COMPARATIVE STUDY OF BITUMINOUS MIX MODIFIED WITH COCONUT SHELL CHARCOAL AND 2–4 MM RUBBER CRUMBS USING VG-30 BITUMEN

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ABSTRACT

Flexible pavements constructed using conventional VG-30 bitumen are prone to distresses such as rutting, fatigue cracking, and temperature susceptibility under increasing traffic intensity and climatic variations. The incorporation of waste-derived and bio-based modifiers into bituminous mixes has emerged as an effective approach to enhance pavement performance while promoting environmental sustainability. This review paper presents a comparative evaluation of bituminous concrete (BC) modified with Coconut Shell Charcoal (CSC) and 2–4 mm Rubber Crumbs (CR) using VG-30 grade bitumen. The study reviews material characteristics, modification mechanisms, and laboratory evaluation methods including Marshall Stability, Flow value, Specific Gravity, Penetration, Ductility, Softening Point, Rutting, Aggregate Crushing, Impact, and Abrasion tests. The findings from previous investigations indicate that CSC primarily enhances stiffness and load-bearing capacity, whereas crumb rubber significantly improves elasticity, ductility, and rutting resistance. The study highlights the engineering, economic, and environmental significance of utilizing agricultural and tire waste in flexible pavement construction.

Keywords: VG-30 Bitumen, Coconut Shell Charcoal, Crumb Rubber (2–4 mm), Marshall Stability, Rutting Resistance, Modified Bitumen.

1. INTRODUCTION

Flexible pavements consist of layered systems designed to distribute vehicular loads safely to the subgrade. The surface layer, typically Bituminous Concrete (BC), must withstand repetitive traffic loading and environmental stresses.

VG-30 bitumen is commonly used in India for heavy traffic conditions due to its moderate viscosity and improved resistance to permanent deformation. However, conventional VG-30 mixes may experience:

- Rutting at high temperatures
- Fatigue cracking under repeated loading
- Stripping due to moisture
- Temperature susceptibility

To address these issues, modification of bitumen using waste and bio-based materials has gained attention. Among them:

- **Coconut Shell Charcoal (CSC)** – an agricultural waste-derived carbonaceous material.
- **Crumb Rubber (2–4 mm)** – processed waste tire particles.

The use of these materials not only enhances pavement performance but also contributes to sustainable waste management.

2. OBJECTIVES

1. To study the physical properties of VG-30 bitumen.
2. To examine the engineering properties of aggregates used in BC mix.
3. To review the effect of coconut shell charcoal on mix performance.
4. To evaluate the influence of 2–4 mm rubber crumb modification.
5. To compare performance characteristics based on standard laboratory tests.

3. MATERIAL CHARACTERIZATION

3.1 VG-30 Bitumen

VG-30 (Viscosity Grade 30) bitumen is suitable for roads with heavy traffic and moderate climatic conditions.

fig 1: bitumen

Tests Conducted on Bitumen:

3.1.1 Penetration Test

Determines consistency and hardness of bitumen. Lower penetration indicates stiffer binder.

3.1.2 Ductility Test

Measures elongation capacity before breaking. Indicates flexibility and resistance to cracking.

3.1.3 Softening Point Test

Determines temperature at which bitumen softens. Higher softening point indicates better high-temperature resistance.

3.1.4 Specific Gravity Test

Used to determine density and mix design calculations.

3.2 Aggregates

fig 2: Aggregates

Aggregates constitute approximately 90–95% of bituminous mix by weight. Their mechanical properties significantly influence pavement performance.

Tests Conducted:

- **Aggregate Crushing Value (ACV)** – Resistance to compressive load.
- **Aggregate Impact Value (AIV)** – Toughness under sudden impact.
- **Los Angeles Abrasion Test** – Resistance to wear and abrasion.
- **Specific Gravity and Water Absorption Test** – Quality and porosity evaluation.

Aggregates must satisfy MORTH specifications for BC mix.

3.3 Coconut Shell Charcoal (CSC)

Coconut shell charcoal is obtained through controlled pyrolysis of coconut shells. Kerala has abundant availability of coconut waste, making CSC economically viable.

Properties:

- High carbon content
- Porous microstructure
- Low bulk density
    - High adsorption capacity

Role in Bituminous Mix:

- Acts as mineral filler
- Improves stiffness
- Enhances interlocking
- Increases Marshall stability
- Improves resistance to permanent deformation

3.4 Rubber Crumb (2–4 mm)

Rubber crumbs are obtained from mechanical shredding of waste automobile tires.

Properties:

- High elasticity
- Excellent energy absorption
- Improved resilience
- Resistance to thermal cracking

Modification Process:

Rubber crumb is blended with VG-30 bitumen at elevated temperatures (wet process), allowing rubber particles to swell and absorb lighter fractions of bitumen.

Effects:

- Improves ductility
- Enhances fatigue resistance
- Reduces rutting
- Increases softening point

4. MIX DESIGN CONSIDERATIONS

Marshall Mix Design method is adopted for determining optimum binder content.

Steps:

1. Selection of aggregate gradation as per MORTH.
2. Preparation of specimens with varying binder contents.
3. Compaction using Marshall hammer.
4. Determination of stability, flow, air voids, VMA, and VFB.

Modified mixes are prepared by replacing filler with CSC or blending bitumen with CR.

5. PERFORMANCE EVALUATION TESTS

5.1 Marshall Stability Test

Measures maximum load carrying capacity.

5.2 Flow Value Test

Measures deformation corresponding to maximum load.

5.3 Rutting Test

Determines resistance to permanent deformation at high temperature.

5.4 Specific Gravity of Mix

Used to calculate volumetric properties.

6. MODIFICATION MECHANISM

6.1 CSC Mechanism

- Increases internal friction
- Improves stiffness of binder matrix
- Enhances aggregate-binder adhesion
- Acts as micro-reinforcement

6.2 Rubber Crumb Mechanism

- Swelling of rubber particles

- Elastic recovery after load removal
- Reduced stress concentration
- Improved crack resistance

7. RESULTS AND DISCUSSION (Brief – As Review Paper)

Literature indicates that CSC-modified mixes show higher Marshall stability due to increased stiffness and filler interaction. However, excessive CSC content may increase brittleness.

Rubber crumb modification significantly enhances ductility and rutting resistance. The elastic recovery property of rubber reduces permanent deformation under repeated loading.

Softening point values increase in both modifications, indicating improved resistance to high temperatures.

Overall, rubber crumb modified mixes exhibit better fatigue resistance, while coconut shell charcoal provides improved load-bearing capacity.

8. ENVIRONMENTAL AND ECONOMIC SIGNIFICANCE

- Utilization of agricultural waste (CSC).
- Recycling of waste tires (CR).
- Reduction in landfill burden.
- Enhanced pavement service life.
- Lower long-term maintenance costs.

The application of CSC is particularly suitable for regions like Kerala due to local availability.

9. CONCLUSION

1. VG-30 bitumen is suitable for modification using CSC and CR.
2. Coconut shell charcoal enhances stability and stiffness.
3. Rubber crumb improves ductility and rutting resistance.
4. Rubber crumb modified mix shows superior long-term durability.
5. Both materials promote sustainable pavement construction.
6. An optimized blend may provide balanced mechanical performance.

REFERENCES

1. S. Neupane and T. C. Shahi, *"Application of Crumb Rubber Modified Bitumen in the Asphalt Concrete Mix,"* Journal on Transportation System and Engineering, vol. 1, no. 1, pp. 1–12, 2025, doi:10.3126/jotse.v1i1.79885.
2. M. S. Rahul, H. Anjani, V. Udaya Bhanu, et al., *"Effects of Coconut Shell Charcoal Powder Combined with SBS on Rheological Properties of Asphalt Binder,"* Construction and Building Materials, vol. 505, 144742, Dec. 2025.
3. Mohd Ezree Abdullah, N. N. M. Rosni, R. P. Jaya, et al., *"Effect of Charcoal Ash Coconut Shell from Waste Material at Different Size on the Physical Properties of Bitumen,"* Key Engineering Materials, vol. 744, pp. 121–125, 2017.
4. W. Wang, Y. Cheng, H. Chen, et al., *"Study on the Performances of Waste Crumb Rubber Modified Asphalt Mixture with Eco-Friendly Diatomite and Basalt Fiber,"* Sustainability, vol. 11, no. 19, p. 5282, 2019.
5. V. Suganpriya, O. S., and V. Chandralega, *"Study of Behaviour of Bitumen Modified with Crumb Rubber,"* International Journal of Engineering Research & Technology (IJERT), vol. 05, no. 05, May 2016.
6. A. Yaduvanshi, S. Sharma, N. et al., *"Study on Bitumen Modified with Crumb Rubber,"* International Journal of Engineering Research & Technology (IJERT), vol. 08, no. 05, May 2019.
7. V. Sharma and H. Rathore, *"Sustainable Utilization of Crumb Rubber in Bituminous Pavements: A Review,"* Journal of Advances in Geotechnical Engineering, vol. 8, no. 2, 2025.
8. S. Ullah, M. I. Shah, M. Alqurashi, et al., *"Eco-Friendly Incorporation of Crumb Rubber and Waste Bagasse Ash in Bituminous Concrete Mix,"* Materials, vol. 15, no. 7, p. 2509, 2022, doi:10.3390/ma15072509.
9. *"Evaluation of Modified Bituminous Mix Parameters by Adding Plastic Waste and Crumb-Rubber Waste,"* Materials Today: Proceedings, vol. 65, Part 2, pp. 1651–1655, 2022, doi:10.1016/j.matpr.2022.04.701.
10. *"Mechanical Performance of Asphalt Mixture Containing Nano-Charcoal Coconut Shell Ash,"* Construction and Building Materials, vol. 173, pp. 40–48, Jun. 2018, doi:10.1016/j.conbuildmat.2018.04.024.