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Use Of Recycled Rubber In Cement Mortar For Plastering

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Abstract

The sustainable utilization of waste rubber from end-of-life tyres (ELTs) represents a critical step towards achieving a circular economy. A significant proportion of discarded tyres globally are either landfilled or incinerated—processes that contribute to environmental degradation. This study explores an alternative path by incorporating crumb rubber (CR) as a partial substitute for river sand in cement mortar used for plastering applications. Experimental trials evaluated the performance of mortar containing varying mesh sizes (40, 60, 100) and volume fractions (10–15%) of CR, comparing results against conventional mortar.

Key findings include a marginal reduction in compressive strength (up to 5–10%) and a consistent or improved flexural performance. Additionally, CR-modified mortars demonstrated reduced thermal conductivity (by 7–9%), contributing to energy savings in building interiors. Pull-out (adhesion) strength showed no adverse impact when CR was pre-treated with $KMnO_4$ and NaOH. The reduced density of CR mortars also contributes to lightweight construction. The results support the feasibility of CR as a sustainable material for plastering, precast panels, and energy-efficient construction.

Keywords: Crumb Rubber, Cement Mortar, Energy Efficiency, Thermal Insulation, Circular Economy, Sustainable Construction, Building Materials

1. Introduction

The growing challenge of solid waste management, particularly in the disposal of used tyres, has prompted global efforts to find environmentally friendly and economically viable reuse strategies. Over 1.6 billion tyres are manufactured annually, generating nearly 1 billion ELTs globally. In India alone, over 1.5 million tonnes of tyre waste is produced, with only 4.5 lakh tonnes recycled effectively.

In parallel, the construction sector faces a critical shortage of natural resources—especially river sand—due to over-extraction and regulatory restrictions. This has led civil engineers and researchers to investigate sustainable alternatives such as using polymeric waste in building materials.

This research investigates the use of recycled crumb rubber as a partial replacement for fine aggregate (sand) in cement mortar. Beyond environmental benefits, rubber's low thermal conductivity and shock-absorbing characteristics present a unique opportunity to improve the energy efficiency and performance of construction materials. This study specifically explores the feasibility of using CR-enhanced mortar for plastering walls and other applications, assessing its mechanical, thermal, and bonding properties.

2. Literature Review

Several studies have evaluated the incorporation of waste rubber in cementations materials:

- **Thomas (2021)** emphasized the global environmental crisis caused by ELTs and suggested partial replacement of aggregates with rubber in concrete as a viable solution.
- **Liang He et al. (2022)** proposed a surface modification approach using $KMnO_4$ and $NaHSO_3$ to enhance the interfacial bonding between rubber particles and cement matrix. Their FTIR analysis showed improved hydrophilicity and bonding performance.
- **Chem et al. (2023)** examined the influence of rubber type, surface treatment, and mixing methods on the mechanical behavior of rubberized concrete. Their results indicated notable improvements in compressive and impact strength with optimized rubber-cement interfaces.
- **A.A. Author (2020)** noted that while rubber incorporation reduces compressive strength, it enhances sound and thermal insulation, and flexibility, making it suitable for specific applications like plastering and non-structural components.

3. Materials and Experimental Setup

3.1 Materials Used

- **Crumb Rubber:** Mesh sizes 40, 60, 100 (sourced from Tinna Rubber, Mumbai) – pre-treated with NaOH and $KMnO_4$ to enhance bonding (Table 1).
- **River Sand:** Zone II as per IS 383 (Table 2).
- **Cement:** Grade 43 OPC (M/s Ambuja Cement) (Table 3).
- **Water:** Potable water meeting construction-grade quality (Table 4).

4. Experimental Procedure

4.1 Mix Design and Sample Preparation

Mortar samples were prepared in the ratio 1:2.75 (cement:sand) with 10% and 15% volumetric replacement of sand with CR of different mesh sizes. Water content was kept constant for all mixes. Control and treated samples were compared for compressive strength, flexural strength, thermal conductivity, pull-out strength, and density.(Refer table 5)

4.2 Compressive Strength

Tested as per ASTM C109 using 40 mm cube molds. The results show a strength reduction of 5–10% in CR mixes vs. control samples.

4.3 Flexural Strength

Three-point bending test conducted on 75 mm x 105 mm beams. Results indicate near-equivalent or marginally improved flexural strength for CR mixes due to rubber elasticity.

4.4 Thermal Conductivity (Energy Test)

Thermal resistance measured using a modified adiabatic-box method. CR-mortar samples showed a 7–8% decrease in heat transfer, suggesting potential for energy-efficient wall finishes.

4.5 Pull-Out Test (Adhesion Strength)

Iron wire embedded between plaster and brick to simulate bonding. Treated CR samples demonstrated similar or slightly better adhesion strength than control after 7 days curing.

5. Results and Discussion

5.1 Mechanical Properties

Trial	CR Mesh	Compressive Strength (Kg/cm²)	Flexural Strength (Kg/cm²)
Control	–	24.56	12.87
R110	100	22.65	12.90
R610	60	20.3	12.00
R410	40	20.5	11.89

- **Observation:** Compressive strength decreased within acceptable limits (for plastering). Flexural strength remained stable or improved due to rubber's elastic properties.(Refer table 6 & 7)

5.2 Energy Test

- **Result:** Temperature difference through plaster reduced by ~7.8% using CR-mortar, indicating enhanced thermal insulation. (Refer Graph 1)

5.3 Pull-Out Strength

Type	Strength (KgF)
Control	17.3
With Treated CR	17.5

- **Observation:** No deterioration in wall adhesion, thanks to surface treatment of rubber particles.(Refer table 8)

5.4 Density

	Weight (g)
Control	821
R110	725
R115	701

- **Observation:** Mortar weight reduced by 12–15%, enabling lighter structures.(Refer Table 9

6. Conclusions

This study demonstrates the potential for incorporating treated crumb rubber in cement mortar for plastering applications, contributing to both environmental protection and material efficiency:

- Compressive strength reduction is within functional limits for non-load-bearing applications.
- Flexural performance and adhesion strength are preserved or improved.
- Thermal insulation is significantly enhanced, reducing energy use in buildings.
- The substitution of sand with CR offers environmental benefits by preserving natural resources and utilizing tyre waste effectively.

Applications:

- Wall plastering
- Precast and panelised walls
- Lightweight partition systems
- Energy-efficient construction components

7. Future Work

Further studies will investigate long-term durability, water permeability, sound insulation, and fire resistance properties. Scaling the application in prefabricated building materials is also under consideration.

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Conflict of Interest: None declared.

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Appendix:

Crumb Rubber

S No	Properties	Unit	Value
1	Crumb mesh		95-105
2	Heat Loss	%	Max 1.5
3	Specific gravity	g/cc	1.130-1.170
4	Ash	%	Mx 14
5	Rubber Hydro carbon content	%	45
6	Acetone extraction	%	14 Max

Table 1

River Sand

S No	Properties	Unit	Value
1	Grading of sand	Zone	Zone II as per IS 383
2	Specific gravity	g/cc	2.59-2.90
3	Density	Kg/M^3	1671-1750
4	Water Absorption	%	1.3 0 -160
5	Fineness Modulus		244
6	Fines	%	Max 1

Table 2

Cement

S No	Properties	Unit	Value
1	Grade		43
2	Specific Gravity	g/cc	3.15
3	Loss on agitation	%	Max 4
4	Compressive strength	Mpa	Min 27 on 72 Hrs
5	Initial Setting time	Minute	30
6	Final Setting time	Minute	600
7	SiO_2	%	25.05
8	CaO	%	52.00
9	MgO	%	3.52
10	Al_2O_3	%	6.27
11	Fe_2O_3	%	6.76
12	SO3	%	2.12

Table 3

Water

S No	Properties	Unit	Value
1	pH		6-8.5
2	TDS	PPM	20000
3	Organic Solid	gm/l	Max 300
4	Suspanded soild	gm/l	Max 2000
5	Chloride as CL	gm/l	Max 2000
6	Sulphite SO_3	Gm/l	Max 500

Table 4

Mix Design

Trial No	Cement in gm	Sand in gm	Water in gm	Crumb in gm*	Remarks
Control $_0$	200	551	91	Nil	
$R_1$10	200	496	91	21	100 mesh
$R_1$15	200	470	91	32	
$R_6$10	200	496	91	21	60 mesh
$R_6$15	200	470	91	31	
$R_4$10	200	496	91	21	40 mesh
$R_4$15	200	470	91	31	

Table 5

Test Results of compressive strength

Trial No	Crumb Mesh	After 7 day water curing Compressive strength in Kg / Cm^2	After 14 day water curing Compressive strength in Kg / Cm^2
C $_0$	Nil	22.5	24.56
$R_1$10	100	20.16	22.65
$R_1$15	100		
$R_6$10	60	19.07	20.3
$R_6$15	60		
$R_4$10	40	20.10	20.5
$R_4$15	40		

Table 6

Results of Flexural strength

Trial No	Crumb Mesh	Flexural Strength in Kg/Cm^2	Remarks
C_0	Nil	12.87	
$R_1$10	100	12.90	
$R_1$15	100	12.00	
$R_6$10	60	12.00	
$R_6$15	60	11.90	
$R_4$10	40	11.89	
$R_4$15	40	11.80	

Table 7

Pull out test (adhesion/ bounding between brick wall over plastering)

	Without Crumb Rubber	With Crumb Rubber
Pull Out strength in KgF	17.3	17.5

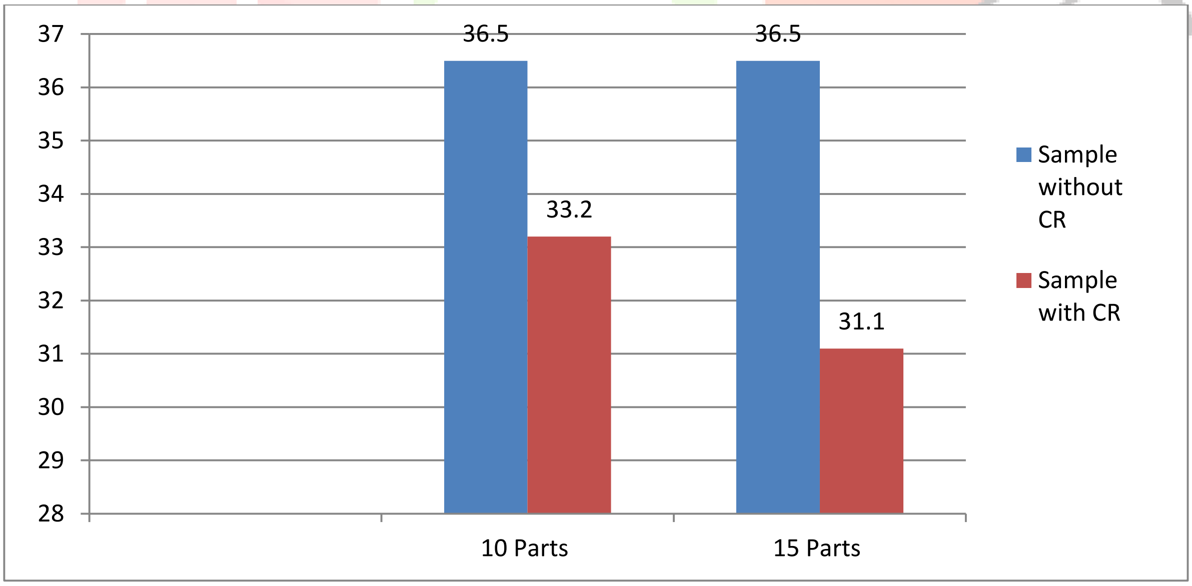
Table 8

Unit Weight / Density

Trial No	Crumb Rubber Mesh	Weight in Gms
C_0	Nil	821
$R_1$10	100	725
$R_1$15	100	701
$R_6$10	60	774
$R_6$15	60	719
$R_4$10	40	749
$R_4$15	40	736

Table 9

Results of Energy Test



Graph 1