Modified Asphalt Testing and Characterization

Understanding Modified Asphalt Binder Technology Workshop
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Objectives

- Gain a basic understanding of modified asphalt, it’s testing and characterization.
- Know the basic purpose of the more common asphalt material tests, including PG, Viscosity and Pen test.
- Be an active participant, ask questions and have fun!
But first, a word about asphalt rheology*

(*From the standpoint of a civil engineer.*)
Rheology

The study of materials whose flow properties exhibit elastic, viscous, and plastic behavior, and whose flow properties may be dependent on the rate at which they are loaded.
Asphalt is a material whose behavior is explained by rheological principles.
How Asphalt Behaves

- Asphalt behavior depends on:
  - temperature
  - time of loading
  - age is also important

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Time 1</th>
<th>Time 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>60°C</td>
<td>1 hour</td>
<td></td>
</tr>
<tr>
<td>25°C</td>
<td>1 hour</td>
<td>10 hours</td>
</tr>
</tbody>
</table>
Viscous Behavior

- High Temperature
  - desert climate
  - summer season
- Sustained Loads
  - slow moving trucks
    - intersections
    - uphill grades

Asphalt tries to act like a viscous fluid.
Elastic Behavior

- Low Temperature
  - cold climate
  - winter weather
- Rapid Loads
  - fast moving trucks

Asphalt tries to act like elastic solid
Okay, which is it viscous or elastic?

Asphalt is viscoelastic
Elastic Solids

Before Load

During Load

Elastic Deformation

After Load

Tension Load

150 lbs?

150 lbs?
Elastic Solids

Axial Stress vs. Axial Strain
Elastic Solids

(Remember Hooke’s Law)

\[ \text{Stress } (\sigma) = E \times \text{strain } (\varepsilon) \]

*elastic modulus*
Viscous Fluids

Deck of cards

Resistance between cards is like viscosity
Viscous Fluids

Shear or Resisting Stress, $\tau$

between Layers

Layer 1

Layer 2

direction of flow
of both layers

velocity layer 1

velocity layer 2
Viscous Fluids

\[ \text{shear stress} = \mu \times \text{rate of shear strain} \]

\text{viscosity}
Viscous Fluids

Shear Stress Between Layers

Bingham plastic (e.g., toothpaste)

Shear thinning

Newtonian (high temp asphalt)

Shear thickening

Rate of Shear Strain

μ
Viscoelastic Materials

Elastic Modulus

Viscous Modulus

Angle indicates relative behavior
Viscoelastic Materials

$G' = \text{complex shear modulus}$

$G'' = \text{phase angle} \delta$
Let’s talk about specifications!
So you want to buy some asphalt...

- Tell me what you want
  - “I want it hot and sticky”
  - “It needs to remain pliable if I chew it 100 times”
  - “If I heat it to 100 F in an oven in an itty bitty cup, it shall not flow out after one hour ± 5 minutes”
  - “Sell me something that works”
You Need a Specification!

- Tells important properties
- Identifies ways to measure important properties
- Part of a contract between a buyer and seller
Early Asphalt Specs

• Early specs written around natural asphalts (Trinidad, Bermudez)
  • color
  • solubility in carbon disulfide

• Later paving specs written around consistency defined by penetration test and even later, viscosity test.
Penetration Test

Purpose
- consistency of asphalt
- intermediate temperature

Grades:
- 40 - 50
- 60 - 70
- 85 - 100
- 120 - 150
- 200 - 300

Penetration:
- 0 sec: 100 g, penetration 0.1 mm
- 5 sec: 100 g

77 F (25 C)
Other Tests Added Later

- Flash point
- Ductility
- Solubility
- Aging in thin films
  - Pen
  - Ductility

Typical Asphalt Terminal
Flash Point (COC)

Purpose

- Safety test
- Analytical test
  - “what’s in there”
  - flammability
Ductility

- Purpose
  - tensile properties
  - cohesive properties
  - homogeneity
Force Ductility

- Purpose
  - Tensile properties
  - Cohesive properties
  - Homogeneity
  - Output is stress-strain
  - Used primarily in modified asphalts
Solubility

- Purpose
  - Purity
  - Foreign extraneous “stuff” in asphalt
Thin Film Oven Aging
## Example Pen Specs

<table>
<thead>
<tr>
<th></th>
<th>40 - 50</th>
<th>200 - 300</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Penetration</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Flash Point, C</strong></td>
<td>450+</td>
<td>350+</td>
</tr>
<tr>
<td><strong>Ductility, cm</strong></td>
<td>100+</td>
<td>100+</td>
</tr>
<tr>
<td><strong>Solubility, %</strong></td>
<td>99.0+</td>
<td>99.0+</td>
</tr>
<tr>
<td><strong>Retained Pen., %</strong></td>
<td>55+</td>
<td>37+</td>
</tr>
<tr>
<td><strong>Ductility, cm</strong></td>
<td>NA</td>
<td>100+</td>
</tr>
</tbody>
</table>
Consistency (pen)

Temperature, C

hard

soft

pen

A

B

C

-15  25  60  135
Viscosity Test and Spec

- **Purpose**
  - Flow properties at high pavement temperature (60°C)

**Grades:**
- AC 2.5, AC 5, AC 10, AC 20, AC 30, AC 40
Absolute Viscosity Test
Kinematic Viscosity Test

- **Purpose**
  - Flow properties at high temperature (135°C)
Elastic Recovery Test

- **Purpose**
  - Detect presence of stretchy polymer dissolved in asphalt
  - Ability of asphalt to snap back to original shape
PG Tests
PG Binder Tests

Construction

Rutting

Fatigue

Cracking

Low Temp Cracking

Pavement Age

No aging

RTFO - aging

PAV - aging
Aged Residue

- **Purpose**
  - Create lab aged sample
  - Plant aging
  - Pavement aging

Rolling Thin Film Oven (HMA Plant Aging)

Pressure Aging Vessel (In-Service Aging)
Dynamic Shear Rheometer

- **Purpose**
  - Flow characteristics at high temps (52-76 C)
  - Evaluates viscous and elastic characteristics
Dynamic Shear Rheometer
*(high temp rutting, intermediate temp fatigue cracking)*

Output is complex shear modulus \((G^*)\) and phase angle \((\delta)\)
Multiple Stress Creep Recovery Test (MSCR)

- Measure ability of binder to recover shear strain after repeated shear stress cycles
- Potentially an analog for elastic recovery and/or replace $G^*/\sin\delta$

\[
J_{nr} = \frac{\text{Unrecovered Shear Strain}}{\text{Applied Shear Stress}}
\]
“Implementation of the Multiple-Stress Creep-Recovery Test and Specification” “It is the Asphalt Institute’s opinion that the MSCR test and specification represent a technical advancement over the current PG specification that will allow for better characterization of the high temperature performance-related properties of an asphalt binder.”
Rotational Viscometer
*(high temp handling, pumping)*

Output is vis at 135 C and temp/vis chart
Bending Beam Rheometer

- **Purpose**
  - Stiffness at low pavement temperatures (-34 – 0°C)
  - Stress relaxation at low pavement temperatures
Bending Beam Rheometer

Output is creep stiffness (S) and creep rate/slope (m value)
Direct Tension Tester

- **Purpose**
  - Determine fracture properties at low pavement temperatures (-34 – 0 C)
  - tensile failure strain
- No longer a common test...but it is in the PG spec
Other Tests on Modified Asphalt

- **Specific Gravity**
  - Performed on any type of binder for mass/volume calculation

- **Toughness & Tenacity**
  - Material is stretched vertically to determine load until it breaks. Load deformation curve is plotted

- **Screen Test**
  - To determine the homogeneity of binder

- **Separation**
  - To check the binder susceptibility to separation
Emulsion

• Emulsion is a system with 2 or more non-miscible liquids

• 1 liquid phase acts as dispersing agent, in which other liquid phase is scattered as fine droplets
Emulsion Tests

Tests on emulsion

Tests on asphalt residue
Emulsion Tests

- Tests on Emulsion
  - viscosity
  - Sieve
  - demulsibility
  - cement mixing
  - storage stability
  - particle charge
  - coating ability
  - percent residue
  - various methods

- Tests on Residue
  - $G^*/\sin \delta$
  - penetration
  - ductility
  - float
  - elastic recovery
  - softening point
  - toughness/tenacity
Emulsion Viscosity

- **Purpose**
  - Flow characteristics at application temps (25 or 50°C)
Emulsion Sieve Test

- **Purpose**
  - Detect presence of coalesced asphalt particles in emulsion
  - Indirect indicator of emulsion chemistry problems

Measure weight of particles that get caught on No. 20 sieve - 20 openings in a linear inch.
Emulsion Percent Residue Test

- **Purpose**
  - measure amount of asphalt binder in emulsion, typically 60%+
- **Many recovery procedures**
  - distillation (177, 200, 230, 260 C)
  - high temp evaporation (163 C)
  - low temp evaporation (60 C)
- **WARNING** – method of recovery affects properties of recovered binder!
Emulsion Percent Residue Test
Float Test

- Purpose
  - Detect the presence of gelled structure in “high float” emulsion residue
Ring and Ball Softening Point Test

- **Purpose**
  - gross indicator of high temperature stiffness
  - Detect presence of elastic or plastic asphalt modifier
Automatic Ring and Ball Softening Point Tester
Storage Stability/Settlement Test

- **Purpose**
  - Determine if there is any settlement of the material inside the storage tank
  - Consistency/uniformity
Simple Laboratory Emulsion Mill
Questions?

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THANK YOU