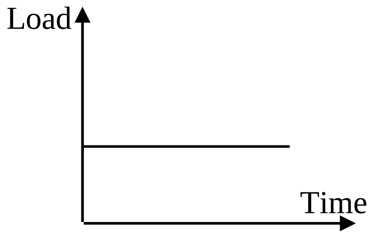
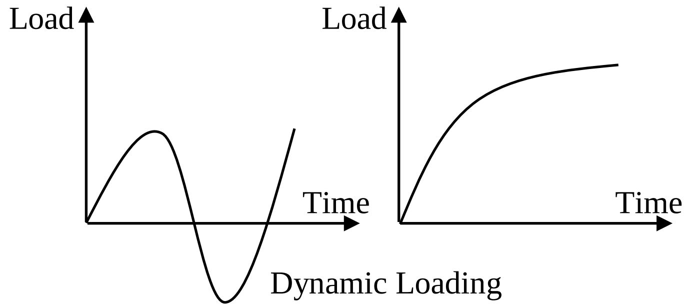
Dynamic Shear Rheometer: DSR

- Dynamic loading vs. static loading.

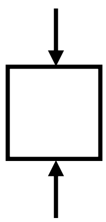


Static Loading

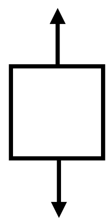


Dynamic Loading

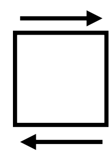
- Types of loading.



Compression, area is normal to load direction



Tension, area is normal to load direction



Shear, area is parallel to load direction

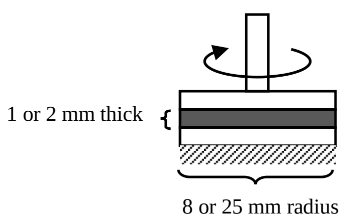
- Elasticity vs. viscosity:
    - Elastic solid: if load applied, deformation will happen, Length.
    - Viscous liquid: if load applied, flow will happen, length/time.

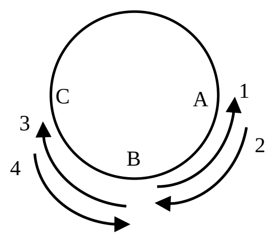
- Asphalt cement are viscoelastic, that means it behaves combination of liquid and solid (has deformation and flow properties).

- Asphalt cement behavior:
    - It behaves like elastic solid under rapid loading and cold temperature (deformation due to loading is recoverable – it is able to return to its original shape after a load is removed)
    - It behaves like viscous liquid under slow loading and high temperature (deformation due to loading is non-recoverable – it cannot return to its original shape after a load is removed).

- The dynamic shear rheometer (DSR) is used to characterize the viscous and elastic behavior of asphalt.

- The basic DSR test uses a thin asphalt sample sandwiched between two circular plates.
- The lower plate is fixed while the upper plate oscillates back and forth across the sample to create a shearing action.
- DSR tests are conducted on unaged, RTFO aged and PAV aged asphalt binder samples.
- Test temperatures greater than 46°C use a sample 1 mm thick and 25 mmin diameter (Unaged asphalt binder and RTFO residue).
- Test temperatures between 4°C and 40°C use a sample 2 mm thick and 8 mm in diameter (PAV residue).

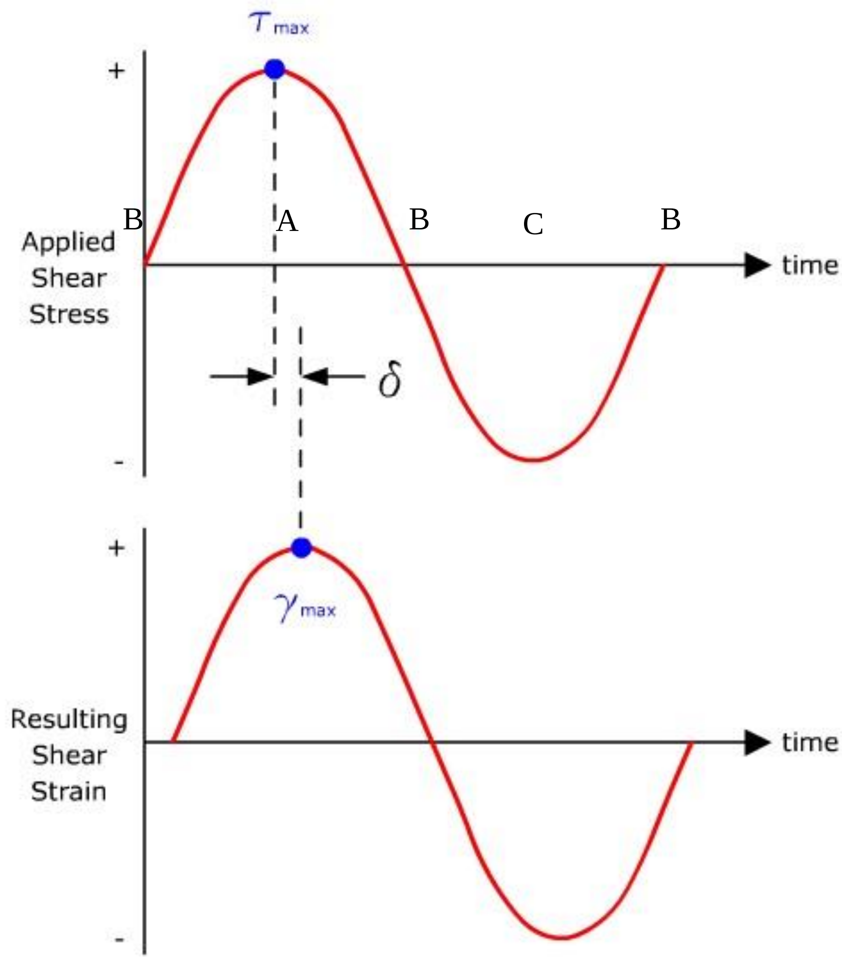


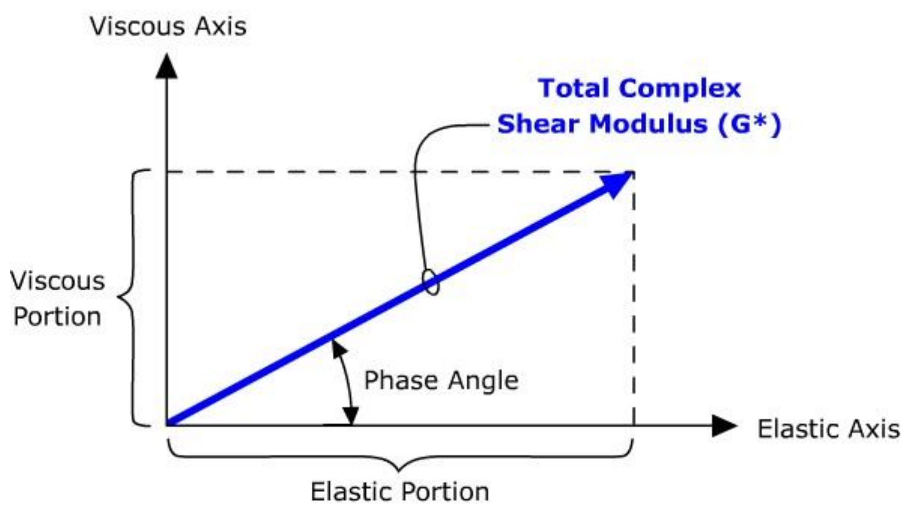


- The DSR measures a specimen's complex shear modulus (G*) and phase angle (δ).

- The complex shear modulus (G*) can be considered the sample's total resistance to deformation when repeatedly sheared.
- The phase angle (δ), is the lag between the applied shear stress and the resulting shear strain.
- The larger the phase angle (δ), the more viscous the material.

- Phase angle (δ) limiting values are:
  - Purely elastic material: δ = 0 degrees.
  - Purely viscous material: δ = 90 degrees.


τ max
+
B
A
B
C
B
Applied
Shear
Stress
time
δ
-
+
γ max
Resulting
Shear
Strain
time
-


Viscous Axis
Total Complex
Shear Modulus (G*)
Viscous
Portion
Phase Angle
Elastic Axis
Elastic Portion

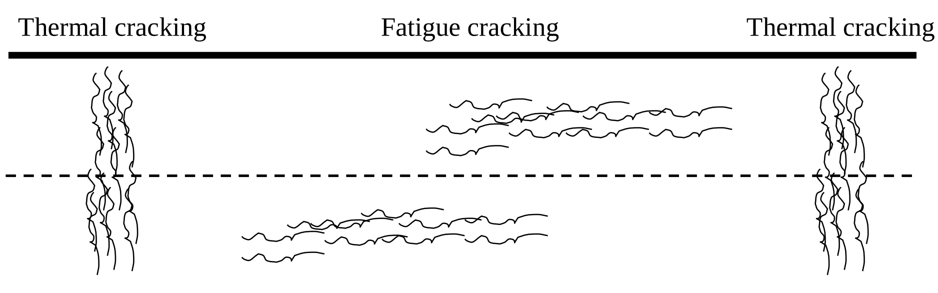
- Parameters:
  - Rutting parameter = $G^* / \sin \delta$
    - In order to resist rutting, an asphalt binder should be stiff and it should be elastic.
    - Therefore, the complex shear modulus elastic portion, $G^*/\sin\delta$, should be large.
    - When rutting is of greatest concern (during an HMA pavement's early and mid-life), a minimum value for the elastic component of the complex shear modulus is specified.
    - The higher the G^* value, the stiffer the asphalt binder is.
    - the lower the δ value, the greater the elastic portion of G^* is.
    - For fresh asphalt, $G^*/ \sin \delta > 1.0$ kPa
    - For RTFOT residue, $G^*/ \sin \delta > 2.2$ kPa
    - Prepared for the maximum pavement temperature in the field.
    - Measured in different temperatures, ± 6°C increments: 58°, 64°, 70°, 76°, and 82°.
    - ➔ Asphalt classification: PG 82, PG76, PG70, PG64, PG58.
    - e.g. PG70 ➔ no rutting until 70° C.
  - Fatigue parameter = $G^* \times \sin \delta$
    - In order to resist fatigue cracking, an asphalt binder should be elastic but not too stiff.
    - Therefore, the complex shear modulus viscous portion, $G^*\times\sin\delta$, should be a minimum.
    - When fatigue cracking is of greatest concern (late in an HMA pavement's life), a maximum value for the viscous component of the complex shear modulus is specified.
    - Prepared for average pavement temperature in the field.
    - Fatigue parameter, $G^* \times \sin \delta > 5000$ kPa

- We find maximum pavement temperature by finding the average of maximum seven days.

- DSR replaces the penetration test and the softening point test.

Bending Beam Rheometer, BBR

- DSR or BBR:
  - To investigate rutting, use DSR at high temperature.
  - To investigate fatigue cracking, use DSR at intermediate temperature.
  - To investigate thermal cracking, use BBR at low temperature.

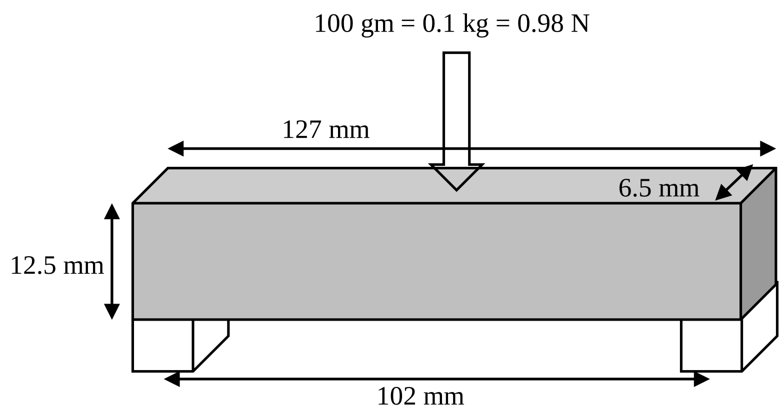


- As surrounding temperatures drop, pavements contract and build up internal stresses.
- If this contraction occurs fast enough, the pavement may crack because it does not have time to relax these stresses.
- This type of crack, typically called a “thermal crack”, or transverse crack.

- Thermal crack can result from either of two related mechanisms:
    - Single thermal cycle below the critical temperature.
      A single severe drop in temperature that causes stress to build up quickly to a critical point that causes cracking.
    - Thermal cycling above the critical temperature.
      Repeated thermal contraction and expansion that occurs above the critical temperature can cause stresses to build up and eventually cause cracking.

- The BBR test provides a measure of low temperature stiffness and relaxation properties of asphalt binders.
- These parameters give an indication of an asphalt binder's ability to resist low temperature cracking.
- The BBR is used in combination with the DTT to determine an asphalt binder's low temperature PG grade.

- The basic BBR test uses a small asphalt beam that is simply supported and immersed in a cold liquid bath.
- A load is applied to the center of the beam and its deflection is measured against time.
- Creep stiffness is calculated based on measured deflection and standard beam properties.
- A measure of how the asphalt binder relaxes the load induced stresses is also measured.
- BBR tests are conducted on PAV aged asphalt binder samples.

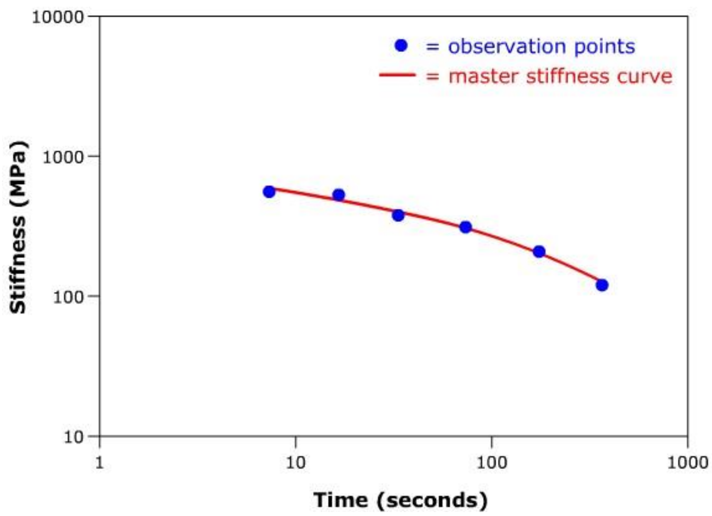


- Properties Measured: (OLD METHOD)
  - Stiffness, S, at 8, 15, 30, 60, 120, and 240 seconds

    S at 60 seconds at test temperature simulates two hours at the field temperature.

    $S \leq 300$ MPa
  - Rate of change of stiffness, m-value, at 8, 15, 30, 60, 120, and 240 seconds.

    M-value ≥ 0.3



Direct Tension Test, DTT

- (OLD METHOD) If S ≥ 300 MPa we have to check strain at failure, if it is ≥ 1% then the binder is OK.

- The basic DTT test measures the stress and the strain at failure of a specimen of asphalt binder pulled apart at a constant rate of elongation.
- Test temperatures are such that the failure will be from brittle or brittle-ductile fracture.
- The test is of little use at temperatures where the specimen fails by ductile failure.
- DTT tests are conducted on PAV aged asphalt binder samples.

- (NEW METHOD)
  - The DTT is used in combination with the BBR to determine an asphalt binder's low temperature PG grade.
  - Convert the master stiffness curve to thermal stress curve and compare it to the failure stress from the DTT.
    - Two DTT test temperatures are used and a line is drawn between these two results.
    - The point at which this DTT curve intersects the BBR thermal stress curve is defined as the critical cracking temperature of a pavement.