

# Comparative Analysis of Conventional and Waste Tyre Rubber Modified Bitumen for Flexible Pavement Applications

Ankita Patel<sup>1</sup> Diksha Hirkane<sup>2</sup> Jahanvi Yadav<sup>3</sup> Priyanka Verma<sup>4</sup>

<sup>1,2,3</sup>Reserch Scholar <sup>4</sup>Assistant Professor

<sup>1,2,3,4</sup>Department of Civil Engineering

<sup>1,2,3,4</sup>Bhilai Institute of Technology, Durg (CG), Affiliated to CSVTU, Bhilai, India

**Abstract** — These instructions give you basic guidelines for preparing your journal quality paper for the Conference Proceedings. Rapid industrialization and large-scale infrastructure development have led to increasing scarcity of construction materials and serious environmental concerns related to waste disposal. This study investigates the feasibility of utilizing waste tyre crumb rubber as a modifier in VG-30 grade bitumen for flexible pavement construction. Crumb rubber obtained from waste tyres was blended with bitumen at 10% by weight, and the modified binder was evaluated through four standard tests: penetration, softening point, ductility, and viscosity, per relevant IS standards. Results indicate that Crumb Rubber Modified Bitumen (CRMB) reduces penetration from 61.8 to 56.3 (0.1 mm), increases softening point from 58.75°C to 62.25°C, decreases ductility from 82 to 61 cm, and substantially increases viscosity from 55.27 to 141.0 seconds. These findings confirm that CRMB offers improved stiffness, better high-temperature resistance, and superior rutting resistance, making it a promising, sustainable, and cost-effective material for road construction in India.

**Keywords:** Crumb Rubber Modified Bitumen (CRMB); VG-30 Bitumen; Penetration; Softening Point; Ductility; Viscosity; Flexible Pavement; Sustainable Pavement Engineering

## I. INTRODUCTION

Rapid industrialization and large-scale infrastructural development in India have resulted in huge scarcity of construction materials and growing disposal issues associated with waste products [1]. Traditionally, soil, stone, aggregates, sand, bitumen, and cement are used for road construction. Natural materials are exhaustible, their quality is declining, and extraction costs are rising. Scientists are therefore exploring alternative materials, particularly waste-derived ones, for road construction [2].

Bitumen, a black, sticky, highly viscous material obtained from distillation of crude oil, is widely used as a binder in flexible pavement construction due to its excellent adhesive and waterproofing properties. Critical properties include viscosity, penetration, ductility, and softening point, which determine bitumen behavior under different temperature and loading conditions [3].

Conventional bitumen has several limitations under present-day traffic and climatic conditions. Roads suffer from rutting, cracking, bleeding, and potholes, reducing service life and increasing maintenance costs. To overcome these limitations, researchers have investigated bitumen modification using polymers, natural rubber, waste plastic, and crumb rubber [4].

Crumb rubber, produced by processing discarded automobile tyres into small granulated particles, offers both

technical benefits and environmental advantages. Waste tyres are non-biodegradable, occupy large landfill space, and cause fire hazards when improperly disposed. Crumb Rubber Modified Bitumen (CRMB) is prepared by blending crumb rubber with hot bitumen under controlled temperature conditions, improving elasticity, stiffness, temperature susceptibility, and durability [5].

This paper presents a laboratory-scale comparative analysis of conventional VG-30 grade bitumen and 10% CRMB, evaluating changes through penetration, softening point, ductility, and viscosity tests. The study provides technical justification and environmental rationale for adopting CRMB in flexible pavement construction.

## II. LITERATURE REVIEW

### A. Rheological and Performance Enhancement

Zhang et al. [5] investigated fatigue resistance and microstructural characteristics of wax-crumb rubber composite modified bituminous binders. Rubber particles significantly enhance elasticity and flexibility, improving resistance to fatigue cracking, while the synergistic interaction between rubber and polymer components leads to improved adhesion and better temperature susceptibility across both high and low temperatures.

Zhang et al. [6] developed high viscosity-elasticity composite modified asphalt using recycled waste tyre rubber. Rubber improves elasticity and crack resistance while polymer additives enhance stiffness and rutting resistance. The modified binders exhibit performance comparable to or superior to conventional polymer-modified bitumen, representing a viable and sustainable alternative.

Su et al. [7] evaluated high-content rubber/SBS composite modified asphalt with rubber content up to approximately 35%, combined with mechanical-thermal desulfurization processing. Results showed superior rheological properties, fatigue resistance, and deformation resistance, with significantly enhanced fatigue life suitable for long-life asphalt pavements (LLAP).

### B. Environmental Ageing and Durability

Mushtaq et al. [8] conducted experimental analysis of advanced rubber modified asphalt subject to environmental ageing, evaluating indirect tensile strength (ITS), unconfined compressive strength (UCS), and tensile strength ratio (TSR). While rubberized asphalt initially exhibits improved flexibility and crack resistance, prolonged environmental exposure leads to reduction in mechanical strength and fracture resistance, highlighting susceptibility to environmental degradation.

### C. Mechanical Performance and Advanced Modifications

Adnan and Wang [9] found that crumb rubber significantly enhances stiffness, deformation resistance, and durability in asphalt mixtures, while graphene further improves performance by strengthening the binder-aggregate interaction, providing improved resistance to both rutting and cracking for heavy traffic conditions.

Li et al. [10] characterized recycled carbon black from lightly pyrolyzed tyre rubber. Despite lower purity than conventional carbon black, recycled carbon black significantly improves high-temperature rheological properties and deformation resistance of asphalt.

### D. Sustainability and Reviews

Ibrahim et al. [11] explored devulcanized tire rubber and waste plastics as green road modifiers. Devulcanized rubber improves elasticity and flexibility, waste plastics contribute increased stiffness, and the combined effect leads to improved rutting resistance and fatigue performance comparable to conventional polymer-modified bitumen.

Alsheyab et al. [12] in a comprehensive state-of-the-art review confirmed that rubber modification increases softening point, viscosity, Marshall stability, and VMA, while penetration, ductility, and specific gravity decrease. The optimum rubber content is generally between 5% and 15%, with approximately 10% providing the best performance.

Haldar et al. [13] reported an optimum rubber content of 8–15% for maximum performance benefits. Das et al. [14] concluded that rubberized bitumen significantly improves strength, elasticity, durability, and resistance to rutting and cracking while reducing environmental pollution. Kamoto et al. [15] demonstrated improved temperature susceptibility and superior durability through waste-derived material combinations. Rangaraj and Mukesh [16] identified an optimum rubber content of approximately 10–12% for maximum Marshall stability.

## III. MATERIALS AND METHODS

### A. Materials Used

Two primary materials were used: (1) VG-30 grade bitumen, procured from a certified supplier conforming to IS standards — the most commonly adopted grade for flexible pavement construction under moderate climatic and traffic conditions in India; and (2) crumb rubber obtained from discarded waste tyres through mechanical shredding, sieved to achieve uniform particle size for better mixing and consistency.

### B. Sample Preparation

Bitumen was heated in the laboratory at 150°C to 170°C to achieve fluid state without overheating. Continuous stirring was performed during heating to maintain uniform temperature distribution. Crumb tyre rubber was gradually added at 10% by weight of bitumen and the mixture was continuously stirred for 30–60 minutes at constant temperature to allow proper rubber-bitumen interaction. Two sample sets were prepared: pure VG-30 bitumen (control) and 10% CRMB.

### C. Testing Methods

Four standard tests were conducted on both sample sets per relevant IS specifications:

#### 1) Penetration Test (IS 1203):

A standard needle penetrates vertically into the bitumen sample under 100 g load for 5 seconds at 25°C. Result expressed in 0.1 mm. Lower penetration indicates harder bitumen with improved deformation resistance.

#### 2) Softening Point Test (IS 1205):

Conducted using the Ring and Ball apparatus. The liquid bath is heated at 5°C/min; the temperature at which softened bitumen drops the steel ball is recorded. Higher softening point indicates better high-temperature resistance.

#### 3) Ductility Test (IS 1208):

A standard briquette specimen is elongated at 5 cm/min at 27°C until it breaks. Distance in cm is recorded. Higher ductility indicates better flexibility and resistance to cracking.

#### 4) Viscosity Test (IS 1206 Part 2):

Time in seconds for 50 ml of bitumen to flow through a standard orifice at specified temperature. Proper viscosity ensures adequate aggregate coating and effective compaction.

## IV. RESULTS AND DISCUSSION

### A. Penetration Test

The penetration value decreased from 61.8 (0.1 mm) for pure VG-30 bitumen to 56.3 (0.1 mm) for CRMB — a reduction of approximately 8.9%. Rubber particles swell and absorb lighter bitumen fractions, increasing apparent viscosity and reducing needle penetration [12]. This enhanced stiffness is desirable for resisting rutting under heavy traffic. The CRMB value still falls within acceptable range, confirming technical suitability.

S. No.	Property	Unit	VG-30	CRMB 10%
1	Penetration @ 25°C, 100g, 5s	0.1 mm	61.8	56.3

Table I: Penetration Test Results

### B. Softening Point Test

The softening point increased from 58.75°C for pure VG-30 bitumen to 62.25°C for CRMB — an improvement of approximately 3.5°C (6%). Crumb rubber modifies the colloidal structure of bitumen, resulting in a stiffer binder at elevated temperatures [5]. This makes CRMB particularly suitable for Indian climatic conditions, where summer temperatures frequently exceed 40°C, directly addressing rutting susceptibility.

S. No.	Property	Unit	VG-30	CRMB 10%
1	Softening Point (Ring & Ball)	°C	58.75	62.25

Table II: Softening Point Test Results

### C. Ductility Test

The ductility of CRMB (61 cm) is lower than pure VG-30 bitumen (82 cm), a decrease of approximately 25.6%. This is well-documented in literature: rubber particles introduce discontinuities in the bituminous matrix, restricting elongation [6]. However, CRMB exhibits improved elastic recovery — returning to its original shape after deformation

— partially compensating for lower elongation. Both values exceed the minimum threshold of 50 cm, confirming technical acceptability.

S. No.	Property	Unit	VG-30	CRMB 10%
1	Ductility @ 27°C, 5 cm/min	cm	82	61

Table III: Ductility Test Results

#### D. Viscosity Test

The viscosity of CRMB (141.0 s) is substantially higher than pure VG-30 bitumen (55.27 s) — an increase of approximately 155.2%. This dramatic increase is due to swelling of rubber particles in bitumen, increasing internal resistance to flow [7]. Higher viscosity ensures better aggregate coating and improved resistance to displacement under traffic loading, leading to improved pavement stability. Care must be taken to ensure increased viscosity does not cause workability difficulties during field mixing and compaction.

S. No.	Property	Unit	VG-30	CRMB 10%
1	Viscosity @ 27°C (Saybolt Furol)	sec	55.27	141.0

Table IV: Viscosity Test Results

#### E. Comparative Summary

Table V presents a consolidated comparison of all test results. CRMB demonstrates improved stiffness (lower penetration), better high-temperature resistance (higher softening point), slightly reduced elongation capacity (lower ductility), and significantly enhanced flow resistance (higher viscosity). These combined improvements make CRMB better suited to withstand the combined effects of heavy traffic loading and elevated temperatures prevalent in Indian conditions.

Property	Unit	VG-30	CRMB 10%	Change
Penetration @ 25°C	0.1 mm	61.8	56.3	-8.9%
Softening Point	°C	58.75	62.25	+6.0%
Ductility @ 27°C	cm	82	61	-25.6%
Viscosity @ 27°C	sec	55.27	141.0	+155.2%

Table V: Consolidated Comparison of All Test Results

### V. CONCLUSION

This study conducted a systematic laboratory-scale comparative analysis of conventional VG-30 grade bitumen and 10% crumb rubber modified bitumen (CRMB). The following conclusions are drawn:

- 1) The penetration value of CRMB ( $56.3 \times 0.1$  mm) is lower than pure VG-30 bitumen ( $61.8 \times 0.1$  mm), confirming rubber modification increases stiffness and hardness, beneficial for resisting permanent deformation under heavy traffic.
- 2) The softening point of CRMB (62.25°C) is notably higher than conventional bitumen (58.75°C), indicating improved temperature susceptibility and better resistance

to rutting at elevated temperatures — a critical advantage for India's hot climatic conditions.

- 3) The ductility of CRMB (61 cm) is reduced compared to pure bitumen (82 cm); however, both values exceed acceptable minimum thresholds, and the elastic recovery characteristics of CRMB partially compensate for the lower elongation capacity.
- 4) The viscosity of CRMB (141.0 s) is significantly higher than that of conventional bitumen (55.27 s), confirming improved flow resistance and better aggregate coating efficiency, which translates to enhanced pavement stability.
- 5) From an environmental standpoint, utilization of waste tyre rubber in CRMB contributes to effective recycling of non-biodegradable waste, reduction of landfill burden, and promotion of sustainable construction practices.
- 6) Overall, CRMB demonstrates superior engineering properties compared to conventional bitumen, making it a technically sound, cost-effective, and environmentally responsible alternative for flexible pavement construction in India.

Future research should evaluate CRMB at varying rubber content proportions (5%, 15%), assess long-term field performance under real traffic and environmental conditions, conduct detailed cost-benefit and lifecycle analyses, and investigate advanced modifications with SBS polymers or graphene to further enhance durability.

#### ACKNOWLEDGMENT

The authors express sincere gratitude to Ms. Priyanka Verma, Assistant Professor, Department of Civil Engineering, Bhilai Institute of Technology, Durg, for her valuable guidance, constant encouragement, and technical support. The authors also thank Dr. Sindhu J. Nair, Head of the Department of Civil Engineering, and the institution for providing the necessary academic environment and laboratory resources.

#### REFERENCES

- [1] Bureau of Indian Standards, IS 73: Paving Bitumen – Specification, New Delhi, India.
- [2] Indian Roads Congress, IRC: 37 – Guidelines for the Design of Flexible Pavements, New Delhi, India.
- [3] Bureau of Indian Standards, IS 1203: Methods for Testing Tar and Bituminous Materials – Determination of Penetration, New Delhi, India.
- [4] Bureau of Indian Standards, IS 1208: Methods for Testing Tar and Bituminous Materials – Determination of Ductility, New Delhi, India.
- [5] H. Zhang, H. Li, S. Khan, A. Khair, M. Liu, J. Pan, L. Wang and H. Zhang, "Enhanced understanding of fatigue resistance in wax crumb rubber composite modified bituminous binders through microstructural and thermo-rheological characterization," *Construction and Building Materials*, 2026.
- [6] D. Zhang, J. Tang, D. Luan, X. Xu, R. P. Borg and O. Lewis, "Waste tire rubber recycling for developing a high viscosity-elasticity composite modified asphalt," *Construction and Building Materials*, 2026.
- [7] Q. Su, L. Xia, J. Tang, M. Zhang, D. Wang and Dongwei, "From waste tires to long-life asphalt pavement:

- Evaluation of rheological and fatigue properties of high-content rubber/SBS composite modified asphalt," *Construction and Building Materials*, vol. 411, 2025.
- [8] M. Mushtaq, M. Corradi and R. Mishra, "An experimental analysis of an advanced rubber modified asphalt subject to environmental ageing," *Journal of Materials in Civil Engineering*, 2025.
- [9] A. M. Adnan and J. Wang, "Evaluation of the mechanical performance of asphalt mixtures containing waste tire rubber and graphene," *Construction and Building Materials*, 2024.
- [10] Y. Li, R. Dong and Y. Qin, "Characteristics of carbon black recycled from lightly pyrolyzed tire rubber and its impact on the high-temperature performance of asphalt," *Sustainable Materials and Technologies*, 2024.
- [11] H. Ibrahim, S. Marini, L. Desidery and M. Lanotte, "Recycled plastics and rubber for green roads: The case study of devulcanized tire rubber and waste plastics compounds to enhance bitumen performance," *J. Mater. Civ. Eng., ASCE*, 2023.
- [12] M. A. T. Alsheyab, T. Khedaywi and O. Ogliati, "Effect of waste tire rubber on properties of asphalt cement and asphalt concrete mixtures: state of the art," *Construction and Building Materials*, 2023.
- [13] S. Haldar, S. V. Thiyagarajan and S. Das, "Application of waste tyre rubber crumbs in strengthening of bituminous roads," *Materials Today: Proceedings*, 2022.
- [14] A. Das, M. E. Chinchghare and A. M. Baig, "Use of waste tyre rubber in flexible pavement as bitumen binder," *International Journal of Engineering Research & Technology (IJERT)*, vol. 10, no. 6, 2021.
- [15] N. Kamoto, J. Govha, G. Danha, T. Mamuvura and E. Muzenda, "Production of modified bitumen from used engine oil, coal tar and waste tyre for construction applications," *Procedia Manufacturing*, 2020.
- [16] A. Rangaraj and P. Mukesh, "An experimental investigation on partial replacement of bitumen using rubber tyre," *International Journal of Engineering Research & Technology (IJERT)*, 2019.
- [17] Bureau of Indian Standards, IS 1205: Methods for Testing Tar and Bituminous Materials – Determination of Softening Point, New Delhi, India.
- [18] Bureau of Indian Standards, IS 1206 (Part 2): Methods for Testing Tar and Bituminous Materials – Determination of Viscosity, New Delhi, India.