

**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)

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

$$I_2 = \sigma_x \sigma_y + \sigma_x \sigma_z + \sigma_y \sigma_z$$

$$I_3 = \sigma_x \sigma_y \sigma_z - \tau_{xy} \tau_{yz} - \tau_{yz} \tau_{zx} - \tau_{zx} \tau_{xy}$$

$$I_4 = \sigma_x \tau_{xy} \tau_{yz} + \sigma_y \tau_{yz} \tau_{zx} + \sigma_z \tau_{zx} \tau_{xy} - \tau_{xy}^2 \sigma_z - \tau_{yz}^2 \sigma_x - \tau_{zx}^2 \sigma_y$$

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

$$\tau_{max} = \frac{\sigma_1 - \sigma_3}{2}$$

See ex. for principal direction

$$\tau_{max} = \frac{\sigma_1 - \sigma_2}{2}$$

$$\tau_{max} = \frac{\sigma_2 - \sigma_3}{2}$$

**Centroidal Bending**

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

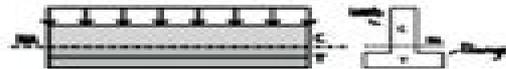
C is distance from NB to point of interest; y is taken for counter-clockwise

I is NB with the MCT neutral axis

bending stress will be MCT (negative) side

MCA is neutral (deformed) stress distribution

tensile bending → positive, compression bending → negative

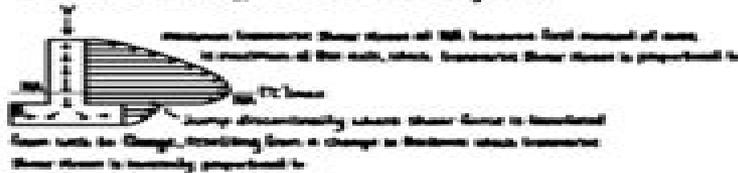


**Transverse Shear**

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

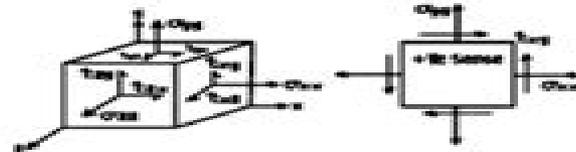
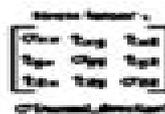
Q → Area, for rectangles along axis but I & Q are with respect to

I & Q will be MCT axis opposite to V (other axis (horizontal))



**Torsion**

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



**Plane Sectional Properties**

$$C_{centroid} = \frac{1}{A} \int y dA$$

Second Moment of Area

$$I = \int y^2 dA = \int x^2 dA$$

$$I_y = \int x^2 dA$$

if I<sub>xy</sub>, then I<sub>xy</sub> is from perspective of y-z axis

if I<sub>xx</sub>, " " z-axis

Area Moment of Inertia

$$J = \int r^2 dA$$

I<sub>x</sub> = I<sub>xx</sub> + I<sub>yy</sub> if bar is used as a shaft; hollow use I<sub>o</sub> - I<sub>i</sub>

First Moment of Area

moment of area above or below point of interest

$$Q = A y_c$$

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

and y<sub>c</sub> 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) — plate or a shell, stress with large constant

(3) — shell has to be in the plane of the plate, etc., same way it goes on.

Strain

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

(2) — symmetric loading condition

**Stress-Strain**

A: point of interest

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

**Stress-Strain Relationship**

$$E_{11} = E(\sigma_x / \epsilon_x) = \nu E(\sigma_y / \epsilon_y) = \nu E(\sigma_z / \epsilon_z)$$

$$E_{22} = E(\sigma_y / \epsilon_y) = \nu E(\sigma_x / \epsilon_x) = \nu E(\sigma_z / \epsilon_z)$$

$$E_{33} = E(\sigma_z / \epsilon_z) = \nu E(\sigma_x / \epsilon_x) = \nu E(\sigma_y / \epsilon_y)$$

$$E_{12} = E(\sigma_x / \epsilon_y) = \nu E(\sigma_y / \epsilon_x) = \nu E(\sigma_z / \epsilon_{xy})$$

$$G = E(1 + \nu)^{-1}$$

**Plane Stress Condition**

$$E_{11} = E(\sigma_x / \epsilon_x) = \nu E(\sigma_y / \epsilon_y)$$

$$E_{22} = E(\sigma_y / \epsilon_y) = \nu E(\sigma_x / \epsilon_x)$$

$$E_{33} = -\nu E(\sigma_x / \epsilon_x) = -\nu E(\sigma_y / \epsilon_y)$$

$$E_{12} = E(\sigma_x / \epsilon_y)$$

# Course Notes Structural Mechanics Mechanical

**Peipei Pang**



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