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Recycled Concrete: Sustainable Solutions for Construction and Waste Reduction

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Abstract: *This paper reviews the utilization of recycled aggregate sourced from construction and demolition waste for concrete production. The use of recycled aggregate has been adopted in numerous construction projects across Europe, America, Russia, and Asia. This research, however, indicates that recycled Aggregates derived from concrete specimens can produce high-quality concreter. Concrete waste from demolished structures is collected, and coarse aggregates in varying percentages are used to produce fresh concrete. In this study, for the 28th day cube compressive strength using OPC was evaluated for 0%, 50%, and 100% RCA and compared with nominal concrete. The study summarizes the results of workability, water absorption, dry density, and compressive strength of HPC made with RA as reported in previous studies. The paper also discusses the microstructure and durability performance of concrete. This study demonstrates that the strength of concrete is influenced by the addition of RCA.*

Keywords: Demolished, Sustainable, Recycled, Concrete waste, Green concrete, New concrete

I. INTRODUCTION

Concrete is the most widely used material in the construction industry worldwide. The concrete industry heavily consumes energy and raw materials. Therefore, reusing industrial waste as an admixture in construction offers both environmental and economic benefits. Concrete is essentially a manufactured material composed of cement, aggregates, water, and admixture. Aggregates make up a significant portion of the mixture and consist of inert granular materials such as sand, crushed some, and gravel. RAC includes materials such as crushed concrete, bricks and old asphalt, help reduce the demand for virgin resources and minimize landfill waste.

The process includes cleaning, crushing, and grading waste concrete to create aggregates suitable for fresh concrete production. Although RAC may exhibit slightly different mechanical properties than traditional concrete, advancements in processing and mix design have made it a practical alternative for both structural and non-structural application.

- **Environmental sustainability:** reduces construction waste and conserves natural resources.
- **Cost-effectiveness:** lowers material costs, especially in regions with limited natural aggregate availability.
- **Energy efficiency:** reduces the energy required for mining and transportation of natural materials.

Desperate some challenges, like lower strength or durability if not properly processed, ongoing research and improved recycling techniques continue to enhance the performance and reliability of recycled aggregate concrete, making it an essential component of modern, eco-friendly construction practices.

Present scenario of demolished waste used in India:

India faces a significant challenge with construction and demolition (C&D) waste, generating an estimated 150 million tonnes annually, but recycling only about 1% of it, leading to environmental problems and resource inefficiencies.

Demolished waste of concrete as a material:

Demolished concrete waste, also known as recycled concrete aggregate (RCA), can be repurposed as a material for various applications, including road base materials, sub-base layers for pavements, and even as a partial replacement for natural aggregates in new concrete construction.

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II. LITERATURE REVIEW

Aiyewalehinmie.o. and adeoyet.e. (2016)

the study estimated that 15% to 20% of construction waste ends up in landfills. They tested four water-cement ratios (0.5, 0.55, 0.60, 0.65) on 96 concrete cubes and found that lower ratios resulted in recycled aggregates having a compressive strength of 16.89 n/mm², compared to 19.93 n/mm² for virgin aggregates. At higher ratios, the strength of recycled aggregates (ranging from 18.07 to 18.37 n/mm²) was close to that of virgin aggregates. The researchers concluded that recycled aggregates can match the strength of virgin aggregates when higher water-cement ratios are used.

Jain, n. Et al. (2015)

this study focused on developing green concrete (m30 grade) using recycled coarse aggregates. The results indicated that the compressive strength of 28-day concrete containing 100% washed recycled aggregates was 7% lower than concrete made with natural aggregates. The study also examined water absorption, carbonation, and chloride penetration, revealing that the concrete.

Garg and jain (2014)

the research reviewed the benefits and limitations of using manufactured and recycled aggregates in concrete. They pointed out that utilizing green concrete in the future could help reduce co2 emissions and minimize environmental impact.

Dhoka (2013)

the study explored the potential of using industrial waste materials such as marble powder, quarry dust, and paper pulp in producing green concrete. The research demonstrated that green concrete made with these industrial by-products, in proper proportions, could satisfy future construction demands due to its versatility and performance.

Naik et al. (2006)

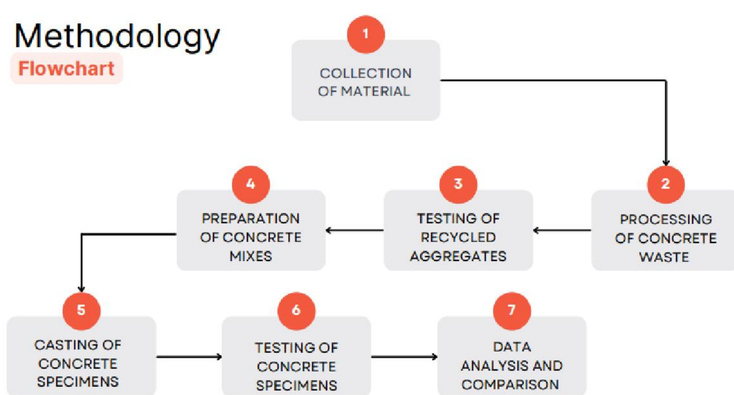
this paper focused on the production of recycled aggregates and their properties, examining their suitability for concrete production. It was found that recycled aggregates exhibited higher water absorption than natural aggregates, along with lower density and strength. These differences in properties impacted the overall performance of concrete.

Natesan et al. (2005)

an experimental investigation was conducted to study the mechanical properties of concrete where natural coarse aggregates were partially replaced with recycled coarse aggregates (RCA). The results showed that the mechanical properties of the concrete improved with the inclusion of RCA. A mix of 75% RCA and 25% natural aggregates demonstrated favorable mechanical performance, with RCA's rough surface enhancing the bond with cement.

Limbachiya et al. (2004)

the study examined the performance of Portland cement concrete using natural and recycled coarse aggregates. It was found that recycled aggregates had a 3-10% lower density and 3-5 times higher water absorption compared to natural aggregates, due to the cement paste attached to them. Despite these differences.



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Test report of aggregate impact value

Size of aggregate: 10mm

Description	Test-1	Test-2
Wt. Of empty measuring cylinder (w1) in gm.	171	171
Wt. Of empty measuring cylinder + wt. Of aggregate sample (w2) in gm.	388	387
Net wt. Of aggregate sample a= (w2-w1) in gm.	217	216
Weight of crush aggregate retained on 2.36mm I.S. sieve after impact (b) in gm.	151	145
Weight of crush aggregate passing through 2.36mm I.S. sieve after impact (c) in gm.	66	71
Aggregate impact value in % = c/a x 100	30.41	32.87
Avg. Aggregate impact value in % = (1+2) / 2	31.64	

Objectives of the study:

- To produce a concrete using locally available materials. (i.e. recycled aggregate concrete).
- To examine the strength properties of green concrete with partial replacement of natural aggregates.
- To analyse the impact of recycled coarse aggregate on concrete strength.
- To examine the impact of recycled coarse aggregate on the workability of concrete.
- To identify the optimal percentage of recycled coarse aggregate in concrete.

Significance of research

- Reducing the burden on landfills caused by construction and demolition debris.
- The possibility of increasing the use of recycled coarse aggregate beyond the recommended 30% limit.
- Preserving natural resources by reducing the use of natural coarse aggregate in concrete production.
- Addressing performance issue, such as low strength, associated with recycled aggregate.
- The potential use of recycled coarse aggregate in structure concrete.

III. MATERIALS

Portland cement

Ordinary Portland cement (OPC) is used specifically 53 grades. (birlashakti cement). The grey colour of cement is due to iron oxide and in the absence of impurities. It remains grey. The following tests will be conducted on the cement.
Following tests will be conducted, on cement:
Initial setting time and final setting time.
Consistency limit test: - three sample were tested.

Sand

The sand used in this study will be natural river sand. Sand passing through 4.75 mm sieve will be used for specimen preparation. Sieve analysis of the sand will be conducted in the laboratory following the procedure outlined in is2386 (part-1)-1963. The sand particles range in size from 2mm to 4.75 micron.

Coarse aggregate

Fresh crushed coarse aggregate

The coarse aggregate used in this study will be 10mm and 20mm crushed granite stone sourced from quarries. The physical properties will be assessed in accordance with is:3286-1963.

Recycled coarse aggregate

The recycled aggregate used in this project is sourced from demolished concrete structures. These concrete wastes are crushed to produce recycled coarse aggregates. The recycled coarse aggregate used in this study will be 10mm and 20mm size.

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Water

The water used in the mix design was potable water from the supply. Free from suspended solids and organic materials that could affect the properties of fresh and hardened concrete.

The presence of tannic acid or iron compounds is undesirable. The requirements for water used in mixing and curing concrete shall comply with is: 456-2000.

Impurities in recycled coarse aggregate:

The presence of impurities recycled coarse aggregate can be reduced, which emanated from demolition process including porous mortar and cement paste attached the parent aggregate. The effect could also lead to general decrease in characteristics of recycled aggregate concrete. Some impurities were identified through visual inspection of the recycled coarse aggregate

Although visual evidence indicates the presence of adhered mortar on the parent material, it was virtually impossible to estimate its percentage. However, the adhered mortar does not appear to be present in significant quantities its impact on the characteristics of recycled course aggregate concrete cannot be overlooked.

Experimental program

Concrete mixes were prepared with both NAC and RAC produced using natural sand as the fine aggregate.

Nac mixes were made using only natural aggregate as the coarse aggregate in the concrete mix.

Meanwhile, rac mixes used demolished waste concrete aggregate as a partial or full replacement for natural aggregate as coarse aggregate.

These mixes were design based on the concrete mix design.

The concrete samples were de-moulded after 24 hours.

Hardened concrete samples were stored in the curing tank at round 20-degree c. For a maximum of 28 days.

Testing of hardened concrete after 28 days of curing.

The combination in concrete mixes after this will be called as ra00, ra50, ra100.

Table below showed the details of concrete mixes.

Table-1: mix designs
(n-a natural aggregate / r-a recycled aggregates)

Mix designation	Description
Rac-0	100% n-a + 0% r-a
Rac-50	50% n-a + 50% r-a
Rac-100	0% n-a + 100% r-a

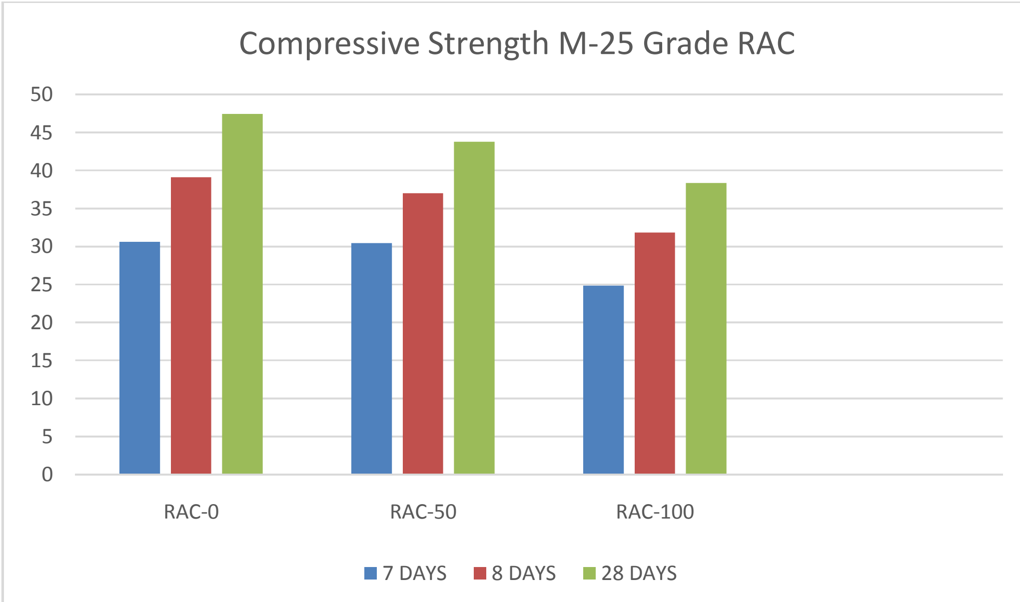
IV. RESULTS AND DISCUSSIONS

Compressive strength

The compressive strength of m25 grade concrete made with varying percentage of natural and recycled aggregates is evaluated. For each concrete mix the compressive strength is tested on three 150x150x150 mm cubes after 7 and 28 days of curing.

The table below presents the compressive strength test results of recycled aggregates concrete the varying aggregates percentages.

Mix	Grade	Compressive strength (n/mm2)		
		7 days	14 days	28 days
Rac-0	M-25	30.62	39.09	47.42
Rac-50	M-25	30.44	37.01	43.78
Rac-100	M-25	24.84	31.8	38.36



V. SUMMARY AND CONCLUSIONS

This study investigates the use of recycled aggregate concrete (rac) derived from construction and demolition waste as a sustainable alternative to natural aggregate concrete (nac). The research evaluates the mechanical properties, durability, and workability of rac in comparison to conventional concrete. Key experiments, including compressive strength tests and aggregate impact assessments, reveal that while rac exhibits slightly lower strength and higher water absorption, its performance can be improved through proper processing and mix design. The findings highlight the potential for rac to be utilized effectively in structural and non- structural applications, contributing to sustainable construction practices by reducing landfill waste and conserving natural resources.

The study demonstrates that recycled aggregate concrete can serve as a viable alternative to natural aggregate concrete, especially when processed correctly. Despite minor reductions in compressive strength, rac offers significant environmental and economic benefits, such as reduced waste disposal and lower demand for virgin materials. With ongoing advancements in recycling technology and mix optimization, the adoption of rac can contribute to more sustainable and eco-friendly construction practices. Further research and regulatory support can enhance its application, making it a standard choice for future construction projects.

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