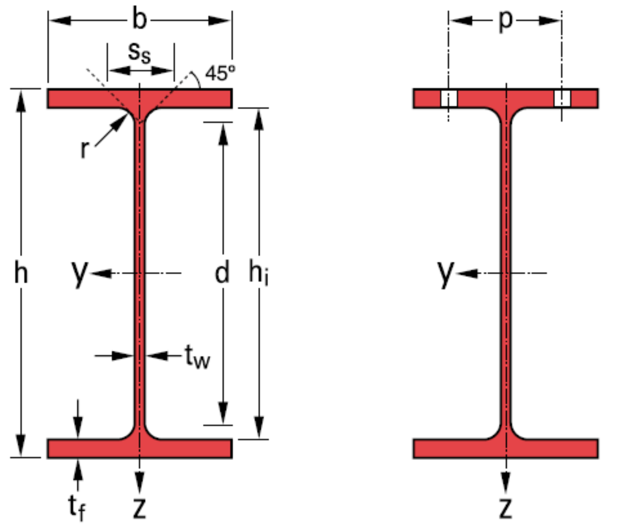
Verification of elements according to the EN 1993-1-1.
Color code: Input - Blue; Result - green; Paremeters for drawing - red

1- Input

1.1 - Cross-section properties



$h := 203.2\ mm$

$b := 266.7\ mm$

$t_w := 6.35\ mm$

$t_f := 9.5\ mm$

$r := 20\ mm$

Area of section $A := 2 \cdot t_f \cdot b + (h - 2 \cdot t_f) \cdot t_w + (4 - \pi) \cdot r^2 = 65.803\ cm^2$

Shear area parallel to web $A_{vz} := A - 2 \cdot b \cdot t_f + (t_w + 2 \cdot r) \cdot t_f = 19.534\ cm^2$

Shear area parallel to flange $A_{vy} := A - (h - 2 \cdot t_f) \cdot t_w = 54.107\ cm^2$

Depth of straight portion of web $d := h - 2 \cdot t_f - 2 \cdot r = 144.2\ mm$

Inner depth between flanges $h_i := h - 2 \cdot t_f = 184.2\ mm$

Depth of the web $h_w := h - 2 \cdot t_f = 184.2\ mm$

Inertias

$$I_y := \frac{1}{12} \cdot \left(b \cdot h^3 - (b - t_w) \cdot (h - 2 \cdot t_f)^3\right) + 0.03 \cdot r^4 + 0.2146 \cdot r^2 \cdot (h - 2 \cdot t_f - 0.4468 \cdot r)^2 = 5351.779\ cm^4$$

$$I_z := \frac{1}{12} \cdot \left(2 \cdot t_f \cdot b^3 + (h - 2 \cdot t_f) \cdot t_w^3\right) + 0.03 \cdot r^4 + 0.2146 \cdot r^2 \cdot (t_w - 0.4468 \cdot r)^2 = 3004.526\ cm^4$$

Radius of giration

$$i_y := \sqrt{\frac{I_y}{A}} = 9.018\ cm$$

$$i_z := \sqrt{\frac{I_z}{A}} = 6.757\ cm$$

Polar radius os gyration $$i_o := \sqrt{\frac{(I_y + I_z)}{A}} = 11.269\ cm$$

Torsion constant

$$I_t := \frac{2}{3} \cdot (b - 0.63 \cdot t_f) \cdot t_f^{\,3} + \frac{1}{3} \cdot (h - 2 \cdot t_f) \cdot t_w^{\,3} + 2 \cdot \left(\frac{t_w}{t_f}\right) \cdot \left(0.145 + 0.1 \cdot \frac{r}{t_f}\right) \cdot \left(\frac{\left(r + \frac{t_w}{2}\right)^2 + (r + t_f)^2 - r^2}{2 \cdot r + t_f}\right)^4 = 24.625\ cm^4$$

Warping constant $$I_w := \frac{t_f \cdot b^3}{24} \cdot (h - t_f)^2 = (2.817 \cdot 10^5)\ cm^6$$

Lenght of stiff bearing $$s_s := t_w + 2 \cdot t_f + (4 - 2 \cdot \sqrt{2}) \cdot r = 48.781\ mm$$

Elastic section modulus $$W_{el.y} := \frac{2 \cdot I_y}{h} = 526.75\ cm^3$$

$$W_{el.z} := \frac{2 \cdot I_z}{b} = 225.311\ cm^3$$

Plastic section modulus

$$W_{pl.y} := \frac{t_w \cdot h^2}{4} + (b - t_w) \cdot (h - t_f) \cdot t_f + \frac{4 - \pi}{2} \cdot r^2 \cdot (h - 2 \cdot t_f) + \frac{3 \cdot \pi - 10}{3}\ r^3 = 574.721\ cm^3$$

$$W_{pl.z} := \frac{b^2 \cdot t_f}{2} + \frac{h - 2 \cdot t_f}{4} \cdot t_w^{\,2} + r^3 \cdot \left(\frac{10}{3} - \pi\right) + \left(2 - \frac{\pi}{2}\right) \cdot t_w \cdot r^2 = 342.343\ cm^3$$

1.2 - Material properties

Yield strenght $f_y := 340\ MPa$

Ultimate strenght $f_u := 445\ MPa$

Modulus of elasticity $E := 210000\ MPa$

Poisson's ratio $\nu := 0.3$

Shear modulus $$G := \frac{E}{2 \cdot (1 + \nu)} = 80769.231\ MPa$$

Shear modulus (for computation) $G := 81000\ MPa$

$$\varepsilon := \sqrt{\frac{235\ MPa}{f_y}} = 0.831$$

1.3 - Partial factors (6.1)

$\gamma_{M0} := 1.0$

$\gamma_{M1} := 1.0$

$\gamma_{M2} := 1.25$

Project: xxxxxxx
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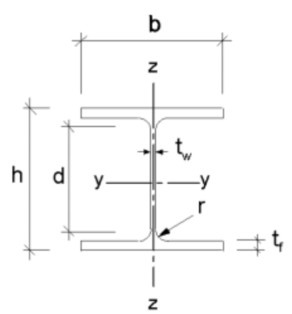
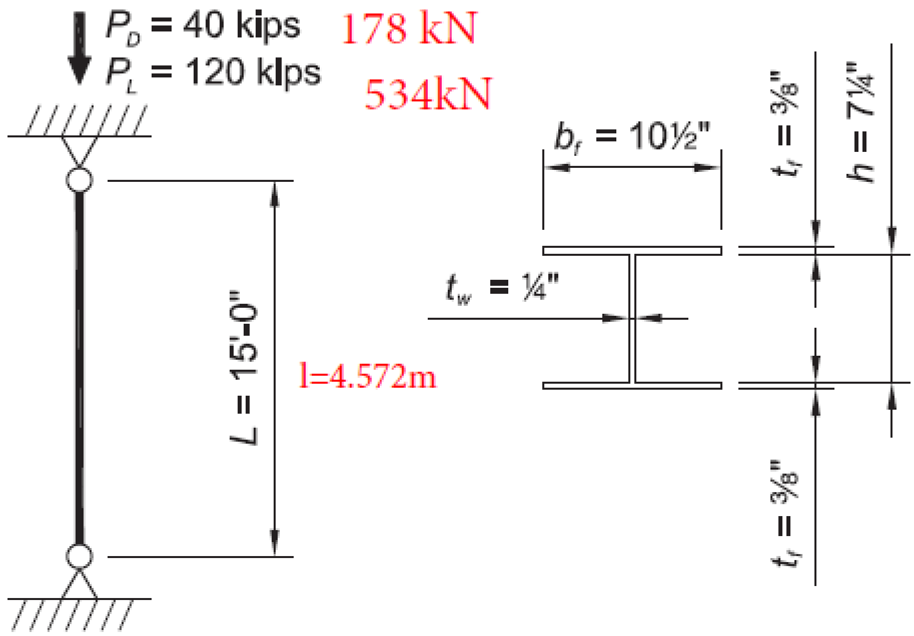
2- Load conditions





2.1- Shear

$V_{y.Ed} := 0 \ kN$

$V_{z.Ed} := 0 \ kN$

2.2- Bending moment

$M_{y.Ed} := 0 \ kN \cdot m$

$M_{z.Ed} := 0 \ kN \cdot m$

2.3- Axial load

Loads corresponding to the LRFD & ASD load combinations:

$$N_{Ed} := \begin{bmatrix} 1067 \ kN \\ 712 \ kN \end{bmatrix}$$

3- Cross-section classification

3.1- Web classification

$c := d = 144.2\ mm \qquad t := t_w = 6.35\ mm$

$$Class_{web.bending} := \begin{cases} \text{if } \frac{c}{t} \le 72 \cdot \varepsilon & 1 \\ \text{else if } \frac{c}{t} \le 83 \cdot \varepsilon & 2 \\ \text{else if } \frac{c}{t} \le 124 \cdot \varepsilon & 3 \\ \text{else} & 4 \end{cases} = 1$$

$$Class_{web.compression} := \begin{cases} \text{if } \frac{c}{t} \le 33 \cdot \varepsilon & 1 \\ \text{else if } \frac{c}{t} \le 38 \cdot \varepsilon & 2 \\ \text{else if } \frac{c}{t} \le 42 \cdot \varepsilon & 3 \\ \text{else} & 4 \end{cases} = 1$$

The worst case scenario is to consider that the entire web is in compression and therefore:

$$Class_{web} := Class_{web.compression} = 1$$

3.2- Flange classification

$c := \frac{b}{2} - \frac{t_w}{2} - r = 110.175\ mm \quad t := t_f = 9.5\ mm$

$$Class_{flange.compression} := \begin{cases} \text{if } \frac{c}{t} \le 9 \cdot \varepsilon & 1 \\ \text{else if } \frac{c}{t} \le 10 \cdot \varepsilon & 2 \\ \text{else if } \frac{c}{t} \le 14 \cdot \varepsilon & 3 \\ \text{else} & 4 \end{cases} = 3$$

$$Class_{flange} := Class_{flange.compression} = 3$$

3.3- Cross-section classification

The worst case scenario is to consider the entire cross-section in compression and therefore:

$$Class := \max\left(Class_{web}, Class_{flange}\right) = 3$$

4- Resistance of cross-section (6.2)

4.1- Tension resistance (6.2.3)

$$N_{t.Rd} := \frac{A \cdot f_y}{\gamma_{M0}} = 2237.313\ kN$$

4.2- Compression resistance (6.2.4)

$$N_{c.Rd} := \begin{cases} \text{if } Class = 4 \\ \quad \text{"N.A."} \\ \text{else} \\ \quad \frac{A \cdot f_y}{\gamma_{M0}} \end{cases} = 2237.313\ kN$$

4.3- Bending moment resistance (6.2.5)

$$M_{c.y.Rd} := \begin{cases} \text{if } Class = 1 \lor Class = 2 \\ \quad \frac{W_{pl.y} \cdot f_y}{\gamma_{M0}} \\ \text{else if } Class = 3 \\ \quad \frac{W_{el.y} \cdot f_y}{\gamma_{M0}} \\ \text{else} \\ \quad \text{"N.A."} \end{cases} = 179.095\ kN \cdot m$$

$$M_{c.z.Rd} := \begin{cases} \text{if } Class = 1 \lor Class = 2 \\ \quad \frac{W_{pl.z} \cdot f_y}{\gamma_{M0}} \\ \text{else if } Class = 3 \\ \quad \frac{W_{el.z} \cdot f_y}{\gamma_{M0}} \\ \text{else} \\ \quad \text{"N.A."} \end{cases} = 76.606\ kN \cdot m$$

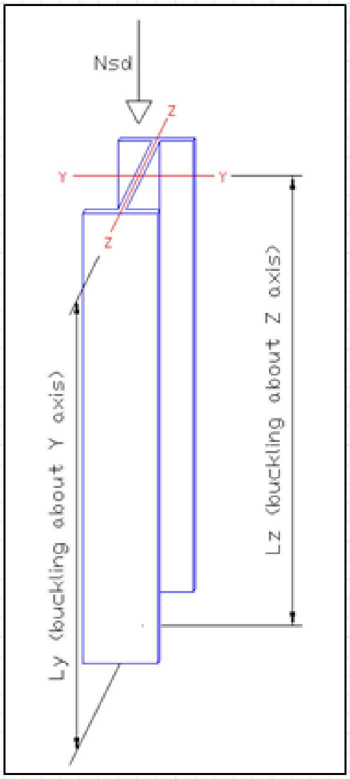
4.4- Shear resistance (6.2.6)

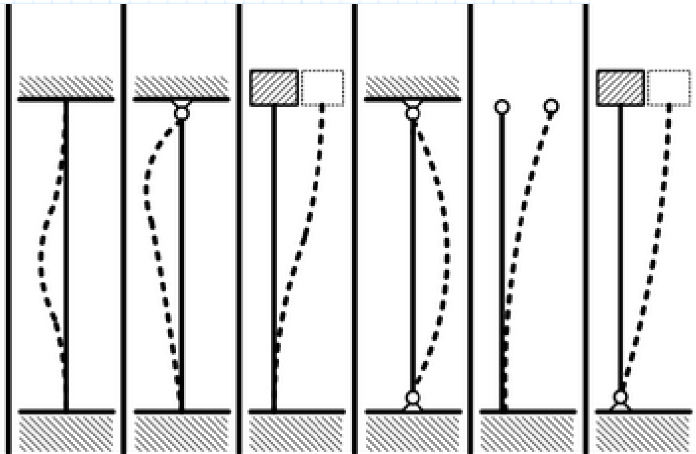
$$V_{pl.y.Rd} := \frac{A_{vy} \cdot \left(\frac{f_y}{\sqrt{3}} \right)}{\gamma_{M0}} = 1062.108\ kN$$

$$V_{pl.z.Rd} := \frac{A_{vz} \cdot \left(\frac{f_y}{\sqrt{3}} \right)}{\gamma_{M0}} = 383.442\ kN$$

5- Buckling resistance of members (6.3)

5.1- Uniform members in compression (6.3.1)



Buckled shape of column shown by dashed line						
Theoretical K value	0.5	0.7	1.0	1.0	2.0	2.0
Recommended design value K	0.65	0.80	1.2	1.0	2.10	2.0

5.1.1- Buckling input

Column unsupported lenght $L_y := 4.572\ m$

Column effective lenght factor $k_y := 1$

Column unsupported lenght $L_z := 4.572\ m$

Column effective lenght factor $k_z := 1$

5.1.2- Buckling resistance (6.3.1)

- *Buckling about z-z axis - weak axis governs*

Column buckling lenght $L_{cr.z} := L_z \cdot k_z = 4.572\ m$

Flexural elastic critial force (Euler) $N_{cr.z.F} := \dfrac{\pi^2 \cdot E \cdot I_z}{L_{cr.z}^{\ 2}} = 2979.082\ kN$

$$\sigma_{cr.z.F} := \frac{N_{cr.z.F}}{A} = 452.725\ MPa$$

Note: Open section shapes may additionally experience buckling by torsion or torsion combined with flexural buckling. These modes are more relevant in U and L shapes. As generally the rotation of the member is avoided by the boundary conditions, the flexural buckling is the limiting effect.

Elastic torsional buckling force $$N_{cr.z.T} := \frac{1}{i_o^2} \cdot \left(G \cdot I_t + \frac{\pi^2 \cdot E \cdot I_w}{L_{cr.z}^2} \right) = 3770.515\ kN$$

Elastic torsional-flexural buckling force

$$N_{cr.z.TF} := \frac{1}{2} \cdot \left(\left(N_{cr.z.F} + N_{cr.z.T} \right) - \sqrt{\left(N_{cr.z.F} + N_{cr.z.T} \right)^2 - 4 \cdot N_{cr.z.F} \cdot N_{cr.z.T}} \right) = 2979.082\ kN$$

Imperfection factor $$\alpha_z = 0.49$$

0 - for beam without torsion buckling modes,
1 - for torsion buckling mode

$$torsion_{mode} := 1$$

Elastic critical force

$$N_{cr.z} := \begin{cases} N_{cr.z.F} & \text{if } torsion_{mode} = 0 \\ min\left(N_{cr.z.F}, N_{cr.z.T}, N_{cr.z.TF}\right) & \text{else} \end{cases} = 2979.082\ kN$$

Non-dimensional slenderness $$\lambda_z := \sqrt{\frac{A \cdot f_y}{N_{cr.z}}} = 0.867$$

Reduction factor $$\Phi_z := 0.5 \cdot \left(1 + \alpha_z \cdot \left(\lambda_z - 0.2 \right) + \lambda_z^2 \right) = 1.039$$

$$\chi_z := min\left(\frac{1}{\Phi_z + \sqrt{\Phi_z^2 - \lambda_z^2}}, 1 \right) = 0.62$$

Design buckling resistance

$$N_{b.z.Rd} := \begin{cases} \text{“N.A.”} & \text{if } Class = 4 \\ \dfrac{\chi_z \cdot A \cdot f_y}{\gamma_{M1}} & \text{else} \end{cases} = 1388.203\ kN$$