Lecture 5b – Grading of bituminous materials (quality control)

- Reading material & learning objectives: 2-3
- Bitumen Grading Systems and list of specifications: 4-16
- Selection of bitumen for asphalt mixtures in Finland: 17
- Conventional Test Methods for Grading: 17-26
- PG Grading and Superpave methods:
- Specifications: US PG Spec and EN Spec: 45
- Review questions: 46-47
Reading Material

• Text book, Cold Regions Engineering,
  – Chapter 7: Mix Design, 7-2-1 Material selection
    • Pages 269-277
  – Chapter 4: Investigation and Testing
    • Pages 169-173

• www.pavementinteractive.org (Internet)
  • Materials/Asphalt
  • Testing/Binder Tests
## Learning objectives

### Oppimistavoitteet

<table>
<thead>
<tr>
<th>(must know)</th>
<th>(should know)</th>
<th>(nice to know)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scientific Knowledge</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Know what is the difference between empirical and rheological tests</td>
<td>Know why we test the material with each test and how does the parameter from the test relates to the traffic loading</td>
<td></td>
</tr>
<tr>
<td>Can list the bitumens grading systems and the main tests used within the system</td>
<td>Knows how the grading systems were developed and knows the direction towards which the future development is going.</td>
<td>Can tell how the tests are done</td>
</tr>
<tr>
<td>Can list the tests for bitumen</td>
<td>Can describe the properties of the bitumen using the specifications.</td>
<td>Knows what is the difference between the European and American standards (ASTM, AASHTO). Understands the PG grading and MSCR test</td>
</tr>
<tr>
<td>Can grade a bitumen when provided a list of parameters</td>
<td>Knows which parameters to test from bitumen in order to predict the possible failure modes of pavement.</td>
<td>Tietää miten Eurooppalaiset standardit eroavat ASTM ja AASHTO standardeista PG luokitus ja MSCR testi</td>
</tr>
<tr>
<td>Can choose the bitumen for the particular application</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Purchasing of Bitumen

• Need to be able to specify desirable characteristics

• “Desirable characteristics” have evolved over time and with increasing technological advances

• Purchasing requires specifications
Early Specifications

- Lake Asphalts
  - Appearance
  - Solubility in carbon disulfide
- Petroleum asphalts (early 1900’s)
  - Consistency
  - Chewing
  - Penetration machine
Asphalt Grades and Specifications

- Asphalt cements are graded according to the following four systems:
  - Penetration grading system
    • PEN
  - Viscosity grading system
    • AC
  - Viscosity-after-aging grading system (California)
    • AR (aged residue, after RTFO test)
  - New Superpave Performance Grading (developed 90’s in the US)
    • PG
Why New Grading System was Needed?

- Binder modification was emerging trend due to improvements in bitumen properties:
  - Increases high temperature viscosity (to reduce rutting)
  - Increases low temperature ductility (to reduce fatigue and thermal cracking)

- Difficulties to grade modified binders using conventional grading systems:
  - Non-linear Newtonian behavior

Modifiers used: Styren Butadien Styren (SBS), Low Density Polyethylene (LDPE), Elvaloy etc.
Consistency

- Bitumen can vary from solid to semisolid to liquid depending on temperature
- Consistency is the measure of the degree of fluidity of the bitumen at any particular temperature:
  - Consistency is measured *indirectly* by either measuring viscosity or penetration
  - **Direct** measurement is the shear (complex) modulus of the asphalt $|G^*|$ which is a function of shear stress ($\tau$) and shear strain ($\gamma$)
Measured Properties: Bitumen (for paving grade bitumen)

- Important Properties in Construction:
  - Consistency at a standard temperature.
  - Viscosity at 60°C and 135°C and penetration 25°C
  - Ring and Ball Softening point
  - Specific gravity
  - Durability (Hardening and aging i.e., effect of heat and air)
  - Ductility (Fracture properties)
  - Flash point (Safety)
  - Solubility (Purity)

- Fraass breaking point is used in countries with very low winter temperatures (Finland, Sweden, Norway and Canada)
List of Bitumen specifications  
(Finnish and international)

- SFS standardit ja EN standardit (European Committee for Standardization)
  - PANK (Päällystealan Neuvottelukunta ry) Asfalttinormit ja PANK-menetelmät
  - DIN (Deutsche Institut für Normung), Germany
  - BS (British Standards) and IP (Institute of Petroleum), UK
  - LCPC (Laboratoire Centrale des Ponts at Chaussées), France
- ASTM (American Society for Testing and Materials), USA
- AASHTO (American Association of State Highway Officials), USA
- SA (Standards Australia), Australia

- All tough test methods for certain bituminous products in ASTM and AASHTO, SFS-EN standards are very similar, however deviations exist and one must be careful to select appropriate standard.
# ASTM D3381: Viscosity Grading

## TABLE 6.1 REQUIREMENTS FOR ASPHALT CEMENT, VISCOSITY GRADED AT 140 °F (16 °C)

<table>
<thead>
<tr>
<th>Test</th>
<th>MAAT &lt; 7°C</th>
<th>MAAT &gt; 24°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity, 140 °F (60 °C), P</td>
<td>250 ± 50</td>
<td>1000 ± 200</td>
</tr>
<tr>
<td>Viscosity, 275 °F (135 °C), min, cSt</td>
<td>80</td>
<td>150</td>
</tr>
<tr>
<td>Penetration, 77 °F (25 °C), 100 g, 5 s, min</td>
<td>200</td>
<td>70</td>
</tr>
<tr>
<td>Flash point, Cleveland open cup, min, °F (°C)</td>
<td>325 (163)</td>
<td>425 (219)</td>
</tr>
<tr>
<td>Solubility in trichloroethylene, min, %</td>
<td>99.0</td>
<td>99.0</td>
</tr>
<tr>
<td>Tests on residue from thin-film oven test:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viscosity, 140 °F (60 °C), max, P</td>
<td>1250</td>
<td>5000</td>
</tr>
<tr>
<td>Ductility, 77 °F (25 °C), 5 cm/min, min, cm</td>
<td>100⁰</td>
<td>50</td>
</tr>
</tbody>
</table>

*Note: Grading based on original asphalt.*

*If ductility is less than 100, material will be accepted if ductility at 60 °F (15.5 °C) is 100 minimum at a pull rate of 5 cm/min.*

*Source: ASTM D3381*

**Absolute viscosity at 60°C (max service temperature)**

**Kinematic viscosity at 135°C (mixing temperature)**
# ASTM D946: Penetration Grading

## TABLE 6.3 REQUIREMENTS FOR ASPHALT CEMENT FOR USE IN PAVEMENT CONSTRUCTION

<table>
<thead>
<tr>
<th>Penetration grade</th>
<th>40–50</th>
<th>60–70</th>
<th>85–100</th>
<th>120–150</th>
<th>200–300</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min</td>
<td>max</td>
<td>min</td>
<td>max</td>
<td>min</td>
</tr>
<tr>
<td>Penetration at 77 °F (25 °C) 100 g, 5 s</td>
<td>40</td>
<td>50</td>
<td>60</td>
<td>70</td>
<td>85</td>
</tr>
<tr>
<td>Flash point, °F (Cleveland open cup)</td>
<td>450</td>
<td>—</td>
<td>450</td>
<td>—</td>
<td>450</td>
</tr>
<tr>
<td>Ductility at 77 °F (25 °C) 5 cm/min, cm</td>
<td>100</td>
<td>—</td>
<td>100</td>
<td>—</td>
<td>100</td>
</tr>
<tr>
<td>Solubility in trichloroethylene, %</td>
<td>99.0</td>
<td>—</td>
<td>99.0</td>
<td>—</td>
<td>99.0</td>
</tr>
<tr>
<td>Retained penetration after thin-film oven test, %</td>
<td>55+</td>
<td>—</td>
<td>55+</td>
<td>—</td>
<td>47+</td>
</tr>
<tr>
<td>Ductility at 77 °F (25 °C) 5 cm/min, cm after thin-film oven test</td>
<td>—</td>
<td>—</td>
<td>50</td>
<td>—</td>
<td>75</td>
</tr>
</tbody>
</table>

*If ductility at 77 °F (25 °C) is less than 100 cm, material will be accepted if ductility at 60 °F (15.5 °C) is 100 cm minimum at the pull rate of 5 cm/min.

*Source: ASTM D946

---

Based on Penetration at 25°C
# PANK Asfalttinormit 2011
(Tiebitumien laatuvaatimukset)

<table>
<thead>
<tr>
<th>Bitumimuokka</th>
<th>Menetelmä</th>
<th>20/30</th>
<th>35/50</th>
<th>50/70</th>
<th>70/100</th>
<th>100/150</th>
<th>160/220</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tunkeuma, 25 °C</td>
<td>0,1 mm</td>
<td>SFS-EN 1426</td>
<td>20-30</td>
<td>35-50</td>
<td>50-70</td>
<td>70-100</td>
<td>100-150</td>
</tr>
<tr>
<td>Pehmenemispiste</td>
<td>°C</td>
<td>SFS-EN 1427</td>
<td>55,0-63,0</td>
<td>50,0-58,0</td>
<td>46,0-54,0</td>
<td>43,0-51,0</td>
<td>39,0-47,0</td>
</tr>
<tr>
<td>Dynaaminen viskositeetti, 60 °C</td>
<td>Pas</td>
<td>SFS-EN 12596</td>
<td>≥ 440</td>
<td>≥ 225</td>
<td>≥ 145</td>
<td>≥ 90</td>
<td>≥ 55</td>
</tr>
<tr>
<td>Kinemaattinen viskositeetti, 135 °C</td>
<td>mm²/s</td>
<td>SFS-EN 12595</td>
<td>≥ 530</td>
<td>≥ 370</td>
<td>≥ 295</td>
<td>≥ 230</td>
<td>≥ 175</td>
</tr>
<tr>
<td>Murtumispiste</td>
<td>°C</td>
<td>SFS-EN 12593</td>
<td>≤ -5</td>
<td>≤ -8</td>
<td>≤ -10</td>
<td>≤ -12</td>
<td>≤ -15</td>
</tr>
<tr>
<td>Ohutkalvokoe</td>
<td>SFS-EN 12607-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- massan muutos</td>
<td>± m-%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- jäänöstunkeuma</td>
<td>%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- pehmenemispisteen nousu</td>
<td>°C</td>
<td>SFS-EN 1427</td>
<td>≤ 10</td>
<td>≤ 11</td>
<td>≤ 11</td>
<td>≤ 11</td>
<td>≤ 12</td>
</tr>
<tr>
<td>Leimahduspiste</td>
<td>°C</td>
<td>SFS-EN ISO 2592</td>
<td>≥ 240</td>
<td>≥ 240</td>
<td>≥ 230</td>
<td>≥ 230</td>
<td>≥ 230</td>
</tr>
<tr>
<td>Liukoisuus toluenein</td>
<td>m-%</td>
<td>SFS-EN 12592</td>
<td>≥ 99,0</td>
<td>≥ 99,0</td>
<td>≥ 99,0</td>
<td>≥ 99,0</td>
<td>≥ 99,0</td>
</tr>
</tbody>
</table>

Murtumispiste: Fraass breaking point
Ohutkalvokoe: Rolling Thin Film Oven Test
### PANK Asfalttinormit 2011
(Pehmeiden tiebitumien laatuvaatimukset)

<table>
<thead>
<tr>
<th>Bitumihuokka</th>
<th>Menetelmä</th>
<th>250/330</th>
<th>330/430</th>
<th>500/650</th>
<th>650/900</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tunkeuma, 15 °C</td>
<td>SFS-EN 1426</td>
<td>70-130</td>
<td>90-170</td>
<td>140-260</td>
<td>180-360</td>
</tr>
<tr>
<td>Dynaaminen viskositeetti, 60 °C</td>
<td>SFS-EN 12596</td>
<td>≥ 18</td>
<td>≥ 12</td>
<td>≥ 7,0</td>
<td>≥ 4,5</td>
</tr>
<tr>
<td>Kinemaattinen viskositeetti, 135 °C</td>
<td>SFS-EN 12595</td>
<td>≥ 100</td>
<td>≥ 85</td>
<td>≥ 65</td>
<td>≥ 50</td>
</tr>
<tr>
<td>Murtumispiste °C</td>
<td>SFS-EN 12593</td>
<td>≤ -16</td>
<td>≤ -18</td>
<td>≤ -20</td>
<td>≤ -20</td>
</tr>
<tr>
<td>Ohutkalvokoe</td>
<td>SFS-EN 12607-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- massan muutos ± m-%</td>
<td></td>
<td>≤ 1,0</td>
<td>≤ 1,0</td>
<td>≤ 1,5</td>
<td>≤ 1,5</td>
</tr>
<tr>
<td>- viskositeettisuhde, 60 °C</td>
<td></td>
<td>≤ 4,0</td>
<td>≤ 4,0</td>
<td>≤ 4,0</td>
<td>≤ 4,0</td>
</tr>
<tr>
<td>Leimahduspiste °C</td>
<td>SFS-EN ISO 2719</td>
<td>≥ 200</td>
<td>≥ 200</td>
<td>≥ 180</td>
<td>≥ 180</td>
</tr>
<tr>
<td>Liukoisuus tolueniin m-%</td>
<td>SFS-EN 12592</td>
<td>≥ 99,0</td>
<td>≥ 99,0</td>
<td>≥ 99,0</td>
<td>≥ 99,0</td>
</tr>
</tbody>
</table>
Kuva 1: Pehmeät asfaltimassat (sininen korostus) sideaineen ja asfaltittyypin perusteella suhteessa muihin Suomessa käytettyihin asfaltittyypeihin (Asfaltinormit 2008, (PANK ry 2007))

Simonen, M. Biofluksattujen bitumien ominaisuudet ja käyttö varastoitavissa pehmeissä asfaltibetonimassoissa. Dipl.työ.2011
Conventional Ways to Measure Bitumen Viscosity

- **Absolute viscosity ASTM D2171**
  - Vacuum capillary viscometers

- **Kinematic viscosity ASTM D2170**
  - Reverse-flow viscometers
Penetration (Tunkeuma)

- Distance in tenth of a millimeter that a standard needle penetrates to a sample under standard condition of loading (100 g), time (5 seconds), and temperature (e.g., 25°C)

- High value of penetration indicates a softer consistency or higher fluidity
Ring and Ball Softening Point $T_{R&B}$
(Pehmenemispiste)

- Way to measure empirical consistency of bitumen used in the Van der Poel (1954) Nomograph for binder stiffness $|G^*|$ (Developed by Shell Oil)
  - Binder stiffness is dependent of loading time and temperature
  - Two binder properties, penetration and $T_{R&B}$ softening point are needed

Nomograph can be found from text book of Huang: Pavement Analysis and Design (2nd ed), page 303
Specific Gravity (tiheys)

- Specific gravity of asphalt is defined as the ratio of the mass of a given volume of asphalt to that of an equal volume of water at 25°C or 15.6°C

- Specific gravity of asphalt cement varies between 0.95-1.05

- Typical value 1.02

- Specific gravity decreases with increasing bitumen temperature
Durability (kestävyyys)

- Durability is defined as the property that permits the pavement material to withstand the detrimental effects of temperature, air, and moisture.
- Durability can be measured from bituminous mixtures and/or binders.

The effect of binder for durability (effect of heat and air) is measured by two tests:
- Thin-film oven test (ASTM D1754)
- Rolling thin-film oven test (ASTM D2872).

- Effect of heat and air is determined to simulate the conditions obtained when the bitumen is used to manufacture hot-mix.
Thin Film Oven (TFO) Test - ASTM D1754 (Ohutkalvokoe)

- In thin-film oven test a film of asphalt is exposed to an air current at 163°C for five hours.
- Significant changes in the properties (for instance viscosity or penetration) of the asphalt after heating may indicate poor durability.
Rolling Thin Film Oven (RTFO) Test - ASTM D1754 (Ohutkalvokoe pyörivässä sylinterissä)
Ductility – ASTM D113 (Venymä)

- Elongation before breaking when specimen is pulled apart at a specified speed (5cm/min) and temperature (25°C)
Flash Point and Solubility
(Leimahduspiste ja liukoisuus)

- Thermometer
- Cup filled with asphalt
- Wand attached to gas line

Solubility to trichloroethylene, min 99.0%
Fraass breaking point
(Murtumispiste)

- Test that can be used to measure bitumen behavior at low (up to -30°C) temperature
- Determines temperature at which bitumen reaches a critical temperature and cracks.
  - A steel plaque coated with 0.5 mm bitumen is slowly flexed and released
  - Temperature of the plaque is reduced at 1°C per minute until bitumen cracks
Superpave Performance Grading System (developed in SHRP program in the USA in 90s)

The grading system is based on climate and expected in-situ performance.

**PG 64 - 22**

- **Performance Grade**
  - High Temp Grade
  - Low Temp Grade

- **Minimum pavement temperature**
- **Average 7-day maximum pavement temperature**

# Performance Grading Asphalt Binder

## Table 6.4 Performance Grades of Asphalt Binder

<table>
<thead>
<tr>
<th>High Temperature Grades</th>
<th>Low Temperature Grades</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG 46</td>
<td>-34, -40, -46</td>
</tr>
<tr>
<td>PG 52</td>
<td>-10, -16, -22, -28, -34, -40, -46</td>
</tr>
<tr>
<td>PG 58</td>
<td>-16, -22, -28, -34, -40</td>
</tr>
<tr>
<td>PG 64</td>
<td>-10, -16, -22, -28, -34, -40</td>
</tr>
<tr>
<td>PG 70</td>
<td>-10, -16, -22, -28, -34, -40</td>
</tr>
<tr>
<td>PG 76</td>
<td>-10, -16, -22, -28, -34</td>
</tr>
<tr>
<td>PG 82</td>
<td>-10, -16, -22, -28, -34</td>
</tr>
</tbody>
</table>
PG Specification

• Based on fundamental material properties related to pavement performance:
  - Rutting → High Temp Grade
  - Fatigue cracking → Intermediate Grade
  - Low-temperature cracking → Low Temp Grade

• Based on specified property at performance temperature which will be determined
  - $|G^*|/\sin\delta > 1 \text{ kPa at } 70^\circ\text{C}$ (High Temp Grade)
### 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></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### (Rotational Viscosity) RV

<table>
<thead>
<tr>
<th></th>
<th>90</th>
<th>90</th>
<th>100</th>
<th>100</th>
<th>(110)</th>
<th>(110)</th>
<th>110</th>
<th>(110)</th>
</tr>
</thead>
</table>

#### (Flash Point) FP

<table>
<thead>
<tr>
<th></th>
<th>46</th>
<th>52</th>
<th>58</th>
<th>64</th>
<th>70</th>
<th>76</th>
<th>82</th>
</tr>
</thead>
</table>

#### (Rolling Thin Film Oven) RTFO

**Mass Loss < 1.00 %**

<table>
<thead>
<tr>
<th></th>
<th>46</th>
<th>52</th>
<th>58</th>
<th>64</th>
<th>70</th>
<th>76</th>
<th>82</th>
</tr>
</thead>
</table>

#### (Pressure Aging Vessel) PAV

**Pressures**

- **20 Hours, 2.07 MPa**
  - PG 46
  - PG 52
  - PG 58
  - PG 64
  - PG 70
  - PG 76
  - PG 82

**S < 300 MPa, m > 0.300**

|                   | 10    | 7     | 4     | 25    | 22    | 19    | 16    | 34    | 31    | 28    | 25    | 22    | 19    | 16    | 34    | 31    | 28    | 25    | 22    | 19    | 16    | 34    | 31    | 28    |
|-------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|

**Report Value > 1.00 %**

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
</table>

#### (Bending Beam Rheometer) BBR

- **“S” Stiffness & “m”-value**
- **Physical Hardening**

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
</table>

#### Dynamic Shear Rheometer DSR

- $G^*/sin \delta$

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
</table>

---

(Continued from previous page)
## How the PG Spec Works

<table>
<thead>
<tr>
<th>Spec Requirement</th>
<th>Remains Constant</th>
<th>Test Temperature Changes</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>

### Spec Requirement Remains Constant

- **PG 58**: 46, 52
- **PG 64**: 70, 76, 82

### Test Temperature Changes

- **PG 58**: 46, 52
- **PG 64**: 70, 76, 82

### Table: Spec Requirements across Grades

<table>
<thead>
<tr>
<th>Grade</th>
<th>Spec Requirement</th>
<th>Test Temperature Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG 58</td>
<td>46, 52</td>
<td></td>
</tr>
<tr>
<td>PG 64</td>
<td>70, 76, 82</td>
<td></td>
</tr>
</tbody>
</table>

### Note:

- The PG Spec works by maintaining certain requirements across grades while allowing test temperatures to change.
- Specified values are constant for specific grades, ensuring consistency across different testing conditions.
Summary of Testing for PG Grading

**Construction**

**Rutting**

**Fatigue**

**Cracking**

**Low Temp**

**Cracking**

<table>
<thead>
<tr>
<th>Testing Method</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTFO</td>
<td>G* sinδ</td>
</tr>
<tr>
<td>Short Term Aging</td>
<td>G*/sinδ</td>
</tr>
<tr>
<td>PAV</td>
<td>Low Temp</td>
</tr>
</tbody>
</table>

**Summary of Testing for PG Grading**

- Summary of Testing for PG Grading
- Construction
- Rutting
- Fatigue
- Cracking
- Low Temp Cracking
- RTFO
- G* / sinδ
- Short Term Aging
- G* sinδ
- PAV
- Long Term Aging
Rotational Viscometer ASTM D4402 (Brookfield Thermosel Apparatus)

- Absolute viscosity
- For unmodified and modified asphalt binders
DSR (Dynamic Shear Rheometer) (dynaaminen leikkausreometri)

- Control either stress or strain rate
- Torque measurement
- Measured property:
  - shear stiffness $|G^*|$ and phase lag $\delta$

Parallel plates
Coaxial cylinders
Aging Properties for PG grading

- **Rolling Thin Film Oven** (Short term aging STA)
  - Simulates aging from hot mixing and construction

- **Pressure Aging Vessel** (Long-term aging LTA)
  - Simulates aging of an asphalt binder for 7 to 10 years
Bending Beam Rheometer (BBR)

Measured property: Creep stiffness $S(t)$ and Slope $m$
Direct Tension Test (DTT)

Measured property: Tensile strain at failure
Summary of How to Use PG Specification

• Determine
  – 7-day max pavement temperature at a depth of 20 mm below the pavement surface:
  – 1-day minimum pavement temperature

• Use specification tables to select test temperatures
  – Determine asphalt cement properties (lab tests) and compare to specification limits

• High temperature is adjusted (grade pumping) for slow traffic
“PG Plus” Tests

- Original PG specification was based on study of neat (nonmodified binders)
  - Linear behavior and not stress sensitive
- Use of modified binders has grown tremendously
  - Nonlinear behavior and stress sensitive
- PG grading AASHTO M 320 alone may not always predicted performance
  - Grade pumping to increasing rutting resistance may not be adequate
  - Recovery of modified binders not adequately captured
- Most states begun requiring additional empirical tests, referred as “PG Plus” tests
  - Tests are not standard across states—difficult to suppliers

Elastic Recovery Test

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

Danny Gierhart, Asphalt Institute, 2011
PG Grading alone does not always 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
Multiple Stress Creep Recovery (MSCR) Test for modified binders

- Allows performance grade binder spec that is blind to modification type
- Can relate polymer modified binders potential rutting performance to in service performance
- New rutting parameters
  - Non-recoverable creep compliance $J_{nr} [1/kPa]$
  - Recovery [%]
Multiple Stress Creep Recovery (MSCR) Test for modified binders

Reducing $J_{nr}$ by half typically reduced rutting by half
New PG grading system (MSCR)

- Environmental grade plus traffic designation i.e. PG 64-22E.
- Four traffic levels.
  - S = Standard: < 10 million ESALs and standard traffic loading
  - H = Heavy: 10 – 30 million ESALs or slow moving traffic loading
  - V = Very Heavy: > 30 million ESALs or standing traffic loading
  - E = Extr. Heavy: > 30 million ESALs and standing traffic loading
US PG Specs

• PG-grading (AASHTO M320-10/ASTM D6373-07e1):
  – PG-luokan määrittäminen (G*/sin\(\delta\) and G*sin\(\delta\)):
    • AASHTO R29-08: Grading or Verifying the Performance Grade (PG) of an Asphalt Binder
    • ASTM D7643 - 10: Standard Practice for Determining the Continuous Grading Temperatures and Continuous Grades for PG Graded Asphalt Binders
  – Multiple Stress Creep Recovery (MSCR) -test:
    • AASHTO TP 70-12: Standard Method of Test for Multiple Stress Creep Recovery (MSCR) Test of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)
    • ASTM D7405 - 10a: Standard Test Method for Multiple Stress Creep and Recovery (MSCR) of Asphalt Binder Using a Dynamic Shear Rheometer
Review Questions

- List bitumen grading systems
- What is the test the viscosity grading system is based on?
- Why PG-grading was developed in the US?
- Should we use PG grading also in Europe?
- What pavement distress penetration is describing?
- How do we know if bitumen ages too much on the road?
- If asphalt mixture is shoving, should contractor change the bitumen type or put less bitumen to asphalt mixture?
- If bitumen cools down below 60 °C during asphalt construction, what consequences it may have?
- While fabricating asphalt mixture, is it more convenient to measure amount of bitumen by mass or by volume?
The deep rutting occurred on the constructed road just after the trafficking. The first assumption was that the bitumen used may have not been according to the mix design. The samples of asphalt were collected from the road and bitumen was recovered from them and evaluated with a few chosen tests. The results are in the table.

<table>
<thead>
<tr>
<th>Ominaisuus</th>
<th>Yksikkö</th>
<th>Testiarvot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viskositeetti 60 °C</td>
<td>Poise</td>
<td>568</td>
</tr>
<tr>
<td>Tunkeuma, 25°C, 100 g, 5s</td>
<td>0,1 mm</td>
<td>128</td>
</tr>
<tr>
<td>Viskositeetti 135 °C</td>
<td>cSt</td>
<td>123</td>
</tr>
<tr>
<td>Leimahuspiste, Cleveland Open cup</td>
<td>°C</td>
<td>190</td>
</tr>
</tbody>
</table>

The mix design assumed the use of bitumen 70/100. Did the contractor use the specified bitumen? If not, what grade of bitumen was used? Support your answer.