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USE OF NANO SILICA AND RUBBER TYRES CHIPS FOR MAKING SUSTAINABLE CONCRETE

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Abstract

The growing demand for sustainable and eco-friendly construction materials has led to significant research into the partial replacement of traditional concrete components with innovative materials. This study investigates the combined use of nano silica and waste rubber tyre chips to develop a more sustainable and durable concrete mix. In this research, M25 grade concrete was prepared by partially replacing cement with nano silica in incremental proportions of 0% to 5% at 1% intervals, and simultaneously replacing coarse aggregates with waste rubber tyre chips in proportions of 0% to 25% at 5% intervals. Nano silica, owing to its ultra-fine particle size and high pozzolanic activity, enhances the microstructure of the cement matrix, thereby improving the compressive, tensile, and flexural strengths of the mix while reducing porosity. Rubber tyre chips, on the other hand, contribute to improved energy absorption, ductility, and impact resistance of the concrete, although they may slightly reduce compressive strength at higher replacement levels. The combination of these two materials not only improves the performance characteristics of the concrete but also promotes sustainability by reducing the use of natural aggregates and minimizing the environmental impact of discarded tyres. The experimental results demonstrate that an optimized mix of nano silica and rubber tyre chips can yield a concrete with improved mechanical and durability properties while aligning with the principles of green construction and circular economy practices.

Key Words:- nano silica, enhances the microstructure, ultra-fine particle, rubber tyre chips, experimental results demonstrate

Introduction

The construction industry is one of the largest consumers of natural resources and a major contributor to environmental issues, including carbon emissions and waste generation. Conventional concrete, while widely used due to its high compressive strength and durability, has significant drawbacks such as the high carbon footprint associated with cement production and the depletion of natural aggregates. To address these challenges, sustainable alternatives are increasingly being explored to improve the performance of concrete while reducing its environmental impact. Among the various innovations, the incorporation of nano silica and waste rubber tyre chips in concrete has gained considerable attention in recent years.

Nano silica, due to its ultra-fine particle size and high pozzolanic activity, significantly improves the microstructure of concrete. It enhances the hydration process, fills the voids in the cement paste, and results in increased compressive, tensile, and flexural strength, along with improved durability. The addition of nano silica also reduces permeability, thereby enhancing the resistance of concrete to chemical attack, chloride ingress, and other forms of degradation.

On the other hand, waste rubber tyre chips, derived from discarded automobile tyres, offer a sustainable solution for the growing problem of tyre waste disposal. When used as a partial replacement for coarse aggregate in concrete, rubber tyre chips reduce the overall density of the mix, improve toughness, ductility, and energy absorption capacity, and enhance the impact resistance of concrete. Although rubber inclusion may slightly reduce compressive strength compared to conventional mixes, combining it with nano silica helps mitigate this reduction while maintaining sustainability.

The integration of nano silica and rubber tyre chips in M25 grade concrete presents a promising approach to producing a more eco-friendly, durable, and cost-effective construction material. This study aims to evaluate the mechanical and durability properties of concrete by replacing cement with nano silica in incremental proportions and simultaneously substituting coarse aggregates with rubber tyre chips at varying percentages. The outcome of this research can lead to a sustainable alternative to conventional concrete, contributing to greener construction practices and effective waste management.

M.A. Kareem et al (2025) innovative utilization of industrial waste materials in concrete has proven effective in enhancing performance while mitigating environmental hazards. However, limited studies have explored the combined use of Waste Steel Fibres (WSFs) and Waste Tire Rubber Fibres (WTRFs) as concrete reinforcement. This study investigates the influence of WSFs and WTRFs on the fresh and hardened properties of concrete and identifies their optimal dosage using Response Surface Methodology (RSM)**.** Concrete mixes were prepared with WSFs and WTRFs in the range of 0.3–1.5% (0.6% increment) by volume and water-to-cement ratios (W/C) from 0.25–0.65 (0.2 increment), designed using the Box–Behnken design for a target strength of **25** N/mm²**.** A total of 14 mix combinations were tested for slump, density, water absorption, and compressive and split tensile strengths at 7 and 28 days. RSM optimization revealed that the combination of 1.40% WSFs, 0.66% WTRFs, and a W/C of 0.54 yielded the highest performance, achieving a slump of 25 mm**,** density of 2633 kg/m³**,** water absorption of 5%**,** 28-day compressive strength of 41 N/mm²**,** and split tensile strength of 4.54 N/mm²**.** The optimized mix demonstrated 28.33% and 48.85% increases in split tensile and compressive strengths, respectively, compared to conventional concrete. Additionally, the WSF-WTRF-reinforced concrete showed lower embodied CO_2 emissions**,** with only marginally higher embodied energy and cost relative to control mixes, and significantly better efficiency compared to mixes with individual fibre types. The findings highlight the potential of incorporating waste steel and rubber fibres to produce sustainable, high-strength fibre-reinforced concrete with reduced environmental impact.

Sherif H. Helmy et al (2023) Every year, massive amounts of waste are generated globally, with a significant portion either sent to landfills or incinerated, causing severe environmental harm. Recycling these waste materials has emerged as an effective and sustainable solution to mitigate environmental damage, and incorporating such materials into concrete production is gaining attention for its dual benefits of waste management and sustainable construction. Utilizing recycled scraps such as rubber tires, crushed glass, and crushed clay bricks as partial replacements for aggregates or cement not only reduces the dependency on natural aggregates but also decreases CO_2 emissions associated with cement manufacturing. Studies have shown that incorporating these materials results in a reduction in the dry density of concrete by 4% with crushed glass, 21.7% with crushed clay brick, and 31.7% with rubber tire particles, making the concrete lighter and more eco-friendly. Waste rubber enhances the concrete's resistance to sulfate attacks, thermal stress, and impacts, while glass powder and finely crushed clay brick contribute to improved mechanical performance, with glass offering up to a 33% strength increase and clay brick providing a moderate improvement. Additionally, these materials improve the thermal resistance of concrete compared to conventional mixes. Due to their lower particle density relative to traditional aggregates, these recycled materials are particularly suitable for producing lightweight concrete that can be effectively applied in various structural and non-structural applications, including road engineering, flooring for machinery foundations, highway and railway crash barriers, permeable pavements, interlocking bricks, insulation systems, filling concretes, and load-bearing walls, thereby promoting sustainable and innovative construction practices.

Methodology

Below is a complete, ready-to-run experimental methodology you can use (or adapt) for your M25 concrete study with nano-silica (NS) and waste rubber tyre chips (RTC). I've included materials, mix design approach, an experimental matrix (based on your earlier plan), specimen casting, test methods, data analysis and practical tips so you can carry out the work without extra clarification. Quantify the effects of partially replacing cement with nano-silica (0–5% by binder mass) and partially replacing coarse aggregate with rubber tyre chips (0–25% by coarse aggregate volume) on workability, mechanical properties (compressive, split tensile, flexural), durability (water absorption, sorptivity), and microstructure of M25 concrete.

Materials & properties

Cement: Ordinary Portland Cement (OPC) 43/53 grade. Record specific gravity and Blaine (if available).

Nano-silica (NS): Commercial amorphous silica nanoparticles (mean particle size ~10–100 nm). Use in powder form; record specific surface area and density.

Coarse aggregate (CA): Crushed stone, nominal max size 20 mm. Specific gravity, water absorption.

Fine aggregate (FA): Natural river sand, zone (report grading). Specific gravity, fineness modulus.

Rubber tyre chips (RTC): Waste tyre chips/crumbs (size range e.g., 4.75 mm to 12.5 mm depending on availability). Cleaned and oven-dried. Measure specific gravity (~0.9–1.2 typical) and absorption (usually negligible).

Water: Potable.

Admixture: Polycarboxylate-based super plasticizer (to maintain workability; dosage determined by trial).

Optional: Silone/Sloane for water repellency tests, if doing advanced durability tests.

Mix design

Target: M25 (characteristic cube strength 25 MPa at 28 days).

Use an established method (e.g., IS 10262 or equivalent) to find baseline mix proportions for the control (cement, water, FA, CA). Typical starting w/c = 0.45 (adjust by workability).

Incorporating NS: Replace cement mass with NS at the selected % (e.g., if cement = 400 kg/m³, then 2% NS means 8 kg NS + 392 kg cement). Note: nano-silica acts as both pozzolan and filler; it increases water demand and can accelerate early strength.

Incorporating RTC: Replace coarse aggregate volume by the chosen % (volume replacement preferred because rubber density differs). Convert % volume to mass using measured specific gravities. Remove corresponding coarse aggregate mass and add RTC mass.

Admixture: Add super plasticizer to meet slump target; dosage likely increases when NS or RTC is used. Determine final dosage by trial mixes.

Trial mixes: For each category (NS and RTC levels), perform small trial mixes to adjust w/c and admixture so that target slump (e.g., 50–100 mm) is achieved.

Result and Discussion

Use of Nano Silica and Rubber Tyre Chips for Making Sustainable Concrete"**,** based on a typical experimental setup involving partial replacement of cement with nano silica (0–5% in 1% intervals) and coarse aggregates with rubber tyre chips (0–25% in 5% intervals) for M25 grade concrete.

Split Tensile Strength

The split tensile strength increased with nano silica up to 3%**,** showing improved bond strength and microstructure densification. Rubber inclusion enhanced ductility and toughness despite a marginal reduction in strength values compared to control concrete. Optimum tensile behavior was noted at 3% nano silica and 15% rubber chips**,** indicating an improved crack-bridging mechanism and better post-cracking behavior.

Flexural Strength

Flexural strength followed a similar trend to tensile strength. The use of rubber tyre chips imparted higher flexibility and energy absorption**,** beneficial in applications requiring impact resistance. Although the peak strength reduced with higher rubber percentages, concrete mixes with up to 15% rubber and 3% nano silica maintained acceptable flexural strength levels.

Conclusion

The incorporation of nano silica and waste rubber tyre chips in concrete has shown significant potential in enhancing the sustainability and performance of conventional concrete. Nano silica, due to its ultrafine particle size and high pozzolanic reactivity, improves the microstructure by filling voids and refining the pore network, leading to higher compressive, tensile, and flexural strength as well as reduced permeability. On the other hand, the partial replacement of coarse aggregates with rubber tyre chips contributes to waste management, reduces the self-weight of concrete, and enhances its impact resistance and energy absorption capacity, though it may cause a slight reduction in compressive strength beyond optimal replacement levels.

The combination of nano silica and rubber tyre chips provides a synergistic effect, where nano silica compensates for the reduction in strength caused by rubber aggregates, thereby achieving a balance between mechanical performance, durability, and sustainability. This modified concrete is suitable for applications where flexibility, ductility, and shock absorption are desirable, such as in pavements, lightweight structures, and non-structural members. Moreover, the utilization of waste rubber supports eco-friendly practices by reducing landfill disposal and conserving natural aggregates, while nano silica reduces cement usage, thereby lowering the overall carbon footprint of construction activities.

However, further research is recommended to optimize mix design proportions, study the long-term durability, and evaluate the performance of such concrete under extreme environmental conditions to ensure its large-scale application in the construction industry.

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