NEAUPG Binder Committee Activities

Binder ETG Meeting
Fall River, MA
May 10, 2018
Gregory A. Harder, P.E.
• What is Delta Tc ($\Delta T_c$)?
  • A new binder parameter used to measure the age related cracking potential of asphalt binders
  • It uses lab testing equipment currently being used in binder specifications

• What is extended aging?
  • Additional laboratory binder aging above and beyond what is required by the current specs
  • When used in conjunction with $\Delta T_c$ can identify binders with increased aging and cracking potential
What is $\Delta T_c$?

- Defined as the difference between S and m criteria with the BBR
  
  \[ \Delta T_c = T_{cs(300\,\text{Mpa})} - T_{cm(0.300)} \]

- $T$ is the grade temperature for either S or m

- $\Delta T_c = -3.0^\circ\text{C}$ - Cracking Warning

- $\Delta T_c = -5.0^\circ\text{C}$ - Cracking Limit
$\Delta T_c$ vs Distress

Gerry noted .... “shows that Total Distress is also well correlated to the $\Delta T_c$ for the binder recovered from the top ½ inch of the 8 year old field cores”
• States agreed that suppliers must indicate on their QC plans the type of modification used
• Inclusion of any of the materials listed would be considered modifying the asphalt binder
• Must list only the materials used but no formulations nor any incidental additives as they may be proprietary
• Must also indicate on the BOL if the grade of binder is modified and if there is any special handling requirements
List of potential Binder Modifiers (AMAP) (01/05)

Types of Modification
- Block Copolymers (SB, SBS)
- SBR Latex
- Polyolefins
- Engineered Binders
- Crumb Rubber
- Chemical Polyolefins (Plastomers)
  - Molecules containing a simple double bond are olefins
  - Types of polyolefins
- Low Density Polyethylene (LDPE)
- Reactive Terpolymer (Elvaloy AM)
- Ethylene Vinyl Acetate (EVA)
- Polyolefin (Vestoplast)
- Functionally modified polyolefin (EE-2)
- Amorphous PolyAlpha Olefins (APAO)

Crumb Rubber
- Crumb Rubber is made up of two different materials from the waste stream
- Reclaimed Rubber (Raw unprocessed rubber)
- Recycled Rubber (Processed used tires)
- Ground tires can contain a wide range of polymers
- Natural Rubber
- SBR
- Polybutadiene
- Tires also contain Carbon Black, Silica and other ingredients

Chemical Modification
- Polyphosphoric Acid (PPA)
  - Oxidized (Air Blown)
- Liquid anti-strip
- Others
RE: Identification of PG Binder Additives

Effective immediately, all additives in PG Asphalt Binder supplied for projects using State, Federal or Chapter 90 funds shall be specifically identified in the Certificates of Analysis (COA). The COA shall include the PGAB grading inclusive of all additives as shipped from the Asphalt Terminal to the HMA Producers facility. The identification of these additives will include the amount of the additive (as a percentage by mass). The PG Binder Supplier shall also provide a statement in the Certificate of Analysis that the PG Binder does not include any additives/modifications not specifically approved by MassDOT.

The following are examples of non-asphalt additives:

- Adhesion agents (e.g. fatty amine derivatives, imidazolines)
- Ground tire rubber
- Emulsifiers
- Natural asphalts
- Petroleum distillates (e.g. Naphtha, kerosene, gas oil)
- Polymers (e.g. Styrene-Butadiene rubbers, Atactic Polypropylene, Ethylene Vinyl Acetate, Ethylene Terpolymers)
- Polyphosphoric Acid (PPA)*
- Residue from Refined Engine Oil Bottoms (REOB), transmission fluid, re-refined oil
- Sulphur
- Waxes (e.g. Synthetic, Natural)
- Bio binders (e.g. Vegetable based components)
- Warm Mix systems (e.g. surfactants, natural or synthetic waxes)
- Air-blown asphalt (and fluxes) and/or asphalt/fluxes subject to accelerated aging methods
- Other non-asphalt additives (organic or inorganic)

*PPA modified binder cannot be used with aggregates or RAP containing limestone.

MassDOT has lifted the restriction on the use of REOB in asphalt binder pending the outcome of its research efforts evaluating the performance of asphalt pavement mixtures containing REOB. The PG binder must not contain any additives/modification not specifically approved by the Department. MassDOT will continue to work with the asphalt industry to ensure that the materials used in construction of our roadways are of the highest quality.

Very truly yours,

John E. Grieo, P.E.
Director, Research and Materials

Cc: P. Leavensworth, Chief Engineer
    M. McGrath, Deputy Chief Engineer of Construction
    E. Nardi, Pavement Management Engineer
    B. Engenre, Binder Lab Supervisor

Four Hundred D Street, Boston, MA 02110
Tel 617-951-0990, FAX 617-913-7306
www.mass.gov/massdot

Lending the Nation in Transportation Excellence
The following are examples of non-asphalt additives:

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- Ground tire rubber
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*PPA modified binder cannot be used with aggregates or RAP containing limestone.
Moving Forward

• Develop list of additives/modifiers
• Develop a protocol on how to use/report this list
• Establish a team to take on this effort
• The result was a Non-Bituminous Component Disclosure – much of which came from IS-230

*Bitumen Industry – Global Perspective*
1. **Modified Bituminous Products**

Products which are mixtures of bitumen with non-bituminous components can be classified as modified asphalt. Modification methods to improve properties of asphalt for desired end use characteristics have been utilized for about as long as asphalt has been used. Modification techniques are primarily dependent on the desired performance of the final product and product specifications.
1.1. Chemical Modification

- Adhesion Promoters (e.g. fatty amine derivatives, imidazolines)
- Phosphorous Compounds (e.g. phosphorous pentoxide, polyphosphoric acid)
- Elemental Sulphur
- Maleic Anhydride
- Warm Mix systems (e.g. Utilizing surfactants or chemical lubricating additives)
- Oxidized Asphalt
- Oxidants (e.g. manganese salts)
- Antioxidants (e.g. lead compounds, carbon, calcium salts)
- Other (e.g. silicone)

Chemical modifiers are generally utilized at levels below 1 %m, as are many of the warm mix systems based on additives blended into the bitumen.
1.2. Polymer and Rubber modification

- Natural Polymers (e.g. Lignin)
- Thermoplastics/plastomers (e.g. polypropylene, polyethylene, ethylene vinyl acetate, ethylene acrylate copolymer, polyvinyl chloride, ethylene propylene, reactive terpolymer, polyolefin)
- Elastomers (e.g. natural rubber, synthetic rubber, polybutadiene, butyl rubber, polychloroprene latex)
- Thermoplastic Elastomers (e.g. styrenic block copolymers, polyolefin blends, thermoplastic polyurethane, styrene isoprene styrene)
- Ground Tire Rubber (e.g. reclaimed scrap tires)

Polymer additives generally range from 1% to typical levels of 3%, to as much as 7% for some applications. Crumb rubber (Ground Tire Rubber) can range from as little as 5% to as much as 20% by weight of the total binder, depending on the properties being targeted.
1.3. Fillers and extending agents

- Waxes (e.g. synthetic such as Fischer-Tropsch, natural such as Montan and amide derivatives such as Ethylene Bis-stearamide)
- Bio-binders (e.g. vegetable based components, animal by-products and waste)
- Warm Mix systems (e.g. synthetic and natural waxes)
- Products from re-refining of lubricating oils (e.g. Re-refined Engine Oil Bottoms (REOB))
- Petroleum Distillates (e.g. naphtha, kerosene, gas oil, aromatic oil, naphthenic oil, paraffinic oil)
- Other non-bituminous additives (organic or inorganic)
1.4. Communication of Additives and Modifiers

Manufacturers of bitumen products should comply with hazard classification and communication regulations for the product and, as appropriate, identify any hazardous additives used in the product, in addition to any hazards or risks arising from the non-bituminous component(s). If appropriate, any risk transferred to the bitumen product should be identified. The non-bitumen blend components identified above are added at varying dosage levels depending on the additive.

All non-bituminous components added to the binder prior to the sampling point for binder certification shall be included on the asphalt binder certificate of analysis identifying their presence but shall not include actual dosage. All non-bituminous components added after the certification sampling point and prior to transport shall be included on the bill of lading. All non-bituminous components added to the binder at the HMA plant shall be identified on the mix plant documentation.

The list above is not all inclusive – any non-bituminous component including those not specifically listed above must be identified appropriately. The list above shall not be considered as an approved product list – check with each individual agency to determine which components are allowed for use.
Where are we now?

• xxDOT – “Standard PG binder shall be defined as “Neat”. Neat PG binders shall be free from modification with: fillers, extenders, reinforcing agents, adhesion promoters, thermoplastic polymers, acid modification, and other additives such as re-refined motor oil, and shall indicate such information on each bill of lading and certified test report.”

“The modified asphalt binder shall be Performance Grade PG 64E-22 asphalt solely modified with a Styrene-Butadiene-Styrene (SBS) polymer.”
Where are we now?

- xxDOT – “The asphalt cement shall be homogeneous, free from water, ... If additives are used for the modification of asphalt, preapproval is required. The addition of any material not normally obtained during the initial refining process shall constitute modified asphalt and shall be labeled appropriately.”

- xxDOT – currently prohibits the use of REOB – now considering banning the use of “VGO” from the re-refining of engine oils

- xxDOT – prohibits air blown asphalts
Where are we now?

- xxDOT – has a specification that requires that PG 70-34 must be made with a minimum of 4% polymer, a minimum of 4% aromatic oil, and shall not contain any other materials including VGO
Why?

- Current 20-hour PAV aging may be insufficient
- Recent work suggests that 40-hour aging in the PAV is approximately 7-15 years in service
- Superpave intended to be blind to modification
- Build confidence in the $\Delta T_c$ parameter and provide a means for DOT’s to get away from restrictive (prescriptive) specs
Why not?

Adding Cigarette Butts to Asphalt Can Improve Roads

It also prevents their noxious chemicals from leaching into waterways.

BY KELSEY KENNEDY    AUGUST 07, 2017
Delta Tc / Extended Aging ILS

• 23 labs (10 suppliers, 9 DOT’s, FHWA, 3 Universities)
• Two binders
  • Binder A – PG 58S-28
  • Binder B – PG 64E-22
• Four Aging Conditions:
  • Method A – Standard 20-hour PAV
  • Method B – 20+20-hour PAV
  • Method C – 20+4+20-hour PAV
  • Method D – 40-hour PAV
Participating Labs (not in order)

- Suit-Kote
- Axeon
- Marathon
- Midland
- Peckham
- Gorman
- Canadian Asphalt
- McAsphalt
- ASMG
- Pike
- NJDOT
- NYSDOT
- NHDOT
- VTAOT
- DelDOT
- MDSHA
- CTDOT
- PennDOT
- RIDOT
- FHWA
- Rutgers
- UCONN
- Rowan
• Objectives:
  • Familiarize labs with these procedures and the impact on lab operations
  • Determine differences in aging methods
  • Build confidence in the $\Delta T_c$ parameter and steer the DOT’s away from restrictive (prescriptive) specs
1. Preheat oven to 275F (135C) for a minimum of 4 hours

2. Remove lid and then place lid loosely on the sample can

3. Heat the binder in the preheated oven at 275F (135C) for 1 hour +/- 10 minutes

4. Remove binder from the oven and stir with a glass or steel rod to insure homogeneity

5. Pour 8 RTFO bottles and perform the RTFO procedure according to AASHTO T-240

6. Remove the bottles from the RTFO and combine the binder by scraping each bottle

7. Pour 4 PAV pans from the combined RTFO material and place in the PAV according to AASHTO R-28

8. Record the date and time when pressurized on the provided worksheet

9. After 20 hours, depressurize the PAV and remove 2 of the pans leaving 2 pans in the PAV.

10. Immediately re-pressurize the PAV with the 2 pans remaining inside for another 20 hours. Record the date and time when pressurized on the provided worksheet

11. Combine the 2 pans of binder that were removed from the PAV and vacuum de-gass.

12. After degassing the first 2 pans, pour 6 BBR beams and test the beams at -18C and -24C in accordance with AASHTO T-313

13. Record stiffness and m-value for each beam on the provided worksheet.

14. After the extended 20 hours of aging, depressurize the PAV and remove the remaining 2 pans.

15. Combine the remaining 2 pans of binder from the PAV and vacuum de-gass.

16. After degassing pour 6 BBR beams and test the beams at -18C and -24C in accordance with AASHTO T-313

17. Record stiffness and m-value for each beam on the provided worksheet.

*Extended Aging Method B*
### Binder A - Method B - m-value @ -18C

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<th>Lab</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<th>s</th>
<th>d</th>
<th>h</th>
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**Cell Statistics**

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</table>

**Critical Values**

- Critical h | 2.29
- Critical k | 2.11
Between-laboratory consistency statistic (h)

Critical Value: +2.59
Critical Value: -2.59

Data removed

Lab Number

Binder A - Method A - m-value @-18C - h value

ASTM E691-16
Within-laboratory consistency statistic (k)

Data removed

Critical Value: 2.22

Binder A - Method A - m-value @-24C - k value

Data selectively removed

ASTM
E691-16
<table>
<thead>
<tr>
<th>Binder A</th>
<th>Method A</th>
<th>Method B</th>
<th>Method C</th>
<th>Method D</th>
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<tr>
<td>m-value @-18C</td>
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<td>8,20</td>
<td></td>
<td>7</td>
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<tr>
<td>Stiffness @ -18C</td>
<td>8,10</td>
<td>20</td>
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<td>m-value @-24C</td>
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<td>22</td>
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<td>10</td>
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<td>Stiffness @ -24C</td>
<td>6,10</td>
<td></td>
<td></td>
<td>10</td>
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<td>Binder B</td>
<td>Method A</td>
<td>Method B</td>
<td>Method C</td>
<td>Method D</td>
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<td>Stiffness @ -12C</td>
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<td>6</td>
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<td>Stiffness @ -18C</td>
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<td>5</td>
</tr>
<tr>
<td></td>
<td>Method A</td>
<td>Method B</td>
<td>Method C</td>
<td>Method D</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>----------</td>
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<tr>
<td>Average m-value @ -18C</td>
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<td>Average stiffness @ -18C</td>
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<td>283</td>
<td>280</td>
<td>278</td>
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<td>Average m-value @ -24C</td>
<td>0.261</td>
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<td>Average stiffness @ -24C</td>
<td>494</td>
<td>530</td>
<td>531</td>
<td>541</td>
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<tr>
<td>Average $\mathbf{T}_c$</td>
<td>0.3</td>
<td>-3.2</td>
<td>-2.6</td>
<td>-2.6</td>
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</table>
### Binder B

<table>
<thead>
<tr>
<th></th>
<th>Method A</th>
<th>Method B</th>
<th>Method C</th>
<th>Method D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average m-value @ -12C</td>
<td>0.347</td>
<td>0.307</td>
<td>0.306</td>
<td>0.304</td>
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<tr>
<td>Average stiffness @ -12C</td>
<td>157</td>
<td>195</td>
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<tr>
<td>Average m-value @ -18C</td>
<td>0.287</td>
<td>0.264</td>
<td>0.258</td>
<td>0.258</td>
</tr>
<tr>
<td>Average stiffness @ -18C</td>
<td>327</td>
<td>363</td>
<td>361</td>
<td>383</td>
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<tr>
<td>Average $\Delta T_c$</td>
<td>-0.5</td>
<td>-3.5</td>
<td>-3.6</td>
<td>-3.2</td>
</tr>
</tbody>
</table>
Conducted an ANOVA on Methods B, C, and D for all lab data for each of the following conditions:
  o M-value at -18C (70 degrees of freedom)
  o M-value at -24C (76 degrees of freedom)
  o Stiffness at -18C (76 degrees of freedom)
  o Stiffness at -24C (76 degrees of freedom)
  o ΔTc (23 degrees of freedom)
  · Conducted paired t-tests on ANOVA sets that indicated a statistically significant difference
  · Conducted an ANOVA on Methods B, C, and D individually for Lab 5 and Lab 10
    o Conducted paired t-tests
Conclusions – Binder A

• When considering all labs together, there generally was no statistically significant difference in m-value or Stiffness between the various methods used to get a PAV40 aged asphalt binder. The exception is Method C for the m-value at -24°C.

• When considering all labs together there was no statistically significant difference in ΔTc value.

• When looking at data for individual labs, there was no statistically significant difference in m-value or Stiffness between the various methods used to get a PAV40 aged asphalt binder for Lab 10.

• The data for Lab 5 indicated that there was a statistically significant difference between methods for 3 of the 4 cases. However, there was not a consistent trend. It is also noteworthy that although a statistically significant difference was indicated, in several cases the values would be within the d2s% limit for single-operator repeatability (indicating a tight grouping of data).

• This data would suggest that Method B and D produce similar values. Method C may be a little different for m-value.
• When considering all labs together, there generally was no statistically significant difference in m-value or Stiffness between the various methods used to get a PAV40 aged asphalt binder. The exception is Method B for the m-value at -18C and Method D stiffness at -18C.

• When considering all labs together, there was no statistically significant difference in $\Delta T_c$ value.

• When looking at data for individual labs, there was no statistically significant difference in m-value or Stiffness between the various methods used to get a PAV40 aged asphalt binder for Lab 10.

• The data for Lab 5 indicated that there was a statistically significant difference between methods for 3 of the 4 cases. However, there was not a consistent trend. It is also noteworthy that although a statistically significant difference was indicated, in several cases the values would be within the d2$s\%$ limit for single-operator repeatability (indicating a tight grouping of data).

• This data would suggest that Method B and D produce similar values. Method C may be a little different for m-value and stiffness.
What’s next

- Round 2
- Engineered binder with very poor aging properties
%Rec @ 3.2 kPa tested at 64C vs. Jnr @ 3.2 kPa tested at 64C for grades 64E, 64V, and 64H.

SUPPLIER 1
SUPPLIER 2
SUPPLIER 3
SUPPLIER 4
SUPPLIER 5

Not my old PG 76-22
Courtesy of T. Bennert
Z-Factor

% ELASTIC RESPONSE

JNR @ 3.2

y = 29.371x^{0.263}
Lab Study

- % Recovery Curve was developed using binders manufactured to meet AASHTO M 320
- Binder today may be a little different
- Test procedure has changed slightly
- Blend current binders at different polymer dosing levels:
  - Three blends at Jnr < 0.5
  - Three blends at 0.5 < Jnr < 1.0
  - One blend at 1.0 < Jnr < 2.0
- Determine Jnr at 0.1 and 3.2 kPa and % recovery
- Determine Jnr difference
- True grade M 320
- Report phase angle
- Elastic recovery – AASHTO T 301?
Testing Schedule

• Seven blends total – preferably using plant produced binders
  • Three E-grades – $\text{J}_n < 0.5 \text{ kPa}^{-1}$
  • Three V-grades – $0.5 < \text{J}_n < 1.0 \text{ kPa}^{-1}$
  • One H-grade – $1.0 < \text{J}_n < 2.0 \text{ kPa}^{-1}$

• One of the blends should be the blend currently being used to supply

• Know the polymer dosage in each blend
Testing Schedule

• For each blend report:
  • Using RTFO material
    • Jnr @ 0.1 kPa
    • % Recovery @ 0.1 kPa
    • Jnr @ 3.2 kPa
    • % Recovery @ 3.2 kPa
    • Jnr difference
  • Test temperatures to be at grade and +6C
• For each blend report:
  • Using Original and RTFO materials
    • $G^*$
    • Phase angle
    • $G^*/\sin \delta$
  • Test temperatures shall be at grade and +6C, +12C, +18C
    • True grading
    • I.e. PG 64E-22 – testing temperatures shall 64C, 70C, 76C, and 82C (if needed)

• Using RTFO materials
  • Elastic recovery – AASHTO T 301
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True HT Grade Based On Actual
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Jnr – All Blends
Elastic Response – All Blends

The diagram shows the relationship between TRUE PG HT GRADE - M320 - ACTUAL and % ELASTIC RESPONSE @ 3.2. Different laboratories (Lab 1 to Lab 6) are represented with various markers and colors, illustrating the variability in their responses.
Elastic Response – E Grades Only

![Graph showing the relationship between true PG HH grade and % elastic response at 3.2.](image)

Legend:
- Lab 1
- Lab 2
- Lab 3
- Lab 4
- Lab 5
- Lab 6

% Elastic Response @ 3.2 vs TRUE PG HH GRADE - M320 - ACTUAL
Jnr vs. Elastic Response - 2018

The graph illustrates the relationship between JNR@3.2 and % Elastic Response for various laboratory tests (Lab 1 to Lab 6). The data points are scattered across the graph, showing a trend that decreases as JNR@3.2 increases. The legend is on the right side of the graph, indicating different symbols for each laboratory.
T 301 vs. MSCR Recovery – E Grades Only

Common Specification

R² = 0.6269
Phase Angle vs. MSCR Recovery – E Grades Only

$R^2 = 0.5104$
MSCR % Recovery vs RTFO Elastic Recovery

\[ y = 10.604e^{0.0238x} \]

\[ R^2 = 0.7702 \]

NJDOT Specification
MSCR % Recovery vs Original Phase Angle

Phase Angle (Original, 76C)

MSCR % Recovery (RTFO, 64C)

R² = 0.9263
## Current Production

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## Current Production

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Questions?

Gregory A. Harder, P.E.
Regional Engineer

5791 Route 80
Tully, NY 13159

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Mobile: 315-807-7306
Fax: 315-238-7000

gharder@asphaltinstitute.org