SUPERPAVE BINDER SPECIFICATIONS & SELECTIONS
New Binder Specification
SUPERPAVE

- Fundamental properties related to pavement performance
- Environmental factors
- In-service & construction temperatures
- Short and long term aging
Pavement Temperature, °C

-20  20  60  135
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 Grades

<table>
<thead>
<tr>
<th>Avg 7-day Max, °C</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>
<tbody>
<tr>
<td>1-day Min, °C</td>
<td>-29</td>
<td>-31</td>
<td>-6</td>
<td>-16</td>
<td>-28</td>
<td>-10</td>
<td>-22</td>
</tr>
</tbody>
</table>

- **ORIGINAL**
  - **(Flash Point)** FP
    - PG 46: 46
    - PG 52: 52
    - PG 58: 58
    - PG 64: 64
    - PG 70: 70
    - PG 76: 76
    - PG 82: 82
  - **(Rotational Viscosity)** RV
    - PG 46: 46
    - PG 52: 52
    - PG 58: 58
    - PG 64: 64
    - PG 70: 70
    - PG 76: 76
    - PG 82: 82

- **(ROLLING THIN FILM OVEN)** RTFO
  - **Mass Loss < 1.00 %**
    - PG 46: 46
    - PG 52: 52
    - PG 58: 58
    - PG 64: 64
    - PG 70: 70
    - PG 76: 76
    - PG 82: 82

- **(PRESSURE AGING VESSEL)** PAV
  - **20 Hours, 2.07 MPa**
    - PG 46: 90
    - PG 52: 90
    - PG 58: 100
    - PG 64: 100
    - PG 70: 100
    - PG 76: 100
    - PG 82: 100
  - **< 5000 kPa**
    - PG 46: 10
    - PG 52: 10
    - PG 58: 10
    - PG 64: 10
    - PG 70: 10
    - PG 76: 10
    - PG 82: 10

- **S < 300 MPa**
  - **m > 0.300**
    - PG 46: 24
    - PG 52: 24
    - PG 58: 24
    - PG 64: 24
    - PG 70: 24
    - PG 76: 24
    - PG 82: 24

- **Report Value**
  - **> 1.00 %**
    - PG 46: 24
    - PG 52: 24
    - PG 58: 24
    - PG 64: 24
    - PG 70: 24
    - PG 76: 24
    - PG 82: 24

- **(Dynamic Shear Rheometer)** DSR
  - **G*/sin δ**
    - PG 46: 46
    - PG 52: 52
    - PG 58: 58
    - PG 64: 64
    - PG 70: 70
    - PG 76: 70
    - PG 82: 82

- **(Bending Beam Rheometer)** BBR
  - **"S" Stiffness & "m"-value**
    - PG 46: 24
    - PG 52: 24
    - PG 58: 24
    - PG 64: 24
    - PG 70: 24
    - PG 76: 24
    - PG 82: 24

- **(Direct Tension)** DT
  - PG 46: 24
  - PG 52: 24
  - PG 58: 24
  - PG 64: 24
  - PG 70: 24
  - PG 76: 24
  - PG 82: 24

- **Supplementary**
  - PG 46: 24
  - PG 52: 24
  - PG 58: 24
  - PG 64: 24
  - PG 70: 24
  - PG 76: 24
  - PG 82: 24
How the PG Spec Works

Spec Requirement Remains Constant

> 230 °C

≤ 3 Pa·s @ 135 °C

≥ 1.00 kPa

(Rolling Thin Film Oven) RTFO

(Mass Loss) Mass Loss ≤ 1.00 %

(Direct Tension) DT

(Bending Beam Rheometer) BBR

Physical Hardening

< 5000 kPa

> 2.20 kPa

(Pressure Aging Vessel) PAV

Test Temperature Changes

Spec Requirement Remains Constant

> 230 °C

≤ 3 Pa·s @ 135 °C

≥ 1.00 kPa

(Rolling Thin Film Oven) RTFO

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Physical Hardening

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(Pressure Aging Vessel) PAV

Test Temperature Changes
## Permanent Deformation

### Superpave Binder Specs & Selections

<table>
<thead>
<tr>
<th>Avg 7-day Max, °C</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>
<tbody>
<tr>
<td>1-day Min, °C</td>
<td>-34</td>
<td>-40</td>
<td>-46</td>
<td>-52</td>
<td>-60</td>
<td>-68</td>
<td>-76</td>
</tr>
</tbody>
</table>

### ORIgINAL

- **(Flash Point) FP**
- **(Rotational Viscosity) RV**
- **(Dynamic Shear Rheometer) DSR G*/sin δ**
  - Unaged
  - RTFO Aged

### (ROLLING THIN FILM OVEN) RTFO Mass Loss < 1.00 %

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

### (PRESSURE AGING VESSEL) PAV

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

### Support Values

- **(Direct Tension) DT**
- **(Bending Beam Rheometer) BBR “S” Stiffness & “m”-value**
- **(Bending Beam Rheometer) BBR Physical Hardening**

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*Note: The values in the table represent test results for different grades of Superpave binders under various conditions.*
Permanent Deformation

- Addressed by high temp stiffness
  - $G^*/\sin \delta$ on unaged binder $\geq 1.00$ kPa
  - $G^*/\sin \delta$ on RTFO aged binder $\geq 2.20$ kPa

> Early part of pavement service life
## Fatigue Cracking

<table>
<thead>
<tr>
<th>Avg 7-day Max, °C</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>
<tbody>
<tr>
<td>1-day Min, °C</td>
<td>34</td>
<td>34</td>
<td>34</td>
<td>34</td>
<td>34</td>
<td>34</td>
<td>34</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>ORIGINAL</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 230 °C</td>
<td>(Flash Point) FP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 3 Pa·s @ 135 °C</td>
<td>(Rotational Viscosity) RV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥ 1.00 kPa</td>
<td>(Dynamic Shear Rheometer) DSR G*/sin δ</td>
<td>46</td>
<td>52</td>
<td>58</td>
<td>64</td>
<td>70</td>
<td>76</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(ROLLING THIN FILM OVEN) RTFO Mass Loss &lt; 1.00 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Dynamic Shear Rheometer) DSR G*/sin δ</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(PRESSURE AGING VESSEL) PAV</th>
<th>90</th>
<th>100</th>
<th>100</th>
<th>100 (110)</th>
<th>100 (110)</th>
<th>110 (110)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>(Dynamic Shear Rheometer) DSR G*sin δ</th>
<th>25</th>
<th>22</th>
<th>19</th>
<th>16</th>
<th>13</th>
<th>10</th>
<th>7</th>
<th>0</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Bending Beam Rheometer) BBR “S” Stiffness &amp; “m”-value</td>
<td>-24</td>
<td>-20</td>
<td>-16</td>
<td>-12</td>
<td>-8</td>
<td>-4</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>(Bending Beam Rheometer) BBR Physical Hardening</td>
<td>24</td>
<td>30</td>
<td>0</td>
<td>-6</td>
<td>-12</td>
<td>-18</td>
<td>-24</td>
<td>-30</td>
<td>0</td>
</tr>
<tr>
<td>Direct Tension) DT</td>
<td>-24</td>
<td>-20</td>
<td>-16</td>
<td>-12</td>
<td>-8</td>
<td>-4</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>
Fatigue Cracking

• Addressed by intermediate temperature stiffness
  – $G \cdot \sin \delta$ on RTFO & PAV aged binder $\leq 5000$ kPa

> Later part of pavement service life
# Low Temperature Cracking

<table>
<thead>
<tr>
<th>Avg 7-day Max, °C</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>
<tbody>
<tr>
<td>1-day Min, °C</td>
<td>-34</td>
<td>-40</td>
<td>-46</td>
<td>-52</td>
<td>-58</td>
<td>-64</td>
<td>-70</td>
</tr>
</tbody>
</table>

### ORIGINAL

- **Flash Point** (FP) ≥ 230 °C
- **Rotational Viscosity** (RV) ≤ 3 Pa·s @ 135 °C
- **Dynamic Shear Rheometer** (DSR) $G^*/\sin \delta$ between 1.00 kPa:
  - 46
  - 52
  - 58
  - 64
  - 70
  - 76
  - 82

### RTFO

- **Rolling Thin Film Oven** (RTFO) Mass Loss ≤ 1.00 %
- **Dynamic Shear Rheometer** (DSR) $G^*/\sin \delta$ between 2.20 kPa:
  - 46
  - 52
  - 58
  - 64
  - 70
  - 76
  - 82

### PAV

- **Pressure Aging Vessel** (PAV)
- **Dynamic Shear Rheometer** (DSR) $G^* \sin \delta$
- **Beam Bending Rheometer** (BBR) “S” Stiffness & “m”-value
- **Direct Tension** (DT)
- **Bending Beam Rheometer** (BBR) Physical Hardening
- **Flash Point** (FP)
- **Rotational Viscosity** (RV)

- **Pressure Aging Vessel** (PAV) Aged
## Low Temperature Cracking

<table>
<thead>
<tr>
<th>Avg 7-day Max, °C</th>
<th>PG 46</th>
<th>PG 52</th>
<th>PG 58</th>
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<th>PG 76</th>
<th>PG 82</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-day Min, °C</td>
<td>-34</td>
<td>-40</td>
<td>-46</td>
<td>-52</td>
<td>-58</td>
<td>-64</td>
<td>-70</td>
</tr>
</tbody>
</table>

### ORIGINAL

#### Flash Point (FP)
- ≥ 230 °C
- ≤ 3 Pa·s @ 135 °C

#### Rotational Viscosity (RV)
- ≥ 1.00 kPa

#### Rolling Thin Film Oven (RTFO)
- Mass Loss ≤ 1.00 %
- ≥ 2.20 kPa

#### Pressure Aging Vessel (PAV)
- Original
- Aged

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

### BBR (Bending Beam Rheometer)
- "S" Stiffness & "m"-value
- Physical Hardening
- Direct Tension (DT)

### Supercalve Binder Specs & Selections 12

<table>
<thead>
<tr>
<th>(Rotational Viscosity)</th>
<th>RV</th>
<th>(Flash Point)</th>
<th>FP</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Dynamic Shear Rheometer)</td>
<td>DSR G*/sin δ</td>
<td>ORIGINAL</td>
<td>≥ 230 °C</td>
</tr>
<tr>
<td>(Rolling Thin Film Oven)</td>
<td>RTFO</td>
<td>Mass Loss ≤ 1.00 %</td>
<td></td>
</tr>
<tr>
<td>(Pressure Aging Vessel)</td>
<td>PAV</td>
<td>≥ 2.20 kPa</td>
<td></td>
</tr>
<tr>
<td>(Dynamic Shear Rheometer)</td>
<td>DSR G*/sin δ</td>
<td>Aged</td>
<td>≥ 2.20 kPa</td>
</tr>
</tbody>
</table>

### Table Example

<table>
<thead>
<tr>
<th>Avg 7-day Max, °C</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>
<tbody>
<tr>
<td>1-day Min, °C</td>
<td>-34</td>
<td>-40</td>
<td>-46</td>
<td>-52</td>
<td>-58</td>
<td>-64</td>
<td>-70</td>
</tr>
</tbody>
</table>

### Chart Example

- PAV Aged
- Supercalve Binder Specs & Selections 12
### Miscellaneous Spec Requirements

<table>
<thead>
<tr>
<th>Spec Requirement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flash Point</strong></td>
<td></td>
</tr>
<tr>
<td>(Rotational Viscosity)</td>
<td>RV</td>
</tr>
<tr>
<td>(Dynamic Shear Rheometer)</td>
<td>DSR</td>
</tr>
<tr>
<td>(Bending Beam Rheometer)</td>
<td>BBR</td>
</tr>
<tr>
<td>(Direct Tension)</td>
<td>DT</td>
</tr>
<tr>
<td><strong>Mass Loss</strong></td>
<td></td>
</tr>
<tr>
<td>(Pressure Aging Vessel)</td>
<td>PAV</td>
</tr>
</tbody>
</table>

#### Supercast Binder Specs & Selections

<table>
<thead>
<tr>
<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>
<tbody>
<tr>
<td>RV</td>
<td>RV</td>
<td>RV</td>
<td>RV</td>
<td>RV</td>
<td>RV</td>
<td>RV</td>
</tr>
<tr>
<td>FP</td>
<td>FP</td>
<td>FP</td>
<td>FP</td>
<td>FP</td>
<td>FP</td>
<td>FP</td>
</tr>
<tr>
<td>RTFO</td>
<td>Mass</td>
<td>Loss</td>
<td>&lt;1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FP</td>
<td>FP</td>
<td>FP</td>
<td>FP</td>
<td>FP</td>
<td>FP</td>
<td>FP</td>
</tr>
<tr>
<td>DSR</td>
<td>G* sin δ</td>
<td>DSR</td>
<td>G* sin δ</td>
<td>DSR</td>
<td>G* sin δ</td>
<td>DSR</td>
</tr>
<tr>
<td>BBR</td>
<td>“S” Stiffness &amp; “m”-value</td>
<td>BBR</td>
<td>“S” Stiffness &amp; “m”-value</td>
<td>BBR</td>
<td>“S” Stiffness &amp; “m”-value</td>
<td>BBR</td>
</tr>
<tr>
<td>DT</td>
<td>DT</td>
<td>DT</td>
<td>DT</td>
<td>DT</td>
<td>DT</td>
<td>DT</td>
</tr>
</tbody>
</table>
Many agencies have established zones

PG 52-28

PG 58-22

PG 58-16

PG 64-10
Developed from Air Temperatures

- Superpave Weather Database
  - 6500 stations in U.S. and Canada
- Annual air temperatures
  - hottest seven-day temp (avg and std dev)
  - coldest temp (avg and std dev)
- Calculated pavement temps used in PG selection

> 20 years

SHRP A-648A
Reliability

- Percent probability of not exceeding design temp

> using Normal Distribution

Frequency of observed temps
(Total area under curve = 100 %)

Reliability is area under curve to the left of $T_{\text{des}}$

$T_{\text{avg}}$ $T_{\text{des}}$
Observed Air Temperatures
Topeka, KS

50 % reliability

98 % reliability

average summer

very hot summer

Standard deviation of 2°C

7-Day Maximum Air Temperatures
Observed Air Temperatures
Topeka, KS

very cold winter

average winter

standard deviation of 4°C

-31 -23

-40 -30 -20 -10 0 10 20 30 40 50 60

Superpave Binder Specs & Selections
Convert to Pavement Temperature

- Calculated by Superpave software
- High Temperature (20 mm below surface of mixture)
- Low Temperature (at surface of mix)
Calculated Pavement Temperatures
Topeka, KS

Calculated Pavement Temperatures
Topeka, KS

pvt > air

pvt > air

-31 -23

-40 -30 -20 -10 0 10 20 30 40 50 60 70

Superpave Binder Specs & Selections
PG Binder Grades
Topeka, KS

PG 64-34 (98% minimum reliability)

PG 58-28 (50 % minimum reliability)

PG grades - six degree increments
Effect of Rounding to Standard Grades

PG 58-28 (50 % minimum reliability)

PG 58 provides 85% reliability

PG -28 provides 90% reliability
Effect of Rounding to Standard Grades

Selected grade for 50% reliability

Rounding depends on actual temps!

Minimum Pavement Temperatures

-28

-23
Effect of Loading Rate on Binder Selection

• Dilemma
  – Specified DSR loading rate is 10 rad/sec
  – What about longer loading times?
• Use binder with more stiffness at higher temps
  – Slow - - increase one high temp grade
  – Stationary - - increase two high temp grades
  – No effect on low temp grade
Effect of Loading Rate on Binder Selection

- Example
  - for toll road
  - for toll booth
  - for weigh stations

90 kph

Slow

Stopping

PG 64-22
PG 70-22
PG 76-22
All Traffic Converted to ESAL's

ESAL = Equivalent Single Axle Loads
ESAL Comparison

- 80 kN (18,000 lb) = 1 ESAL
- 100 kN (22,000 lb) = 2.2 ESAL
- 44 kN (10,000 lb) = 0.09 ESAL
Little Truck

67 kN
15,000 lb
0.48 ESAL

+ 27 kN
6,000 lb
0.01 ESAL

= 0.49 ESALs

BIG TRUCK

151 kN
34,000 lb
1.10

+ 151 kN
34,000 lb
1.10

54 kN
12,000 lb
0.19

= 2.39 ESALs
ESAL Comparison

3,500-5,000

1 Acme Van Lines
Effect of Traffic Amount on Binder Selection

- 10 - 30 x 10^6 ESAL
  - Consider increasing - - one high temp grade
- 30 x 10^6 + ESAL
  - Recommend increasing - - one high temp grade

> Equivalent Single Axle Loads
### How the PG Spec Works

<table>
<thead>
<tr>
<th>Spec Requirement</th>
<th>Remains Constant</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 230°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 3 Pa·s @ 135°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥ 1.00 kPa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥ 2.20 kPa</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Table of Values

<table>
<thead>
<tr>
<th>Test Temperature Changes</th>
<th>PG 58</th>
<th>PG 64</th>
<th>PG 70</th>
<th>PG 76</th>
<th>PG 82</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg 7-day Max, °C</td>
<td>100</td>
<td>100</td>
<td>70</td>
<td>76</td>
<td>82</td>
</tr>
<tr>
<td>1-day Min, °C</td>
<td>58</td>
<td>52</td>
<td>70</td>
<td>76</td>
<td>82</td>
</tr>
<tr>
<td>Rotational Viscosity RV</td>
<td>90</td>
<td>90</td>
<td>100</td>
<td>100</td>
<td>110</td>
</tr>
<tr>
<td>Flash Point FP</td>
<td>46</td>
<td>52</td>
<td>58</td>
<td>64</td>
<td>70</td>
</tr>
<tr>
<td>(Rolling Thin Film Oven)</td>
<td>RTFO</td>
<td>RTFO</td>
<td>Mass Loss ≤ 1.00 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Hardening</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct Tension DT</td>
<td>-34</td>
<td>-40</td>
<td>-46</td>
<td>-10</td>
<td>-16</td>
</tr>
<tr>
<td>(Bending Beam Rheometer)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynamic Shear Rheometer</td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Original</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Pressure Aging Vessel</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S ≤ 300 MPa m &gt; 0.300</td>
<td>200</td>
<td>200</td>
<td>150</td>
<td>150</td>
<td>100</td>
</tr>
<tr>
<td>(Bending Beam Rheometer)</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

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Supporting Image: Diagram illustrating the PG Spec with a magnifying glass highlighting specific values and requirements.
Summary of How to Use PG Specification

• Determine
  – 7-day max pavement temperatures
  – 1-day minimum pavement temperature

• Use specification tables to select test temperatures

• Determine asphalt cement properties and compare to specification limits
## PG Grade Increments

<table>
<thead>
<tr>
<th>Average 7-day Maximum Pavement Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>46</td>
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</table>

<table>
<thead>
<tr>
<th>Average 1-day Minimum Pavement Temperature</th>
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</thead>
<tbody>
<tr>
<td>+2</td>
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### Prediction of PG Grades for Crude Blends

<table>
<thead>
<tr>
<th>Low Temp C</th>
<th>High Temp C</th>
<th>C</th>
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</thead>
<tbody>
<tr>
<td>-10</td>
<td>52-16</td>
<td></td>
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<tr>
<td></td>
<td>58-16</td>
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<td></td>
<td>64-16</td>
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<tr>
<td></td>
<td>70-16</td>
<td>76-16</td>
</tr>
<tr>
<td>-16</td>
<td>52-22</td>
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<td></td>
<td>58-22</td>
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<td>64-22</td>
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<tr>
<td></td>
<td>70-22</td>
<td>76-22</td>
</tr>
<tr>
<td>-22</td>
<td>52-28</td>
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<td>58-28</td>
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<tr>
<td>-28</td>
<td>52-34</td>
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<tr>
<td>-34</td>
<td>52-40</td>
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<td>76-40</td>
</tr>
<tr>
<td>-40</td>
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</tr>
</tbody>
</table>

- **Green** indicates Low Quality Crudes
- **Yellow** indicates High Quality Crudes
- **Red** indicates Modifier Required

Superpave Binder Specs & Selections
Is a PG a Modified Binder?

“Rule of 90”

Effect of Loading Rate  
Reliability

Rounding

Effect of Traffic

Example: PG 64 - 34 has a temperature range of 64 to -34 or 98 C. Therefore, this binder is probably modified!! (Depends on Asphalt Source!)
Questions – does it all make sense?