

Digestion of crumb rubber in bitumen

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Understand digestion of crumb rubber in bitumen, for different crumb rubber types and sizes, at variable blending temperatures and times

Background

Crumb rubber has been used in Western Australia for almost 40 years to modify bitumen used in spray sealing applications. In recent years, crumb rubber-modified binders (CRMBs) have also been used in asphalt.

Regardless, a detailed understanding of how the crumb rubber and bitumen interact at different mixing temperatures over time and how the source and size of the crumb rubber affect CRMB properties is yet to be gained.

This research investigated the changes in binder properties as they occur during crumb rubber digestion at different blending times and temperatures when varying the size and type of crumb rubber.

Approach

This multi-stage project investigated the impacts of crumb rubber type and size as well as digestion temperature and time on the characteristics, handling properties, and performance of the resultant CRMBs.

In addition, it sought to provide an understanding of the effects of the chemical and physical characteristics of the different crumb rubbers on their digestion behaviour.

The project followed the following process:

- Literature review: investigated the composition and manufacture of the crumb rubbers, described the process of crumb rubber digestion in bitumen and the various parameters that impact it.

- CRMB preparation: obtained 4 different types of crumb rubber (truck tyre (TR), car tyre (CT), conveyor belt (CB), and mining tyre (MT)), and prepared CRMBs, with varying crumb rubber sizes (size 16 and 30), blending temperatures (165 and 190 °C) and blending times (1, 2, 4, 11, 24 and 36 hours).
- Sample preparation: separated the liquid and solid phase of the CRMBs for testing, as required.
- Test the materials: conducted tests on the unmodified binder, as-received crumb rubbers, the CRMBs, extracted crumb rubber and extracted liquid binder phase.
- Analyse results and report findings: prepared a final report summarising the findings, including considering binder oxidation, effect of crumb rubber type on digestion, and compliance with current Western Australian and Austroads specifications.

Mining tyre



Source: NTRO 2024

Findings

The digestion behaviour of the different rubber types and crumb rubber sizes under the investigated blending conditions was assessed through:

- rubber swelling analysis
- crumb rubber dissolution using AGPT-T142:2020
- crumb rubber dissolution using high performance liquid chromatography – gel permeation chromatography (HPLC-GPC)
- crumb rubber composition and dissolution using thermogravimetric analysis (TGA)
- crumb rubber composition and dissolution and CRMB oxidation using Fourier-transform infrared spectroscopy (FTIR)
- S16 crumb rubber particle morphology before and after digestion using optical microscopy.

Generally, the swelling of all rubber types was more rapid at the higher blending temperature of 190 °C. Of the methods used, HPLC-GPC yielded the most insightful results. Crumb rubber dissolution was found to generally increase with blending time. TGA was particularly useful in understanding the composition and relevant variability of each crumb rubber source.

A wide range of binder characterisation methods were also used, according to Main Roads Western Australia (MRWA) and Austroads specifications, to evaluate the performance of the resultant binders. Overall, results were comparable for TR-, CT-, and CB-derived CRMBs and for all blending temperatures, blending times, and crumb rubber size gradations investigated.

The results for MT-derived CRMBs were often markedly different and often inconsistent.

Crumb rubber particles



Source: NTRO 2024

Conclusion

Apart from minor exceptions, all CRMBs incorporating TR-, CT-, and CB-derived crumb rubber were within the specified limits of both MRWA Specification 511:2025 and Austroads ATS 3110:2023.

These findings provide confidence that CRMBs that derive from these 3 different rubber sources can be used interchangeably in MRWA practice.

MT-derived CRMBs did not all meet either specification limits. The characterisation and performance test results of these CRMBs were often markedly different to the other 3 rubber sources.

As MT-derived crumb rubber could have a wide resource stream and the test results were promising, it is recommended that additional work be undertaken before MT-derived crumb rubber is considered a direct alternative to the other sources for MRWA practice.

It would also be valuable to better understand how these variations would translate to asphalt performance.

Crumb rubber modified binder



Source: NTRO 2025

References

- Austroads Technical Specification ATS3110:2023, *Supply of Polymer Modified Binders*
- MRWA Specification 511:2025, *Materials for Bituminous Treatments*