Optimizing Chemical & Rheological Properties of Rejuvenated Bitumen

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# Introduction

Bitumen has long been a material used in the construction of roadways, yet new pavement only consists of 15% of recycled materials due to poor compatibility of aged bitumen and new materials.

Chemical additives such as rejuvenators have been used in an attempt to re-balance the chemical composition and restore the physical properties of aged bitumen back to its virgin state. However, a fundamental understanding of how rejuvenators revitalize bitumen is needed before developing the optimum rejuvenator.

# Objectives

- Use Fourier-transform infrared (FTIR) spectroscopy to determine the changes in chemical properties of virgin, aged, and rejuvenated bitumen.
- Employ a linear amplitude sweep (LAS), a procedure using a dynamic shear rheometer (DSR), to investigate rheological properties.
- Relate resulting chemical evolution to changes in macroscopic mechanical properties of the revitalized bitumen.

## FTIR Index Data

<table>
<thead>
<tr>
<th>INDEX</th>
<th>Characteristic Functional Groups</th>
<th>Approximate Wavenumber [cm⁻¹]</th>
<th>Index Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Acid: COOH &amp; Ether: 1745, 1156, 1377</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VG 7.5%</td>
<td>0.0077</td>
<td>0.0056</td>
<td>0.0013 ( \times 10^{-3} )</td>
</tr>
<tr>
<td>VG 15%</td>
<td>0.0107</td>
<td>0.0089</td>
<td>0.0033 ( \times 10^{-3} )</td>
</tr>
<tr>
<td>RTFO 7.5%</td>
<td>0.0157</td>
<td>0.0133</td>
<td>0.0043 ( \times 10^{-3} )</td>
</tr>
<tr>
<td>RTFO 15%</td>
<td>0.0193</td>
<td>0.0169</td>
<td>0.0052 ( \times 10^{-3} )</td>
</tr>
<tr>
<td>VG 15% SB</td>
<td>0.1658</td>
<td>0.1379</td>
<td>0.0070 ( \times 10^{-3} )</td>
</tr>
<tr>
<td>RTFO 15% SB</td>
<td>0.0455</td>
<td>0.0438</td>
<td>0.0095 ( \times 10^{-3} )</td>
</tr>
<tr>
<td>VG 15%</td>
<td>0.0878</td>
<td>0.0593</td>
<td>0.0024 ( \times 10^{-3} )</td>
</tr>
<tr>
<td>Soybean Oil</td>
<td>0.3651</td>
<td>0.2837</td>
<td>0.0002 ( \times 10^{-3} )</td>
</tr>
</tbody>
</table>

Table 1: Absorbance of characteristic functional groups in virgin (VG), rolling thin film oven (RTFO) aged, pressure aging vessel (PAV) aged, and rejuvenated bitumen.

Where \( I_{COOH} = A_{1745 cm^{-1}} \times \sum A \)

\( \sum A = \text{Total Peak Areas} \)

# FTIR Analysis

- FTIR analysis of \( I_{COOH} \) and \( I_{Et} \) confirms that soybean oil has been introduced to bitumen in the rejuvenation process. \( I_{COOH} \) indicates soybean oil may have already been partially oxidized.

\( I_{COOH} \) and \( I_{Et} \) decrease in RTFO and PAV samples suggesting the aging process in the aged bitumen has been reversed from rejuvenation with soybean oil. \( I_{COOH} \) and \( I_{Et} \) also decrease due to rejuvenation, indicating chain scission and aromatization that occurs during aging has been reversed.

# LAS Analysis

A frequency sweep test followed by a strain sweep test with linear increasing amplitude were used to calculate important binder parameters, A and B, used to determine fatigue performance (N).

\[
A = \frac{f_0}{k(m N_{f})} \quad B = -2a \quad N_f = A_{(max)}^a
\]

# Conclusions

The relation of FTIR and LAS results indicates rejuvenation of aged bitumen with soybean oil reverses the aging process at a molecular level and as a result, increases the fatigue life of the bitumen.

# Acknowledgements

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# References


