Background of SHRP Asphalt Performance Tests

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How Asphalt Behaves

Behavior Depends on

- Temperature
- Time of Loading
- Age of asphalt

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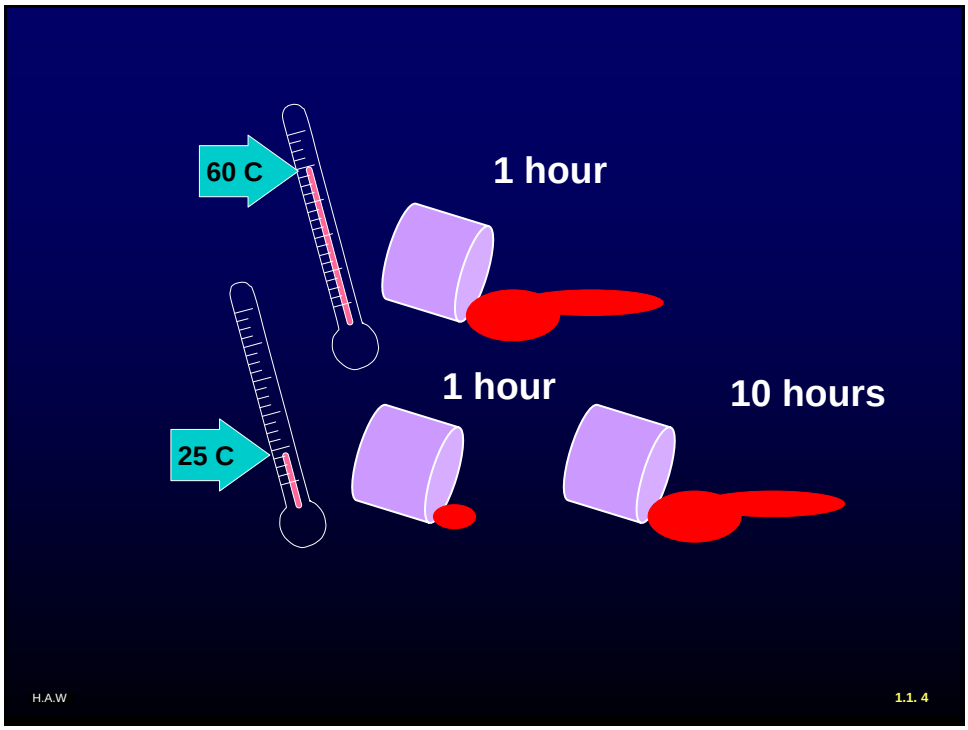

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High Temperature Behavior

- High Temperature
  - -- desert climate
  - -- summer
- Sustained Loads
  - -- slow moving trucks
  - -- intersection

viscous liquid

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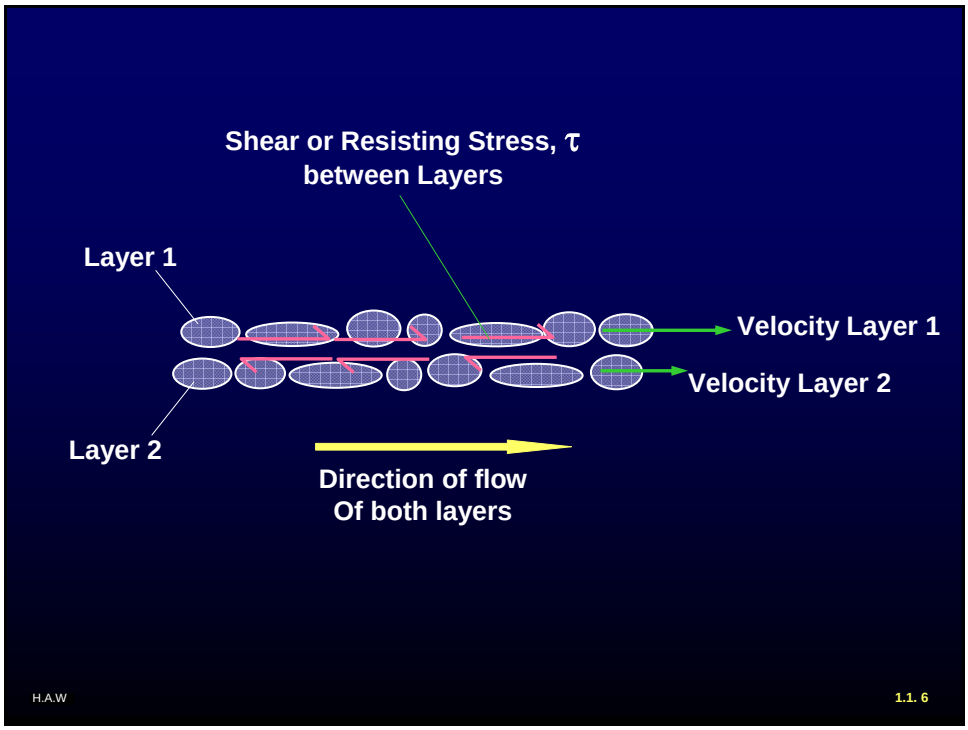
Shear or Resisting Stress, τ
between Layers
Layer 1
Velocity Layer 1
Velocity Layer 2
Layer 2
Direction of flow
Of both layers
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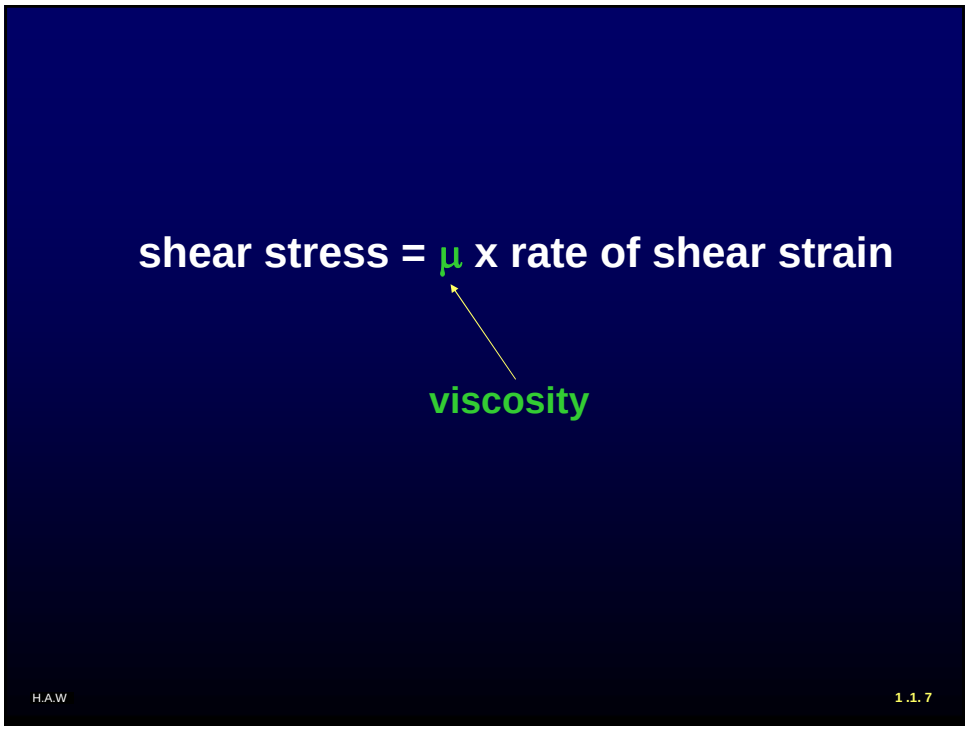
shear stress = μ x rate of shear strain
viscosity
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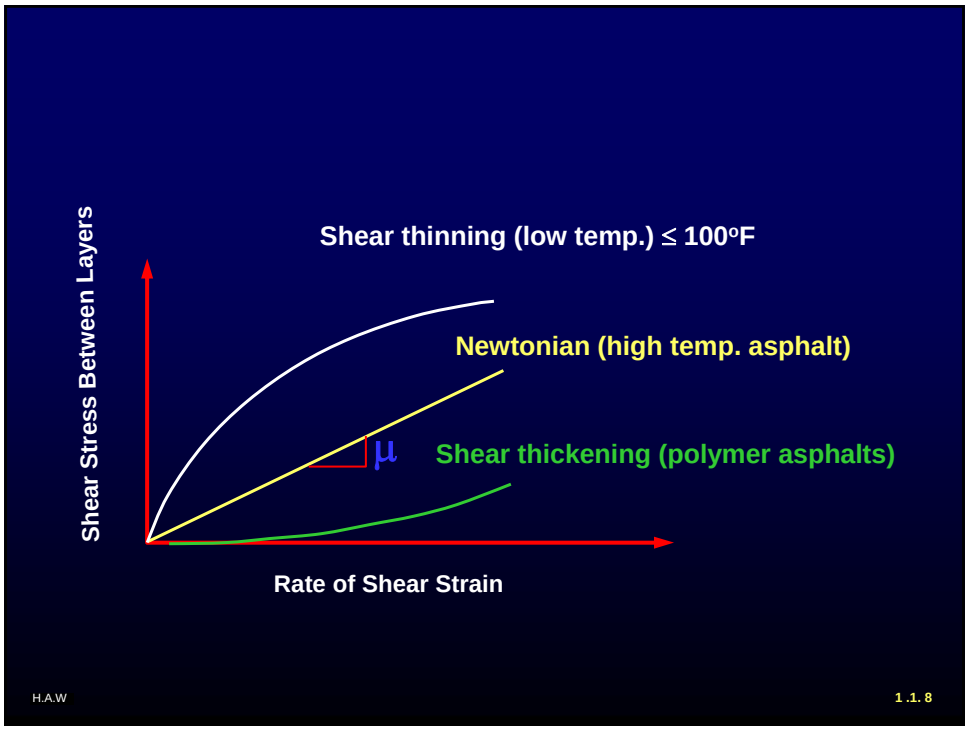

Viscosity Characteristics

- **Newtonian Fluid**
  - -- viscosity does not depend on shear strain rate
  - -- *for example… hot asphalt*
- **Shear Thinning Fluid**
  - -- viscosity decrease as shear strain rate increase
  - -- *for example… warm asphalt*
- **Shear Thickening Fluid**
  - -- viscosity increase as shear strain rate increase
  - -- *for example… some polymers*

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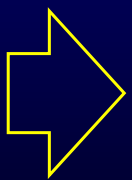
Pavement Behavior-High Temperature

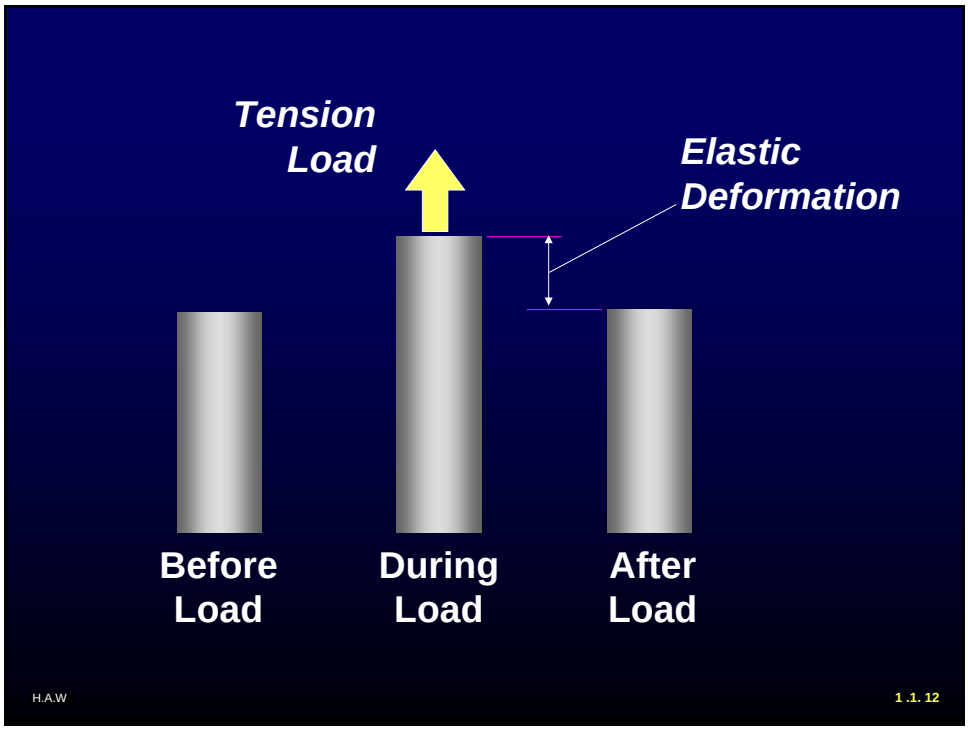
- **Permanent Deformation**
- **Mixture is *Plastic***
  - -- wheel path rutting
  - -- shoving at intersections
- **Shear Thickening Fluid**
  - -- asphalt cement (some)
  - -- mineral aggregate (lots)

Low Temperature Behavior

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



elastic liquid



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) ≃ 90%
  - -- mineral aggregate (little) ≃ 10%

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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

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Pavement Behavior- Aging

- Durability Cracks
- Mixture is *Brittle*
  - -- random, wandering cracks
- Depend on
  - -- asphalt cement (lots)
  - -- mineral aggregate (some)

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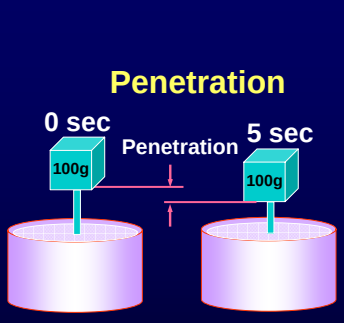
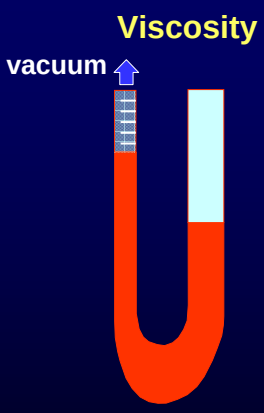
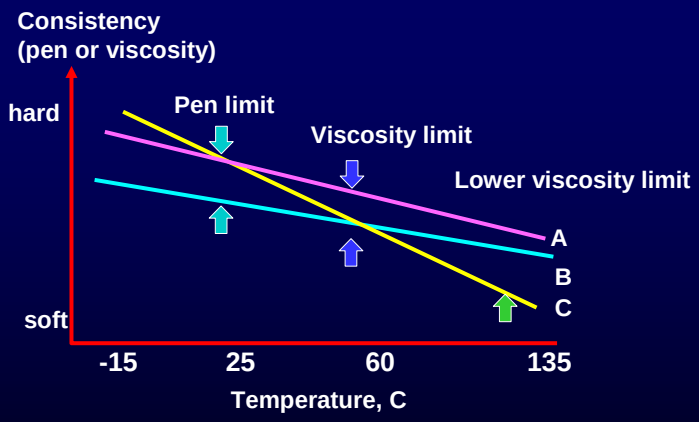
Current Ways to Measure Asphalt Properties

- Penetration
- Viscosity







3- 60/70 AC Asphalts meeting specs

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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

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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

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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)

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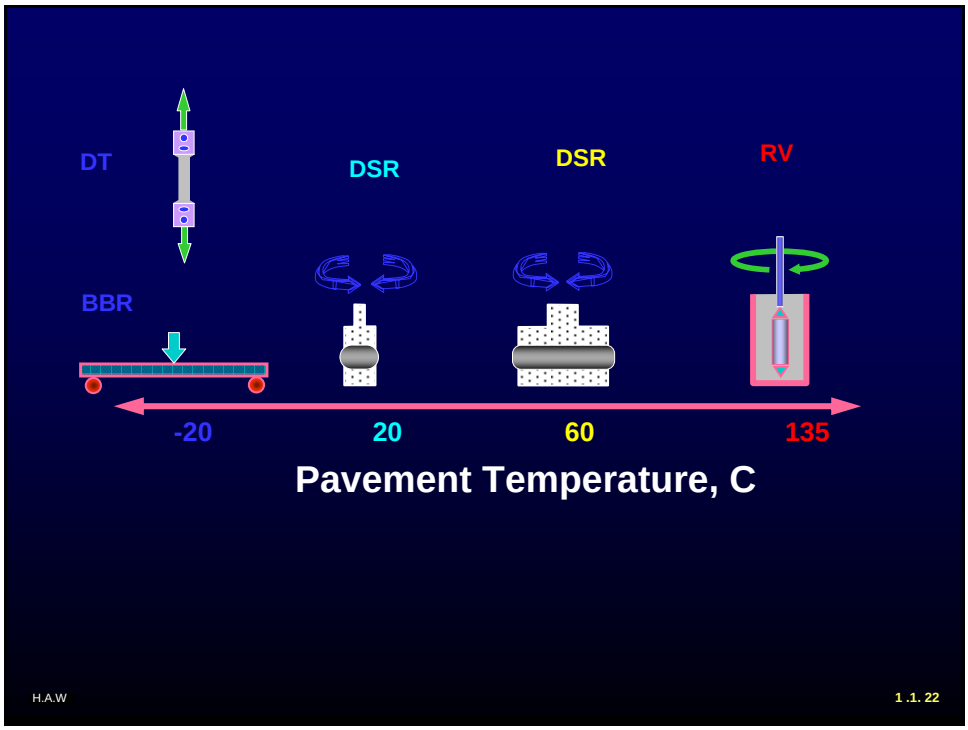

Dynamic Shear Rheometer- DSR

- **Evaluates**
  - -- elastic & viscous properties
  - -- time & temperature effects
- **Other Names**
  - -- oscillatory shear rheometers
  - -- dynamic rheometers
- **Output**
  - -- complex shear modulus (G*)
  - -- phase angle (δ)

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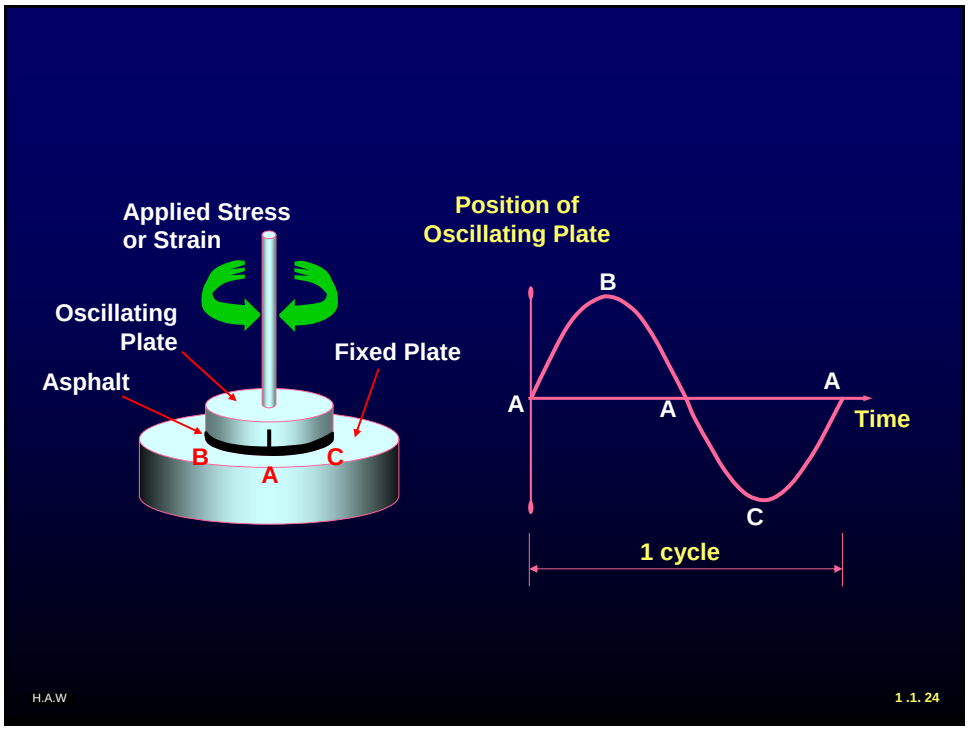
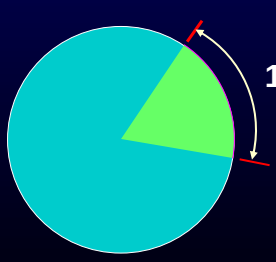


DSR Frequency of Oscillation

- 10 radians per second
- 1.59 Hz

360 degrees per circle = 2 π radian per circle



1 radian ≅ 57.3 degrees

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Dynamic Shear Rheometer

- **Constant Stress DSR**

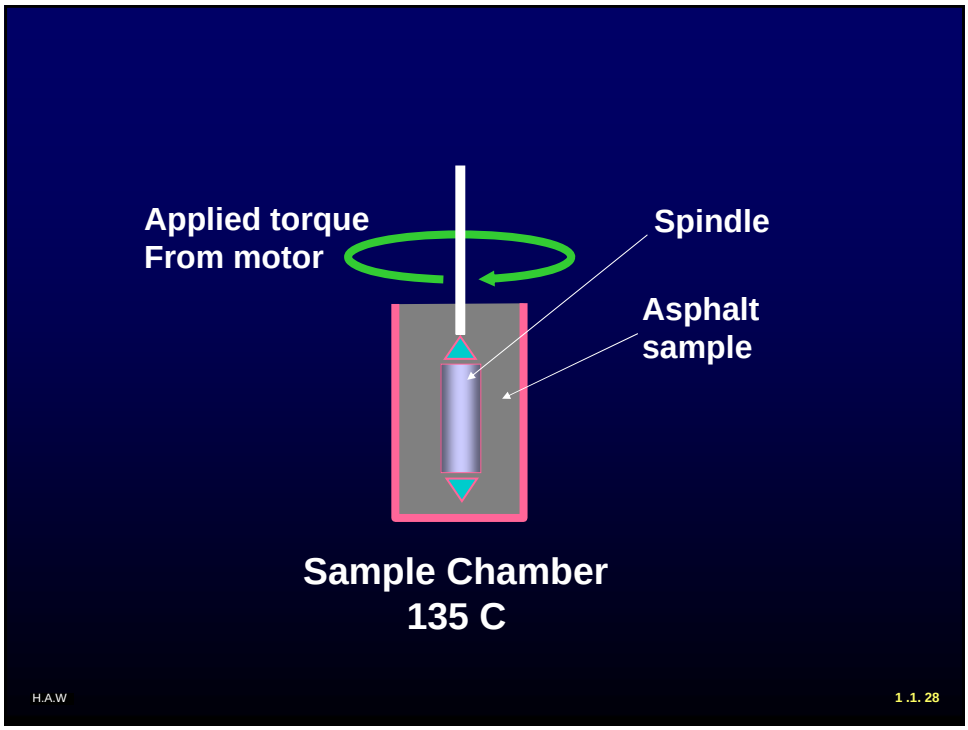
  -- apply fixed torque to achieve approx shear strain

- **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
Spindle
Asphalt
sample
Sample Chamber
135 C
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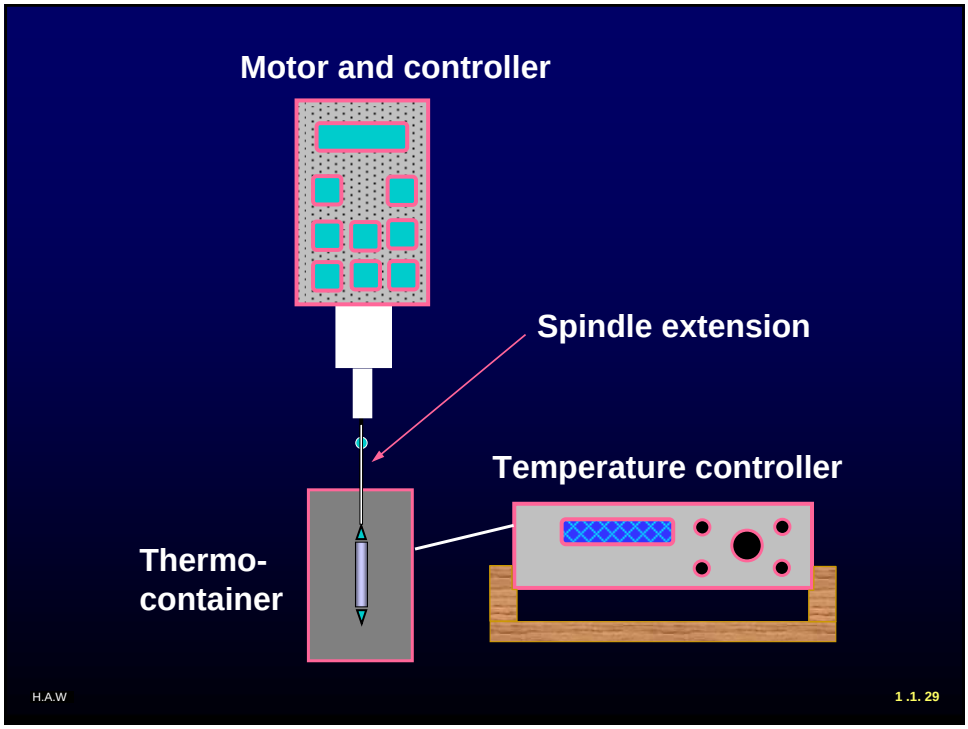
1 .1. 28


Motor and controller
Spindle extension
Temperature controller
Thermo-
container
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1 .1. 29

Bending Beam Rheometer- BBR

- **Evaluates**
  - -- low temperature stiffness properties
- **Output**
  - -- creep stiffness
  - -- m-value

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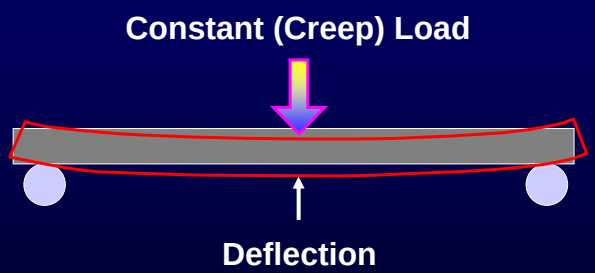

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Direct Tension Tester- DT

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

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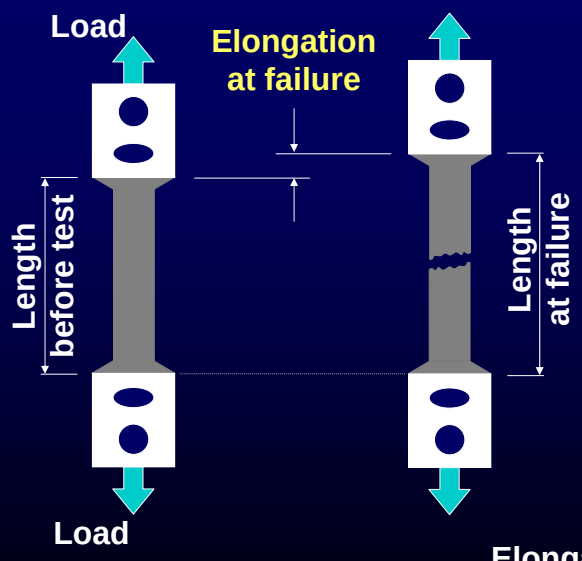

$$\text{Failure strain} = \frac{\text{Elongation}}{\text{Length before test}}$$

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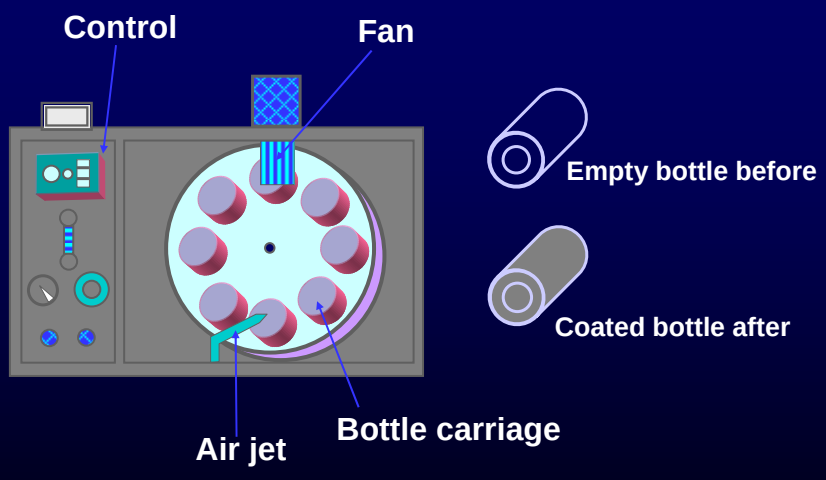
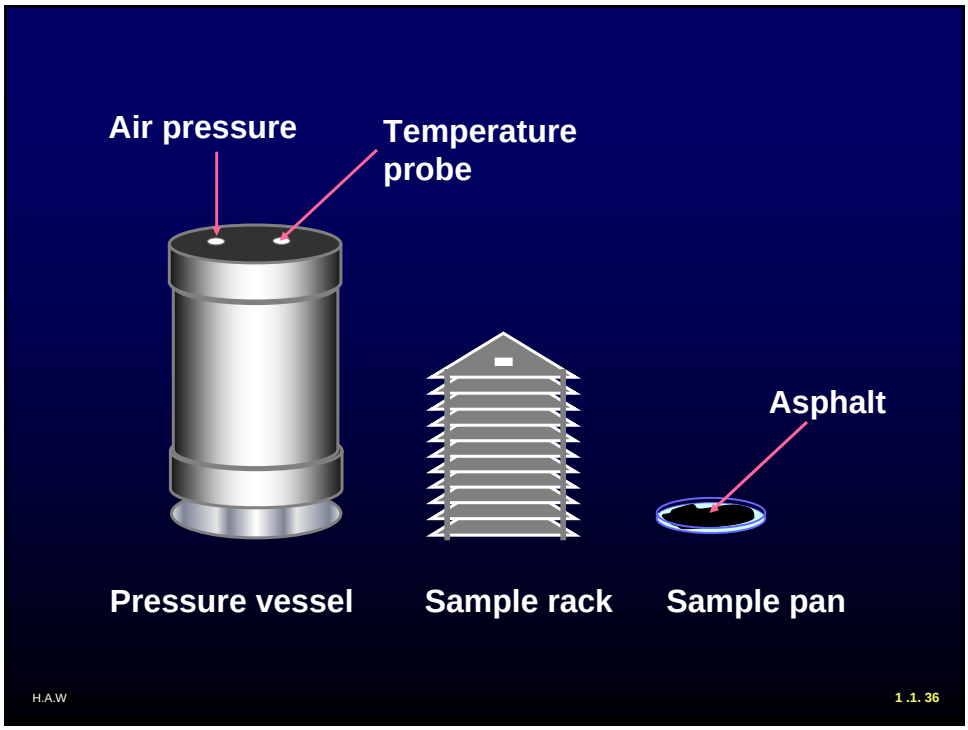
1 .1. 33

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




Air pressure
Temperature probe
Asphalt
Pressure vessel
Sample rack
Sample pan
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1.1. 36