Light Weight Concrete (Partial Replacement of Coarse Aggregate Using Recycled Tyres)

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ABSTRACT

The increasing generation of waste tyres has emerged as a significant environmental challenge, necessitating sustainable methods for their disposal and reuse. One promising approach is the incorporation of recycled tyre aggregates into concrete production to develop lightweight and eco-friendly construction materials. This study investigates the effect of partial replacement of natural coarse aggregates with recycled tyre chips in lightweight concrete. Experimental work was carried out with varying percentages of tyre replacement to evaluate fresh and hardened properties, including density, workability, compressive strength, and impact resistance. The results demonstrate that although the inclusion of tyre aggregates leads to a reduction in compressive strength compared to conventional concrete, it significantly improves ductility, energy absorption, and weight reduction. These findings suggest that recycled tyre-based lightweight concrete offers potential for application in non-load-bearing structural elements, pavements, and impact-resistant construction, thereby promoting resource conservation and environmental sustainability. An attempt has been made to check the possibility of reuse of recycled tyres in Light Weight Concrete by investigating compressive strength of M25 grade plain concrete and compressive behaviour of RC member for 20 and 30% replacement by recycled tyres.

Keyword: Lightweight Concrete, Compressive strength comparison, Recycled tyre replacement, Aggregates.

INTRODUCTION

Concrete is the most widely used construction material in the world due to its durability, versatility, and cost-effectiveness. However, the increasing demand for natural aggregates in concrete production has led to rapid depletion of natural resources, rising material costs, and adverse environmental impacts. Simultaneously, the disposal of waste tyres has become a significant environmental challenge, as millions of discarded tyres accumulate annually, posing risks of land pollution, fire hazards, and ecological imbalance. These issues have driven researchers to explore sustainable alternatives for concrete production by integrating waste materials into its composition.

Lightweight concrete, which is characterized by reduced density and improved thermal and acoustic properties, has gained considerable attention in sustainable construction. One promising approach involves the partial replacement of natural coarse aggregates with recycled tyre chips. Tyre-derived aggregates not only help in reducing the self-weight of concrete but also contribute to waste management by providing a constructive use for discarded rubber. Furthermore, the incorporation of tyre rubber can enhance certain properties of concrete, such as impact resistance, energy absorption, and toughness, making it suitable for non-structural and specialized structural applications.

The investigation of recycled tyres in lightweight concrete thus aligns with global sustainability goals by addressing two critical concerns: the reduction of solid waste and the conservation of natural aggregates. By optimizing the proportion of tyre replacement, researchers aim to balance mechanical performance with environmental benefits, paving the way for greener and more resource-efficient construction practices.

Objectives

1. **To investigate feasibility** – Assess the potential of using recycled tyre rubber as a partial replacement for natural coarse aggregate in lightweight concrete.
2. **To promote sustainability** – Reduce the environmental impact of discarded tyres by recycling them into construction materials, minimizing land pollution and waste accumulation.
3. **To study mechanical properties** – Evaluate the effect of tyre aggregate on the compressive strength, flexural strength, and split tensile strength of concrete.
4. **To analyze durability performance** – Examine resistance to water absorption, abrasion, shrinkage, and chemical attack when rubber aggregates are incorporated.
5. **To achieve weight reduction** – Develop lightweight concrete suitable for non-structural and semi-structural applications by lowering the density of concrete using tyre aggregate.
6. **To enhance energy absorption and ductility** – Determine the improvement in impact resistance, toughness, and crack resistance due to the elastic nature of tyre particles.
7. **To establish optimum mix design** – Identify the appropriate replacement percentage of coarse aggregate with tyre rubber that provides a balance between strength, durability, and weight reduction.
8. **To contribute to cost-effectiveness** – Assess whether using recycled tyres can reduce construction costs and dependence on natural aggregates.
9. **To support eco-friendly construction practices** – Encourage green building materials that align with sustainable development and circular economy principles.

Advantages

1. **Reduced Density & Self-Weight**

- Concrete with tyre aggregate is lighter, reducing dead load on structural elements.
- Helps in designing economical foundations and high-rise structures.

2. **Improved Ductility & Flexibility**

- Rubber particles enhance energy absorption and deformation capacity.
- Provides better impact resistance compared to normal concrete.

3. **Eco-Friendly & Sustainable**

- Utilizes waste tyres that otherwise cause environmental hazards.
- Reduces the need for natural coarse aggregates, conserving natural resources.

4. **Good Thermal & Sound Insulation**

- Rubber improves insulation properties, making concrete suitable for acoustic and thermal applications.

5. **Better Resistance to Cracking**

- Tyre aggregates increase toughness and decrease brittleness, reducing crack propagation.

6. **Shock & Vibration Absorption**

- Suitable for pavements, railway platforms, industrial floors, and structures exposed to dynamic loads.

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Disadvantages

1. **Reduced Compressive Strength**

- Rubber particles are less stiff than natural aggregates, lowering strength when replacement percentage is high.

2. **Weak Bonding with Cement Matrix**

- Smooth surface and hydrophobic nature of rubber reduce interfacial bonding with cement paste.

3. **Higher Water Absorption & Workability Issues**

- May require admixtures or higher water-cement ratio to achieve good workability.

4. **Durability Concerns**

- Increased porosity can affect long-term durability if not properly designed or treated.

5. **Limited Structural Applications**

- Not ideal for load-bearing elements requiring high compressive strength (e.g., columns, beams) unless reinforced with other materials.

6. **Variation in Tyre Aggregate Properties**

- Size, shape, and processing of recycled tyres affect performance, making standardization difficult.

METHDOLOGY

A. Materials

The material used in this project are cement, sand, coarse aggregate tyre rubber and sodium hydroxide. The cement, coarse aggregate, sand and sodium hydroxide are easilyavailable in the construction industry while the tyre rubber is available at very few sources.

1) Cement–OPC43 Grade

2) Coarseaggregate–coarseaggregateof10mmand20mmwithsizesof38%and62%wereused.

3) Fine aggregate-Artificial sand (crushed sand) was used.

4) Wastetyrechippedrubberpiecesareusedarecuttingbymanuallybyhandandinvaryingsizesrangingfrom10mm-15mm x 10mm.

5) Water–ordinary portable water(pHrangesbetween6.0to8.5)

6) Concretegrade–M20&Watercementratio–0.48

B. Quantity Estimation

Table1 Cube (150mmx150mmx150mm, v=0.003375m^3)

Replacement In%	Cement (kg)	Coarse Aggregate(kg)	Fin Aggregate(kg)	Water (Ltr.)	Rubber(kg)
Normal	1.35	3.85	2.28	646	0
20%	1.35	3.66	2.28	646	0.193
30%	1.35	3.27	2.28	646	0.578

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Table2 Cylinder (150mm diameter L=300mm, v=0.0053m^3)

Replacement In %	Cement (kg)	Coarse Aggregate(kg)	Fine Aggregate (kg)	Water (Ltr.)	Rubber(kg)
Normal	2.11	6.05	3.59	1.01	0
20%	2.11	5.75	3.59	1.01	0.302
30%	2.11	5.14	3.59	1.01	0.907

Table3 Beam (100mmX100mmX500mm diameter, v=0.005m^3)

Replacement In%	Cement (kg)	Coarse Aggregate(kg)	Fine Aggregate(kg)	Water (Ltr.)	Rubber (kg)
Normal	2.00	5.71	3.38	0.958	0
20%	2.00	5.42	3.38	0.958	0.285
30%	2.00	4.82	3.38	0.958	0.856

C. Mix Proportion

Table No.4 Mix design

Replacement of coarse aggregate	w/c ratio	Cement content (kg/m3)	Coarse aggregate (kg/m3)	Fine Aggregate (kg/m3)	Rubber content (kg/m3)
Normal concrete/ 0% Replacement	0.48	399.12	1141.59	676.7	0
20% Replacement	0.48	399.12	1084.51	676.7	57.08
30%Replacement	0.48	399.12	970.35	676.7	171.24

D. Experimental Work

The moulds used for the preparation of samples were cubes of size (15cmx15cmx15cm) for compressive strength testing, the beams of size (50cm x 10cm x 10cm) for flexural testing and the cylinders of size (10cm x 30cm) for split tensile strength testing. Concrete is prepared as premix design and then poured in to casting mould. While casting mould is oiled from inside for smooth surface finish and easy removal from mould. Then they are kept in water tank for required curing period and properly tested and results are noted down. For compressive test compressive test as well as split tensile strength, compressive testing machine (CTM) is used and for beam two point loading method is adopted.

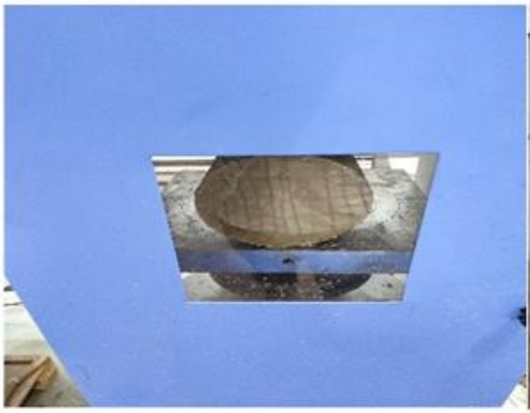


Fig. no. Split tensile strength test, Fig. no. flexural strength test

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RESULTS & DISCUSSIONS

A. Water Absorption

The purpose of this test is to find out water absorption of replaced concrete specimens. water absorption test was conducted on concrete samples containing 20% and 30% partial replacement of rubber. Specimens are weighed before being kept into water tank for curing. After the 28 days of curing the specimens are removed from water tank and surface moisture is removed by dry cloth then weight is checked and compared with initial weight before kept in water tank. So, a higher percentage of waste tyre rubber should not be used for building for main structural members or components. A lower water absorption rate is not always a indicator of better frost resistance while a high one does not always mean poor frost resistance. The data is shown in Figure with necessary details.

B. Slump Values

Slump tests of fresh concrete with coarse aggregates replaced by waste tyrerubber particles.

TableNo.5

Rubber content (%)	slump
0%	68
20%	62
30%	51

According to the obtained test values workability gets reduced with increasing percentage of chipped waste tyre rubber. This low workability occurs due to improper movement of rubber pieces with other concrete materials. So, it is not recommended to use this in heavily reinforced concrete members and where high w/c ratio required.

C. CompressiveStrength

Table shows the variations in compressive strength obtained at 7 and 28 days with respect to the percentage of coarse aggregate replaced by untreated chipped waste tyre rubber. Gradual decrease in compressive strength was noticed as the percentage of untreated chipped waste tyre rubber is increased. Each 3 specimens are tested and average value is taken.

The compressive strength Fc is found out from the given equation - Fc = P/A Where, P= Compressive load at failure(N) A= Cross sectional area(mm^2)

TableNo.6Compressive strength (avg.of3 specimens) of concrete cube

Curing period	%Replacement of Waste tyrerubber	Load (KN)	Compressive strength (N/mm^2)
7Days	Conventional concrete/0%Replacement	330.97	14.71
	20% Replacement	285.97	12.34
	30% Replacement	241.42	9.53
28Days	Conventional concrete/0%Replacement	500.40	22.24
	20% Replacement	466.42	20.73
	30% Replacement	387.00	17.20

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D. Split Tensile Strength

Split tensile test is carried out on cylindrical specimens of 150 mm diameter and 300 mm height. The test is carried as per IS 5816- 1999. The test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine, and the load is applied until failure of the cylinder.Split tensile strength is calculated by given equation-Tsp= 2P/ 3.14 x D x L

Where,

TSP=Split tensile strength

P=Tensile loadat failure (N)D= Diameter (mm) L=Length of the specimen(mm)

TableNo.7Spli ttensile strength (avg. of3specimens) of concretecy linder

Curing period	%Replacement of Wastety rerubber	Load(KN)	Split tensile strength (N/mm^2)
7Days	Conventional concrete/0%Replacement	87.61	1.24
	20% Replacement	110.21	1.56
	30% Replacement	132.82	1.88
28Days	Conventional concrete/0%Replacement	223.96	3.17
	20% Replacement	240.92	3.41
	30% Replacement	273.41	3.87

E. Flexural Test

Standard beams of size100mmx100mmx500mm are used to determine the flexural strength. The specimens are placed in the machine such that the load is applied to the top surface. Mark the specimen along two sides spaced 13.33cm apart and 5cm from both ends. Two-point loading method is used for loading. The load is applied until the specimen failed and the maximum load applied to the the test is recorded. Also failure crack distance from nearer support is also measured and this value (a) is noted down. Flexural strength is determined from the equation given below.If value of(a) greater than 13cmthen Flexural strength or modulus of rupture =PL/bxd^{2}Where, P= Flexural load(N) L=Length of specimen(mm) b = Width of specimen (mm) d=Height of specimen (mm)

TableNo.8 Flexural strength (avg. of3specimens) of concrete beams

Curing period	%Replacement of Waste tyre rubber	Load (KN)	Flexural strength (N/mm^2)
7Days	Conventional concrete/0%Replacement	4.52	2.26
	20% Replacement	4.98	2.49
	30% Replacement	5.42	2.71
28Days	Conventional concrete/0%Replacement	8.36	4.18
	20% Replacement	8.92	4.46
	30% Replacement	9.48	4.74

DISCUSSIONS

1) According to the results obtained by compressive strength test when partial replacement of waste tyre rubber in percentage is increased, it negatively affects the compressive strength. Compressive strength gets reduced due to rubber is weak in compression.

2) It was observed that conventional concrete specimens possess brittle failure and was broken into two pieces while testing. Rubberized concrete did not show brittle failure under tensile loading conditions. This is because of elastic properties of rubber.

3) When we use rubber directly in concrete it can't make proper bond with other concrete materials results in early crack formation.

4) Absorption of water by waste tyre rubber was observed. So, for that higher dose of plasticizers can be used or higher w/c ratio can used if possible, for better workability.

5) If proper compaction is not done then it creates honeycomb at surface of the concrete. So, avoid this phenomenon proper compaction is required. And it is suggested that do not use in complex reinforced structural members.

CONCLUSION

This study represents the effect of waste tyre chipped rubber of size 10-15mm x 10mm used in concrete on compressive, flexural and split tensile strength. From the results obtained during tests & investigations on the basis of following conclusions canbe drawn:

1) Asweincrease% of replaced rubberby coarse aggregateitreduces work ability nearly about 10-12%.

2) For better workability admixtures such as plasticizers or higher water cement ratios without compromising strength should be used.

3) For complex structural elements or highlyre in forced concrete sections this replaced concreteis not suitable.

4) Also,thereis2-4.5% of water absorptionalsoob served.Which affects the properties of concrete.

5) Compressive strength of waste tyre rubber concreteisd ecreases with in creas in gpercentage replacement of waste tyre rubber. That is about 10-20% reduction in compressive strength with different proportions of replacement.

6) 10-20%splittensilestrengthisincreased. Due to rubberis goodin tension.

7) 15-20% increase in flexural strength is increased .Highest strength is obtained with 15% replacement of wastety rerubber concrete after 28 days that is 4.74 N/mm^2

8) By replacing natural aggregates with light weight wastety rerubber,weight of concreteis alsogets reduced.

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