

# Experimental Investigation on Recycled Concrete Aggregate with Bituminous Mixture

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**Abstract**—The construction industry generates a substantial amount of demolition waste every year, leading to environmental concerns and depletion of natural resources. Recycled Concrete Aggregate (RCA), obtained from crushed waste concrete, has emerged as a sustainable alternative to natural aggregates in pavement construction. This study investigates the performance of bituminous mixtures incorporating recycled concrete aggregate. Laboratory tests were conducted to determine the physical and mechanical properties of natural aggregates, recycled concrete aggregates, and VG-30 bitumen. Marshall Mix Design was employed to evaluate stability and flow characteristics of bituminous mixes containing varying percentages of RCA. Experimental results revealed that RCA satisfies the required standards for pavement construction and can effectively replace natural aggregates up to an optimum replacement level of 30%. The study concludes that RCA-based bituminous mixtures offer an environmentally friendly and economically viable solution for sustainable road construction.

**Index Terms**—Recycled Concrete Aggregate, Bituminous Mix, Marshall Stability, Flexible Pavement, Sustainable Construction, Road Engineering.

## I. INTRODUCTION

Rapid urbanization and infrastructure development have resulted in a significant increase in construction and demolition activities. Large quantities of concrete waste generated from demolished structures are often disposed of in landfills, causing environmental and economic challenges. Simultaneously, increasing demand for natural aggregates in road construction has led to depletion of natural resources.

Recycled Concrete Aggregate (RCA) is produced by crushing and processing demolished concrete structures. The use of RCA in pavement construction

reduces the consumption of virgin aggregates and minimizes waste disposal problems. RCA possesses a rough surface texture due to attached mortar, which influences the performance of bituminous mixtures.

The present investigation evaluates the suitability of recycled concrete aggregate in asphalt pavement construction using Marshall Mix Design methodology. The study focuses on aggregate characterization, bitumen properties, and performance evaluation of RCA-modified asphalt mixtures.

## II. OBJECTIVES OF THE STUDY

The objectives of the study are:

1. To determine the engineering properties of recycled concrete aggregate.
2. To compare the properties of RCA and natural aggregates.
3. To evaluate the performance of bituminous mixes containing RCA.
4. To determine the optimum percentage of RCA replacement.
5. To assess the feasibility of RCA for pavement construction.
6. To promote sustainable utilization of construction and demolition waste.

## III. MATERIALS USED

### 3.1. Fine Aggregates

Fine aggregates consist of particles passing through a 4.75 mm sieve and are used to fill voids between coarse aggregate particles. Fine aggregates improve workability, density, and stability of bituminous mixes.

### 3.2. Coarse Aggregates

Coarse aggregates provide structural strength and load-carrying capacity to pavement layers. The quality of coarse aggregates significantly affects pavement durability and performance.

### 3.3. Recycled Concrete Aggregate

Recycled concrete aggregate is obtained by crushing demolished concrete structures. RCA contains residual mortar attached to aggregate particles, resulting in higher porosity and water absorption compared to natural aggregates.

#### Advantages of RCA

- Reduction in construction waste.
- Conservation of natural resources.
- Cost savings.
- Sustainable construction practices.
- Reduced landfill requirements.

### 3.4. Bitumen

VG-30 grade bitumen was used for preparing bituminous mixtures. VG-30 is widely used in India for heavy-duty pavements due to its desirable viscosity and durability characteristics.

## IV. EXPERIMENTAL PROGRAMME

The experimental programme consisted of:

1. Aggregate property tests.
2. Bitumen property tests.
3. Marshall Mix Design.
4. Preparation of RCA-modified asphalt specimens.
5. Marshall Stability and Flow analysis.

## V. AGGREGATE TESTING

Aggregate properties were evaluated according to IS 2386 standards.

### 5.1. Aggregate Crushing Value Test

The aggregate crushing value indicates resistance to compressive loads. Lower values represent stronger aggregates suitable for pavement applications.

### 5.2. Los Angeles Abrasion Test

The abrasion test determines resistance to wear and surface deterioration caused by traffic movement.

### 5.3. Aggregate Impact Test

The impact test measures aggregate toughness and resistance to sudden shocks.

### 5.4. Shape Test

Flakiness and elongation characteristics were determined to evaluate particle shape.

### 5.5. Water Absorption Test

Water absorption indicates aggregate porosity and influences binder demand and pavement durability.

## VI. AGGREGATE TEST RESULTS

Property	Natural Aggregate	RCA
Crushing Value (%)	19.07	23.16
Abrasion Value (%)	16.92	19.16
Impact Value (%)	14.37	23.31
Shape Test (%)	33.2	32.3
Water Absorption (%)	1.01	2.53

All test results were within the permissible limits specified by IS standards, indicating the suitability of RCA for pavement applications.

## VII. BITUMEN TESTING

VG-30 grade bitumen was evaluated through standard laboratory tests.

### Softening Point Test

The softening point determines the temperature at which bitumen attains a specified degree of softening.

### Penetration Test

The penetration test measures bitumen consistency and grading characteristics.

### Flash and Fire Point Test

These tests determine the safety limits of bitumen during heating and mixing operations.

### Ductility Test

Ductility measures the elongation capacity of bitumen before rupture and indicates adhesive properties.

VIII. BITUMEN TEST RESULTS

Test	Result
Ductility	63 cm
Softening Point	49.7°C
Penetration	62.3
Flash Point	210°C
Fire Point	240°C

The obtained values satisfied the requirements of VG-30 grade bitumen.

IX. MARSHALL MIX DESIGN

Marshall Mix Design was used to determine optimum bitumen content and evaluate the performance of asphalt mixtures.

Design Criteria

- Marshall Stability  $\geq$  900 kg
- Flow Value = 2–4 mm
- Air Voids = 3–6%
- Voids Filled with Bitumen = 65–75%

Procedure

1. Selection of aggregate gradation.
2. Preparation of trial mixes.
3. Compaction of specimens.
4. Determination of density and void characteristics.
5. Stability and flow measurements.
6. Determination of optimum binder content.

X. PREPARATION OF RCA MODIFIED MIXES

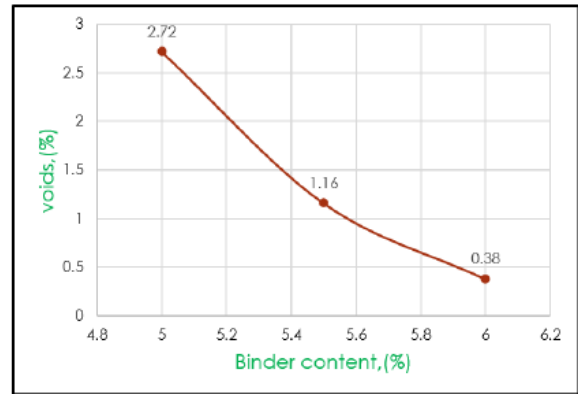


Sample

Natural aggregates were replaced with RCA at different percentages:

- 10%
- 20%
- 30%

The Marshall procedure was repeated for each replacement level to evaluate performance characteristics.



XI. RESULTS AND DISCUSSION

The Marshall Stability values increased with increasing RCA content up to 30%. The rough surface texture of RCA improved interlocking between aggregate particles and contributed to higher stability values.

Beyond 30% replacement, the increase in porosity and water absorption of RCA negatively influenced mix performance. Therefore, 30% RCA replacement was identified as the optimum level.

The optimum bitumen content was found to be 5.5%, satisfying all Marshall design requirements.

XII. ENVIRONMENTAL IMPACT

Use of RCA provides several environmental benefits:

- Reduction of landfill waste.
- Conservation of natural aggregates.
- Lower energy consumption.
- Reduction in greenhouse gas emissions.
- Promotion of sustainable construction practices.

XIII. ECONOMIC ANALYSIS

The use of RCA reduces the cost associated with:

- Aggregate procurement.

- Waste transportation.
- Landfill disposal.
- Quarrying operations.

Consequently, RCA contributes to more economical pavement construction.

#### XIV. FUTURE SCOPE

1. Investigation of higher replacement percentages.
2. Long-term field performance studies.
3. Use of treated RCA.
4. Evaluation of fatigue and rutting resistance.
5. Incorporation of polymer-modified binders.
6. Life-cycle cost assessment.

#### XV. CONCLUSION

1. Recycled concrete aggregate satisfies the engineering requirements for pavement construction.
2. Aggregate and bitumen properties were within IS code limits.
3. Marshall Mix Design successfully evaluated the performance of RCA mixtures.
4. Stability values improved up to 30% RCA replacement.
5. Optimum bitumen content was found to be 5.5%.
6. Optimum RCA content was found to be 30%.
7. RCA can partially replace natural aggregates without significant performance loss.
8. Utilization of RCA promotes sustainable and economical road construction.
9. The use of recycled materials supports environmental conservation and circular economy principles.

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