Optimization of Recycled Coarse Aggregate Replacement Ratio in Structural Concrete

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Abstract - This research evaluates the use of recycled coarse aggregates (RCA) as a partial replacement for natural coarse aggregates in M20 grade concrete, focusing on compressive strength performance at 7 and 28 days. Concrete mixes were prepared with 0%, 25%, and 50% RCA replacement, and results showed a gradual decrease in strength with increasing RCA content due to higher porosity and weaker bonding caused by adhered mortar. However, concrete with 25% replacement exhibited strength comparable to conventional concrete, while 50% replacement showed acceptable performance for structural use. The findings indicate that RCA can be effectively utilized up to 50% replacement without significant loss in compressive strength, supporting sustainable construction practices.

Key Words: recycled coarse aggregate, RCA, M20 concrete, compressive strength, sustainable construction, aggregate replacement

1.INTRODUCTION

The construction industry faces significant environmental challenges due to the depletion of natural aggregates and the growing volume of construction and demolition waste, which often ends up in landfills. Recycled coarse aggregates (RCA), derived from crushed demolished concrete, offer a sustainable alternative by reducing the demand for virgin materials and promoting resource circularity. While previous studies have explored RCA in concrete mixes, results show varying compressive strength performance particularly in M20 grade concrete due to factors like adhered mortar increasing porosity and weakening interfacial bonding. This study investigates RCA replacement at 0%, 25%, and 50% levels, focusing on 7- and 28-day compressive strength to determine viable limits for structural applications, bridging gaps in standardized M20 mix data and advancing eco-friendly construction practices.

2. Methodology

M20 grade concrete cube specimens measuring 150 mm × 150 mm × 150 mm were cast to evaluate strength characteristics across different mixes. Six sets of specimens were prepared, incorporating recycled coarse aggregate (RCA) as partial replacement for natural coarse aggregate at 0%, 25%, and 50% levels by weight, with three cubes per mix per curing age.

2.1 Mixing and Workability

All materials were thoroughly blended to achieve a homogeneous, workable concrete mix following IS 10262 guidelines (w/c = 0.50). Fresh concrete workability was evaluated prior to casting using standard tests: slump test per IS 1199 to measure consistency, and compacting factor test per BS 1881 Part 103 (1983) using the compacting factor apparatus for self-compaction assessment.

2.2 Mix Design for M20 Grade Concrete (IS 10262 & IS 456)

Concrete cubes (150 mm × 150 mm × 150 mm) were prepared for compressive strength evaluation. Mix design followed IS 10262 guidelines with a target water-cement ratio of 0.50 and nominal proportion of 1:1.5:3. Recycled coarse aggregate (RCA) replaced natural coarse aggregate (NCA) by weight at 25% and 50% levels. All material quantities were accurately weighed prior to batching to ensure consistency.

Table -1: Mix Proportions per Cube (150 mm)

Mix Designation	Cement (kg)	FA (kg)	NCA (kg)	RCA (kg)	Total CA (kg)
Normal (0% RCA)	1.38	2.49	4.60	0.00	4.60
25% RCA	1.38	2.49	3.45	1.15	4.60

Mix Designation	Cement (kg)	FA (kg)	NCA (kg)	RCA (kg)	Total CA (kg)
50% RCA	1.38	2.49	2.30	2.30	4.60

2.3 Casting and Curing

Fresh concrete was filled into steel moulds in three equal layers. Each layer received 35-55 strokes of tamping rod compaction to eliminate voids and ensure dense packing. Molds remained undisturbed for 24 hours at ambient conditions. Cubes were then demoulded carefully and immersed in a clean water curing tank maintained at 27±2°C for 7 and 28 days to achieve optimal hydration and strength development.

2.4 Testing Protocol

Compressive strength tests followed IS 516 protocols using a calibrated compression testing machine at 140 kg/cm²/min loading rate. Workability results guided mix adjustments, confirming all mixes remained practical for structural placement despite RCA's higher absorption.

Fig -1: Materials for Concrete

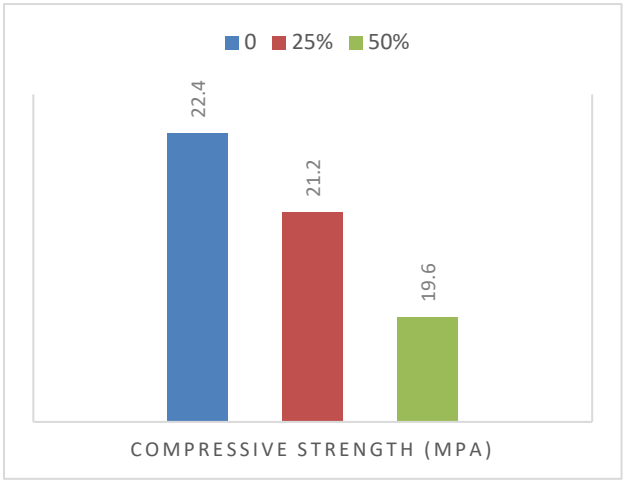
2.4 Results

Compressive strength tests on 150 mm cubes showed that concrete strength gradually decreased as the percentage of recycled coarse aggregate (RCA) increased. This reduction occurs because the adhered mortar on RCA surfaces creates weaker bonding with the cement paste in the interfacial transition zone, leading to higher porosity and reduced overall structural integrity compared to conventional natural aggregate concrete.

Table -2: Compressive Strength Results (N/mm²)

Sr. No.	% RCA	Curing Days	Compressive Strength (N/mm²)
1	0	7	16.2
2	25	7	15.4
3	50	7	14.1
4	0	28	22.4
5	25	28	21.2
6	50	28	19.6

Chart -1: Compressive Strength Results (N/mm²)



3. CONCLUSIONS

The experimental investigation demonstrates that recycled coarse aggregates (RCA) can be effectively incorporated into M20 grade structural concrete up to 50% replacement of natural coarse aggregates without compromising the minimum characteristic strength requirement (>20 N/mm² at 28 days). Key findings include:

- 25% RCA replacement yields compressive strengths (15.4 N/mm² at 7 days, 21.2 N/mm² at 28 days) nearly identical to conventional concrete (16.2 & 22.4 N/mm²), making it ideal for primary structural applications.
- 50% RCA replacement shows acceptable performance (14.1 & 19.6 N/mm²) suitable for

secondary/low-load elements, with only 12% strength reduction attributable to adhered mortar effects.

These results validate RCA's practical viability for sustainable construction, reducing natural aggregate consumption and construction-demolition waste while maintaining structural integrity. Optimal recommendation: 25% RCA replacement for balanced performance and sustainability benefits.

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