Asphalt Binders - Paving the Way with Innovation

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Goals of this Presentation:

- Where does asphalt come from?
- So how did we get to where we are today?
- What are we doing today with asphalt?
- Where we will be in the near future?
Where does Asphalt come from!?

- Refining process of crude oils
- About 2.5% of a barrel of crude oil depending on source becomes asphalt
- In Ohio, asphalt from a refinery is considered neat binder.
- Asphalt Cement is neat binder only
- Asphalt Binder is neat and modified binders
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So how did we get to where we are today?

- In the 1800’s, asphalt was used in the UK and some in the US to pave roads.
- 1\textsuperscript{st} use in US was 1870 in Newark, NJ
- Pavement issues started arising soon after
So how did we get to where we are today?

- First method of asphalt binder grading?
So how did we get to where we are today?

- First method of asphalt binder grading?
- Chewing to determine hardness
So how did we get to where we are today?

- Second method of asphalt binder grading?
  - Penetration Grading
    - Adopted by ASTM in 1903 and AASHTO in 1931
    - Test performed at one load, time, and temperature
    - Ductility, solubility %, and flash point also tested
So how did we get to where we are today?

Penetration Grading

Pros

- Quick and easy test
- Not that expensive to run
- Smaller the pen number, harder the binder (at 77°F)
So how did we get to where we are today?

- Penetration Grading
- Cons
  - Temperature susceptibility due to only one temperature tested
  - Only considers short term aging

http://users.rowan.edu/~mehta/cematerials_files/ptc.15b.pdf
So how did we get to where we are today?

- Third method of asphalt binder grading?
  - Viscosity Grading (e.g. AC-10, AC-20)
  - Developed in early 1960’s
  - Improved the penetration grading system by adding a viscosity at two temperatures (140°F and 275°F)
So how did we get to where we are today?

- Viscosity Grading
  - Pros
    - Larger range of temperatures, including near mixing/compaction temperatures
    - Viscosity is considered a fundamental engineering property
So how did we get to where we are today?

- **Viscosity Grading**

  - **Cons**
    - Still no testing done at cold temperatures for cracking
    - Doesn’t work well with modified binders
    - Still had tender mixes
So how did we get to where we are today?

- Fourth method of asphalt binder grading?
  - Aged Residue (AR) Grading (e.g. AR-1000, AR-2000)
    - Developed in 1960’s after the viscosity grade
    - Developed to solve the tender mix issue
    - Used more in western states
So how did we get to where we are today?

- **Aged Residue Grading**
  - **Pros**
    - Same as viscosity grading
    - Tests ran on aged binder to simulate binder properties after going through a hot mix asphalt plant
So how did we get to where we are today?

- Aged Residue Grading
  - Cons
    - Still no testing done at cold temperatures for cracking
    - Doesn’t work well with modified binders
    - More testing and longer to do
So how did we get to where we are today?

After all of these grading systems and still dealing with pavement performance issues, engineers realized the shortcomings and a more innovative grading system was needed.

The Strategic Highway Research Program (SHRP) was developed and plans were released in May 1986.

In 1987 U.S. Congress established the 5 year, $150 million dollar program to address multiple concerns and approximately $50 million was designated to asphalt pavements.
So how did we get to where we are today?

Along comes the fifth grading system: Performance Grading (PG)

The PG binder system addresses the high and low temperature properties as well as long term aging to simulate the aging that occurs after 5-10 years that were shortcoming in the previous systems.

Performance testing developed to ensure longer performing pavements from previous grading systems.

Currently, ODOT’s asphalt binder grading system

1st used in 1994 in Fulton County
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What are we doing today with asphalt?

- Performance Grading (PG) binders

Example: PG 64 -22

- Average 7-day maximum pavement temperature, °C
- Minimum pavement temperature, °C

Useful Temperature Interval (UTI) is the range of between the high and low temp:

For a PG 64-22, the UTI is 86

UTI > 86 typically needs modified
What are we doing today with asphalt?

- Performance Grading (PG) binders

Different Grades of PG Binders for ODOT:

- PG 58-28 (neat)
- PG 64-22 (neat) - “Base Binder”
- PG 64-28 (neat, PPA only modified, polymer modified)
- PG 70-22M (polymer or GTR modified)
- PG 76-22M (polymer or GTR modified)
- PG 88-22M (polymer modified)

PG Binder must meet ODOT C&MS 702.01
What are we doing today with asphalt?

- Performance Grading (PG) binders
- Used LTPP data (LTPPBind developed by FHWA)
What are we doing today with asphalt?

- Performance Grading (PG) binders
  - Three aging levels:
    - Original - Age at plant tank prior to mixing
    - Tested at high temp for rutting potential
What are we doing today with asphalt?

- Performance Grading (PG) binders
  - Three aging levels:
    - RTFO - Age after mixing and compaction
      - Tested at high temp for rutting potential
What are we doing today with asphalt?

- Performance Grading (PG) binders
  - Three aging levels:
    - PAV - Age about 5 to 10 years after placement
      - Tested at intermediate and cold temperatures for fatigue and low temperature cracking
What are we doing today with asphalt?

- **Performance Grading (PG) binders**
- **AASHTO M320**

<table>
<thead>
<tr>
<th>Performance Grade</th>
<th>PG 46</th>
<th>PG 52</th>
<th>PG 58</th>
<th>PG 64</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average 7-day max pavement design temp, °C</td>
<td>&lt;46</td>
<td>&lt;52</td>
<td>&lt;58</td>
<td>&lt;64</td>
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<tr>
<td>Min pavement design temperature, °C</td>
<td>~34</td>
<td>~40</td>
<td>~46</td>
<td>~52</td>
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<tr>
<td>Flash point temp, T 48, min °C</td>
<td>230</td>
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<tr>
<td>Viscosity, T 316°</td>
<td>135</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Dynamic shear, T 315°</td>
<td>46</td>
<td>52</td>
<td>58</td>
<td>64</td>
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<tr>
<td>Rolling Thin-Film Oven Residue (T 240)</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Mass change, max, percent</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAV aging temperature, °C</td>
<td>90 (100, 110)</td>
<td>90 (100, 110)</td>
<td>100 (100, 110)</td>
<td>100 (100, 110)</td>
</tr>
<tr>
<td>Dynamic shear, T 315°</td>
<td>10</td>
<td>7</td>
<td>4</td>
<td>16</td>
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<tr>
<td>Creep stiffness, T 313°</td>
<td>25</td>
<td>22</td>
<td>19</td>
<td>16</td>
</tr>
<tr>
<td>Direct tension, T 314°</td>
<td>10</td>
<td>7</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>Performance Grade</td>
<td>PG 70</td>
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<tr>
<td>-------------------</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>16</td>
<td>22</td>
<td>28</td>
</tr>
<tr>
<td>Average 7-day max pavement design temperature, °C &lt;70</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Min pavement design temperature, °C  ≥10  ≥16  ≥22  ≥28</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Flash point temp, T 48, min °C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viscosity, T 316: max 3 Pa*s, test temp, °C</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynamic shear, T 315: $G^*/\sin \delta$, min 1.00 kPa test temp @ 10 rad/s, °C  70</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass change, max, percent,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynamic shear, T 315: $G^*/\sin \delta$, max 2.20 kPa test temp @ 10 rad/s, °C  70</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAV aging temperature, °C/  100 (110)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynamic shear, T 315: $G^* \sin \delta$, max 5000 kPa test temp @ 10 rad/s, °C  34  31  28  25</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Creep stiffness, T 313: $S$, max 300 MPa $m$-value, min 0.300 test temp @ 60 s, °C  0  -6  -12  -18</td>
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<td></td>
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</tr>
</tbody>
</table>
What are we doing today with asphalt?

- Performance Grading (PG) binders
- PG Plus Specifications

### TABLE 702.01-1

<table>
<thead>
<tr>
<th>Test / Requirement</th>
<th>SBR Polymer</th>
<th>Pre Blended Binder</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final PG Binder Grade</td>
<td>70-22M (a. b)</td>
<td>64-28 (b)</td>
<td>70-22M (a.k)</td>
</tr>
<tr>
<td>Actual Pass Temperatures</td>
<td>Report</td>
<td></td>
<td>i</td>
</tr>
<tr>
<td>RTFO Mass Change, percent max</td>
<td>0.75</td>
<td></td>
<td>d</td>
</tr>
<tr>
<td>Phase Angle, max</td>
<td>78</td>
<td>78</td>
<td>74</td>
</tr>
<tr>
<td>Elastic Recovery, min</td>
<td>65</td>
<td>75</td>
<td>90</td>
</tr>
<tr>
<td>Toughness, in. lb</td>
<td>125</td>
<td>105</td>
<td>f. d</td>
</tr>
<tr>
<td>Tenacity, in lb.</td>
<td>70</td>
<td>80</td>
<td>f. d</td>
</tr>
<tr>
<td>Elongation, in. min</td>
<td>20</td>
<td>20</td>
<td>f. d</td>
</tr>
<tr>
<td>Ductility, in. min</td>
<td>28</td>
<td>28</td>
<td>j. d</td>
</tr>
<tr>
<td>Separation, F max</td>
<td>10</td>
<td></td>
<td>g. d</td>
</tr>
<tr>
<td>Homogeneity</td>
<td>None Visible</td>
<td></td>
<td>h. d</td>
</tr>
</tbody>
</table>

- a - b: See Table 703.01-1
- c - i: See Table 704.01-1
- j - k: See Table 705.01-1
What are we doing today with asphalt?

Performance Grading (PG) binders

Pros
- Addressed rutting issues
- Addressed fatigue and low temperature cracking, however, didn’t resolve them
- Covers entire range of temperatures
What are we doing today with asphalt?

- Performance Grading (PG) binders
  - Cons
    - Aging and tests were developed around neat binders
    - Studies show long term aging may not be 5-10 years but 1-2 years
    - Fatigue and cold temperature cracking isn’t resolved
What are we doing today with asphalt?

Along comes the sixth grading system: Multiple Stress Creep Recovery (MSCR):

- Developed to help characterized polymer binders better
- Developed to predict rutting performance better than PG binder system
- Potentially replace PG Plus tests such as elastic recoveries using Table in AASHTO M332
- Grade bumps handled in grading designations
What are we doing today with asphalt?

- **Multiple Stress Creep Recovery (MSCR):**
  - Testing temperatures are at base binder
  - **Grading system designation:**
    - S = Standard <10 mill ESALs & std traffic loading
    - H = Heavy 10-30 mill ESALs or slow moving traffic loading
    - V = Very Heavy >30 mill ESALs or std traffic loading
    - E = Extremely Heavy >30 mill ESALs & std traffic loading
  - Example: PG 64H-22 would be similar to PG 70-22M
What are we doing today with asphalt?

Information provided from Asphalt Institute’s website
What are we doing today with asphalt?

- **Multiple Stress Creep Recovery (MSCR):**
  - **Cons**
    - Reduced polymer loading compared to ODOT’s PG grades
    - Have to RTFO age binder for meaningful results
    - Still a lot of variation in precision & bias
Goals of this Presentation:

- Where does asphalt come from? ✓
- So how did we get to where we are today? ✓
- What are we doing today with asphalt? ✓
- Where we will be in the near future?
Where will we be in near future?

- Better performance predicting tests for fatigue and low temperature cracking
- Better lab aging protocols to better predict field aging
- Extenders, additives, others
- Bio-polymers and binders
Where will we be in near future?

- Binder Fatigue Cracking Test(s)
  - Current NCHRP Project 09-59
    - Completion: Approximately January 2018
  - Replace fatigue test in M320 with a fatigue test(s) that predicts fatigue performance better
Where will we be in near future?

- Binder Low Temperature Cracking Test(s)
  - Numerous research efforts nationally
  - Replace low temperature test or add to it in M320 that predicts low temperature performance better
Where will we be in near future?

- Better lab aging protocols to better predict field aging
- Current NCHRP Project 09-61
  - Completion: Approximately October 2019
- Adjust lab aging procedures
- Add a longer aging range beyond 10 years
Where will we be in near future?

- More and more extenders, additives, and bio polymers and binders
- Current NCHRP Project 09-60
  - Completion: Approximately October 2019
  - Addressing impacts of changes in asphalt binder formulation and manufacturing on pavement performance
Where will we be in near future?
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Questions?

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