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Utilization of Waste Rubber Tube in the Production of Sustainable Lightweight Concrete

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ABSTRACT

The swift expansion of the building sector has resulted in the overutilization of natural aggregates and the accumulation of industrial rubber waste. This study examines the creation of sustainable lightweight concrete through the partial substitution of natural coarse aggregates with recovered demolition materials and discarded rubber tube particles. Concrete mixtures were formulated with 4%, 8%, and 12% rubber substitution and evaluated for density, compressive strength, split tensile strength, and flexural strength at 7, 14, and 28 days. The findings indicated that the density of concrete diminished as the rubber content increased, corroborating its lightweight properties. The compressive, tensile, and flexural strengths exhibited a minor reduction with increased rubber content; nevertheless, enhancements were noted in ductility, crack resistance, and energy absorption capacity. Mixtures including 4–8% rubber demonstrated an ideal equilibrium between strength and toughness.The utilization of recycled aggregates and waste rubber mitigates environmental pollution, conserves natural resources, and fosters sustainable construction practices. This method offers a sustainable option for non-structural and semi-structural concrete uses.

Keywords: Cement (PPC 43), M-Sand, Waste Rubber Tube, Water

1. INTRODUCTION

Concrete is among the most extensively utilized construction materials globally, owing to its strength, durability, and versatility. It is essential for infrastructure development, encompassing buildings, bridges, roads, and other civil engineering structures. The swift progression of urbanization and industrialization has resulted in a substantial demand for natural resources, including river sand and coarse aggregates. The overexploitation of these materials has led to environmental deterioration, resource depletion, and ecological imbalance. (Dafedar et al., 2024) Simultaneously, industrial trash, including wasted rubber tubes from cars and manufacturing sectors, presents significant environmental issues. Rubber is a non-biodegradable substance, and its accumulation in landfills results in enduring environmental risks. Integrating discarded rubber into concrete mitigates disposal challenges while enhancing specific concrete qualities, including flexibility, ductility, and impact resistance. Da Silva et al. (2021); Hallmark-Haack et al. (2019); Manan et al. (2024).

Lightweight concrete has garnered significant interest in contemporary construction owing to its diminished self-weight, enhanced thermal insulation, and superior seismic performance. The decrease in dead load results in financial savings in structural design and foundation specifications. Utilizing discarded rubber particles as a partial substitute for coarse aggregates can yield sustainable lightweight concrete characterized by improved ductility, energy absorption, and crack resistance. (Beytekin et al., 2024; Helmy et al., 2023) While rubber aggregates enhance ductility and impact resistance, they may somewhat diminish the strength of concrete. Therefore, this study focuses on the experimental investigation of sustainable lightweight concrete by partially replacing conventional coarse aggregates with waste rubber tube particles. The objective is to assess the mechanical qualities and viability of incorporating rubber aggregates in real construction applications, while fostering environmental sustainability.

2. MATERIALS AND METHODOLOGY

2.1 Cement (PPC 43)

Portland Pozzolana Cement (PPC 43 Grade), compliant with IS 1489, was utilized. It serves as the principal binding agent that generates C-S-H gel during hydration.

2.2 M-Sand

Manufactured sand (M-Sand), compliant with IS 383, was utilized as fine aggregate. It enhances grading, strength, and workability.

2.3 Waste Rubber Tube

Waste rubber tube fragments were gathered, purified, and severed into minuscule bits, as shown in Fig.1. They served as a partial substitute (4%, 8%, 12%) for coarse aggregates.

Fig.1. Rubber aggregate (RA)

2.4 Mix Proportions

This investigation involved the preparation of M20 grade concrete with Portland Pozzolana Cement (PPC 43), manufactured sand (M-Sand) as fine aggregate, and natural coarse aggregates partially substituted with Waste rubber tube particles were utilized. All materials were quantified in accordance with the specified mix proportions (1:1.5:3) and a water-cement ratio of 0.50. The dry materials were initially combined thoroughly, after which water was added to achieve a consistent and workable mixture. The concrete was subsequently moulded into cubes, cylinders, and prisms to assess compressive, split tensile, and flexural strengths, respectively. The specimens were removed from the moulds after 24 hours and immersed in water for curing periods of 7, 14, and 28 days. Standard IS procedures were employed to assess the mechanical performance, workability, and durability of the concrete. This methodology facilitates the evaluation of the impact of rubber particles on the characteristics of sustainable lightweight concrete. Testing methoads are depicted in Fig.2 & 3.

Fig.2 Compressive Testing

Fig.3.Split Tensile Strength

Table.1 Density and Compressive Strength of Concrete

Mix	**Density (kg/m³)**	**Compressive Strength (N/mm²)**		
		7 days	**14 days**	**28 days**
Conventional Concrete	2450	19.5	27.7	30.8
4% RA	2320	11.90	21.90	25.20
8% RA	2250	10.20	19.80	23.20
12% RA	2150	7.09	12.40	15.20

The density and compressive strength of M20 grade sustainable lightweight concrete were markedly affected by the incorporation of recovered demolition materials and waste rubber tube particles, as presented in Table.1. The density diminished from 2450 kg/m³ for conventional concrete to 2150 kg/m³ for concrete with 12% rubber substitution, affirming the lightweight characteristics of the formulated mixtures. The decrease in self-weight can diminish structural dead load and potentially minimize foundation expenses.

The compressive strength diminished with the rise in rubber content, attributable to the elastic properties of rubber particles, which offer minimal contribution to load-bearing capacity. Mixtures with 4% and 8% rubber replacement exhibited adequate strength values of 25.20 N/mm² and 23.20 N/mm² at 28 days, as shown in Fig.4. The 12% substitution demonstrated a notable decrease in compressive strength to 15.20 N/mm², suggesting that high rubber content negatively impacts load-bearing capacity. The results indicate that the systematic substitution of natural aggregates with recycled materials and rubber can yield environmentally sustainable lightweight concrete with adequate mechanical properties.

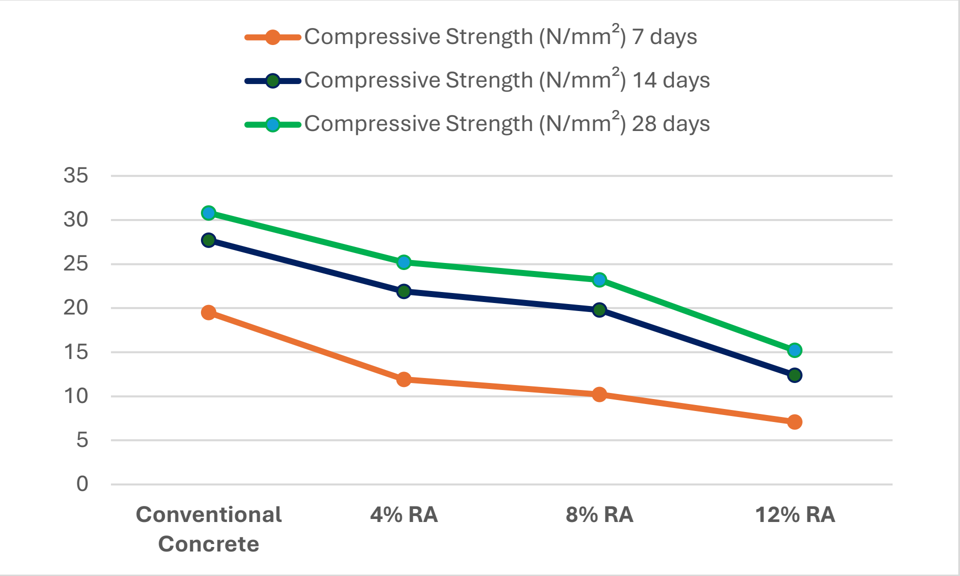

Fig.4. Compressive strength results

4.3 Split Tensile Strength

The split tensile strength of M20 grade concrete including recycled demolition materials and discarded rubber tube particles exhibited a marginal reduction as rubber content increased. At 7 days, ordinary concrete had a compressive strength of 1.89 N/mm², whereas mixtures containing 4%, 8%, and 12% rubber attained strengths of 1.29, 1.27, and 1.20 N/mm², respectively. At 28 days, conventional concrete attained a compressive strength of 3.30 N/mm², while the rubberized mixes containing 4%, 8%, and 12% rubber exhibited strengths of 1.38, 1.36, and 1.37 N/mm², respectively, demonstrating a slower strength increase for the rubberized formulations. Although tensile strength diminished, the inclusion of rubber particles improved the ductility and crack resistance of the concrete. non-structural and semi-structural uses.

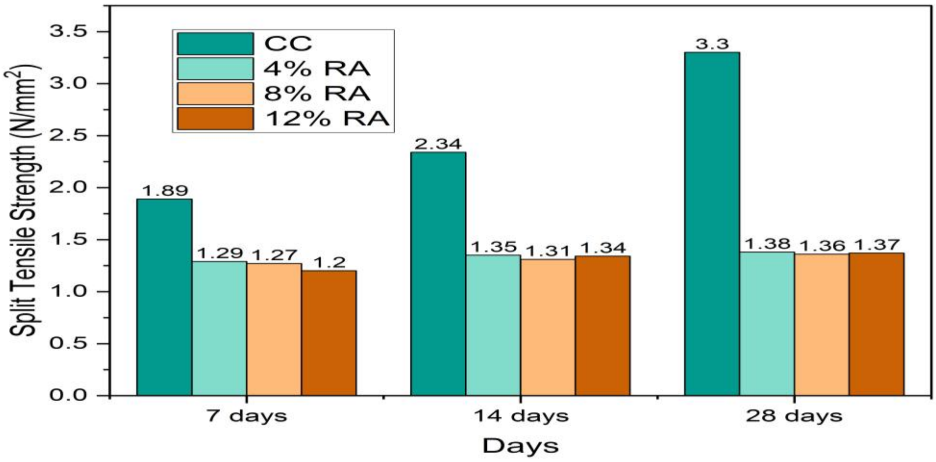

Fig.5. Split tensile strength results

The elastic properties of rubber facilitate the absorption of tensile stresses and impede crack propagation, which is especially advantageous under dynamic or impact loading situations. The 12% rubber mix exhibited slight enhancement at later ages, indicating that the synergistic action of recycled aggregates and rubber enhances toughness and energy absorption, despite a lower peak tensile strength compared to traditional concrete. The results suggest that mixtures containing 4%–8% rubber offer an optimal equilibrium between strength and improved ductility for

4.4 Flexural Strength

The flexural strength of M20 grade concrete exhibited a progressive decline with elevated rubber content, concurrently enhancing the ductility and energy absorption capacity of the mixtures. At 7 days, conventional concrete had a flexural strength of 3.2 N/mm², while the mixtures including 4%, 8%, and 12% rubber attained strengths of 2.8, 2.6, and 2.1 N/mm², respectively. At 28 days, ordinary concrete attained a compressive strength of 4.5 N/mm², whereas the rubber mixes containing 4%, 8%, and 12% achieved strengths of 3.9, 3.6, and 3.0 N/mm², respectively.

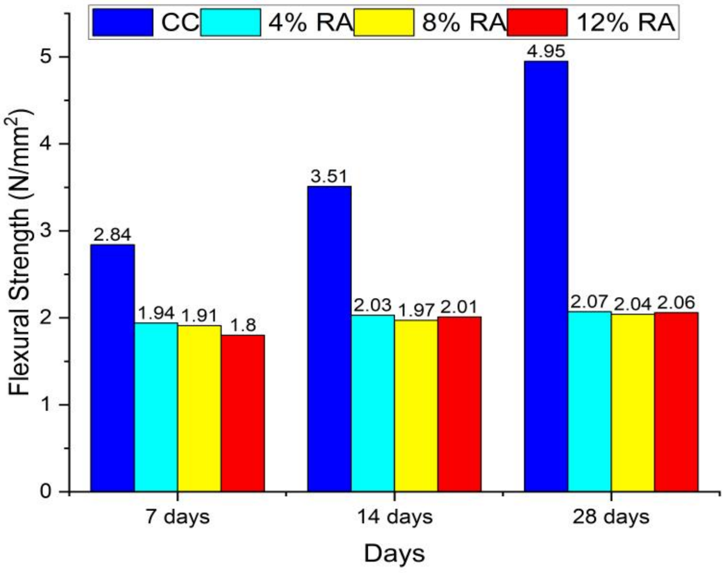

Fig.6. Flexural strength results

5. CONCLUSIONS

I. The density of concrete diminished as rubber content increased, resulting in lighter mixes.
II. The compressive strength diminished with an increase in rubber content; however, mixtures containing 4–8% rubber still provided enough strength for non-structural and semi-structural applications.
III. The split tensile and flexural strengths marginally diminished with increased rubber content; nevertheless, ductility, crack resistance, and toughness exhibited enhancement.
IV. A rubber substitution of 4–8% combined with recycled aggregates achieves an optimal equilibrium of strength, ductility, and lightweight characteristics.
V. Utilizing recycled demolition materials and waste rubber promotes environmental sustainability by diminishing the consumption of natural resources and minimizing landfill trash.
VI. Sustainable lightweight concrete incorporating recycled aggregates and rubber represents a viable and environmentally responsible choice for green construction.

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