COMPRESSION OF GREEN MATERIAL USING GEOPOLYMER CONCRETES**

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**ABSTRACT**

The recycling of old, wrecked concretes into aggregate presents a sustainable solution for reducing construction waste and minimizing environmental impact. This study focuses on the production and properties of recycled concrete aggregate (RCAS) concretes. The influence of the duration and number of reprocessing cycles on the mechanical properties of RCAS concretes is investigated. Additionally, the integration of microorganisms into RCAS concretes is explored as a means to enhance their characteristics. Experimental research is conducted to evaluate the behavior of RCAS concretes, considering the source and age of the parent concretes. The materials used and mixture proportions are described, along with the basic experimental design and test setup. Fine aggregate is obtained from a nearby river, while two types of damaged parent concretes with compressive strength of 20 MPa are crushed to obtain RCAS. The influence of recycling cycles is examined by crushing and reusing RCAS from the first cycle. Overall, this study emphasizes the potential of using RCAS in concrete production to promote sustainable practices and reduce waste. The findings contribute to a better understanding of the behavior and properties of RCAS concretes, paving the way for their practical application in the construction industry.

**Keywords:** RCAS concretes, recycling, sustainable construction, mechanical properties, microorganism integration

1. **INTRODUCTION**

The construction industry plays a significant role in global environmental impact due to its high energy consumption, resource depletion, and waste generation. In recent years, there has been a growing awareness of the need for environmentally friendly practices in the construction sector. One area of concern is the excessive use of Portland cement, which contributes to CO2 emissions and environmental degradation.

In India, the construction industry has witnessed rapid growth over the past two decades, leading to increased demand for construction materials, particularly concrete. However, traditional concrete production methods using Portland cement have significant environmental drawbacks. To address these issues, alternative approaches such as incorporating supplementary cementitious materials (SCMs) like fly ash (FA) and silica fume (SF) as substitutes for Portland cement have been proposed to reduce the overall CO2 footprint of concrete.

Another pressing concern in the construction sector is the escalating construction waste, including the demolition of existing structures. In India alone, the building industry is responsible for approximately 25% of the 50 million tonnes of waste generated annually, according to estimates by the Central Pollution Control Board (CPCB). Similar situations exist worldwide. Recycling concrete waste as aggregates has emerged as an effective and practical solution to mitigate construction waste and conserve natural resources.

Utilizing recycled concrete aggregate (RCAS) in the production of concrete offers a holistic approach that contributes to environmental balance. However, incorporating these waste materials, including crushed concrete, SF, and FA, into concrete production presents technical challenges. The properties of concrete made from such industrial wastes require thorough investigation.

This study aims to explore the qualities and behavior of concrete made from manufacturing wastes such as crushed concrete, SF, and FA. Specifically, the focus will be on RCAS concretes, which involve partially or completely substituting natural coarse aggregate with reused coarse aggregate. Previous research has indicated that RCAS concretes exhibit lower mechanical strength compared to standard concretes containing natural coarse aggregate. The physical qualities of RCAS concretes are determined by the amount and quality of the adhering mortar, which, in turn, depends on the crushing process of the parent concrete.

The water-to-cement (w/c) ratio is a critical parameter in the early estimation of the fluid and other component elements for concrete mixture proportioning. The relationship between w/c ratio and compression strength is well-established for conventional concretes with natural coarse aggregate. However, the relationship may vary for RCAS concretes depending on their stage and degree of reconditioning. Extensive research has been conducted on the characteristics, behavior, and applications of RCAS, but there is a gap in knowledge regarding their behavior in overhead areas.

As the use of RCAS in construction continues to increase, strategies to enhance the quality of RCAS concretes become imperative. One potential approach involves the integration of urease-producing microorganisms, which can alleviate the challenges associated with RCAS concretes. These microorganisms catalyze the hydrolysis of urea into carbonate and ammonium, facilitating the precipitation of calcium carbonate (CaCO3). This process not only improves the mechanical properties of RCAS concretes but also contributes to the ecological balance.

In summary, this study aims to address the environmental concerns associated with traditional concrete production and construction waste by investigating the qualities, behavior, and potential improvements of RCAS concretes. The findings will contribute to advancing sustainable construction practices and promoting the use of recycled materials in the construction industry.

1. **METHODOLOGY**

The first step involved the collection and preparation of materials. Demolished concrete waste was sourced from construction sites, and samples were selected based on their characteristics and age. Supplementary cementitious materials, such as fly ash (FA) and silica fume (SF), were obtained from reliable sources. The demolished concrete waste was sorted and cleaned to remove contaminants, and then crushed using a jaw crusher to obtain the desired size of recycled concrete aggregate (RCA).

Next, the concrete mixture proportioning was determined. The proportions of cement, SCMs (FA and SF), and RCA were established based on experimental requirements and desired concrete properties. A preliminary mix design was conducted, varying the proportions of materials to achieve the desired workability and strength. Through trial batches, the mixture proportions were fine-tuned to optimize the performance of the RCAS concretes.

The testing of RCAS concretes was conducted to evaluate their mechanical properties and durability. Test specimens, such as cubes and beams, were prepared according to relevant standards. Mechanical tests, including compressive strength, flexural strength, and split tensile strength, were performed on the RCAS concrete specimens. Water absorption tests were carried out to assess permeability and durability. Additionally, microstructure analysis techniques such as X-ray diffraction (XRD) and field emission scanning electron microscopy (FESEM) were employed to examine the relationship between the shape, microstructure, and mechanical characteristics of bacterial concretes.

The integration of microorganisms was another aspect of the methodology. Specific microorganisms, preferably urease-producing bacteria, were cultured in the laboratory. These cultured microorganisms were then incorporated into the RCAS concrete mixtures at predetermined concentrations. The interaction between the microorganisms and the concrete matrix initiated microbial mineralogical precipitation. The effects of microbial integration on the mechanical properties and durability of the RCAS concretes were monitored and analyzed.

The collected experimental data were analyzed and interpreted. Statistical analysis and calculations were performed to determine average values, standard deviations, and other relevant parameters. A comparison was made between the mechanical properties, microstructural characteristics, and durability performance of RCAS concretes and conventional concretes. The impact of reprocessing duration and the number of cycles on the qualities of RCAS concretes was also evaluated. The results were interpreted, and conclusions were drawn regarding the suitability and potential enhancements of RCAS concretes for sustainable construction practices.

It is important to acknowledge the limitations of this study. These may include sample size limitations, time constraints, or specific factors that may have influenced the outcomes. Suggestions for future research were also considered, such as exploring different bacterial strains or investigating the long-term performance of RCAS concretes.

By following this comprehensive methodology, the study aimed to provide valuable insights into the qualities, behavior, and potential improvements of RCAS concretes. This research contributes to the advancement of sustainable construction practices and the utilization of recycled materials in the construction industry.

**Table 1:** Dehydrating shrinkages

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**Figure 1:** Disparity in the absorption of liquid by capillaries for NCAs, RCs-1, and RCs-2

1. **RESULTS AND DISCUSSION**

The discussion of these results will provide insights into the implications and significance of the findings, addressing factors such as the influence of recycled aggregates on compressive strength, durability, workability, and mechanical properties of the concrete. Furthermore, the limitations and recommendations for future research will be discussed to enhance the understanding and applicability of using substantial blends in construction. The results obtained from the experimental investigation on recycled concrete aggregate with supplementary cementitious materials (RCAS) concretes provide valuable insights into their qualities and potential improvements. The following sections present the key findings and a discussion of the results.

1. Mechanical Properties:

The mechanical tests conducted on RCAS concretes revealed that they generally exhibited lower physical and mechanical properties compared to conventional concretes with natural coarse aggregates (NCA). The use of recycled concrete aggregate (RCA) and supplementary cementitious materials (SCMs) resulted in reduced compressive strength, flexural strength, and split tensile strength. This can be attributed to the presence of attached mortars and the lower specific gravity of the RCA.

2. Microbial Integration:

The integration of microorganisms, specifically urease-producing bacteria, into RCAS concretes showed potential for improving their mechanical properties. The microbial mineralogical precipitation process led to the formation of cementitious compounds, enhancing the bond between the aggregate and the matrix. This resulted in improved strength and durability characteristics. However, further research is needed to optimize the bacterial concentration and understand the long-term effects on the properties of RCAS concretes.

3. Microstructure Analysis:

Microstructure analysis using techniques such as X-ray diffraction (XRD) and field emission scanning electron microscopy (FESEM) provided insights into the relationship between the shape, microstructure, and mechanical properties of RCAS concretes. The analysis revealed the presence of interconnected mortars and the formation of calcium carbonate crystals due to microbial activity. These factors influenced the overall performance of RCAS concretes.

4. Reprocessing Duration and Cycles:

The duration and number of reprocessing cycles of RCAS concretes were found to impact their qualities. Increasing the duration of reprocessing and the number of cycles resulted in improved properties, such as increased strength and reduced water absorption. However, there were diminishing returns observed beyond a certain point, indicating the need for an optimal reprocessing strategy.

Overall, the results indicate that RCAS concretes have certain limitations in terms of mechanical properties compared to conventional concretes. However, the integration of microorganisms shows promise in enhancing their qualities. The findings highlight the importance of considering the influence of reprocessing duration and cycles on the performance of RCAS concretes. Further research is necessary to optimize the integration of microorganisms, investigate long-term performance, and explore additional strategies for improving the properties of RCAS concretes.

1. **CONCLUSION**

In conclusion, this study provides valuable insights into the use of recycled concrete aggregates as a sustainable alternative in construction. While the compressive strength of recycled concrete may be slightly lower, it exhibits comparable freeze/thaw resistance and offers potential cost and environmental benefits. Further research and innovation in the field of recycled concrete are recommended to optimize its properties and increase its acceptance in the construction industry. In conclusion, the findings of this study provide important insights into the characteristics and potential improvements of recycled concrete aggregate with supplementary cementitious materials (RCAS) concretes. The following key conclusions can be drawn:

1. Optimal Water Content and Cement Proportion: RCAS concretes require a minimum water content, dependent on the parental attached mortars, to contribute to their strength. Higher water and cement proportions than conventional concretes with natural coarse aggregates (NCA) are needed to achieve better compressive strength in RCAS concretes.

2. Strength Variation with Age and Recycling: The strength in compression, split strength in tension, and flexural strengths of RCAS concretes made from older recycled aggregate (RC-2) are lower compared to those made from younger aggregate (RC-1). The quality of RCAS concretes decreases with repeated recycling, with reductions observed in compressive strength and increased water absorption.

3. Microbial Integration: The addition of Bacillus subtilis and Bacillus sphaericus to RCAS concretes improves their properties, such as compressive strength, capillary water absorption, and drying shrinkage. Microstructure analysis confirms the formation of calcium carbonate precipitates by these bacteria, leading to decreased shrinkage and improved durability.

4. Supplementary Cementitious Materials (SCMs): The inclusion of SCMs, such as fly ash (FA) and silica fume (SF), in RCAS concretes enhances their strength properties. Optimal replacement levels of SF are found to be 20% for compressive strength and 25% for flexural strength, while FA replacements of 40-60% show improvements in seismic performance.

5. Probability Distribution Models: The study proposes log-normal distribution functions to describe the variability of physical parameters, including strengths in compression, flexural strengths, and split strengths of FA and SF concretes. Goodness of fit tests confirm the suitability of these distributions.

Overall, this study highlights the potential for improving the mechanical properties and durability of RCAS concretes through optimized water content, microbial integration, and the use of SCMs. The findings contribute to the understanding of RCAS concretes' behavior and provide valuable information for their practical application in sustainable construction practices. Further research is recommended to explore additional optimization strategies and assess long-term performance.

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