Monitoring Oxidation Signals of Asphalt Pavement Surfaces by Portable Infrared Spectroscopy: in-situ testing of % RAP in HMA

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Outline

Need for quick field indicator of oxidation level of an HMA

Laboratory studies of oxidation of asphalt by FT-IR
  Well known

Nondestructive testing of oxidation levels in HMA by FT-IR

Proposed AASHTO Standard Practice on measuring oxidation in HMA by FT-IR

Potential of incorporating in-situ pavement oxidation index into PMS

Oxidation as major factor of HMA pavement deterioration

SHRP 2 advances in field applications of portable FT-IR

Use of Portable Infrared Spectroscopy for: in-situ testing of RAP
Infrared Spectroscopic Methods

**Fourier-Transform Infra-Red (FTIR) Spectroscopy**

- Bending vibration
- Stretching vibration

“Oxidation Signal”
From binder and mixture
Evolution of FT-IR Sampling Modes in Asphalt Studies

Transmission (since 1960s and SHRP - 1980s)

**Destructive**
1. Dissolve sample
2. Prepare KBr pellets
3. Place sample into a cell

Attenuated Total Reflection (ATR) (1990s and SHRP2 2009-2014)

**Non-invasive for binders**

**Mildly invasive for mixtures**
1. Sieve or drill
2. Bring sample to instrument

Hand-Held Diffuse Reflection (DR) - This study (Idaho 2015)
(a.k.a. Portable Infrared Spectrometer, or PIRS)

**Non-destructive**
(point-and-shoot)
1. Bring instrument to sample
First Demonstration Study - Idaho

Monitoring the consistency of HMA/RAP samples and in-place Pavement using a Portable Infrared Spectroscopy Device (PIRS)

Objectives:
1. Evaluate PIRS capability of estimating %RAP.
2. Provide recommendations for use of PIRS on future paving projects.

Select projects
- Low RAP
- Medium RAP
- High RAP

Collect materials
- Virgin binder
- Virgin agg.
- RAP

Mix calibration samples
- Vary %RAP
  - (0-15-30-100)
  - (0-25-50-100)

Measure oxidation in mixes
- Lab (calibration)
- Plant, pavement (validation)

Analyze data
- Variability
- Agreement between lab, plant, and pavement
- Influencing factors

Compare with Field results and Develop Recommendations
# First Demonstration Study - Idaho

## 3 Projects and Materials - Mix Designs

<table>
<thead>
<tr>
<th>Mix Design</th>
<th>Project 1</th>
<th>Project 2</th>
<th>Project 3</th>
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<tbody>
<tr>
<td>Project ID</td>
<td>“Karcher”</td>
<td>“Fruitland”</td>
<td>“Lewiston”</td>
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<td>Location</td>
<td>Nampa, ID</td>
<td>Nampa, ID</td>
<td>Lewiston, ID</td>
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<td>Traffic Level [ESAL]</td>
<td>1 - 10 mln</td>
<td>1 – 10 mln</td>
<td>10 – 30 mln</td>
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<tr>
<td>NMAS</td>
<td>12.5 mm</td>
<td>12.5 mm</td>
<td>12.5 mm</td>
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<td>Target PG</td>
<td>70-28</td>
<td>70-28</td>
<td>76-28</td>
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<tr>
<td>RAP [by agg.]</td>
<td>17%</td>
<td>54%</td>
<td>45% (40% mill + 5% pit)</td>
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<tr>
<td>Adjusted virgin PG</td>
<td>70-28</td>
<td>52-34</td>
<td>70-34</td>
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<tr>
<td>Target $P_b$</td>
<td>5.3</td>
<td>5.3</td>
<td>5.6</td>
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<tr>
<td>RAP $P_b$</td>
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<td>RAP PG (est.)</td>
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<td>PG 88-XX</td>
<td>PG 76(82)-XX (mill)</td>
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<tr>
<td>Antistrip</td>
<td>0.5%</td>
<td>0.5%</td>
<td>0.75%</td>
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</table>
First Implementation Study - Idaho

Lab mix sample processing for PIRS scanning

- Sieve through No.8- No. 30

Fill sampling cylinder

Use a hammer to compact sample

Plant mix sample processing for PIRS scanning
Example of Sampling cylinder with compacted HMA

D = ½ “  X  L = 2 “
Testing in the Field (PIRS pavement monitoring)

AT THE HMA PLANT-Lewiston

Karcher test section

Lewiston: in-place pavement
IR scans and oxidation signals

Calculation of Oxidation Signal from an absorbance spectrum of an asphalt mix sample.

\[ O \times S = \frac{A_{1700}}{A_{2920}} = \frac{1.245}{1.280} = 0.973 \]

- \( A_{2920} = 1.280 \)
- \( A_{1700} = 1.245 \)
Laboratory Results for RAP-HMA mixtures

Objective of analysis: Evaluate compliance with Beer Law (BL)

\[ OxS(a*A + b*B) = a*OxS(A) + (1-a)*OxS(B) \]

- \( A = \text{pure RAP (100\% RAP)} \)
- \( B = \text{virgin mixture (0\% RAP)} \)
- \( a = \% \text{RAP} \)
- \( b = \% \text{virgin mix} \)
- \( a + b = 100\% \)

If Meas. = BL then full blending
If Meas. < BL then partial blending
If Meas. > BL then
%RAP incorrect or sample overheated
Laboratory Calibration Curves for RAP-HMA

Objective of analysis:
2. Detect deviation of plant and pavement samples from the JMF

Results:
✓ All pavement measurements remained within 1 st.d. from JMF
✓ Plant signals were higher than pavement ones.
✓ Lewiston plant sample may be not representative (night time paving)
Example of Comparison of oxidation signals from JMF, HMA plant and in-place pavement

Mean and standard deviation; the error bars are one standard deviation from the mean of five samples.
Standard Method of Test for (proposed Provisional Standard)

Evaluation of Oxidation Level of Asphalt Mixtures by a Portable Infrared Spectrometer
What have we learned about RAP-HMA?

✓ On average, every 20% RAP to 0.1 unit Ox.Signal with St.d. = 10% RAP

✓ %RAP in HMA can be determined with 82% reliability based on no-RAP and 100% RAP measurements
Was developed by SRHP2 R06B research team for aged asphalts.

Was modified for RAP and submitted to AASHTO TS-2a by PPS, LLC

Scope:

✓ Covers semi-quantitative evaluation of the oxidation level in HMA.
✓ Based on the quantitative analysis of ATR or DR infrared spectrum.
✓ Sample is obtained from the pavement surface.
✓ Sample may be modified by adding RAP and/or RAS.
✓ Oxidation level in the samples is calculated based on the intensity of the signal associated with carbonyl content.

The oxidation signal from pavement surface is compared with predetermined signals from JMF and plant samples.

Testing frequency of threshold is established by an agency based on a pilot study.
Acknowledgements

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For further information:

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The Road Ahead