International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 9 Issue 5, Sep-Oct 2025 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Sustainable Cement Concrete Utilizing a Combination of Rubber Tyre Crumbs and Human Hair

Shaista Zainab[1], Dr. Preetpal Singh[2]

[1]Research Scholar, Department of Structural Engineering, Rayat Bahra University, Sahauran, Kharar, Punjab, India
[2]HOD, Department of Structural Engineering, Rayat Bahra University, Sahauran, Kharar, Punjab, India

ABSTRACT

This study presents an experimental investigation into the sustainable use of waste materials in cement concrete by incorporating rubber tyre crumbs and human hair as partial substitutes for natural aggregates. Fibre-reinforced concrete is known to improve crack resistance and mechanical properties, addressing the inherent tensile weakness of conventional concrete. Human hair, an abundantly available non-degradable material, offers an economical reinforcement option, while rubber tyre crumbs enhance sustainability by reducing environmental pollution. Together, these materials contribute to better ductility, crack control, and durability of concrete. Concrete remains the most widely consumed construction material worldwide due to its strength and versatility, but the growing demand for infrastructure is exerting pressure on natural resources, leading to higher costs and ecological concerns. To overcome these challenges, this research replaces natural aggregates with rubber tyre crumbs at varying proportions (0%, 3%, 6%, 9%, and 12%) while maintaining a fixed 1.5% human hair content. The mixes were evaluated through standard tests, including compressive strength, flexural strength, split tensile strength, bulk density, water absorption, impact value, and crushing value, with a constant water–cement ratio of 0.5.

Results indicated that workability decreased as the percentage of rubber tyre crumbs increased. However, compressive and tensile strengths improved up to an optimal replacement level of around 20%, after which strength properties declined. This demonstrates the potential of rubber tyre crumbs and human hair as sustainable alternatives in concrete production, promoting cost-effectiveness and environmental conservation in construction.

How to cite this paper: Shaista Zainab | Dr. Preetpal Singh "Sustainable Cement Concrete Utilizing a Combination of Rubber Tyre Crumbs and Human Hair" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-9 | Issue-5, October 2025, pp.479-489, URL: www.ijtsrd.com/papers/ijtsrd97543.pdf

IJTSRD97543

KEYWORDS: *Sustainable concrete, Rubber tyre crumbs, Human hair fibre, Mechanical properties, Waste utilization.*

1. GENERAL INTRODUCTION

Concrete is the most widely used construction material across the globe due to its high compressive strength, durability, and versatility. However, conventional concrete faces sustainability challenges due to the depletion of natural resources, high energy consumption in cement production, and disposal issues of industrial and domestic wastes. Incorporating alternative materials into concrete has emerged as an effective way to address both environmental and engineering concerns.

1.1. Waste Management and Sustainability in Construction

The construction industry plays a vital role in reducing waste generation by reusing and recycling non-biodegradable materials. Rubber tyre crumbs, a byproduct of discarded tyres, and human hair, an abundantly available biodegradable waste, are two potential reinforcements that can reduce environmental pollution while improving the mechanical properties of concrete.

1.2. Role of Rubber Tyre Crumbs in Concrete

Rubber tyre crumbs improve flexibility, energy absorption, and resistance to impact and shrinkage cracks in concrete. Their use also addresses the environmental hazards of waste tyre disposal, which is a significant global concern.

1.3. Significance of Human Hair in Fibre-Reinforced Concrete

Human hair, being non-degradable, lightweight, and strong in tension, serves as a natural fibre to enhance the ductility and crack resistance of concrete. Its integration controls micro-cracks and improves tensile strength, thereby enhancing the long-term performance of concrete structures.

1.4. Objectives of Study

1. To design M40 grade concrete and evaluate its compressive strength at 7 days and 28 days of curing.
2. To design M40 grade concrete and assess its tensile strength at 7 days and 28 days.
3. To investigate the effect of adding human hair fibers (HHF) at 1.5% by weight of cement in 45 cubes, 15 cylinders, and 15 beams, and compare the compressive, tensile, and flexural strengths with conventional plain cement concrete.
4. To study the durability characteristics of concrete cylinders containing a combination of crushed concrete aggregates and human hair fibers, prepared in the same proportions as above.

1.5. Research Gap

From the review of literature, it has been observed that most of the existing research has focused on the individual use of materials such as rubber tyre chips as a partial replacement for coarse aggregates. However, there is a notable lack of studies exploring the combined utilization of rubber tyre chips and human hair fibers along with crushed recycled concrete aggregates (CRCA) in concrete. While separate investigations on rubber tyre chips or human hair as reinforcing agents have demonstrated positive effects on the strength and durability of concrete, their synergistic role when used together particularly with recycled aggregates remains largely unexplored.

Therefore, the present study aims to address this gap by evaluating the strength properties of concrete incorporating rubber tyre chips and human hair fibers in combination with CRCA as a partial replacement for natural coarse aggregates.

To achieve this, an experimental program has been designed, which involves the following stages:

1. **Properties of materials** used in the study.
2. **Concrete mix design** in accordance with IS 10262:2009.
3. **Workability tests** on fresh concrete mixes.
4. **Casting and curing** of test specimens.
5. **Strength tests** on hardened specimens (compressive, split tensile and flexural strength).

2. RESEARCH METHODOLOGY

2.1. Materials Used

1. Ordinary Portland Cement (OPC 43 Grade):

The cement used is OPC of 43 grades, consisting of calcareous, siliceous, and aluminous components obtained by grinding clinker into fine powder. Its specific gravity is 3.15. The initial and final setting times are approximately 45 minutes and 600 minutes, respectively. The typical oxide composition includes 60–67% CaO, 17–25% SiO_2, 3–8% Al_2O_3, 0.5–0.6% Fe_2O_3, and 0.1–0.4% MgO.

2. Recycled Crushed Coarse Aggregate:

Aggregates retained on IS Sieve No. 480 (4.75 mm) are classified as coarse aggregates. The sizes used in this study were 20 mm (60%), 16 mm (20%), and 12 mm (20%), all angular and crushed. The aggregates were cleaned to remove dust before use, and their relative density was determined as 2.74.

3. Fine Aggregate (Enore Sand):

Locally sourced sand conforming to Zone II grading was used. It was first sieved through a 4.75 mm sieve and washed to remove impurities. The relative density of the fine aggregate was 2.65, with a fineness modulus of 3.35.

4. Rubber Tyre Crumbs:

In this study, waste tyre crumbs (15–20 mm) were used as partial coarse aggregate replacement. Locally available and low-cost, the triangular particles offer a textured surface for bonding. Though rubber's low stiffness may reduce compressive strength, it improves impact resistance, toughness, and energy absorption, supporting sustainable construction.

5. Water:

Potable water, conforming to IS: 456–2000 standards, was used for both mixing and curing. Such water, free from harmful substances like oils, acids, salts, or organic matter, ensures concrete quality and durability. Maintaining the same water quality throughout mixing and curing minimized variability, ensuring consistent hydration and strength development.

6. Human Hair Fibres (HHF):

2.2. Properties of Material

The test specimens were prepared using the following materials: cement, fine aggregate (natural river sand), natural coarse aggregates, human hair fibers (HHF), rubber tyre chips, crushed recycled concrete aggregates (CRCA), a plasticizer (PermaPlast MF), and potable water. In general, all materials conform to the specifications laid down in the relevant Indian Standard (IS) codes. The specific properties of each material are detailed below.

2.2.1. Cement

Ordinary Portland cement (OPC 43 grade) of brand name Bangur/TCI was used in this study. The cement was procured from a local dealer in kashmir. The physical properties of the cement, as determined through various standard tests, conform to the requirements of IS 1489 (1991). The test results of cement properties are presented in Table 2.1.

Table 2.1: Physical properties of cement

S. No	Properties	Observations
	Bulk density	1450 kg/m3
1	Specific gravity	3.15
2	Initial setting time	30 min
3	Final setting time	600 min
4	Standard Consistency	5-7%
5	Fineness (90 micron IS Sieve)	5%
6	28-days compressive strength	42.17Mpa

2.2.2. Fine Aggregates

2.2.2.1. Natural Sand

The fine aggregate utilized in this study was natural river sand,. The sand used was clean and free from deleterious materials such as clay, silt, and organic impurities, ensuring its suitability for concrete production. It was sieved through a 4.75 mm IS sieve, thereby conforming to the grading requirements for fine aggregates as per IS: 383–1970 specifications.

To determine its suitability and quality, a sieve analysis was carried out on the collected sand sample to establish its particle size distribution. This analysis ensures that the fine aggregate lies within the prescribed grading zone for concrete, which directly affects workability, strength, and durability.

The physical properties of the fine aggregate, obtained through laboratory testing, are presented in Table 2.2, while the corresponding particle size distribution curve is shown in Figure 2.1. For accuracy and representativeness of results, a total sample weight of 2000 grams of natural fine aggregate (NFA) was taken for the analysis.

Table 2.2: Fineness modulus of natural fine aggregates (NFA)

I.S. Designation	Weight Retained (gm)	% Retained	Cumulated % Retained (x)	Cumulative % Passing (100 x)	Requirement as per I.S 383-1970
					ZONE II
10	0	0.000	0	100.00	100
4.750	19	0.950	0.950	99.05	90-100
2.360	21	1.050	2	98.00	75-100
1.80	179	8.950	10.950	89.05	55-90
0.60	974	48.7	59.650	40.35	35-59
0.30	484	24.2	83.850	16.15	8/30/
0.150	216	10.8	94.650	5.35	0-10
Pan	107	5.350	-	-	-

Fineness modulus of fine aggregates = (sum total of cumulated % retained/100)

$$\frac{252.05}{100} \times 2.52$$

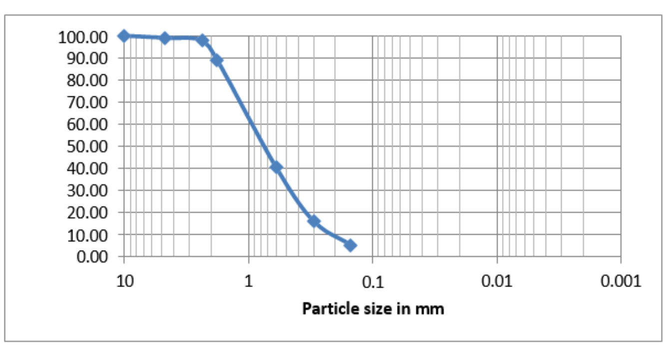

Fig. 2.1 Graph showing particle size distribution of Natural sand

Compressive Strength

Compressive strength tests were conducted on cubes and cylinders to study the effect of replacing coarse aggregate with rubber tyre crumbs and adding human hair fibres (1.5% by weight of cement). Results were analyzed graphically and analytically, and compared with control concrete and previous studies. Tests were performed using a Universal Testing Machine (UTM) on cube specimens (150 × 150 × 150 mm) after 7, 14, and 28 days of curing. For each mix and age, three specimens were tested, and average values were reported.

The compressive strength $F_c = P/A$ of each specimen was calculated using the relation:

$$F_c = P/A$$

Where:

- F_c = Compressive strength (MPa)
- P = Maximum load applied (N)
- A = Cross-sectional area of specimen (mm²)

Figure 2.2: compressive strength test setup for cubes

Split Tensile Strength

The split tensile strength test was carried out to determine the tensile strength of concrete specimens. The test was performed on cylindrical specimens of 300 mm length and 150 mm diameter after 7, 14, and 28 days of curing, using the Universal Testing Machine (UTM).

The split tensile strength $F_{ct} = 2P/\pi ld$ was calculated using the following relation:

$$F_{ct} = 2P/\pi ld$$

Where:

- F_{ct} = Split tensile strength (MPa)
- PP = Maximum load applied (N)

Figure 2.3: Split tensile strength test setup for cylinders.

Flexural Strength

The flexural strength test was conducted to evaluate the flexural behavior of concrete specimens. The test was performed on prismatic specimens of dimensions 100 × 100 × 500 mm, cured for 7, 14, and 28 days.

The strength was determined using the two-point loading method and the flexural strength $Fb=PL/bd^2$ Mpa was calculated using the following expression:

$$Fb=PL/bd^2 \text{ Mpa}$$

Where:
- Fb = Flexural strength (MPa)
- P = Maximum load applied (N)
- L = Effective span length of specimen (mm)
- b = Width of specimen (mm)
- d = Depth of specimen (mm)

Figure 2.4: Flexural strength test setup for prism

Workability

Replacing natural coarse aggregate with scrap tyre rubber reduces the workability of concrete, as indicated by lower slump values with increasing rubber content. This reduction is mainly due to the rough texture, irregular shape, and low specific gravity of rubber particles. An exception was observed in mix MCR-09 (9% replacement), which showed a slight slump increase, likely due to reduced inter-particle friction. Overall, tyre rubber incorporation adversely affects workability, with greater reductions at higher replacement levels.

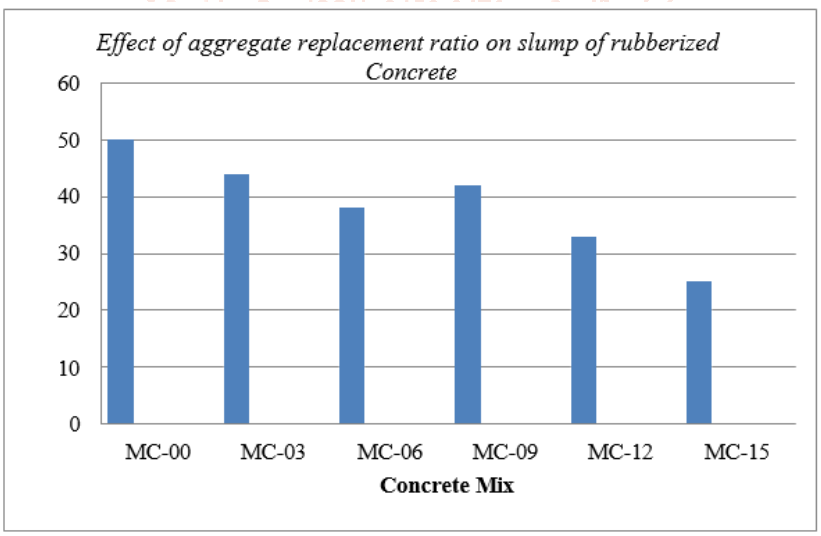

Fig. 2.5 Graph showing the slump of concrete with replacement ratio of rubberized concrete

3. RESULTS AND DISCUSSIONS

3.1. Fine Aggregates

3.1.1. Natural Sand

Natural River sand, free from impurities and conforming to IS: 383-2016, was used as fine aggregate. The sand was sieved through a 4.75 mm IS sieve to ensure proper grading. Sieve analysis determined particle size distribution, with results classified as per IS specifications. Physical properties are shown in Table 3.2, and the particle size distribution curve in Figure 3.1. A 2000 g sample of natural fine aggregate (NFA) was used for testing and mix preparation.

Water absorption of fine aggregates (sand) as per IS 456:2000

S. No.	Particulars	Weight in gms
1	Weight of sample(W1)	1800.0
2	Weight of sample after oven dry(W2)	1456.0
3	Weight of saturated surface dry aggregate in air (W3)	1483.0

Water absorption of sand= $\frac{W3-W2}{W2}\times 100$

$= \frac{1483-1456}{1456}\times 100$

= 1.850%

Based on oven-dry (W2 = 1456 g) and saturated surface-dry (W3 = 1483 g) masses, the sand's water absorption is 1.85%, indicating low porosity and acceptable quality for concrete (≤2%). The as-received mass (W1 = 1800 g) exceeded SSD by 317 g, showing ~21.4% free surface moisture, which would add water to the mix if unadjusted. In practice, (i) oven-dry sand absorbs ~18.5 kg water per 1000 kg to reach SSD, and (ii) batch water must be reduced by ~0.214 kg per kg of sand to maintain the w/c ratio. Thus, while absorption is satisfactory, precise moisture correction is essential to avoid excess water that could reduce strength and workability.

Determination of Specific Gravity of Fine Aggregates

Observations: The sample was collected from the stockyard, with the source being a natural river deposit.

S. No	Particulars	Weight in gms
1	Weight of pycnometer (W1)	434.0
2	Weight of pycnometer + sand (W2)	1054.0
3	Weight of pycnometer + water + sand (W3)	1669.0
4	Weight of pycnometer + water (W4)	1277.0

Calculations:

Specific gravity = $\frac{(W2-W1)}{((W4-W1)-(W3-W2))}$

$= \frac{(1054-434)}{((1277-434)-(1669-1054))}$

= 2.710

From the pycnometer data (W_1 = 434.0 g, W_2 = 1054.0 g, W_3 = 1669.0 g, W_4 = 1277.0 g), the dry mass of sand is W_2-W_1= 620 g and the mass of water displaced by the sand solids is W_3 - W_4 = 392 g; hence the mass of water equal to the true solid volume is $(W_2-W_1)-(W_3-W_4)$=228.0g. Using the standard pycnometer formula for bulk specific gravity (oven-dry),

$$\frac{(W2-W1)}{((W4-W1)-(W3-W2))}$$

= 620/228 ≈2.72

indicating a specific gravity typical of quartz-rich, sound fine aggregates (commonly ~2.60–2.75). This value implies the sample has normal mineralogy with no abnormal porosity or lightweight contaminants, and it is suitable for concrete mix design calculations particularly for converting mass to absolute volume, yield checks, and accurate water–cement ratio control.

Table 3.3 Physical properties of fine aggregate

Sr. No.	Properties	Normal fine aggregate (NFA)
1.	Fineness modulus	2.520
2.	Specific gravity	2.710
3.	Water absorption (%)	1.850

The normal fine aggregate (NFA) shows a fineness modulus of 2.520, classifying it as medium sand with a well-graded size distribution suitable for workable concrete. Its specific gravity of 2.710 reflects typical quartz-based aggregates, confirming standard quality without impurities. The water absorption of 1.850% lies within the acceptable limit (<2%), indicating moderate porosity and minimal impact on water–cement ratio. Overall, the aggregate is of good quality and suitable for standard concrete production.

3.2. Coarse Aggregate

The coarse aggregate utilized in the preparation of concrete was sourced from a nearby quarry. Its sieve analysis outcomes along with other physical characteristics are presented in Table 3.5. For testing purposes, a representative sample of 2000 grams of coarse aggregates was taken for analysis.

Table 3.4 Fineness modulus of coarse aggregates

I.S. Sieve (mm)	Weight Retained (gm)	% Retained	Cumulated% Retained (x)	Cumulative% Passing (100- x)	Requirement as per I.S 383-1970
40	0	0.000	0	100	100
20	195	9.750	9.750	85.50	85-100
10	1598	79.900	89.650	10.450	0-20
4.750	197	9.850	99.50	0.50	0-5
2.360	0	0.000	99.500	0.50	_
1.180	0	0.000	99.500	0.50	_
0.60	0	0.000	99.500	0.50	_
0.30	0	0.000	99.500	0.50	_
0.150	0	0.000	99.500	0.50	_
Pan	10	0.50		100	_

The fineness modulus of coarse aggregates is calculated by dividing the total sum of the cumulative percentage retained on the specified sieves by 100.

$$= \frac{686.4}{100} = 6.8640$$

The sieve analysis results show that 9.75% of material was retained on the 20 mm sieve, 79.90% on the 10 mm sieve, and 9.85% on the 4.75 mm sieve, with only 0.5% passing through the pan. The cumulative percent passing at the 10 mm sieve is 10.45%, which lies within the IS: 383–1970 limit of 0–20%. Similarly, the 0.5% passing at the 4.75 mm sieve falls within the permissible range of 0–5%. These results indicate that the aggregate is well-graded, predominantly in the 10 mm size range, with minimal fines. Such grading ensures good packing density, reduced voids, and enhanced workability of concrete. Since all parameters satisfy IS: 383–1970 requirements, the aggregate is considered suitable for use in concrete production.

3.2.1. Specific gravity of 20mm coarse aggregates

Observations:

S. No	Particulars	Weight in gms
1	Weight of pycnometer (W1)	434.0
2	Weight of pycnometer + aggregates (W2)	953.0
3	Weight of pycnometer + water + aggregates (W3)	1438.0
4	Weight of pycnometer + water (W4)	1093.0

Calculations:

$$\text{Specific gravity} = \frac{(W2 - W1)}{((W4 - W1) - (W3 - W2))}$$

$$= \frac{(953 - 434)}{((1093 - 434) - (1438 - 953))}$$

$$= 2.980$$

The obtained specific gravity of 2.98 is slightly higher than the typical range for natural aggregates (2.6–2.8), suggesting the material is very dense, possibly due to the presence of heavier minerals or reduced porosity. Such aggregates are suitable for high-strength concrete applications, as higher specific gravity generally indicates better quality and higher load-bearing capacity.

3.2.2. Water absorption of coarse aggregates as per IS 456:2000

S. No	Particulars	Weight in gms
1	Weight of sample (W1)	2000.0
2	Weight of sample after oven dry (W2)	1969.0
3	Weight of saturated surface dry aggregate in air (W3)	1989.0

Water absorption of coarse aggregate $= \frac{W3 - W2}{W2} \times 100$

$$= \frac{1989-1969}{1989} \times 100$$

$$= 1.010\%$$

From the measured masses ($W_1 = 2000$ g as-received, $W_2 = 1969$ g oven-dry, $W_3 = 1989$ g at saturated-surface-dry), the sand's water absorption is $W_3 - W_2/W_2 \times 100 = 20/1969 \times 100 \approx 1.02\%$ indicating low intrinsic porosity and a material quality acceptable for concrete (commonly ≤2%). The sample's as-received moisture content is $W_1 - W_2/W_2 \times 100 = 31/1969 \times 100 \approx 1.57\%$ subtracting the absorption (1.02%) shows the sand carried about 0.55% free (surface) water above SSD. Practically, this means oven-dry sand would absorb ≈10.16 kg of water per 1000 kg of sand to reach SSD, and because the tested sand was wetter than SSD, the batch mixing water should be reduced by roughly 0.55% of the sand mass (≈5.5 kg per 1000 kg of sand) to maintain the intended effective water–cement ratio and avoid unintended changes in workability and strength. Overall, the aggregate properties are satisfactory, but routine moisture corrections are necessary in mix calculations.

Summary of Physical properties of Normal coarse aggregate (NCA)

Table 3.5 Physical properties of NCA

S. No.	Properties	Value
1.	Fineness modulus	6.8640
2.	Specific gravity (20mm)	2.980
3.	Water absorption %	1.010

The coarse aggregate shows a fineness modulus of 6.864, specific gravity of 2.98, and water absorption of 1.01%, indicating a coarse, dense, and low-porosity material. The high fineness modulus reflects a coarse grading that reduces paste demand and improves dimensional stability, but may lower workability unless finer fractions or admixtures are added. The high specific gravity suggests a strong, durable mineral composition suitable for high-strength concrete, while the low absorption minimizes moisture corrections in mix design. Overall, the aggregates are well suited for normal to high-strength concrete, provided gradation and workability adjustments are properly managed.

Crushed recycled concrete aggregates

The recycled crushed concrete aggregates used in the mix were sourced from tested concrete cubes obtained from the laboratory. The results of the sieve analysis and other physical properties are presented in Table 3.4 and Table 3.6, respectively. A total of 2000 grams of coarse aggregate was taken as the sample.

Table 3.6 Fineness modulus of Crushed recycled concrete aggregates

I.S. Sieve (mm)	Weight Retained (gm)	% Retained	Cumulated% Retained (x)	Cumulative% Passing(100-x)	Requirement As per I.S383-1970
40.0	0	0.000	0	100	100
20.0	412.0	20.600	20.600	85.50	85-100
10.0	1478.0	73.900	94.500	10.450	0-20
4.750	105.0	5.250	99.750	0.50	0-5
2.360	0	0.000	99.750	0.50	_
1.180	0	0.000	99.750	0.50	_
0.60	0	0.000	99.750	0.50	_
0.30	0	0.000	99.750	0.50	_
0.150	0	0.000	99.750	0.50	_
Pan	5.0	0.50		100	_

Fineness modulus of Crushed recycled concrete aggregates = (sum total of cumulated % retained/100)

$= \frac{702.60}{100} = 7.0260$

The sieve analysis shows the coarse aggregate is well-graded and meets IS 383-1970 requirements for 20 mm nominal size. About 20.6% was retained on the 20 mm sieve (within 85–100% passing), 73.9% on the 10 mm sieve (10.45% passing, within 0–20%), and 5.25% on the 4.75 mm sieve (0.5% passing, within 0–5%). Negligible fines (<1%) were observed, indicating absence of excess dust. Overall, the grading falls within IS limits, confirming suitability for concrete production.

Specific gravity of recycled crushed concrete aggregates

Observations:

S. No	Particulars	Weight in gms
1	Weight of pycnometer (W1)	434.0
2	Weight of pycnometer + recycled crushed concrete aggregates (W2)	997.0
3	Weight of pycnometer + water + recycled crushed Concrete aggregates (W3)	1419.0
4	Weight of pycnometer + water (W4)	1088.0

Calculations:

$$\text{Specific gravity} = \frac{(W2-W1)}{((W4-W1)-(W3-W2))}$$

$$= \frac{(997-434)}{((1088-434)-(1419-997))}$$

$= \quad 2.250$

Here, the data provided represents the specific gravity test of recycled crushed concrete aggregates using a pycnometer. The weights recorded are: empty pycnometer (W_1) = 434 g, pycnometer with aggregates (W_2) = 997 g, pycnometer with aggregates and water (W_3) = 1419 g, and pycnometer with water only (W_4) = 1088 g. Using these values, the specific gravity of the aggregates can be calculated from the formula:

$$\text{Specific Gravity (G)} = \frac{W2-W1}{(W2-W1)-(W3-W4)}$$

Thus, the specific gravity of the recycled crushed concrete aggregates is about 2.43, which is slightly lower than that of natural aggregates (generally 2.6–2.9), indicating the presence of adhered mortar and higher porosity in recycled material.

Water absorption of CRCA as per IS 456:2000

S. No.	Particulars	Weight in gms
1	Weight of sample (W1)	1350.0
2	Weight of sample after oven dry (W2)	1290.0
3	Weight of saturated surface dry aggregate in air (W3)	1310.0

$$\text{Water absorption of Crushed Glass waste} = \frac{W3-W2}{W2}\times 100$$

$$= \frac{1485-1458}{1485}\times 100$$

$=1.820\%$

the aggregates have water absorption of ~1.55%, which is within the typical range for natural aggregates (0.5–2%). The moisture content is ~4.65%, indicating that the sample initially contained some free surface moisture.

Summary of Physical properties of crushed recycled concrete aggregate (CRCA)

Table 3.7: Physical properties of CRCA

Sr. No.	Properties	Value
1.	Fineness modulus	7.0260
2.	Specific gravity	2.250
3.	Water absorption	1.550

The aggregates have a fineness modulus of 7.026, confirming their coarse nature as per IS classification. Their specific gravity of 2.25 is lower than natural aggregates (2.6–2.9), indicating recycled origin with adhered mortar and higher porosity. Water absorption of 1.55% is within the acceptable limit (<2%), suggesting moderate porosity and suitability for concrete, though the lower specific gravity may slightly reduce strength and density.

3.3. Experimental Program

An experimental study was conducted to evaluate the combined effect of human hair fibers and rubber tyre chips on concrete. A total of 45 cubes (150 × 150 × 150 mm), 15 beams (150 × 150 × 700 mm), and 15 cylinders (150 × 300 mm) were cast and tested.

The test specimens were grouped into five categories:

1. **Control Mix:** Conventional concrete without any addition of fibers or rubber tyre chips.
2. **Group II:** Concrete with 1.5% human hair fibers by weight of cement and 3% rubber tyre chips by weight of coarse aggregate**.**
3. **Group III:** Concrete with 1.5% hair fibers and 6% rubber tyre chips.
4. **Group IV:** Concrete with 1.5% hair fibers and 9% rubber tyre chips**.**
5. **Group V:** Concrete with 1.5% hair fibers and 12% rubber tyre chips**.**

4. CONCLUSION AND FUTURE SCOPE

4.1. Conclusion

The study demonstrated that incorporating waste tyre crumbs and 1.5% human hair as partial replacements in concrete influences both strength and workability. Increasing rubber content reduced compressive and flexural strength due to poor bonding, lower density, and reduced stiffness, though tensile strength and ductility improved. Human hair fibres effectively bridged micro-cracks, partially compensating for strength loss. Overall, rubber–hair concrete offers a trade-off: reduced strength but enhanced ductility, crack resistance, and sustainability, making it suitable for specific applications.

Strength trends:

- 7 days: +5.7% compressive, –21.9% flexural, –3.1% tensile
- 14 days: –9.9% compressive, +22.5% flexural, +9.9% tensile
- 28 days: –19.8% compressive, +9.2% flexural, +15.3% tensile

4.2. Future Scope

Further studies are recommended in the following areas:

1. **Mix Optimization** – Determining the optimum rubber and hair content for balanced strength and durability.
2. **Surface Treatment** – Enhancing rubber–cement bonding using chemical, plasma, or coating methods.
3. **Durability Studies** – Evaluating resistance to water absorption, sulphate attack, chloride penetration, freeze–thaw, and carbonation.
4. **Microstructural Analysis** – Using SEM, XRD, and FTIR to study bonding mechanisms and hydration products.
5. **Practical Applications** – Exploring use in pavements, crash barriers, lightweight blocks, and sound-proof structures.
6. **Sustainability Assessment** – Conducting life cycle analysis (LCA) to quantify environmental benefits.

References

[1] S.A. Yıldızel, et al. (2025). *Confirmed the feasibility of using human hair as a sustainable fiber in concrete: Optimization using artificial neural networks, response surface methodology, and analysis of variance.* Nature.

[2] Hasan, A., et al. (2024). *Mechanical properties of concrete incorporating crumb rubber and human hair fiber: Optimal combination of 5% crumb rubber and 1% human hair fiber for improved strength.* ResearchGate / SBT Durabi.

[3] Gupta, J. (2024). *Effects of human hair as a reinforcing material in concrete: Improving durability and strength.* ResearchGate / ScienceDirect.

[4] Hasan, A., Rana, M. M. & Khan, R. M. (2024). *Mechanical properties of concrete using crumb rubber and human hair fiber.* Int. J. Sustain. Build. Technol. Urban Dev. 15, 97–108.

[5] Ullah, K., Mustafa, B., Ahmed, M. & Sohail, S. (2024). *Use of human hair as natural fibre in fibre reinforced concrete.*

[6] Nasreddine, H., Salem, T., Omikrine-Metalssi, O. & Fen-Chong, T. (2024). *Potential use of human hair fibres for reinforcement and thermal insulation in construction.* J. Mater. Cycles Waste Manag. 26, 970–985.

[7] Bheel, N. et al. (2024). *A comprehensive study on the impact of human hair fibre and millet husk ash on concrete properties: Response surface modeling and optimization.* Sci. Rep. 14, 13569. https://doi.org/10.1038/s41598-024-63050-7

[8] Gupta, J. (2024). *Effects on mechanical properties of concrete by using natural human hair as fibrous material.* Materials Today: Proceedings.

[9] S.M.I.S. Zainal, et al. (2023). *Fresh and hardened properties of crumb rubber mortar enhanced with synthetic and natural fibers: Development of 18 mix designs.* MDPI.

[10] Hashim, S., et al. (2023). *Influence of recycled asphalt pavement and crumb rubber on concrete properties.* nahje.com.

[11] Akbar, M., Umar, T., Hussain, Z., Pan, H. & Ou, G. (2022). *Effect of human hair fibers on the performance of concrete incorporating high dosage of silica fume.* Appl. Sci. 13, 124.

[12] M. Akbar, et al. (2022). *Effect of human hair fibers on concrete performance: Compressive, split tensile, and flexural strengths with silica fume enhancement.* MDPI.

[13] Ahmed, J. K. & Al-Numan, B. S. (2022). *Investigation of using human hair as fiber reinforcement in concrete.* Eur. J. Sci. Eng. 7, 194–200.

[14] A.A. Thakare, et al. (2022). *Micro and macro-structural properties of waste tyre rubber fiber-reinforced self-compacting mortar.* ScienceDirect.

[15] J. Ahmad, et al. (2022). *Overview of concrete performance with waste materials including scrap tire rubber.* PMC.