Research Team

- Fujie Zhou, Ph.D., P.E.  
  Texas A&M Transportation Institute
- Michael Elwardany, Ph.D., P.E.  
  Florida State University
- David Mensching, Ph.D., P.E.  
  Federal Highway Administration
Outline

- Introduction
- Estimation of equivalent aging temperatures for 20 hours
- Laboratory evaluation of the equivalent aging temps. using IDEAL-CT
- Laboratory verification of the equivalent aging temps. using IFIT and OT
- Comprehensive BMD
- Summary and conclusions
Introduction

- Many DOTs are turning to BMD to address several inter-related issues:
  - Mix durability, recycled materials, additives and ever-changing binders
- One critical issue for BMD is loose mix aging protocol for new pavement.
- Objective of this study is to develop a practical long-term aging protocol, considering of pavement life and distresses.
  - Aging temperature
  - Aging duration
  - Loose mix thickness
Introduction

- Long-Term aging protocols:
  - AASHTO R30 specifies 120 hours (5 days) at 85°C using compacted specimens.
  - Based on literature review, researchers suggested to age loose mixtures at 135°C for 24 hours.
  - NCHRP 9-54 suggested to age loose mixtures at 95°C from 1 day to more than 20 days depending on location, years, and depth from pavement surface.
Introduction

- Definition of “long-term” for new asphalt pavements
  - Design life of new asphalt pavement is about 15-20 years
  - Fatigue cracking often occurs at 2/3 of the pavement life, around 10-13 yrs
    - Fatigue cracking initiates at the bottom of asphalt layers

- Summary:
  - 12 years for fatigue cracking
Introduction

- This study recommends:
  - Loose mix thickness: 1.5-2.0" - R 30
  - Duration: 20 hrs
  - Temperature: TBD
Dr. Elwardany et al. applied kinetics models with the universal reaction kinetics constant values to make the estimation.

\[ y = -0.1833x^2 + 6.694x + 92.078 \]

\[ R^2 = 0.99 \]
Laboratory evaluation of equivalent aging temp.

- Seven mixes with various asphalt binders

<table>
<thead>
<tr>
<th>Mixture type</th>
<th>Aggregates</th>
<th>Virgin binder</th>
<th>RAP</th>
<th>Total asphalt content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>9.5 mm Superpave</td>
<td>PG64-22-Source 1</td>
<td>None</td>
<td>5.5</td>
</tr>
<tr>
<td>#2</td>
<td>9.5 mm Superpave</td>
<td>PG64-22-Source 2</td>
<td>None</td>
<td>5.5</td>
</tr>
<tr>
<td>#3</td>
<td>9.5 mm Superpave</td>
<td>SHRP AAG</td>
<td>None</td>
<td>5.5</td>
</tr>
<tr>
<td>#4</td>
<td>9.5 mm Superpave</td>
<td>SHRP AAD</td>
<td>None</td>
<td>5.5</td>
</tr>
<tr>
<td>#5</td>
<td>9.5 mm Superpave</td>
<td>PG76-22-Source 3</td>
<td>None</td>
<td>5.5</td>
</tr>
<tr>
<td>#6</td>
<td>9.5 mm Superpave</td>
<td>PG76-28-Source 4</td>
<td>None</td>
<td>5.5</td>
</tr>
<tr>
<td>#7</td>
<td>9.5 mm Superpave</td>
<td>Granites</td>
<td>PG64-28-Source 5</td>
<td>15% RAP</td>
</tr>
</tbody>
</table>

- Laboratory test: IDEAL cracking test with 4 replicates
Laboratory evaluation of equiva. aging temp.

- Loose mix aging conditions before compacting IDEAL-CT specimens
  - Aging conditioning 1: 20-hr at 100°C
  - Aging conditioning 2: 20-hr at 115°C
  - Aging conditioning 3: 20-hr at 125°C
  - Aging conditioning 4: 3-day at 95°C
  - Aging conditioning 5: 6-day at 95°C

- Total IDEAL-CT specimens: 140
  - 7 mixes × 5 agings × 4 replicates
Laboratory evaluation of equiva. aging temp.

- IDEAL-CT test results at multiple aging conditions
  - 3-day@95°C ≈ 112°C@20hr
  - 6-day@95°C ≈ 120°C@20hr
Laboratory evaluation of equiva. aging temp.

- IDEAL-CT test results at multiple aging conditions
  - 3-day@95°C ≈ 112°C@20hr
  - 6-day@95°C ≈ 120°C@20hr
Laboratory evaluation of equiva. aging temp.

- Equivalent aging temperatures for 7 mixes
  - 3-day @ 95°C ≈ 110-112°C @ 20hr
  - 6-day @ 95°C ≈ 120°C @ 20hr

<table>
<thead>
<tr>
<th>Asphalt Mixes</th>
<th>Aging Temp.-20hrs for 3-day at 95°C</th>
<th>Aging Temp. -20 hrs for 6-day at 95°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix 1 with PG64-22-Source 1</td>
<td>112°C</td>
<td>120°C</td>
</tr>
<tr>
<td>Mix 2 with PG64-22-Source 2</td>
<td>110°C</td>
<td>120°C</td>
</tr>
<tr>
<td>Mix 3 with SHRP AAG</td>
<td>112°C</td>
<td>120°C</td>
</tr>
<tr>
<td>Mix 4 with SHRP AAD</td>
<td>110°C</td>
<td>120°C</td>
</tr>
<tr>
<td>Mix 5 with PG76-22-Source 3</td>
<td>112°C</td>
<td>120°C</td>
</tr>
<tr>
<td>Mix 6 with PG76-28-Source 4</td>
<td>112°C</td>
<td>120°C</td>
</tr>
<tr>
<td>Mix 7 with PG64-28-Source 5</td>
<td>112°C</td>
<td>120°C</td>
</tr>
</tbody>
</table>
Laboratory verification of equivalency aging temperature.

- Two mixes: one from Massachusetts and one from Texas

<table>
<thead>
<tr>
<th>Mixture type</th>
<th>Aggregates</th>
<th>Virgin binder</th>
<th>RAP</th>
<th>Total asphalt content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>9.5 mm Superpave</td>
<td>Igneous</td>
<td>HiMA binder PG-28</td>
<td>None</td>
</tr>
<tr>
<td>#7</td>
<td>9.5 mm Superpave</td>
<td>Granites</td>
<td></td>
<td>15% RAP</td>
</tr>
</tbody>
</table>

- Five aging conditions as previous
  - Aging conditioning 1: 20-hr at 100°C
  - Aging conditioning 2: 20-hr at 112°C
  - Aging conditioning 3: 20-hr at 120°C
  - Aging conditioning 4: 3-day at 95°C
  - Aging conditioning 5: 6-day at 95°C
Laboratory verification of equiva. aging temp.

- Two cracking tests: IFIT for Massachusetts mix and OT for Texas mix
Laboratory verification of equivalent aging temp.

- IFIT for Massachusetts mix
Laboratory verification of equiva. aging temp.

- OT for Texas mix
Summary and Conclusions

- IDEAL-CT data showed that equivalent aging temperatures for 20 hrs to match 3 and 6 days aging at 95°C are 110°C and 120°C, respectively. This observation is confirmed by OT and IFIT.

- MassDOT BMD integrates both short-and long-term loose mix aging protocols into a coherent BMD.
Outcome of the Study: Comprehensive BMD

1. Volumetric Mixture Design

2. Mixture Performance Test
   Short-Term Oven Aging (STOA)

3. Mixture Performance Test
   Long-Term Oven Aging (LTOA)

4. Performance Tests During
   QC/QA
   Short-Term Oven Aging (STOA)

- Rutting
  STOA Criteria

- Cracking
  STOA Criteria

- Cracking
  LTOA Criteria
Thank You