Asphalt Binder Basics
Specifications, History and Future

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Asphalt Binder

“A dark brown to black cementitious material in which the predominating constituents are bitumens which occur in nature or are obtained in petroleum processing.” – ASTM D8

The glue that binds the aggregate together and waterproofs the pavement.
First US hot mix asphalt (HMA) constructed in 1870’s

- Pennsylvania Ave.

- Used naturally occurring asphalt from surface of lake on Island of Trinidad
Demand for paved roads exceeded the supply of lake asphalts in late 1800’s
Led to use of petroleum asphalts
Petroleum Asphalt

Sweet vs. Sour
Light vs. Heavy
Crude Distillation Temperatures

Crude Oil Distillation

Degrees - C

Percent Distilled

Gas
Gasoline
Kerosene / Jet Fuel
Diesel
Gas oil
Asphalt
Historical Grading Systems

• Penetration
  — Developed in early 1900s (first ASTM 1947)
  — Tested @ 25°C (77°F)

• Viscosity
  — Developed in 1950s
  — Absolute Viscosity
    • Tested @ 60°C (140°F)
  — Kinematic Viscosity
    • Tested @ 135°C (275°F)
Penetration (1900s)

0 sec

100 g

penetration

5 sec

100 g
## Penetration Specification

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>AASHTO</th>
<th>ASTM</th>
<th>Penetration Grades</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetration, 77°F, 100 g, 5 sec</td>
<td>T49</td>
<td>D5</td>
<td>40 - 50 60 - 70 85 - 100 120 - 150 200 - 300</td>
</tr>
<tr>
<td>Visc. @ 275°F Kinematic, Cs Saybolt Furol, SSF</td>
<td>T201</td>
<td>D2170 E102</td>
<td>240 + 200 + 170 + 140 + 100 +</td>
</tr>
<tr>
<td>Flash Point, °F, Clev Open Cup</td>
<td>T48</td>
<td>D92</td>
<td>450 + 450 + 450 + 425 + 350 +</td>
</tr>
<tr>
<td>Thin Film Oven Test Pen on Residue, 77°F, % Orig.</td>
<td>T179</td>
<td>D1754 D5</td>
<td>55 + 52 + 47 + 42 + 37 +</td>
</tr>
<tr>
<td>Ductility @ 77°F, cm @ 60°F, cm</td>
<td>T51</td>
<td>D113</td>
<td>100 + 100 + 100 + 60 + 60 +</td>
</tr>
<tr>
<td>Sol. In Trichloroethylene, %</td>
<td>T44</td>
<td>D2042</td>
<td>99.0 + 99.0 + 99.0 + 99.0 + 99.0 +</td>
</tr>
</tbody>
</table>

**General Requirement** – The asphalt shall be prepared by the refining of petroleum. It shall be uniform in character and shall not foam when heated to 350°F.
Viscosity (1950s)

Measure time of flow between lines.
### AASHTO M 226 – Table 1

**Viscosity Specification**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>AC-2.5</th>
<th>AC-5</th>
<th>AC-10</th>
<th>AC-20</th>
<th>AC-30</th>
<th>AC-40</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Test</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visc. @ 140°F Kinematic, P</td>
<td>250 ± 50</td>
<td>500 ± 100</td>
<td>1000 ± 200</td>
<td>2000 ± 400</td>
<td>3000 ± 600</td>
<td>4000 ± 800</td>
</tr>
<tr>
<td>Visc. @ 275°F Kinematic, Cs, Min.</td>
<td>125</td>
<td>175</td>
<td>250</td>
<td>300</td>
<td>350</td>
<td>400</td>
</tr>
<tr>
<td>Penetration, 77°F, 100 g, 5 sec, Min.</td>
<td>220</td>
<td>140</td>
<td>80</td>
<td>60</td>
<td>50</td>
<td>40</td>
</tr>
<tr>
<td>Flash Point, °F, C.O.C., Min.</td>
<td>325</td>
<td>350</td>
<td>425</td>
<td>450</td>
<td>450</td>
<td>450</td>
</tr>
<tr>
<td>Sol. In Trichloroethylene, %</td>
<td>T44 99.0 +</td>
<td>99.0 +</td>
<td>99.0 +</td>
<td>99.0 +</td>
<td>99.0 +</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tests on TFOT Residue</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss on Heating, %, Max.</td>
<td>1.0</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Visc. @ 140°F Kinematic, P, Max.</td>
<td>1000</td>
<td>2000</td>
<td>4000</td>
<td>8000</td>
<td>12000</td>
<td>16000</td>
</tr>
<tr>
<td>Ductility @ 77°F, cm, Min.</td>
<td>100</td>
<td>100</td>
<td>75</td>
<td>50</td>
<td>40</td>
<td>25</td>
</tr>
</tbody>
</table>
Asphalt is a *thermoplastic* material that softens as it is heated and hardens when cooled.
Consistency varies with temperature.
Grading System Based on Climate

PG 58-22

- Performance Grade
- Average 7-day max pavement design temp
- Min pavement design temp

MS-2
Section 2.1.1
Testing Temperature – Climate based

Pavement Temperature, °C

Values for PG 64-22
LTPPBIND Software

http://www.fhwa.dot.gov/PAVEMENT/ltpp/ltppbind.cfm

7928 Weather Stations in the US and Canada
Low Temperature Grades
Binder grades are at 6-degree increments

- PG 58-28 is the first available grade to meet 50% Reliability
- PG 64-34 is the first available grade to meet a reasonable design grade
Asphalt Flow Behavior

Time & Temperature Dependent

- 60°C: 1 hour
- 25°C: 1 hour
- 25°C: 10 hours
Effect of Loading Rate on Binder Selection

Example:

- Toll road
  PG 64-22
  90 kph (55 MPH)

- Toll booth
  PG 70-22
  Slow

- Weigh stations
  PG 76-22
  Stopping
Effect of Traffic Amount on Binder Selection

- 10 to 30 million ESALs
  - Consider increasing one high temperature grade
- > 30 million ESALs
  - Increase one high temperature grade
- Newer recommendations are based on more gradual bumping in LTPPBind version 3.0+
## Performance Grades

<table>
<thead>
<tr>
<th>Max. Design Temp.</th>
<th>PG 46</th>
<th>PG 52</th>
<th>PG 58</th>
<th>PG 64</th>
<th>PG 70</th>
<th>PG 76</th>
<th>PG 82</th>
</tr>
</thead>
</table>

### Original

- **Flash Point**
- **Rotational Viscosity**

#### Dynamic Shear Rheometer

| DSR G*/sin δ | 46 | 52 | 58 | 64 | 70 | 76 | 82 |

### (Rolling Thin Film Oven) RTFO, Mass Change < 1.00%

- **DSR G*/sin δ** (Dynamic Shear Rheometer)

| 46 | 52 | 58 | 64 | 70 | 76 | 82 |

### (Pressure Aging Vessel) PAV

- **DSR G*/sin δ** (Dynamic Shear Rheometer)

| 90 | 90 | 100 | 100 | 100(110) | 100(110) | 100(110) |

- **Intermediate Temp.** = \((\text{Max.} + \text{Min.})/2 + 4\)

#### Bending Beam Rheometer

- **BBR S (creep stiffness) & m-value**

| -24  -30 -36 | 0  -6 | -12  -18  -24  -30 | -36  -6 | -12  -18  -24  -30 | 0  -6 | -12  -18  -24  -30 | 0  -6 | -12  -18  -24  -30 | 0  -6 | -12  -18  -24  -24 |

### If BBR m-value ≥ 0.300 and creep stiffness is between 300 and 600, the Direct Tension failure strain requirement can be used in lieu of the creep stiffness requirement.

#### Direct Tension Tester (DTT)

| -24  -30 -36 | 0  -6 | -12  -18  -24  -30 | -36  -6 | -12  -18  -24  -30 | 0  -6 | -12  -18  -24  -30 | 0  -6 | -12  -18  -24  -24 | 0  -6 | -12  -18  -24 |

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Is a PG a Modified Binder?

Effect of Loading Rate

“Rule of 92”

PG 64 - 34 => 64 - - 34 = 98

Probably modified

Depends on asphalt source

Rounding

Effect of Traffic

Reliability
The use of polymer modified binders has grown tremendously over the past several years.

However, the most widely used binder specification in the U.S., AASHTO M320, was based on a study of neat (unmodified) binders, and may not properly characterize polymer modified binders.
Does PG Grading Predict Performance?

Study of the two mixes with the same aggregate structure, but different binders.

PG 63-22 modified, no rutting

PG 67-22 unmodified, 15mm rut
What happened as a result of M 320’s inability to fully characterize polymer-modified binders?

• Most states began requiring additional tests to the ones required in AASHTO M 320

• These mostly empirical tests are commonly referred to as “PG Plus” tests

• These tests are not standard across the states – difficult for suppliers

• Even some of the tests that are the most common, e.g. Elastic Recovery, are not run the same way from state to state
ER Information and Test Time

• The Elastic Recovery Test is an excellent tool to establish the presence of polymer modification.
  – It takes about 4 hours to prepare and test samples for this information.

• However, it is a poor tool to evaluate the rutting performance of polymer-modified binders.

• The MSCR test can use the same sample already being run in the DSR to give more information in a few extra minutes.
Multiple Stress Creep Recovery Test

• Performed on RTFO-aged Binder

• Test Temperature
  — Environmental Temperature
  — Not Grade-Bumped

• 10 cycles per stress level
  — 1-second loading at specified shear stress
    • 0.1 kPa
    • 3.2 kPa
  — 9-second rest period
ALF Loading

• The pavement was heated to a constant 64°C.
• The FHWA ALF uses an 18,000 lb. single wheel load with no wheel wander.
• The speed is 12 MPH.
• This is a extreme loading condition far more severe than any actual highway.
ALF Loading – M 320 vs. M 332

**Traditional M 320**
- PG Spec
- $R^2 = 0.13$

**New M 332**
- PG Spec
- $R^2 = 0.82$
## Performance Grades (AASHTO M332)

<table>
<thead>
<tr>
<th>High PG</th>
<th>PG 52</th>
<th>PG 58</th>
<th>PG 64</th>
<th>PG 70</th>
<th>PG 76</th>
</tr>
</thead>
</table>

### Original

- **Flash Point, AASHTO T 48**
  - **230 °C**
- **Rotational Viscosity @ 135° C, AASHTO T 316**
- **DSR G*\(\sin\) \(\delta\) (Dynamic Shear Rheometer), AASHTO T 315**
  - **1.00 kPa**
  - **SHVE**
  - **52**
  - **64**
  - **70**
  - **76**

### RTFO (Rolling Thin Film Oven), AASHTO T 240

- **Mass Change**
  - **≤ 1.00%**
  - **≤ 4.5 kPa**
  - **≤ 2.0 kPa**
  - **≤ 1.0 kPa**
  - **≤ 0.5 kPa**
  - **SHVE**
  - **52**
  - **58**
  - **64**
  - **70**
  - **76**

### PAV (Pressure Aging Vessel), AASHTO R28

- **Intermediate Temp. = \(\frac{(High \ PG + Low \ PG)}{2} + 4\)**
  - **5000 kPa**
  - **6000 kPa**
  - **6000 kPa**

  - **DSR G*\(\sin\) \(\delta\) (Dynamic Shear Rheometer), AASHTO T 315**
  - **52**
  - **58**
  - **64**
  - **70**
  - **76**

- **BBR S (creep stiffness) & m-value (Bending Beam Rheometer), AASHTO T 313**
  - **≤ 300 MPa**
  - **SHVE**
  - **0 -6 -12 -18 -24 -30 -36 -6 -12 -18 -24 -30 -6 -12 -18 -24 -30 -6 -12 -18 -24**

### Notes:
- If BBR m-value > 0.300 and creep stiffness is between 300 and 600, the Direct Tension failure strain requirement of ≥ 1.00% can be used in lieu of the creep stiffness requirement.
- Binder shall be homogeneous, free from water, contain no deleterious materials, be at least 98.0% soluble, and contain no particles larger than 250 μm.
Performance of US 212 SMA

- >10 million ESALs → Concrete Pavement
- <10 million ESALs → LCCA → Alternate Bid

- Majority of project was > 10 million, but
- Westerly 2.7 miles < 10 million ESALs

- Alternate Bid:
  - Bituminous option: 9” Bit (top 2” is SMA)
  - Concrete option: 10” Concrete
    - BOTH: 6” Aggregate Base over 24” Sel Granular over 24” compaction subcut.
Performance of US 212 SMA

ONE THERMAL CRACK IN 2.7 MILES
For More Binder Information

MS-25

MS-26
Brought to you by our Members
Thank You - Questions ?