How Asphalt Behaves

Behavior Depends on

• Temperature
• Time of Loading
• Age of asphalt
High Temperature Behavior

- High Temperature
  -- desert climate
  -- summer

- Sustained Loads
  -- slow moving trucks
  -- intersection

Viscous liquid
Shear or Resisting Stress, $\tau$ between Layers

Layer 1

Layer 2

Direction of flow Of both layers

Velocity Layer 1

Velocity Layer 2

Shear stress = $\mu \times$ rate of shear strain

viscosity
Viscosity Characteristics

- **Newtonian Fluid**
  -- viscosity does not depend on shear strain rate
  -- *for example*... *hot asphalt*

- **Shear Thinning Fluid**
  -- viscosity decreases as shear strain rate increases
  -- *for example*... *warm asphalt*

- **Shear Thickening Fluid**
  -- viscosity increases as shear strain rate increases
  -- *for example*... *some polymers*
Pavement Behavior-High Temperature

- Permanent Deformation
- Mixture is Plastic
  - wheel path rutting
  - shoving at intersections
- Shear Thickening Fluid
  - asphalt cement (some)
  - mineral aggregate (lots)

Low Temperature Behavior

- Low Temperature
  - cold climate
  - winter
- Rapid Loads
  - fast moving trucks
Pavement Behavior-Low Temperature

- **Thermal Cracks**
  - internal stresses included by temperature change
  - stress exceed strength
- **Mixture is Brittle**
  - transverse cracks
- **Depend on**
  - asphalt cement (lots) \( \simeq 90\% \)
  - mineral aggregate (little) \( \simeq 10\% \)
Aging Behavior

- **Asphalt Reacts with Oxygen**
  - “oxidative” or “age” hardening
- **During Construction – Short Term**
  - hot mixing
  - placing/compaction
- **In Service – Long Term**
  - hot climate worse than cool climate
  - summer worse than winter
- **Volatilization – Short term**
  - volatile components evaporate during construction

Pavement Behavior- Aging

- **Durability Cracks**
- **Mixture is Brittle**
  - random, wandering cracks
- **Depend on**
  - asphalt cement (lots)
  - mineral aggregate (some)
Current Ways to Measure Asphalt Properties

- Penetration
- Viscosity
Problems with Current System

- **Viscosity**
  - viscous effects only
- **Penetration**
  - empirical measure of viscous and elastic effects
- **No low Temperature Properties Measured**
- **Problems with Modified Asphalt Characterization**
- **Long Term Aging not Considered**
- **Specification Proliferation**
SHRP Program

• 5 year, $50 million on asphalt
• Products
  -- performance based spec for “binder”
  -- system for asphalt mixtures design and analysis
  -- performance based spec for mixtures
• Measure Physical Properties to Predict Performance

Asphalt Binder Projects

• High/Intermediate Temperature Properties
  -- dynamic shear rheometer (DSR)
  -- rotational viscometer (RV)
• Low Temperature Properties
  -- bending beam rheometer (BBR)
  -- direct tension tester (DTT)
• Durability Properties
  -- rolling thin film oven (RTFO)
  -- pressure aging vessel (PAV)
Dynamic Shear Rheometer- DSR

- **Evaluates**
  - elastic & viscous properties
  - time & temperature effects
- **Other Names**
  - oscillatory shear rheometers
  - dynamic rheometers
- **Output**
  - complex shear modulus ($G^*$)
  - phase angle ($\delta$)
Fixed Plate Asphalt Oscillating Plate Applied Stress or Strain

Position of Oscillating Plate

A B C

1 cycle

Time

H.A.W

DSR Frequency of Oscillation

- 10 radians per second
- 1.59 Hz

360 degrees per circle = \( 2\pi \) radian per circle

1 radian \( \approx \) 57.3 degrees

H.A.W
Dynamic Shear Rheometer

- Constant Stress DSR  
  -- apply fixed torque to achieve approx shear strain
- Constant Strain DSR  
  -- apply variable torque to achieve fixed shear strain

Rotational Viscometer- RV

- Evaluates  
  -- handling & pumping properties
- ASTM D 4402
- Other Name  
  -- Brookfield viscometer
  -- rotational coaxial cylinder viscometer
- Output  
  -- viscosity at 135C
  -- viscosity temperature chart for mix design
Applied torque from motor
Asphalt sample
Sample Chamber 135 C

Motor and controller
Spindle extension
Thermo-container
Temperature controller
Bending Beam Rheometer - BBR

- **Evaluates**
  - low temperature stiffness properties

- **Output**
  - creep stiffness
  - m-value
Direct Tension Tester- DT

- **Evaluates**
  - low temperature ability to stretch
- **Output**
  - tensile strain at failure

Failure strain = \[
\frac{\text{Elongation at failure}}{\text{Length before test}}
\]
Binder Aging Methods

- **Rolling Thin Film Oven**
  - simulates aging from hot mixing & construction
  - determines mass loss
- **Pressure Aging Vessel**
  - simulates long term aging
- **Output**
  - aged samples for testing with DSR, BBR, & DTT
Pressure vessel
Sample rack
Sample pan
Asphalt

Air pressure
Temperature probe