MICROSTRUCTURAL AND MECHANICAL INSIGHTS OF CONCRETE INCORPORATING SHREDDED PLASTIC AND CRUMB RUBBER

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ABSTRACT- *The quick rise in plastic waste and old car tires has generated major environmental difficulties because they can't break down and are thrown away in the wrong way. This research investigates the microstructural and mechanical characteristics of concrete that integrates crumb rubber and shredded plastic as partial replacements for fine aggregates. We mixed M30-grade concrete with different amounts of replacements and tested them for both fresh and hardened quality. We used slump and compaction factor tests to see how easy it was to work with concrete, and we used rebound hammer and ultrasonic pulse velocity tests after 28 days of curing to see how strong it was when it was firm.*

The tests indicated that moderate amounts of replacement made the workability better, but higher amounts of replacement made the compressive strength poorer because the cement matrix and waste elements didn't connect as well. Concrete with a low replacement rate, on the other hand, was robust enough for usage that didn't involve building. The study reveals that employing shredded plastic and crumb rubber can improve the environment, save natural resources, and support building approaches that are helpful for sustainable future. So, using trash to make concrete is a green way to build infrastructure that will last.

1 INTRODUCTION

The construction industry is essential for socio-economic development, providing infrastructure such as buildings, roads, and utilities. With rapid urbanization, the demand for construction materials—especially concrete—has increased significantly. Concrete, composed of cement, water, and aggregates, relies heavily on fine aggregates like natural

sand, which improve strength and workability. However, excessive sand extraction has caused environmental issues such as riverbank erosion and ecological imbalance, creating a need for sustainable alternatives.

At the same time, non-biodegradable wastes like plastic and rubber are accumulating rapidly, posing serious environmental and health risks due to improper disposal methods like burning and dumping. A sustainable solution is the use of these waste materials in concrete.

Crumb rubber from waste tyres and shredded plastic from recycled waste can partially replace fine aggregates. Rubber improves flexibility and impact resistance, while plastic reduces density and enhances durability. However, strength may decrease due to weak bonding. This study evaluates their effects on concrete properties, aiming to promote sustainable construction and efficient waste management.

1.1 Background and Environmental Concerns

Conventional concrete production is associated with several environmental and resource-related challenges affecting sustainability. The continuous use of natural resources, high energy demand, and waste accumulation require a shift from traditional practices. The major concerns are as follows: **Natural Resource Depletion:**
Concrete requires large quantities of sand and gravel, extracted from rivers and quarries. Excessive mining disturbs ecosystems, lowers groundwater levels, and causes erosion, while quarrying leads to deforestation and land degradation.

Carbon Emissions:
Cement production releases significant CO_2 during clinkerformation, contributing to greenhouse gas emissions and climate change.
Energy Consumption:
Processes like extraction, crushing, transportation, and mixing consume high energy, increasing the carbon footprint.

Plastic Waste Pollution:
Plastic waste is non-biodegradable, pollutes land and water, harms wildlife, and forms microplastics that affect health.

Waste Tire Disposal:
Discarded tyres occupy landfill space, collect stagnant water, and release toxic gases when burned.

Landfill Overload:
Accumulation of plastic and rubber waste leads to overburdened landfills and long-term pollution.

Environmental Pollution:
Construction activities and waste disposal cause air, water, and soil pollution, affecting ecosystems and human health.

Sustainability Challenge:
These issues highlight the need for eco-friendly alternatives. Using crumb rubber and shredded plastic as partial replacements for fine aggregates reduces resource depletion, manages waste, and supports sustainable construction.

1.2 MATERIAL USED

The basic components utilized in this study are:

1. Ordinary Portland Cement (OPC) of grade 43
2. Fine aggregates (Sand)
3. Coarse aggregates
4. Crumb Rubber
5. Shredded Plastic
6. Water

a. Ordinary Portland Cement (OPC43)

One kind of hydraulic cement that is frequently utilized in the building sector is Ordinary Portland Cement (OPC) 43. After 28 days of curing, the cement's compressive strength is indicated by the "43" in its name. The minimum strength of Ordinary Portland Cement 43 is 43 MPa (megapascals), or around 6,200 psi (pounds per square inch).OPC 43 is but one variety of Portland cement that is offered; each has unique qualities and uses. A building project's needs should be taken into account while selecting a type of cement. Elements like as needed strength, durability, setting time, and cost should all be taken into account.

Table 1: Chemical composition of Ordinary Portland Cement

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

Tests for Cement:

1) Fineness of Cement

The workability, strength development, and rate of hydration of concrete are all impacted by the fineness of the cement. Finer cement often has a better initial strength, but it might also require more water and be harder to work with.

Cement is sieved through a series of sieves with varying mesh sizes to determine its fineness. Plotting a particle size distribution curve involves measuring the amount of cement retained on each sieve. The proportion of cement retained on a specific sievetypically a 90-micron (No. 170) sieveis used to indicate the fineness of the cement.

2) Initial and Final setting time of Cement

4.) Specific Gravity of Cement

The cement's initial and ultimate setting times are crucial measurements that show how long the cement paste can be worked on before it begins to set and harden.

Standardized tests, such the Vicat apparatus method, are commonly used to assess these qualities. In this approach, a needle is inserted into the cement paste and allowed to travel through it until it reaches certain locations that indicate the initial and final setting durations.

Initial Setting Time: This is the amount of time that has passed between adding water to the cement and the point at which the cement paste becomes less malleable and becomes difficult to pierce with a regular needle. The standard needle used in this test has a mass of 113.4 grams and a diameter of 1 mm. The window of time allotted for pouring and compacting concrete before it begins to set is indicated by the initial setting time.

Final Setting Time: This is the amount of time needed for the cement paste to solidify to the point where a standard needle can no longer pierce it. The point at which concrete becomes stiff and cannot be molded or disturbed without weakening it is indicated by the final setting time.

3.) Consistency of Cement

The consistency of cement determines its flowability. It is important because it affects how workable and manageable cement paste, mortar, and concrete are. Cement consistency is determined by the Vicat consistency test, which usually makes use of the Vicat equipment.
The specific gravity of cement is used to assess its density relative to the density of water. It indicates how much heavier or lighter cement is compared to an equal volume of water. The specific gravity of cement is classically established utilizing the Le Chatelier Flask method.
Computation: Determine the cement's specific gravity (SG) by applying the following formula:

$$SG = W2\ (W3-W1)-(W4-W1)$$

- W2 is the weight of cement when it is not wet.
- W1 represents the weight of the flask when it is empty.
- W3 is the sum of the weight of the flask and the liquid (kerosene/naphtha).
- W4 is equal to the combined weight of the flask and water.

Outcomes:
The density of cement relative to water is determined by calculating its specific gravity.

Table 2: Properties of Ordinary Portland Cement

S.No.	PROPERTY	RESULT
1.	Fineness	8%
2.	Specific Gravity	3.08
3.	Initial Setting Time	30 minutes
5.	Consistency	34%

Fig 1. Specific Gravity of Cement Test

Fig 2. Initial Setting Time test for Cement

b. Fine Aggregate (Sand)

Sand is a multifunctional, highly usable material in construction and civil engineering. M-sand with specific gravity 2.67 was used. The size of Fine Aggregate was less than 4.75 mm. Fig. 7, Bulking of Sand shows the change in the volume with varying percentage of crumb rubber.

Sand is used in the various fields to produce concrete and mortar, improve drainage and create recreational grounds. Sustainable sourcing and responsible extraction practices are crucial to preserve natural resources and minimize the environmental impact associated with sand as a construction material.

Fine Aggregate Gradation Test

This test is widely applied for the determination of the particle size distribution of both coarse and fine aggregates using the sieve analysis sketched in Table 3 below. To segregate the aggregate material per size,a sample is placed on a stack of nested sieves and rattled manually or mechanically. The grading of the material, commonly expressed as a percentage passing each sieve, can then be found using the resulting data. Aggregate grading is highly crucial due to its effects on the workability, strength, and durability of concrete and other materials in the construction field. An incorrectly graded aggregate mix may lead to poor workability, poorer strength, and higher susceptibility to cracking, whereas a well-graded mix will produce a product that is more dense, strong, and durable. 3.15 obtained as Fineness Modulus value as per the test result which lies between the standard values 2.0 to 3.5 as shown in table 3.

Table 3. Fine Aggregate Sieve Analysis Test

Wt. of Sample		18431			
	SIEVE ANALYSIS OF FINE AGGREGATE As per IS 383-2016				
IS Sieve mm	Wt. Retained (in gms)	Cumulative Wt.of retained (in gms)	Cum. Percentage retained	Percentage of passing	Specification limit IS:383
10.00	0	0	0	100	100
4.75	1017	1017	5.52	94.48	90-100
2.36	3578	4595	24.93	75.07	60-95
1.18	993	5588	30.32	69.68	30-70
0.60	7021	12609	68.41	31.59	15-34
0.30	4893	17502	94.96	5.04	5-20
0.15	-732	16770	90.99	9.01	0-10
PAN					
FINENESS MODULUS		3.1513			Specified value 2.0 to 3.5

c.) Coarse Aggregates

Coarse aggregates are a fundamental construction material commonly used in a wide range of building and infrastructure projects. These aggregates play a crucial role in providing structural stability and durability to concrete and other construction materials.10 mm and 20 mm aggregates are used in the ratio of 4:6 respectively. The specific gravity of 10 mm aggregate was 2.7 whereas specific gravity of 20 mm aggregate stood at 2.85.

Coarse aggregates are a vital construction material that contributes to the strength, durability, and stability of various construction materials, particularly concrete. Proper selection, gradation, and quality control of coarse aggregates are essential to ensure the structural integrity and performance of construction projects.

AGGREGATE IMPACT VALUE TEST

Aggregates deteriorate considerably with time. To carry loads from the pavement surface to the underlying layers and, eventually, the subgrade, aggregates must be robust and resilient enough to survive crushing, degradation, and disintegration. The strength of aggregates in concrete cannot be accurately measured solely by testing the strength of the source rock. As a result, a standardized sample of bulk aggregates is utilized to determine their strength. As a result, a variety of tests are conducted to assess the quality and stability of roadways. One such test is the Aggregate Impact Value Test, which is performed using an Impact Testing Machine, as illustrated in the figure. The impact test is a type of highway pavement quality control test that determines if aggregates are suitable for use in highway pavements. Aggregates might break into smaller pieces as a result of impact loading from moving vehicles on the road. As a result, the aggregates must be sufficiently robust to withstand impact- induced disintegration. The impact value test is used to assess this aggregate property

$$\text{Impact Value Test } = \frac{W3}{W2-W1}$$

Where, W1= Empty Weight of Cylinder
W2= Weight of Cylinder with the Aggregate
W3=Weight of Aggregate passing through 2.36mm sieve

Table 4. Aggregate Impact Value Test

Determinations	Units	Trial No.1	Trial No. 2
Empty Weight of Cylinder (W1)	g	1911.5	1911.5
Weight of Cylinder with the Aggregate (W2)	g	2410	2450
Weight of Aggregate passing through 2.36mm sieve (W3)	g	106	106
A.I.V=[W3/(W2-W1)]100	%	21.26	19.67
Avg. Value of A.I.V.	%	20.46	

c. Crumb Rubber

Crumb rubber used in construction is obtained from recycled tyres, helping reduce waste and promote sustainable disposal. It typically ranges in size from 0.0075 mm to 4.75 mm, with a unit weight of about 660 kg/m^3. Due to its high elasticity and flexibility, crumb rubber improves resistance to cracking and deformation. Its inclusion enhances impact resistance and durability, making it suitable for surfaces subjected to mechanical stress. It can be used to produce workable and lightweight concrete, which also shows good resistance to freeze–thaw cycles, acid attack, and chloride penetration. The addition of silica fume further improves strength and durability.

Properties:
Elasticity and Flexibility:
Provides high resilience, reducing cracking and deformation.
Impact Resistance:
Enhances durability and performance under mechanical stress.
Reduced Water Demand:
Requires less water for workability, minimizing shrinkage cracks and improving durability.

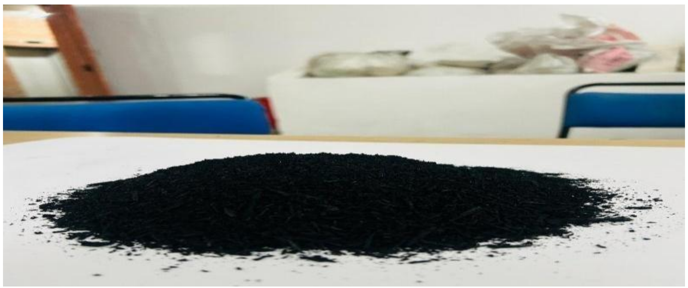

Fig 3. Rubber Crumb

d. Shredded Plastic

Shredded plastic used in construction is obtained from recycled waste such as bottles, packaging, and containers. It is processed into small particles and used as a partial replacement for fine aggregates, helping reduce environmental pollution and promote sustainable construction.
The particle size typically ranges from 0.075 mm to 4.75mm. Due to its lower density (about 900–950 kg/m^3), shredded plastic helps produce lightweight concrete. It is durable, non-biodegradable, and resistant to moisture and chemical attack, which improves the durability and service life of construction materials when used in controlled proportions.
The use of shredded plastic also reduces dependence on natural aggregates and supports effective waste management through recycling.

Properties:
Lightweight Characteristic: Reduces the overall weight of concrete, suitable for lightweight applications.
Resistance to Moisture and Chemicals: Improves durability by resisting water penetration and chemical damage.
Low Water Absorption: Does not absorb water, maintaining workability and reducing moisture-related issues.
Environmental Benefit: Promotes recycling, reduces landfill waste, and supports sustainable construction.

Fig 4. Shredded Plastic

CHAPTER-2 LITERATURE REVIEW

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1. Choi et al. (2005) investigated concrete containing recycled plastic waste. The study reported a reduction in density and compressive strength with increased plastic content, whereas ductility and impact resistance improved. Microstructural analysis highlighted poor bonding between plastic particles and cement paste, emphasizing the need for surface treatment and particle optimization.
2. Ganjian, Khorami and Maghsoudi (2009) analyzed the mechanical behavior of rubberized concrete. Results showed that higher rubber content leads to decreased compressive and tensile strength but improved toughness and energy absorption. Thereduction in strength was attributed to a weakinterfacial transition zone (ITZ) between rubber particles and the cement matrix.
3. Al-Hadithi and Hilal (2016) evaluated the effect of shredded plastic fibers on concrete. Their research demonstrated improved crack resistance and ductility due to the fiber-bridging mechanism across microcracks. However, a slight reduction in compressive strength was observed.
4. Eldin and Senouci (1993) studied the performance of concrete containing tyre rubber particles. The results indicated reduced compressive strength with increasing rubber content due to weak bonding, but enhanced resistance to impact and deformation. Microstructural analysis confirmed the presence of voids around rubber particles.
5. Ismail and Al-Hashmi (2008) investigated the replacement of natural sand with plastic waste. The study showed reduced density and increased ductility, but compressive strength decreased at higher replacement levels. Microstructural findings indicated void formation around plastic particles, limiting their effectiveness at higher proportions.
6. Khatib and Bayomy (1999) focused on the durability of rubberized concrete. Their findings revealed reduced compressive strength but significantly improved resistance to abrasion and impact. The study concluded that such concrete is suitable for applications requiring flexibility rather than high strength.
7. Sharma and Bansal (2016) provided a comprehensive review of plastic waste utilization in concrete. They reported that plastic aggregates decrease density and strength while enhancing thermal insulation and impact resistance. Weak bonding between plastic and cement paste was identified as the primary limitation.
8. Li, Stubblefield, Garrick, and Pang (2004) examined the microstructural behavior of rubberized concrete. The study found that rubber particles improve toughness and crack resistance but reduce compressive strength due to microvoidsat the interface.
9. Raghatate (2012) investigated concrete with plastic aggregates. The findings indicated reduced unit weight and improved chemical resistance; however, compressive strength declined at higher replacement levels due to the smooth surface of plastic particles, which limits bonding.
10. Topçu and Bilir (2009) reported that rubberized concrete exhibits enhanced flexibility and impact resistance but reduced compressive strength. The presence of weak zones within the cement matrix was identified as the primary cause of strength reduction.
11. Batayneh, Marie, and Asi (2007) examined plastic waste as aggregate replacement. The results showed reduced density and increased flexibility, but lower mechanical strength due to poor bonding between plastic particles and the cement matrix.
12. Gesoğlu, Güneyisi, and Khoshnaw (2014) highlighted that crumb rubber enhances durability and crack resistance, particularly under cyclic loading. Microstructural observations indicated the formation of flexible zones within the concrete matrix.
13. Kou, Lee, and Poon (2009) reported that plastic aggregates improve thermal insulation but reduce compressive strength due to interfacial gaps. The study recommended surface modification techniques to improve bonding.

14. Saikia and De Brito (2012) concluded that recycled plastic aggregates reduce density and are suitable for lightweight concrete applications. However, compressive strength decreases with increasing plastic content due to weak interfacial bonding.Overall, the literature consistently indicates that the incorporation of crumb rubber and plastic waste reduces compressive strength due to weak bonding and increased porosity. However, these materials enhance ductility, impact resistance, and energy absorption capacity. Microstructural studies emphasize the significance of the interfacial transition zone in determining concrete performance. Optimizing replacement levels and improvingbonding through surface treatments or supplementarymaterials can enhance the effectiveness of these sustainable alternatives.

CHAPTER-3 EXPERIMENTALWORK

3.1 DESIGN MIX

For M30 grade concrete, a design mix with a weight proportion of 1:1.83:3.01:0.5 (cement: fine aggregate: coarse aggregate: water) is prepared in accordance with Indian Standard Code 10262–2009. Graded aggregates are utilized in two fractions as 60% of 20 mm and 40% of 10 mm of coarse aggregate in the composition of concrete to improve workability during the mixing process.

Table 5. Design Mix for Conventional M- 30 Concrete Mix

S.No.	Materials	3cubes (kg)*
1	Cement (OPC43)	3.66
2	Fine Aggregates	6.9
3	Coarse Aggregates	11.34
4	Water	0.486

3.2 CASTING OF SPECIMEN

In accordance with the mixed design percentage of M30 grade concrete, weigh batching is used, three cube samples measuring 150 × 150 × 150 mm are cast. The samples were evaluated after 28 days of curing, in accordance with Indian Standard Code 456-2000.

Fig 5. Concrete Specimen

3.3 TESTING PROCEDURE

3.3.1 SLUMP VALUE

The workability of concrete refers to ease of compacting, placing and transportation during construction. Several factors influence the workability such as water-cement ratio, cementitious materials, mix-proportion, consistency, transportation and placement etc.

Fig 6. Slump Cone Apparatus

In this testing bottom diameter, top diameter and height are 200, 100 and 300mm respectively was used as a dimension of slump cone as seen in Fig 6 In order to eliminate air spaces, new concrete was used in this test and layered three times within a slump cone. Each layer was then compressed by a tamping rod 25 times. The concrete drop was calculated as the height difference between the displaced concrete and the cone's initial height after the cone was carefully raised vertically.

3.3.2 COMPACTION FACTOR TEST

The compaction factor test evaluates the workability of fresh concrete by using compaction factor apparatus. It measures how easily concrete can be compacted into a dense form, crucial for achieving desired strength anddurability. This test involved placing a sample offreshly mixed concrete into a standard apparatus as shown in Fig 7. The compaction factor was determined by dividing the weight of the partially compacted concrete by the weight of the fully compacted concrete. The concrete was compacted by periodically raising and dropping the mould from a predetermined height.

Fig 7. Compaction Factor Apparatus

Fig 8. Compaction Factor Test

3.3.3 REBOUND NUMBER

Rebound Hammer Test is a non-destructive test which is used to estimate the compressive strength of the existing structure on the field by using Rebound Hammer equipment as shown in figure 9. It's a quick and convenient way to estimate quality and uniformity of existing concrete structure as shown in table 15.

Fig 9. Rebound Number testing Apparatus

In this testing prepared the surface, calibrated the hammer, and select test locations. Hold the hammer perpendicular to the surface, strike it, and record the rebound numbers. Rebound hammer charts were used to correlate rebound numbers with compressive strength.

Table 6. Quality of Concrete Corresponding to different Rebound Number

Average Rebound Number	Quality of Concrete
30-40	Good
20-30	Fair
<20	Poor
0	Delaminated

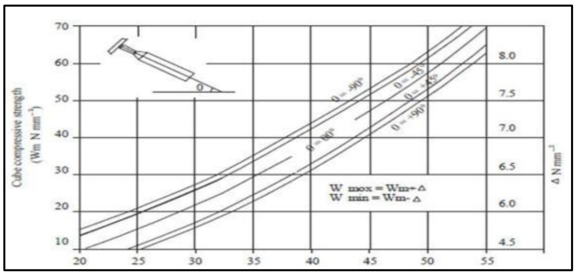

Fig 10. Rebound Hammer Chart

3.3.3 ULTRASONIC PULSE VELOCITY

The ultrasonic pulse velocity test (Fig. 11) is one of the non-destructive tests (NDTs) that are performed on concrete specimens to determine the mechanical characteristics of the material without inflicting any damage. Any concrete specimen may be evaluated using this method to determine its density, homogeneity, uniformity, and other characteristics. The ultrasonic pulse velocity test results demonstrate whether or not the concrete was properly compacted during casting.

The range of data supporting the quality of the concrete may be used to classify it as excellent, good, medium, or unclear in accordance with Indian Standard Code 13311 (Part 1) 1992. Table 7 presents the findings.

Fig 11.Ultrasonic Pulse Velocity Apparatus.

Table 7.Concrete classification using ultrasonic pulse velocity testing.

Pulse Velocity (Km/s)	Concrete Quality
Above 4.5	Excellent
3.5 to 4.5	Good
3.0 to 3.5	Medium
Below 3.5	Doubtful

In USPV testing transducers were greased and placed on a smooth concrete surface. Ultrasonic waves travel from transmitter to receiver transducers through the specimen. Time taken for propagation is recorded by the electronic timing device, along with specimen length. Velocity of propagating waves were calculated using equation-(2).

$$\text{Pulse Velocity} = \frac{\text{Width of structure}}{\text{Time taken by pulse to go through}} \quad \text{--------------------}(2)$$

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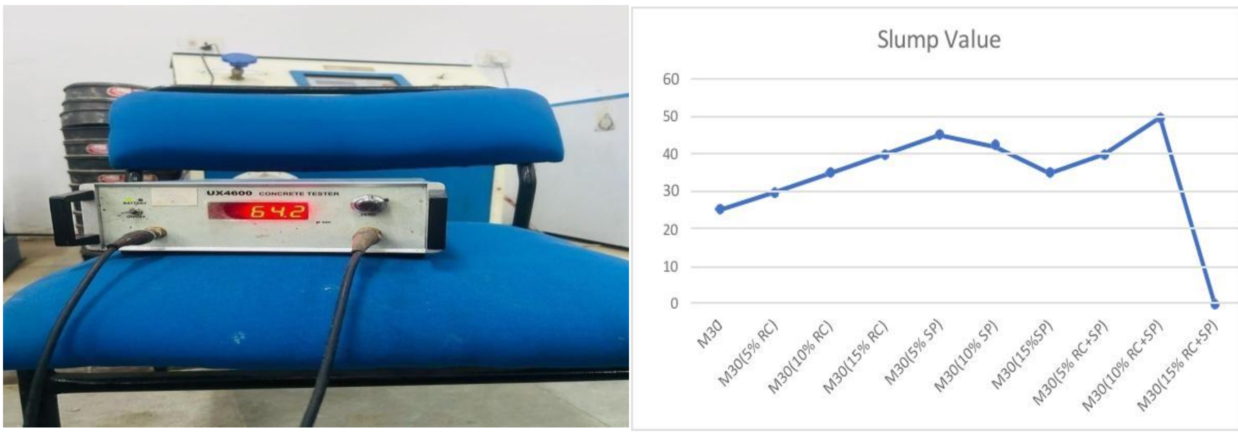

Fig 12. Ultrasonic Pulse Velocity meter

CHAPTER-4 RESULT AND DISCUSSION

4.1 SLUMP

When crumb rubber and shredded plastic are used as partial replacements for fine aggregates in M30 concrete, the workability of the mix changes noticeably. At lower replacement levels (5% and 10%), the slump value increases, indicating improved workability. However, beyond this range (15%), the slump decreases, making the concrete stiffer and less workable.

This reduction at higher replacement levels is due to the properties of crumb rubber and shredded plastic, such as irregular particle shape, surface texture, and lower specific gravity compared to natural sand. The variation in slump values for 0%, 5%, 10%, and 15% replacements is shown in Figure 13.

Table 8. Slump Values at Different Design Mix

Design Mix	Compaction Factor
M30	0.93
M30(5% RC)	0.97
M30(10% RC)	0.94
M30(15% RC)	0.91
M30 5% SP	0.88
M30 10% SP	0.73
M30 15% SP	0.7
M30 5% RC+SP	0.78
M30 10% RC+SP	0.74
M30 15% RC+SP	0

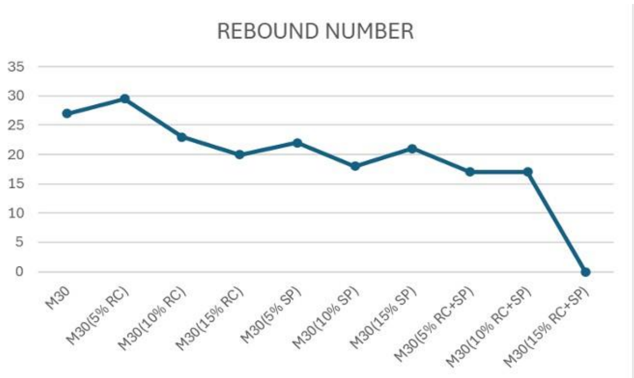

Fig 13. Slump values of concrete with replacement of RC and SP

4.2 COMPACTION FACTOR

Outline of this test is presented in Figure 14, which shows the comparison of compaction factor values for 0%, 5%, 10%, 15% replacement of fine aggregate with crumb rubber and shredded plastic. The compaction factor test is used to assess the workability of the concrete mix. A higher compaction factor value indicates improved workability and ease of compaction, whereas a lower value reflects a stiffer mix that may be more difficult to place and properly compact. The results help in understanding the effect of incorporating crumb rubber and shredded plastic on the workability characteristics of the concrete.

Table 9. Compaction Factor at Different Design Mix

Design Mix	Slump Value
M30	25
M30(5% RC)	30
M30(10% RC)	35
M30(15% RC)	40
M30(5% SP)	45
M30(10% SP)	42

M30(15%SP)	35
M30(5% RC+SP)	40
M30(10% RC+SP)	50
M30(15% RC+SP)	0

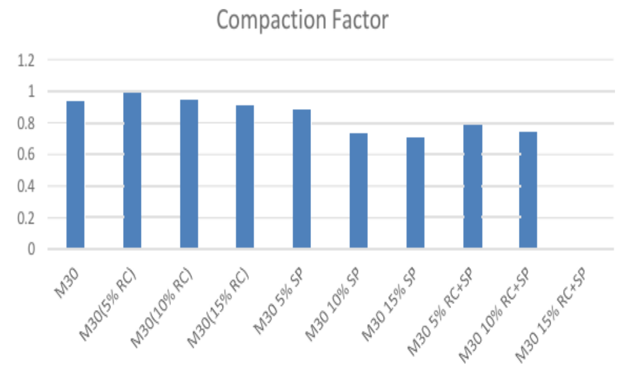

Fig 14. Compaction factor values for concrete with replacement of RC and SP

4.3 REBOUND HAMMER

The rebound hammer test is an important non-destructive method used to estimate the compressive strength of concrete. This test is based on the principle of surface hardness, where the rebound of a spring-controlled hammer striking the concrete surface indicates the hardness of the concrete near the surface of the cube specimen. Figure 15 illustrates the variation in rebound number for 0%, 5%, 10%, 15% replacement of fine aggregate with crumb rubber and shredded plastic. An increase in the rebound number is observed at 5% replacement, indicating an improvement in surface hardness at this level. However, as the percentage of crumb rubber and shredded plastic increases further, a noticeable decline in the rebound number is observed, suggesting a reduction in surface hardness.

Table 10. Rebound Number at Different Design Mix

Specimen No.	DOC	DOT	RESULT
M30	10-12-2025	06-01-2026	27
M30(5% RC)	15-12-2025	13-01-2025	29.5
M30(10% RC)	16-12-2025	14-01-2026	23
M30(15% RC)	23-12-2025	20-01-2026	20
M30(5% SP)	21-01-2026	17-02-2026	22
M30(10% SP)	22-01-2026	18-02-2026	18
M30(15% SP)	27-01-2026	24-02-2026	21
M30(5% RC+SP)	28-01-2026	25-02-2026	17
M30(10% RC+SP)	29-01-2026	26-02-2026	17
M30(15% RC+SP)	29-01-2026	26-02-2026	0

Fig 15. Rebound Number values for different RC and SP replacement.

Table 11. Compressive strength obtained from Rebound Number

Specimen No.	Rebound No.(R)	Compressive Strength(Fck)
M30	27	23.2
M30 5% RC	29.5	27.2
M30 10% RC	23	16.8
M30 15% RC	20	12
M30 5% SP	22	15.2

M30 10% SP	18	8.8
M30 15% SP	21	13.6
M30 5% RC+SP	17	7.2
M30 10% RC+SP	17	7.2
M30 15% RC+SP	0	0

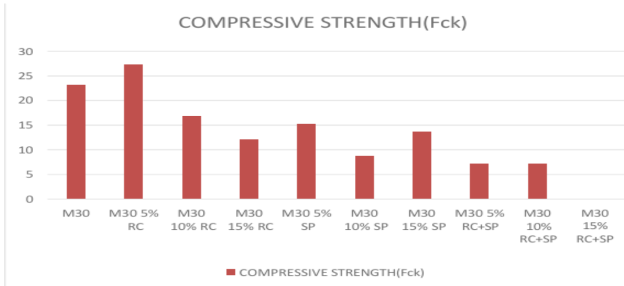

Fig 16. Compressive strength obtained from Rebound Number

4.4 ULTRASONIC PULSE VELOCITY

For concrete with 0% to 15% replacement of fine aggregate by crumb rubber and shredded plastic, a gradual decrease in ultrasonic pulse velocity (UPV) is observed. This reduction is due to changes in the internal structure of the concrete, including weaker bonding in the C–S–H gel and the presence of rubber and plastic particles. These materials may create voids or discontinuities in the matrix, affecting the transmission of ultrasonic waves. The UPV values for 0%, 5%, 10%, and 15% replacement levels are shown
in Figure 17.

Table 12. Ultrasonic Pulse Velocities at different Design Mixes

Specimen No.	DOC	DOT	RESULT
M30	10-12-2025	06-01-2026	5172.41

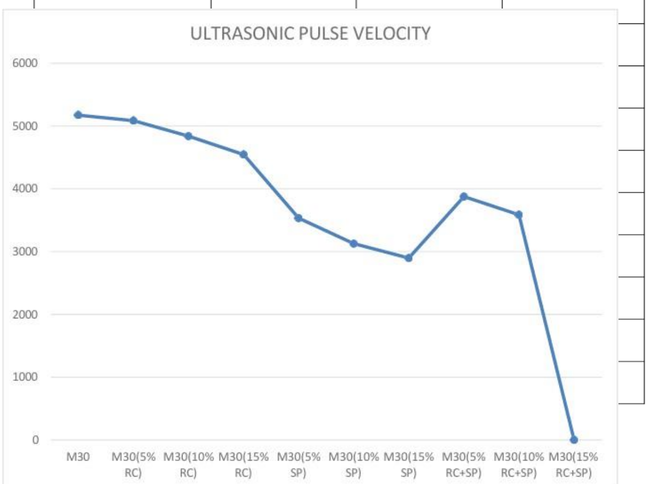

Fig 17. USPV values for different design mix.

CHAPTER-5 GAPS IN THE LITERATURE AND POSSIBLE AREAS FOR FUTURE RESEARCH

Although significant research exists on waste materials in concrete, the combined use of crumb rubber and shredded plastic as fine aggregate replacement still needs further study. Key research gaps include:

5.1 Optimization of Replacement Levels: Identify optimum proportions that maintain strength while ensuring efficiency for various applications.
5.2 Long-Term Durability Performance: Assess behavior under conditions like chemical exposure, moisture, abrasion, and freeze–thaw cycles.
5.3 Mechanical and Structural Behavior: Evaluate effects on compressive, tensile, and flexural strength, and overall structural performance.
5.4 Microstructural and Bonding Characteristics: Study interaction and bonding between waste materials and cement matrix.
5.5 Environmental and Sustainability Assessment: Conduct life-cycle analysis to measure environmental benefits and impacts.
5.6 Workability and Mix Design Improvements: Develop improved mix designs using admixtures or modified techniques.
5.7 Economic Feasibility: Analyze cost-effectiveness compared to conventional concrete.
5.8 Standardization and Guidelines: Establish proper standards and testing methods for consistent use.
5.9 Potential Applications: Explore uses in pavements, lightweight structures, and impact-resistant elements.

Addressing these gaps will support the development of sustainable and efficient concrete while promoting recycling of rubber and plastic waste.

CHAPTER-6 RECOMMENDATIONS FOR FUTURE RESEARCH

Some recommendations for further investigation are summarized below:

1. Improve processing methods of crumb rubber and shredded plastic to modify properties like density, shape, texture, and hydrophobic behavior, enhancing compatibility with the cement matrix.
2. Conduct detailed experimental and parametric studies to develop reliable prediction models, especially for air content and workability.
3. Perform long-term studies to evaluate durability and life-cycle performance under various environmental conditions.
4. Investigate behavior under extreme conditions such as fire and blast loading to understand performance and failure characteristics.
5. Study thermal behavior, including volume changes at elevated temperatures (expansion or shrinkage).
6. Identify factors affecting durability properties like toughness, abrasion resistance, chloride penetration, acid and sulphate resistance, and corrosion, as existing results vary.

CHAPTER-7 CONCLUSION

The study highlights the potential of using crumb rubber and shredded plastic as partial replacements for fine aggregates in concrete to address environmental challenges. Rising demand for natural aggregates and increasing non- biodegradable waste require sustainable construction solutions.
Results show that these materials influence both fresh and hardened properties of concrete. At lower replacement levels, workability remains acceptable, while higher levels reduce strength due to weak bonding with the cement matrix.
Despite strength reduction, the concrete shows improved ductility, impact resistance, and energy absorption, making it suitable for non-structural uses like pavements and lightweight elements.
The use of waste materials reduces dependence on natural aggregates and helps manage plastic and rubber waste, minimizing pollution and landfill load. However, non- destructive tests indicate increased voids and reduced uniformity at higher replacements, affecting durability.
In conclusion, crumb rubber and shredded plastic offer a sustainable alternative in concrete. Proper proportioning is essential, and further research is needed to improve bonding, optimize mix design, and assess long-term performance.

REFERENCES

1. Ahmad, J., et al. (2022). Toward sustainable concrete: Substituting aggregates with plastic waste—review with SEM insights. Crystals.
2. Al-Luhybi, A. S., et al. (2021). Mechanical properties of concrete with recycled plastic wastes. Civil and Environmental Engineering.
3. Alqahtani, F. K., et al. (2022). Producing sustainable concrete with plastic waste: A review. Environmental Challenges, 9, 100626.
4. American Concrete Institute (ACI). Guide for Concrete Materials and Sustainability.

5. Babafemi, A. J., et al. (2018). Waste recycled plastic in concrete: Engineering and durability properties. MDPI Sustainability Journal.
6. Babafemi, A. J., Šavija, B., Paul, S. C., & Anggraini,
V. (2018). Engineering properties of concrete with waste recycled plastic: A review. Sustainability, 10(11), 3875.
7. Dai, P., et al. (2024). Effect of waste plastic fibers on printability and mechanical properties of 3D- printed mortar. Additive Manufacturing Letters.
8. Dhanalakshmi, K., et al. (2025). Recycled e-waste plastic as coarse aggregate: Strength & microstructure. International Journal of Concrete Structures and Materials.
9. Duraiswamy, S., et al. (2024). Impact of plastic-fiber and recycled aggregates on strength and microstructure. Scientific Reports.
10. El-Aidy, K. E., et al. (2024). Mechanical and physical properties of eco-friendly recycled plastic concrete (RPC). Additive Manufacturing Letters.