

**Principal Stress & Maximal Shear Stress**

**2-Dimensional**

$$\sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$\tau_{max} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$\sigma_{x'} = \frac{\sigma_x + \sigma_y}{2} + \left(\frac{\sigma_x - \sigma_y}{2}\right) \cos 2\theta + \tau_{xy} \sin 2\theta$$

$$\sigma_{y'} = \frac{\sigma_x + \sigma_y}{2} - \left(\frac{\sigma_x - \sigma_y}{2}\right) \cos 2\theta + \tau_{xy} \sin 2\theta$$

$$\tau_{x'y'} = -\left(\frac{\sigma_x - \sigma_y}{2}\right) \sin 2\theta + \tau_{xy} \cos 2\theta$$

$$\theta = \frac{1}{2} \tan^{-1} \left( \frac{2\tau_{xy}}{\sigma_x - \sigma_y} \right)$$

$$I_{xx} = \int y^2 dA, I_{yy} = \int x^2 dA, I_{xy} = \int xy dA, I_{xx'} = I_{xx} \cos^2 2\theta - I_{xy} \sin 2\theta + I_{yy} \sin^2 2\theta$$

**3-Dimensional**

Determinants Equations (Stress Invariants)

$$I_1 = \sigma_x + \sigma_y + \sigma_z$$

$$I_2 = \sigma_x \sigma_y + \sigma_x \sigma_z + \sigma_y \sigma_z - \tau_{xy}^2 - \tau_{yz}^2 - \tau_{xz}^2$$

$$I_3 = \sigma_x \sigma_y \sigma_z + 2\tau_{xy} \tau_{yz} \tau_{xz} - \sigma_x \tau_{xy}^2 - \sigma_y \tau_{yz}^2 - \sigma_z \tau_{xz}^2 - 3\tau_{xy} \tau_{yz} \tau_{xz}$$

$\sigma_{1,2,3}$  = roots of  $\lambda^3 - I_1 \lambda^2 + I_2 \lambda - I_3 = 0$ , where  $\sigma_{1,2,3}$  are

$$\sigma_{max}, \sigma_{int}, \sigma_{min} = \frac{I_1}{3} \pm \sqrt{\frac{J_2}{3}}$$

See text for principal direction

$$\tau_{max} = \sqrt{\frac{J_2}{3}}$$

$$\tau_{int} = \sqrt{\frac{J_2}{3}}$$

$$\tau_{min} = \sqrt{\frac{J_2}{3}}$$

**Centroidal Bending**

$$\sigma_{max} = \frac{M y}{I}$$

$C$  is distance from  $NA$  to point of interest;  $y$  is taken for counter-clockwise

$I$  is  $NA$  will be  $NA$  centroid axis

bending stress will be  $NA$  longitudinal axis

$NA$  is used (longitudinal) stress distribution

tension bending  $\rightarrow$  positive, compression bending  $\rightarrow$  negative

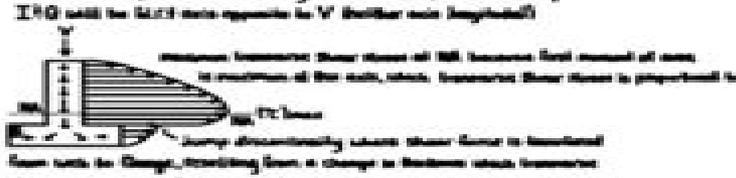


**Transverse Shear**

$$\tau = \frac{VQ}{It}$$

Trans  $\rightarrow$   $Q$  is the first moment of area of the area above the point of interest with respect to  $NA$

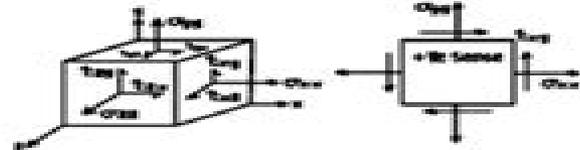
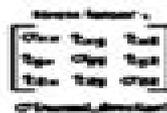
$Q$  will be  $NA$  axis opposite to  $Y$  (other axis longitudinal)



Shear stress is  $Q$  is the first moment of area of the area above the point of interest with respect to  $NA$

**Twisting**

$$\tau = \frac{T\rho}{J}$$



**Case Sectional Properties**

$$Centroid: \bar{y} = \frac{\sum y_i A_i}{\sum A_i}$$

Second Moment of Area

$$I = \sum I_{xxi} + \sum A_i d_i^2$$

$$d_i = (y_i - \bar{y})$$

If  $I_{xx}$ ,  $I_{yy}$  are in the same perspective of  $y$ -axis

If  $I_{xx}$ ,  $I_{yy}$  are in different perspective

$I = I_{xx} \cos^2 2\theta + I_{yy} \sin^2 2\theta + 2I_{xy} \sin 2\theta \cos 2\theta$

$I_{xy} = I_{xx} \sin 2\theta \cos 2\theta + I_{yy} \sin 2\theta \cos 2\theta + 2I_{xy} \cos^2 2\theta - 2I_{xy} \sin^2 2\theta$

Equal Moment of Area

moment of area about  $x$  or  $y$  axis of interest

$$Q = A y$$

where  $A$  is the remaining cross sectional area above or below that point

and  $y$  is the distance between the centroid of that area to the centroid of the entire cross section

**2-Dimensional Plane Stress & Strain**

Stress

(1) — one dimension compared to other two dimensions is very small

(2) — like a plate or a shell, stress with large constant

(3) — total has to be in the plane of the plate, etc., same way it's same for strain

Strain

(1) — one dimension compared to other two dimensions is very large

(2) — symmetric loading condition

**Stress-Strain**

$$\begin{bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{bmatrix} = \begin{bmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{bmatrix} \begin{bmatrix} \epsilon_x \\ \epsilon_y \\ \gamma_{xy} \end{bmatrix} \rightarrow \begin{bmatrix} E_{11} & E_{12} & E_{13} \\ E_{21} & E_{22} & E_{23} \\ E_{31} & E_{32} & E_{33} \end{bmatrix} \begin{bmatrix} \epsilon_x \\ \epsilon_y \\ \gamma_{xy} \end{bmatrix} \rightarrow \begin{bmatrix} E_{11} & E_{12} & E_{13} \\ E_{21} & E_{22} & E_{23} \\ E_{31} & E_{32} & E_{33} \end{bmatrix}$$

**Stress-Strain Relationship**

$$E_{11} = E(\nu_x \nu_y + \nu_x \nu_z + \nu_y \nu_z)$$

$$E_{22} = E(\nu_x \nu_y + \nu_x \nu_z + \nu_y \nu_z)$$

$$E_{33} = E(\nu_x \nu_y + \nu_x \nu_z + \nu_y \nu_z)$$

$$E_{12} = E(\nu_x \nu_y + \nu_x \nu_z + \nu_y \nu_z)$$

$$E_{13} = E(\nu_x \nu_y + \nu_x \nu_z + \nu_y \nu_z)$$

Plane Stress Condition

$$E_{11} = E(\nu_x \nu_y + \nu_x \nu_z + \nu_y \nu_z)$$

$$E_{22} = E(\nu_x \nu_y + \nu_x \nu_z + \nu_y \nu_z)$$

$$E_{33} = -E(\nu_x \nu_y + \nu_x \nu_z + \nu_y \nu_z)$$

$$E_{12} = E(\nu_x \nu_y + \nu_x \nu_z + \nu_y \nu_z)$$

# Course Notes Structural Mechanics Mechanical

**M Walker**



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