Performance Grade Binder
(SuperPAVE)

Contents Courtesy of
1. Roberts et.al 1996
2. Atkins 2003
3. WSDOT Pavement Guide

เนื้อหาที่สำคัญใน SuperPave (2 hrs)

• Problem Statement
  – Pavement Temperature
  – Existing grading system
• Rise of Modified Binder
• Introduction to Superpave
• Basic of Visco-elasticity
• DSR – complex modulus and phase angle
• Performance Grading
  – Statistical Temperature
  – Selecting binder grade
Limitations of asphalt cement standards

1. Tests are empirical and not directly related to HMA pavement performance.
2. Tests are conducted at one standard temperature in spite of different climatic conditions.
3. Entire range of pavement temperatures at project site is not considered.
4. Long term aging of asphalt cement in service is not considered.
5. Asphalt cement of the same grading can have different temperature and performance characteristics.
6. Previous tests and specifications are not applicable to modified asphalt binders which are gaining popularity.

Note: previous standards include penetration grading system and viscosity grading system

Modified Asphalt binder

**PMA** มาจากกำรผสม ยางมะตอย (Asphalt Cement) ด้วยสาร Polymer ทั้งแบบจากธรรมชาติคือ ยางพารา และแบบสังเคราะห์ เช่น SBS EVA และ Additive ใ

Modified AC Storage Tank
Demands on properties of asphalt binder

- Lower stiffness (or viscosity) at the high temperatures associated with construction. This facilitates pumping of the liquid asphalt binder as well as mixing and compaction of HMA.
- Higher stiffness at high service temperatures. This will reduce rutting and shoving.
- Increased adhesion between the asphalt binder and the aggregate in the presence of moisture. This will reduce the likelihood of stripping.
- Lower stiffness and faster relaxation properties at low service temperatures. This will reduce thermal cracking.
The RV high-temperature (135° C) viscosity measurements are meant to simulate binder workability at mixing and laydown temperatures. Since the goal is to ensure the asphalt binder is sufficiently fluid for pumping and mixing, Superpave specifies a maximum RV viscosity. The RV is more suitable than the capillary viscometer used for kinematic viscosity for testing modified asphalt binders because some modified asphalt binders (such as those containing crumb rubber particles) can clog the capillary viscometer and cause faulty readings.
Bending Beam Rheometer – Superpave

subjects a simple asphalt beam to a small (100-g) load over 240 seconds

Output is creep stiffness of asphalt binder which relates to Low temperature cracking

Direct Tension Test – Superpave

loads a small sample of asphalt binder in tension until it breaks. Failure strain is then calculated. Failure strain is related to Low temperature cracking
Rolling Thin-Film Oven Test

Short-term aging

Rolling Thin-Film Oven Test
163°C for 85 minutes

Pressure Aging Vessel

Air pressure 300 psi 90-110°C for 20 hours
Simulate aging of 7-10 years

Pressure Aging Vessel

Use Sample from RTFO

Long-term aging
Original Properties, Rutting, and Fatigue

DSR Equipment

Computer Control and Data Acquisition
Dynamic Shear Rheometer – Superpave

Relates to Rutting and Fatigue cracking

Dynamic Shear Rheometer (DSR)

- Parallel Plate
  - Shear flow varies with gap height and radius
  - Non-homogeneous flow

\[
\tau_R = \frac{2M}{\pi R^3}
\]

\[
\gamma_R = \frac{R \Theta}{h}
\]
Test operates at 10 rad/sec or 1.59 Hz

$360^\circ = 2\pi$ radians per circle

$1\text{ rad} = 57.3^\circ$

- Strain in-phase: $\delta = 0^\circ$
- Strain out-of-phase: $\delta = 90^\circ$
Complex Modulus, $G^*$

Viscous Modulus, $G''$

Storage (elastic) Modulus, $G'$

Complex Modulus is the vector sum of the storage and viscous modulus

Permanent Deformation

Addressed by:

$G^*/\sin \delta$ on unaged binder $> 1.00$ kPa

$G^*/\sin \delta$ on RTFO aged binder $> 2.20$ kPa

For the early part of the service life
Permanent Deformation

**Question:** Why a minimum $G^*/\sin \delta$ to address rutting

**Answer:** We want a *stiff, elastic* binder to contribute to mix rutting resistance

**How:** By increasing $G^*$ or decreasing $\delta$

Fatigue Cracking

- $G^* (\sin \delta)$ on RTFO and PAV aged binder
- The parameter addresses the later part of the fatigue life
- Value must be $\leq 5000$ kPa
Fatigue Cracking

- **Question:** Why a maximum $G^*$ sin $\delta$ to address fatigue?

  **Answer:** We want a *soft elastic* binder (to sustain many loads without cracking)

  **How:** By decreasing $G^*$ or decreasing $\delta$

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Superpave Asphalt Binder Specification

The grading system is based on Climate

- **PG 64 - 22**
  - Performance Grade
  - Min pavement temperature
  - Average 7-day max pavement temperature
### Performance Grade System for asphalt binder

<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>Performance Grade</td>
<td>34</td>
<td>40</td>
<td>46</td>
<td>10</td>
</tr>
<tr>
<td>Average 7-day Maximum Pavement Design Temperature, °C&lt;sup&gt;a&lt;/sup&gt;</td>
<td>&lt; 46</td>
<td>&lt; 52</td>
<td>&lt; 58</td>
<td>&lt; 64</td>
</tr>
<tr>
<td>Minimum Pavement Design Temperature, °C&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-34</td>
<td>-40</td>
<td>-46</td>
<td>-52</td>
</tr>
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**ORIGINAL BINDER**

| Flash Point Temp, T 48, Minimum (°C) | 230 |
| Viscosity, ASTM D 4402<sup>b</sup> | 135 |
| Dynamic Shear, TP 5<sup>c</sup> | G'/sinδ, Minimum, 1,00 kPa | 70 | 76 | 82 |
| Test Temp @ 10 rad/s, °C | |
| Mass Loss, Maximum, percent | 1.00 |
| Dynamic Shear, TP 5<sup>c</sup> | G'/sinδ, Minimum, 2.20 kPa | 70 | 76 | 82 |
| Test Temp @ 10 rad/s, °C | |

**ROLLING THIN FILM OVEN RESIDUE (T 240)**

<table>
<thead>
<tr>
<th>Physical Hardening&lt;sup&gt;e&lt;/sup&gt;</th>
<th>Report</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creep Stiffness, TP 1</td>
<td>Determine the critical cracking temperature as described in PP 42</td>
</tr>
<tr>
<td>Direct Tension, TP 3</td>
<td>Determine the critical cracking temperature as described in PP 42</td>
</tr>
</tbody>
</table>

**PRESSURE AGING VESSEL RESIDUE (PP 1)**

| Dynamic Shear, TP 5<sup>c</sup> | G*sinδ, Maximum, 5000 kPa | 34 | 31 | 28 | 25 | 22 | 19 | 16 | 13 | 10 | 7 | 4 | 25 | 22 | 19 | 16 | 13 | 10 | 7 | 4 |
| Test Temp @ 10 rad/s, °C | 46 | 52 | 58 | 64 |

**Report**

- Original binder: 230
- Rollover thin film oven residue (T 240)
- Pressure aging vessel residue (PP 1)
## Performance Grading System for asphalt binder

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### ORIGINAL BINDER

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<td>Mass Loss, Maximum, percent</td>
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<td>Creep Stiffness, TP 1</td>
<td>Spec requirement to control fatigue cracking</td>
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<tr>
<td>Direct Tension, TP 3</td>
<td>Spec requirement to control low temp. cracking</td>
</tr>
</tbody>
</table>

### Roll-Off/Thin Film Oven Residue (T 240)

<table>
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<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Binder</td>
<td>Spec requirement to control rutting</td>
</tr>
</tbody>
</table>

### Prediction of PG Grade for different crude oil blends

- **High Temperature, °C**
  - 52: 52-16
  - 58: 58-16
  - 64: 64-16
  - 70: 70-16
  - 76: 76-16

- **Low Temperature, °C**
  - -16: 52-16
  - -22: 52-22
  - -28: 52-28
  - -34: 52-34
  - -40: 52-40

### Symbols

- **Green** = Crude Oil
- **Yellow** = High Quality Crude Oil
- **Red** = Modifier Required
record of temperature

Figure 2–53. Distribution of High and Low Design Air Temperatures for Topeka, KS (56)

Figure 2–54. Distribution of High and Low Design Pavement Temperatures for Topeka, KS (56)
Selecting PG grade based on record of temperature

Find hottest 7-day period air temp of each year to calculate average max air temp

Find average 1-day coldest temperature

Alternatives:
1. Use mean temp = 50% reliability
2. Use Mean+/- 2sd.=98% reliability

Comparison between Superpave and Conventional Asphalt Specifications

**Conventional**
- Does not specify highest and lowest service temperatures
- Requires different properties, but at the same testing temperatures
- Does not specify low-temperature properties
- Does not specify properties after long-term aging
- Less expensive
- Lots of experience with the tests used

**Superpave**
- Specify highest and lowest temperatures
- Requires the same properties, but at different temperatures
- Specifies low-temperature properties
- Specifies properties after long-term aging in service
- Specified tests much more expensive to conduct
- Very limited experience with the new tests specified
Design Adjustment

• Dynamic Shear Rheometer (DSR) test is conducted at a rate of 10 radians per second, which corresponds to a traffic speed of about 90 km/hr

• Pavements subject to significantly slower (or stopped) traffic such as intersections, toll booth lines and bus stops should contain a stiffer asphalt binder than that which would be used for fast-moving traffic.

• Superpave allows the high temperature grade to be increased
  – by one grade for slow transient loads
  – by two grades for stationary loads.
  – Additionally, the high temperature grade should be increased by one grade for anticipated 20-year loading in excess of 30 million ESALs.

Table 5.9: Examples of Design Pavement Temperature Adjustments for Slow and Stationary Loads

<table>
<thead>
<tr>
<th>Original Grade</th>
<th>Grade for Slow Transient Loads (increase 1 grade)</th>
<th>Grade for Stationary Loads (increase 2 grades)</th>
<th>20-yr ESALs &gt; 30 million (increase 1 grade)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG 58-22</td>
<td>PG 64-22</td>
<td>PG 70-22</td>
<td>PG 64-22</td>
</tr>
<tr>
<td>PG 70-22*</td>
<td>PG 76-22</td>
<td>PG 82-22</td>
<td>PG 76-22</td>
</tr>
</tbody>
</table>

*the highest possible pavement temperature in North America is about 70°C but two more high temperature grades were necessary to accommodate transient and stationary loads.

• For pavements with multiple conditions that require grade increases only the largest grade increase should be used.