

Tapered members - Galambos



Setup for Units is the default to SI

Initialization

ORIGIN ≡ 1

Count with fingers

TOL := 10<sup>-2</sup>

CTOL := 10<sup>-2</sup>

ton := 1000·kgf

ksi := 70.307· $\frac{\text{kgf}}{\text{cm}^2}$

psi :=  $\frac{\text{ksi}}{1000}$

kip := 453.592·kgf

MPa := 10<sup>6</sup>·Pa

AND2(a,b) :=  $\left\{ \begin{array}{l} \text{if } a = 1 \\ \left| \begin{array}{l} 1 \text{ if } b = 1 \\ 0 \text{ otherwise} \end{array} \right. \\ 0 \text{ otherwise} \end{array} \right.$

OR2(a,b) :=  $\left\{ \begin{array}{l} 1 \text{ if } a = 1 \\ \text{otherwise} \\ \left| \begin{array}{l} 1 \text{ if } b = 1 \\ 0 \text{ otherwise} \end{array} \right. \end{array} \right.$

DIV(a,b) := floor( $\frac{a}{b}$ )

GPa := 1000·MPa



Section is a double tee

E := 200000·MPa

v := 0.3

F<sub>y</sub> := 260·MPa

φ<sub>b</sub> := 0.9

φ<sub>c</sub> := 0.85

L<sub>x</sub> := 4·m

L<sub>y</sub> := 4·m

h<sub>0</sub> := 20·cm

h := 35·cm

b<sub>f</sub> := 25·cm

t<sub>f</sub> := 2·cm

t<sub>w</sub> := 1·cm

K<sub>x</sub> := 1

K<sub>y</sub> := 1

P := 120·ton

M<sub>x</sub> := 8·m·ton

M<sub>y</sub> := 3·m·ton

V := 15·ton

factored loads

C<sub>mx</sub> := 1

C<sub>my</sub> := 0.85

BIAXIAL SQUASHING, to be checked anywhere



$\gamma := \frac{h - h_0}{h_0}$

Taper where h must be bigger in our data than h<sub>0</sub>.

Tapers only towards one end, wedge like

$I_{x0} := b_f \cdot \frac{h_0^3}{12} - (b_f - t_w) \cdot \frac{(h_0 - 2 \cdot t_f)^3}{12}$

$I_{y0} := 2 \cdot t_f \cdot \frac{b_f^3}{12} + (h_0 - 2 \cdot t_f) \cdot \frac{t_w^3}{12}$

$g := 1 - 0.375 \cdot \gamma + 0.08 \cdot \gamma^2 \cdot (1 - 0.0775 \cdot \gamma)$

g = 0.76

$$P_{ey} := \frac{\pi^2 \cdot E \cdot I_{y0}}{(K_y \cdot L_y)^2} \qquad P_{ex} := \frac{\pi^2 \cdot E \cdot I_{x0}}{(K_x \cdot g \cdot L_x)^2}$$

$$A := 2 \cdot b_f \cdot t_f + \left(h_0 - 2 \cdot t_f\right) \cdot t_w \qquad \text{Area of this Section} \qquad A_w := t_w \cdot \left(h_0 - 2 \cdot t_f\right)$$

$$r_x := \sqrt{\frac{I_{x0}}{A}} \qquad r_y := \sqrt{\frac{I_{y0}}{A}}$$

$$\text{max\_slenderness} := \frac{L_y}{r_y} \qquad \text{max\_slenderness} = 59.69$$

$$\lambda_c := \frac{\text{max\_slenderness}}{\pi} \cdot \sqrt{\frac{F_y}{E}} \quad \lambda_c = 0.69 \qquad \text{Slenderness Parameter}$$

$$F_{cr} := F_y \cdot \left\{ \begin{array}{l} .658^{\left(\lambda_c^2\right)} \quad \text{if } 0 \leq \lambda_c \leq 1.5 \\ \frac{.877}{\lambda_c^2} \quad \text{otherwise} \end{array} \right.$$

$$P_n := F_{cr} \cdot A$$

$$P_y := A \cdot F_y \qquad \text{theoretical squashing load of very short column}$$

$$Z_x := b_f \cdot \frac{h_0^2}{4} - \left(b_f - t_w\right) \cdot \frac{\left(h_0 - 2 \cdot t_f\right)^2}{4} \qquad Z_y := t_f \cdot 2 \cdot \frac{b_f^2}{4} + \left(h_0 - 2 \cdot t_f\right) \cdot \frac{t_w^2}{4}$$

$$M_{px} := Z_x \cdot F_y$$

$$M_{py} := F_y \cdot Z_y$$

$$\tau_y := \frac{F_y}{\sqrt{3}}$$

$$\tau := \frac{V}{A}$$

$$\tau = 0.08 \tau_y$$

$$kt := \sqrt{1 - \frac{\tau}{\tau_y}}$$

$$kt = 0.96$$

$$\text{Ratio}_9 := \frac{\frac{P}{\phi_c \cdot P_y} + 0.85 \cdot \frac{M_x}{\phi_b \cdot M_{px}} + 0.6 \cdot \frac{M_y}{\phi_b \cdot M_{py}}}{kt}$$

Pillai

$$M_{pcx} := M_{px} \cdot \begin{cases} 1 & \text{if } \frac{P}{P_y} \leq 0.15 \\ 1.18 \cdot \left(1 - \frac{P}{P_y}\right) & \text{otherwise} \end{cases}$$

$$M_{pcy} := M_{py} \cdot \begin{cases} 1 & \text{if } \frac{P}{P_y} \leq 0.4 \\ 1.19 \cdot \left[1 - \left(\frac{P}{P_y}\right)^2\right] & \text{otherwise} \end{cases}$$

$$\alpha := 1.6 - \frac{\frac{P}{P_y}}{2 \cdot \ln\left(\frac{P}{P_y}\right)}$$

$$\tau := \frac{V}{A}$$

$$\tau = 0.08 \tau_y$$

$$kt := \sqrt{1 - \frac{\tau}{\tau_y}}$$

$$kt = 0.96$$

$$\text{Ratio}_{10} := \frac{\left(\frac{M_x}{\phi_b \cdot M_{pcx}}\right)^{\alpha} + \left(\frac{M_y}{\phi_b \cdot M_{pcy}}\right)^{\alpha}}{kt}$$

Chen and Atsuta



$$M_{ucx} := M_{ux} \cdot \begin{cases} 1 - \left(\frac{P}{P_y}\right)^2 \cdot \frac{A^2}{4 \cdot t_w \cdot Z_x} & \text{if } \frac{P}{P_y} \leq \frac{A_w}{A} \\ A \cdot \left(1 - \frac{P}{P_y}\right) \cdot \left[h_0 - \frac{A}{2 \cdot b_f} \cdot \left(1 - \frac{P}{P_y}\right)\right] \cdot \frac{1}{2 \cdot Z_x} & \text{otherwise} \end{cases}$$

$$M_{ucy} := M_{uy} \cdot \begin{cases} 1 - \left(\frac{P}{P_y}\right)^2 \cdot \frac{A^2}{4 \cdot h_0 \cdot Z_y} & \text{if } \frac{P}{P_y} \leq \frac{A_w}{A} \\ \left[\frac{4 \cdot b_f \cdot t_f}{A} - \left(1 - \frac{P}{P_y}\right)\right] \cdot \left(1 - \frac{P}{P_y}\right) \cdot \frac{A^2}{8 \cdot t_f \cdot Z_y} & \text{otherwise} \end{cases}$$

$$\eta := \begin{cases} 0.4 + \left(\frac{P}{P_y} + \frac{b_f}{h_0}\right) & \text{if } \frac{b_f}{h_0} \geq 0.3 \\ 1 & \text{otherwise} \end{cases}$$

$$Ratio_{15} := \frac{\left(\frac{C_{mx} \cdot M_x}{\phi_b \cdot M_{ucx}}\right)^\eta + \left(\frac{C_{my} \cdot M_y}{\phi_b \cdot M_{ucy}}\right)^\eta}{kt}$$

note that we apply strength reductions and keep solicitations at the proper factored level in the equations

$$Tapered_{member\_3} := \begin{cases} \text{"OK, The member would be valid against BUCKLING per the 8.21 (AISC) equation"} & \text{if } Ratio_{12} \leq 1 \\ \text{"Not OK, The section is NOT valid against BUCKLING per the 8.21 (AISC) equation"} & \text{otherwise} \end{cases}$$

$$Tapered_{member\_4} := \begin{cases} \text{"OK, The member would be valid against BUCKLING per the 8.24 equation"} & \text{if } Ratio_{15} \leq 1 \\ \text{"Not OK, The section is NOT valid against BUCKLING per the 8.24 equation"} & \text{otherwise} \end{cases}$$



Ratio <sub>12</sub> = 1.21	Tapered <sub>member_3</sub> = "Not OK, The section is NOT valid against BUCKLING per the 8.21 (AISC) equation"
Ratio <sub>15</sub> = 0.33	Tapered <sub>member_4</sub> = "OK, The member would be valid against BUCKLING per the 8.24 equation"

If one of both equations gives the section as valid, the section IS theoretically valid, since both are assumed to give safe solutions.