beams: shear stress
Transverse Loading and Shear

- perpendicular loading
- internal shear
- along with bending moment
Bending vs. Shear in Design

- bending stresses dominate
- shear stresses exist horizontally with shear
- no shear stresses with pure bending
Shear Stresses

- horizontal & vertical
Shear Stresses

- horizontal & vertical
Beam Stresses

- horizontal with bending

long sand bag (distributed load)

draw vertical marker lines before loading to show horizontal shear movement
Equilibrium

• horizontal force $V$ needed

$$V_{\text{longitudinal}} = \frac{V_T Q}{I} \Delta x$$

• $Q$ is a moment area
Moment of Area

- **Q is a moment area with respect to the n.a. of area above or below the horizontal**

- **$Q_{\text{max}}$ at $y=0$** (neutral axis)

- **$q$ is shear flow:**
  
  $q = \frac{V_{\text{longitudinal}}}{\Delta x} = \frac{V_T Q}{I}$
Shearing Stresses

\[ f_v = \frac{V}{\Delta A} = \frac{V}{b \cdot \Delta x} \]

\[ f_{v-ave} = \frac{VQ}{Ib} \]

- \( f_v = 0 \) on the top/bottom
- \( b \) min may not be with Q max
- with \( h/4 \geq b \), \( f_{v-max} \leq 1.008 f_{v-ave} \)
Rectangular Sections

\[ I = \frac{bh^3}{12} \quad Q = A\bar{y} = \frac{bh^2}{8} \]

\[ f_v = \frac{VQ}{lb} = \frac{3V}{2A} \]

- \( f_{v\text{-max}} \) occurs at n.a.
Steel Beam Webs

- **W and S sections**
  - \( b \) varies

- Stress in flange negligible
- Presume constant stress in web

\[ f_{v_{\text{max}}} = \frac{3V}{2A} \approx \frac{V}{A_{\text{web}}} \]
Shear Flow

- loads applied in plane of symmetry
- cut made perpendicular

\[ q = \frac{VQ}{I} \]
Shear Flow Quantity

- sketch from $Q$

$$q = \frac{VQ}{I}$$
Connectors Resisting Shear

- plates with
  - nails
  - rivets
  - bolts
- splices

\[
\frac{V_{\text{longitudinal}}}{p} = \frac{VQ}{I}
\]

\[
nF_{\text{connector}} \geq \frac{VQ_{\text{connected area}}}{I} \cdot p
\]
Vertical Connectors

• *isolate an area with vertical interfaces*

\[ nF_{\text{connector}} \geq \frac{VQ_{\text{connected area}}}{I} \cdot p \]
Unsymmetrical Shear or Section

- member can bend and twist
  - not symmetric
  - shear not in that plane
- shear center
  - moments balance

![Diagram showing unsymmetrical shear or section](image-url)