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>Carboxylic Acid</th>
<th>Other</th>
<th>Sulphone</th>
<th>Sulfoxide</th>
<th>Aliphatic</th>
<th>Aromatic</th>
<th>Wavelength (cm⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VG</td>
<td>713.65</td>
<td>724.51</td>
<td>744.14</td>
<td>755.93</td>
<td>767.33</td>
<td>777.94</td>
<td>788.52</td>
</tr>
<tr>
<td>VG 7.5% SB</td>
<td>713.65</td>
<td>724.51</td>
<td>744.14</td>
<td>755.93</td>
<td>767.33</td>
<td>777.94</td>
<td>788.52</td>
</tr>
<tr>
<td>VG 15% SB</td>
<td>713.65</td>
<td>724.51</td>
<td>744.14</td>
<td>755.93</td>
<td>767.33</td>
<td>777.94</td>
<td>788.52</td>
</tr>
</tbody>
</table>

FTIR 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 (Nf).

\[ A = \frac{L{\gamma}}{k} \times (BCv)^\alpha \]

\[ B = -2a \]

\[ N_f = (A_{max})^\beta \]

LAS Analysis

FTIR analysis of I_C=O and I_S=O confirms that soybean oil has been introduced to bitumen in the rejuvenation process. I_C indicates soybean oil may have already been partially oxidized. I_C and I_S decrease in RTFO and PAV samples suggesting the aging process in the aged bitumen has been reversed from rejuvenation with soybean oil. I_C and I_S also decrease due to rejuvenation, indicating chain scission and aromatization that occurs during aging has been reversed.

LAS analysis of PAV samples manifests fatigue resistances (Nf) of bitumen samples increases at every applied shear strain as a result of increasing concentration of rejuvenator.

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.

References


Acknowledgements

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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 \[ I_C=O = A_{1700-1500cm^{-1}} \times \sum A \]

\[ \sum A = \text{Total Peak Areas} \]

Fig 1: FTIR spectra of VG, VG 7.5% SB, and VG 15% SB bitumen samples.

Fig 2: FTIR spectra of RTFO, RTFO 7.5% SB, and RTFO 15% SB bitumen samples.

Fig 3: FTIR spectra of unmodified VG, RTFO, and PAV bitumen samples.

Fig 4: FTIR spectra of VG 15% SB, RTFO 15% SB, and PAV 15% SB bitumen samples.