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Innovative Roof Waterproofing Using Tyre Rubber Crumb: A Sustainable Approach

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Abstract:

Analysing the viability of employing recycled rubber tires in the construction industry, particularly for roof waterproofing applications, is the primary goal of this study. The goal of this project is to create a novel rubber-concrete mixture by adding calcium lignosulfonate (C20H24CaO10S2), a sustainable additive, and recycled rubber tire fragments. The goal is to increase concrete's ability to waterproof while encouraging environmental sustainability by reusing waste resources. To ascertain if the modified concrete is suitable for practical application in roofing systems, the study assesses its performance in terms of strength, durability, and water permeability.

***Index Terms* - Waste tire rubber crumbs, Concrete, Water Absorption, Compressive Strength, Calcium Lignosulfonate, Eco-friendly Admixtures, Workability, Rubberized Concrete, Innovative Waterproofing Solutions.**

1. INTRODUCTION

Modern structures require waterproofing solutions to protect structures from water damage which leads to mold formation. Construction methods that utilize chemical materials frequently count as both expensive and environmentally damaging to earth systems. This research means to create an environmentally friendly waterproofing system using recycled tyre rubber crumbles from discarded tires because of their flexibility and water-blocking properties. The research explores enhancing insulation along with weight reduction in structures and drainage improvement through the combination of rubber crumb with aerated concrete and self-curing concrete mixed with permeable pavement created from shredded plastic. Laboratory and outdoor testing will evaluate this system to develop a sustainable waterproofing solution which suits different climate conditions.

Figure 1. Waste tyres

2. IMPORTANCE OF THE STUDY

Building a sustainable and lasting waterproofing system involves the combination of recycled rubber tire crumbs and calcium lignosulfonate which comes from the paper industry. The research adds rubber particles to concrete to create a more flexible waterproof solution which works effectively as roofing material. Adding calcium lignosulfonate to concrete enhances its workability as well as its strength characteristics and self-curing ability. The environmentally friendly solution properly resolves both waste tire management issues and helps achieve sustainable building practices through minimized natural resource usage. The project upholds sustainable building methods to create affordable durable leak-proof roofing systems usable in residential and commercial spaces.

3. MATERIALS USED

3.1. Tyre rubber crumb

The recycled product from automobile tyres named tyre rubber crumb functions as a water-resistant substance that maintains flexibility while offering durability when used in construction and waterproofing applications. Recycled materials from vehicle tires serve as an insulation against heat and noises while they decrease waste dumped in landfills and decrease greenhouse gas emission. Manufactured via machine grinding it consists of rubber and carbon black with traces of steel or fibers. The material remains durable because it sustains high temperatures and absorbs little water and shows low chemical leakage properties. Concrete and waterproofing systems become stronger with the addition of crumb rubber which helps support sustainable and affordable construction methods.

Figure 2. Tyre Rubber Crumb

3.2. Cement

Cement is a fine inorganic binder that hardens with water and is used to give strength to concrete and mortar.

3.3. Aggregate

Aggregate is a granular material like gravel, or crushed stone used in construction to provide volume, stability, and strength to concrete and mortar.

3.4. Sand

Sand is a fine granular material made of tiny rock and mineral particles, commonly used in construction for making concrete, mortar, and for filling and levelling surfaces.

3.4. Calcium lignosulfonate (CLS)

The paper industry generates eco-friendly Calcium lignosulfonate (CLS) substance which enhances concrete workability while minimizing water dependency during construction. The chemical characteristics of this compound allow it to separate cement particles which results in improved density and durability together with higher strength and lower shrinkage and porosity. The mechanism of CLS produces both inter-particle repulsion between cement grains while simultaneously developing a lubricating film that improves flow characteristics together with hydration behavior. The material functions as an admixture component that sustains other admixture integration at 0.2 percent to 1.5 percent of cement weight levels. The incorporation of CLS creates concrete products which become stronger and more durable and environmentally friendly.

3.5. Water

Water in concrete activates cement for the hydration process, helping it set and harden, and also provides workability for mixing, placing, and finishing.

4. METHODOLOGY

4.1. Testing on materials

1. Cement
   a) Initial and final setting time
   b) Consistency test
2. Aggregate
   a) Specific gravity
   b) Water absorption
   c) Flakiness index
   d) Abrasion test
3. Sand
   a) Specific gravity test
   b) Silt content test
4. Tyre Rubber Crumb
   a) Specific gravity test

4.2. Mix design

The mix design methodology involves choosing appropriate concrete components including cement, sand, aggregates along with water and admixtures before setting their optimal blend ratios to optimize strength performance while maintaining cost-effectiveness. Concrete performs properly according to planned conditions such as burden-bearing situations and environmental conditions and water exposure. M20 grade concrete is the selected material for this project because it must reach 20 MPa (megapascals) compressive strength after 28 days of curing. The M20 grade serves general construction applications because it combines strong performance with proper workability in elements such as slabs, beams and footings. The concrete's robustness and water-resistant properties improve through the addition of rubber crumb and acrylic copolymer and calcium lignosulfonate admixtures that make it fit for advanced roofing applications.

We use w/c ratio of 0.4 to 0.6 as per IS Code 10262 for M15 grade concrete.

Table 1. M20 Design Mix Ratio

Mix	Ratio
M20	1:1.5:3

- We know that
  - 1meter cube = 1440kg/m3
  - 1 bag cement = 50kg
  - 1 bag cement = 50/1440 = 0.03472m3

- We can say 1 bag cement = 35 liter
  W/C ratio = 0.5
  Weight =35*0.5 = 17.5 liter water/bag

- Volume of cube = 150mm*150mm*150mm
  = 0.15m*0.15m*0.15m
  =0.003375m3

- Wet volume = 1.54*0.003375m3
  = 0.005197m3

- Sum of ratio = 1+1.5+3 = 5.5

- Cement = 0.005197/5.5
  = 0.0009449m3
  In kg = 0.0009449*1440kg
  = 1.36kg

- Sand = 1.36*1.5
  = 2.04kg

- Aggregate = 1.36*3
  = 4.08kg

4.2.1 Quantity of material used for <u>conventional concrete cube</u>

Weight of cement = 5160gm
Weight of sand = 7725gm
Weight of aggregate = 15480gm

4.2.2 Quantity of material used for rubber concrete <u>cube with 10% crumb replacement</u> of fine aggregate.

Weight of cement = 5160gm
Weight of sand = 6952.5gm
Weight of rubber crumb = 772.5gm
Weight of aggregate = 15480gm

4.2.3 Quantity of material used for rubber concrete <u>cube with 12.5% crumb replacement</u> of fine aggregate.

Weight of cement = 1070gm
Weight of sand = 6759.5gm
Weight of rubber crumb = 965.5gm
Weight of aggregate = 15480gm

4.2.4 Quantity of material used for rubber concrete <u>cube with 15% crumb replacement</u> of fine aggregate.

Weight of cement = 1070gm
Weight of sand = 6566.5gm
Weight of rubber crumb = 1158.5gm
Weight of aggregate = 15480gm

4.3 Test on Concrete Specimen

4.3.1 Slum Cone Test

The slump cone test assesses fresh concrete workability through its operation. Fresh concrete receives layer-by-layer application into a cone-shaped mold which requires rod compaction to achieve compaction before each addition. When the test apparatus is removed the concrete settles which leads to the measurement of slump height as the slump value. The slump value shows the mix's workability because both higher and lower values show different results. The test determines concrete consistency to ensure it will be easily placed and compacted.

Figure 3. Slum Cone Test

4.3.2. 24-Hour Water Absorption Test

The slump cone test assesses fresh concrete workability through its operation. Fresh concrete receives layer-by-layer application into a cone-shaped mold which requires rod compaction to achieve compaction before each addition. When the test apparatus is removed the concrete settles which leads to the measurement of slump height as the slump value. The slump value shows the mix's workability because both higher and lower values show different results. The test determines concrete consistency to ensure it will be easily placed and compacted.

Figure 4. 24-Hour Water Absorption Test

4.3.3 Compression Test

Testing concrete cubes through compression measures their strength development at various curing durations spanning from the seventh day to fourteen days and the final twenty-eighth day. The cube molds receive concrete poured into their 150 mm × 150 mm × 150 mm dimensions before receiving proper compaction and 24-hour setting time. After demolding the cubes receive immersion in a water-filled curing tank that sustains proper water preservation. The compression testing machine receives one cube for testing each testing day after removing it from the water and drying its surface. The testing machine applies increasing pressure which leads to cube failure. The test instruments determine compressive strength in N/mm² through quantification of the maximum failure load. The measurement of early concrete strength occurs at the 7 and 14 days mark yet the 28-day test produces the official concrete strength rating.

4.3.4 Construction of Prototype Tank with 12.5% Tyre Rubber Crumb.

A prototype tank was developed using a specially designed M25 grade concrete mix, where 12.5% of the fine aggregate was substituted with tyre rubber crumb and calcium lignosulfonate was incorporated as a plasticizing agent. This innovative blend was intended to improve both the waterproofing capability and the workability of the concrete, benefiting from the water-repelling and flexible characteristics of rubber crumb along with the water-reducing effect of calcium lignosulfonate. The tank, with dimensions of 0.914 m × 0.61 m, was constructed using conventional formwork methods and carefully compacted to reduce internal voids. Following a 28-day curing period under controlled moisture conditions, the tank was tested to evaluate its water impermeability and structural performance, highlighting its potential for eco-friendly and durable waterproofing solutions.

Figure 5. Construction of Prototype Tank with 12.5% Tyre Rubber Crumb

Figure 6. Prototype Tank with 12.5% Crumb in Curing Period.

4.0 RESULTS

4.1 Results of Tests Conducted on Materials Used

1. Cement

a) Initial setting time and final setting time = 70 min and 180 (initial setting time should be more than 30 min and final setting time should be less than 600 min)
b) Consistency test = 31 % range (25-35 %)

2. Aggregate

a) Specific gravity = 2.5 range (2.5 to 3.0)
b) Water absorption =2.67% (it should not exceed 3%)
c) Flakiness index = 8.56% (it should be less than 35%)
d) Abrasion test = 9.5 % (it should be less than 18 %)

All the values are within limit so we can use the aggregates.

3. Sand

a) Specific gravity = 2.56 % (it should be around 2.65 to 2.67)
b) Silt content test = 3.77 % (it should not exceed 8%)

4. Rubber Crumb

a) Specific gravity test = 0.73

After performing all the experiments on various materials and all the values are within limit therefore our material is suitable for further use.

4.4 Results of Tests Conducted on Concrete Specimen

4.2.1 Slum Cone Test

Table 2. Slum Cone Test

Specimen	Water Cement Ratio	Tyre Rubber Crumb (in %)	Slump (in mm)
1	0.5	0%	79
2		10%	81
3		12.5%	86
4		15%	92

As rubber content increases, concrete workability improves due to the flexible nature and lower specific gravity of tyre rubber crumb, which reduces internal friction, making the mix easier to place and compact.

4.2.2 24-Hour Water Absorption Test

1. Water Absorption Test for Conventional Concrete Cube.

Table 3. Water Absorption Test for Conventional Concrete Cube.

Specimen	Tyre Rubber Crumb (in%)	Oven Dry Mass (in Kg)	Wet Mass (in Kg)	Water Absorption (in %)
1	0%	8.32	7.86	5.52%
2		8.55	8.04	5.91%
3		8.81	8.41	4.54%
Average				5.32%

2. Water Absorption Test for Concrete Cube with 10% Tyre Rubber Crumb Substitution.

Table 4. Water Absorption Test for Concrete Cube with 10% Tyre Rubber Crumb Substitution.

Specimen	Tyre Rubber Crumb (in%)	Oven Dry Mass (in Kg)	Dry Mass (in Kg)	Water Absorption (in %)
1	10%	7.67	7.42	3.26%
2		7.74	7.47	3.58%
3		7.96	7.67	3.69%
Average				3.51%

3. Water Absorption Test for Concrete Cube with 12.5% Tyre Rubber Crumb Substitution.

Table 5. Water Absorption Test for Concrete Cube with 12.5% Tyre Rubber Crumb Substitution.

Specimen	Tyre Rubber Crumb (in%)	Oven Dry Mass (in Kg)	Dry Mass (in Kg)	Water Absorption (in %)
1	12.5%	6.83	6.64	2.91%
2		6.96	6.75	3.03%
3		7.13	6.89	3.45%
Average				3.13%

4. Water Absorption Test for Concrete Cube with 15% Tyre Rubber Crumb Substitution.

Table 6. Water Absorption Test for Concrete Cube with 10% Tyre Rubber Crumb Substitution.

Specimen	Tyre Rubber Crumb (in%)	Oven Dry Mass (in Kg)	Dry Mass (in Kg)	Water Absorption (in %)
1	15%	6.21	6.07	2.24%
2		6.46	6.21	2.59%
3		6.58	6.41	2.61%
Average				2.48%

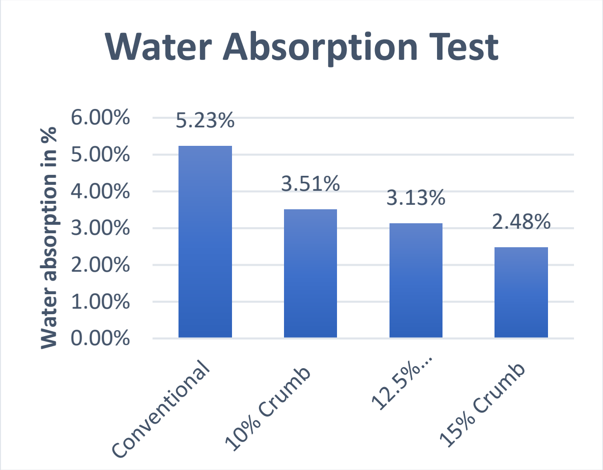

Figure 7. Water Absorption Test Results.

The 24-hour water absorption test showed that increasing rubber crumb reduced water absorption, suggesting lower porosity and better moisture resistance, making the mix more suitable for waterproofing.

4.2.3 Compression Test

1. Compressive Strength of Conventional Concrete Cubes.

Table 7. Compressive Strength of Conventional Concrete Cubes.

Specimen	Water Cement Ratio	7 Days Strength (in MPa)	14 Days Strength (in MPa)	28 Days Strength (in MPa)
1	0.5	13.9	16.8	19.6
2		14.6	17.3	21.5
3		15.1	17.6	22.8
Average		14.5	17.2	21.3

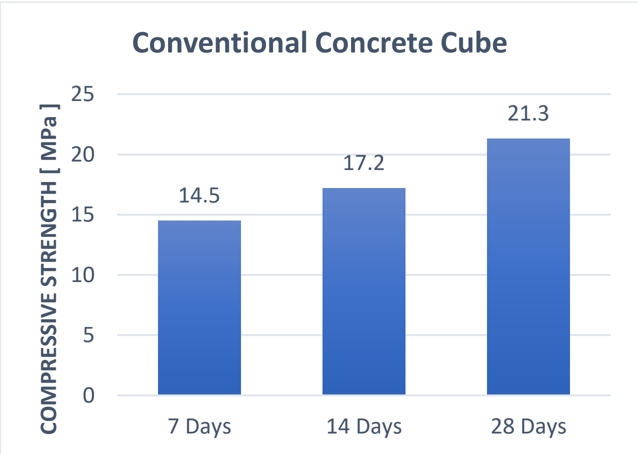

Figure 8. Compressive Strength of Conventional Concrete Cubes Results.

2. Compressive Strength of Concrete Cube with 10% Tyre Rubber Crumb Substitution.

Table 8. Compressive Strength of Concrete Cube with 10% Tyre Rubber Crumb Substitution.

Specimen	Water Cement Ratio	7 Days Strength (in MPa)	14 Days Strength (in MPa)	28 Days Strength (in MPa)
1	0.5	12.8	14.6	16.4
2		13.4	14.9	16.7
3		13.7	15.2	16.9
Average		13.3	14.9	16.7

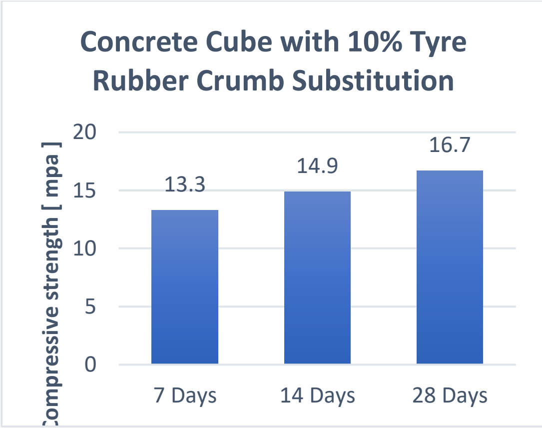

Figure 9. Compressive Strength of Concrete Cube with 10% Tyre Rubber Crumb Substitution Results.

3. Compressive Strength of Concrete Cube with 12.5% Tyre Rubber Crumb Substitution.

Table 9. Compressive Strength of Concrete Cube with 12.5% Tyre Rubber Crumb Substitution.

Specimen	Water Cement Ratio	7 Days Strength (in MPa)	14 Days Strength (in MPa)	28 Days Strength (in MPa)
1	0.5	10.8	14.6	16.0
2		11.0	14.9	16.3
3		11.4	15.1	16.5
Average		11.1	14.8	16.2

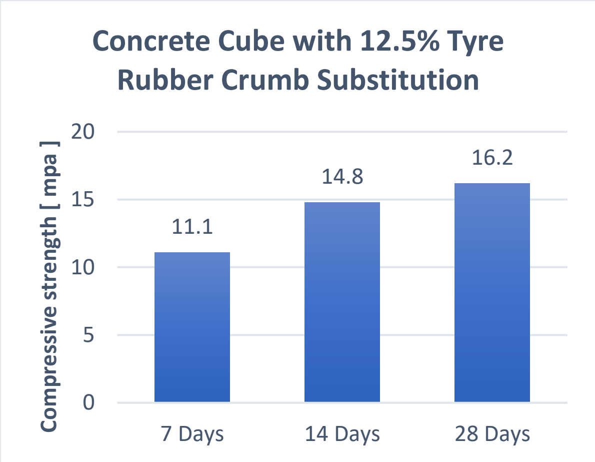

Figure 10. Compressive Strength of Concrete Cube with 12.5% Tyre Rubber Crumb Substitution Results.

4. Compressive Strength of Concrete Cube with 15% Tyre Rubber Crumb Substitution.

Table 10. Compressive Strength of Concrete Cube with 15% Tyre Rubber Crumb Substitution.

Specimen	Water Cement Ratio	7 Days Strength (in MPa)	14 Days Strength (in MPa)	28 Days Strength (in MPa)
1	0.5	9.4	12.8	14.6
2		9.6	13.1	14.7
3		9.8	13.4	15.1
Average		9.6	13.1	14.8

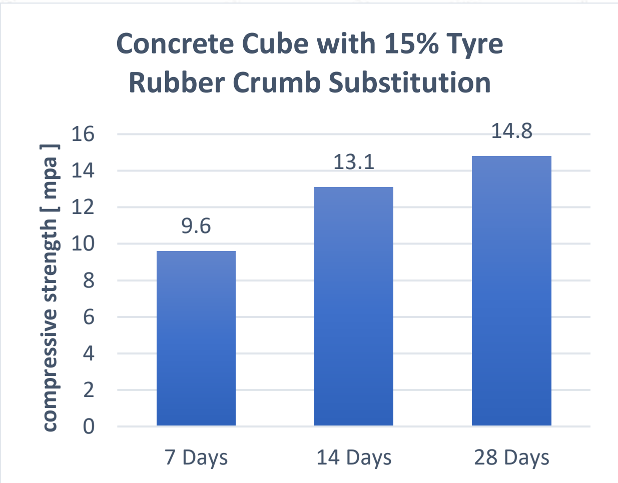

Figure 11. Compressive Strength of Concrete Cube with 15% Tyre Rubber Crumb Substitution Results .

5. Comparison of Compressive Strength.

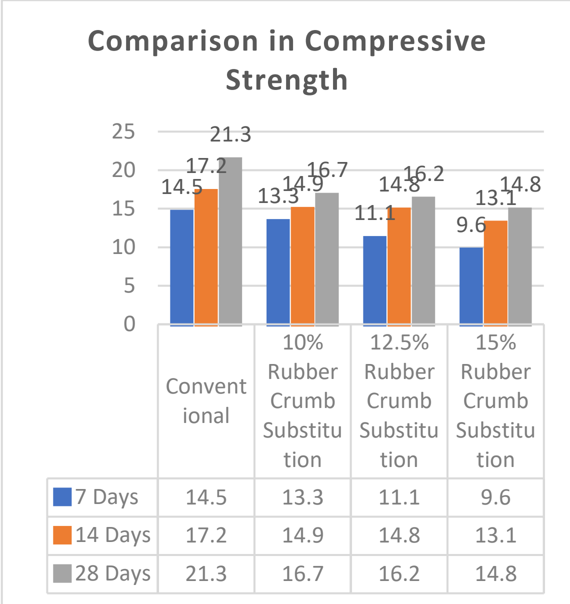

Figure 12. Comparison of Compressive Strength.

5.0 CONCLUSION

This research confirms the effectiveness of using tyre rubber crumb in concrete to improve roof waterproofing. Modified concrete mixes with 10%, 12.5%, and 15% rubber content showed better water resistance and fewer surface cracks compared to conventional concrete. The mix with 12.5% rubber offered the best balance of strength and flexibility, making it a strong candidate for solving common roofing issues like leakage and reduced durability. Additionally, incorporating calcium lignosulfonate—a natural plasticizer from lignin—enhanced workability, ensured uniform rubber distribution, reduced water demand, and improved compaction. This led to a denser, less permeable concrete without affecting its strength. Overall, the combination of rubber crumb and calcium lignosulfonate provides a sustainable, efficient approach to waterproof concrete roofing, addressing both environmental and structural challenges, and paving the way for further exploration and real-world application.

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