

Rubberised Bitumen In Road Construction

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ABSTRACT

The increasing traffic volume and heavy axle loading on flexible pavements require binders with improved resistance to deformation and cracking, while the accumulation of waste automobile tyres creates a persistent environmental burden. This study experimentally investigated rubberised bitumen prepared by the wet process using crumb rubber contents of 0%, 4%, 6%, and 8% by weight of bitumen. Conventional 60/70 penetration-grade bitumen and the modified binders were evaluated through penetration, softening point, and ductility tests, and the corresponding asphalt mixtures were assessed using Marshall stability and flow measurements. Increasing crumb rubber content reduced penetration from 67 to 55 (0.1 mm), increased softening point from 48 to 57 °C, and increased ductility from 78 to 89 cm. Marshall stability increased from 10.2 to 14.0 kN, whereas flow decreased from 3.8 to 3.2 mm. Within the tested range, the 8% crumb-rubber mixture produced the highest reported stability and the most favorable combination of binder stiffness, temperature resistance, ductility, and deformation response. The findings support the use of wet-process crumb rubber modification as a technically promising route for improving flexible pavement performance while diverting waste tyres from disposal. The reported conclusions are limited to the laboratory values and dosage range documented in the thesis.

Keywords: Rubberised Bitumen; Crumb Rubber; Waste Tyres; Flexible Pavement; Marshall Stability; Sustainable Road Construction.

1. INTRODUCTION

Flexible pavements are extensively used because they are economical to construct, provide satisfactory riding quality, and can be maintained in stages. Bitumen binds the aggregate skeleton, limits water entry, and contributes to load transfer and flexibility. Conventional bitumen, however, is temperature susceptible: it softens under high pavement temperatures and can become brittle under low-temperature or repeated-loading conditions. These responses contribute to rutting, cracking, ravelling, bleeding, and other forms of premature distress.

Waste automobile tyres present a parallel environmental problem because vulcanized rubber is non-biodegradable and difficult to dispose of safely. Processing waste tyres into crumb rubber and incorporating the particles into paving bitumen creates a potential material-recovery route while modifying the binder. During wet-process blending, the rubber absorbs lighter aromatic fractions, swells, and alters the viscosity and elastic response of the bitumen.

The thesis investigated crumb rubber modified bitumen as a pavement material and compared its laboratory performance with conventional 60/70 penetration-grade bitumen. The objectives were to examine the effect of crumb rubber on penetration, softening point, ductility, Marshall stability, and flow; compare conventional and rubberised binders and mixtures; assess the best-performing dosage within the tested range; and consider the sustainability benefit associated with waste-tyre utilization.

2. RELATED WORK

The studies reviewed in the thesis describe crumb rubber modification as a combined pavement-performance and waste-management strategy. Lo Presti summarized the development of recycled-tyre-rubber-modified binders and emphasized their improved deformation and cracking resistance [1]. Barišić et al. discussed the environmental value of recycling waste tyres in road construction [2], while Provatorova and Provatorova and Vikhrev described the use of rubber or other modifiers to improve binder and asphalt-concrete performance [3,4].

Laboratory investigations using dry-process and wet-process approaches have reported improved stability, fatigue response, rutting resistance, and flexibility when rubber is appropriately incorporated [5-8]. Vasudevan similarly discussed the use of crumb rubber and waste plastic for more durable and sustainable flexible pavements [9]. The literature also indicates that performance depends on rubber content, particle size, blending

temperature, digestion time, and base-binder characteristics. The present work therefore focuses on a controlled comparison of four crumb-rubber contents using the wet process and standard binder and Marshall tests.

3. MATERIALS AND METHODS

3.1 Materials

The experimental programme used conventional 60/70 penetration-grade paving bitumen as the base binder. Crushed angular aggregates were selected to provide mechanical interlock and resistance to deformation. The modifier was crumb rubber produced from recycled automobile tyres; the thesis describes it as a mixture of natural and synthetic rubber, carbon black, sulphur compounds, and reinforcing additives. The reported rubber contents were 0%, 4%, 6%, and 8% by weight of bitumen.



Figure 1. Crumb rubber used for bitumen modification, reproduced from the thesis.

3.2 Preparation of rubberised bitumen

Rubberised bitumen was prepared by the wet process. The base bitumen was heated within the reported range of approximately 160-180 °C. Pre-weighed crumb rubber was then added gradually while the binder was continuously mixed. Blending was maintained for approximately 30-60 min to promote dispersion, absorption of lighter binder fractions, and swelling of the rubber particles. Temperature control and continuous agitation were used to limit local overheating and non-uniform distribution.



Figure 2. Wet-process preparation sequence reported in the thesis.

3.3 Experimental programme

The binders were evaluated using penetration, softening point, and ductility tests. Asphalt mixtures prepared with the same rubber contents were evaluated through Marshall stability and flow testing. Marshall stability represents the maximum load sustained by the specimen, while flow represents the corresponding deformation. The thesis reports the test values for each dosage but does not clearly state replicate counts, measures of dispersion, or inferential statistical analysis; accordingly, the article presents the reported values as laboratory trends rather than population estimates.



Figure 3. Marshall stability testing machine used in the experimental programme.

4. RESULTS AND DISCUSSION

4.1 Penetration

Table 1. Penetration test results.

Crumb Rubber Content	Penetration Value (0.1 mm)
0%	67
4%	63
6%	59
8%	55

Penetration decreased progressively as crumb rubber content increased. The value fell from 67 for the unmodified binder to 55 at 8% crumb rubber, a reduction of approximately 17.9%. The thesis attributes this response to absorption of lighter aromatic fractions and the resulting increase in binder viscosity. Within the tested range, the modified binder therefore showed greater resistance to needle penetration and a stiffer high-temperature response.

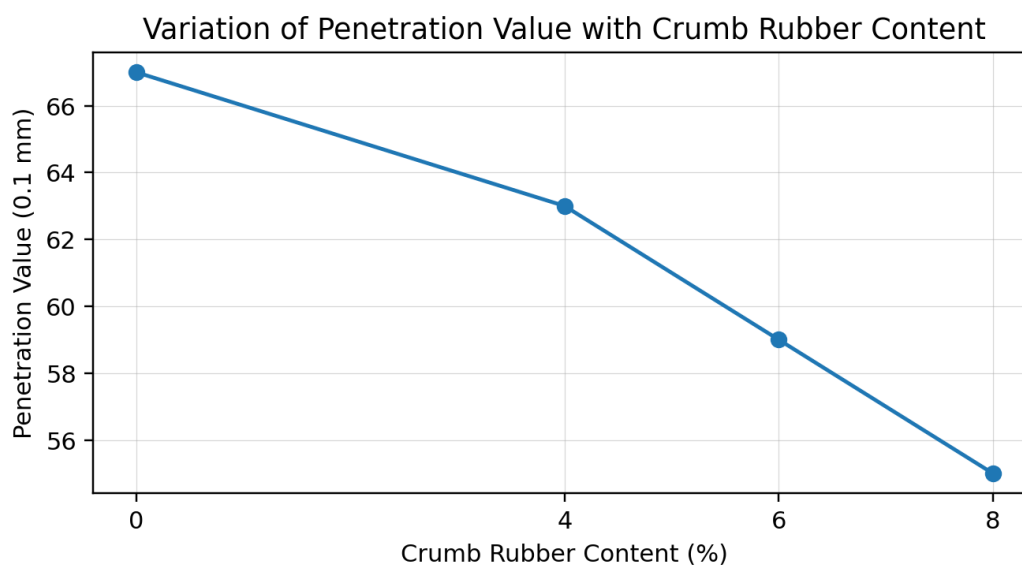


Figure 4. Variation of penetration value with crumb rubber content.

4.2 Softening point

Table 2. Softening point test results.

Crumb Rubber Content	Softening Point (°C)
0%	48
4%	51
6%	54
8%	57

The softening point increased from 48 °C for conventional bitumen to 57 °C at 8% crumb rubber. The 9 °C rise indicates that the modified binders remained resistant to softening at higher temperatures. This trend is consistent with the increased viscosity and elastic network created by the swollen rubber phase and supports the thesis interpretation of improved rutting resistance under elevated pavement temperatures.

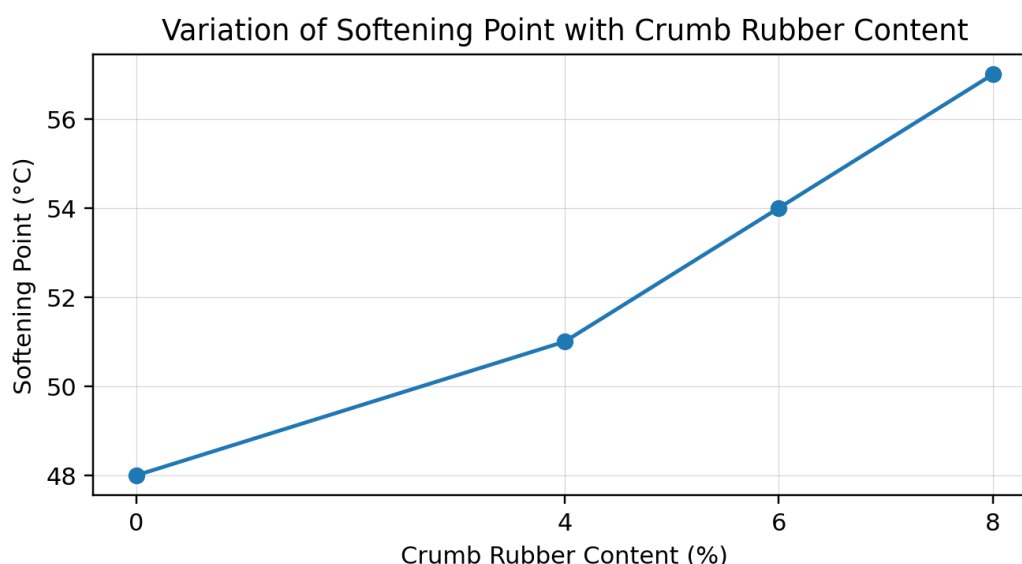


Figure 5. Variation of softening point with crumb rubber content.

4.3 Ductility

Table 3. Ductility test results.

Crumb Rubber Content	Ductility (cm)
0%	78
4%	82
6%	86
8%	89

Ductility increased from 78 cm for the control binder to 89 cm at 8% crumb rubber. The reported trend indicates improved deformation capacity before rupture, which the thesis relates to enhanced elastic recovery and flexibility. The simultaneous decrease in penetration and increase in ductility suggests that rubber modification increased stiffness without producing a brittle response over the tested dosage range.

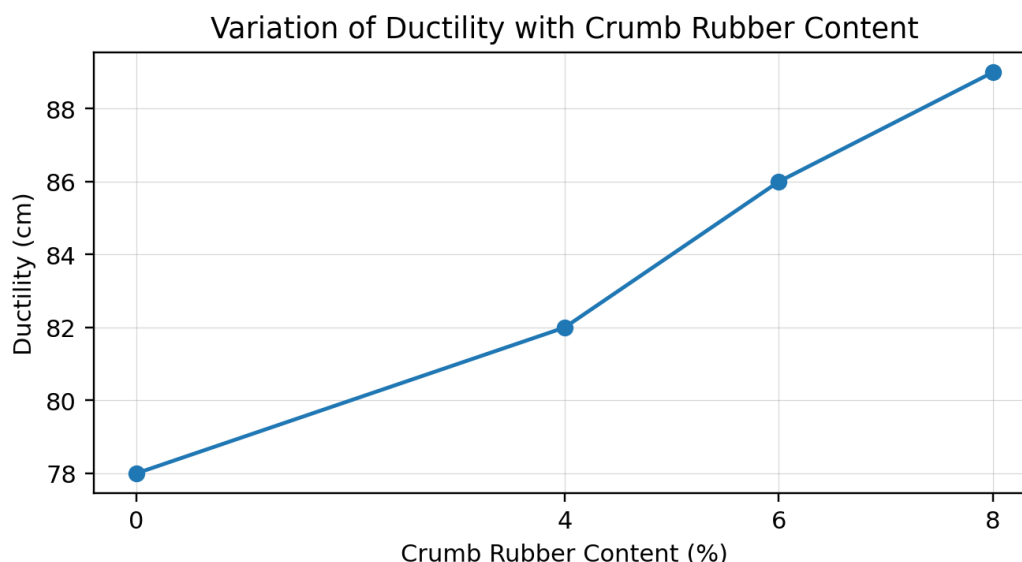


Figure 6. Variation of ductility with crumb rubber content.

4.4 Marshall stability

Table 4. Marshall stability results.

Crumb Rubber Content	Marshall Stability (kN)
0%	10.2
4%	11.8
6%	13.1
8%	14.0

Marshall stability increased continuously from 10.2 kN for the unmodified mixture to 14.0 kN at 8% crumb rubber, representing an increase of approximately 37.3%. The thesis associates this improvement with stronger aggregate-binder interaction, increased elastic response, and greater resistance to permanent deformation. Among the tested mixtures, the 8% dosage had the highest reported load-carrying capacity.

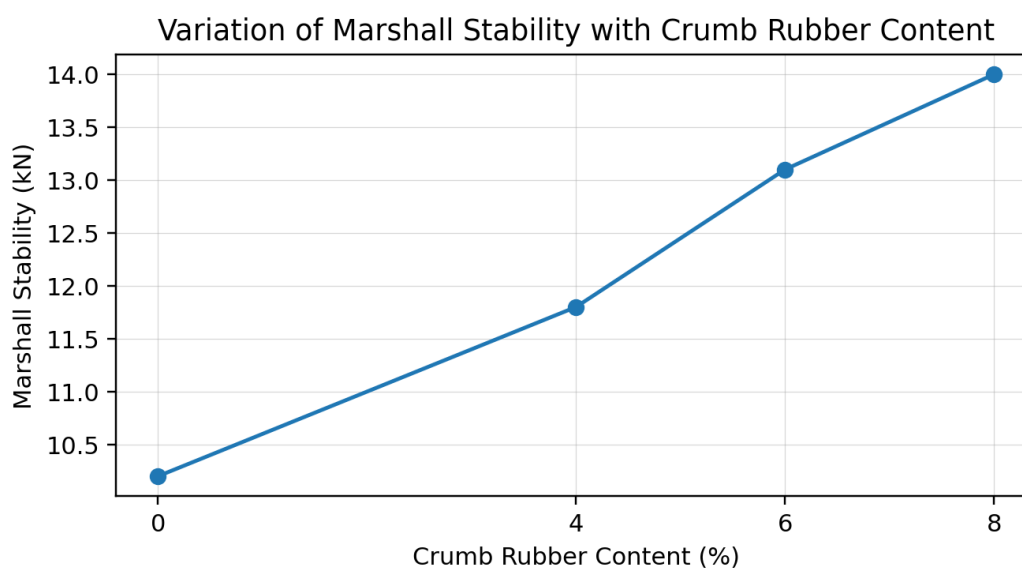


Figure 7. Variation of Marshall stability with crumb rubber content.

4.5 Flow value

Table 5. Flow value results.

Crumb Rubber Content	Flow Value (mm)
0%	3.8
4%	3.5
6%	3.3
8%	3.2

Flow decreased from 3.8 mm at 0% crumb rubber to 3.2 mm at 8%. The decline indicates lower deformation at the maximum Marshall load. When considered together with the stability increase, the results show a more stable mixture response as rubber content increased. The thesis reports that the flow values remained satisfactory for the investigated mixtures.

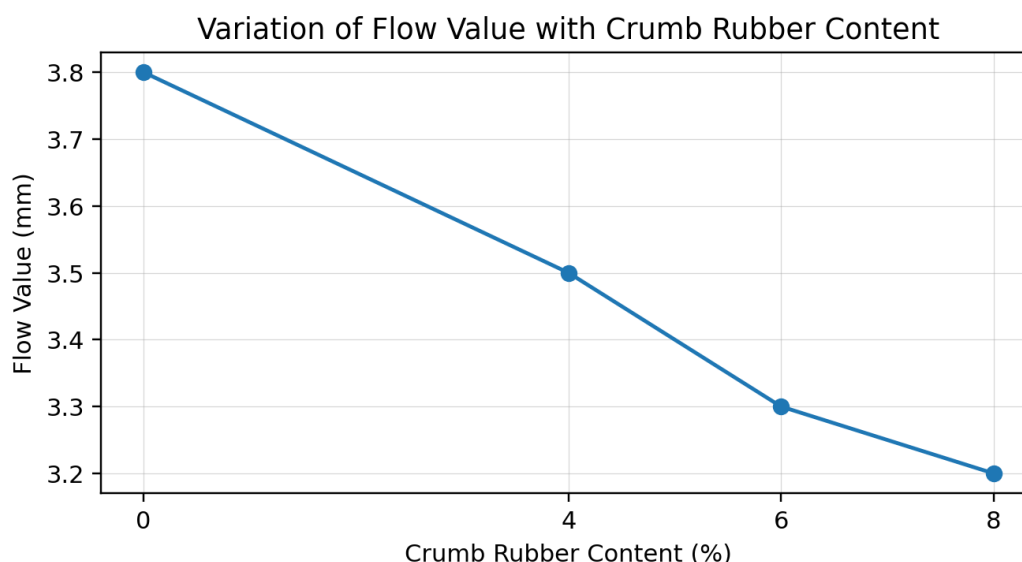


Figure 8. Variation of flow value with crumb rubber content.

4.6 Overall performance and limitations

Across all five reported response variables, increasing crumb rubber content produced consistent trends: penetration and flow decreased, while softening point, ductility, and Marshall stability increased. The 8% mixture was the best-performing tested dosage and was identified in the thesis as the optimum content for the experimental programme. This conclusion is limited to the four dosages and materials evaluated; it does not establish that 8% is universally optimum for other binders, aggregate sources, climatic regions, production equipment, or traffic conditions.

The evidence supports a favorable structural and functional effect of wet-process crumb rubber modification, but the thesis does not report replicate numbers, standard deviations, statistical significance, fatigue testing, rutting-wheel testing, moisture susceptibility, aging, or long-term field monitoring. These omissions should be addressed before broad design recommendations are made. The environmental benefit is also qualitative in the present work because tyre diversion quantities and life-cycle impacts were not quantified.

5. CONCLUSION

- Crumb rubber modification reduced penetration from 67 to 55 (0.1 mm), indicating increased binder stiffness and improved resistance to high-temperature deformation.
- The softening point increased from 48 to 57 °C, demonstrating improved temperature resistance within the tested range.
- Ductility increased from 78 to 89 cm, showing that the modified binder retained and improved deformation capacity.
- Marshall stability increased from 10.2 to 14.0 kN, while flow decreased from 3.8 to 3.2 mm, indicating improved load-carrying capacity and reduced deformation.

- Among the investigated dosages, 8% crumb rubber produced the strongest overall laboratory response and was identified as the best-performing tested content.
- Rubberised bitumen offers a technically promising use for waste-tyre rubber, but field validation, replicate testing, advanced rheological characterization, moisture and fatigue assessment, and life-cycle analysis are required before generalized implementation.

DECLARATIONS

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REFERENCES

- [1] D. Lo Presti, "Recycled Tyre Rubber Modified Bitumens for Road Asphalt Mixtures: A Literature Review," Construction and Building Materials, vol. 49, 2013.
- [2] I. Barišić, M. Zvonarić, I. Netinger Grubeša, and S. Šurdonja, "Recycling Waste Rubber Tyres in Road Construction," Archives of Civil Engineering, vol. 67, no. 1, 2021.
- [3] O. Provatorova, "Application of Waste Rubber in Road Construction," IOP Conference Series: Materials Science and Engineering, vol. 896, 2020.
- [4] G. Provatorova and A. Vikhrev, "Modification of Bitumen for Road Construction," IOP Conference Series: Materials Science and Engineering, vol. 896, 2020.
- [5] N. A. Hassan et al., "Engineering Properties of Crumb Rubber Modified Dense-Graded Asphalt Mixtures Using Dry Process," IOP Conference Series: Earth and Environmental Science, vol. 220, 2019.
- [6] F. Hernandez-Olivares et al., "Rubber-Modified Hot-Mix Asphalt Pavement by Dry Process," International Journal of Pavement Engineering, vol. 10, no. 4, 2009.
- [7] M. S. Ranadive and S. Tapase, "Use of Waste Tyres in Flexible Pavements," International Journal of Research in Engineering and Technology, vol. 4, no. 11, 2015.
- [8] S. N. Amirkhanian, "Crumb Rubber Utilization in Asphalt Pavements: State of the Art," International Journal of Pavement Engineering, vol. 2, no. 3, 2001.
- [9] R. Vasudevan, "Utilization of Waste Plastic and Crumb Rubber in Flexible Pavement," Indian Highways, vol. 34, no. 7, 2006.