International Journal of Research and Technology (IJRT)
International Open-Access, Peer-Reviewed, Refereed, Online Journal
ISSN (Print): 2321-7510 | ISSN (Online): 2321-7529
| An ISO 9001:2015 Certified Journal |

# Mitigating Environmental Impact Of C&D Waste Through Experimental Development of Eco-Sustainable Concrete with Recycled Coarse

**Ashish Kumar Misra[1]*, Mr. Durgesh Nandan[2]***

1* Post Graduate scholar in Civil Engineering, Dr. K. N. Modi University, Newai, Rajasthan 304021, India.

2* Assistant Professor, Department of Civil Engineering, Dr. K. N. Modi University, Newai, Rajasthan 304021, India. (Email: durgesh.civil@dknmu.org)

**Abstract**

The rapid expansion of the construction industry has resulted in massive consumption of natural aggregates, leading to resource depletion and environmental degradation. Simultaneously, the accumulation of construction and demolition (C&D) waste poses severe ecological and waste management challenges. Recycling and reusing this waste as construction material offers a dual benefit of reducing environmental impact and conserving natural resources. This research investigates the feasibility of utilizing recycled coarse aggregates (RCA) derived from C&D waste in concrete production, with the objective of developing eco-sustainable concrete. An experimental program was conducted in which natural coarse aggregates were partially and fully replaced with RCA at varying proportions of 25%, 50%, 75%, and 100%. The study evaluated fresh concrete properties (workability), mechanical performance (compressive, split tensile, and flexural strength), and durability behavior (water absorption, chloride penetration, and acid resistance). Results indicated that RCA concrete exhibits slightly reduced workability due to higher water absorption but maintains acceptable performance levels with optimized mix design. Compressive strength showed a decline at higher replacement levels but remained within structural applicability up to 50% replacement. Durability tests revealed moderate resistance compared to natural aggregate concrete, highlighting the need for surface treatments or blended cement for improvement. The findings affirm that RCA can be a viable alternative to natural aggregates,

International Journal of Research and Technology (IJRT)
International Open-Access, Peer-Reviewed, Refereed, Online Journal
ISSN (Print): 2321-7510 | ISSN (Online): 2321-7529
| An ISO 9001:2015 Certified Journal |

contributing to sustainable concrete development while mitigating the environmental impact of C&D waste. This study underscores the role of recycled aggregates in transitioning towards circular economy practices in construction.

***Keywords*****:** Recycled Coarse Aggregate, Construction and Demolition Waste, Sustainable Concrete, Circular Economy, Environmental Mitigation

**Introduction**

The construction sector is one of the most resource-intensive industries globally, consuming billions of tonnes of raw materials annually. According to recent estimates, the sector contributes to nearly 40% of global material consumption and approximately 30% of total waste generation. Among the various waste streams, construction and demolition (C&D) waste has emerged as a critical challenge, particularly in rapidly urbanizing regions. C&D waste primarily consists of concrete debris, brick masonry, metals, glass, wood, and plastics, with concrete fragments being the most abundant component. Improper disposal of this waste not only consumes valuable landfill space but also leads to environmental pollution through leachates and dust emissions.

Simultaneously, the demand for natural aggregates in concrete production has been rising exponentially, driven by urban infrastructure expansion, housing development, and industrial growth. The extraction of natural aggregates, particularly through quarrying of stones and riverbed mining, is associated with adverse environmental impacts such as habitat destruction, groundwater depletion, and erosion. This dual problem of aggregate depletion and waste accumulation necessitates sustainable interventions in concrete technology.

Recycling C&D waste into aggregates provides a potential solution, aligning with global sustainability goals and circular economy principles. Recycled coarse aggregates (RCA) obtained from processed demolition waste can replace natural aggregates in concrete, reducing dependency on virgin resources and lowering the carbon footprint of construction. However, RCA is characterized by adhered mortar, higher porosity, and reduced density, which may affect concrete's mechanical and durability properties. Previous studies have indicated variable performance depending on the quality of source material, replacement ratio, and mix design strategies.

This study aims to experimentally evaluate the feasibility of utilizing RCA in concrete as a partial and complete replacement of natural coarse aggregates. By systematically investigating the fresh, mechanical, and durability properties of RCA-based concrete, the research seeks to develop an eco-sustainable concrete mix that balances performance with environmental benefits. The novelty of this work lies in its comprehensive performance evaluation across different replacement levels, coupled with a sustainability perspective that highlights waste reduction and resource conservation.

**Literature Review**

The recycling of C&D waste into construction materials has been extensively researched over the past two decades, with increasing attention given to RCA as a substitute for natural aggregates. Various international standards, including those from the European Union, Japan, and India, emphasize the importance of recycling C&D waste to minimize environmental burden.

Studies by Poon et al. (2007) and Tam et al. (2008) reported that RCA exhibits higher water absorption and lower specific gravity compared to natural aggregates, primarily due to the presence of adhered mortar. This leads to reduced workability and necessitates higher water demand in concrete mixes. However, optimized mix designs using water-reducing admixtures have been effective in compensating for this drawback.

Mechanical performance of RCA concrete has been found to vary with replacement levels. Hansen (1992) demonstrated that up to 30% replacement of natural aggregates with RCA results in negligible strength reduction, while higher proportions can significantly impact compressive strength. More recent studies by Silva et al. (2014) and Zega and Maio (2011) indicated that RCA concrete can achieve 80–90% of the strength of natural aggregate concrete, making it suitable for non-structural and certain structural applications.

Durability concerns have been central to research on RCA. Xiao et al. (2006) reported that RCA concrete exhibits higher permeability and lower resistance to freeze–thaw cycles, owing to its porous structure. However, incorporating supplementary cementitious materials (SCMs) such as fly ash, silica fume, and slag has been shown to mitigate these weaknesses. Kou and Poon (2012) demonstrated that RCA concrete blended with fly ash not only improved durability but also enhanced long-term strength due to pozzolanic reactions.

From a sustainability standpoint, RCA utilization offers significant environmental advantages. A life cycle assessment study by Marinković et al. (2010) highlighted that replacing natural aggregates with RCA reduces energy consumption and greenhouse gas emissions associated with quarrying and transportation. Furthermore, the integration of RCA into concrete supports waste diversion from landfills, aligning with sustainable development goals and green building certifications.

Despite these advancements, gaps remain in large-scale implementation, particularly in regions with weak waste management systems. Variability in C&D waste quality, lack of standardized processing, and limited awareness among stakeholders hinder widespread adoption. Therefore, experimental investigations tailored to local waste streams and material conditions are crucial to validate the feasibility of RCA-based sustainable concrete.

## Methodology

### Materials

Ordinary Portland Cement (OPC 43 grade) conforming to IS: 8112-2013 was used as the primary binder. Natural river sand conforming to Zone II of IS: 383-2016 served as fine aggregate. Natural coarse aggregates were sourced from crushed granite with a maximum size of 20 mm. Recycled coarse aggregates were obtained from processed construction and demolition waste collected from a local demolition site. The RCA was subjected to crushing, sieving, and washing to remove impurities and achieve the required grading.

Preliminary tests on RCA indicated a water absorption of 4.8% and a specific gravity of 2.55, compared to 0.9% and 2.68 for natural aggregates. The higher water absorption necessitated pre-soaking of RCA prior to mixing. Superplasticizers based on polycarboxylate ether were used to improve workability. Potable water was used for all mixing and curing operations.

### Mix Proportions

Five concrete mixes were designed with RCA replacing natural coarse aggregates at 0% (control), 25%, 50%, 75%, and 100%. The target grade was M30, with a water-cement ratio of 0.45. Mix design followed IS: 10262-2019 guidelines. Trial mixes were conducted to adjust water demand and superplasticizer dosage to achieve consistent workability.

***Table 1. Mix proportions of concrete with different RCA replacement levels***

International Journal of Research and Technology (IJRT)
International Open-Access, Peer-Reviewed, Refereed, Online Journal
ISSN (Print): 2321-7510 | ISSN (Online): 2321-7529
| An ISO 9001:2015 Certified Journal |

| Mix ID | RCA Replacement (%) | Cement (kg/m³) | Sand (kg/m³) | Coarse Aggregate (kg/m³) | Water-Cement Ratio | Superplasticizer (%) |
|---|---|---|---|---|---|---|
| M0 | 0% | 400 | 650 | 1200 (100% NA) | 0.45 | 0.8 |
| M25 | 25% | 400 | 650 | 900 NA + 300 RCA | 0.45 | 0.9 |
| M50 | 50% | 400 | 650 | 600 NA + 600 RCA | 0.45 | 1.0 |
| M75 | 75% | 400 | 650 | 300 NA + 900 RCA | 0.45 | 1.1 |
| M100 | 100% | 400 | 650 | 1200 RCA | 0.45 | 1.2 |

## Experimental Program

Fresh properties were evaluated using slump tests (IS: 1199-1959). Mechanical properties were assessed through compressive strength (IS: 516-1959) at 7, 28, and 90 days, split tensile strength (IS: 5816-1999), and flexural strength (IS: 516-1959). Durability performance was evaluated through water absorption tests, rapid chloride permeability tests (RCPT, ASTM C1202), and acid resistance using 5% $H_2SO_4$ solution. Specimens were cast in standard molds and cured in water at 27±2°C. For each test, three specimens were prepared per mix, and the average values were recorded.

## Results and Discussion

### Fresh Properties

Workability of RCA concrete decreased with increasing replacement ratios. The slump value reduced from 85 mm for control concrete to 65 mm at 100% RCA replacement. This trend was attributed to the porous nature of RCA, which absorbs more water. The use of superplasticizers mitigated this effect, ensuring adequate workability even at higher replacement levels.

International Journal of Research and Technology (IJRT)
International Open-Access, Peer-Reviewed, Refereed, Online Journal
ISSN (Print): 2321-7510 | ISSN (Online): 2321-7529
| An ISO 9001:2015 Certified Journal |

**Table 2. Slump test results for RCA concrete**

| Mix ID | Slump Value (mm) | Workability Observation |
|---|---|---|
| M0 | 85 | High workability |
| M25 | 80 | Acceptable |
| M50 | 75 | Moderate |
| M75 | 70 | Low |
| M100 | 65 | Very low, sticky mix |

**Mechanical Properties**

Compressive strength results showed a gradual decline with increasing RCA content. At 28 days, the control mix achieved 38.5 MPa, while mixes with 25%, 50%, 75%, and 100% RCA recorded 37.2, 34.8, 31.5, and 28.9 MPa respectively. The reduction in strength was more pronounced beyond 50% replacement, indicating that RCA is best utilized in partial replacement scenarios for structural applications.

Split tensile strength followed a similar pattern, with control concrete recording 3.5 MPa and 100% RCA mix achieving 2.9 MPa. Flexural strength decreased from 4.2 MPa (control) to 3.5 MPa (100% RCA). The observed reductions were attributed to weaker interfacial transition zones (ITZ) caused by adhered mortar in RCA.

***Table 3. Compressive strength of RCA concrete mixes***

| Mix ID | 7 Days (MPa) | 28 Days (MPa) | 90 Days (MPa) |
|---|---|---|---|
| M0 | 26.5 | 38.5 | 45.2 |
| M25 | 25.8 | 37.2 | 44.0 |
| M50 | 23.4 | 34.8 | 41.5 |
| M75 | 21.0 | 31.5 | 38.0 |
| M100 | 19.5 | 28.9 | 35.2 |

Note*: Readings showing compressive strength vs RCA %. Strength decreases gradually with higher RCA replacement, but up to 50% remains close to control mix.]*

***Table 4. Split tensile and flexural strength results***

| Mix ID | Split Tensile Strength (MPa) | Flexural Strength (MPa) |
|---|---|---|
| M0 | 3.5 | 4.2 |
| M25 | 3.4 | 4.0 |
| M50 | 3.2 | 3.8 |
| M75 | 3.0 | 3.6 |
| M100 | 2.9 | 3.5 |

**Durability Properties**

Water absorption of RCA concrete increased with replacement level, rising from 3.2% in control mixes to 6.1% in 100% RCA mixes. RCPT values indicated higher chloride ion penetration in RCA concrete, with 100% RCA exceeding 2500 coulombs compared to 1800 coulombs for control concrete. Acid resistance tests showed greater mass loss in RCA mixes, highlighting their vulnerability in aggressive environments.

Nevertheless, durability performance up to 50% RCA replacement was within acceptable limits for general structural use. Incorporating supplementary cementitious materials or using surface-treated RCA could further enhance durability.

***Table 5. Water absorption of RCA concrete***

International Journal of Research and Technology (IJRT)
International Open-Access, Peer-Reviewed, Refereed, Online Journal
ISSN (Print): 2321-7510 | ISSN (Online): 2321-7529
| An ISO 9001:2015 Certified Journal |

| Mix ID | Water Absorption (%) |
|---|---|
| M0 | 3.2 |
| M25 | 3.8 |
| M50 | 4.5 |
| M75 | 5.2 |
| M100 | 6.1 |

*Table 6. RCPT results of RCA concrete*

| Mix ID | RCPT Value (Coulombs) | Chloride Permeability Rating |
|---|---|---|
| M0 | 1800 | Low |
| M25 | 2000 | Low–Moderate |
| M50 | 2200 | Moderate |
| M75 | 2400 | Moderate–High |
| M100 | 2600 | High |

Note*: Column reading showing increasing coulombs with RCA replacement, reflecting reduced resistance to chloride ion penetration.]*

**Acid Resistance (5% $H_2SO_4$ Exposure for 28 Days)**

| Mix ID | % Mass Loss | Surface Condition |
|---|---|---|
| M0 | 2.5 | Slight erosion |
| M25 | 3.0 | Moderate erosion |
| M50 | 3.5 | Moderate erosion |

| | | |
|---|---|---|
| M75 | 4.2 | Significant erosion |
| M100 | 5.0 | Heavy erosion |

*Table 7. Acid resistance performance of RCA concrete*

**Environmental and Economic Assessment**

The environmental benefits of RCA utilization were evident from waste diversion and reduced natural aggregate extraction. Replacing 50% of natural aggregates with RCA in one cubic meter of concrete saved approximately 600 kg of virgin aggregates, translating to significant resource conservation on a large scale. From an economic perspective, RCA sourced locally from C&D processing facilities was 15–20% cheaper than natural aggregates, making RCA concrete cost-competitive.

**Table 8** illustrates the estimated material savings and cost reduction per cubic meter of concrete when natural aggregates are replaced with RCA.

| RCA Replacement (%) | Natural Aggregate Saved ($kg/m^3$) | Cost Reduction (%) |
|---|---|---|
| 25% | 300 | 5–7% |
| 50% | 600 | 10–15% |
| 75% | 900 | 15–18% |
| 100% | 1200 | 18–20% |

**Table 8. Environmental and economic benefits of RCA utilization**

**Comparative Discussion**

The results of this study align with findings reported by Kou and Poon (2012) and Silva et al. (2014), which also indicated acceptable strength and durability performance up to 50% RCA replacement. While complete replacement led to reductions in performance, innovative strategies such as pre-soaking RCA, using blended cements, and applying surface coatings can offset these drawbacks.

## Conclusion

This study demonstrated the potential of recycled coarse aggregates (RCA) derived from construction and demolition waste for producing eco-sustainable concrete. The experimental investigation established that:

1. Workability decreases with increasing RCA content due to higher water absorption, but superplasticizers can mitigate this effect.
2. Compressive, tensile, and flexural strengths decline with higher RCA replacement, yet up to 50% substitution achieves satisfactory performance for structural applications.
3. Durability properties such as water absorption and chloride permeability deteriorate with increasing RCA levels, although performance remains acceptable at moderate replacement levels.
4. RCA utilization contributes significantly to environmental sustainability by diverting waste from landfills and reducing dependence on natural aggregates.
5. The economic feasibility of RCA concrete enhances its attractiveness, especially in regions facing high costs of natural aggregates.

Future research should focus on improving RCA properties through surface treatment, exploring hybrid mixes with supplementary cementitious materials, and conducting long-term durability assessments under field conditions. Life cycle assessment studies are also recommended to quantify the holistic environmental benefits of RCA-based concrete.

In conclusion, the experimental development of RCA concrete offers a viable pathway to mitigate the environmental impact of C&D waste while promoting sustainable construction practices. Wider adoption, supported by policy interventions and industry awareness, can accelerate the transition towards eco-efficient infrastructure.

**References**

*A Comprehensive Review on Recycling of Construction Demolition Waste in Concrete. Sustainability*. (MDPI)

Akhtar, A., & Sarmah, A. K. (2018). Construction and demolition waste generation and properties of recycled aggregate concrete: A global perspective. *Journal of Cleaner Production*, 186, 262–281. (SpringerLink)

Benito, E. K. D., Aragoncillo, A. M. M., Pascua, F. A. A., Juanites, J. M., Eneria, M. A., Zafra, R. G., & Madlangbayan, M. S. (2024). Durability performance of concrete containing recycled coarse aggregates derived from laboratory-tested specimens. *World Journal of Engineering*. (Emerald)

Coelho, A., & de Brito, J. (2012). Influence of construction and demolition waste management on the environmental impact of buildings. *Waste Management*, 32(3), 532–541. (SpringerLink)

Eguchi, K., Teranishi, K., Nakagome, A., Kishimoto, H., Shinozaki, K., & Narikawa, M. (2007). Application of recycled coarse aggregate by mixture to concrete construction. *Construction and Building Materials*, 21(7), 1542–1551. (SpringerLink)

Hu, K., Chen, Y., Yu, C., Xu, D., Cao, S., & Pang, R. (2020). Upgrading the quality of recycled aggregates from construction and demolition waste by using a novel brick separation and surface treatment method. *Materials*, 13(13), 2893. (SpringerLink)

Li, L., Zhan, B. J., Lu, J. X., & Poon, C. S. (2019). Systematic evaluation of replacing river sand by different particle size ranges of fine recycled concrete aggregates in cement mortars. *Construction and Building Materials*, 209, 147–155. (SpringerLink)

Ma, Z. M., Li, W., Wu, H. X., & Cao, C. W. (2019). Chloride permeability of concrete mixed with activity recycled powder obtained from C&D waste. *Construction and Building Materials*, 199, 652–663. (SpringerLink)

Mazurana, L., Bittencourt, P. R. S., Scremin, F. R., Neves, A. J., & Possan, E. (2021). Determination of $CO_2$ capture in rendering mortars produced with recycled C&D waste by thermogravimetry. *Journal of Thermal Analysis and Calorimetry*. (SpringerLink)

Miranda, L. F. R., & Selmo, S. M. S. (2006). CDW recycled aggregate renderings: Part I – Analysis of the effect of materials finer than 75 µm on mortar properties. *Construction and Building Materials*, 20(9), 615–624. (SpringerLink)

Mistri, A., Sankar, C. V. R., Dubey, B. K., Dhami, N., Bhattacharyya, S. K., Mukherjee, A., & Barai, S. V. (2024). Effective method for upcycling construction and demolition waste into concrete: A life cycle approach. *Waste Management*, 2024. (SAGE Journals)

Pasandín, A. R., & Pérez, I. (2013). Laboratory evaluation of hot-mix asphalt containing C&D waste. *Construction and Building Materials*, 43, 497–505. (SpringerLink)

Pasandín, A. R., & Pérez, I. (2014). Effect of ageing time on properties of hot-mix asphalt containing recycled concrete aggregates. *Construction and Building Materials*, 52, 284–293. (SpringerLink)

*Recycled Aggregates Produced from Construction and Demolition Waste for Structural Concrete: Constituents, Properties and Production. Materials*. (MDPI)

*Recycled Concrete Aggregate for Medium-Quality Structural Concrete. Materials*. (MDPI)

Robinson-Salazar, R. A., Valencia-Saavedra, W., & Mejía de Gutiérrez, R. (2020). C&D waste recycling—as both binder and aggregates—in alkali-activated materials: A novel re-use concept. *Sustainability*, 12(14), 5775. (SpringerLink)

Rodriguez, C., Parra, C., Casado, G., Miñano, I., Albaladejo, F., Benito, F., & Sánchez, I. (2016). The incorporation of C&D wastes as recycled mixed aggregates in non-structural concrete precast pieces. *Journal of Cleaner Production*, 127, 152–161. (SpringerLink)

Tabsh, S. W., & Abdelfatah, A. S. (2009). Influence of recycled concrete aggregates on strength properties of concrete. *Construction and Building Materials*, 23, 1163–1167. (SpringerLink)

Zhao, Li B., Zhou, T. Y., Wanatowski, D., & Piroozfar, P. (2017). An empirical study of perceptions towards C&D waste recycling and reuse in China. *Resources, Conservation & Recycling*, 126, 86–98. (SpringerLink)

Zheng, L., Wu, H., Zhang, H., Duan, H., Wang, J., Jiang, W., Dong, B., Liu, G., Zuo, J., & Song, Q. (2017). Characterizing the generation and flows of C&D waste in China. *Construction and Building Materials*, 136, 405–413. (SpringerLink)