

Performance Analysis of Sustainable concrete with Partial Replacement of Coarse aggregate by Recycled Rubber Aggregates

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Abstract— The drive towards sustainable construction practices has led to the exploration of innovative materials that can reduce the environmental impact of concrete production. This study focuses on the performance analysis of concrete incorporating recycled rubber aggregates (RRA) as a partial replacement for coarse aggregates. The investigation aims to assess the mechanical properties of the developed sustainable concrete through compressive, split tensile, and flexural strength tests at curing ages of 7, 14, and 28 days. In this research, conventional coarse aggregates were partially replaced with recycled rubber aggregates in varying proportions. The RRA were obtained from discarded automobile tires, contributing to waste reduction and promoting the reuse of materials that would otherwise contribute to landfills. The experimental program involved the preparation of concrete specimens with different percentages of RRA replacement (0%, 10%, 20%, and 30%) while maintaining a constant water-cement ratio to ensure consistent workability. The compressive strength test was conducted to evaluate the load-bearing capacity and durability of the sustainable concrete. These tests were carried out at specified curing intervals to analyze the evolution of mechanical properties over time.

Index Terms— Sustainable concrete, recycled rubber aggregates, partial replacement, coarse aggregates, compressive strength.

I. INTRODUCTION

The global construction industry is undergoing a transformative shift towards sustainability, driven by the imperative to reduce the environmental impact of conventional practices. As a response to this

challenge, there is a growing exploration of innovative materials that can mitigate the ecological footprint associated with concrete production. Concrete, a fundamental building material, has historically relied heavily on natural resources, particularly coarse aggregates. In this context, the present study delves into the performance analysis of sustainable concrete, specifically focusing on the partial replacement of conventional coarse aggregates with recycled rubber aggregates (RRA).

The motivation behind this investigation lies in the dual objective of addressing waste management concerns and promoting the use of environmentally friendly materials in construction. The recycled rubber aggregates utilized in this study were derived from discarded automobile tires, a pervasive environmental challenge due to their slow decomposition and potential contribution to landfills. By repurposing these rubber aggregates in concrete production, we aim not only to mitigate the environmental impact of tire disposal but also to contribute to the larger discourse on sustainable construction practices.

Our primary goal is to comprehensively assess the mechanical properties of the developed sustainable concrete. To achieve this, we have conducted a series of rigorous tests, including compressive, split tensile, and flexural strength assessments at different curing ages (7, 14, and 28 days). By incorporating varying proportions of recycled rubber aggregates into the concrete mix (0%, 10%, 20%, and 30%), we aim to understand the influence of RRA content on the performance characteristics of the sustainable

concrete. Importantly, we maintained a constant water-cement ratio throughout the experimental program to ensure consistent workability and facilitate a more accurate comparison of results.

The choice of recycled rubber aggregates as a partial replacement for conventional coarse aggregates not only aligns with sustainability goals but also addresses the issue of waste reduction. Automobile tires, once considered as discarded waste, now find a new purpose in the construction industry. This dual benefit of waste reduction and material reuse underscores the potential of incorporating recycled rubber aggregates in concrete production.

II. LITERATURE REVIEW

Rayeh Nasr Salam Al-Dalaien (2020) studied on the use of shredded waste tires to partially replace coarse aggregates in concrete, several replacement percentages (30%, 40%, and 50%) were tested alongside a control mix. The study considered two key factors: the size of the waste tire rubber aggregate and the volume fraction of this rubber aggregate. During the fresh state of the concrete, it was observed that workability improved as the percentage of tire crumb replacement increased. However, in the hardened concrete, as the fraction of tire rubber increased and the size of the rubber particles grew larger, several mechanical properties suffered. This included a reduction in compressive strength, tensile strength, and flexural strength. Additionally, the apparent unit weight of the concrete decreased as both the size and percentage of rubber replacement increased.

Mohammad_MomeenUl Islam et al (2023) introduces the production of structural lightweight concrete (SLWC) using 100% coarser waste tire rubber, representing a pioneering step in investigating its durability characteristics. To enhance the strength and durability of rubberized concrete without traditional coarse aggregates, two newly designed casting molds were employed. The fresh rubberized concrete mixes exhibited varying slump values in the range of 84 to 122 mm, meeting the requirements stipulated by ACI 213R. The study further determined the density and compressive strength of this novel SLWC. The durability properties of this concrete, which include water absorption, sorptivity, shrinkage, susceptibility to sulfate attack, and rapid chloride penetration, were assessed at various time points, namely 28, 56, 90, and 180 days.

Fengming_Ren and Fengming_Ren (2020) focused on the utilization of recycled rubber tires as a partial substitute for coarse aggregates in concrete construction, using locally sourced waste tires. The initial section of this thesis provided an overview of the study's background and the scope of the issue under consideration. The research involved conducting comprehensive tests on the raw materials to assess their properties and suitability for the experiment. Concrete mix designs were formulated in accordance with Indian standard methods, resulting in the preparation of nine different concrete mixes, spanning three distinct grades (M15, M25, and M30). These mixes included various percentages of coarse aggregate replacement, specifically 10% and 25% with rubber aggregate. Additionally, a control mix was created, devoid of any replacement of the coarse aggregate, for the purpose of comparative analysis. The prepared specimens comprised concrete cubes, cylinders, and beams, and were subjected to a series of laboratory tests. These tests encompassed assessments of slump, unit weight, compressive strength, splitting tensile strength, and flexural strength. The data collected was primarily derived from the experiments performed on the prepared specimens in the laboratory.

Fengming_Ren et al (2022) assessed the performance of concrete incorporating crumb rubber as a fine aggregate, offering supporting evidence for the design and application of crumb rubber concrete (CRC) materials. Crumb rubber possesses distinct characteristics, including low specific gravity, hydrophobic properties, and a propensity for air entrapment, which differ from natural fine aggregates. These characteristics lead to a substantial decrease in the workability of fresh CRC and result in inadequate bonding with the cementitious matrix. The review summarizes how the compressive and tensile strength, elastic modulus, and fracture behavior of CRC are affected at various rubber content levels. It also presents predictive models for strength reduction factors. The primary factors contributing to the decline in strength are the subpar performance of the interface transition zone (ITZ) and the uneven distribution of rubber particles within the concrete.

Mohamed Atef et al (2021) focused on the development of innovative methods for recycling rubber powder to be used effectively in robust construction applications. Recycled rubber particles

(RRP) are blended with ordinary Portland cement (OPC) while varying the water-to-binder ratio (W/B) at values of 0.3 and 0.4. The study involves the measurement of Fourier transform-infrared (FT-IR) spectra for RRP and an investigation into the compressive strength (C.S) of rubberized cement pastes at different curing periods, including 1, 3, 7, 14, and 28 days.

The primary objective of the study is to enhance the compressive strength of rubberized cement pastes by improving the bonding strength between RRP and OPC, specifically through the use of fine RRP particles. This approach aims to maintain high levels of compressive strength while also taking advantage of RRP's vibration-damping properties. Consequently, rubberized cement pastes can be considered suitable alternatives to conventional concrete in a wide range of construction applications.

III. MATERIALS & METHODOLOGY

1. Recycled Rubber Aggregates:

a. Source Material: The primary focus of the research is on recycled rubber aggregates derived from discarded tires and other rubber products. These materials are sourced from established recycling facilities where end-of-life tires undergo processing. The source material includes whole tires, tire treads, and other rubber components that are subjected to shredding, granulation, and sieving processes.

b. Size Distribution: Recycled rubber aggregates exhibit a diverse size distribution, ranging from granules to larger particles. The size distribution is carefully characterized using sieve analysis, ensuring that the resulting aggregates are suitable for various construction applications. This characterization is essential for understanding the physical properties and optimizing the incorporation of recycled rubber in construction materials.

c. Composite Aggregates: In addition to rubber from tires, the research explores the use of recycled rubber in composite aggregates. This involves combining rubber with other materials, such as crushed concrete or asphalt, to create hybrid aggregates. The goal is to assess the feasibility of integrating recycled rubber in conjunction with traditional construction materials to achieve optimal performance and sustainability outcomes.

2. Conventional Construction Materials:

a. Natural Aggregates: As a point of reference for performance evaluations, conventional construction materials such as natural aggregates are used. These include sand and gravel, which are commonly employed in the production of concrete and asphalt. The properties of natural aggregates provide a benchmark against which the performance of recycled rubber aggregates can be compared.

b. Cement: Ordinary Portland cement is utilized in concrete mix designs as the binder material. The cement provides cohesion to the concrete mix and undergoes chemical reactions with other components during the curing process. This standard construction material is used to create control mixes for comparison with mixes containing recycled rubber aggregates.

c. Asphalt Binder: For asphalt mix designs, a conventional asphalt binder is used. The binder is selected based on regional specifications and industry standards. The use of a standard binder in control 3.

3. Concrete Mix Design: The concrete mix design phase involves formulating mixtures that incorporate varying percentages of recycled coarse aggregates. Key considerations include:

a. Proportioning of Ingredients:

- Recycled Coarse Aggregates: Different percentages (e.g., 0%, 25%, 50%, and 100%) of recycled coarse aggregates are substituted for natural coarse aggregates in the mixtures.
- Cement Content: The cement content is adjusted based on the targeted compressive strength and durability requirements.
- Water-Cement Ratio: The water-cement ratio is carefully selected to ensure workability and meet strength and durability criteria.
- Admixtures: The inclusion of admixtures, such as superplasticizers and air-entraining agents, is considered to enhance workability and mitigate potential issues associated with recycled aggregates.

b. Performance Objectives:

- Compressive Strength: Concrete specimens are cast and subjected to compressive strength tests at various curing ages (e.g., 7, 28, and 56 days) to assess the impact of recycled coarse aggregates on the concrete's strength development.

- **Durability Tests:** Various durability tests, including water absorption, chloride ion penetration, and freeze-thaw resistance, are conducted to evaluate the long-term performance and resistance to environmental factors.

mixes facilitates the comparison of performance characteristics, including rutting resistance and fatigue resistance, between conventional and rubberized asphalt.

4. Concrete Mix Design Materials:

a. **Aggregates (Recycled Rubber, Natural):** The concrete mix design phase involves the use of recycled rubber aggregates alongside natural aggregates. The proportions of these aggregates are carefully adjusted to achieve optimal fresh and hardened concrete properties. The selection of aggregates influences the workability, strength, and durability of the concrete mix.

b. **Cement:** Ordinary Portland cement, a standard construction material, is used as the binder in concrete mix designs. The cement content is varied to optimize the balance between workability and strength. The incorporation of recycled rubber aggregates requires adjustments to the overall mix design to maintain the desired performance characteristics.

c. **Admixtures:** Depending on specific performance objectives, admixtures such as water reducers, plasticizers, and air-entraining agents may be employed. These additives contribute to the workability, durability, and setting time of the concrete mix. The use of admixtures is carefully controlled to ensure compatibility with recycled rubber aggregates.

V. RESULTS AND DISCUSSIONS

Compressive Strength of concrete

Compressive strength of concrete refers to its maximum resistance to axial loading, commonly assessed through compression tests on hardened concrete specimens. The simplicity of the testing process makes it widely utilized. Typically, cubes measuring 150 x 150 x 150 mm are employed to determine compressive strength. The focus on compressive strength determination is crucial since concrete is primarily designed to withstand compressive stresses.

The standardized method outlined in IS 516-1959 is followed for testing, involving six specimens in each batch. The compression tests are conducted at both 28 and 90 days of concrete age. The resulting strengths for each percentage of pumice aggregate used are documented, and differences among them are highlighted. The average strength, obtained by repeating the test on six specimens and calculating the mean, provides a comprehensive representation of the concrete's compressive strength at various stages of maturity.

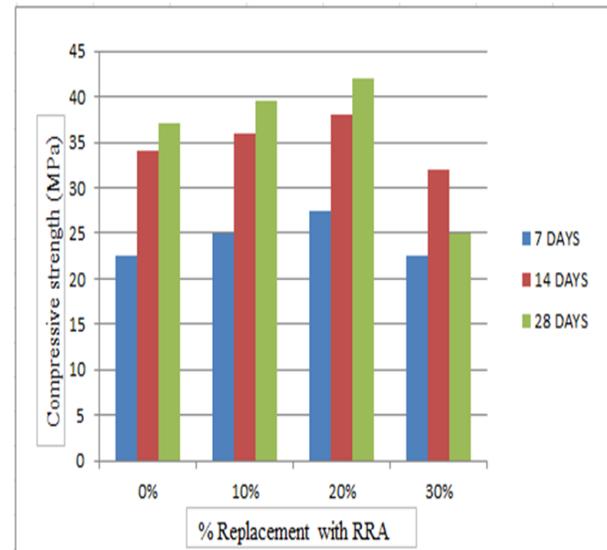


Fig. 1: Compressive Strength

V. CONCLUSIONS

The objective of this investigation was to evaluate the fresh and mechanical properties of self-compacting concrete (SCC) incorporating ceramic waste powder (CWP) as a partial replacement for fine aggregates. Based on the findings, the following conclusions can be drawn:

- Compressive Strength and Curing Time:** The compressive strength of concrete generally increases with curing time, reflecting its maturity and strength development.
- Optimal Replacement Percentage:** No significant reduction in compressive strength is observed for up to 20% replacement with recycled aggregates (RRA).
- Impact of Higher Replacements:** Replacement levels above 20%, such as 30% RRA, may lead to a noticeable reduction in compressive strength.

- iv. Recommended Replacement Level: To maintain satisfactory compressive strength, the optimal replacement percentage is up to 20% RRA.

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