Evaluation of the Asphalt Binder Cracking Device (ABCD)

Presented By:

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Acknowlegements

- Work be conducted under the NJDOT Pavement Support Program (Manager: Robert Blight)
- Rutgers Asphalt Pavement Lab (RAPL) Staff
  - Asphalt Binder: Nick Cytowicz, Chris Ericson
AASHTO T313

Deflection Transducer

Asphalt Beam
Original Position

Asphalt Beam
Deflected Position

Deflection

\[ \Delta(t) \]

simulates stiffness after 2 hours at 10°C lower temp

Log Creep Stiffness, \( S(t) \)

slope = m-value

Log Loading Time, \( t \) (sec)

AASHTO T314

Load

\[ \Delta L \]

\[ L \]

\[ L + \Delta L \]

Failure Strain, %

\[ \varepsilon_f = \frac{\Delta L}{L} \]

brittle - ductile

ductile

stress

brittle

brittle-ductile

ductile

Temperature

AASHTO R49 (1999)

Thermal Stress

Fracture Stress

\[ T, ^\circ C \]

AASHTO T313 and T314 diagrams illustrate the deflection and creep stiffness of asphalt beams, with the 1990s AASHTO standards (T313 and T314) and failure strain calculations.
As asphalt binders age, the relaxation properties (m-value) are negatively affected at greater rate than the stiffness (S).

The difference between the low temperature cracking grade of m-value and S is defined as the $\Delta T_c$

$$\Delta T_c = T_{c,S} - T_{c,m\text{-value}}$$

AAPT (Anderson et al., 2011) showed that the $\Delta T_c$ correlated to non-load associated cracking on airfields (i.e. – cracking due to lose of ductility from aging)
\[ \Delta T_c \text{ from BBR Testing} \]

<table>
<thead>
<tr>
<th>Agency</th>
<th>(\Delta T_c) Requirement, °C</th>
<th>PAV Aging Duration, hrs.</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Florida DOT</td>
<td>(\geq -5.0)</td>
<td>20</td>
<td>Current</td>
</tr>
<tr>
<td>Utah DOT</td>
<td>(\geq -2.0)</td>
<td>20</td>
<td>Current</td>
</tr>
<tr>
<td>PANYNJ</td>
<td>(\geq -5.0)</td>
<td>40</td>
<td>Current</td>
</tr>
<tr>
<td>Vermont DOT</td>
<td>(\geq -5.0)</td>
<td>40</td>
<td>Current</td>
</tr>
<tr>
<td>Maryland DOT</td>
<td>(\geq -5.0)</td>
<td>40</td>
<td>Current</td>
</tr>
<tr>
<td>Kansas DOT</td>
<td>(\geq -5.0)</td>
<td>40</td>
<td>Current</td>
</tr>
<tr>
<td>Ontario MTO</td>
<td>(\geq -5.0)</td>
<td>20</td>
<td>Current</td>
</tr>
<tr>
<td>Texas DOT</td>
<td>(\geq -6.0)^4</td>
<td>20</td>
<td>Current</td>
</tr>
<tr>
<td>Oklahoma DOT</td>
<td>(\geq -6.0)</td>
<td>20</td>
<td>2020^3</td>
</tr>
<tr>
<td>Delaware DOT</td>
<td>(\geq -5.0)</td>
<td>40</td>
<td>2020^3</td>
</tr>
</tbody>
</table>

1. Consult Asphalt Institute website for current asphalt binder specification database (www.asphaltinstitute.org)
2. Only applies to binders with \(\geq 92^\circ C\) temperature spread; BBR creep stiffness \(\geq 150\) MPa
3. Applies to project tendered for bid beginning 1/1/2020
4. Only applies to Balanced Mix Design projects. For comparison, TxDOT requirement is shown using \(\Delta T_c\) computed by \(\Delta T_c = T_{cs} - T_{cm}/2\); actual requirement is \(\Delta T_c \leq 6^\circ C\) using the equation \(\Delta T_c = T_{cm} - T_{cs}\). (41)
\( \Delta T_c \) from BBR Testing

- \( \Delta T_c \) has shown to provide good relationship to observed field cracking
  - Found to be related to relaxation properties of asphalt binders
  - Sensitive to asphalt binder elements that may accelerate age hardening
- However, some concern over heavily polymer modified binders
  - Asphalt binder phase angle related to \( \Delta T_c \) (relaxation properties)
  - High PMA reduces \( \delta \), which results in poor performance with \( \Delta T_c \)
- There is a need for a test method that can capture fracture & strain tolerance properties (properties enhanced by polymers)
Asphalt Binder Cracking Device (ABCD) – AASHTO T387
The ABCD determines the critical cracking temperature due to thermally induced stress

- Asphalt binder poured between an invar and latex mold to form a ring
- Chamber cools the specimens at -20°C per hr
- Strain gauge determines when "cracking" occurs and specimen temperature when this occurs is determined as $T_{cr}$
Asphalt Binder Cracking Device (ABCD)

- System utilizes four (4) rings and temperature chamber
  - ≈ 11 grams binder per ring
  - Rings instrumented with thermistor and strain gauge

- Precision/Bias for $T_{cr}$
  - Single Operator Range of Results
    - Cracking Temp = 2.69°C
    - Fracture Stress = 2.43 MPa
  - Multiple Operator Range of Results
    - Cracking Temp = 3.85°C
    - Fracture Stress = 3.20 MPa
In general, colder ABCD $T_{cr}$ than low temperature PG

![Graph showing the relationship between ABCD low temperature critical cracking and low temperature PG grade.](image)

- For ABCD low temperature critical cracking ($^\circ$C):
  - $y = 0.8997x + 2.4418$
  - $R^2 = 0.7426$

- For low temperature PG grade ($^\circ$C):
  - $y = 0.5286x - 11.008$
  - $R^2 = 0.7643$
The $T_{cr}$ parameter by itself may not provide a good correlation to cracking for all binders

- $T_{cr}$ is a function of fracture strength, which in turn is a function of the stiffness
  - Modifiers like REOB reduces stiffness

- To normalize the impact of stiffness, NCHRP 9-60 researchers recommended $\Delta T_f$

$$\Delta T_f = T_{c_r} - S - T_{cr}$$
NCHRP 9-60 Approach

Fracture Toughness

Age Hardening/Relaxation Properties

Good

Poor

Proposed Criteria

DENT CTOD @ 25°C

y = -11.58ln(x) + 2.7963

R² = 0.7508
As the asphalt industry moves towards Balance Mixture Design, suppliers will turn to the liquid supplier for guidance. A methodology that better predicts/ranks cracking potential of asphalt binders is critical. Rutting is pretty well defined with the high temperature PG grade and Multiple Stress Creep Recovery (MSCR) tests.
Sensitivity to Asphalt Modifiers
REOB used to obtain low temperature grades from stiffer asphalts

- Small dosages with compatible base can be helpful
- Higher dosages will drive binder performance to lower left of space
  - Increased age hardening
  - Decrease in fracture strength
Increase in SBS will improve fracture toughness

However, lower resultant phase angles may show more negative $\Delta T_c$

NCHRP 9-60 identified in early studies how SBS performed, resulting in curved area

(Elwardany et al., 2020)
Sensitivity to Modifiers – Recycled Asphalt

- Asphalt binder recovered from top ½” of FHWA ALF
  - Higher recycled content/harder recycled asphalt drives to lower left of space
  - Approach could provide insight into rejuvenator selection
Different recycled plastic types high shear milled into a PG64-22 and PG58-28 asphalt binder

- Differentiates the impact of plastic type & base asphalt binder grade
Field Performance
Field Verification

- Multiple pavements noted as having top-down cracking used to help validate tests and proposed criteria
  - Asphalt airfield pavements
    - PANYNJ field engineers observations
    - FAA Extended Pavement Life project
      - Consultant visual distress surveys
  - FHWA ALF Experiment
    - Cycles to 1\textsuperscript{st} Crack
  - NYSDOT Modifier Study
Asphalt Airfield Pavements

<table>
<thead>
<tr>
<th>Airfield Pavement</th>
<th>Intermediate Temp</th>
<th>ΔTc</th>
<th>ΔTf</th>
<th>Visual Distress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuscon</td>
<td>29</td>
<td>-4.2</td>
<td>-2.0</td>
<td>Block, L&amp;T Cracking, PCI = 56 (+/- 20)</td>
</tr>
<tr>
<td>Kansas City</td>
<td>22</td>
<td>-6.8</td>
<td>-1.8</td>
<td>Block, L&amp;T Cracking, PCI = 57 (+/- 17)</td>
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<tr>
<td>BWI</td>
<td>25</td>
<td>0.4</td>
<td>2.2</td>
<td>Low Severity Weathering, PCI = 93 (+/- 3)</td>
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<tr>
<td>Columbus</td>
<td>22</td>
<td>-1.2</td>
<td>3.3</td>
<td>No Cracking, PCI = 100</td>
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<tr>
<td>Greensboro</td>
<td>27</td>
<td>-4.0</td>
<td>1.8</td>
<td>Low Severity Weathering/Cracking, PCI = 89 (+/- 2)</td>
</tr>
</tbody>
</table>
FHWA ALF Sustainability Study

<table>
<thead>
<tr>
<th>Lane</th>
<th>(\Delta T_c)</th>
<th>(\Delta T_f)</th>
<th>ABCD (T_{cr})</th>
<th>(LT) (s)</th>
<th>(LT) (m)</th>
<th>Cycles to 1st Crack</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane 1</td>
<td>-1.9</td>
<td>-5.1</td>
<td>-23.0</td>
<td>-28.1</td>
<td>-26.2</td>
<td>368,254</td>
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<tr>
<td>Lane 3</td>
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<td>-12.3</td>
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<td>-27.3</td>
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<td>Lane 4</td>
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<td>-18.7</td>
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<tr>
<td>Lane 5</td>
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<tr>
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<td>Lane 11</td>
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<td>-21.1</td>
<td>-25.0</td>
<td>-21.0</td>
<td>81,044</td>
<td></td>
</tr>
</tbody>
</table>
NYSDOT Modifier Study

- NYSDOT evaluated different asphalt modifiers
  - Plant produced and placed in field for evaluation
- NY Rt. 32 SB
  - 9.5mm surface course, 5.7% AC
  - Binders formulated to achieve 76-22
- 5 years of surface life (2020) – no distress observed on any section
Current research at Rutgers looking at how the mixture performance results fall within the NCHRP 9-60 approach

- Asphalt binders recovered from mixture performance specimens
General Conclusions and Observations
The ABCD test shows promise in characterizing asphalt binders
- BBR good for stiffness and relaxation & $\Delta T_c$
- ABCD for thermal contraction, strain tolerance, fracture toughness

Combined with $\Delta T_c$, a performance space can be generated that shows good correlation to field performance
- Support and guidance on asphalt binder selection will be needed as we move into BMD

NCHRP 9-60 proposed inclusion in grading
- Determine $\Delta T_c$ from BBR
- If $-6 \degree C < \Delta T_c < -2 \degree C$, conduct ABCD to evaluate fracture toughness
Thank you for your time!
Questions?

BE CAREFUL WHEN YOU ONLY
READ CONCLUSIONS...

Reference: The Anscombe's quartet, 1973

Designed by @YLMSportScience

These four datasets have identical means, variances & correlation coefficients.

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