Structural Steel Pipes

$F_y := 260 \cdot MPa$ $E := 200000 \cdot MPa$ $\nu := 0.3$ $\phi_b := 0.9$ $\phi_c := 0.85$ $\phi_v := 0.85$

$D := 50 \cdot cm$ external diameter $t := 6 \cdot mm$ $L := 4 \cdot m$ $K := 1$ assume corresponds to real plane of buckling

$support := 0$

0 for simply supported
1 for clamped

- out of roundness imperfection less than 1%
- if more the checks could become unconservative

$$I := \frac{\pi}{4} \cdot \left[\left(\frac{D}{2}\right)^4 - \left(\frac{D - 2 \cdot t}{2}\right)^4\right] \qquad A := \pi \cdot \left[\left(\frac{D}{2}\right)^2 - \left(\frac{D - 2 \cdot t}{2}\right)^2\right] \qquad r := \sqrt{\frac{I}{A}}$$

$$S := \frac{I}{\frac{D}{2}} \qquad Z_p := S \cdot \frac{4}{\pi} \cdot \left(1 + \frac{t}{D}\right)$$

$$G := \frac{E}{2 \cdot (1 + \nu)} \qquad Z := 2 \cdot \left(\frac{L}{D}\right)^2 \cdot \left(\frac{D}{t}\right) \cdot \sqrt{1 - \nu^2} \qquad C := 0.165$$

Axial Load Strength

$$k_c := \begin{cases} 4 + \dfrac{3 \cdot Z^2}{\pi^4} & \text{if } support = 1 \\ \dfrac{12 \cdot Z^2}{\pi^4} & \text{otherwise} \end{cases}$$

critical stress

$$\sigma_{xc} := \begin{cases} k_c \cdot \dfrac{\pi^2 \cdot E}{12 \cdot (1+\nu^2) \cdot \left(\dfrac{L}{t}\right)^2} & \text{if } Z < 2.85 \\ \text{otherwise} & \\ \quad \begin{cases} \dfrac{2 \cdot C \cdot E}{\dfrac{D}{t}} & \text{if } 2.85 \le Z \wedge Z < \dfrac{1.2 \cdot \left(\dfrac{D}{t}\right)^2}{C} \\ \dfrac{\pi^2 \cdot E}{\left(\dfrac{K \cdot L}{r}\right)^2} & \text{otherwise} \end{cases} \end{cases}$$

plate buckling

diamond bulge buckling

column buckling

$$F_{y1} := \min\left(\begin{pmatrix} F_y \\ \sigma_{xc} \end{pmatrix}\right)$$

the interaction between column buckling and local buckling is made by porting Fy (the lesser of Fy or critical stress) to the column buckling equation.

$$\lambda_c := \frac{K \cdot L}{r \cdot \pi} \cdot \sqrt{\frac{F_{y1}}{E}} \qquad \lambda_c = 0.26$$

$$\sigma_n := F_{y1} \cdot \begin{cases} 0.658^{\left(\lambda_c^{\,2}\right)} & \text{if } 0 \le \lambda_c \le 1.5 \\ \dfrac{0.877}{\lambda_c^{\,2}} & \text{otherwise} \end{cases}$$

$$P_n := \sigma_n \cdot A$$

$P_n = 239.84\,ton$ $\phi_c \cdot P_n = 203.86\,ton$ $\sigma_n = 0.97\,F_y$

Bending Strength

$$\alpha := \frac{\frac{E}{F_y}}{\frac{D}{t}}$$

$M_p := Z_p \cdot F_y$ $M_y := S \cdot F_y$

$$M_n := \begin{cases} 0.9 \cdot M_p \cdot \begin{cases} 1 & \text{if } \alpha \le 14 \\ 0.775 + 0.016 \cdot \alpha & \text{otherwise} \end{cases} & \text{if } Z < \dfrac{1.2 \cdot \left(\frac{D}{t}\right)^2}{C} \\ S \cdot \dfrac{\pi^2 \cdot E}{\left(\frac{K \cdot L}{r}\right)^2} & \text{otherwise} \end{cases}$$

$M_n = 34.94\,m \cdot ton$ $\phi_b \cdot M_n = 31.44\,m \cdot ton$ $M_n = 0.9\,M_p$ $M_n = 1.16\,M_y$

$$K_s := \begin{cases} \begin{cases} 5.35 + 0.213 \cdot Z & \text{if } support = 0 \\ 8.98 + 0.1 \cdot Z & \text{otherwise} \end{cases} & \text{if } Z < 100 \\ \begin{cases} 0.85 \cdot Z^{0.75} & \text{if } 100 \le Z \wedge Z < 19.2 \cdot \left(1 - \nu^2\right) \cdot \left(\frac{D}{t}\right)^2 \\ \dfrac{0.406 \cdot Z}{\left(1 - \nu^2\right)^{0.25} \cdot \left(\frac{D}{t}\right)^{0.5}} & \text{otherwise} \end{cases} & \text{otherwise} \end{cases}$$

strictly it should be <50

$K_s = 861.15$

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

$$\tau_{c\_t\_e} := K_s \cdot \frac{\pi^2 \cdot E}{12 \cdot \left(1 - \nu^2\right) \cdot \left(\frac{L}{t}\right)^2}$$

$$\tau_{c\_t} := \begin{cases} \tau_{c\_t\_e} & \text{if } \tau_{c\_t\_e} \le 0.8 \cdot \tau_y \\ \sqrt{0.8 \cdot \tau_y \cdot \tau_{c\_t\_e}} & \text{otherwise} \end{cases}$$

$$\tau_{c\_v} := 1.25 \cdot \tau_{c\_t}$$

Beam-column: Axial load, bending, torsion and shear combined

Factored loads

$P_u := 125 \cdot ton$ $T_u := 2 \cdot m \cdot ton$ $V_u := 10 \cdot ton$ $M_u := 8 \cdot m \cdot ton$

- substitute amplified moment if required
- combine vectorially Mx and My at the point to get Mu

Note that a proper K must be entered in former input above for a proper check.

$$\tau_c := \begin{cases} \tau_{c\_v} & \text{if } T_u = 0 \cdot m \cdot ton \\ \tau_{c\_t} & \text{otherwise} \end{cases}$$

$$Shear\_buckling := \begin{cases} \text{"elastic"} & \text{if } \tau_{c\_t} \le 0.8 \cdot \tau_y \\ \text{"inelastic"} & \text{otherwise} \end{cases}$$

$Shear\_buckling = \text{"inelastic"}$

$\tau_c = 1.37\,\tau_y$

- inelastic shear action is assumed to start at buckling stress= $0.8 \cdot \tau_y$
- the elastic or inelastic critical shear buckling stress, hence

$$\tau_n := \begin{cases} \tau_c & \text{if } \tau_c \le \tau_y \\ \tau_y & \text{otherwise} \end{cases}$$

this statement establishes that if there's no buckling, the shear yield can be attained

$\tau_n = 1\,\tau_y$

for most common structural pipes the nominal shear stress will correspond to yield stress

$$\sigma_u := \frac{\frac{P_u}{\phi_c}}{A} + \frac{\frac{M_u}{\phi_b}}{S}$$

$$\tau_u := \frac{\frac{V_u}{A} + \frac{2 \cdot T_u \cdot \frac{D}{2}}{\pi \cdot \left[\left(\frac{D}{2}\right)^4 - \left(\frac{D - 2 \cdot t}{2}\right)^4\right]}}{\phi_v}$$

$$\frac{\sigma_u}{\sigma_n} + \left(\frac{\tau_u}{\tau_n}\right)^2 = 0.94$$

- must be equal to or less than 1 for the strength to be OK (interaction supported in p.172)
- note that the different strength reduction factors have already been taken into account by enlarging (in the collapsed area) the factored longitudinal and transverse stresses to be checked

- the failure to consider interaction with high shear stresses may be one fundamental cause of failure under earthquake or strong wind forces
- when strong lateral forces are being considered, don't forget to consider shear plus all other actions combined at both the joints and members