Solvent Extraction-Recovery Procedures and their Effect on Recovered Asphalt Properties

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Solvent Extraction-Recovery Procedures and their Effect on Recovered Asphalt Properties

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Sudbury, April 16th: Doubra Ambaiowei, Ph.D. – Technical Director, ORBA/OAPC
Ottawa, April 18th: Steve Goodman, Ph.D., PEng. – Gemtec Consulting Engineers and Scientists
Introduction

Asphalt binders specified based on their properties in an original state
• Performance Graded by AASHTO or ASTM

What about properties of in-situ asphalt mixtures?
• Research
• Forensic investigation
• Correct asphalt used in production
• Evaluate properties of blended asphalt binder (RAP or RAS)
Introduction

What options do we have to determine in-situ asphalt properties?
• Performance testing of asphalt mixture

• Physical properties of recovered asphalt
  • Since early 1900’s
Current known challenges with recovered asphalt testing:

1. Physical properties test results of recovered binders have much higher variability compared to unrecovered binders.

2. The choice of procedure and solvent can have an impact on the resulting physical properties of the recovered asphalt binder.

3. The effect of solvent extraction on polymer modified binders and impact on physical properties is still being investigated.
Single lab repeatability (d2s%) of G*/sinδ
NCHRP Project 09-12: RAP in Superpave System

Project Goal:
To develop guidelines for incorporating RAP in the Superpave System.

Part of research evaluated effect of different extraction-recovery procedures and solvents on high temperature properties of recovered asphalt binders.
NCHRP Project 09-12: RAP in Superpave System

![Graph showing G*/sin δ at 64°C, kPa for Kentucky RAP with different procedures and solvents.]

- Procedure-Solvent:
  - Centrifuge
  - Abson
  - TCE
  - Rotovapor
  - Toluene
  - SHRP

- Kentucky RAP

- Axes:
  - G*/sin δ at 64°C, kPa
  - Procedure-Solvent

- Data points for different procedures and solvents.
Why does it matter?

Most specifications don’t identify one extraction-recovery method.

It makes a difference in acceptance/rejection of material.
Research Objectives

1. Compare physical properties and testing variability of original (tank) asphalt to recovered asphalt

2. Compare laboratory aging and field aging through chemical analysis of functional groups of asphalt
Sampling Plan

Sample A - Terminal

Sample C – Plant Mix (Performance Testing)

Sample B – Tank Asphalt

Sample D – Job Site (Recovered)
**Asphalt Materials Collected**

<table>
<thead>
<tr>
<th>HMA Mix Class</th>
<th>PG Grade</th>
<th>RAP Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>HL1</td>
<td>70-28</td>
<td>0</td>
</tr>
<tr>
<td>12.5FC2</td>
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</tr>
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<tr>
<td>12.5FC1</td>
<td>58-34</td>
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</tr>
</tbody>
</table>
Research Objectives

1. Compare physical properties and testing variability of original (tank) asphalt to recovered asphalt

2. Compare laboratory aging and field aging through chemical analysis of functional groups of asphalt
Tank Asphalt and Recovered Asphalt

PG High Temp

<table>
<thead>
<tr>
<th>Tank Asphalt</th>
<th>Recovered Plant Mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG High Temp (°C)</td>
<td></td>
</tr>
</tbody>
</table>

Standard Deviation

Tank = 0.7 to 1.7
 Recovered = 1.7 to 9.4


- $y = x$
- $R^2 = 1$
- $y = 1.2027x - 7.6234$
- $R^2 = 0.5761$

PG High Temperature (Tank vs Recovered Asphalt)
$y = x$

$R^2 = 1$

$y = 1.2027x - 7.6234$

$R^2 = 0.5761$

PG High Temp (Tank vs Recovered Asphalt)

• HMA with 15% RAP
Standard Deviation

Tank = 0.3 to 2.4

Recovered = 0.5 to 10.6
PG Low Temperature (Tank vs Recovered Asphalt)

\[ y = 0.3517x - 20.693 \]
\[ R^2 = 0.0075 \]

\[ y = x \]
\[ R^2 = 1 \]
PG Low Temperature (Tank vs Recovered Asphalt)

$y = 0.3517x - 20.693$
$R^2 = 0.0075$

$y = x$
$R^2 = 1$

- HMA with 15% RAP
Tank Asphalt and Recovered Asphalt

Nonrecoverable Compliance

Standard Deviation

Tank = 0.04 to 0.17

Recovered = 0.01 to 3.69
Non Recoverable Compliance
(Tank vs Recovered Asphalt)

\[ y = 2.2203x - 0.3535 \]
\[ R^2 = 0.5895 \]

\[ y = x \]
\[ R^2 = 1 \]
Non Recoverable Compliance (Tank vs Recovered Asphalt)

- $y = 2.2203x - 0.3535$
  - $R^2 = 0.5895$
- $y = x$
  - $R^2 = 1$

- HMA with 15% RAP
Ash Content

• Test established in Ontario to determine inorganic content in asphalt cement

• Implemented by MTO “to prevent over-modification of AC with Re-Refined/Recycled Engine Oil Bottoms (REOB).”\(^1\)

• What about inorganic aggregate fines in recovered asphalt from plant produced mix?

Tank Asphalt and Recovered Asphalt
Ash Content

Standard Deviation

Tank = 0.02 to 0.14
Recovered = 0.68 to 2.92
Ash Content (Tank vs Recovered Asphalt)

\[ y = -1.6882x + 3.379 \]
\[ R^2 = 0.0285 \]

\[ y = x \]
\[ R^2 = 1 \]

- HMA with 15% RAP
The removal of mineral fines during the recovery procedure is critical to obtaining valid test results.

SHRP rotavapor procedure has a cartridge filter that helps remove more fine aggregate from effluent.
Research Objectives

1. Compare physical properties and testing variability of original (tank) asphalt to recovered asphalt

2. Compare laboratory aging and field aging through chemical analysis of functional groups of asphalt
Review: Asphalt Cement Properties

Asphalt is composed of extremely large number of organic molecules

Can be grouped into various molecular types and fractions:
- Saturates; Aromatics; Resins; Asphaltenes

Reacts with oxygen from environment

Oxidation/aging process changes the concentrations of these fractions
Aging Index

\[
\text{Absorbance AI} = \frac{\text{Toluene Soluble Asphaltenes}}{\text{Resins}}
\]

Aging index calculated using data from SAR-AD® on asphalt binders collected after various stages of aging in lab and field:

- RTFO lab aged binder
- 20hr PAV lab aged binder
- 40hr PAV lab aged binder
- Plant Mix (Recovered binder from mix that is field short term aged)
Lab aging getting close to field aging as difference approaches zero.
Aging Index of asphalt recovered from mix sampled from job site (field short term aged) is higher, or more oxidized than original (unaged) binder.
Aging Index of asphalt recovered from mix sampled from job site (field short term aged) is higher, or more oxidized than asphalt binder that is aged with RTFO (lab short term aged).
Aging Index of asphalt recovered from mix sampled from job site (field short term aged) is similar to, or just as oxidized as asphalt binder that is aged with RTFO+20hr PAV (lab long term aged).
Aging Index of asphalt recovered from mix sampled from job site (field short term aged) is less than, or less oxidized than asphalt binder that is aged with RTFO+40hr PAV (lab extended aging).
Summary

• The choice of procedure and solvent can have an impact on the resulting physical properties of the recovered asphalt binder

• During recovery aggregate fines remains in the recovered asphalt that will affect the physical properties
Summary

• Standard deviation on recovered asphalt binder are greater than the same values measured on tank asphalt binder.

• Asphalt aging in the field is more severe than what is currently done with lab aging (ie. Plant produced asphalt is not equal to RTFO aged asphalt)
Recommendations

• SHRP rotavapor method for recovery uses lower temperature and higher vacuum which could help minimize hardening during the recovery process

• Cartridge filter in SHRP rotavapor toluene procedure may remove more fine aggregate from the effluent

• Toluene solvent has least interference with polymers in asphalt

• Investigate performance testing for accessing asphalt mix quality