1. DESIGN OF THE TRUSS SUPPORT JOINT

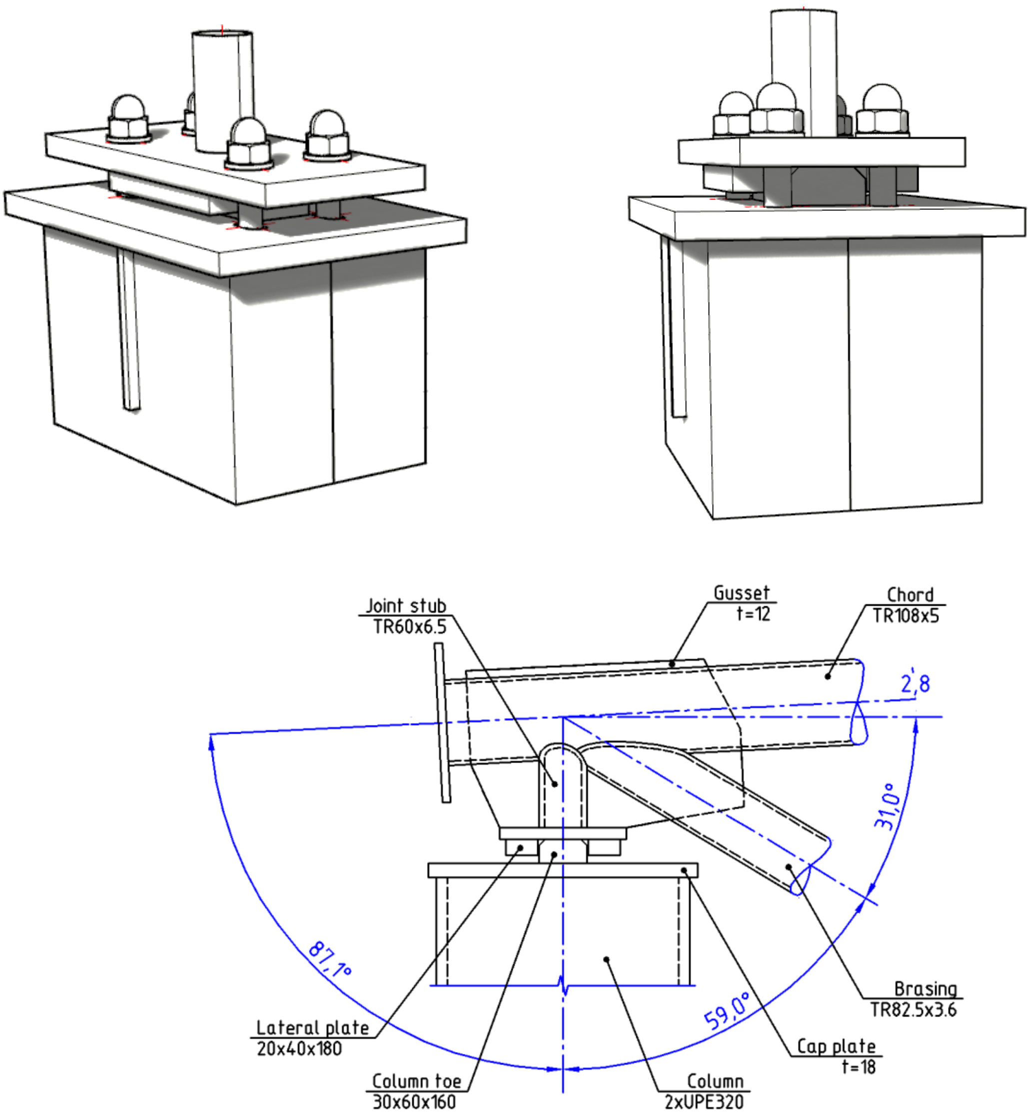

Figure 1.1. Details of the joint
(Gusset plate and truss elements are conventionally not shown on the 3D model on the joint)

1.1. Input data

Steel mechanical properties:
Truss chord, truss bracing, gusset plates (S355): f_{yk} = 355 MPa, E_s = 210000 MPa.
Welding (S275): f_{yk} = 275 MPa, f_u = 430 MPa.

Partial safety factors for joints (2.2(2), Tab.2.1, EN 1993-1-8:2003; 6.1(1), EN 1993-1-1:2005):
γ_{M0}=1.0, γ_{M2}=1.25, γ_{M5}=1.0

1.2. Design forces

Column:

	Design forces	
Design combinations	N_{Ed}	V_{Ed}
	[kN]	[kN]
LG1	-140.8	-4.8
LG2	36.4	20.3

Truss:

Design Combination	Design forces		
	N_{t_Ed} [kN]		
	KZS(1)	KZS(4)	KZS(5)
Brasing	213.9	31.5	61.3
Chord	-182.8	-41.2	-47.1

1.3. Geometry of sections

Column 2[] UPE 320: h_w = 0.32m, b_w = 0.2m, t_w = 0.014m, A_c = 0.01515m^2.

Column toe: l_t = 0.12m, b_t = 0.6m, A_t = 0.0072m^2.

Truss chord: TR 108 x 5: d_0 = 0.108m, t_0 = 0.005m A_{ch} = 0.001618m^2.

Truss bracing: TR 82.5 x 3.6: d_1 = 0.0825m, t_1 = 0.004m A_b = 0.000892m^2.

Truss joint stub: TR 60 x 6.5: d_{01} = 0.06m, t_{01} = 0.0065m A_{st} = 0.000579m^2.

Gusset plate: t_g = 0.012m.

1.4. Design of axial resistance of the joint (case of N-joint, EN 1993-1-8:2003)

Range of validity:

d_1/d_0 = 0.0825 / 0.108 = 0.764 – satisfied (7.4.1(3), Tab.7.1),

d_0/t_0 = 0.108 / 0.005 = 21.6 – satisfied (class 2, 7.4.1(3), Tab.7.1)

d_1/t_1 = 0.0825 / 0.004 = 22.9 – satisfied (class 2, 7.4.1(3), Tab.7.1)

1.4.1. Chord face failure according to 7.4.2(1) EN 1993-1-8 (Table 7.2)

Angles according to the figure x.1.: θ_1 = 87.1°, θ_2 = 33.8°

Chord width-to-double-thickness ratio: $\gamma = d_0/2t_0 = 10.8$

Joint overlapping (see Figure x.1): $g = -0.02$m; $g/t_0 = 4$

Overlapping factor (7.4.2(1), Tab.7.2):

$$k_g = \gamma^{0.2} \times \left(1 + \frac{0.024\times\gamma^{0.2}}{1+\exp(g/2t_0 - 1.33)}\right) = 10.8^{0.2} \times \left(1 + \frac{0.024\times 10.8^{0.2}}{1+\exp(4/2 - 1.33)}\right) = 2.258$$

Calculation of the factor of pre-stresses in the truss chord:

$$N_{p,Ed} = N_{t,ch,Ed} - N_{t,br,Ed}\cos\theta_2 - N_{t,c,Ed}\cos\theta_1 =$$

$= |-182.8 - 213.9 \times \cos(33.8°) - (-140.8 \times \cos(87.1°))| = 354.776$kN (7.2.1 (3), Eq.7.2)

$$n_p = \frac{N_{p,Ed}}{N_{p0,Ed}} = 182.8/354.8 = 0.515$$

$k_p = 1 - 0.3\, n_p \times (1 + n_p) = 1 - 0.3 \times 0.515 \times (1 + 0.515) = 0.766$

Resistance against chord face's failure (7.4.2(1), Tab.7.2):

$$N_{1,Rd} = \frac{k_g k_p f_{yo} t_0^2}{\sin\theta_1}\left(1.8 + 10.2\frac{d_1}{d_0}\right) * \frac{1}{\gamma_{M5}} =$$

$= 1/[\sin(87.12°)] \times 2.258 \times 0.515 \times 355000 \times 0.0052 \times (1.8 + 10.2 \times 0.06/0.108) \times 1/1.0 = 114.7$ kN

$$N_{2,Rd} = N_{1,Rd}\frac{\sin\theta_1}{\sin\theta_2} = 114.7 \times \sin(87.12°) / \sin(33.8°) = 205.9\text{kN}$$

Design check ratio:

$$\eta = \frac{N_{1,Ed}}{2N_{1,Rd}} = 213.9/(2 \times 114.7) = 0.932$$ - Eq.7.3, EN 1993-1-8 is satisfied

1.4.2. Chord face failure according to 7.4.2(1) EN 1993-1-8 (Table 7.2)

Validity of the punching shear check:

$d_1 = 0.0825 < d_0 - 2 \times t_0 = 0.108 - 2 \times 0.005 = 0.098$ – satisfied (7.4.2(1), Tab.7.2)

Resistance against the punching shear failure (7.4.2(1), Tab.7.2):

$$N_{1p,Rd} = \frac{f_{y,0}}{\gamma_{M5}\sqrt{3}} t_0 \pi d_1 \frac{1+\sin\theta_1}{2\sin^2\theta_1} = \frac{355000}{1.0\times\sqrt{3}} \times 0.005 \times \pi \times 0.0825 \times \frac{1+\sin(33.8)}{2\sin^2(33.8)} = 273.3\text{ kN}$$

$$N_{2p,Rd} = \frac{f_{y,0}}{\gamma_{M5}\sqrt{3}} t_0 \pi d_{01} \frac{1+\sin\theta_1}{2\sin^2\theta_1} = \frac{355000}{1.0\times\sqrt{3}} \times 0.005 \times \pi \times 0.06 \times \frac{1+\sin(87.1)}{2\sin^2(87.1)} = -952.4\text{ kN}$$

$$\eta_1 = \frac{N_{1,Ed}}{N_{1p,Rd}} = 213.9 / 273.3 = 0.783$$ - Eq.7.3, EN 1993-1-8 is satisfied

$$\eta_2 = \frac{N_{2,Ed}}{N_{2p,Rd}} = -140.8 / -952.4 = 0.148$$ - Eq.7.3, EN 1993-1-8 is satisfied

1.5. Welding of the truss members to the gusset according to 4.5.3.2 EN 1993-1-8

1.5.1. Weld of the stub member to gusset plate

Adopted welding throat: a = 0.005m.

Length of the weld seam considered: l_{eff} = 2 × (l_{side} – 2 × 0.01m) = 2 × (0.12 – 2 × 0.01m) = 0.2m.

Normal stress perpendicular to the throat: $\sigma_{\perp} = \frac{N_{1,Ed}}{\sqrt{2}\times a\times\, l_{eff}} = \frac{140.2}{\sqrt{2}\times 0.005\times 0.2}$ = 199121 kN/m^2.

Shear stress perpendicular to the axis of the weld: $\tau_{\perp} = \sigma_{\perp}$ = 199121.3 kN/m^2.

Shear stress (in the plane of the throat) parallel to the axis of the weld: $\tau_{\|}$= 0 kN/m^2.

Correlation factor: β_w =0.9.

Acting stresses in the fillet weld (4.5.3.2(6), Eq. 4.1).

$$\sigma_{Ed,w} = \sqrt{\sigma_{\perp}^2 + 3\times\left(\tau_{\perp}^2+\tau_{\|}^2\right)} = \sqrt{199121.3^2 + 3\times(\,199121.3^2+0)}$$ = 398242.5 kN/m^2.

Design resistance of the fillet weld (4.5.3.2(6), Eq. 4.1).

$\sigma_{Rd,w}$ = f_u /(γ_{M2} × β_w) = 490000/1.25/0.9 = 435555.6 kN/m^2.

$\eta_{w1} = \frac{\sigma_{Ed,w}}{\sigma_{Rd,w}}$ = 398242.5 / 435555.6 = 0.914 < 1.000

1.5.2. Weld of the brace member to gusset plate

Adopted welding throat: a = 0.005m.

Length of the weld seam considered: l_{eff} = 2 × (l_{side} – 2 x 0.01m) = 2 × (0.18 – 2 × 0.01m) = 0.32m.

Normal stress perpendicular to the throat: $\sigma_{\perp} = \frac{N_{1,Ed}}{\sqrt{2}\times a\times\, l_{eff}} = \frac{213.9}{\sqrt{2}\times 0.004\times 0.32}$ = 189062.7 kN/m^2.

Shear stress perpendicular to the axis of the weld: $\tau_{\perp} = \sigma_{\perp}$ = 189062.7 kN/m^2.

Shear stress (in the plane of the throat) parallel to the axis of the weld: $\tau_{\|}$= 0 kN/m^2.

Correlation factor: β_w =0.9.

Acting stresses in the fillet weld (4.5.3.2(6), Eq. 4.1).

$$\sigma_{Ed,w} = \sqrt{\sigma_{\perp}^2 + 3\times\left(\tau_{\perp}^2+\tau_{\|}^2\right)} = \sqrt{189062.7^2 + 3\times(\,189062.7^2+0)}$$ = 378125.4 kN/m^2.

Design resistance of the fillet weld (4.5.3.2(6), Eq. 4.1).

$\sigma_{Rd,w}$ = f_u /(γ_{M2} × β_w) = 490000/1.25/0.9 = 435555.6 kN/m^2.

$\eta_{w} = \frac{\sigma_{Ed,w}}{\sigma_{Rd,w}}$ = 378125.4 / 435555.6 = 0.868 < 1.000

1.6. Design Check of section net according to 6.2.4 EN 1993-1-1

1.6.1. Check of the support bracing's net-area

$A_{b,net} = A_b - 2 \times t_w \times t_1 = 0.000892 - 2 \times 0.012 \times 0.004 = 0.000806 m^2$

$N_{Rd,b,net} = f_y / \gamma_{M0} \times A_{b,net} = 355000 / 1.0 \times 0.000806 = 285.9 kN$

$\eta_{net,1} = N_{t,Ed,bracing} / N_{Rd,b,net} = 213.9 / 285.9 = 0.748 < 1.000$

1.6.2. Check of the support chord's net-area

$A_{ch,net} = A_{ch} - 2 \times t_w \times t_0 = 0.001618 - 2 \times 0.012 \times 0.005 = 0.001498 m^2$

$N_{Rd,ch,net} = f_y / \gamma_{M0} \times A_{ch,net} = 355000 / 1.0 \times 0.001498 = 531.8\ kN$

$\eta_{net,1} = N_{t,Ed,chord} / N_{Rd,cb,net} = 182.8 / 531.8 = 0.344 < 1.000$

1.6.3. Check of the support stub's net-area

$A_{st,net} = A_{st} - 2 \times t_w \times t_{01} = 0.000579 - 2 \times 0.012 \times 0.0065 = 0.000423 m^2$

$N_{Rd,st,net} = f_y / \gamma_{M0} \times A_{st,net} = 355000 / 1.0 \times 0.000423 = 150.3\ kN$

$\eta_{net,1} = N_{t,Ed,stub} / N_{Rd,st,net} = 140.8 / 150.3 = 0.937 < 1.000$

1.7. Design of support pin

1.7.1. Welding of the limit (lateral) plates

Adopted welding throat: a = 0.004m.

Length of the weld seam considered: $l_{eff} = 2 \times (l_{side} - 2 \times 0.01m) = 2 \times (0.18 - 2 \times 0.01m) = 0.32m$.

Normal stress perpendicular to the throat: $\sigma_{\perp} = \frac{N_{1,Ed}}{\sqrt{2} \times a \times l_{eff}} = \frac{140.2}{\sqrt{2} \times 0.005 \times 0.2}$ = 22428.5 kN/m^2.

Shear stress perpendicular to the axis of the weld: $\tau_{\perp} = \sigma_{\perp}$ = 22428.5 kN/m^2.

Shear stress (in the plane of the throat) parallel to the axis of the weld: $\tau_{\parallel}$= 0 kN/m^2.

Correlation factor: β_w =0.9.

Acting stresses in the fillet weld (4.5.3.2(6), Eq. 4.1).

$$\sigma_{Ed,w} = \sqrt{\sigma_{\perp}^2 + 3 \times (\tau_{\perp}^2 + \tau_{\parallel}^2)} = \sqrt{22428.5^2 + 3 \times (22428.5^2 + 0)} = 44857.1\ kN/m^2.$$

Design resistance of the fillet weld (4.5.3.2(6), Eq. 4.1).

$\sigma_{Rd,w}$ = f_u /(γ_{M2} × β_w) = 490000/1.25/0.9 = 435555.6 kN/m^2.

$\eta_w = \frac{\sigma_{Ed,w}}{\sigma_{Rd,w}}$ = 44857.1/ 435555.6 = 0.103 < 1.000

1.7.2. Collapse of the column toe

Area of crushed zone - A_{toe} = 0.0072m^2, yield strength - f_y=255 MPa, partial safety factor - γ_{M2}=1.25.

$N_{Rd,toe}$ = f_y / γ_{M2} × A_{toe} = 275000 / 1.25 × 0.0072 = 1224 kN

η_{toe} = $N_{t,Ed,stub}$ / $N_{Rd,toe}$ = 140.8 / 1224 = 0.115 < 1.000

1.8. Design of the column cap details

1.8.1. Welding of the cup plate to the column face

Adopted welding throat: a = 0.004m.

Length of the weld seam considered: l_{eff} = 2 × (l_{side} – 2 × 0.01m) = 2 × (0.32 – 2 × 0.01m) = 0.60m.

Normal stress perpendicular to the throat: $\sigma_{\perp} = \frac{N_{1,Ed}}{\sqrt{2} \times a \times l_{eff}} = \frac{140.8}{\sqrt{2} \times 0.004 \times 0.6}$ = 82967.2 kN/m^2.

Shear stress perpendicular to the axis of the weld: $\tau_{\perp} = \sigma_{\perp}$ = 82967.2 kN/m^2.

Shear stress (in the plane of the throat) parallel to the axis of the weld: $\tau_{\parallel}$= 0 kN/m^2.

Correlation factor: β_w =0.9.

Acting stresses in the fillet weld (4.5.3.2(6), Eq. 4.1).

$$\sigma_{Ed,w} = \sqrt{\sigma_{\perp}^2 + 3 \times \left(\tau_{\perp}^2 + \tau_{\parallel}^2\right)} = \sqrt{82967.2^{\,2} + 3 \times (82967.2^{\,2} + 0)} = 165934.4 \text{ kN/m}^2.$$

Design resistance of the fillet weld (4.5.3.2(6), Eq. 4.1).

$\sigma_{Rd,w}$ = f_u /(γ_{M2} × β_w) = 490000/1.25/0.9 = 435555.6 kN/m^2.

$\eta_w = \frac{\sigma_{Ed,w}}{\sigma_{Rd,w}}$ = 165934.4/ 435555.6 = 0.381 < 1.000

1.8.2. Thickness of the cap plate

Design width of column section: $a_{c,o}$ = a_c – s = 0.2 – 2×0.0175 = 0.165m

Design length of column section: $b_{c,o}$ = b_c – t_w = 0.32 – 2×0.014 = 0.292m

Length-to –width ratio: $b_{c,o}$ / $a_{c,o}$ = 0.292 / 0.165 = 1.770

Specific load: $q = N_{1,Ed} / a_{c,o} / b_{c,o}$ = 140.8 / 0.165 / 0.292 = 2922.4 kPa

Moments in plate: $M_1 = \alpha_1 \times q \times (a_{c,o})^2$ = 0.0931 × 2922.4 × (0.165)^2 = 7.407kNm/m,

$M_2 = \alpha_2 \times q \times (a_{c,o})^2$= 0.0480 × 2922.4 × (0.165)^2 = 3.819 kNm/m

Data for interpolation:

b/a	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
α_1	0.048	0.055	0.063	0.069	0.075	0.081	0.086	0.091	0.094	0.098	0.1
α_2	0.048	0.049	0.05	0.05	0.05	0.05	0.049	0.048	0.048	0.047	0.046

$t_{w,d} = \sqrt{\frac{6\times M_1}{f_{yo}}}$ = √[(6 ×7.407)/275000] = 0.0132 m

Adopted thickness of the cap plate: t_w = 0.018 m.

$\eta_t = \frac{t_{w,d}}{t_w}$ = 0.0132/ 0.018 = 0.733 < 1.000

1.9. Design of bolts

There is no need to perform deign of bolts since they are used for assembly only. Assigned size of bolts is 4 x M20. In the cap plate the slotted holes are used in out-of-plane direction to allow sliding caused by temperature deformations.

Before to close the column with the cap plate, nuts must be fixed by point weld (two points by each nut) to make further assembly possible.