Analyzing the Application of Untreated and Treated Rubber Aggregate on the Mechanical Properties of Concrete

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Abstract — The disposal of waste tyres poses a serious environmental challenge due to their non-biodegradable nature and increasing generation worldwide. Incorporating waste tyre aggregate in concrete has emerged as a sustainable alternative that addresses both solid waste management and conservation of natural aggregates. This study investigates the feasibility and performance of concrete in which a portion of conventional fine aggregate is replaced with processed waste tyre aggregate. Emphasis is placed on evaluating the mechanical properties of tyre aggregate concrete under varying replacement levels. Experimental results indicate that the inclusion of waste tyre aggregate leads to a reduction compressive strength compared to conventional concrete. Higher replacement ratios adversely affect strength parameters, optimized proportions show potential for non-structural and semi-structural applications such as pavements, barriers, and vibration-damping elements. The present study deals with the comparative study of untreated and acetic acid treated rubber aggregate on the mechanical properties of concrete. The study highlights that with proper mix design and proportioning, waste tyre aggregate can be effectively utilized in concrete, contributing to sustainable construction practices by reducing environmental pollution and promoting resource efficiency.

Keywords: Rubber Aggregate, Sustainable Concrete, Waste Rubber Tire, Mechanical Properties

I. INTRODUCTION

Concrete is one of the most widely used construction materials in the world due to its durability, versatility, and reliability. Its annual global consumption has reached nearly 10 billion tonnes, reflecting the scale at which cement, sand, and coarse aggregates are extracted. This extensive demand has led to severe depletion of natural aggregate resources, particularly from riverbeds and water bodies. Such uncontrolled extraction has contributed to environmental issues including flooding, landslides, and deterioration of water quality, as natural sand layers that support groundwater filtration are progressively lost [1].

At the same time, waste management has emerged as a critical global challenge, with discarded tyres representing a major concern. Hundreds of millions of waste tyres are generated annually, placing immense pressure on landfills and local authorities. Tyres degrade very slowly, occupy large volumes, and create health hazards by serving as breeding grounds for pests. Although some industries use tyres as fuel, this practice is costly and environmentally undesirable. Recycling options such as reuse in rubber products, road safety barriers, and marine structures exist, yet they ultimately lead back to disposal issues [2].

In this context, incorporating waste tyre rubber into concrete offers a sustainable alternative. Using rubber as a partial replacement for natural aggregates or as fibres in concrete not only reduces environmental pollution but also conserves natural resources. Rubberized concrete thus presents an opportunity to convert waste into a value-added construction material with long-term service potential.

Waste tyre rubber has become a persistent environmental concern worldwide due to the rapid growth of automobile production and the limited capacity of disposal facilities. As vehicle usage continues to rise, large quantities of worn-out tyres are generated each year, creating serious challenges for waste management systems. Many countries have restricted or prohibited the disposal of waste tyres in landfills, as these sites are increasingly scarce and unsuitable for long-term storage of non-biodegradable materials. Consequently, researchers have focused on identifying effective and sustainable methods for managing tyre waste [3].

Recycling has emerged as a promising solution, as waste tyre rubber possesses several beneficial properties, including elasticity, high energy absorption, low density, and thermal and acoustic insulation. These characteristics make recycled rubber suitable for various construction-related applications. End-of-life tyres, which are no longer safe for vehicular use due to surface wear, are often disposed of in landfills or dumped illegally if not recycled or used as fuel. Such practices pose significant fire hazards and environmental risks, while also contributing to greenhouse gas emissions and air pollution [4].

Waste tyres are no longer suitable for reuse and present serious environmental challenges, making their disposal increasingly problematic. Due to their non-biodegradable nature and large volume, tyres are undesirable in landfills and are often classified as an environmental hazard. Although whole tyres have been used in applications such as artificial reefs, erosion control systems, highway safety barriers, and playground equipment, these uses address only a limited portion of the growing waste stream. Traditionally, landfilling was the primary disposal method; however, shrinking landfill capacity has rendered this approach unsustainable [5].

Discarded tyres in landfills create additional risks by trapping methane gas, which can migrate to the surface and promote mosquito and insect breeding, increasing the spread of diseases. Methane movement and liner damage also threaten groundwater and surface water quality. Furthermore, chemical additives in tyres, such as stabilizers and flame retardants, negatively affect soil health by destroying beneficial microorganisms. While the use of waste tyres as alternative fuel has been practiced, it raises concerns related to emissions and environmental safety [6].

Stockpiling of tyres, both legal and illegal, further aggravates the issue. Large tyre dumps pose a high fire risk, with fires that are difficult to control and capable of burning for extended periods, leading to severe air, soil, and water pollution. Consequently, recycling waste tyres into useful products has emerged as a necessary and sustainable solution to mitigate environmental, health, and land-use challenges [7].

II. MATERIALS AND METHODOLOGY

Materials used in the current study are: cement, natural sand, acetic acid treated fine rubber aggregate, coarse aggregate, water, and superpalsticizer. Concrete samples was designed for M25, M30, and M35 grades after following the guidelines of IS:10262-2019 [8]. The properties of different materials are presented in Table1, 2 and 3. Cement used in this study was of M53 grade and its properties were tested according to IS: 269-2015 [9].The objective of the present investigation is to identify the potential use of crumb rubber in concrete. Henceforth extensive research has been carried out to study the mechanical properties of rubberized concrete. The replacement of crumb rubber with fine aggregate ranged from 2% to 20% by weight fraction. Waste tire rubber fibers added to a rubberized concrete mix is expressed as a percentage of the total weight of concrete. Concrete slabs of the optimum percentage of treated crumb rubber aggregate replacement with rubber fibers are cast to derive the impact resistance and ductility index. Experimental investigations have been carried out flexural behaviour of the designed grade of concrete slabs with designing reinforcement.

Sp. gravity	Fineness	Standard consistency	Initial sett. time	Final sett. time	Compressive strength of cement-mortar at 28 days
3.1	4%	30%	35 minutes	512 min.	53.8 MPa

Table 1. Properties of concrete

S. No.	Properties	Sand	Rubber aggregate
1	Sp. Gravity	2.62	1.3
2	Water absorption	2%	1.3%
3	Fineness modulus	3.56	4.15

Table 2. Properties of sand and rubber aggregate

S. No.	Properties	Coarse aggregate
1	Sp. Gravity	2.72
2	Water absorption	1%
3	Fineness modulus	4.72

Table 3. Properties of coarse aggregate

III. RESULTS AND DISCUSSION

A. Compressive strength of rubber aggregates mixed concrete

From Figure crumb rubber replacements of 2%, 4%, 6%, 8% and 10% shows lower compressive strength compared with conventional concrete. The performance of CRAC of fine crumb rubber replacements in M25 grade concrete (Figure 1) is quite discouraging up to 10% replacements has meagre compressive strength. In the lot, 10% replacement of crumb rubber performs comparatively lower than that of 70% achievement of 28 days compressive strength of conventional cube. 8% replacement of crumb rubber aggregate almost equals the 10% replacement specimen, and 4% and 6% replacements also have equal strength. 2% replacement show higher values compared with other replacements.

Untreated CRAC compression test results indicated that there was a substantial reduction in the strength values with the increase in rubber content. The reduction in strength is because of the rubber has more elasticity than hardened cement paste surrounding it; fracture would begin from their interface and propagate through concrete. The bond developed between the particles and the surrounding matrix is improved. Significantly higher compressive strength of rubberized concrete could be obtained, and to achieve enhanced adhesion, it is necessary to pre-treat the rubber aggregate. Three types of acidic solutions are used to treat the crumb rubber and study the effect of this treatment on the mechanical properties of CRAC. Compressive strength results for concrete samples with untreated and treated rubber aggregate are presented in Figures 1 & 2, respectively.

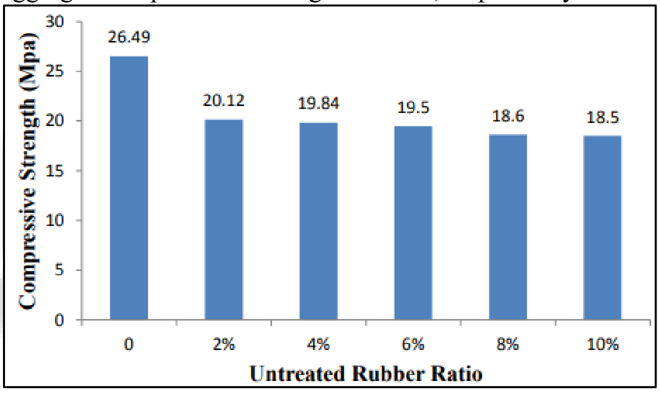

Fig. 1: Compressive strength results for untreated rubber aggregate mixed concrete

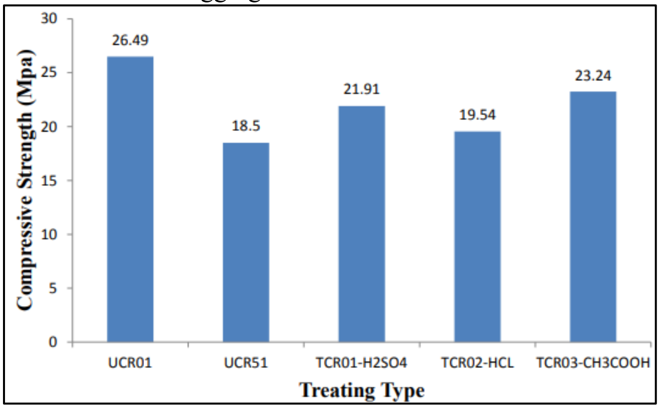

Fig. 2: Compressive strength for treated rubber aggregate (10% content) mixed concrete

B. Tensile strength of rubber aggregate mixed concrete

From Figure crumb rubber replacements of 2%, 4%, 6%, 8% and 10% shows lower tensile strength compared with conventional concrete. The performance of CRAC of fine crumb rubber replacements in M25 grade concrete is quite discouraging. Up to 10% of replacements, the tensile strength was very low. In the lot, 10% replacement of crumb rubber performs comparatively lower than that of 60% achievement of 28 days tensile strength of conventional cylinder. 2% replacement show higher values compared with other replacements. 2%, 4%, 6%, 8% and 10% replacements perform lower strength compared to conventional concrete. 2% replacement of crumb rubber performs comparatively lower than that of 80% achievement of 28 days tensile strength of concrete cylinder.

Untreated CRAC tension test results indicated that there was a large reduction in the strength values with the increase in rubber content. Figure 4 shows the tensile strength of rubberized concrete (10% crumb rubber) for different acidic solution treatment. It is found that the average decrease in the tensile strength, when added 10% rubber particles and treat it with CH3COOH (5%), is about 11.87% from conventional concrete so that the CH3COOH (5%) was very effective in improving the tensile strength by about 45.56% from untreated rubberized concrete. On the other hand, when the rubber particles of the waste tire were treated with H2SO4 (35%) to improve its split tensile strength by about 17.08% from untreated rubberized concrete, and HCL (5%) treatment also improve the tensile strength is about 14.55% from untreated rubberized concrete. Using crumb rubber treating with CH3COOH (5%) increase tensile strength more than H2SO4 (35%) and HCL (5%). Crumb rubber treated withCH3COOH improved cement concrete properties when compared with untreated rubberized concrete. Tensile strength results for concrete samples with untreated and treated rubber aggregate are presented in Figures 3 & 4, respectively.

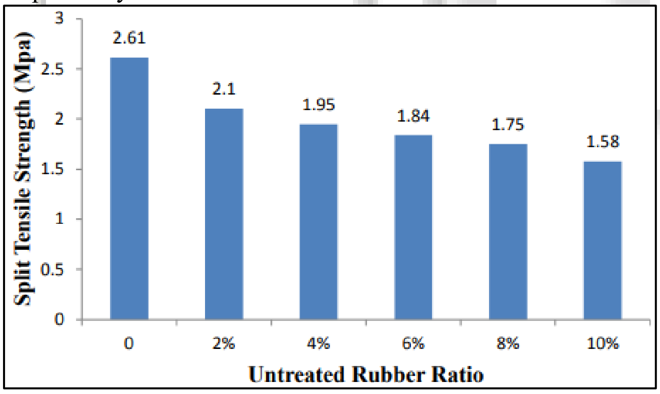

Fig. 3: Tensile strength results for untreated rubber aggregate mixed concrete

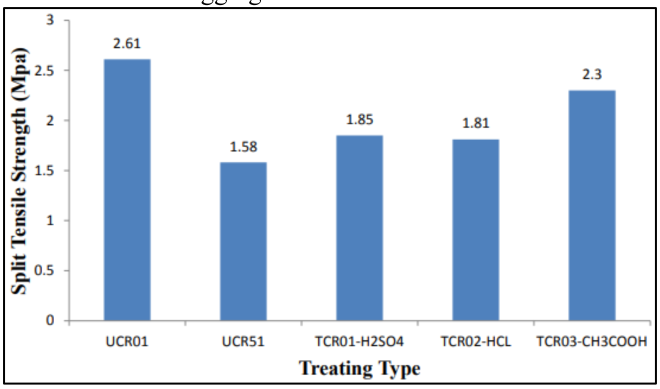

Fig. 4: Tensile strength results for treated rubber aggregate (10% content) mixed concrete

C. *Flexural strength of rubber aggregate mixed concrete*

From Figure crumb rubber replacements of 2%, 4%, 6%, 8% and 10% shows lower flexural strength compared with conventional concrete. The performance of CRAC of fine crumb rubber replacements in M25 grade concrete (Figure 5) is quite encouraging up to 10% replacements perform very high flexural strength. In the lot, 10% replacement of crumb rubber performs comparatively almost equal to the 28 days flexural strength of conventional prism.

Untreated CRAC flexural test results indicated that there was a significant increase in the strength values with the increase in rubber content. Figure 6 shows the flexural strength of rubberized concrete (10% crumb rubber) for different acidic solution treatment. It is found that the average increase in the flexural strength, when added 10% rubber particles and treat it with CH3COOH (5%), shows 31.12% higher strength than the conventional concrete so that the CH3COOH (5%) was very effective in improving the flexural strength by about 33.82% from untreated rubberized concrete. On the other hand, when the rubber particles of the waste tire were treated with H2SO4 (35%) to improve its flexural strength by about 10.29% from untreated rubberized concrete and HCL (5%) treatment decrease the flexural strength is about 8.82% from untreated rubberized concrete. Using crumb rubber treating with CH3COOH (5%) increase flexural strength more than H2SO4 (35%) and HCL (5%).

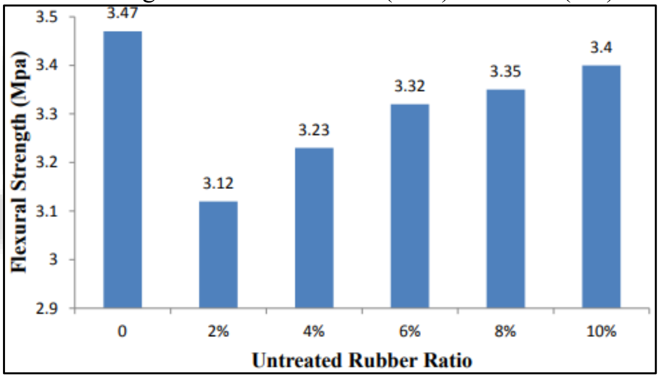

Fig. 5: Flexural strength results for untreated rubber aggregate mixed concrete

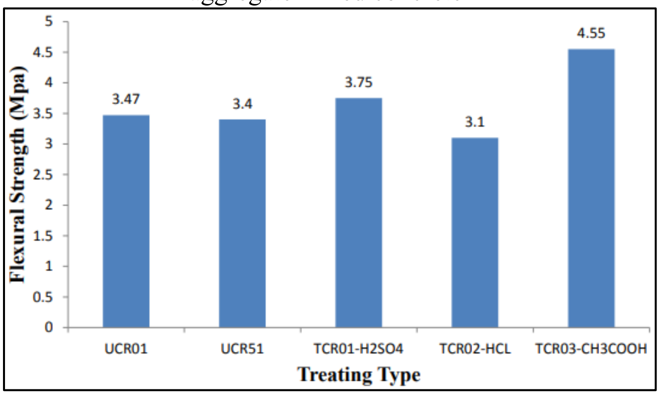

Fig. 6: Flexural strength results for treated rubber aggregate (10% content) mixed concrete

IV. Conclusion

Concrete specimens mixed with the untreated rubber aggregate contents showed a reduced compressive strength, tensile strength, and flexural strength. After the treating of raw untreated rubber aggregate by acetic acid in a scientific manner increased all the mechanical attributes of concrete viz., compressive strength, tensile strength, and flexural strength all round. The application of untreated rubber aggregate in conventional concrete may not be found satisfactory for the concrete requiring high mechanical strength and it may be limited to the inferior works only. On the other hand, the application of treated rubber aggregate may serve the purpose of advanced concrete due to its enhanced load carrying capacity. The application of rubber aggregate will not only help to reduce the dependency on the natural sand by replacing it with rubber aggregate aggregate, but also solve the disposal problems of waste rubber tyre. The application of rubber aggregate in concrete will save the environment as well as solve the problem of quarrying sand from rivers, thus providing a two-fold benefits.

REFERENCES

[1] Abrham Kebede Seyfu 2010, „The Use of Recycled Rubber Tyres as a Partial Replacement for Coarse Aggregates in Concrete Construction", Msc Thesis, The School of Graduate Studies of the Addis Ababa University.
[2] ACI 544.2R–89. 1999, „Measurement of Properties of Fiber Reinforced Concrete", Reported by ACI Committee 544.
[3] Adams, C, Lamborn, M & Shuler, S 1985, „Asphalt – Rubber Binder Laboratory Performance", Report FHWA/TX-8571, 347 – 1F, Texas Department of Highways and Public Transportation.
[4] Adhikari, B, De, D & Maiti, S 2000, „Reclamation and Recycling of Waste Rubber", Progress in Polymer Science, vol. 25, no. 7, pp. 909-948.
[5] Ahmed, I 1993, „Laboratory Study on Properties of Rubber-soils", PhD Thesis, School of Civil Engineering, Perdue University, W Lafayette.
[6] Ahmed, I. & Lovell, C.W 1992, „Use of Waste Materials in Highway Construction: State of the Practice and Evaluation of Shredded Waste Products", Transportation Research Board, Washington DC, pp. 1-9.
[7] Ahmed, R & Arnold van de Klundert 1996, „Rubber Waste Options for Small-scale Resource Recovery", Urban Solid Waste Series 3, Waste, Nieuwehaven 201, 2801 CW Gouda, the netherlands.
[8] IS:10262-2019, „ Concrete Mix Proportioning-Guidelines
[9] IS: 269-2015, „ Ordinary Portland Cement-Specification