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Effect of Crumb Rubber by Partial Replacement on Compressive Strength and Flexural Strength of Concrete

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ABSTRACT- The utilization of discarded rubber tires contributes to environmental protection and helps in preserving natural aggregates. The proper disposal of waste materials is a significant global concern. The management of waste tires poses a major challenge since this material decomposes very slowly over time. For this universal concern, significant research inquiries have been conducted to explore diverse applications of rubber derived from tires crumb rubber. Across the globe are actively pursuing alternative substances that are economical and for the conservation of limited natural resources such as sand and aggregate.

The focal point of this research involves the partial replacement of fine aggregate (by weight) with crumb rubber in M-25 and M-35 grade concrete mixes at various percentages: 0%, 5%, 10%, and 15%.

I. INTRODUCTION

Concrete is a fundamental material extensively employed in construction works. Its utilization as a primary building material is attributed to its cost-effectiveness, excellent durability, malleability, and convenience in on-site production. The ability of concrete to be shaped and sized according to specific requirements is due to its plasticity during the early stages and subsequent hardening, which is crucial and advantageous for achieving strength.

Concrete is an engineering material that necessitates meticulous design considerations pertaining to properties such as strength, durability, workability, and stability. Its adaptability during the initial stages and subsequent strengthening to attain robustness allow structures to withstand challenging environmental conditions.

A. Crumb Rubber

The deliberate disposal of industrial waste is often responsible for significant harm to the environment. The utilization of crumb rubber in road construction has gained significant traction as an environmentally-friendly approach to enhance pavement performance and durability. Consequently, a significant quantity of waste tires exists, as illustrated in Figure 1 and Figure 2. Over the previous 5 years, the average recycling of waste tires has exceeded 100,000 metric tons. The Crumb rubber used in the current exploration is taken from the factory area market Patiala Punjab.

Figure 1: Disposed Tire Waste in an Exposed Location

Figure 2: Waste type dump on heat ignited

B. Targets

The targets of the study are summarized below.

- To investigate the strength of cube specimens by incorporating crumb rubber at varying proportions.
- To examine the bending resistance of concrete beam specimens at varying proportions.
- To analysis the strength with varying percentages of Crumb Rubber combines effects.

C. Various ways to use Crumb Rubber in Construction

Many of the following uses are deliberated further below:

- It can produce rubberized concrete, which exhibits improved impact resistance and vibration damping properties.
- It helps reduce noise transmission in roads.
- Rubberized roofing materials, such as shingles or membranes, can be manufactured using crumb rubber, offering weather resistance, and insulation.
- It can be utilized in erosion control systems, to stabilize slopes and prevent soil erosion.
- It can be used as landscaping mulch, providing weed suppression, moisture retention.

II. LITERATURE REVIEW

- Habib Abdurrahman[1]- This research article investigates the structural characteristics and permeability of concrete incorporating crumb rubber as a supplementary component in the concrete mixture, with varying ratios of 10%, 20%, and 30% by volume of fine aggregates. As a reference blend, Ordinary Portland Cement (OPC) concrete mix is employed in this examination.
- Subashree P[2]- This research aims to examine the strength, deflection, impact energy absorption, and ductility index of a modified type of concrete called Crumb Rubber Aggregate Concrete. The fine aggregates are obtained through the partial substitution of waste tire rubber aggregates. The characteristics of the rubberized concrete containing crumb rubber are evaluated after treatment with three distinct acidic solutions (acetic acid (5%), H2SO4 (35%), and HCL (5%).
- Manoharan.P [3]-It is the primary construction material employed in civil engineering and aggregates, along with supplementary cementitious materials, are the key resources employed in concrete production. The mix design for different grades (M30 and M40) was formulated in accordance with the guidelines outlined in IS 10262 2009. To explore the effects, the concrete was manufactured by substituting fine aggregate with crumb rubber, from 3% to 15%. Additionally, a control mix without crumb rubber was created for comparative analysis.
- Patricia Kara De Maeijer [4]- This up-to-date review aimed to conduct an extensive examination of the existing literature to consolidate the knowledge gained from the past three decades regarding its in concrete as crumb rubber.
- Mayanket al.[5]- In this empirical investigation, it was analyzed by partially substituting fine aggregates. Accordingly, concrete mixes were prepared by replacing sand with 1%, 3%, and 5%. The concrete cubes were subjected to testing after a curing duration of 7 and 28 days, utilizing M25 grade concrete and Pozzolana Portland Cement.

III. MATERIAL USED

Materials used in concrete production are consulted in this section with their important features and properties.

A. Cement

Cement is a crucial binding agent in construction, responsible for providing strength and durability to concrete structures. For making concrete OPC 43 grade (Ultratech Cement) was used. The chemical enquiry of good OPC is shown in Table 1 and Table 2.

Table 1: Chemical content of standard Portland cement oxides

Oxide	%	Average
Lime	60-65	62
Na2o+K2o	0.5-1.3	1.0
Magnesia	0.5-4	2.4
Iron oxide	0.5-6	3.3
Sulfur trioxide	1-2	1.5
Silica	17-25	21
Alumina	3-5.9	6.2

Source: M L Gambhir, Concrete technology 5th Edition: 2013 Page no. 19

Table 2: Chemical content of ordinary Portland cement

Compound	% by mass in cement
C3A	5-12
C4AF	6-12
C2S	20-45
C3S	25-50

Source: M L Gambhir, Concrete technology 5th Edition: 2013 Page no. 22

B. Aggregate

Aggregates are composite material of components concrete and asphalt. The supreme function of aggregate is to deliver strength to concrete while mixing with cement and water to form a paste. Aggregate are low-priced than cement and responsible for healthier and large volume strength and durability to concrete. Aggregates are classified into two classes namely fine aggregates and coarse aggregates [7]. Compound composition is shown in Table 3 Physical properties are shown in Table 4.

Table 3: Compounds composition

Compound	Oxides Contents (%)
Aluminum Oxide Al_2O_3	0.77
Ferric Oxide Fe_2O_3	0.37
Calcium Oxide CaO	13.33
Magnesium Oxide MgO	9.59
Potassium Oxide K_2O	0.09
Silicon Oxide SiO_2	55.57

Table 4: Physical properties of aggregate.

Aggregate	Aggregate (Coarse)	Sand
Loose unit Weight (kg/ cm^3)	1.345	1.691
Sieve 200	1.29%	6.85%
Specific Weight (g/ cm^3)	2.70	2.57
H_2O Absorption (%)	1.15	1.83
Compact unit Weight (kg/ m^3)	1.547	1.848
Surface percentage (%)	---------	6.00

C. Crumb Rubber

This involves the conversion into small powdered pieces through mechanical methods. The components of the tires are also extracted during this operation. Crumb rubber comprises particles ranging from 4.75 mm to sizes less than 0.075 mm. Generally, strategies are utilized to convert discarded tires into crumb rubber. These techniques are as follows.

- Granular process
- Micro mill process.
- Cracker mill process

The cracker mill approach diminishes the size of tire rubber by transferring the material between rotating grooved steel drums. This procedure generates particles of irregular shape with a substantial surface area. These particles are commonly referred to as shredded crumb rubber and have sizes ranging from 5mm to 0.5mm. In the granular process, the rubber is separated into granulated crumb rubber particles by means of rotating steel plates. It can vary in size from 9.5mm to 0.5mm. Chemical composition of rubber hydrocarbon is shown in Table 5. Physical characteristics of aggregates are shown in Table 6. Chemical Composition.

Table 5: Compounds composition

Rubber hydrocarbon	Content %	Limits
Rubber hydro carbon (SBR)	48%	≥ 42
Carbon black	31%	≥ 28
Acetone extract	15%	≤ 22
Ash	2%	≤ 8
Residue chemical balance	4%	
Stearic acid	0.50 %	
Extender oil	1.90 %	

Table 6: Physical properties of aggregate

Physical Properties	Test Results
Elongation at break	150%
Fineness modulus	4.48%
Moisture Content	2%
Density	0.95 g/cm^3
Ultimate tensile strength	9 MPa
Appearance	Black & Rough
Hardness shore A	64
Specific Gravity	1.72

IV. RESULT AND CONCLUSION

In this section, we describes the experimental strength results of M-25 and M-35 cubical and beam specimens containing different percentage of crumb rubber. The concrete specimens were made of M-25 and M-35 grade of concrete and checked for their compressive strength and flexural strength. A total four groups of specimens comprising M-25 and M-35 grade concrete were prepared for testing. Each group consisted of samples with varying proportions of Crumb Rubber (0%, 5%, 10%, and 15%) as a partial replacement of Fine Aggregate. The results for compressive strength and flexural strength of these samples can be located in Table 7, Table 8, Table 9, Table 10, Table 11, Table 12, Table 13, and Table 14, correspondingly. Therefore total 240 concrete cube and 60 beams specimens were made of M-25 and M-35 grade of concrete, tested for their compressive strength and flexural strength. Figure 3 depicts the impact of Fine Aggregate replacement with Crumb Rubber at varying percentages (0%, 5%, 10%, and 15%) on the Flexural Strength of M25 grade concrete. Likewise, Figure 4 displays influence of Fine Aggregate replacement with Crumb Rubber at various proportions (0%, 5%, 10%, and 15%) on the Flexural Strength of M35 grade concrete. Fig 5 shows the compressive strength of M25 at 0%, 5%, 10% & 15% replacement of Fine Aggregate by Crumb Rubber after 7,14,21 & 28 days. Figure 6 illustrates the compressive strength of M35 grade concrete at (7, 14, 21, and 28 days) for different proportions of Fine Aggregate substitution with Crumb Rubber (0%, 5%, 10%, and 15%).

A. Influence of Crumb Rubber on the Flexural Strength of Concrete Beams with M-25 Grade

Table 8: Flexural strength with 5% substitution of Fine Aggregate by Crumb Rubber.

S.No.	Days	Ultimate load (kN)	Average ultimate load (kN)	Flexural strength ($Newton/mm^2$)
1	28	107	107.33	4.78
		107		
		108		

Table 9: Flexural strength for 10% substitution of Fine Aggregate by Crumb Rubber.

S.No.	Days	Ultimate load (kN)	Ave ultimate load (kN)	Flexural strength (N/mm^2)
1	28	102	102	4.53
		101		
		103		

Table 10: Flexural strength for 15% substitution of Fine Aggregate by Crumb Rubber.

S.No.	Days	Ultimate load (kN)	Ave ultimate load (kN)	Flexural strength (N/mm^2)
1	28	97	96.33	4.28
		96		
		96		

Flexural Resistance for 0%, 5%, 10%, 15% substitution of Fine Aggregate with Crumb Rubber.

Strength in 28 days

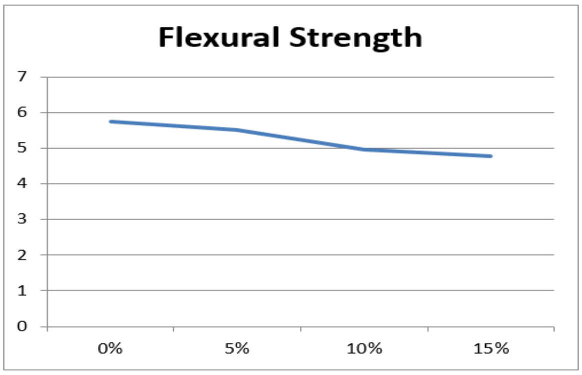


Figure 3: Flexural Strength for 28 days varying from 0%, 5%, 10%, 15% replacement of Fine Aggregate by Crumb Rubber

B. *Influence of Crumb Rubber on Flexural Strength of M-35 Concrete Beam*

Table 11: Flexural strength for 0% substitution of Fine Aggregate by Crumb Rubber.

S.No.	Days	Ultimate load (kN)	Ave ultimate load (kN)	Flexural strength (N/mm^2)
1	28	152	152	6.76
		151		
		153		

Table 12: Flexural strength for 5% substitution of Fine Aggregate by Crumb Rubber.

S.No.	Days	Ultimate load (kN)	Ave ultimate load (kN)	Flexural strength (N/mm^2)
1	28	140	140.33	6.23
		141		
		141		

Table 13: Flexural strength for 10% substitution of Fine Aggregate by Crumb Rubber.

S.No.	Days	Ultimate load (kN)	Average ultimate load (kN)	Flexural strength (N/mm^2)
1	28	131	130	5.78
		129		
		130		

Table 14: Flexural strength for 15% substitution of Fine Aggregate by Crumb Rubber

S.No.	Days	Ultimate load (kN)	Average ultimate load (kN)	Flexural strength (N/mm^2)
1	28	126	124	5.51
		124		
		122		

Flexural Strength for 0%, 5%, 10%, 15% substitution of Fine Aggregate by Crumb Rubber
Flexural Strength for 0%, 5%, 10%, 15% replacement of Fine Aggregate by Crumb Rubber

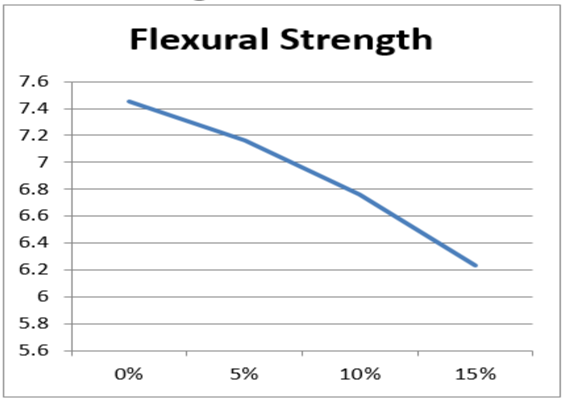


Figure 4: Flexural Strength for 0%, 5%, 10%, 15% replacement of Fine Aggregateby Crumb Rubber

C. *Compressive strength at Substitution of Fine aggregate for grade M25.*

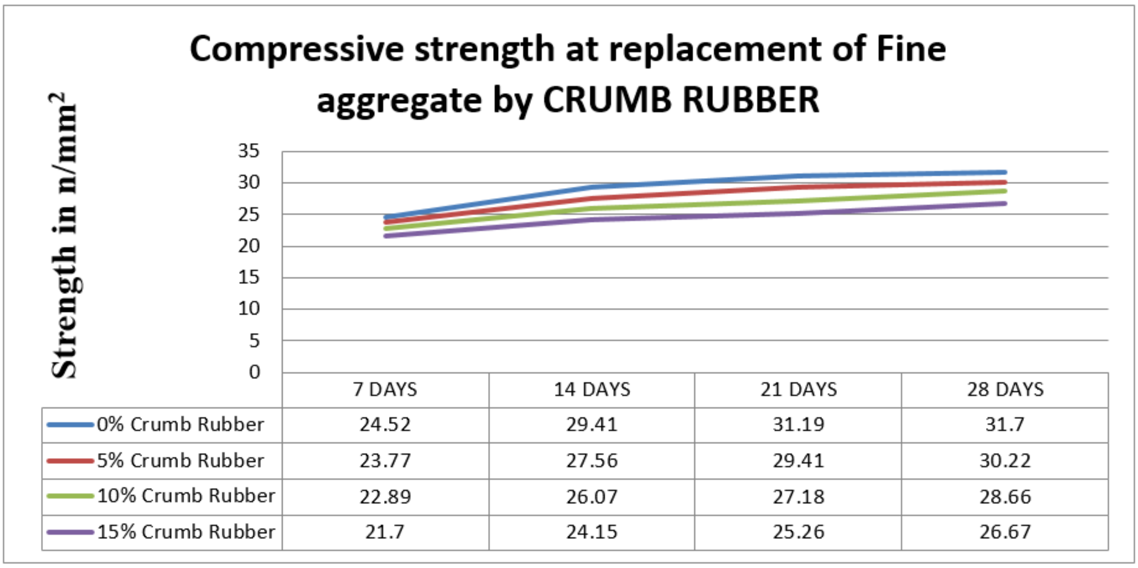
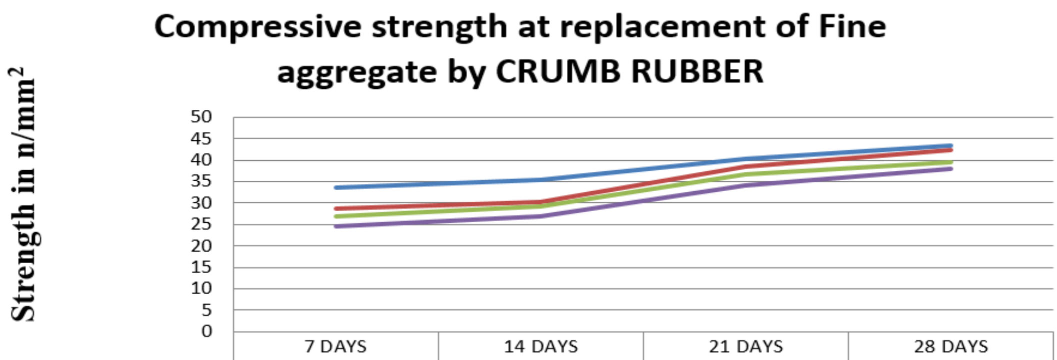


Figure 5: Compressive strength substitution of Fine Aggregate by Crumb Rubber after 7, 14, 21 & 28 days for M25

D. Aggregate by CRUMB RUBBER (M-35)



	7 DAYS	14 DAYS	21 DAYS	28 DAYS
0% Crumb Rubber	33.58	35.45	40.35	43.4
5% Crumb Rubber	28.74	30.37	38.44	42.27
10% Crumb Rubber	26.81	29.11	36.67	39.46
15% Crumb Rubber	24.59	26.89	34.22	37.96

Figure 6: Compressive strength at 0%, 5%, 10% & 15% replacement of Fine Aggregate by Crumb Rubber after 7,14,21 & 28 days (M-35)

V. CONCLUSION

This paper encompasses a sequence of investigations centered on Crumb rubber as a partial replacement for fine aggregate in concrete, with different ratios of 0%, 5%, 10%, and 15% by weight of fine aggregate. The results of this study exhibit substantial promise for the utilization of discarded tires in concrete mixtures. The experiments were carried out following the guidelines prescribed in the relevant IS-code practices for M-25 and M-35 grades of concrete. [6][8].

The following points are observed:

- The compressive strength and flexural strength of M25 and M35 grade concrete exhibit a reduction after 28 days when Crumb rubber is incorporated into the concrete mix.
- The strength of the modified concrete is reduced with an increase in the rubber content however lower unit weight meets the criteria of light weight concrete that fulfill the strength requirements.
- The 7-day compressive strength of M25 grade concrete experiences a reduction of 3.05%, 6.66%, and 11.50%, respectively, compared to the normal concrete mix, When adding 5%, 10%, and 15% Crumb Rubber for fine aggregate.
- When adding 5%, 10%, and 15%, the 14-day compressive strength of M25 grade concrete experiences a reduction of 6.29%, 11.35%, and 17.88%, respectively, in comparison to the standard concrete mix.
- When using 5%, 10%, and 15% Crumb Rubber replacement for fine aggregate, the 21-day compressive strength of M25 grade concrete experiences a reduction of 5.70%, 12.85%, and 19.01%, respectively.
- While 5%, 10%, and 15% Crumb Rubber as a partial substitution for fine aggregate, the 28-day compressive strength of M25 grade concrete experiences a reduction of 4.67%, 9.59%, and 15.86%, respectively, compared to the normal concrete mix.
- When incorporating 5%, 10%, and 15% Crumb Rubber substitution for fine aggregate, the 7-day compressive strength of M35 grade concrete experiences a reduction of 14.41%, 20.16%, and 26.77.
- On addition of 5%,10% & 15% Crumb Rubber with fine aggregate, 14 days compressive strength decreases as 14.34%,17.88% & 24.15% with respect to normal concrete mix for M35 grade of concrete.
- On addition of 5%,10% & 15% Crumb Rubber as substitution with fine aggregate, 21 days compressive strength decreases as 4.73%,9.12% & 15.19% with respect to normal concrete mix for M35 grade of concrete.
- During incorporating 5%, 10%, and 15% , 28-day compressive strength of M35 grade concrete experiences a reduction of 2.60%, 9.07%, and 12.53%, respectively, in comparison to the normal concrete mix.
- On addition of 5%,10% & 15% Crumb Rubber as replacement with fine aggregate, 28 days flexural strength decreases as 7.84%, 14.49% & 18.49% with respect to normal concrete mix for M25 grade of concrete.
- When added 5%, 10%, and 15% Crumb Rubber substitution for fine aggregate, the 28-day flexural strength of M35 grade concrete experiences a reduction of 3.62%, 8.67%, and 13.70%, respectively, compared to the normal concrete mix.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest

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