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PARTIAL REPLACEMENT OF COARSE AGGREGATE IN CONCRETE BY WASTE TYRE RUBBER

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Abstract : The enormous development on production of vehicles resulted in growing amount of waste rubber tyre. Consequently, waste rubber is considered as one of the most waste materials that might cause environmental problems. Incorporating tyre rubbers in concrete pavement has been widely studied as one of the promising and sustainable solutions to these current environmental problems. Non-biodegradable waste has become a big problem in the world in recent years. Increased consumption of materials such as plastic, rubber, and glass in domestic and industrial operations in quickly emerging countries such as India has impacted our daily lives. Our research focuses on how to correctly use waste Rubber as a Coarse Aggregate Replacement Material in Concrete while minimising the use of coarse aggregate. By substituting rubber for coarse aggregate, the environment will be protected from rubber pollution and aggregate extraction through quarrying. This will be really beneficial to the environmental. The results of replacing fine and coarse particles in concrete mix with tyre rubber are proposed in this research. It goes through the effects of using rubberized concrete in structural elements on ultimate compressive strength. Rubcrete also has strong mechanical qualities, making it one of the most efficient and cost-effective ways to recycle used tyres. This paper explored the effect of replacing coarse aggregate with waste tyre rubber on respective percentages. Three replacement ratios were suggested to substitute the coarse aggregate in concrete of 5%, 10% and 15%and comparing the compressive strength, flexural strength and split tensile strength in partial replacement of waste rubber tyre cubes. The M20 grade concrete specimen was chosen as the reference concrete specimen in this experimental study. In place of typical coarse aggregate, scrap tyre rubber chips were used as coarse aggregate.

***IndexTerms* - Cement Concrete, Compressive Strength, Flexural Strength, Rubcrete, Split Tensile Strength, Waste Rubber Tyre**

I. INTRODUCTION

Concrete is one of the most widely used construction materials globally, offering strength, durability, and versatility. However, the growing demand for concrete has led to environmental concerns, especially due to the excessive consumption of natural resources like sand, gravel, and crushed stone for coarse aggregates. Additionally, the disposal of waste materials, such as used tyres, presents a significant environmental challenge.

In response to these concerns, researchers and engineers have explored the potential for replacing conventional coarse aggregates in concrete with alternative materials, such as waste tyre rubber. Tyre rubber, a by-product of the automobile industry, is often discarded as waste, contributing to environmental pollution. However, its properties make it an interesting candidate for partial replacement in concrete production.

The incorporation of waste tyre rubber into concrete not only provides a sustainable solution for managing tyre waste but can also lead to improvements in the material properties of concrete. Waste tyre rubber offers benefits like reduced density, improved workability, and increased flexibility, which could be advantageous in specific applications, such as lightweight or impact-resistant concrete.

This research explores the feasibility of using waste tyre rubber as a partial replacement for coarse aggregate in concrete, investigating its effects on the mechanical properties, durability, and overall performance of the concrete. By examining the potential advantages and challenges, this study aims to contribute to the development of more sustainable construction practices while addressing environmental concerns related to waste tyre disposal.

II. LITERATURE REVIEW

N. D. Luong (2023): The study found that the compressive strength of concrete decreases with the replacement of coarse aggregate by rubber, with coarse rubber particles reducing strength more than fine rubber particles. At higher replacement proportions (20%-50%), the strength reduction becomes more pronounced, though fine rubber shows less reduction compared to coarse rubber.

G. N. Kumar (2023): As the percentage of rubber powder in concrete increases, the compressive strength, density, and modulus of elasticity decrease, while water absorption and thermal insulation increase. Rubber powder also improves the flexibility and impact resistance of concrete, making it a viable lightweight concrete alternative.

Reza Hassanli (2022): The study observed a significant reduction in compressive, split tensile, and flexural strengths with higher rubber content, attributing this to poor adhesion between rubber and cement paste, leading to weak spots in the concrete. Rubber's softer nature and stiffness difference from cement also causes early cracking.

Venkatesh.P (2022): The inclusion of 10% reused foundry sand and 5% waste tyre rubber in concrete improved compressive strength, split tensile strength, and flexural strength, with the concrete displaying better impact resistance and toughness. The use of rubber reduced the concrete density due to rubber's lower density compared to traditional aggregates.

Dr. J KDattatreya & S. Suresh Raghu N.E (2022): The study showed that rubberized concrete, when confined by FRP sheets, exhibited increased ductility, which is beneficial in seismic applications. The confined concrete displayed similar volumetric behavior to conventional concrete but with better ductility and energy dissipation.

Kotresh K.M & Mesfin Getahun Belachew (2022): Despite the reduction in compressive strength, rubberized concrete offers significant potential in construction, especially for non-load bearing applications, by reusing discarded tyres. Improving the bond between rubber aggregates and cement can further enhance strength and usability.

Mohd. Mohsin Khan (2021): Crumb rubber can partially replace coarse aggregates in concrete, leading to reduced strength but offering benefits in toughness and deformability, making it suitable for non-structural applications where flexibility and vibration damping are essential.

Prof. (Dr) J. Bhattacharjee (2020): The study concluded that replacing up to 10% of fine aggregate with crumb rubber does not significantly reduce compressive strength, maintaining more than 65% strength after 7 days and 99% after 28 days. This suggests that low replacement levels can be effective in concrete mixes.

L A Khan (2019): Replacing 10% silica fume with cement and 2.5% rubber aggregates with coarse aggregates improved concrete's compressive and flexural strength. This combination provided an optimal mix for strength enhancement and overall concrete performance.

S. A. A. Mustafa (2019): Rubberized concrete shows lower compressive strength than conventional concrete, but a replacement ratio of less than 20% can still yield acceptable strength. To improve rubber's performance in concrete, the use of coupling agents to enhance adhesion is recommended.

Mr. P Gorde (2018): While tyre rubber reduces the strength of concrete, it has potential for use in earthquake-prone regions or dynamic structures like railway sleepers. The use of a controlled amount of rubber can reduce environmental impact and make concrete more cost-effective in specific applications.

Zeineddine Boudaoud & Miloud Beddar (2017): The study concluded that waste tyre rubber can be used in concrete, despite the reduction in compressive strength. It is most suitable for non-load-bearing applications such as pavements, offering a cheaper, more eco-friendly alternative to traditional concrete.

Akinwonmi & Seckley (2016): The study found that up to 2.5% replacement of natural aggregates with shredded rubber increased compressive strength slightly, but any higher percentage caused a significant drop in strength. Crumb rubber, however, showed poor results and was not recommended for use in concrete.

Amjad A. Yasin (2016): Replacing natural aggregates with shredded tyre rubber significantly reduced the compressive, tensile, and flexural strength of concrete, making it unsuitable for structural components where high strength is required. However, it could be used in non-structural applications like pavements or road barriers.

Taha et al. (2015): Replacing 100% of natural aggregates with rubber aggregates resulted in a drastic reduction in compressive strength by about 75%. The concrete failed easily, highlighting the need for careful consideration of rubber content in concrete mixes.

III. METHODOLOGY

The methodology is shown in Fig 1.

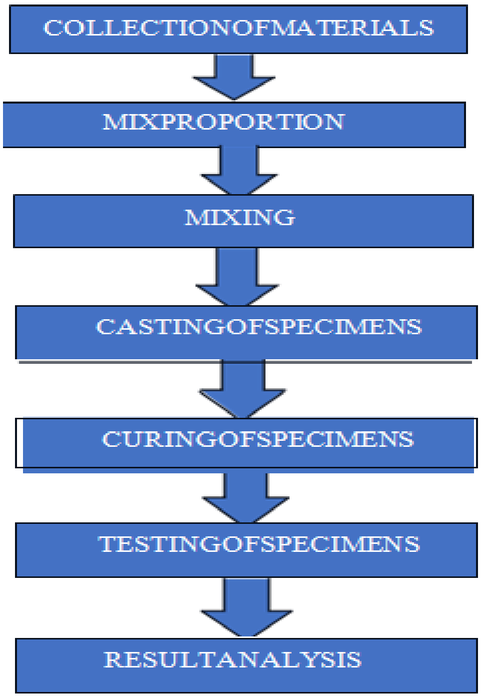


Fig 1: Methodology

IV. EXPERIMENTALPROCEDURE

The experimental procedure for the partial replacement of coarse aggregate with waste tyre rubber in concrete involves several steps, beginning with the collection and preparation of materials. The essential materials used in this study include Ordinary Portland Cement (OPC), fine aggregate such as clean river sand, and conventional coarse aggregate in the form of crushed stone. Waste tyre rubber is collected, shredded, or chipped to a suitable size to serve as a partial replacement for coarse aggregate. Potable water is used for mixing and curing, while chemical admixtures may be incorporated to improve workability and strength characteristics.

The next step involves mix proportioning, where a reference concrete mix is designed as a control sample. Various concrete mixes are then prepared by replacing a specific percentage of coarse aggregate with waste tyre rubber. The water-cement ratio is kept constant across all mixes to ensure consistency in comparison. The replacement percentages are determined based on previous research or trial experiments to assess the effect of rubber content on the properties of concrete.

Batching and mixing follow, where the required amounts of cement, fine aggregate, and coarse aggregate are weighed accurately. The waste tyre rubber is then added in predetermined proportions. Dry mixing is carried out first to achieve uniformity, followed by the gradual addition of water while mixing. The mixing process continues until a homogenous concrete mixture is obtained. If chemical admixtures are used, they are incorporated as per standard guidelines to enhance the properties of the fresh concrete.

Once mixing is complete, the concrete is poured into standard molds for cubes, cylinders, and beams, which are pre-coated with a release agent to facilitate demolding. The concrete is placed in layers, and each layer is compacted properly to remove air voids. After filling the molds, the surface is leveled and the specimens are left undisturbed for an initial setting period before demolding.

After demolding, the specimens undergo curing to ensure proper hydration and strength development. The samples are submerged in water tanks for a predefined curing period, typically 7, 14, and 28 days. Curing plays a vital role in the development of concrete properties and ensures that the influence of waste tyre rubber on strength and durability can be assessed accurately.

Several tests are conducted on both fresh and hardened concrete specimens. The workability of fresh concrete is evaluated using the slump test, which helps determine the consistency and ease of placement. Compressive strength tests are performed on cube specimens using a compression testing machine to measure their load-bearing capacity. The flexural strength of beam specimens is determined through a bending test, while the split tensile strength test is conducted on cylindrical specimens to assess their tensile resistance and is shown in Fig 2,3,4

Fig 2: CTM

Figure 3:FlexuralStrength TestMachine

Figure 4:Splittensiletestmachine

V. RESULTS AND DISCUSSION

The material results were shown in Table 1 to 4

Table 1:TEST RESULTS ONCEMENT

S.No	Tests	Testresults	CodalValues
1	StandardConsistency	31%	25%-35%
2	SpecificGravity	3.13	Range(3-3.15)
3	FinenessofCement	8%	(notlessthan 10%)

Table2:TEST RESULTS ON FINE AGGREGATE

S.No	Tests	Testresults	CodalValues
1	SpecificGravity	2.67	Range(2.6-2.9)
2	FinenessModulus	3.05	Range(2.9-3.2)

Table 3:TESTRESULTSONCOARSEAGGREGATE

S.No	Tests	Testresults	CodalValues
1	SpecificGravity	2.87	Range(2.6-2.9)
2	FinenessModulus	7.61	Range(5.5-8.0)(coarse sand)

Table 4:TEST RESULTS ON WASTE RUBBERTYRE

S.No	Tests	Testresults	CodalValues
1	SpecificGravity	1.07	Range(1-1.5)

The strength results were shown in Table 5 to 7 and Figure 5 to 7.
Table 5 :compressive strength results

S.No	%ofrubberaggregates	Compressivestrength (N/mm^2)	
		7Days	28Days
1	5	16.15	19.26
2	10	13.62	15.48
3	15	10.37	12.14

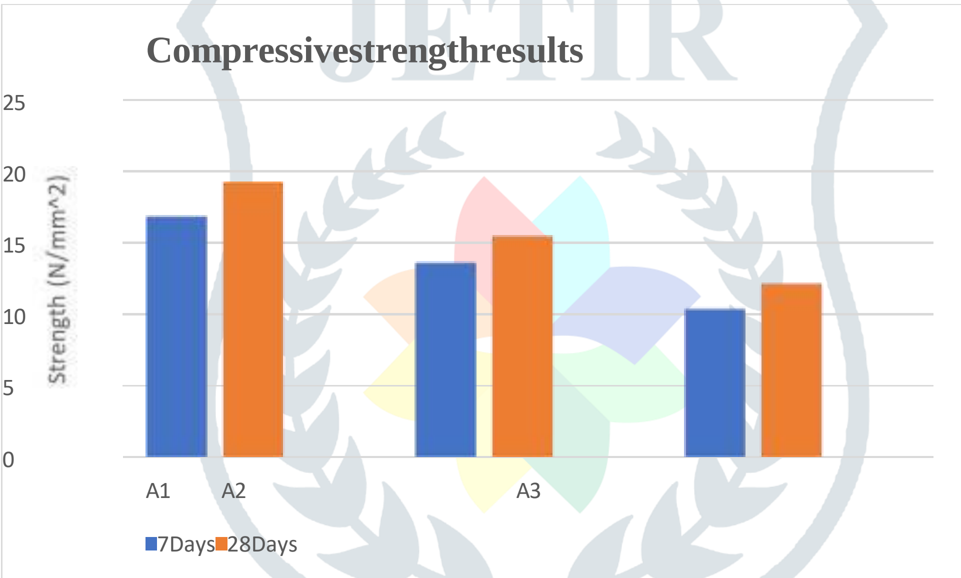


Figure 5:Graph result for CompressiveStrength

Table 6:Flexural strength results

S.no	%ofrubberaggregates	Flexuralstrength (N/mm^2)	
		7Days	28Days
1	5	2.49	4.46
2	10	2.51	4.53
3	15	2.71	4.74

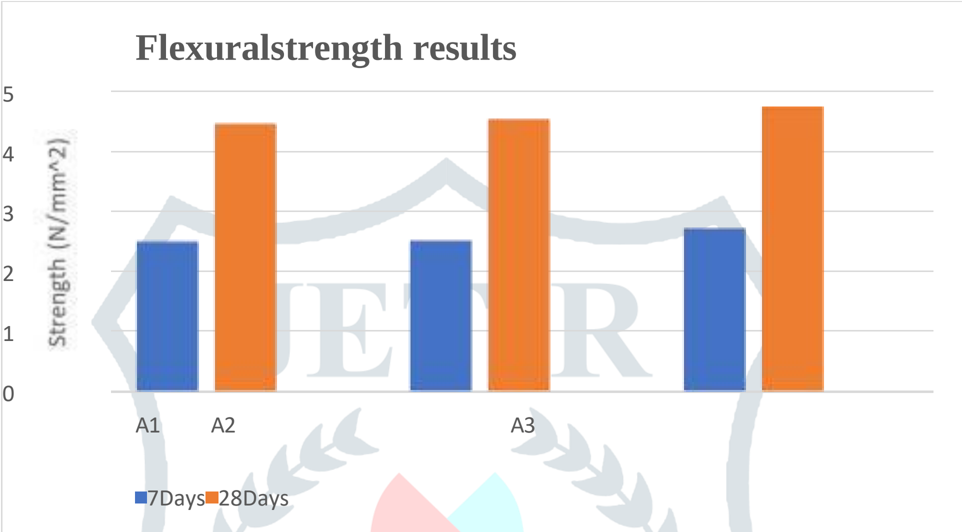
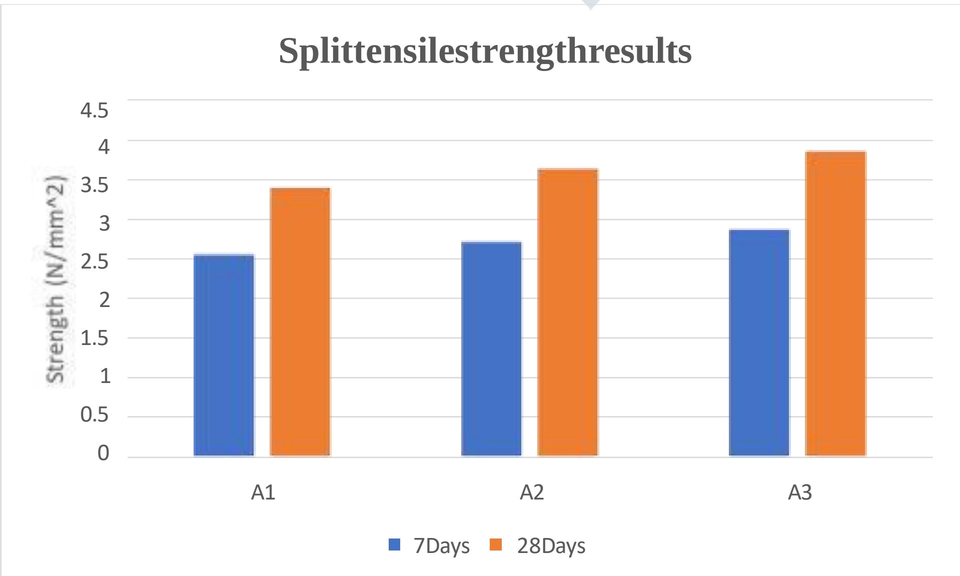


Figure 6:Graph results For flexural strength

Table6.7:Split tensile strength results

S.no	%ofrubberaggregates	Splittensilestrength (N/mm^2)	
		7Days	28Days
1	5	2.56	3.41
2	10	2.72	3.65
3	15	2.88	3.87

Figure 7:Graph results for split tensile strength



VI. CONCLUSIONS

Based on the experimental study, various samples of rubberized concrete were tested, and the following key conclusions were drawn:

1. Compressive Strength Results:
   - For 5% rubber replacement, the compressive strength obtained was 16.15 N/mm² at 7 days and 19.26 N/mm² at 28 days.
   - For 10% rubber replacement, the compressive strength was 13.62 N/mm² at 7 days and 15.48 N/mm² at 28 days.
   - For 15% rubber replacement, the compressive strength was 10.37 N/mm² at 7 days and 12.14 N/mm² at 28 days.

The highest compressive strength of 19.26 N/mm² was obtained with 5% replacement after 28 days, indicating that rubberized concrete maintains reasonable strength at lower replacement levels.

2. Potential Applications of Rubberized Concrete:

The lightweight nature of rubberized concrete makes it suitable for several applications, including:

- Architectural uses, such as false facades, interior construction, and decorative elements.
- Structural applications, such as earthquake shock absorbers, vibration damping in foundation pads for machinery, and railway stations.
- Impact and explosion-resistant structures, including Jersey barriers, railway buffers, bunkers, and trench filling.
- Pavement applications, such as PCC beds in foundations and flooring layers, where a reduction in dead load is beneficial.
- Partition walls and non-load-bearing structures, where lightweight properties are required.
- Roof insulation and waterproofing, with a 20mm rubberized concrete rendering improving thermal insulation.

3. Tensile and Flexural Strength Improvements:
   - Split tensile strength increased by 10-20%, with the highest value of 3.87 N/mm² at 15% rubber replacement after 28 days.
   - Flexural strength improved by 15-20%, with the highest value of 4.74 N/mm² at 15% rubber replacement after 28 days.
   - These improvements are attributed to the tensile properties of rubber, making rubberized concrete more flexible and resilient to cracking.
4. Weight Reduction in Concrete:
   - The inclusion of waste tyre rubber significantly reduces the unit weight of concrete, making it an ideal material for lightweight concrete applications.

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