Strength of Materials and Structures

DDPA2103

Topic : Stress-Strain

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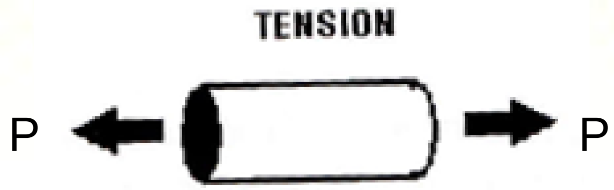
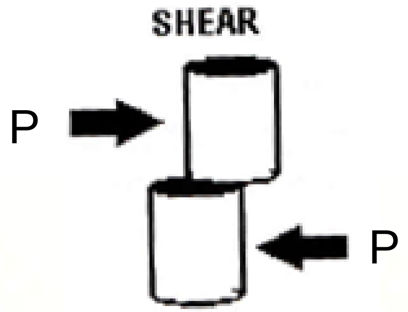
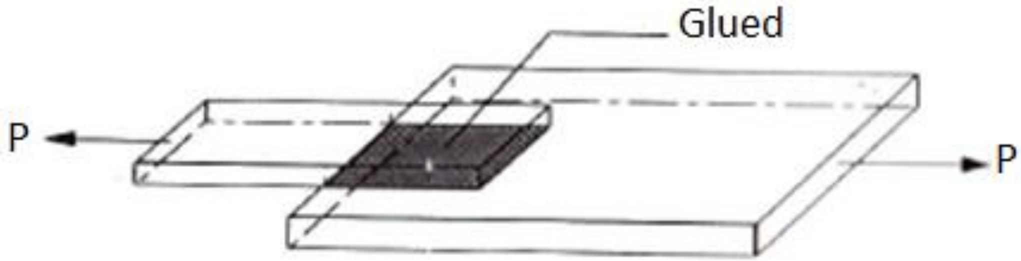
TYPES OF FORCES

1. Normal Forces

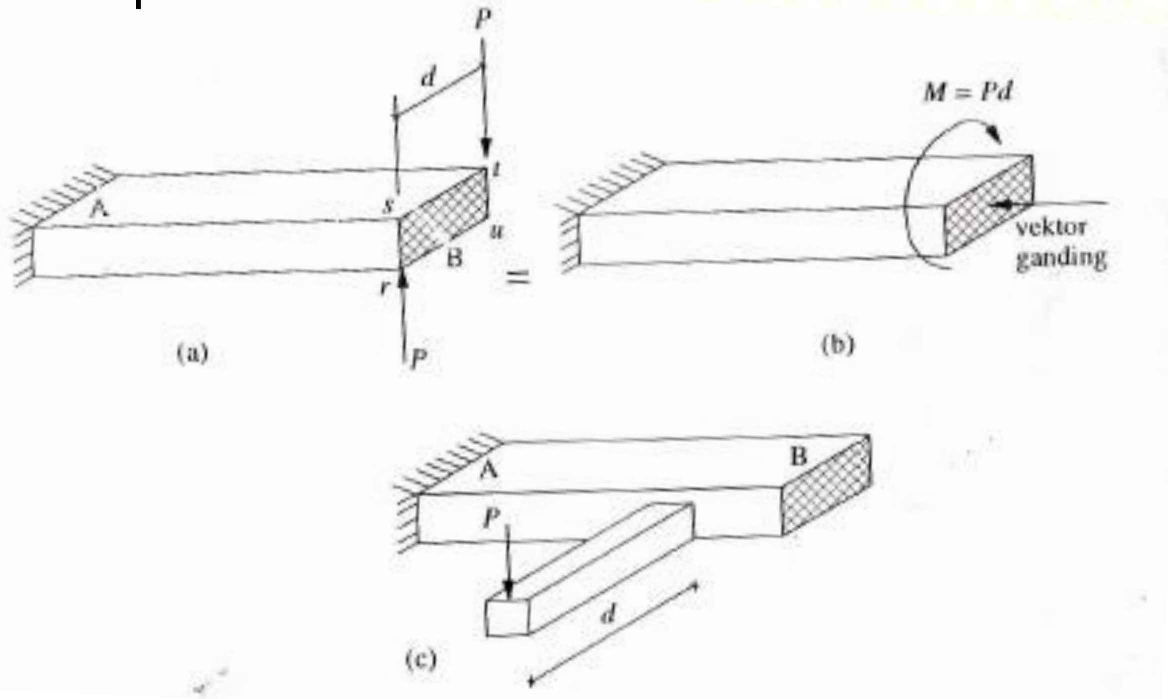


2. Shear force





3. Torque



TYPES OF STRESSES

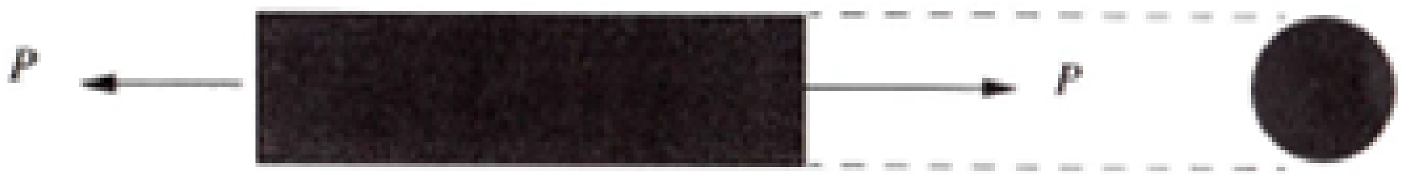
1. Normal stress

$\sigma = P/A$

Where σ = normal stress

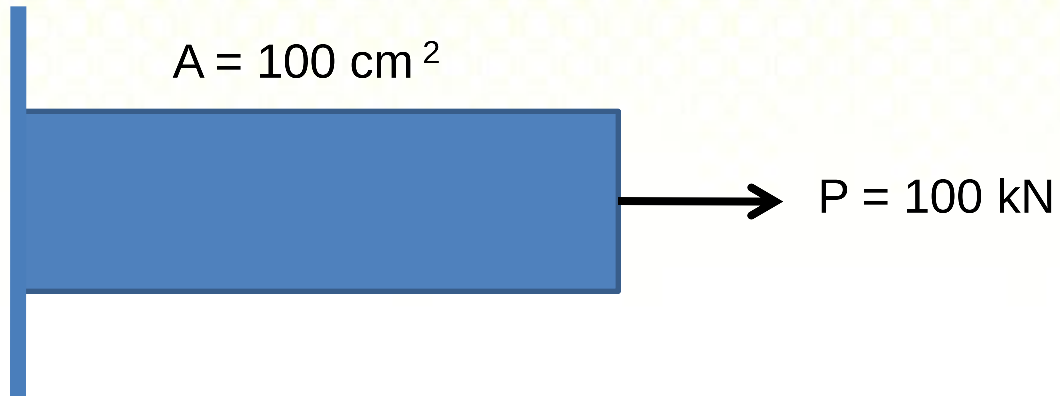
p = force

A = cross sectional area perpendicular to force P



A = cross sectional area

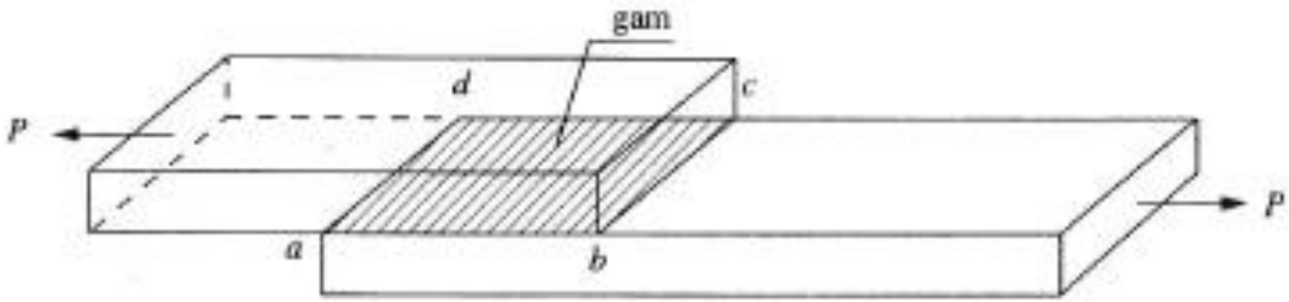
Example



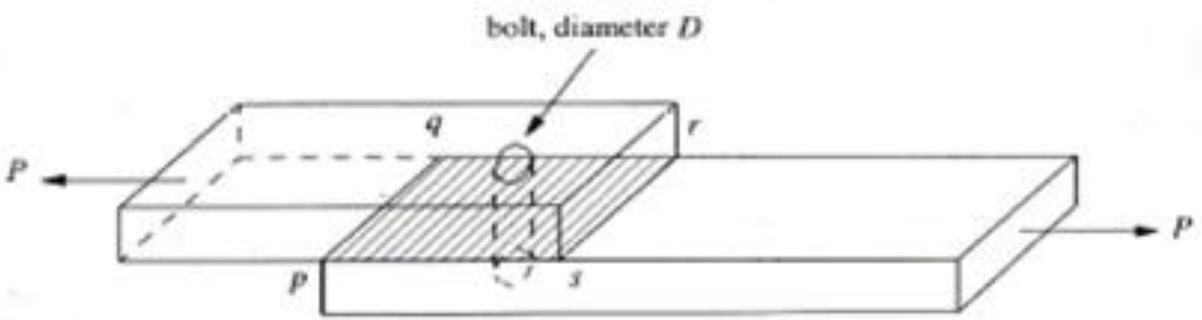
$$\sigma = P/A = 100/10 = 10\ kN/cm^2$$

$\tau = P/A_{abcd}$

2. Shear stress



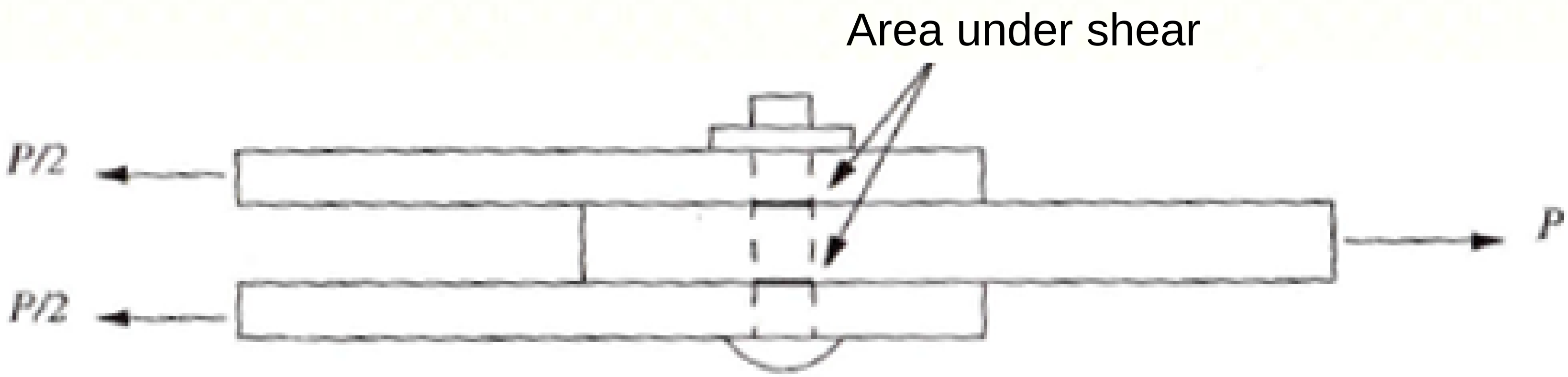
$\tau = P/A_{abcd}$



$\tau = P/A_{bolt}$

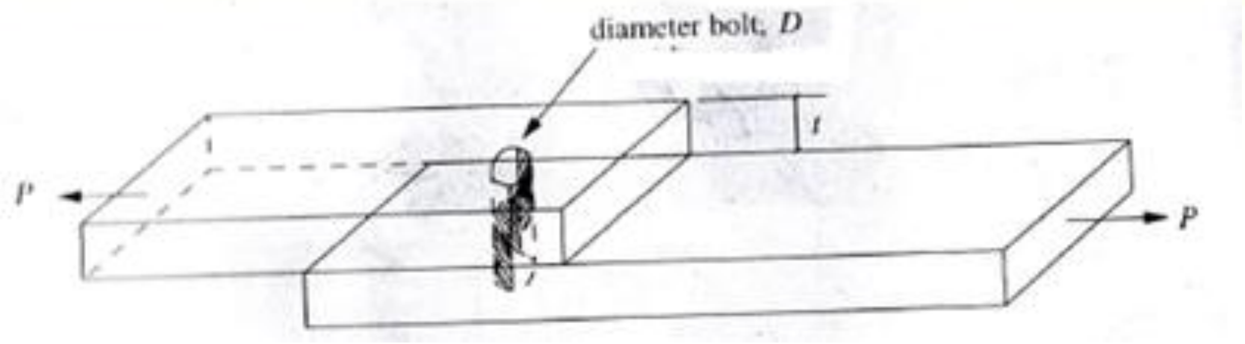
$\tau = P/(\pi d^2/4)$

Double shear failure



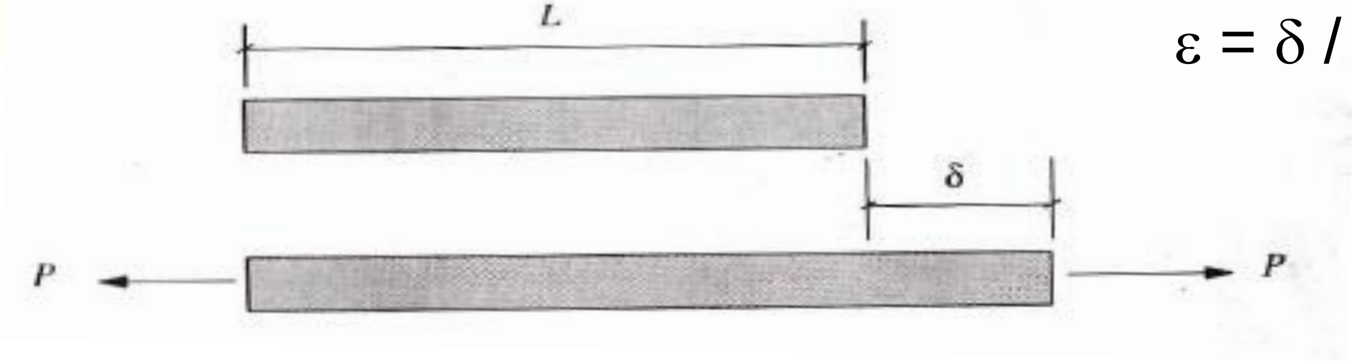
$$\tau = P/2\ A_{bolts})$$
$$\tau = P(2\pi D^2/4) = 2P/D^2$$

3. BEARING STRESS



= P/A = P/tD

Strain, ε



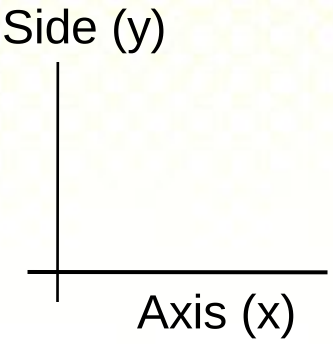
$$\varepsilon = \delta / L$$

Elasticity and Hooke's Law

$$\sigma = E\varepsilon$$

$$P/A = E\,\delta/L \quad \Rightarrow \quad \delta = PL/AE$$

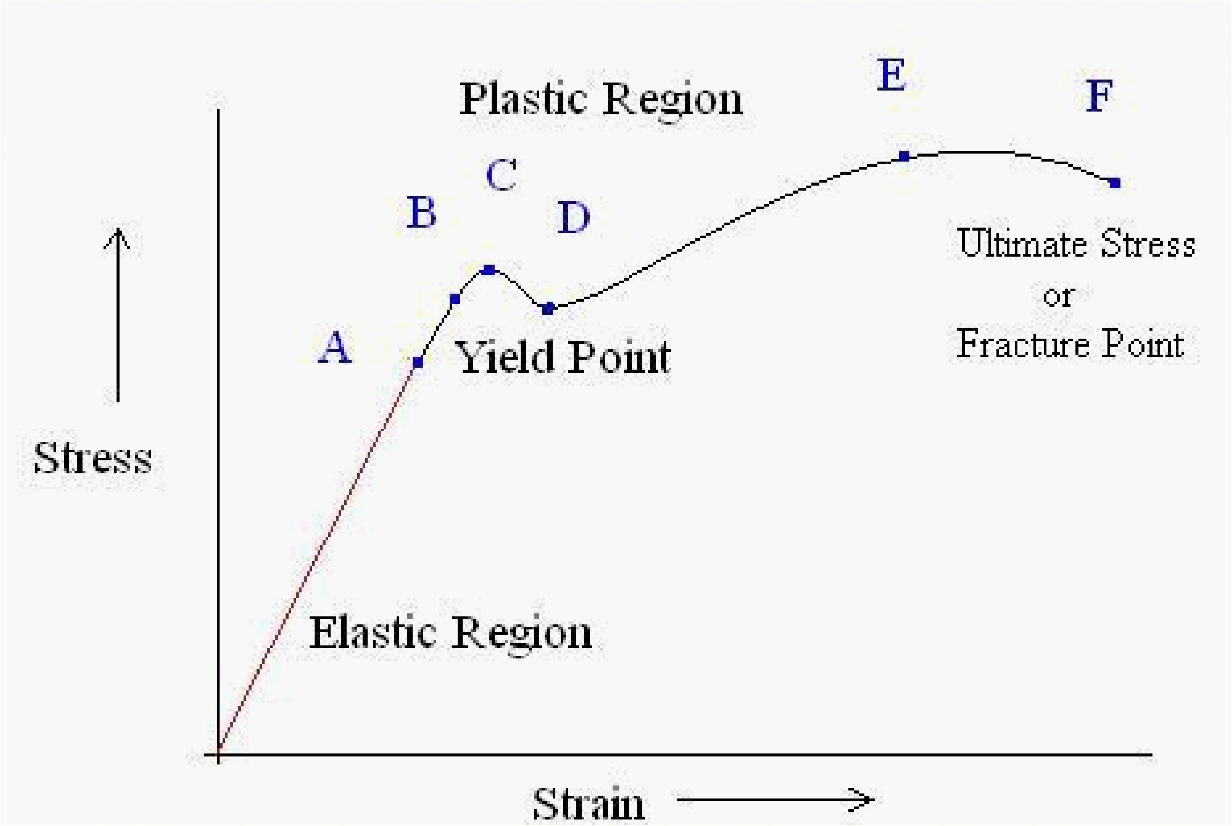
Poisson ratio



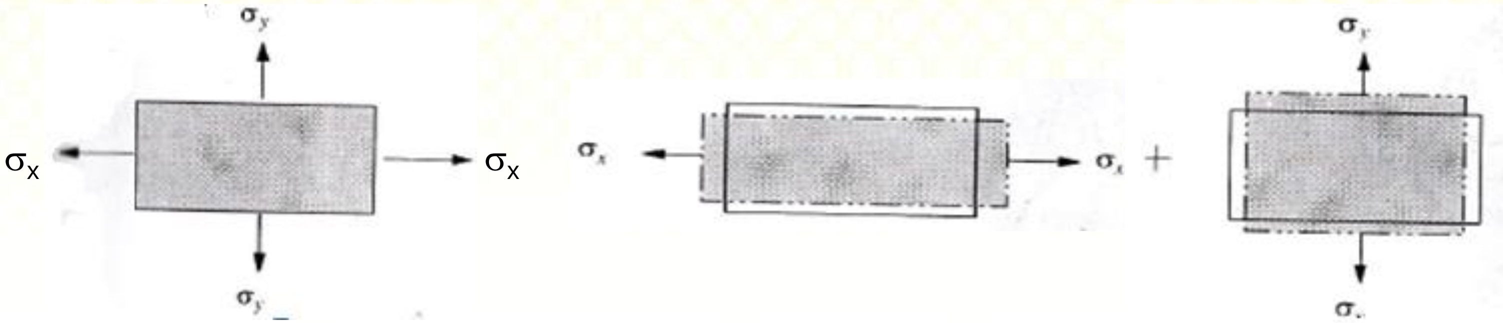
v = side strain/axis strain = $\varepsilon_y/\varepsilon_x$

$\varepsilon_y = -v\varepsilon_x = -v\,\sigma_x/E$

Typical Stress-strain curve for mild steel



Stress-strain relationship subjected to duo stresses in x and y direction



Strain in x-direction due to stess in x-direction,

$$\varepsilon_{xx} = \sigma_x / E$$

Strain in x-direction due to stess in y-direction,

$$\varepsilon_{xy} = -v\,\sigma_y / E$$

Therefore, $\varepsilon_x = \varepsilon_{xx} + \varepsilon_{xy}$

$$= \sigma_x/E - v\sigma_y/E$$

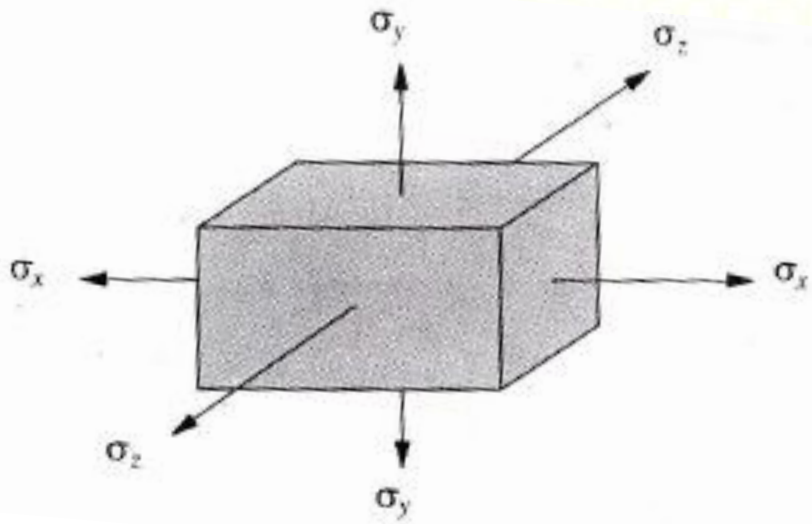
$$\varepsilon_x = 1/E(\sigma_x - v\,\sigma_y)$$

$$\varepsilon_y = 1/E(\sigma_y - v\,\sigma_x)$$

$$\sigma_x = \frac{(\varepsilon_x + \nu\varepsilon_y)}{1-\nu^2}E$$

$$\sigma_y = \frac{(\varepsilon_y + \nu\varepsilon_x)}{1-\nu^2}E$$

Stress-strain relationship (3 axes – x, y and z)

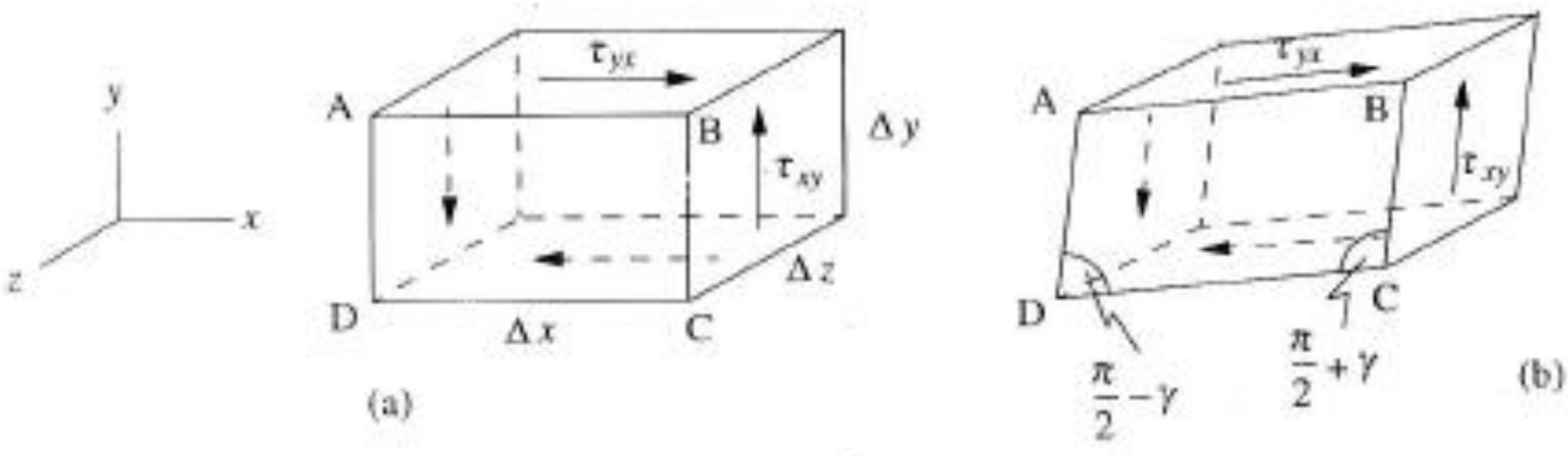


$$\varepsilon_x = \frac{1}{E}[\sigma_x - \nu(\sigma_y + \sigma_z)]$$

$$\varepsilon_y = \frac{1}{E}[\sigma_y - \nu(\sigma_x + \sigma_z)]$$

$$\varepsilon_z = \frac{1}{E}[\sigma_z - \nu(\sigma_x + \sigma_y)]$$

Shear stress and shear strain



$\tau = G\gamma$

$G = E / 2(1 + v)$

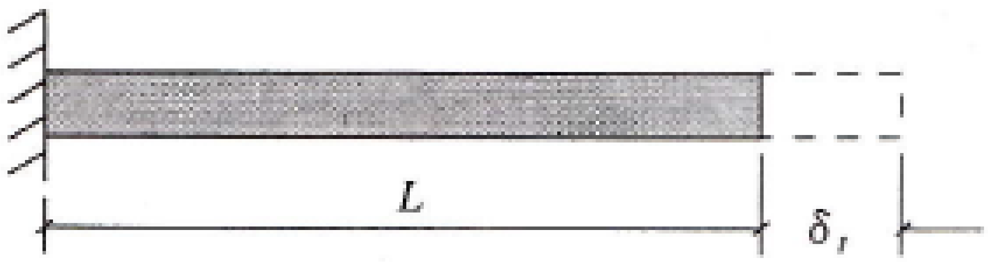
Working stress and allowable stress, σ_{allow}

$\sigma_{allow} = \sigma_{yield} / n$ for ductile material

$\sigma_{allow} = \sigma_{elastic} / n$ for brittle materials

Factor of Safety (FOS) = Actual Strength/ Required Strength

2.11 THERMAL STRESS



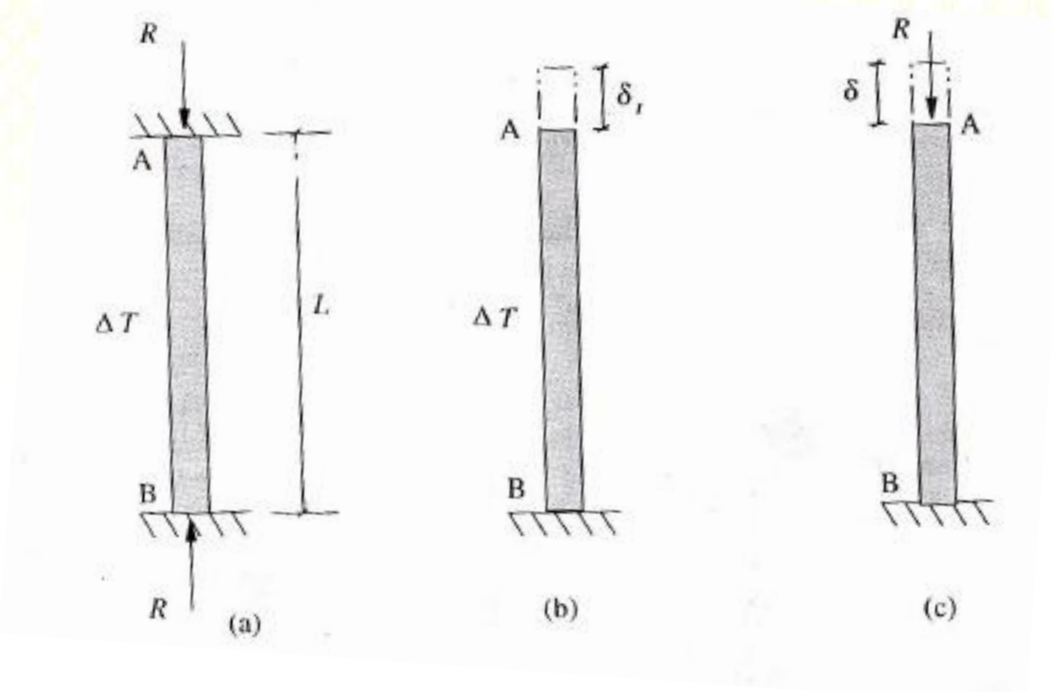
$$\varepsilon_t = \delta_t / L \qquad (2.16)$$

$$\varepsilon_t = \alpha(\Delta T)$$

α : Coefficient of expansion
ΔT : Change in temperature

$$\delta_t = \varepsilon_t L = \alpha(\Delta T) L \qquad (2.17)$$

Thermal tresses

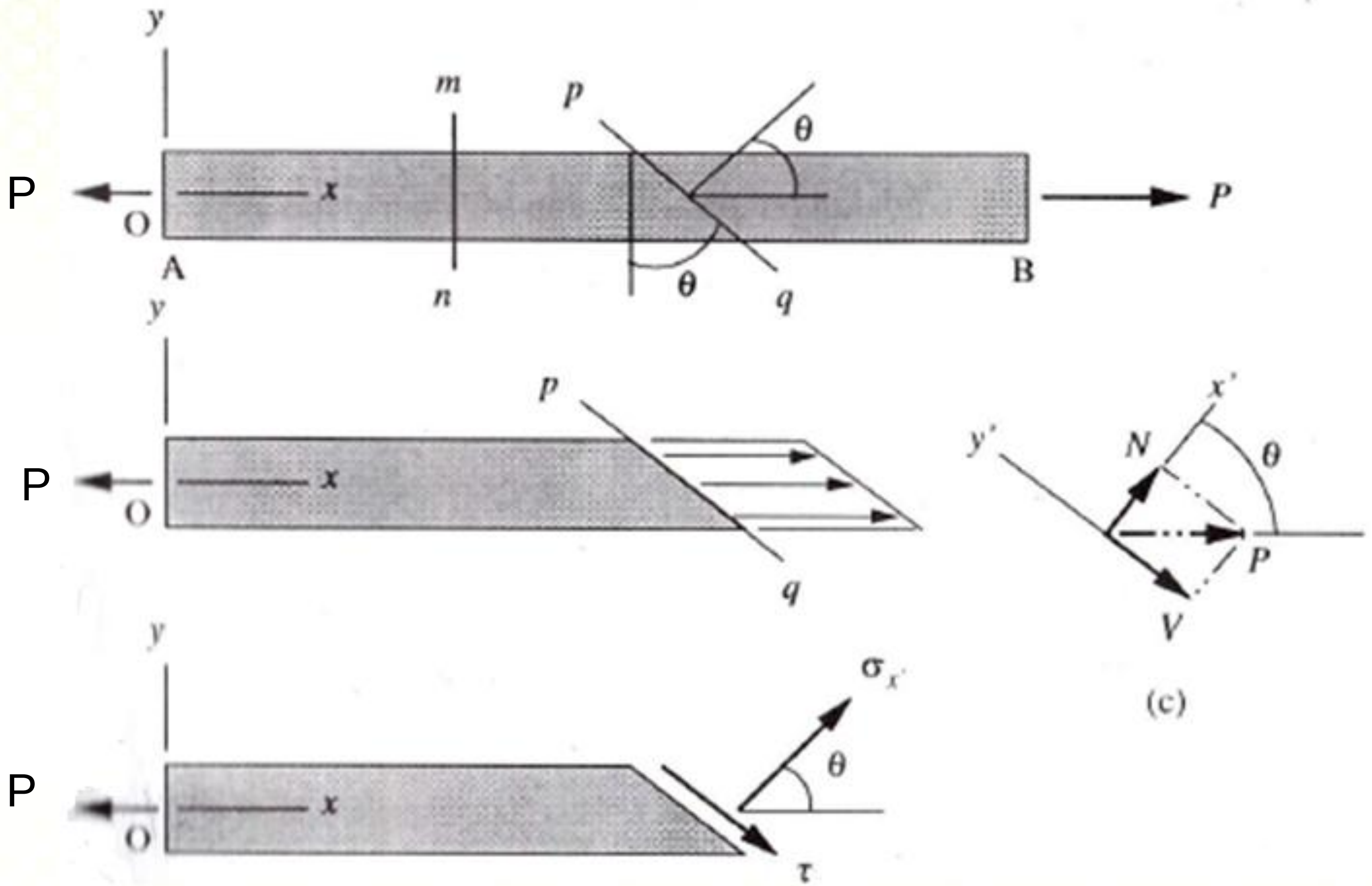


$$\delta = RL/AE$$

$$R = EA\alpha(\Delta T)$$

$$\sigma = R/A = E\alpha(\Delta T)$$

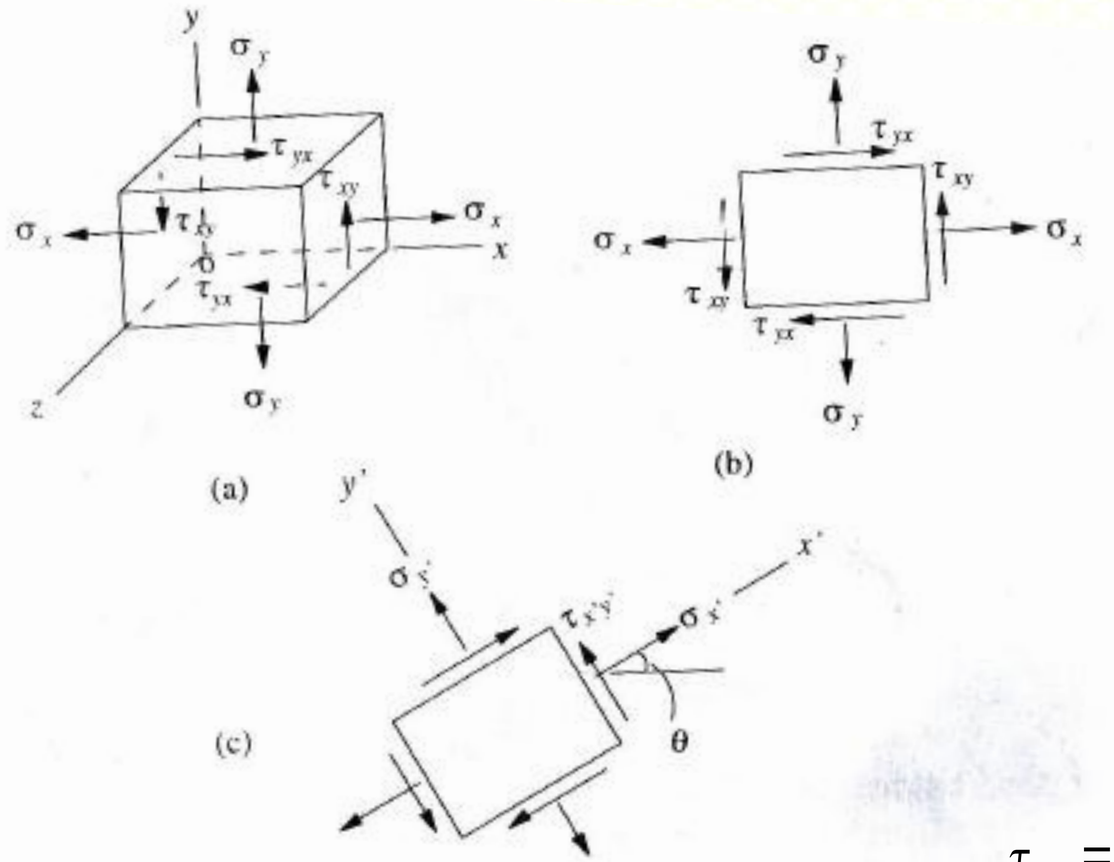
Stresses on inclined plane



$$N = P \cos\theta; \text{ dan } V = P \sin\theta$$

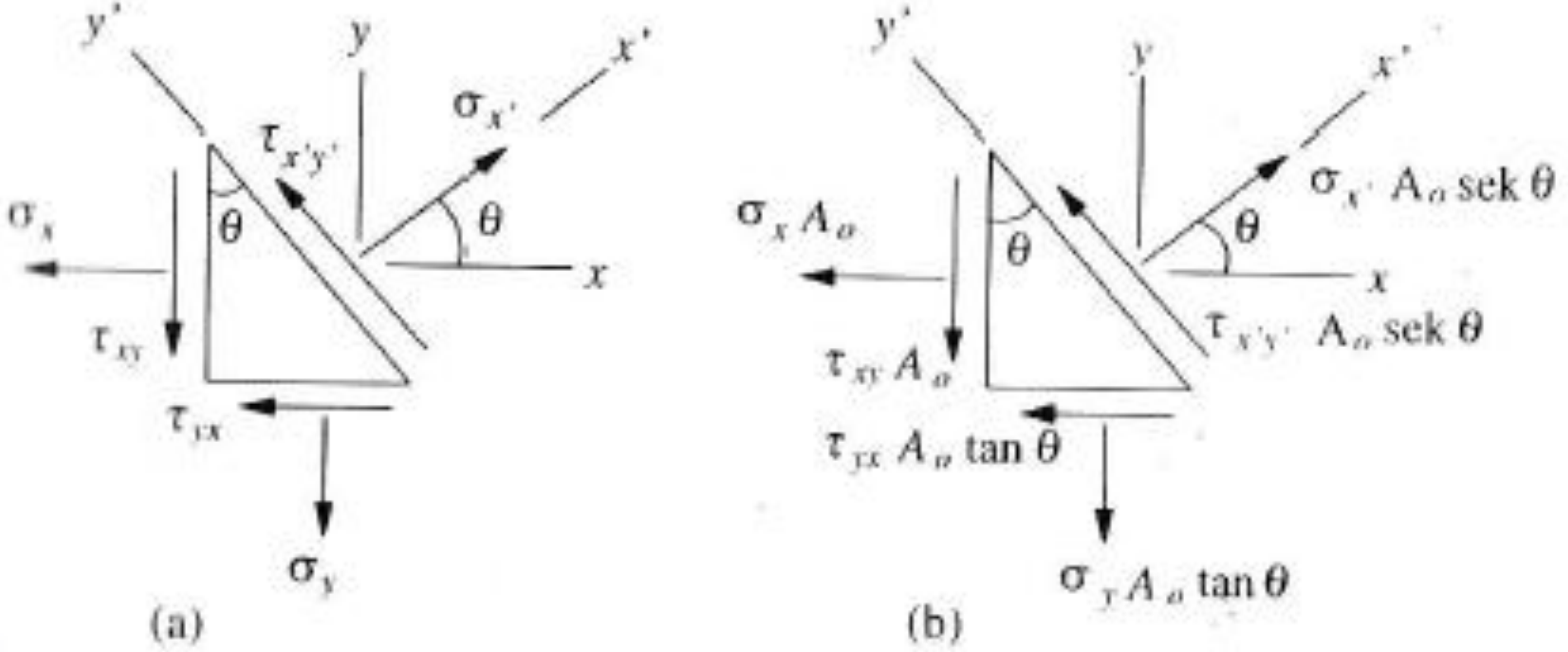
Plane Stresses – 2 Axial Forces – Equations

1. Equations Method



$$\tau_{xy} = \tau_{yx}$$

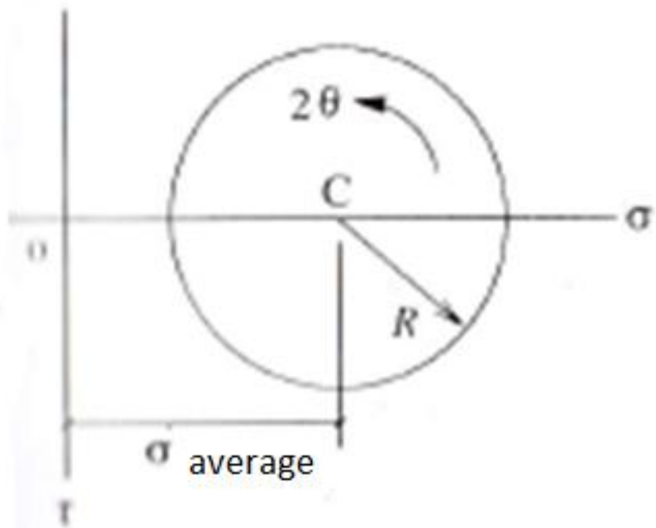
$$\tau_{x'y'} = \tau_{y'x'} \tag{2.20}$$

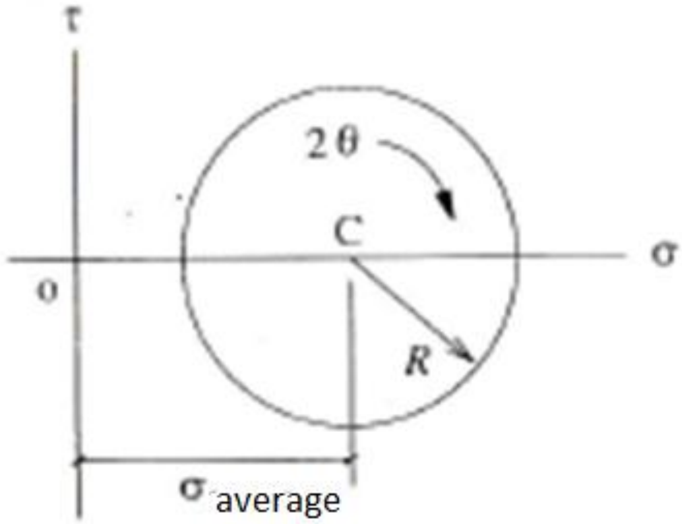


2. Mohr's Circle

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

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





$$\left[\sigma_{x'} - \left(\frac{\sigma_x + \sigma_y}{2}\right)\right]^2 + \tau_{x'y'}^2 = \left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2$$

Persamaan ini boleh dipermudah lagi, iaitu

$$(\sigma_{x'} - \sigma_{\text{purata}})^2 + \tau_{x'y'}^2 = R^2 \qquad (2.26)$$

$$\text{dengan } \sigma_{\text{purata}} = \left(\frac{\sigma_x + \sigma_y}{2}\right)$$

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