MOS

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$\sigma = \frac{P}{A}$ $\quad \epsilon = \frac{\delta l}{l}$ & lateral $\epsilon = \frac{\delta d}{d}$

hooks law $\sigma = E\epsilon$ $\quad E \to$ youngs modulus

$\mu = \frac{\text{lateral strain}}{\text{linear strain}}$

elongation % > 5% → ductile

< 5% Brittle

$\delta l = \frac{Pl}{AE}$, $\frac{\sigma_1}{\sigma_2} = \frac{E_1}{E_2}$ → Modular ratio (Composite bar)

$\Delta L = L\alpha\Delta t$, $\sigma = E\alpha\Delta t$

$\sigma_{th} = \left(\frac{\Delta L - \delta}{L}\right)E$ $\qquad \epsilon = \frac{\Delta L}{L} \to \frac{\Delta L - \delta}{L}$

$\epsilon_1 + \epsilon_2 = (\alpha_2 - \alpha_1)\Delta t$

strain energy $U = \frac{\sigma^2}{2E} AL$

$\sigma_\theta = \frac{\sigma_x + \sigma_y}{2} + \left(\frac{\sigma_x - \sigma_y}{2}\right)\cos 2\theta + \tau \sin 2\theta$

$\tau_\theta = -\left(\frac{\sigma_x - \sigma_y}{2}\right)\sin 2\theta + \tau \cos 2\theta$

$\tan 2\theta_p = \frac{2\tau}{\sigma_x - \sigma_y}$

$\sigma_\theta = \sigma_x \cos^2\theta + \sigma_y \sin^2\theta$ (when only σ_x & σ_y)

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

$\tau_{max} = \frac{\sigma_1 - \sigma_2}{2}$, $\boxed{\theta_s = \theta_p + 45^\circ}$

$= \sigma_x + \sigma_y$

Teacher's Signature

* Stresses in beams:

$$\frac{M}{I} = \frac{E}{R} = \frac{\sigma}{y}$$

$\frac{BD^3}{12}$ $\qquad$ $\frac{\pi}{64}D^4$ $\qquad$ $\frac{BD^3}{36}$

Section modulus : $Z = \frac{I}{y_{max}}$

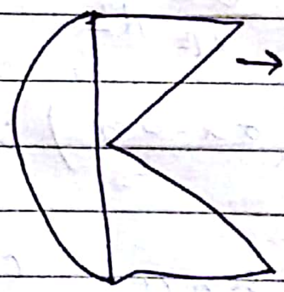
Beam of uniform strength: having same M along the longitudinal axis.

$$\tau = \frac{F}{ZI} A\bar{y}$$

$\tau_{max} = 1.5\ \tau_{avg}$ $\qquad$ $\tau_{max} = (4/3)\ \tau_{avg}$

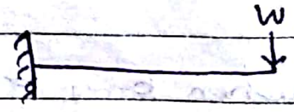
$\tau_{max} = 9/8\ \tau_{avg}$

shear stress ←

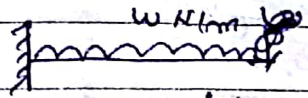


→ Bending stress $\qquad \frac{\sigma_1}{\sigma_2} = \frac{y_1}{y_2}$

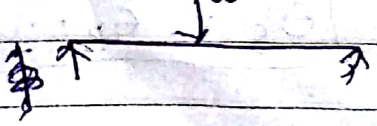
* Slope and deflection: $\boxed{EIy'' = M}$



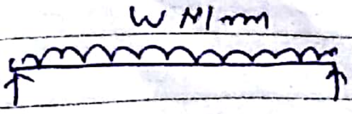
$y = \frac{Wl^3}{3EI}$, $y' = \frac{Wl^2}{2EI}$



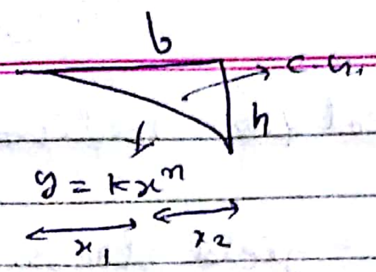
$y = \frac{wl^4}{8EI}$, $y' = \frac{wl^3}{6EI}$



$y = \frac{Wl^3}{48EI}$, $y' = \frac{Wl^2}{16EI}$



$y = \frac{5\ wl^4}{384\ EI}$, $y' = \frac{wl^3}{24EI}$



$x_1 = \left(\frac{n+1}{n+2}\right) b$, $x_2 = \frac{b}{(n+2)}$

Area $= \frac{bh}{n+1}$

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* Torsion:

$$\frac{T}{J} = \frac{\tau}{R} = \frac{C\theta}{l}$$

$\frac{T}{J} = \frac{\tau}{R} \rightarrow$ strength

$\frac{T}{J} = \frac{C\theta}{L} \rightarrow$ stiffness, rigidity

~~streng~~

Rigidity: $EI \rightarrow$ flexure rigidity

$CJ \rightarrow$ Torsional rigidity

Polar modulus $Z_p = \frac{J}{R}$ (strength of shaft)

Power $= T\omega$, $\omega = \frac{2\pi N}{60}$

Strain energy $U = \frac{1}{2} T\theta = \frac{\tau^2}{4C} \times$ Volume (solid shaft)

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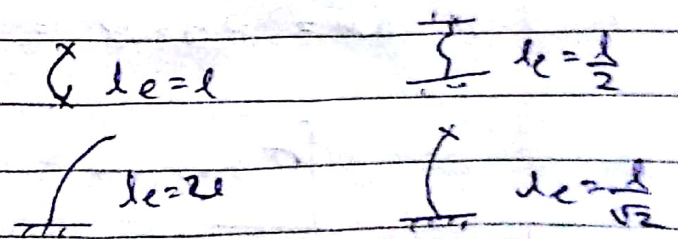
* Columns:

slenderness ratio $\rightarrow \frac{l}{K}$ here $K = \sqrt{\frac{I}{A}}$ (length of gyration)

$32 < \frac{l}{K} < 120$ (short, medium & long)

$$P_{cr} = \frac{\pi^2 EI}{l_e^2}$$

$$= \frac{\pi^2 E}{(l_e/K)^2}$$



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Euler's formula: correct for medium & larger columns,
when critical value = yield stress.

Rankine's Empirical formula:

$$\frac{1}{P_r} = \frac{1}{P_c} + \frac{1}{P_e}$$

$P_r \rightarrow$ Critical load
$P_c \rightarrow$ direct load ($\sigma_y . A$)
P_e = euler's load

Short column $\Rightarrow P_r = P_c$
long column $\Rightarrow P_r = P_e$

$$\boxed{P_r = \frac{\sigma_y . A}{1 + a(l/k)^2}}$$

$a \rightarrow$ Rankine Constant $\frac{\sigma_y}{\pi^2 E}$

⇒ Eccentric load: $y_{max} = e \sec \frac{\alpha l}{2}$ (secant formula)

$$\boxed{\sigma_{max/min} = \frac{P}{A} \pm \frac{M y_c}{I}}$$ $M = P y_{max}$

$$\alpha^2 = \frac{P}{EI}$$

perry's formula:

$$\boxed{\left(\frac{\sigma_{max}}{\sigma_0} - 1\right)\left(1 - \frac{\sigma_0}{\sigma_e}\right) = \frac{1.2\, e\, y_c}{k^2}}$$

For min $\frac{l}{k} \Rightarrow$ $\boxed{P_e = P_c}$

→ Initial curve:

$$B.M = P y_{max} = \frac{P\, C P_e}{P_e - P}$$

$$\boxed{\sigma_{max/min} = \frac{P}{A} \pm \frac{M y_c}{I}}$$

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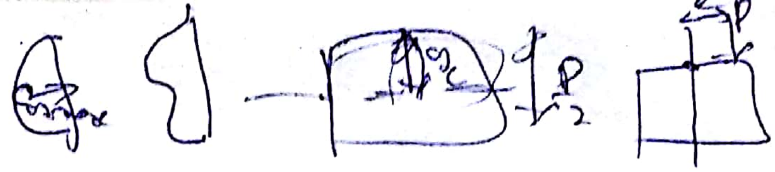

$$\boxed{\left(\frac{\sigma_{max}}{\sigma_0}-1\right)\left(1-\frac{\sigma_0}{\sigma_e}\right)=\frac{c\,y_c}{k^2}}$$

* Pressure vessels:

$\frac{t}{d} < \frac{1}{20}$ thin, $\frac{t}{d} > \frac{1}{20}$ thick

$\boxed{F_V = P_i d l}$ $\sigma_c = \frac{P_i d}{2t}$, $\sigma_l = \frac{P_i d}{4t}$

→ For cylindrical.

Max shear stress $= \frac{\sigma_c - \sigma_l}{2} = \frac{P_i d}{8t}$

$\frac{\delta d}{d} \Leftarrow$ hoop strain $\epsilon_h = \frac{\sigma_h}{E} - \mu\frac{\sigma_l}{E} = \frac{Pd}{2tE}\left(1-\frac{\mu}{2}\right)$

$\frac{\delta l}{l} \Leftarrow$ longitudinal strain $\epsilon_l = \frac{\sigma_l}{E} - \mu\frac{\sigma_h}{E} = \frac{Pd}{2tE}\left(\frac{1}{2}-\mu\right)$

$\frac{\delta v}{V} \Leftarrow$ Volumetric strain $\boxed{\begin{matrix}\epsilon_v = 2\epsilon_h + \epsilon_l \\ \frac{\delta v}{v} = 2\frac{\delta d}{d} + \frac{\delta l}{l}\end{matrix}} = \frac{Pd}{4tE}(5-4\mu)$

$\sigma_{spherical} = \frac{Pd}{4t} = \sigma_h = \sigma_l$

$\epsilon_v = 3\epsilon = \frac{3Pd}{4tE}(1-\mu)$

$\epsilon_h = \epsilon_l = \frac{Pd}{4tE}(1-\mu)$

$\epsilon_h = \sigma_0 - \mu\sigma$

Thin cylinder shell with hemispherical ends:

$\frac{Pd}{2t_c} = \frac{Pd}{4t_s} \Rightarrow \boxed{t_c = 2t_s}$

To avoid distortion:

$\frac{Pd}{2t_cE}\left(1-\frac{\mu}{2}\right) = \frac{Pd}{4t_sE}(1-\mu) \Rightarrow \boxed{\frac{t_c}{t_s} = \frac{2-\mu}{1-\mu}}$