Eco-Friendly Road Construction Practices Using Recycled Materials

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Introduction
Civil engineering is increasingly adopting recyclable materials to promote sustainability and reduce environmental impact. A key challenge is reusing waste materials without compromising the performance of construction products. Among the bulk abandoned resources, recycled coarse aggregates (RCA) and recovered polymers present significant potential for repurposing in road construction. The primary objectives of this study are to minimize environmental harm and reduce costs by incorporating recycled polymers as partial bitumen replacements and RCA in varying proportions. This research evaluates the feasibility and optimal mix design for sustainable road construction using these materials.

Materials and methods
The study involved twelve batches of bituminous samples, with three replicates per batch to ensure repeatability. The first batch served as the control, containing no RCA or recycled polymer. The second batch replaced 15% of the bitumen with recycled polymer while retaining natural coarse aggregates. Batches 3 to 12 incorporated 15% polymer-modified bitumen along with RCA replacing natural coarse aggregates in increments of 10% (from 10% to 100%). Standardized testing methods were employed to assess material properties and performance and these include: Sieve analysis used to determine aggregate gradation; Impact test and Los Angeles abrasion test used to evaluate RCA durability; Penetration test used to measure bitumen hardness; and Marshall Stability test used to assess the strength and workability of asphalt mixes.

Results and discussion
The Sieve analysis revealed a fineness modulus (FM) of 4% for RCA, indicating a uniform gradation. The Specific gravity of RCA was 2.61, classifying it as coarse-grained soil while the Impact test results showed 9.3% aggregate toughness, well below the 30% regulatory limit for road construction. The Los Angeles abrasion test recorded 19.07%, confirming acceptable wear resistance. Whereas the Penetration test for 15% polymer-modified bitumen averaged 58 mm, compared to 63.7 mm for conventional bitumen, indicating improved stiffness and Marshall Stability test demonstrated that Batch 5 (15% polymer-modified bitumen + 80% RCA) provided the best performance, enhancing stability, flow, and density. These findings suggest that RCA and recycled polymers can be effectively utilized in road construction without compromising structural integrity.

Conclusion
This study confirms that incorporating recycled polymers (15% bitumen replacement) and RCA (up to 80% coarse aggregate replacement) improves asphalt mix performance while supporting sustainability. The optimal mix (Batch 5) enhances mechanical properties, reduces environmental impact, and lowers material costs. Future research could explore long-term durability and field performance of these recycled materials in real-world road applications.

Keywords: Recycled Coarse Aggregate, Recycled Polymers, Bitumen,