

The Survey: Reuse of TYRE Waste Dust as Partial Replacement of Fine Aggregate in Concrete

Rushikesh V. Bhalerao¹, Prashant O. Modani², Swapnil A. Deshmukh³

¹Student, Pankaj Laddhad Institute of Technology and Management Studies, Buldhana

^{2,3}Professor, Pankaj Laddhad Institute of Technology and Management Studies, Buldhana

Abstract—The disposal of waste tyres has become a serious environmental concern due to their non-biodegradable nature and increasing accumulation. One sustainable approach to address this issue is the utilization of tyre waste dust as a partial substitute for fine aggregate in concrete. This study investigates the effect of incorporating tyre dust on the compressive strength of concrete. Concrete cubes of M25 grade were prepared by replacing a portion of fine aggregate with varying percentages of tyre waste dust by weight. The specimens were cured in water for specified durations before testing. Experimental results indicate that the compressive strength decreases as the percentage of tyre dust increases, with a noticeable reduction beyond 15% replacement compared to conventional concrete.

Index Terms—Concrete, Cement, Fine Aggregate, Tyre Waste Dust, Compressive Strength.

I. INTRODUCTION

reusing industrial by-products in construction. Materials considered as waste in one process can often serve as valuable resources in another. In this context, waste tyres represent a significant opportunity for recycling in civil engineering applications.

Globally, approximately one billion tyres are produced each year. In India, the rapid increase in vehicle ownership has led to a substantial rise in tyre consumption, both for new vehicles and replacements. The automotive sector is expected to grow steadily, further increasing tyre waste generation. Managing this waste effectively has become a major environmental challenge.

Tyre waste poses serious environmental risks because it does not decompose easily. Over time, tyres break down into small particles that contribute to pollution. These particles contain synthetic polymers and

harmful additives, which can negatively impact ecosystems and human health.

Tyre-Related Pollution

Tyre degradation leads to both direct and indirect forms of pollution:

- Direct Pollution:

During vehicle operation, friction between tyres and road surfaces generates fine rubber particles. These particles become airborne and contribute to particulate pollution.

- Indirect Pollution:

Improper tyre maintenance, such as underinflation, increases wear and fuel consumption. This results in higher emissions from vehicles, indirectly worsening environmental conditions.

- Accumulated Tyre Waste:

Large quantities of discarded tyres create disposal challenges, often leading to landfills or illegal dumping.

Components of Tyre Pollution

Tyres are composed of various materials that contribute to environmental contamination:

- Microplastic Particles:

Tyre wear generates micro-sized particles that behave similarly to microplastics and persist in the environment.

- Toxic Substances:

Tyres contain additives such as carbon black, synthetic rubber, and heavy metals like zinc, lead, and copper, which can be harmful to living organisms.

Environmental Impacts

The effects of tyre waste are widespread and affect multiple environmental systems:

- **Air Quality Degradation:** Fine particles released from tyres can remain suspended in the air and be inhaled, leading to air pollution.
- **Water Contamination:** Rainwater runoff carries tyre particles into rivers and lakes, where they can harm aquatic organisms and disrupt ecosystems.
- **Soil Pollution:** Accumulation of tyre-derived pollutants in soil can reduce fertility and negatively affect plant growth and soil organisms.

Health Impacts

Exposure to tyre-derived pollutants poses several risks to human health:

- **Respiratory Problems:** Inhalation of fine rubber particles can cause irritation, inflammation, and long-term lung issues.
- **Systemic Health Effects:** Toxic elements present in tyre particles may enter the human body, potentially causing broader health complications over time.

Factors Contributing to Increased Tyre Pollution

Several factors influence the rate at which tyre-related pollution is generated:

- **Vehicle Load:** Heavier vehicles exert greater pressure on tyres, resulting in increased friction with road surfaces. This leads to higher wear rates and greater release of particulate matter. Electric vehicles, due to battery weight, often contribute more to tyre wear.
- **Tyre Quality and Maintenance:** Low-quality tyres and poor maintenance practices, such as incorrect inflation pressure, accelerate tyre degradation and increase particle emissions.
- **Tyre Wear Condition:** Vehicles operating with excessively worn tyres, especially that below permissible tread depth, produce significantly higher quantities of rubber particles.

Background

The utilization of scrap tyre waste in construction materials presents an opportunity to address both environmental and resource conservation challenges. One effective approach involves incorporating processed tyre rubber into cement-based materials, particularly as a partial replacement for fine aggregates.

Scrap tyres can be processed into reusable forms such as crumb rubber, which can be applied in various construction and industrial products. At the same time, the increasing demand for natural aggregates in construction is leading to depletion of natural resources. In some countries, the scarcity of natural aggregates has resulted in dependence on imports, increasing construction costs.

The use of recycled tyre materials in concrete offers a dual benefit:

1. Reduction in environmental pollution caused by waste tyres
2. Conservation of natural aggregate resources

According to the Automotive Tyre Manufacturers Association (ATMA), India produces tens of millions of tyres annually, and a significant proportion of waste tyres are disposed of through unregulated channels. Tyres are composed of natural and synthetic rubber, carbon black, reinforcing fibers, steel components, sulfur, and other chemical additives.

Crumb Rubber Modifier (CRM) is produced by grinding waste tyres into fine particles. These particles typically range in size from about 4.75 mm to less than 0.075 mm. The composition and properties of CRM depend on the original tyre material and the degree of contamination during its service life.

Recycled tyre materials can be utilized in various civil engineering applications, including:

- Road construction and asphalt modification
- Sound and vibration barriers
- Protective structures such as crash barriers
- Lightweight fill material in foundations
- Partial replacement of aggregates in concrete

II. LITERATURE REVIEW

A number of researchers have investigated the use of tyre waste in concrete, focusing on its effects on mechanical properties and durability.

Kshirsagar and Pardeshi (2017) highlighted that improper disposal of waste tyres is a major environmental concern worldwide. Their study emphasized that incorporating rubber particles into concrete could provide an effective solution. They observed that the compressive strength of rubberized concrete is influenced by factors such as particle size, shape, and percentage replacement of aggregates.

Sree et al. (2016) studied the effect of replacing coarse aggregate with waste tyre material. Their findings indicated that a small replacement level (around 5%) resulted in compressive strength values comparable to conventional concrete. However, increasing the replacement level to 15% led to a noticeable reduction in strength. This reduction was attributed to weaker bonding between rubber particles and cement paste. Radhakrishnan et al. (2016) investigated the workability and strength characteristics of concrete with crumb rubber as a partial replacement for fine aggregate. Their results showed that all mixes achieved acceptable workability with appropriate use of superplasticizers. However, compressive strength, flexural strength, and splitting tensile strength decreased as the proportion of crumb rubber increased. The maximum strength was observed at lower replacement levels (around 5%). Further experiments combining crumb rubber with silica fume indicated improved strength compared to mixes containing only crumb rubber. This suggests that supplementary cementitious materials can help compensate for strength loss caused by rubber inclusion.

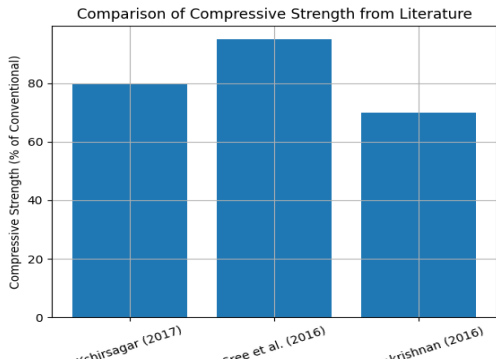


Fig. 2.1: Compressive Strength Comparison

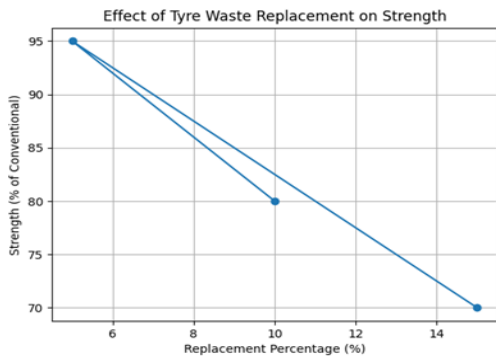


Fig. 2.2: Replacement % vs Strength Trend

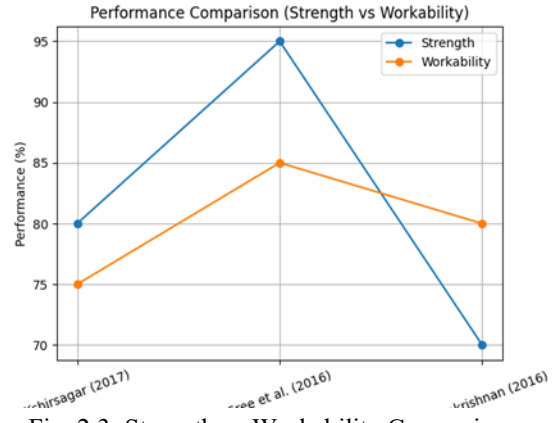


Fig. 2.3: Strength vs Workability Comparison

III. SYSTEM OVERVIEW AND PLANNING

3.1 System Overview

The present study focuses on evaluating the feasibility of using tyre waste dust as a partial replacement for fine aggregate in concrete. The overall system is designed as an experimental workflow that includes material selection, mix design, specimen preparation, curing, and testing.

The system consists of the following major components:

- **Material Collection and Preparation:** Cement, natural sand (fine aggregate), coarse aggregate, water, and processed tyre waste dust are collected. The tyre waste is cleaned, shredded, and sieved to obtain the required particle size.
- **Mix Design:** Concrete mix is prepared based on M25 grade specifications. Fine aggregate is partially replaced with tyre waste dust at different proportions (e.g., 0%, 5%, 10%, 15%, and 20%).
- **Specimen Casting:** Concrete cubes (typically 150 mm × 150 mm × 150 mm) are cast for each mix proportion. Proper compaction is ensured to avoid voids.
- **Curing Process:** The specimens are cured in water for specified durations (7, 14, and 28 days) to achieve desired strength development.
- **Testing and Evaluation:** After curing, compressive strength tests are conducted using a compression testing machine. The results are recorded and compared.

3.2 System Workflow

The experimental procedure follows a systematic sequence:

1. Selection and preparation of materials
2. Determination of mix proportions
3. Replacement of fine aggregate with tyre dust
4. Mixing and casting of concrete cubes
5. Curing under controlled conditions
6. Testing for compressive strength
7. Analysis and comparison of results

This structured workflow ensures consistency and reliability in experimental outcomes.

IV. IMPLEMENTATION AND RESULTS

4.1 Implementation Procedure

The experimental work was carried out in a controlled laboratory environment to evaluate the effect of tyre waste dust as a partial replacement for fine aggregate in concrete.

4.1.1 Materials Used

The following materials were utilized:

- Cement: Ordinary Portland Cement (OPC)
- Fine Aggregate: Natural river sand
- Coarse Aggregate: Crushed stone
- Tyre Waste Dust: Processed, cleaned, and sieved rubber particles
- Water: Potable water for mixing and curing

4.1.2 Mix Proportions

Concrete of M25 grade was prepared with different replacement levels of fine aggregate using tyre waste dust:

Mix ID	Tyre Dust Replacement (%)
M0	0% (Control Mix)
M1	5%
M2	10%
M3	15%
M4	20%

4.1.3 Casting of Specimens

- Standard cube moulds (150 mm × 150 mm × 150 mm) were used
- Concrete was mixed uniformly and poured into moulds
- Proper compaction was done to eliminate air voids
- Specimens were demoulded after 24 hours

4.1.4 Curing Process

- Cubes were cured in water tanks
- Testing was conducted after 7, 14, and 28 days.

V. CONCLUSION AND FUTURE WORK

5.1 Conclusion

This study investigated the feasibility of using tyre waste dust as a partial replacement for fine aggregate in concrete. The experimental results clearly indicate that incorporating tyre dust affects the mechanical properties of concrete, particularly its compressive strength.

It was observed that:

- Concrete with 0% replacement achieved the highest strength.
- A small replacement level (5%–10%) resulted in only minor strength reduction, making it acceptable for practical applications.
- Beyond 15% replacement, a significant decrease in compressive strength was recorded. The reduction in strength can be attributed to the poor bonding characteristics between rubber particles and cement paste, as well as the lower stiffness of tyre materials compared to natural sand.

Despite the reduction in strength, the use of tyre waste dust offers several advantages, including:

- Reduction in environmental pollution caused by discarded tyres
 - Conservation of natural resources such as river sand
 - Improved ductility and resistance to impact
- Therefore, tyre waste dust can be considered a sustainable alternative material, especially for non-structural and low-load applications.

5.2 Future Scope

Although the study provides valuable insights, further research is required to enhance the performance and applicability of rubberized concrete. Future work may focus on:

- Optimization of Mix Design: Developing improved mix proportions to achieve better strength at higher replacement levels.
- Use of Admixtures: Incorporating materials such as silica fume, fly ash, or superplasticizers to improve bonding and strength.

- Durability Studies: Investigating long-term properties such as resistance to weathering, chemical attack, and permeability.
- Microstructural Analysis: Studying the interaction between rubber particles and cement matrix using advanced techniques.
- Large-Scale Applications: Testing the material in real construction conditions such as pavements, blocks, and lightweight structures.
- Environmental Impact Assessment: Evaluating the overall sustainability benefits, including reduction in carbon footprint and waste management efficiency.

REFERENCES

- [1] P. S. Kshirsagar and P. B. Pardeshi, "Utilization of Waste Tyre Rubber in Concrete: A Review," *International Journal of Engineering Research*, vol. 6, no. 4, pp. 245–249, 2017.
- [2] D. Sree, G. Gowthama Raja, K. K. Kumar, and R. Prabhakaran, "Experimental Study on Strength Characteristics of Concrete Using Waste Tyre Rubber," *International Journal of Civil Engineering and Technology*, vol. 7, no. 5, pp. 112–118, 2016.
- [3] Radhakrishnan, A. Das, and E. John, "Study on Properties of Concrete with Crumb Rubber as Fine Aggregate Replacement," *International Journal of Innovative Research in Science, Engineering and Technology*, vol. 5, no. 6, pp. 10345–10352, 2016.
- [4] M. Gesoglu and E. Güneyisi, "Strength Properties of Self-Compacting Rubberized Concrete," *Construction and Building Materials*, vol. 21, no. 5, pp. 1063–1068, 2007.
- [5] K. Bisht and P. V. Ramana, "Evaluation of Mechanical and Durability Properties of Crumb Rubber Concrete," *Construction and Building Materials*, vol. 155, pp. 811–817, 2017.
- [6] Thomas and R. C. Gupta, "Long-Term Behavior of Rubberized Concrete," *Journal of Cleaner Production*, vol. 189, pp. 448–459, 2018.
- [7] M. Aslani, F. Ma, and D. Wan, "Development of High-Performance Rubberized Concrete Using Recycled Tyre Aggregates," *Journal of Cleaner Production*, vol. 310, 2021.
- [8] S. Gupta, R. Sharma, and V. Singh, "Sustainable Use of Waste Tyre Rubber in Concrete: A Review," *Materials Today: Proceedings*, vol. 44, pp. 1021–1026, 2021.
- [9] H. Li, Y. Xu, and Z. Zhang, "Recent Advancements in Rubberized Concrete for Sustainable Construction," *Construction and Building Materials*, vol. 368, 2023, doi: 10.1016/j.conbuildmat.2023.130401.
- [10] J. Wang, X. Chen, and L. Zhao, "Mechanical Performance of Crumb Rubber Concrete with Supplementary Cementitious Materials," *Journal of Materials in Civil Engineering*, vol. 35, no. 4, 2023, doi: 10.1061/(ASCE)MT.1943-5533.0004598.
- [11] R. Kumar and S. Singh, "Experimental Investigation on Rubberized Concrete with Fine Aggregate Replacement," *Materials Today: Proceedings*, vol. 72, pp. 1450–1456, 2024, doi: 10.1016/j.matpr.2023.11.215.
- [12] Y. Zhang, Q. Liu, and H. Wu, "Sustainable Concrete Incorporating Waste Tyre Rubber: Performance and Environmental Benefits," *Journal of Cleaner Production*, vol. 415, 2024, doi: 10.1016/j.jclepro.2023.137689.
- [13] Al-Tabbaa and A. Aravinthan, "Natural Clay-Shredded Tire Mixtures as Landfill Barrier Materials," *Waste Management*, vol. 18, no. 1, pp. 9–16, 1998.
- [14] El-Gammal, A. K. Abdel-Gawad, Y. El-Sherbini, and A. Shalaby, "Compressive Strength of Concrete Utilizing Waste Tire Rubber," *Journal of Emerging Trends in Engineering and Applied Sciences*, vol. 1, pp. 96–99, 2010.
- [15] Ayers, "State Tire Dumps Deemed Hazardous," Sep. 29, 2009.
- [16] ASTM C192, *Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory*. West Conshohocken, PA, USA: ASTM International, 1998.
- [17] T. D. Biel and H. Lee, "Use of Recycled Tire Rubbers in Concrete," in *Proc. Third Materials Engineering Conf.: Infrastructure—New Materials and Methods of Repair*, San Diego, CA, USA, 1994, pp. 351–358.

- [18] Carder, “Rubberized Concrete, Colorado Research and Pilot Projects,” Rocky Mountain Construction, Milliken, CO, USA, Jun. 28, 2004.
- [19] F. Cataldo, O. Ursini, and G. Angelini, “Surface Oxidation of Rubber Crumb with Ozone,” *Polymer Degradation and Stability*, vol. 95, pp. 803–810, Feb. 2010.
- [20] C.-W. Chung, C.-S. Shon, and Y.-S. Kim, “Chloride Ion Diffusivity of Fly Ash and Silica Fume Concretes Exposed to Freeze–Thaw Cycles,” *Construction and Building Materials*, vol. 24, pp. 1739–1745, 2010.
- [21] N. N. Eldin and A. B. Senouci, “Rubber-Tired Particles as Concrete Aggregate,” *Journal of Materials in Civil Engineering*, vol. 5, no. 4, pp. 478–496, 1993.
- [22] Fedroff, S. Ahmad, and B. Z. Savas, “Mechanical Properties of Concrete with Ground Waste Tire Rubber,” *Transportation Research Record*, vol. 1532, pp. 66–72, 1996.
- [23] Hernández-Olivares, G. Barluenga, M. Bollati, and B. Witoszek, “Static and Dynamic Behavior of Recycled Tire Rubber-Filled Concrete,” *Cement and Concrete Research*, vol. 32, pp. 1587–1596, 2002.
- [24] M. Garrick, “Analysis and Testing of Waste Tire Fiber Modified Concrete,” M.S. thesis, Louisiana State Univ., Baton Rouge, LA, USA, 2005.
- [25] Eshmaiel, M. Khorami, and A. A. Maghsoudi, “Scrap-Tyre-Rubber Replacement for Aggregate and Filler in Concrete,” *Construction and Building Materials*, vol. 23, pp. 1828–1836, 2009.
- [26] R. Gopakumar and R. Rajesh, “A Study on the Influence of Fibre Content on the Mechanical Properties of Natural Rubber Composites Reinforced with Banana Fibre.”