

Principal Stress & Maximal Shear Stress

2-Dimensional

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

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

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

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

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

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

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

3-Dimensional

Determinants Equations (Stress Invariants)

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

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

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

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

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

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

Continued Bending

$$\sigma_{max} = \sum \frac{M y}{I} + \frac{P}{A}$$

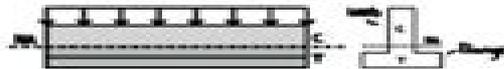
C is distance from NB to point of interest; it differs for Consider each

I & A will be the same

bending stress will be the same (symmetrical axis)

NOA is used (symmetrical) stress distribution

tensile bending → positive, compression bending → negative

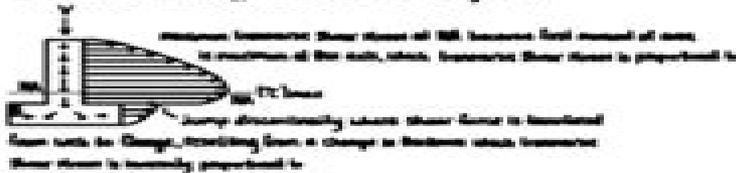


Shear Flow

$$v = \frac{VQ}{I}$$

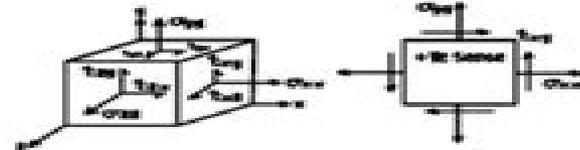
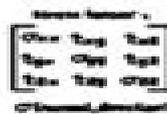
Q → Area, for Section along axis that I & Q are with respect to

I & Q will be the same opposite to V (another axis (symmetrical))



Twist

$$t = \frac{J\theta}{L}$$



Case Sectional Properties

$$C_{centroid} = \frac{\sum (y_i A_i)}{\sum A_i}$$

Second Moment of Area

$$I = \sum (I_{centroid} + A_i d_i^2)$$

$$d_i = (y_i - y_c)$$

If I_{yy}, then d_i is the distance of y_i from

If I_{xx}, then d_i is the distance of x_i from

Area Moment of Inertia

$$J = \sum (I_{xx} + I_{yy})$$

$$I_x = \sum (I_{xx} + A_i d_i^2)$$

First Moment of Area

moment of area above or below point of interest

$$Q = A y_c$$

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

and y_c is the distance between the centroid of that area to the centroid of the entire case 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) — load has to be in the plane of the plate, etc., same way it does not

Strain

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

(2) — symmetric loading condition

Stress-Strain

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

Stress-Strain Relationship

$$E_{11} = \frac{E}{1 - \nu_{12}\nu_{21} - \nu_{13}\nu_{31} - \nu_{23}\nu_{32}}$$

$$E_{22} = \frac{E}{1 - \nu_{12}\nu_{21} - \nu_{13}\nu_{31} - \nu_{23}\nu_{32}}$$

$$E_{33} = \frac{E}{1 - \nu_{12}\nu_{21} - \nu_{13}\nu_{31} - \nu_{23}\nu_{32}}$$

$$E_{12} = \frac{E\nu_{12}}{1 - \nu_{12}\nu_{21} - \nu_{13}\nu_{31} - \nu_{23}\nu_{32}}$$

$$C = \frac{E\nu_{12}}{1 - \nu_{12}\nu_{21} - \nu_{13}\nu_{31} - \nu_{23}\nu_{32}}$$

Plane Stress Condition

$$E_{11} = \frac{E}{1 - \nu_{12}\nu_{21} - \nu_{13}\nu_{31} - \nu_{23}\nu_{32}}$$

$$E_{22} = \frac{E}{1 - \nu_{12}\nu_{21} - \nu_{13}\nu_{31} - \nu_{23}\nu_{32}}$$

$$E_{33} = -\frac{E\nu_{13}}{1 - \nu_{12}\nu_{21} - \nu_{13}\nu_{31} - \nu_{23}\nu_{32}}$$

$$E_{12} = \frac{E\nu_{12}}{1 - \nu_{12}\nu_{21} - \nu_{13}\nu_{31} - \nu_{23}\nu_{32}}$$

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JE Gale



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