



EXPERIMENTAL INVESTIGATION ON CONCRETE WITH PARTIAL REPLACEMENT OF FINE AGGREGATES AND COARSE AGGREGATES BY RECLAIMED ASPHALT PAVEMENT (RAP)

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Abstract : The increasing demand for natural aggregates in concrete production has resulted in significant environmental concerns, including resource depletion and ecological imbalance due to continuous quarrying activities. At the same time, large volumes of Reclaimed Asphalt Pavement (RAP) are generated from road maintenance and resurfacing operations, posing disposal and sustainability challenges. The effective utilization of RAP in concrete can contribute to sustainable construction practices by reducing dependence on natural aggregates and promoting the reuse of waste materials. This study presents an experimental investigation on the use of RAP as a partial replacement for both fine and coarse aggregates in concrete. Concrete cube specimens were prepared with replacement levels of 5%, 10%, and 15%, along with a conventional control mix. The specimens were cured for 7, 14, and 28 days under standard laboratory conditions. The mechanical performance of the concrete was evaluated through compressive strength testing using a Compression Testing Machine (CTM). The research primarily focuses on assessing the feasibility and performance characteristics of RAP-incorporated concrete. The study aims to determine the suitability of RAP as an alternative aggregate material in concrete production and to examine its potential contribution toward sustainable and environmentally responsible construction practices.

IndexTerms - Reclaimed Asphalt Pavement (RAP), Partial Replacement, Compressive Strength, Sustainable Construction, Aggregate Substitution.

I. INTRODUCTION

Concrete remains the most extensively used construction material worldwide due to its versatility, durability, and cost-effectiveness. As urbanization and infrastructure development continue to accelerate, the demand for concrete has increased significantly, placing immense pressure on natural resources—particularly fine and coarse aggregates, which constitute nearly 70–75% of the total concrete volume. Excessive extraction of river sand and crushed stone has led to environmental degradation, including riverbank erosion, loss of biodiversity, groundwater depletion, and alteration of natural landscapes. These challenges highlight the urgent need to explore alternative, sustainable materials that can partially or fully substitute natural aggregates without compromising the structural performance of concrete.

Reclaimed Asphalt Pavement (RAP) has emerged as a promising alternative material in this context. RAP is obtained from the milling, removal, and recycling of existing asphalt layers during road maintenance, rehabilitation, and reconstruction activities. It consists of a mixture of well-graded aggregates bonded with aged bitumen. Owing to its mineral composition and availability in large quantities, RAP offers potential benefits when used as a replacement for conventional aggregates in concrete. Utilizing RAP not only reduces the burden on landfills but also contributes to circular economy practices in the construction industry by reintroducing waste materials into new infrastructure applications.

Previous studies indicate that the presence of aged bitumen in RAP can influence the workability, density, and mechanical performance of concrete. While small proportions of RAP may not significantly deteriorate concrete strength, higher replacement levels often lead to reductions in compressive strength due to the weaker bond between cement paste and bitumen-coated particles. Nonetheless, RAP can enhance sustainability by lowering environmental impact, reducing the extraction of virgin aggregates, and minimizing construction waste. The challenge lies in identifying an optimum replacement level that balances mechanical performance with sustainable resource utilization.

This study focuses on evaluating the feasibility of incorporating RAP into M25 grade concrete as a partial replacement for natural fine and coarse aggregates. Controlled experimental testing is conducted to assess key parameters such as workability and

compressive strength at varying replacement levels. The objective is to determine a replacement percentage that yields acceptable structural performance while promoting environmentally responsible construction practices. The findings of this research are expected to contribute valuable insights into the sustainable use of RAP in concrete and support future initiatives aimed at resource conservation and waste reduction in the construction sector.

II. LITERATURE REVIEW

Huang et al. (2005) conducted a detailed investigation on the utilization of Reclaimed Asphalt Pavement (RAP) in concrete as a partial replacement for natural aggregates. The study focused on evaluating the mechanical properties, particularly compressive strength. It was observed that the presence of aged bituminous binder in RAP reduces the bonding between cement paste and aggregates. A gradual decrease in compressive strength was reported with an increase in RAP content. However, at lower replacement levels, the strength remained within acceptable limits. The study also highlighted that RAP improves flexibility and energy absorption capacity. Proper processing and gradation were recommended for better performance. The authors concluded that RAP can be used in non-structural concrete applications.

Kumar et al. (2007) investigated RAP as a partial replacement for coarse aggregates in concrete. The study involved testing fresh and hardened properties of concrete mixes. It was observed that workability decreases slightly due to the presence of bitumen-coated aggregates. Compressive strength also reduced with higher RAP content. However, acceptable strength was achieved at optimum replacement levels. The study emphasized proper mix proportioning and water-cement ratio control. RAP was found to contribute to cost reduction and sustainability. The authors concluded that RAP can be effectively used with controlled replacement.

Gopi et al. (2008) studied RAP as a replacement for fine aggregates in concrete. The research focused on workability and compressive strength characteristics. It was observed that RAP increases water demand and slightly reduces workability. The compressive strength showed a marginal decrease with increasing RAP content. However, acceptable performance was obtained at lower replacement levels. The study recommended proper grading of RAP material. It concluded that RAP can be used as a sustainable alternative for fine aggregates.

Sharma et al. (2009) carried out an experimental study on RAP incorporation in concrete for both fine and coarse aggregate replacement. The study evaluated workability, compressive strength, and durability aspects. It was found that RAP reduces workability due to the presence of bituminous coating. The compressive strength decreased with increasing RAP content, but remained within acceptable limits at optimum levels. The study emphasized the importance of determining the optimum replacement percentage. It also highlighted the environmental benefits of RAP usage. The authors concluded that RAP can be used effectively with proper mix design.

Singh et al. (2010) examined the influence of RAP on compressive strength and durability of concrete. The study reported a gradual decrease in strength with increasing RAP percentage. However, lower replacement levels provided satisfactory results. RAP was found to improve the ductility and energy absorption capacity of concrete. The study recommended limiting RAP content for structural applications.

Rao et al. (2011) investigated the effect of RAP gradation on concrete properties. It was observed that properly processed RAP improves compaction and workability characteristics. The compressive strength decreased at higher RAP content. The study emphasized the need for proper crushing and screening of RAP materials. It concluded that RAP can be used with adequate quality control.

Patel et al. (2012) studied RAP in concrete for non-structural applications. The results showed a reduction in compressive strength due to weak bonding. However, the strength was sufficient for low-load applications. The study highlighted cost savings and environmental benefits. It concluded that RAP is suitable for economical construction.

Narasimhan et al. (2013) evaluated alternative materials including RAP in concrete. The study emphasized sustainability and resource conservation. It was observed that RAP reduces environmental impact. The compressive strength was slightly lower than conventional concrete. The study recommended controlled replacement levels.

Verma et al. (2014) investigated the thermal and mechanical properties of RAP concrete. It was observed that RAP reduces density and improves thermal insulation. However, compressive strength decreased with higher RAP content. The study concluded that RAP is suitable for lightweight and non-structural applications.

Reddy et al. (2015) studied the bonding characteristics of RAP aggregates in concrete. It was found that bitumen coating reduces adhesion between cement paste and aggregates. This resulted in lower compressive strength. The study recommended surface treatment of RAP for better bonding. It concluded that RAP requires proper processing before use.

Mehta et al. (2016) emphasized the role of RAP in sustainable construction. The study highlighted reduction in natural resource consumption. RAP was found to be beneficial in reducing construction costs. The authors concluded that RAP promotes eco-friendly construction practices.

Chavan et al. (2017) conducted an experimental study on RAP concrete. The results showed that optimum replacement levels maintain acceptable strength. Workability was slightly affected by RAP inclusion. The study recommended proper mix design adjustments. It concluded that RAP can be used effectively in concrete.

Gupta et al. (2018) analyzed the workability and compaction characteristics of RAP concrete. It was observed that RAP reduces workability due to its surface texture. Proper water adjustment improved performance. The study concluded that RAP requires careful mix proportioning.

Karthik et al. (2019) studied RAP as a replacement for both fine and coarse aggregates. The study showed that RAP can be used effectively with proper mix design. Compressive strength decreased at higher replacement levels. The study recommended optimum replacement percentage for best results.

Srinivas et al. (2020) evaluated the modulus of elasticity of RAP concrete. It was observed that RAP reduces stiffness compared to conventional concrete. However, the performance was acceptable for certain applications. The study concluded that RAP can be used in flexible concrete structures.

Bansal et al. (2020) studied RAP concrete for low-load applications. The results indicated that RAP reduces strength but remains suitable for non-structural use. The study highlighted economic benefits. It concluded that RAP is a viable alternative material.

Joshi et al. (2021) focused on environmental benefits of RAP usage. The study reported reduction in construction waste and conservation of resources. RAP was found to improve sustainability index. The authors concluded that RAP is beneficial for eco-friendly construction.

Desai et al. (2022) investigated durability aspects of RAP concrete. It was observed that durability depends on replacement levels. Higher RAP content reduced resistance to environmental exposure. The study recommended optimum usage. It concluded that RAP can be used with proper design considerations.

Agarwal et al. (2023) studied the economic and sustainability aspects of RAP concrete. The study reported significant cost savings and reduced environmental impact. RAP was found to enhance sustainable construction practices. The authors concluded that RAP has high potential in modern concrete technology.

III. EXPERIMENTATION

Experimental investigations were carried out to evaluate the properties of cement, fine aggregates, and coarse aggregates in accordance with relevant IS code provisions. Standard laboratory tests were performed to determine the physical and mechanical characteristics required for concrete mix design.

Tests on cement included determination of normal consistency using the Vicat apparatus, where the required water content was identified based on standard penetration criteria. Initial and final setting times were evaluated to assess the hydration characteristics of cement. Soundness of cement was determined using the Le-Chatelier method to measure volumetric stability, and specific gravity was evaluated using a Le-Chatelier flask.

Fine aggregates were tested for specific gravity using a pycnometer method and for grading characteristics through sieve analysis. The fineness modulus was calculated to understand particle size distribution and its influence on workability and strength.

Coarse aggregates were subjected to mechanical and physical tests including aggregate crushing value to assess strength, and flakiness and elongation index tests to evaluate shape characteristics. Specific gravity was determined under saturated surface dry conditions, and sieve analysis was carried out to determine grading and fineness modulus.

All tests were conducted following standard procedures to ensure accuracy and reliability of results, which were further used in the design and preparation of concrete mixes incorporating Reclaimed Asphalt Pavement (RAP).

IV. MIX DESIGN

Final mix proportions

Cement	=	383.16 kg/m ³
Coarse aggregate	=	1125.618377 kg/m ³
Fine aggregate	=	675.5494888 kg/m ³
Water	=	191.58 kg/m ³

Dimensions of Cube:

150mm × 150mm × 150mm:	$0.15 \times 0.15 \times 0.15 = 0.003375\text{m}^3$
Cement	$= 383.16 \times 0.003375 = 1.293165\text{ kgs}$
Coarse Aggregate	$= 1125.618377 \times 0.003375 = 3.798962022\text{ kgs}$
Fine Aggregate	$= 675.5494888 \times 0.003375 = 2.0279979525\text{ kgs}$
Water	$= 191.58 \times 0.003375 = 0.64565825\text{ lit}$
Replacement of C.A	$= 3.798962022 \times 5\% = 0.189948101\text{ kgs}$
Replacement of F.A	$= 2.279979525 \times 5\% = 0.11399897625\text{ kgs}$
Replacement of C.A	$= 3.798962022 \times 10\% = 0.3798962022\text{ kgs}$
Replacement of F.A	$= 2.279979525 \times 10\% = 0.2279979525\text{ kgs}$

Replacement of C.A = $3.798962022 \times 15\% = 0.5698443033\text{kgs}$
 Replacement of F.A = $2.279979525 \times 15\% = 0.34199692875\text{kgs}$

V. METHODOLOGY

The methodology adopted in this study includes batching, testing of fresh concrete, casting, curing, and strength evaluation of both conventional and replacement concretes. Batching of materials was carried out by weight to ensure accuracy in mix proportions. Workability of fresh concrete was assessed using slump cone, compaction factor, and Vee-Bee tests. Concrete cubes of size 150 mm × 150 mm × 150 mm were cast in three layers with proper compaction, followed by 24-hour setting and curing in water for 7, 14, and 28 days. Curing ensured adequate hydration and strength development. Hardened concrete tests were performed using a Compression Testing Machine (CTM) to determine the compressive strength of both traditional and replacement concrete mixes, and the results were compared to evaluate performance variations.

VI. RESULTS AND DISCUSSION

6.1 MATERIAL TEST RESULTS

The results of various laboratory tests conducted on cement, fine aggregate, and coarse aggregate to determine their physical properties are summarized in the following tables.

Table 6.1: Cement Test Results

S. No	Test Conducted	Result
1	Normal Consistency	32%
2	Initial Setting Time	30 minutes
3	Final Setting Time	600 minutes
4	Soundness (Le-Chatelier)	2 mm
5	Specific Gravity	3.14

Table 6.2: Fine Aggregate Test Results

S. No	Test Conducted	Result
1	Specific Gravity	2.59
2	Fineness Modulus	2.65

Table 6.3: Coarse Aggregate Test Results

S. No	Test Conducted	Result
1	Aggregate Crushing Value	25%
2	Flakiness Index	15%
3	Elongation Index	20%
4	Specific Gravity	2.64
5	Fineness Modulus	6.8

6.2 HARDENED CONCRETE TEST RESULTS

A detailed comparison of compressive strength development for traditional and replacement concrete mixes is provided in the following tables for 7, 14, and 28 days.

Table 6.4: Compressive Strength of Traditional Concrete

Age of Concrete	Failure Load (kN)	Compressive Strength (N/mm ²)
7 Days	425	18.89
14 Days	475	21.11
28 Days	650	28.88

Table 6.5: Compressive Strength of Replacement Concrete (5% Replacement)

Age of Concrete	Failure Load (kN)	Compressive Strength (N/mm ²)
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7 Days	450	20
14 Days	540	24
28 Days	610	27.11

Table 6.6: Compressive Strength of Replacement Concrete (10% Replacement)

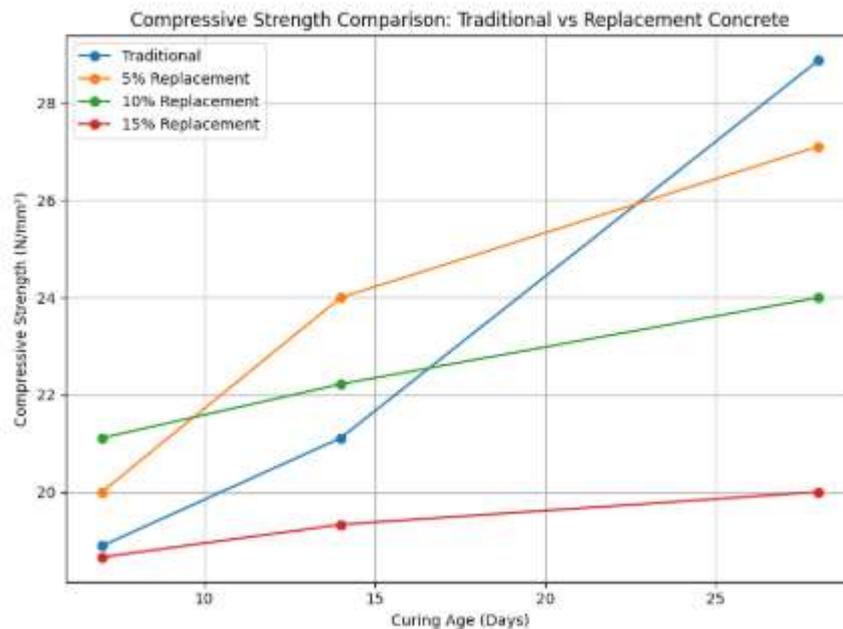
Age of Concrete	Failure Load (kN)	Compressive Strength (N/mm ²)
7 Days	475	21.11
14 Days	500	22.22
28 Days	540	24

Table 6.7: Compressive Strength of Replacement Concrete (15% Replacement)

Age of Concrete	Failure Load (kN)	Compressive Strength (N/mm ²)
7 Days	420	18.66
14 Days	435	19.33
28 Days	450	20

Table 6.8: Comparative Compressive Strength Results of Traditional and Replacement Concrete

Age	Traditional Concrete (N/mm ²)	5% Replacement (N/mm ²)	10% Replacement (N/mm ²)	15% Replacement (N/mm ²)
7 Days	18.89	20	21.11	18.66
14 Days	21.11	24	22.22	19.33
28 Days	28.88	27.11	24	20



VII. CONCLUSIONS AND FUTURE SCOPE

7.1 Conclusions

The effect of partial replacement of fine aggregates and coarse aggregates by Reclaimed Asphalt Pavement (RAP) on the compressive strength of concrete was evaluated and compared with the reference mix (0% replacement).

- The compressive strength of conventional concrete was found to be 18.89 MPa, 21.11 MPa, and 28.88 MPa at 7, 14, and 28 days respectively.
- The compressive strength of concrete with 5% RAP replacement was observed as 20 MPa, 24 MPa, and 27 MPa, indicating improved early-age strength and comparable 28-day strength with conventional concrete.
- The compressive strength of concrete with 10% RAP replacement was found to be 21.11 MPa, 22.22 MPa, and 24 MPa, showing moderate performance with slight reduction in later age strength.
- The compressive strength of concrete with 15% RAP replacement was observed as 18.66 MPa, 19.33 MPa, and 20 MPa, indicating a significant reduction in strength compared to conventional concrete.
- The decrease in strength at higher RAP content is attributed to weaker bonding and presence of bituminous coating on RAP aggregates, which affects the interfacial transition zone.
- It is concluded that RAP can be effectively used up to 5%–10% replacement level without significant loss in compressive strength.
- The use of RAP contributes to sustainable construction practices by reducing the consumption of natural aggregates.

7.2 Future Scope

- Since strength reduction is observed at 15% RAP, future work should focus on identifying the exact limiting replacement percentage through finer intervals rather than broad values.
- The influence of bitumen-coated RAP surface on bond strength needs to be studied in detail, as it is the primary reason for reduced strength at higher replacement levels.
- Modification of RAP usage by combining RAP separately in fine and coarse fractions can be investigated instead of replacing both simultaneously.
- The effect of RAP on early-age vs later-age strength gain pattern should be analyzed to understand hydration and strength development behavior.
- Experimental validation can be extended by testing real structural conditions (load behavior, cracking pattern) rather than only cube strength.

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