



Monitoring the Degradation of Bitumen

Application Note M189

Introduction

Bitumen undergoes oxidative ageing, leading to embrittlement and loss of flexibility. Monitoring these changes is essential for predicting pavement durability. Attenuated Total Reflectance (ATR) Fourier Transform Infrared (FT-IR) Spectroscopy provides a non-destructive method to analyze ageing-induced chemical changes, particularly the formation of carbonyl and sulfoxide groups, which serve as markers for progressing oxidation.

This study focuses on detecting and quantifying oxidation-related changes in bitumen using ATR FT-IR spectroscopy. The method tracks the formation of carbonyl and sulfoxide groups in laboratory- and field-aged samples.

Materials & Methods

Bitumen samples underwent ageing under defined short-term (RTFOT; Rolling Thin Film Oven Test at 163°C) and long-term (PVA; Pressure Ageing Vessel at 100°C) conditions. FT-IR-ATR spectra were collected using a Bruker ALPHA II spectrometer with a diamond ATR crystal, scanning the Mid-Infrared range, taking about 30 seconds per measurement. Spectral normalization was applied, and oxidation markers were quantified at 1660–1800 cm^{-1} (carbonyls) and 1079–984 cm^{-1} (sulfoxides).

Results & Discussion

The FT-IR spectra of bitumen show characteristic peaks corresponding to its chemical composition and also reveal oxidation markers with ageing. The main functional groups identified include:

- Aliphatic hydrocarbons (CH stretching at 2920 cm^{-1} and 2850 cm^{-1})
- Aromatic compounds (C=C stretching at 1600 cm^{-1})
- Carbonyl groups (C=O stretching at 1700 cm^{-1} ; indicator of oxidation)
- Sulfoxide groups (S=O stretching at 1030 cm^{-1} ; oxidation marker)
- SBS polymer indicators (Butadiene absorption at 966 cm^{-1} and 910 cm^{-1} , and Styrene absorption at 698 cm^{-1})

Comparisons between laboratory-aged and field-aged samples showed that PAV closely simulates real-world ageing, but field samples exhibited additional oxidation effects due to UV exposure and moisture. This suggests that current laboratory ageing methods may underestimate real-world oxidative impacts.

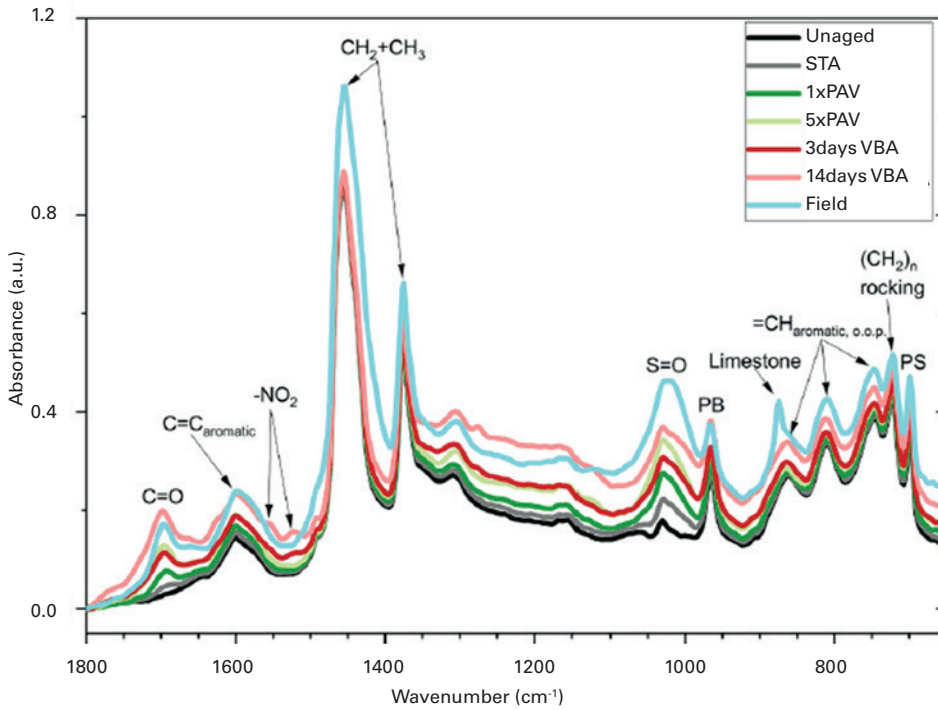


Fig. 1 FT-IR spectra of Unaged vs Short Term Aging (STA) vs Pressure Aging Vessel (PAV) vs Viennese Binder aging (VBA) vs Field Aging tests of PMB, highlighting the discrepancies between laboratory and field-aged samples.

RTFOT caused moderate carbonyl accumulation, while PAV led to significant oxidation, confirming long-term exposure exacerbates degradation. Sulfoxide formation occurred more rapidly than carbonyl formation, indicating sulfur oxidation precedes other oxidation pathways. ATR FT-IR proved highly sensitive in detecting oxidation variations, demonstrating its utility for ageing analysis. The correlation between oxidation indices and bitumen performance confirms its potential as a predictive tool for long-term durability assessments.

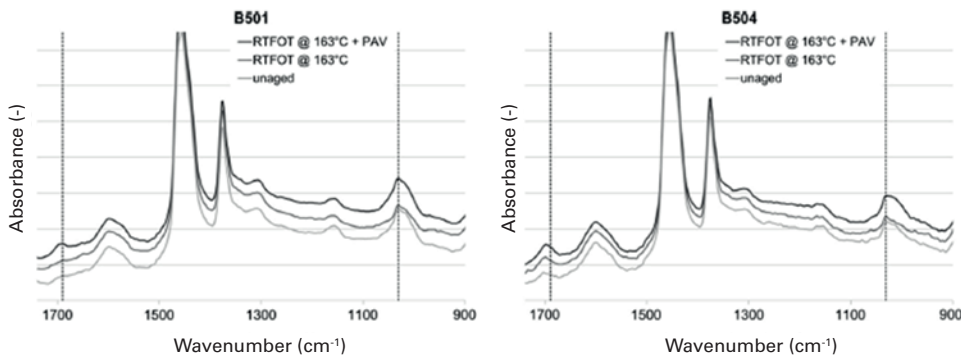


Fig. 2 FT-IR spectra for unaged, RTFOT-aged, and PAV-aged bitumen samples (B501 and B504), highlighting the carbonyl and sulfoxide regions.

Conclusion

Overall, FT-IR-ATR effectively characterizes oxidation in bitumen, providing a precise method for tracking degradation. The ability to quantify ageing markers supports its application in durability studies, ensuring more accurate predictions of pavement longevity. Bruker's FT-IR-ATR technology delivers reliable spectral analysis, making it a valuable tool for bitumen ageing research.

References

- ^[1] Hofko, B., Porot, L., Falchetto Cannone, A., Poulidakos, L., Huber, L., Lu, X., Mollenhauer, K., & Grothe, H. (2018). FT-IR Spectral Analysis of Bituminous Binders: Reproducibility and Impact of Ageing Temperature. *Materials and Structures*, 51, 45. <https://doi.org/10.1617/s11527-018-1170-7>
- ^[2] Mirwald, J., Nura, D., & Hofko, B. (2022). Recommendations for Handling Bitumen Prior to FT-IR Spectroscopy. *Materials and Structures*, 55, 26. <https://doi.org/10.1617/s11527-022-01884-1>
- ^[3] Werkovits, S., Primerano, K., Bacher, M., Rosenau, T., Hofko, B., & Grothe, H. (2025). An Analytical Framework to Assess the Chemical Changes in Polymer-Modified Bitumen Upon Natural and Simulated Ageing. *Fuel*, 381, 133257.

Bruker Optics GmbH & Co. KG

info.bopt.de@bruker.com

[bruker.com](https://www.bruker.com)

