Forensic Analysis of a 22-Year Old 35% RAP Interstate Project

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Field Sections

- Paved in 1987
- I-93 Travel & Shoulder
  - 20,000 ADT
  - 35% RAP Surface
  - 35% RAP Binder
- I-89 Travel & Shoulder
  - 36,000 ADT
  - 0% RAP Surface
  - 15% RAP Binder
- 19 mm max size
- AC-10 virgin binder
- Cores taken in 2010
Field Cores

• Cores cut for test specimens
  – 1.5” thick specimens
  – Surface layer
  – Intermediate layer

• Testing
  – IDT mode
  – Dynamic Modulus
  – Creep and Strength
## Air Voids

<table>
<thead>
<tr>
<th>Pavement</th>
<th>Lane</th>
<th>Layer</th>
<th>Air Void</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-93</td>
<td>Travel</td>
<td>Surface</td>
<td>2.2%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intermed</td>
<td>5.1%</td>
</tr>
<tr>
<td></td>
<td>Shoulder</td>
<td>Surface</td>
<td>3.8%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intermed</td>
<td>5.0%</td>
</tr>
<tr>
<td>I-89</td>
<td>Travel</td>
<td>Surface</td>
<td>4.0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intermed</td>
<td>2.6%</td>
</tr>
<tr>
<td></td>
<td>Shoulder</td>
<td>Surface</td>
<td>7.6%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intermed</td>
<td>5.1%</td>
</tr>
</tbody>
</table>
Binder Testing

• Extraction & Recovery by NHDOT
  – AASHTO T-164 & T-170
• Recover binder at 3 depths
  – Top & middle from surface
    • Except I89 Travel Lane
  – Bottom from intermediate
• Testing
  – DSR frequency sweep
  – BBR
  – DT

<table>
<thead>
<tr>
<th>Surface</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5” Top</td>
</tr>
<tr>
<td></td>
<td>1.0” Middle</td>
</tr>
<tr>
<td></td>
<td>1.0” Bottom</td>
</tr>
</tbody>
</table>
Project Objectives

• Evaluate differences
  – High RAP and low/no RAP sections
  – Travel vs Shoulder
  – Pavement layer

• Recovered binder and mixture testing
Binder Testing & Results
High Temperature Grade
Low Temperature Grade

Low PG Spec Temperature, C

-34.0
-28.0
-22.0
-16.0

9335t
9335m
9335b
9375t
9375m
9375b
8950t
8950m
8950b
8970t
8970m*
8970b

S value
m value
Difference between m-temp and S-temp
Critical Cracking Temperature

Critical Cracking Temperature, °C
G* Master Curves

![G* Master Curves Graph]

- |G*| (MPa)
- Reduced Frequency (Hz)
- 93T35t
- 93T35m
- 93T35b
- 93S35t
- 93S35m
- 93S35b
- 89T0t
- 89T15m*
- 89T15b
- 89S0t
- 89S15m
- 89S15b
Travel Lane G* Ratios with Depth

Ratio of $|G^*|$ Master Curves

Reduced Frequency

I-93 Top/Mid
I-93 Mid/Bot
I-93 Top/Bot
I-89 Top/Mid
I-89 Mid/Bot
I-89 Top/Bot
Shoulder G* Ratios with Depth

![Graph showing Shoulder G* Ratios with Depth](image_url)

- I-93 Top/Mid
- I-93 Mid/Bot
- I-93 Top/Bot
- I-89 Top/Mid
- I-89 Mid/Bot
- I-89 Top/Bot
RAP Level G* Ratios with Depth

Ratio of |G*| Master Curves

Reduced Frequency

I-93 Tr/ I-89 Tr Top
I-93 Tr/ I-89 Tr Mid
I-93 Tr/ I-89 Tr Bot
I-93 Sh/I-89 Sh Top
I-93 Sh/I-89 Sh Mid
I-93 Sh/I-89 Sh Bot
Mixture Testing & Results
Dynamic Modulus Master Curves

- 93 Tr Surf 2.2% AV
- 93 Tr Int 5.1% AV
- 93 Sh Surf 3.8% AV
- 93 Sh Int 5.0% AV
- 89 Sh Surf 7.6% AV
Low Temperature Strength

Strength at -10°C (psi)

- I93 Tr Surf 2.2% AV
- I93 Tr Int 5.1% AV
- I93 Sh Surf 3.8% AV
- I93 Sh Int 5.0% AV
- I89 Sh Surf 7.6% AV
Mix Cracking Temperature

Cracking Temperature (°C)

-12 -9 -6 -3 0

I93 Tr Surf 2.2% AV
I93 Tr Int 5.1% AV
I93 Sh Surf 3.8% AV
I93 Sh Int 5.0% AV
I89 Sh Surf 7.6% AV
Summary and Conclusions
Summary of Binder Results

- High PG grades
  - similar between high RAP and low/no RAP
  - Shoulders stiffer than travel lanes (2 grades at top)
- Low PG grades & CCT
  - Most m-controlled
  - Shoulder stiffer than travel lanes - more with low/no RAP
  - Impact of RAP observed in travel lanes, not as large of a difference in shoulder lanes
- Master Curves
  - Larger differences with depth for low/no RAP
  - Little impact of RAP at surface
Summary of Mixture Results

- Only one virgin mixture, air void differences
- RAP mixes decrease in stiffness and strength with depth
- Mixed results comparing travel and shoulder
- Virgin mix stiffest, lowest strength, warmest cracking temperature
Overall Conclusions

- Binder data indicates there is difference in how RAP mixtures and low/no RAP mixtures age
- More uniform properties between layers and lanes in high RAP pavements
- Differences between RAP and low/no RAP are smaller at the surface and in shoulder
- Implications in terms of how properties/performance change over life of pavement
Future Work

• Include test sections of wider range of RAP contents
  – PG 58-28: 0%, 15%, 25% RAP
  – PG 52-34: 25%, 30%, 40% RAP

• Evaluate initial mixture and binder performance

• Evaluate mixture and binder performance at regular time intervals throughout pavement service life
Acknowledgements

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Infrastructure and Climate Network (ICNet)

- www.theicnet.org
- Webinar series

CLIMATIC CHANGE IMPACTS ON FUTURE PAVEMENT PERFORMANCE AND MAINTENANCE COSTS

Wednesday October 30, 2013 at 2pm EDT
Questions?