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Strength Studying the Use of "Recycled Aggregate" for the Application in Concrete

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ABSTRACT

Crushed and graded inorganic particles from building and demolition debris make up recycled aggregates. The purpose of this study is to assess recycled aggregates' strength properties in light of their possible use in the construction of concrete pavement. Comparing the compressive strength, flexural strength, and sulphate resistance of concrete with different percentages of recycled aggregates is the main goal of the study. Workability, flexural strength, compressive strength, and sulphate resistance evaluations are among the tests carried out. With a constant water-to-cement ratio of 0.38, five concrete mixes were created by substituting recycled aggregates for coarse aggregates at percentages of 0%, 10%, 20%, 30%, and 40%. According to the findings, the workability of concrete decreased as the percentage of recycled aggregates rose. According to strength testing, recycled aggregate concrete performed similarly to concrete built with natural aggregates. An environmentally friendly way to reduce the negative effects of building and demolition waste is to use recycled aggregates in concrete. In addition, this paper offers a thorough analysis of the entirety of research on recycled aggregates, focussing into their characteristics, the variables affecting their use in concrete, and the pros and cons of doing so.

KEYWORDS: *compressive strength, flexural strength, sulphate Resistance, Concrete.*

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1. INTRODUCTION

Preserving old structures can lead to better economic benefits through conservation efforts. Since its discovery, concrete has been a leading construction material due to its durability, versatility, ease of maintenance, and ability to be molded into any shape or size. Cement, aggregates, sand, and water are the ingredients of concrete, which solidifies into a stone-like substance when the water combines with the cement and aggregates. It is made up of inactive substances like sand and coarse aggregates as well as active ones like cement and water. Concrete has low tensile strength despite having great compressive strength; this is usually fixed by adding steel reinforcement to create reinforced cement concrete (RCC).

Due to deterioration brought on by a variety of circumstances, structures intended to last 50 years or more frequently need to be demolished after 20 to 30 years.

This has led to increased demolition rates, higher disposal costs, and a shortage of landfill space. Instead of discarding this demolished concrete, recycling it into reusable aggregates can significantly reduce costs and conserve non-renewable energy resources. Using recycled concrete also reduces dependence on natural aggregates, minimizing environmental damage and preserving natural resources. Recycled aggregates are derived from crushed, graded inorganic materials recovered from demolished structures, roads, and bridges that have reached the end of their service life due to aging, natural disasters, or conflicts.

2. Aim

The aim of this study is to explore the feasibility and benefits of using recycled concrete aggregates as a sustainable alternative to natural aggregates in construction. The study seeks to evaluate the properties, performance, and environmental impact of recycled aggregates while addressing the challenges of waste management, resource conservation, and environmental sustainability in the construction industry.

3. Materials

Recycled Coarse Aggregate:

Recycled coarse aggregate (RCA) is derived from crushed, graded, and processed demolition and construction debris. In M43 and M53 recycled concrete mixes, recycled aggregates replace natural aggregates to varying extents while maintaining the desired structural and performance characteristics. RCA is an eco-friendly alternative that helps in reducing waste and conserving natural resources.

Material Properties

- **Recycled Coarse Aggregate**

Property	Recycled Coarse Aggregate (RCA)	M43 Concrete Requirement	M53 Concrete Requirement
Specific Gravity	2.35 - 2.50	≥ 2.5	≥ 2.6
Water Absorption (%)	3.0 - 6.0	≤ 3.0	≤ 3.0
Crushing Value (%)	20 - 30	≤ 25	≤ 20
Impact Value (%)	20 - 25	≤ 25	≤ 20
Los Angeles Abrasion (%)	25 - 35	≤ 30	≤ 25
Density (kg/m³)	2,200 - 2,400	≥ 2,400	≥ 2,500

- **Natural coarse Aggregate**

Natural coarse aggregate refers to naturally occurring rock or stone materials that are mined, crushed, or sieved into particles of a specific size range, typically larger than 4.75 mm in diameter, as per standard classification. These aggregates are used in concrete, asphalt, and other construction applications to provide bulk, strength, and stability.

Material Properties

Property	Typical Values	Remarks
Particle Size	10mm (nominal size)	Passes through a 12.5mm sieve and retained on a 10mm sieve.
Shape	Rounded or angular	Depends on the source (e.g., river gravel is rounded; quarried stone is angular).
Specific Gravity	2.6 - 2.8	Indicates the density of the aggregate compared to water.
Bulk Density	1450 - 1550 kg/m³	Depends on the packing, particle shape, and grading.
Water Absorption	0.1% - 2%	Lower absorption indicates higher durability.
Porosity	2% - 6%	Affects water absorption and durability of the concrete.
Fineness Modulus (FM)	6.5 - 7.5	Represents the aggregate's coarseness.
Abrasion Resistance	< 30% (Los Angeles Abrasion Test)	Ensures the aggregate can withstand mechanical wear.
Crushing Value	< 25%	Indicates the resistance to crushing under a compressive load.
Impact Value	< 20%	Measures toughness to resist impact forces.
Flakiness Index	< 15%	Limits flaky particles to maintain workability and strength.
Moisture Content	0.1% - 2%	Depends on storage conditions and environmental factors.
Hardness	High	Ensures the material can resist weathering and mechanical loads.
Color	Light to medium gray	Color does not affect concrete performance but indicates the aggregate source.

➢ **Cement**

This cement is Ordinary Portland Cement (OPC), a common building ingredient used as a binding agent in plaster, mortar and concrete.It is manufactured by grinding clinker with a small percentage of gypsum. OPC is available in different grades based on its compressive strength, such as **43 Grade** and **53 Grade**, which conform to the **IS: 8112-1989** specification. The number indicates the cement's compressive strength (in MPa) after 28 days of curing.

Material properties

Property	43 Grade OPC (Typical Values)	53 Grade OPC (Typical Values)	Test Standard	Remarks
Compressive Strength	≥ 43 MPa (28 days)	≥ 53 MPa (28 days)	IS: 4031 (Part 6)	Defines the strength of cement mortar cubes under standard conditions.
Initial Setting Time	≥ 30 minutes	≥ 30 minutes	IS: 4031 (Part 5)	Time taken for the paste to stiffen to a certain degree.
Final Setting Time	≤ 600 minutes	≤ 600 minutes	IS: 4031 (Part 5)	Time taken for the paste to fully harden.
Fineness	≥ 225 m²/kg (Blaine's Specific Surface Area)	≥ 225 m²/kg	IS: 4031 (Part 2)	Indicates the particle size of cement, affecting hydration and strength.
Soundness	≤ 10 mm (Le Chatelier)	≤ 10 mm	IS: 4031 (Part 3)	Ensures volume stability after setting and hardening.
Consistency	27% - 33%	27% - 33%	IS: 4031 (Part 4)	Amount of water needed for standard paste consistency.
Specific Gravity	3.1 - 3.15	3.1 - 3.15	IS: 4031 (Part 11)	Indicates the density of cement compared to water.
Dry Shrinkage	≤ 0.15%	≤ 0.15%	IS: 4031 (Part 10)	Measures shrinkage during drying to ensure crack resistance.
Soundness (Autoclave)	≤ 0.8%	≤ 0.8%	IS: 4031 (Part 3)	Assesses the expansion of cement under steam curing.
Heat of Hydration	Moderate	Higher than 43 Grade	Not directly tested here	Affects early-age strength development; 53 Grade is more reactive.

- **Sand**

Sand typically refers to the fine aggregate portion that is a by-product of crushing demolished concrete structures. When used in concrete, crushed concrete sand must meet specific requirements outlined in **IS: 2386-1963**, which specifies the methods of testing for aggregates (including fine aggregates like sand) used in concrete. Crushed concrete sand can be used as a partial or complete replacement for natural sand, as long as it meets the necessary physical and mechanical properties outlined in the standard.

Property	Typical Range/Value	Test Standard	Remarks
Particle Size Distribution	Fine aggregate passing 4.75mm sieve	IS: 2386 (Part 1)	The sand particles should pass through a 4.75 mm sieve to be considered fine aggregate. Grading affects the workability and strength of concrete.
Fineness Modulus	2.5 - 3.0	IS: 2386 (Part 1)	Represents the average size of particles in the sand. Affects the workability and strength of the concrete.
Water Absorption	1% - 2%	IS: 2386 (Part 3)	Higher absorption can affect the water-cement ratio and concrete mix consistency.
Specific Gravity	2.5 - 2.7	IS: 2386 (Part 3)	Measures the density of the sand. Higher specific gravity indicates better quality and denser concrete.
Moisture Content	0.5% - 2%	IS: 2386 (Part 3)	The moisture content can vary depending on storage conditions. Excess moisture can affect the water-cement ratio.
Clay, Silt, and Dust Content	≤ 5% (by mass)	IS: 2386 (Part 2)	Excess clay, silt, and dust can harm the strength and durability of concrete by reducing bonding with cement.
Particle Shape	Angular or sub-angular	IS: 2386 (Part 4)	Crushed concrete sand may be angular or sub-angular, which affects the workability and compaction of the concrete.
Organic Impurities	Non-detectable (usually)	IS: 2386 (Part 2)	Organic matter should be absent to avoid affecting setting times and strength of the concrete.
Soundness	≤ 5%	IS: 2386 (Part 5)	Tests the resistance of sand to weathering and ensures long-term durability of concrete exposed to outdoor conditions.
Bulk Density	1300 - 1600 kg/m³	IS: 2386 (Part 3)	Has an indirect impact on the strength of the hardened concrete and the volume of the concrete mix.
Grading	Well-graded (zone II or III)	IS: 383:1970 (for grading)	Grading influences the amount of cement required in the mix and the strength and workability of concrete.

4. Experimental Procedure

Type of Mix Used	Recycled Aggregate (%)	Natural Aggregate (%)
m0	0	100
m1	10	90
m2	20	80
m3	30	70
m4	40	60

The first mix, designated m0, served as the control mix. For cement, fine aggregates, and coarse aggregates, the corresponding ratios are 1:1.23:2.52. Using the super plasticiser (0.6% of cement), the water-to-cement ratio was determined to be 0.38. Five different concrete mix batches were made using different amounts of recycled coarse particles. Following batch preparation, the compaction factor and slump tests were used to gauge the concrete's workability. 150 x 150 x 150 mm cubes were used for compressive strength testing, 100 x 100 x 500 mm beams for flexural strength testing, and 150 x 150 x 150 mm cubes for sulphate resistance testing. IS: 516-1959 was followed in the casting of the samples. Compressive strength tests were performed on the samples at 7, 28, 56, and 90 days of age. Beams were tested for flexural strength at 7, 28, and 90 days of age. The cubes were evaluated for sulphate resistance at 7, 28, and 56 days of maturity. Saturated and surface-dried aggregates were utilised. The tests were conducted in accordance with the applicable Indian Standard requirements. Batching was carried out based on weight.

5. RESULTS

Test Results for Compressive Strength using M53 grade

S. No.	Mix	W/C		Compressive strength (MPa)		
			7 Days	28Days	56 Days	90 Days
1.	m0	0.38	42.43	50.06	51.20	51.8
2.	m1	0.38	42.47	50.36	50.89	51.23
3.	m2	0.38	41.84	50.20	50.68	50.80
4.	m3	0.38	42.60	49.11	50.68	51.4
5.	m4	0.38	40.27	52.36	53.24	53.26

Compressive strength test results at 7, 28, 56, and 90 days. For all composites, the water cement rate was maintained at 0.38. 0.6 percent cement was employed as super plasticiser. Compressive strength at varying days for each composite. When RCA is used instead of natural total, the compressive strength does not follow an invariant pattern of proliferation or reduction, according to the numbers and table. In 28 days, all of the composites achieved the desired strength of 48.26 for cement of M53 grade.

Results of Flexural Strength

S. No.	Mix	W/C	Fle	xural strength (MPa)	
			7 Days	28Days	90 Days
1	m0	0.38	4.20	5.32	5.64
2	m1	0.38	4.31	5.60	5.67
3	m2	0.38	4.10	5.40	5.8
4	m3	0.38	4.12	5.38	5.62
5	m4	0.38	4.22	5.40	5.58

Two-point lading was used to test the dry shafts on a flexural testing equipment. Transverse bending test was used.

The variation of flexural strength at 7 and 28 days is estimated for a blockish sample under a cargo in a two-point bending configuration where the lading span was one-third of the support span.

Test Results for Sulphate Resistance

S. No.	Mix	Type Of Solution	Compressive Strength(MPa)		
			7 Days	28 Days	56 Days
1	m0	5% of $MgSO_4$	41.75	48.74	48.3
2	m1	5% of $MgSO_4$	41.79	49.05	49.23
3	m2	5% of $MgSO_4$	38.8	48.26	47.62
4	m3	5% of $MgSO_4$	41.8	45.6	49.03
5	m4	5% of $MgSO_4$	39.53	50.73	49.38

The impact of the sulphate result on the compressive strength of RCA concrete was examined in this study part. Following a typical 28-day curing period, concrete cells were maintained in magnesium sulphate for 7, 28, and 56 days. Cells' compressive strength was measured using CTM, which provides test results at a certain age in days. Details of the potential decrease in compressive strength at a given age of a given number of days are provided in the table.

6. Conclusions

1. The compressive strength of all composites exceeded at the age of 28 days. Compressive strength of control blend i.e. of m0 is50.05 MPa which is lesser than the target strength of48.25 for M40 concrete. Compressive strength of m1 is slightly increased to50.36. So the compressive strength increases by0.5. For m2, compressive strength is increased to50.20 MPa, it also showed an increase in compressive strength by0.3. Compressive strength of m3 is dropped to49.11 MPa that showed a drop in compressive strength by1.9. But in case of m4, there's unforeseen increase in compressive strength that raises the compressive strength to52.36 MPa. Compressive strength is increased by4.5. So the results of test show that compressive strength doesn't follow a regular trend from m0 to m4. But from the results it's also concluded that compressive strength no way went below the target strength for 28 days. This indicates that RCA can be used as relief summations for compressive strength.
2. Flexural strength also followed the same pattern as of compressive strength. Flexural strength of control blend is5.32 MPa at age of 28 days. Flexural strength of blend m1 increased to5.60 MPa. It shows that the increase in flexural strength is 5 for m1. For m2 flexural strength at age of 28 days is5.40 MPa, which shows an increase in flexural strength by1.5. Flexural strength of blend m3 is5.38 and the flexural strength increased by 1. For the blend m4, flexural strength is5.40 MPa. It shows that the flexural strength increased by1.5 at the age of 28 days. From the results and discussion of the results it's set up that the flexural strength of RCA concrete is similar to the natural total concrete which is a positive point. So the RCA concrete can be used for flexural strength by adjusting W/ C rate.
3. Use of 5 of MgSO4 result caused the reduction in compressive strength. Effect of sulphate result increased when volume of Crushed concrete total increase affected. So with increase in sulphate caused reduction in compressive strength of concrete.
4. It was set up that the RCA concrete have fairly lower bulk viscosity, specific graveness and high water immersion as compared to natural concrete. This was due to the presence of mortar in present on recycled coarse summations
5. In this study, trial castings were done to arrive at water content and asked plasticity. So it was judicious to carry out trial castings with Crushed concrete total proposed to be used in order to arrive at the water content and its proportion to match the plasticity situations and strengths conditions independently.
6. From this study it was observed that the persecuted concrete was feasible source for construction of concrete pavements. provident and environmental pressures justify felicity of RCA concrete as indispensable to the natural concrete. Where there's on-availability of natural total from new jewels RCA can be a good or feasible relief option for natural coarse total in pavement construction. From above conclusions it can be said that it's Eco-friendly and creative to use persecuted concrete in construction of concrete pavements.

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