Torsional Stress & Displacement

- $\tau = \dfrac{Tc}{J}$ $\qquad J = \dfrac{\pi c^4}{2}$
- $\theta = \dfrac{TL}{GJ}$ $\qquad \theta = \sum_{i=1}^{n} \dfrac{T_i L_i}{G_i J_i}$

Stress Concentration

$$\tau_{\max} = K\frac{Tc}{J}$$

Torsion of Noncircular Sections

- $\tau_{\max} = \dfrac{T}{\alpha a^2 b}$ $\qquad \theta = \dfrac{TL}{\beta a^3 bG}$

Torsion of Thin-Walled Tubes – Shear Flow

- $\tau = \dfrac{T_r}{2At}$ $\qquad T_r = q(2A)$

Elastic Flexure Formula

- $\sigma = \dfrac{M\ y}{I}$ $\qquad \sigma_{\max} = \dfrac{Mc}{I} = \dfrac{M}{S}$

$I = \dfrac{bh^3}{12}$ $\qquad I_{x'} = I_c + d_x^2 A$

Buckling of Long Straight Columns

$P_{cr} = \dfrac{n^2\pi^2 EI}{L'^2} = \dfrac{n^2\pi^2 EAr^2}{L'^2}$

$L' = kL$ $\qquad r = \sqrt{\dfrac{I}{A}}$

$\sigma_{cr} = \dfrac{P_{cr}}{A} = \dfrac{\pi^2 E}{(L'/r)^2}$ $\qquad P_{cr} = \dfrac{\pi^2 EI}{(L')^2}$

$P_{all} = \dfrac{\pi^2 EI}{(L')^2 (FS)}$ $\qquad FS = \dfrac{P_u}{P_{all}}$

Deflection

- $EI\dfrac{d^2 v}{dx^2} = M(x)$
- $EI\dfrac{d^3 v}{dx^3} = V(x)$
- $EI\dfrac{d^4 v}{dx^4} = w(x)$

Combined Loading

- $\sigma = \pm\dfrac{P}{A} \pm \dfrac{M_{x-x}Z}{I_{x-x}} \pm \dfrac{M_{z-z}X}{I_{z-z}}$

Shearing Stress in Beams

- $\tau = \dfrac{VQ}{It}$ $\qquad Q = y_c A$

Shearing Stresses in Thin-Walled Open Sections

- Shear flow, $q = \tau t$

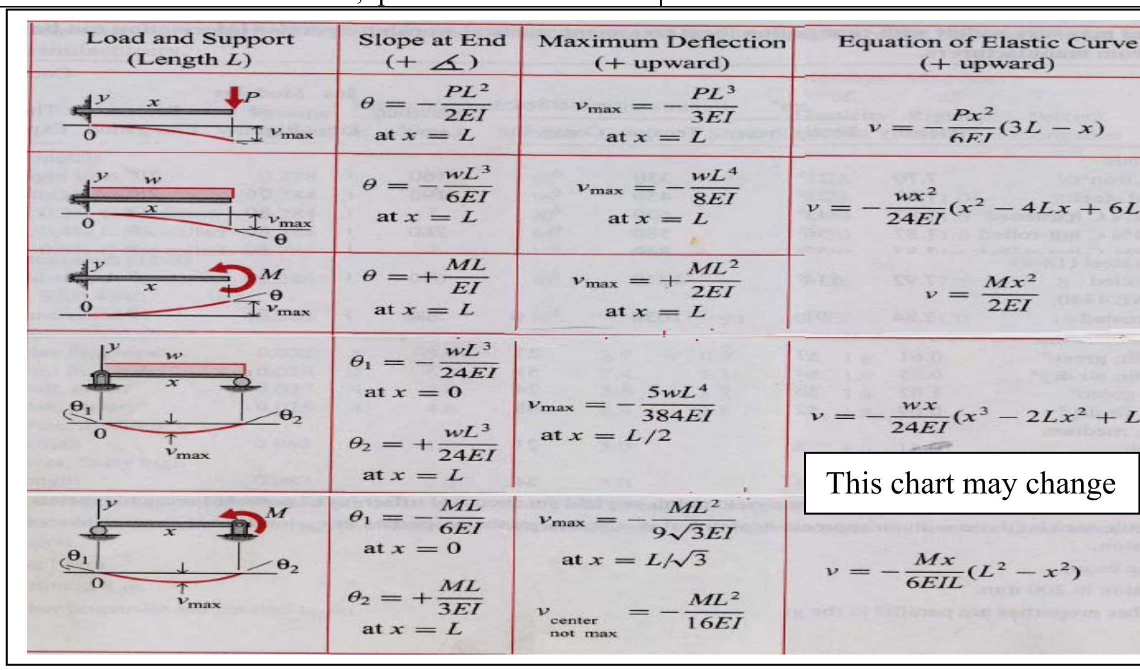
Eccentrically Loaded Columns

Allowable Stress Method

$$\frac{P}{A} + \frac{Mc}{I} \le \sigma_{all}$$

Interaction Method

$$\frac{P/A}{\sigma_a} + \frac{Mc/I}{\sigma_b} \le 1$$



Load and Support (Length L)	Slope at End (+ ∡)	Maximum Deflection (+ upward)	Equation of Elastic Curve (+ upward)
Cantilever, end load P	$\theta = -\dfrac{PL^2}{2EI}$ at $x = L$	$v_{\max} = -\dfrac{PL^3}{3EI}$ at $x = L$	$v = \dfrac{Px^2}{6EI}(3L - x)$
Cantilever, uniform load w	$\theta = -\dfrac{wL^3}{6EI}$ at $x = L$	$v_{\max} = -\dfrac{wL^4}{8EI}$ at $x = L$	$v = -\dfrac{wx^2}{24EI}(x^2 - 4Lx + 6L^2$
Cantilever, end moment M	$\theta = +\dfrac{ML}{EI}$ at $x = L$	$v_{\max} = +\dfrac{ML^2}{2EI}$ at $x = L$	$v = \dfrac{Mx^2}{2EI}$
Simply supported, uniform load w	$\theta_1 = -\dfrac{wL^3}{24EI}$ at $x = 0$; $\theta_2 = +\dfrac{wL^3}{24EI}$ at $x = L$	$v_{\max} = -\dfrac{5wL^4}{384EI}$ at $x = L/2$	$v = -\dfrac{wx}{24EI}(x^3 - 2Lx^2 + L^3$
Simply supported, end moment M	$\theta_1 = -\dfrac{ML}{6EI}$ at $x = 0$; $\theta_2 = +\dfrac{ML}{3EI}$ at $x = L$	$v_{\max} = -\dfrac{ML^2}{9\sqrt{3}EI}$ at $x = L/\sqrt{3}$; $v_{\text{center not max}} = -\dfrac{ML^2}{16EI}$	$v = -\dfrac{Mx}{6EIL}(L^2 - x^2)$

This chart may change

Maximum Normal Stress Theory

$\sigma_{p1} = \sigma_f \qquad \sigma_{p3} = \sigma_f \qquad \sigma_{\max} < \sigma_f \ \ where...\sigma_f = \sigma_y$

- $\sigma_{p1}, \sigma_{p3} = \dfrac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\dfrac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$

Maximum Shear Stress Theory

$\tau_{\max} = \tau_f \qquad \tau_{\max} = \dfrac{\sigma_{\max} - \sigma_{\min}}{2}$

$\tau_{\max} < \tau_f \ \ where...\tau_f = \dfrac{\sigma_f}{2} = \dfrac{\sigma_y}{2}$

Maximum Distortion-Energy-Theory

$\sigma^2_{p1} - \sigma_{p1}\sigma_{p3} + \sigma^2_{p3} < \sigma^2_f$

$where...\sigma_f = \sigma_y$

Code No.	Material	Compression-Block and/or Intermediate Range Formulas and Limitations (L/r is the effective ratio L'/r) :	Slender Range
1	Structural steel with a yield point σ_y	$0 \le \dfrac{L}{r} \le C_c$ $\qquad \sigma_{all} = \dfrac{\sigma_y}{FS}\left[1 - \dfrac{1}{2}\left(\dfrac{L/r}{C_c}\right)^2\right]$ $C_c^2 = \dfrac{2\pi^2 E}{\sigma_y}$ $\qquad FS = \dfrac{5}{3} + \dfrac{3}{8}\left(\dfrac{L/r}{C_c}\right) - \dfrac{1}{8}\left(\dfrac{L/r}{C_c}\right)^3$	$\dfrac{L}{r} \ge C_c$ $\sigma_{all} = \dfrac{\pi^2 E}{1.92(L/r)^2}$
4	Timber with a rectangular cross section b x d where d<b	$\dfrac{L}{d} \le 11$ $\qquad \sigma_{all} = F_c$ $11 \le \dfrac{L}{d} \le k$ $\qquad \sigma_{all} = F_c\left[1 - \dfrac{1}{3}\left(\dfrac{L/d}{k}\right)^4\right]$ $\qquad k = 0.671\sqrt{E/F_c}$	$k \le \dfrac{L}{d} \le 50$ $\sigma_{all} = \dfrac{0.30E}{(L/d)^2}$