Performance Graded (PG) Asphalts

SUPERPAVE Update for NJDOT/NEAUPG Mechanistic Pavement Design Seminar
Princeton, NJ - Feb. 25, 2003
What is SUPERPAVE?

- New Asphalt Binder specification
- New Mix Design procedure using a new laboratory compaction device
We Have Three Asphalt Binders

Q. How do we determine which asphalt binder is best for our project?

A. The asphalt binder that gives the best performance.
Q. What areas of poor performance do we want to avoid?

Or, in other words, how do our asphalt pavements fail?
How do asphalt pavements fail?
Low Temperature Cracking
How Did We Measure Asphalt Properties Before the PG Grading System?

- Penetration Grading
- Viscosity Grading
Penetration

0 sec

5 sec

Viscosity

vacuum

25° C

25° C

60° C
Problem with one temperature grading

PEN

VISC

HARD

SOFT

25°C

60°C

A

B

C

A

B

C

VISC

PEN
Problem with one temperature grading

- According to the Penetration system:

\[
\begin{align*}
\text{A} & = \text{C} \\
\text{B} & = \text{C}
\end{align*}
\]

- According to the Viscosity System:

\[
\begin{align*}
\text{A} & = \text{C} \\
\text{B} & = \text{C}
\end{align*}
\]
Need to Correct this Problem

- Develop Preformance Related tests and specification
- Asphalt is a visco-elastic material
- Protocols need to be Temperature based
Temperatures

1. Rutting occurs at high pavement temperatures, $T_{(high)}$

2. Fatigue Cracking occurs at intermediate pavement temperatures, $T_{(inter)}$, and

3. Low Temperature Cracking occurs at low pavement temperatures, $T_{(low)}$. 
Aging

- Asphalt binders undergo aging through the loss of volatiles (a.k.a. loss of light ends) and oxidation.

- From the standpoint of determining an asphalt binder's performance there are three key ages we need to address.
Key Aging

◆ New material - no aging

◆ During construction
  ◆ Aging in the plant
  ◆ Aging during placement

◆ Late in the pavement's life
  ◆ 7 - 10 years of service
Asphalt binder’s response to loading is a function of . . .

1. age
2. temperature
Pavement Temperature, C
<table>
<thead>
<tr>
<th>Average 7-day Maximum Pavement Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>46</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Average 1-day Minimum Pavement Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10</td>
</tr>
</tbody>
</table>
Superpave Asphalt Binder Specification

- Grading System Based on Climate

PG 64-22

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

Rutting

Fatigue

Cracking

Low Temp

Cracking

[PV][RV]

[DSR]

[DTT]

[BBR]

Pavement Age

No aging

RTFO - aging

PAV - aging
Dynamic Shear Rheometer, 
DSR

- Apply a oscillating shear stress
- Measure strain

- A materials modulus is
  - Modulus = Stress / Strain
  - A measure of material stiffness
DSR provides $G^*$ and $\delta$

- $G^*$, Complex Shear Modulus
- $\delta$, Phase Angle

- $G^*/\sin\delta$
  - Correlates to rutting resistance.

- $G^*\sin\delta$
  - Correlates to fatigue resistance.
Rutting Specification - Minimum Stiffness @ $T_{(high)}$

- $G^* / \sin \delta > 1.00 \text{ kPa}$ on unaged binder
- $G^* / \sin \delta > 2.20 \text{ kPa}$ on RTFO aged binder
Construction

Rutting

Fatigue

Cracking

Low Temp

Cracking

[RV]

[DSR]

[DTT]

[BBR]

Pavement Age

No aging

RTFO - aging

PAV - aging
Fatigue Cracking Specification
- Maximum Stiffness @ $T_{(inter)}$

- $G^* \sin \delta < 5000 \text{ kPa on PAV aged binder}$
The Bending Beam Rheometer (BBR) determines the Creep Stiffness (S) of an asphalt binder at low temperatures.

If a binder is too stiff at service temperatures, you can expect low temperature cracking.
Bending Beam Rheometer, BBR
**Bending Beam Rheometer, BBR**

- Binder specimen in mold
- Rubber O-rings
- Acetate strips
- Aluminum mold

Dimensions:
- 125 mm
- 12.7 mm
- 6.35 mm

125 mm
**Bending Beam Rheometer, BBR**

980 mN (100 g) Load

Asphalt Beam

Original Position

Deflected Position
**Bending Beam Rheometer, BBR**

![Diagram showing test load and deflection over time.]
**Bending Beam Rheometer, BBR**

Deflection

\[ \Delta (t) \]

Time

60 sec

Simulates stiffness after 2 hours at 10 °C lower temp
**BBR Data - Relaxation**

**Log Creep Stiffness, S**

$slope = m\text{-value}$

**PG Spec**

- Log Loading Time
- 8, 15, 30, 60 sec, 120, 240
Low Temperature Cracking Specification

- Maximum Creep Stiffness Value (S)
  - $S < 300 \text{ MPa}$

- Minimum $m$-value
  - $m > 0.300$
Direct Tension Test, DTT

failure strain ($\varepsilon_f$) = \frac{\text{change in length ($\Delta L$)}}{\text{effective gauge length ($L_e$)}}
Rotational Viscometer

- Applied torque from motor
- Spindle
- Asphalt sample
- Sample chamber
Rotational Viscometer

- Digital readout
- Control keys
- Spindle extension
- Temperature controller
- Brookfield viscometer
- Thermo-container (Thermosel™)
Rotational Viscometer
Rotational Viscometer Specification

- Viscosity @ 135°C < 3.0 Pa-s
- Run viscosity at both 135°C and 165°C to determine laboratory mixing and compaction temperatures
Lab Mixing & Compaction Temperatures for Unmodified Asphalt

Viscosity, Pa·s

Temperature, C

Compaction Range
Mixing Range
Asphalt binder’s response to loading is a function of:

1. age
2. temperature
3. rate of loading
Time vs. Temperature

60°C for 1 hour

25°C for 1 hour

Temperatures:
- 60°C
- 25°C
FHWA ALF Binder Study

Rut Depth @ 5000 passes of ALF
11 mph @ 58ºC

Asphalt Binder Grade

- PG 58-28: 30 mm
- PG 64-22: 24 mm
- PG 76-22: 4 mm

Colors:
- AC-10
- AC-20
- PMA
Effect of Loading Rate on Binder Selection

Example

- for 55 mph highway
  - PG 64-22

- for 30 mph highway
  - PG 70-22

- for intersections
  - PG 76-22

Standard Grade

Slow - Bump
one grade

Stopped - Bump
one grade
67 kN + 27 kN = 0.49 ESALs

15,000 lb + 6,000 lb = 0.01 ESAL

151 kN + 151 kN + 54 kN = 2.39 ESALs

34,000 lb + 34,000 lb + 12,000 lb = 1.10 + 1.10 + 0.19
Effect of Traffic Amount on Binder Selection

- Traffic Loads on the pavement are measured in Equivalent Single Axle Loads (ESAL)
- 20 year ESAL measurements are required in the SUPERPAVE system to correctly determine asphalt binder PG grade
Effect of Traffic Amount on Binder Selection

- **10 - 30 \times 10^6** ESAL
  - Consider increasing -- one high temp grade
- **30 \times 10^6 +** ESAL
  - Recommend increasing -- one high temp grade

80 kN ESALs

> Equivalent Single Axle Loads

---

80 kN ESALs

---
SUPERPAVE Asphalt Binder Specification

- Selection is based on
  - Climate
  - Traffic speed
  - Amount of traffic - measured in ESALs
  - PG grade
  - Asphalt content of mix - durability
Rule #1

PG 82
PG 76
PG 70
PG 64
PG 58

The higher the Grade, the stiffer the binder. The more rut resistance.
Rule # 2

\[ \text{PG} \quad -22 \quad -28 \quad -34 \quad \text{The lower the number, the more resistant to thermal cracking.} \]
Rule # 3
Mix Cost + 15-20%

Mix Cost + 3 - 5%

The greater the difference
the higher the cost.
Questions?