Experimental Investigation of Green Concrete Incorporating Recycled Concrete Aggregates

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***Abstract*—The rapid growth of the construction industry has led to excessive consumption of natural resources and generation of large volumes of construction and demolition waste. In response to these challenges, the concept of green concrete has emerged as a sustainable alternative. This study presents a detailed experimental investigation on the use of Recycled Concrete Aggregates (RCA) as a partial replacement for natural coarse aggregates in concrete. Concrete mixes were prepared with replacement levels of 0%, 25%, 50%, 75%, and 100% RCA. Various tests were conducted to evaluate fresh and hardened properties, including slump, compressive strength, split tensile strength, flexural strength, density, and water absorption. The results indicate that while mechanical properties decrease with increasing RCA content, satisfactory performance can be achieved up to 50% replacement. The study highlights the potential of recycled aggregate concrete as a sustainable construction material and provides insights into its practical applications.**

***Index Terms*—Green Concrete, Recycled Aggregates, Sustainable Construction, Compressive Strength, Durability**

I. INTRODUCTION

The construction sector is one of the largest consumers of natural resources worldwide. Aggregates, which constitute nearly 70–80% of concrete volume, are extracted extensively from natural sources such as rivers and quarries. This has resulted in environmental degradation, depletion of natural resources, and ecological imbalance. At the same time, the demolition of old structures generates a significant amount of construction and demolition (C&D) waste. Disposal of this waste poses serious environmental challenges, including land pollution and increased landfill usage. Recycling of this waste into usable construction materials presents a viable solution. Green concrete is an innovative concept that incorporates waste materials such as recycled aggregates, fly ash, and industrial by-products into concrete production. Among these, Recycled Concrete Aggregates (RCA) have gained considerable attention. RCA is obtained by crushing demolished concrete and reusing it as aggregate in new concrete. However, RCA differs from natural aggregates due to the presence of adhered mortar, higher porosity, and increased water absorption. These characteristics influence the mechanical and durability properties of concrete. Therefore, it is essential to study the behavior of concrete made with RCA through systematic experimental investigation.

The objective of this study is to evaluate the feasibility of using RCA in concrete and to determine the optimum replacement level for practical applications.

II. LITERATURE REVIEW

Ref. No.	Authors	Title	Journal / Source	Year	Key Findings
[1]	Katz, A.	Properties of concrete made with recycled aggregate	Cement and Concrete Research	2003	RCA increases porosity and reduces strength due to adhered mortar
[2]	Limbachiya, M. et al.	Use of recycled concrete aggregate in high-strength concrete	Construction and Building Materials	2000	Up to 30% RCA gives comparable strength

[3]	Poon, C.S. et al.	Effect of microstructure on recycled aggregate concrete	Cement and Concrete Research	2004	Weak ITZ leads to reduced strength
[4]	Tam, V.W.Y.	Concrete recycling in construction industry	Resources, Conservation and Recycling	2009	Highlights sustainability and recycling benefits
[5]	BIS	IS 10262: Concrete Mix Design Guidelines	Bureau of Indian Standards	2019	Provides standard mix design procedure
[6]	BIS	IS 516: Methods of Tests for Concrete	Bureau of Indian Standards	1959	Standard testing methods for concrete
[7]	Islam, Z.U. et al.	Mechanical properties of recycled aggregate concrete	Discover Civil Engineering	2025	Strength decreases with RCA but acceptable up to 50%
[8]	Moodi, F. et al.	Fully recycled geopolymer concrete	RSC Advances	2025	Improves sustainability and mechanical performance
[9]	Yao, Y. & Hong, B.	Scientometric review of recycled concrete	Low-carbon Materials & Green Construction	2024	Shows global research trends
[10]	Al-Naghi, A.A. et al.	Strength improvement using fly ash & silica fume	Scientific Reports	2025	Enhances durability and strength
[11]	Patil, R.D. et al.	Performance with blended admixtures	ETASR Journal	2025	Admixtures improve RCA concrete performance
[12]	Xiao, J. et al.	Design and challenges of RAC	Nature Reviews Clean Technology	2026	Discusses large-scale application challenges
[13]	Zhang, X. et al.	Mineralization of recycled aggregate	Int. Journal of Concrete Structures	2026	Improves strength of 100% RCA concrete
[14]	Alyhya, W.S. et al.	HCl treatment of recycled aggregates	Civil Engineering Journal	2025	Treatment improves bonding and strength
[15]	Trivedi, P.V. et al.	RCA in self-compacting concrete	Australian Journal of Structural Engineering	2025	Suitable for SCC applications
[16]	Ali, T. et al.	Use of fly ash & fibers in RAC	Scientific Reports	2025	Improves mechanical and durability properties
[17]	Bai, J. et al.	Recycled aggregate for sustainable concrete	Materials	2025	Confirms RCA as sustainable solution

III. MATERIALS AND METHODS

3.1 Materials

The following materials were used in this study:

- Cement: Ordinary Portland Cement (OPC 43 Grade)
- Fine Aggregate: Natural river sand conforming to IS specifications
- Coarse Aggregate: Natural Coarse Aggregate (NCA) and Recycled Concrete Aggregate (RCA)
- Water: Clean potable water
- Admixture: Superplasticizer (used to improve workability)

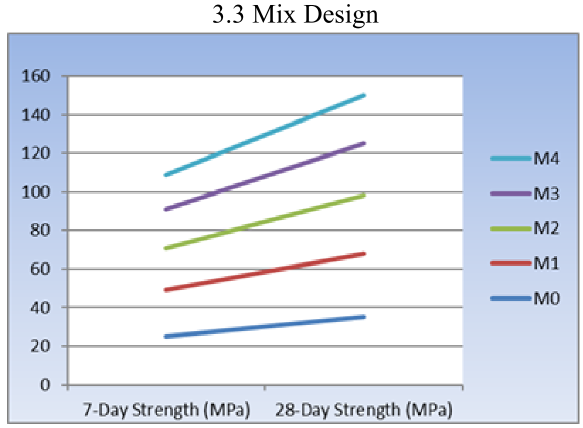
Properties of Materials

Physical properties of aggregates were determined prior to mix preparation. RCA exhibited higher water absorption and lower specific gravity compared to natural aggregates.

3.2 Graph: Strength vs RCA %

Mix	7-Day Strength (MPa)	28-Day Strength (MPa)
M1	25	35
M2	24	33
M3	22	30
M4	20	27
M5	18	25

3.3 Mix Design



Concrete mix design was carried out using IS 10262 guidelines for M30 grade concrete. Five different mixes were prepared with varying RCA content:

M1	0%	RCA
M2	25%	RCA
M3	50%	RCA
M4	75%	RCA
M5	100%	RCA

3.3.1. Mix Design Calculations (M30 Grade Example as per IS 10262)

3.3.2 Target Mean Strength

f′ck=fck+1.65 X S

f′ck = fck + 1.65 X S

f′ck=fck+1.65×S =30+1.65×5=38.25 MPa

3.3.3 Water-Cement Ratio

- Assume: 0.45 (from IS recommendations for M30)

3.3.4 Water Content

- For 20 mm aggregate: 186 kg/m^3
- Adjusted (with admixture): 180 kg/m^3

3.3.5 Cement Content

Cement=Water/ w/c=180/45=400 kg/m^3

3.3.6 Aggregate Calculation

Assume:

- Fine aggregate = 35%
- Coarse aggregate = 65%

Total aggregate:

=1− (Cement + Water + Air)

=1− (0.127 + 0.18 + 0.02) = 0.673 m^3

Fine Aggregate:

0.673 × 0.35 = 0.235 m^3

Coarse Aggregate:

0.673 × 0.65 = 0.438 m^3

3.3.7 RCA Replacement Example (50%)

- Natural aggregate = 50%
- RCA = 50%

CA Natural=0.219 m^3 and CA RCA=0.219 m^3

3.3.8 Final Mix Proportion

Material	Quantity (kg/m^3)	Material	Quantity (kg/m^3)
Cement	400	Natural Coarse Aggregate	585kg (0.218m^3)
Water	180	Natural Coarse Aggregate	585kg (0.218m^3)
Fine Aggregate (Natural Sand)	675kg (0.235m^3)	Admixture (super plasticizer)	1% of cement (4kg)

Final Mix Proportion (by weight)

Cement: Fine Aggregate: Coarse Aggregate

1: 1.70: 2.90 with w/c = 0.45

3.4 Specimen Preparation

Concrete was mixed using a standard procedure and cast into moulds:

- Cubes: 150×150×150 mm
- Cylinders: 150×300 mm
- Beams: 100×100×500 mm

After casting, specimens were demoulded after 24 hours and cured in water at room temperature until testing.

3.5 Testing Procedures

The following tests were conducted:

- Slump Test for workability
- Compressive Strength Test at 7, 14, and 28 days
- Split Tensile Strength Test
- Flexural Strength Test
- Water Absorption Test
- Density Test

VI. EXPERIMENTAL SETUP

4.1 Mixing Process

Description:

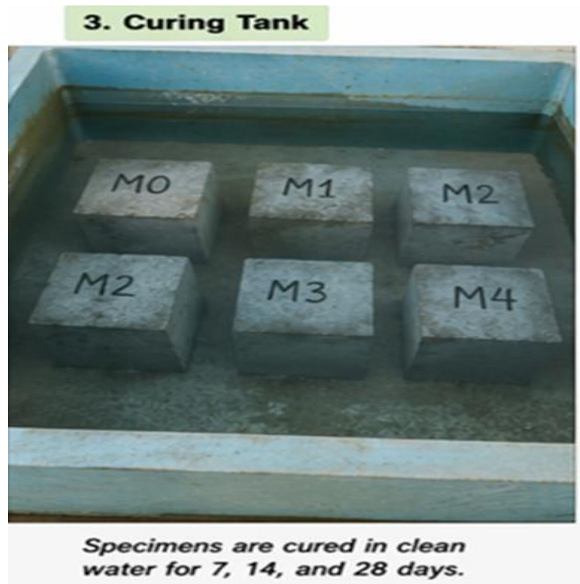
- Concrete mixed using hand mixing or mixer machine
- Materials weighed and mixed uniformly

Mixing of concrete ingredients for recycled aggregate concrete

4.2 Casting of Specimens
Description:
- Concrete placed in cube molds (150×150×150 mm)
- Compacted using tamping rod or vibrator

Casting of concrete cubes with varying RCA percentages

4.3 Curing Tank
Description:
- Specimens submerged in water for 7, 14, 28 days
- Water curing of concrete specimens



Water curing of concrete specimens

4.4 Compression Testing Machine
Description:
- Cube placed in CTM
- Load applied until failure

Compressive strength testing using compression testing machine

4.5 Slump Test Setup

Description:

- Slump cone filled and lifted
- Workability measured

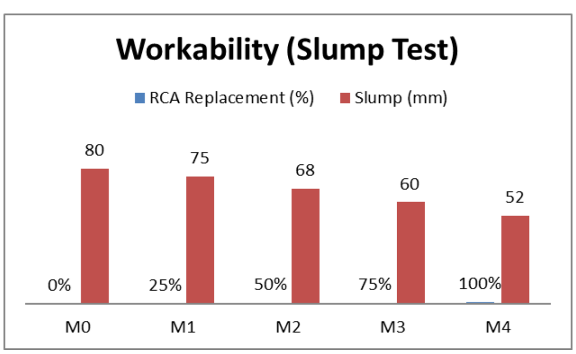
Slump test conducted to determine workability

V. EXPERIMENTAL RESULTS

5.1 Workability

The slump value decreased with increasing RCA content due to higher water absorption and angular shape of recycled aggregates.

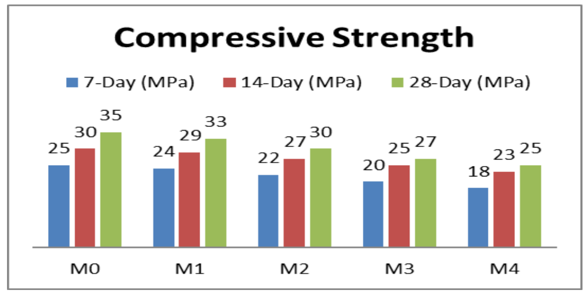
Mix ID	RCA Replacement (%)	Slump (mm)
M0	0%	80
M1	25%	75
M2	50%	68
M3	75%	60
M4	100%	52



5.2 Compressive Strength

Results showed a gradual reduction in compressive strength with increasing RCA percentage. However, up to 50% replacement, the strength remained within acceptable limits.

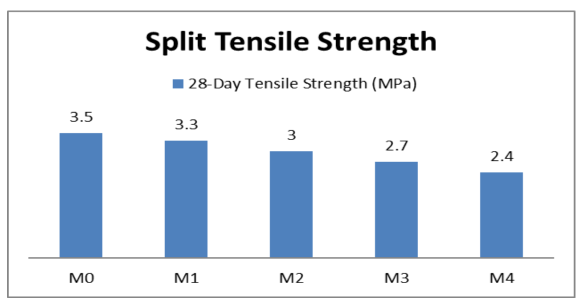
Mix	7-Day (MPa)	14-Day (MPa)	28-Day (MPa)
M0	25	30	35
M1	24	29	33
M2	22	27	30
M3	20	25	27
M4	18	23	25



5.3 Split Tensile Strength

A similar decreasing trend was observed in tensile strength, indicating reduced bonding characteristics

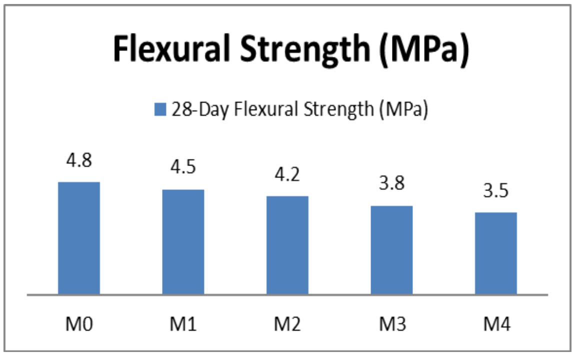
Mix	28-Day Tensile Strength (MPa)
M0	3.5
M1	3.3
M2	3
M3	2.7
M4	2.4



5.4 Flexural Strength

Flexural strength decreased moderately with increasing RCA content but remained adequate for structural applications up to 50% replacement.

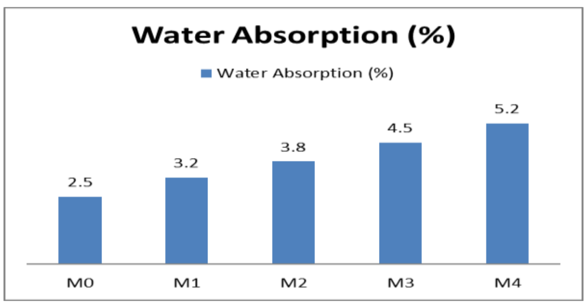
Mix	28-Day Flexural Strength (MPa)
M0	4.8
M1	4.5
M2	4.2
M3	3.8
M4	3.5



5.5 Water Absorption

Water absorption increased significantly with RCA content, indicating higher porosity.

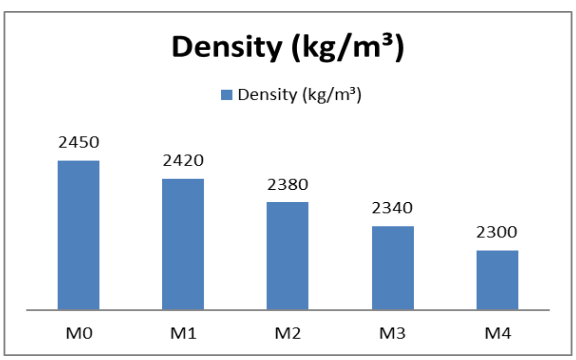
Mix	Water Absorption (%)
M0	2.5
M1	3.2
M2	3.8
M3	4.5
M4	5.2



5.6 Density

Density of concrete decreased slightly with higher RCA replacement due to lower specific gravity of recycled aggregates.

Mix	Density (kg/m³)
M0	2450
M1	2420
M2	2380
M3	2340
M4	2300



VI. DISCUSSION

The results clearly indicate that recycled aggregates influence both fresh and hardened properties of concrete. The reduction in workability is mainly attributed to the porous nature of RCA, which absorbs more water during mixing. The decrease in compressive strength is due to weaker interfacial bonding and presence of micro-cracks in recycled aggregates. However, the strength reduction is not significant up to 50% replacement. The increase in water absorption highlights durability concerns, as higher porosity can lead to reduced resistance to environmental effects. This can be mitigated by using mineral admixtures and proper curing techniques. Despite these limitations, recycled aggregate concrete offers significant environmental benefits and can be effectively used in various construction applications.

VII. CONCLUSION

Based on the experimental study, the following conclusions are drawn:

- Recycled aggregates can be successfully used in concrete production.
- Workability decreases with increasing RCA content.
- Compressive strength reduces gradually but remains acceptable up to 50% replacement.
- Water absorption increases, indicating higher porosity.
- Recycled aggregate concrete is suitable for sustainable construction practices.

VIII. FUTURE SCOPE

- Use of nano-materials to enhance strength
- Development of advanced RCA treatment methods
- Long-term durability studies
- Application in high-performance concrete

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