Experimental Investigation on Properties of Scrap Rubber Tyre as Fine Aggregate in Concrete

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Abstract. In the current work, Investigation of a cube, cylinder, and beams cast of M35 grade by replacing 5,10,15 and 20 percent of rubber tyre with fine aggregate as well as 0.5%,1%,1.5%, and 2% of conplast SP430 superplasticizer were added respectively and their properties were articulated. Waste tyre concrete, also known as rubberized concrete, is an innovative and sustainable construction material that addresses both environmental concerns and the need for enhanced concrete properties. The waste tyre rubber inclusion in concrete not only decreases the environmental effect of tyre disposal but also enhances the concrete's mechanical and durability characteristics. The process of producing waste tyre concrete involves shredding and grinding waste tyres into small rubber particles, which are then mixed with cement, fine aggregates, and water to form the concrete mixture. The appropriate mix design ensures an optimal balance between rubber content and other ingredients to achieve the desired performance. From the study, it is endorsed that 10 percent of rubber tyre partially replace the fine aggregate which provides the optimum compressive strength of 36.42 N/mm^2 using a superplasticizer. The rubber concrete of 10% replacement shows an improvement of 1.6 times when compared with the traditional concrete.

Keywords: Rubber tyre, Superplasticizer, concrete, Partial replacement, Compressive strength

1 Introduction

In recent years, the rapid expansion of urban infrastructure and industrialization has led to an alarming rise in the generation of waste materials, posing significant environmental and sustainability challenges. Among these materials, scrap rubber tyres have gained important attention because of their non-biodegradable nature and potential to cause environmental hazards if improperly disposed of. As a result, researchers and engineers have been exploring innovative approaches to repurpose these discarded tyres, mitigating their negative impact and

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transforming them into valuable resources. Concrete, being among the most broadly utilized construction materials globally, presents an intriguing avenue for the integration of scrap rubber tyres. Traditional concrete production relies heavily on natural aggregates, such as sand and gravel, which are becoming increasingly scarce and environmentally unsustainable. Moreover, the disposal of waste tyres in landfills or through incineration contributes to pollution and energy consumption. Therefore, seeking sustainable alternatives to conventional construction materials is of paramount importance. This experimental investigation proposes to explore the feasibility of using scrap rubber tyre particles as a partial replacement for fine aggregate within concrete. The potential benefits of this approach is multifaceted, ranging from environmental conservation and waste reduction to improved material properties and enhanced mechanical performance by systematically analyzing the effects of incorporating scrap rubber tyre particles into concrete mixtures, this research objective is to shed light on the structural, mechanical, and durability properties of the resulting composite material. The study will delve into various aspects, including the optimal percentage of rubber tyre particles that can be added to the concrete mixture without compromising its durability and strength. Special emphasis will be placed on evaluating the flexural strength, compressive strength, tensile strength, as well as workability of the rubberized concrete. Furthermore, the study will delve into the potential benefits of rubberized concrete in terms of energy absorption, noise reduction, and enhanced thermal insulation in future research. These properties could find applications in various construction contexts, from road pavements and bridge decks to sound barriers and energy-efficient structures. As the world seeks sustainable solutions to its growing waste management and resource utilization challenges, the findings of this experimental investigation hold promise for revolutionizing concrete production and contributing to an eco-friendly construction industry. By harnessing the latent potential of scrap rubber tyres and exploring their incorporation into concrete, may pave the way for a more resilient and environmentally conscious future. In the subsequent sections of this paper will delve into the experimental methodology, materials, and procedures employed to carry out the investigation, followed by an in-depth analysis of the obtained results and their implications for the field of construction materials.

2 Objective and prior research

Evaluating the impact of incorporating scrap rubber tyre as fine aggregate in the concrete makes the construction field and Mother Earth sustainable for the future generations. A brief review of trials using scrap rubber as a replacement for above mentioned concrete, citing significant contributions if review articles are presented. Gajendra Rajan, R. et al. [1] recommended using a surface modification method to modify the rubber's surface to produce a strong chemical connection between the cement and rubber matrix. The flexural and compressive strength of CRC (“Crumb Rubber Concrete”), which is slightly higher than that of NAC (“Natural Aggregate Concrete”), is only possible with fine CR size replacements for sand, and the ideal CR replacement level from 0 percent to 10 percent in terms boosts compressive strength by 2%. A. Sofi et al. [3] For coarse aggregates, different weight percentages of chipped rubber were substituted, and for cement in the second set, scrap tyre powder. A few typical mechanical and durability testing was conducted, and the findings were examined. Guo, S. et al. [4] The samples with a 25 percent replacement rate might still meet the strength needs for rigid pavement construction. Rubber concrete has a greater electrical resistance than regular concrete, which suggests that it is more durable and has less permeability. Thomas et al. [5] reported that waste tyre rubber in the type of crumb rubber has been substituted with natural fine aggregates in increments of 2.5 percent from 0 to 20 percent. Utilizing Abaqus, analytical investigations were carried out, and the outcomes have been compared to flexural and compressive strengths discovered in the lab. R. Bharathi Murugan and Co. [6] The substitution of crumb rubber enhanced the flexural strength by up to 15%. By utilizing design codes, it was possible to investigate the link between the elasticity's static modulus and the flexural and compressive strength of concrete that included and did not contain crumb rubber. Results from Wakchaure, M. R., and Chavan, M. P. A. [7] showed that replacing waste tyre crumb rubber particles with fine aggregate within concrete at proportions of 0.5 & 1 percent had no impact on the concrete's properties, but at 1.5 percent and 2 percent, substantial modifications were seen in comparison to same normal concrete. et al. [8] Issa, C. A. By replacing a volume of fine aggregates with crumb rubber, an adequate compressive strength might be attained with as little as 25 percent of the original volume. Senthil Vadivel, R. Thenmozhi, and Thiyagarajan [9] Ninety cubes, cylinders, and beam samples overall were cast, and they were contrasted with 18 standard samples by replacing the fine aggregate with rubber shreds in proportions of 2, 4, 6, 8, and 10% by weight. Workability, flexural, tensile, compressive, and strength were examined, and lastly, it is suggested that waste tyre rubber aggregate be used in M20 concrete at a replacement rate of 6%. Maghsoudi, A., Ganjian, E., et al. [10] The findings suggested that up to 5% replacement in each set would not significantly alter the concrete properties; but, when replacement ratios were increased, significant modifications were seen.

3 Experimental investigation

Materials used

- Cement, a fundamental building material plays a pivotal role in construction and infrastructure development. Comprising a mixture of finely grounded clinker, gypsum, and other additives, cement is used as a binding agent to hold various construction materials together. In this project, "Ordinary Portland Cement" grade53 was used. The OPC physical properties and test results were compared with the requirement according to IS 12269-1987 in Table 1

Table 1. Properties of Ordinary Portland Cement (Grade 53)

S.no	Properties	Results	Requirement according to IS 12269-1987
1	Compressive strength of cement	53 MPa	53MPa
2	The fineness of cement	4.90%	Should be less than 10%
3	Specific gravity	3.15	--
4	Setting time of cement a) Initialsetting b) Final setting	38 mins 452 mins	Not less than 30 mins Not more than 600 mins
5	Consistency	33%	--

- Fine aggregate is a crucial component in the field of construction, typically with a particle size of 4.75mm or less. Many additional minerals could be present as ingredients, including mica, feldspars, and shale, based on the kind of rock from which it was recovered and the amount of erosive action it has experienced.

- Coarse aggregates are essential components of concrete and play a crucial role in construction projects. They are granular materials with particle sizes larger than 4.75 mm (0.19 inches) and serve to provide bulk and stability to the concrete mixture. These aggregates form the skeleton of the concrete, occupying approximately 60-75% of its volume.
- Rubber aggregate is an innovative and eco-friendly construction material that incorporates recycled rubberparticles into the concrete mix. The production of rubber aggregate involves shredding and grinding waste tyres into small, granular rubber particles. These particles are then mixed with the concrete mixtureduring the batching process. The specific gravity of the Scrap tyre is 1.5

Fig. 1. Powdered scrap rubber tyre

- Conplast SP430 is used for its highly effective superplasticizer admixture that significantly improves the performance and workability of concrete mixes. Itsability to reduce water content while enhancingstrength and durability. Added 0.5%, 1%, 1.5%, and 2% to raise the workability of the concreterespectively

4 Mix Design

In this study, M35 grade on concrete is used as per 10262:2009[11]. The proportion of the mix is shown in Table 2

Table 2. Mix Proportion

Mix proportion for M35 Grade	Cement	Fine Aggregate	Coarse Aggregate	Admixture	W/c Ratio
1:1.6:2.6	426.67	703.42	1116.64	Conplast SP430	0.45

Fig. 2. Mixing as per proportion (10% replacement)

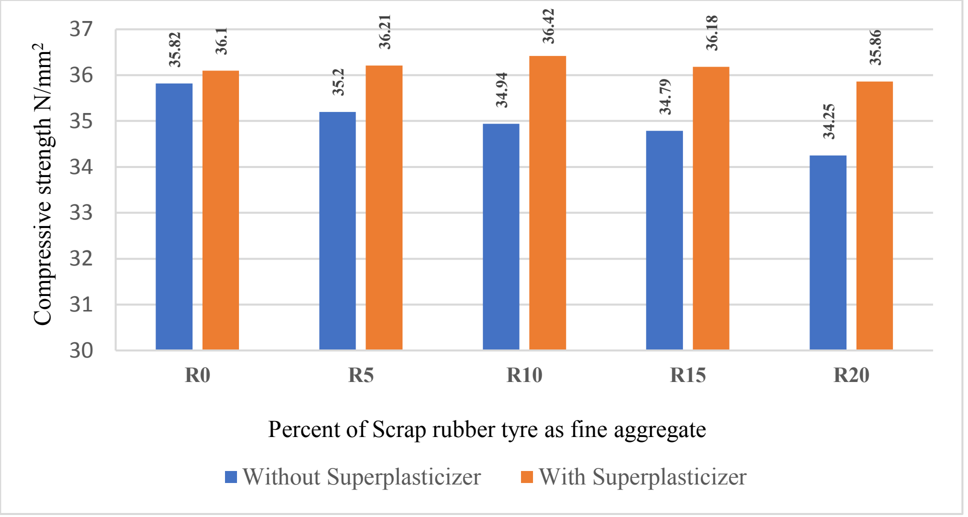
5 Results and Discussion

5.1 Compressive strength test

The Rubber aggregate was mixed with the cement, coarse aggregate, fine aggregate, admixture and water are in the appropriate amounts according to the mix design, and the mixture is poured into a cube mould of specimen 150mm X 150mm X 150mm. The sample is then cured under controlled conditions for twenty-eight days to achieve the desired strength development. The test was carried out in two phases (i.e.,) without superplasticizer and with superplasticizer. Here R0 is conventional concrete, R5% denotes 5% of replacement of rubber tyre as fine aggregate, and R15 and R20 are 15% and 20 % of replacement respectively, In a total of 10 cubes were prepared. The findings attained are shown in Table 3. From the findings, it is able to understand the 10% replacement (R10) with superplasticizer gives an optimal value when compared with the other Mix percentages.

Table 3. Results of M35 grade compressive strength N/mm^2

Mix	Without Superplasticizer	With Superplasticizer
R0	35.82	36.10
R5	35.20	36.21
R10	34.94	36.42
R15	34.79	36.18
R20	34.25	35.86

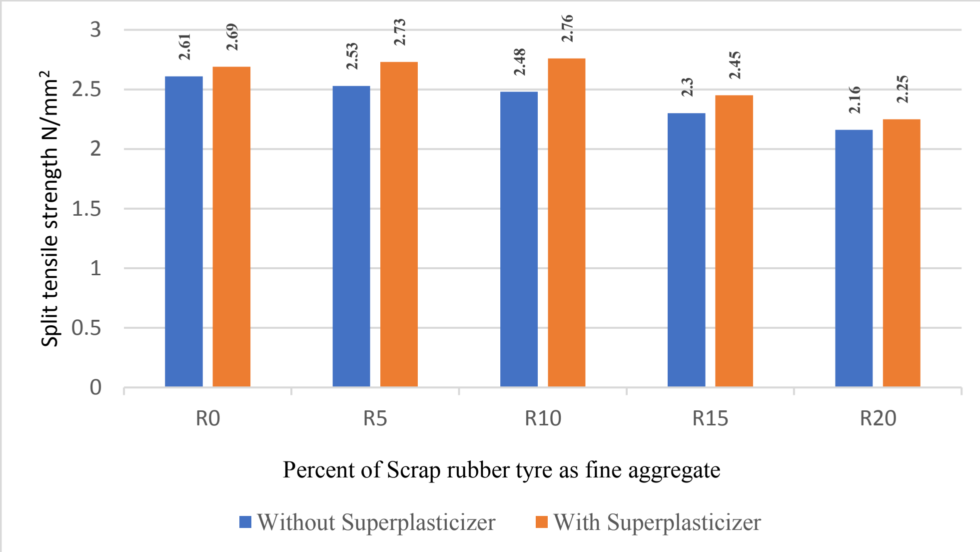


5.2 Split tensile test

The cylindrical specimens of 150mm X 300mm were used for the test. The concrete is cured under controlled conditions for 28 days to achieve the desired strength development. The test was carried out in two phases (i.e.,) without superplasticizer and with superplasticizer, in which a total of 10 cylinders were moulded for the test. The findings attained are shown in Table 4. From the results, it is can able to understand the mix percent of 10 (R10) with superplasticizer gives a gilt–edge value when compared with the other Mix percentage.

Table 4. Results of M35 grade split tensile strength N/mm^2

Mix	Without Superplasticizer	With Superplasticizer
R0	2.61	2.69
R5	2.53	2.73
R10	2.48	2.76
R15	2.30	2.45
R20	2.16	2.25



5.3 Flexural strength test

The results attained from the compression and split tensile test show that the test values of rubber concrete without superplasticizer are below the conventional only. So, the flexural strength trial on the beam was carried out for the concrete with rubber tyre as a partial replacement as well as the superplasticizer conplast SP430 to the concrete at a level of 0.5%, 1%, and 1.5% respectively. In total 3 beams of cross section 150mm X 200mm and a length of 1200mm were cast and cured. And the test result after twenty-eight days of curing has been revealed in Table 5. From this test result, it is neat as pin showed that the 10% replacement of rubber tyre laid out an optimal strength evidently when compared with another mix percentage such as R5 and R15.

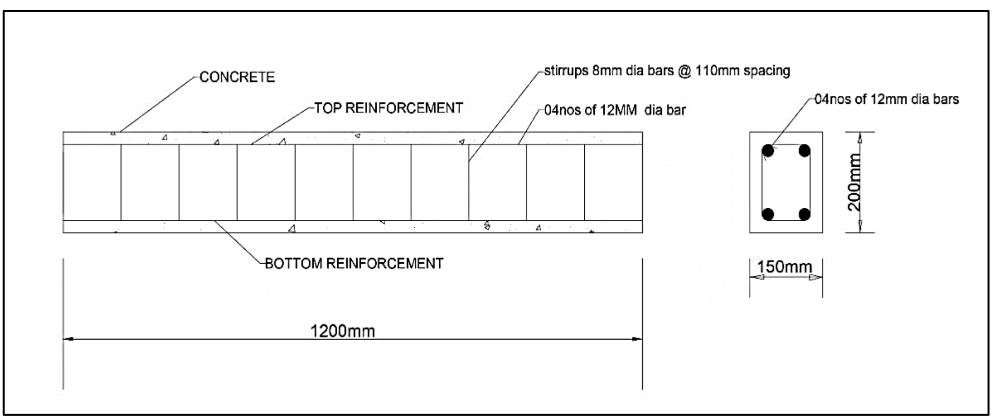


Fig. 3. Schematic representation of the test specimen

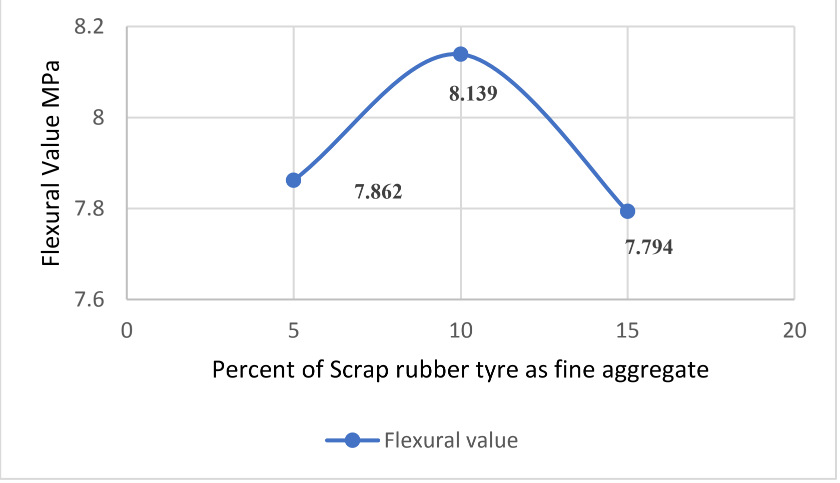
Fig. 4. Casted beams of R5, R10 and R15

Fig. 5. Beam placed for loading frame of 100 Ton capacity

Fig. 6. Flexural strength test on a beam

Table 5. Results of M35 grade flexural strength MPa

Mix	Flexural value MPa
R5	7.862
R10	8.139
R15	7.794



5.4 FEA using Abaqus

Abaqus is a widely used Finite element analysis software primarily used for simulating and analysing the behavioural of complex structure and materials. By applying this software on the partially replaced scrap rubber tyre it derived the output of the beam, due to deflection has been showed in below

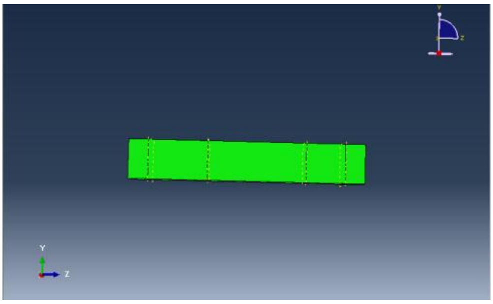


Fig. 7. Before Meshing of beam

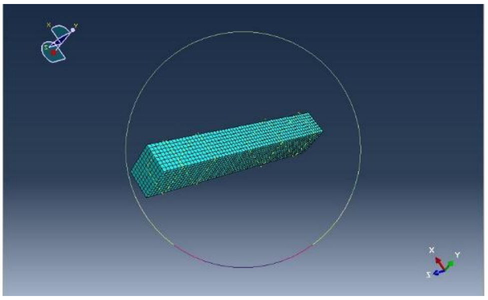


Fig. 8. After Meshing of beam

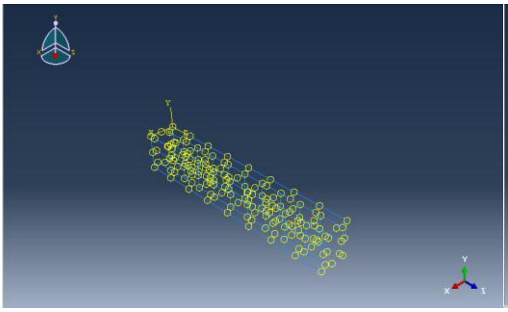


Fig. 9. Interaction module

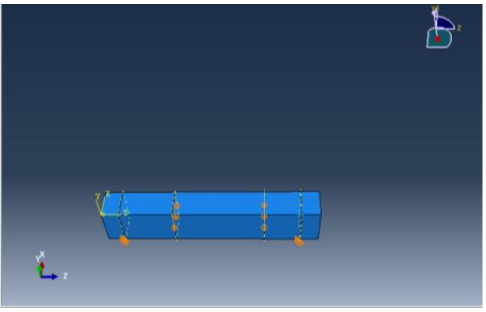


Fig. 10. Load applied to the beam

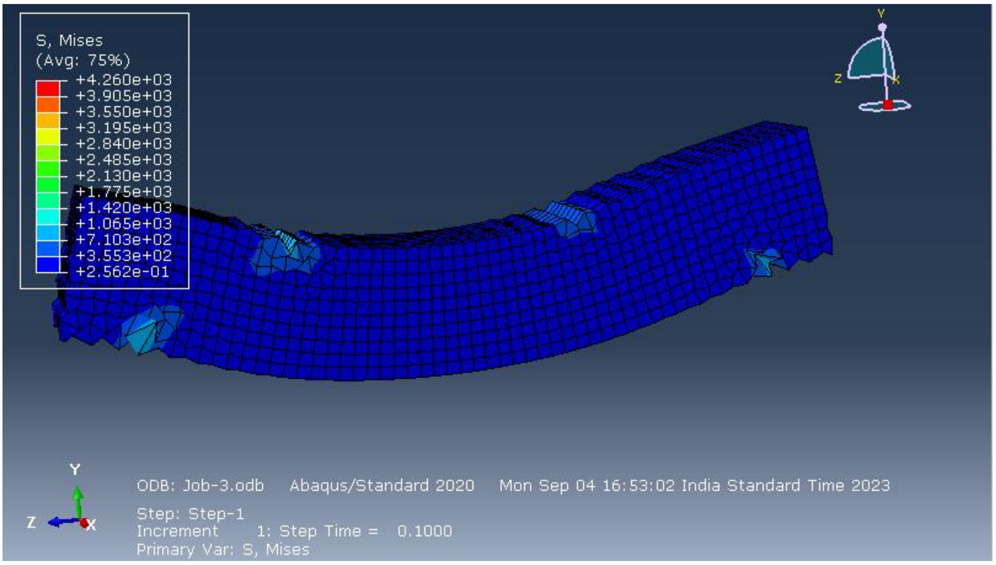


Fig. 11: Deflection on beam

6 Conclusion

In conclusion, the usage of scrap rubber tyre as fine aggregate in concrete has revealed promising findings in terms of improving the concrete's mechanical properties while reducing its environmental impact. The scrap rubber tyre and superplasticizer incorporation in concrete mixtures can increase the flexural strength, compression strength, and toughness of concrete. Additionally, using scrap rubber tyre as fine aggregate in concrete could also offer a sustainable solution for the waste tyres disposal, which is a substantial environmental concern globally. During ambient curing, the compressive strength was highly increased in 28 days. It is concluded that the scrap rubber tyre can be replaced with fine aggregate at 10% to achieve appreciable compressive strength in twenty-eight days of ambient curing. The maximum compressive strength achieved in this project work for scrap rubber tyre replaced fine aggregate in concrete is 36.42 N/mm^2 in the compressive strength test and 8.139 MPa in flexural strength test. Considering the strength criteria, the Sand replacement with a scrap rubber tyre is feasible. Moreover, the concrete containing scrap rubber will also prove to be more economical and environmentally friendly in comparison to traditional concrete. Overall, the usage of scrap rubber tyre as "fine aggregate" in concrete shows great potential for enhancing the sustainability and performance of concrete structures while addressing the challenges of waste tyre management.

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