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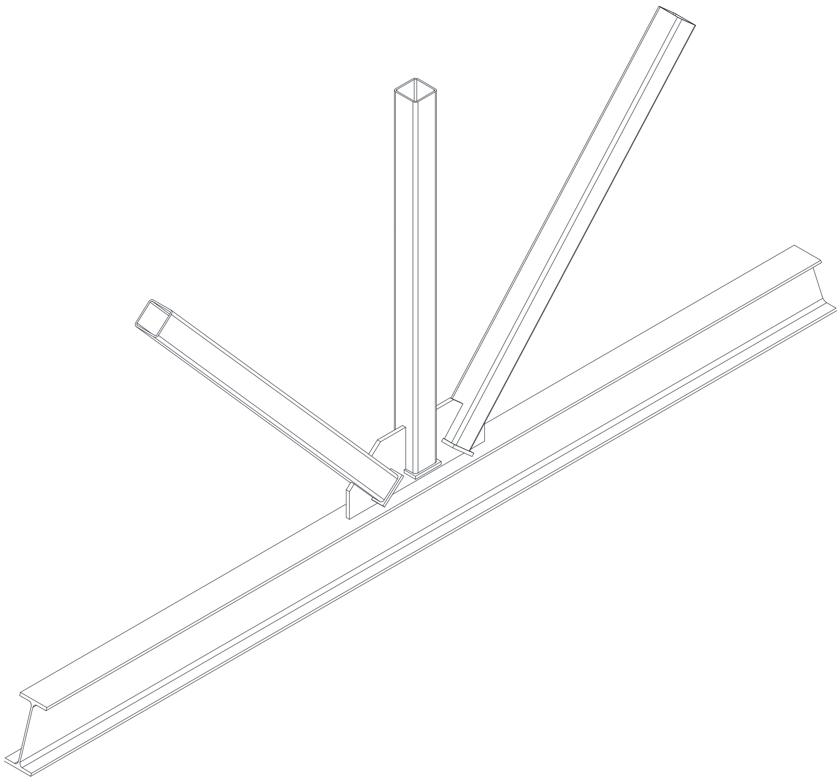
Metal Structures II

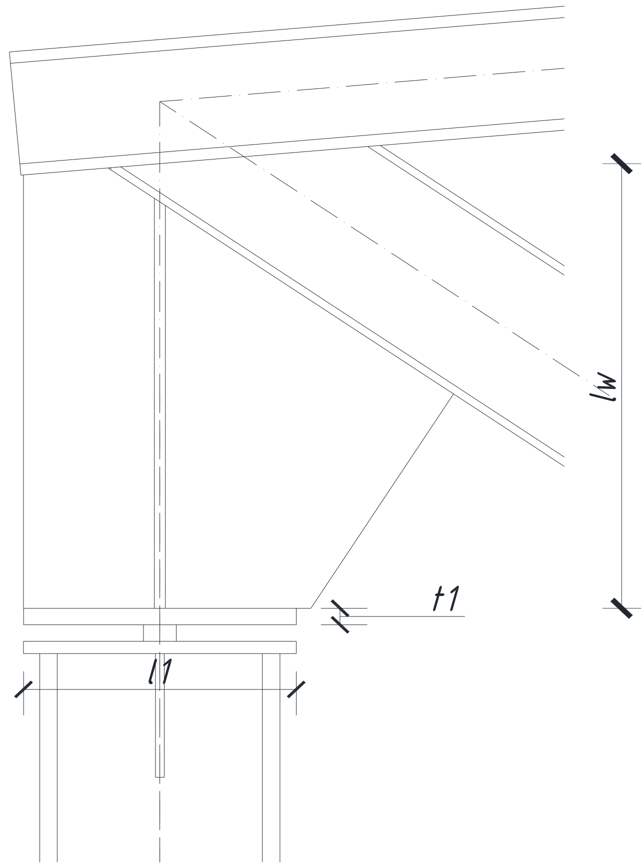
Truss conections



Conditions:

1. Finishing layers of the roof:	Insulated
2. Steel grade:	S235
3. Span of the truss:	$L = 29.4m$
4. Length: n x l, where :	$n = 10$ $l = 6.0m$
5. Hight (max) at the ridge:	$H = 7.2m$
6. Roof slope:	$\alpha = 3deg$
7. Snow load:	I zone
8. Wind load:	I zone

5.7. Girder support



Dimensions::

$b_1 = 190mm$

$l_1 = 190mm$

$t_1 = 12mm$

$t_2 = 12mm$

$t_s = 8mm$

$b_s = (b_1 - t_2) \cdot 0.5 = 89 \cdot mm$

$l_w = 400mm$

$\varepsilon = \sqrt{\frac{235MPa}{f_y}} = 0.924$

$E = 210GPa$

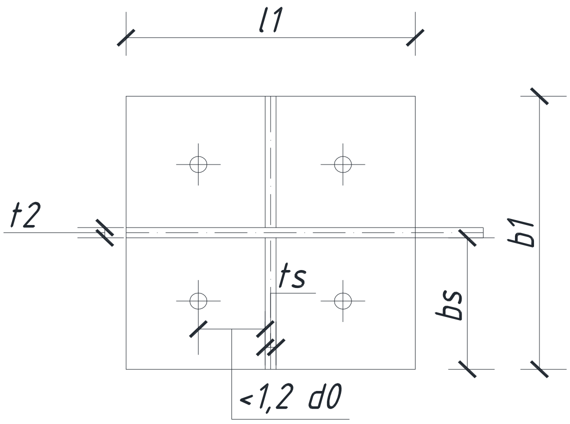
5.7.1. Fillet dimensioning

Width cooperate of sheet node:

$b_{wb} = 15 \cdot \varepsilon \cdot t_2 = 15 \cdot 12 \cdot mm$

$b_{wb} = 180 \cdot mm$

Area of cooperate cross-section:



$$A_{st} = 2 \cdot b_s \cdot t_s + (2 \cdot 15 \cdot \varepsilon \cdot t_2 + t_s) \cdot t_2 = 2 \cdot 89 \cdot mm \cdot 8 \cdot mm + (2 \cdot 15 \cdot \varepsilon \cdot 12 \cdot mm + 8 \cdot mm) \cdot 12 \cdot mm \quad \rightarrow A_{st} = 5840 \cdot mm^2$$

Moment of inertia of cooperate cross-section:

$$J_{st} = 2\cdot\left[\frac{t_s\cdot b_s^3}{12} + t_s\cdot b_s\cdot\left(0.5\cdot b_s + 0.5\cdot t_2\right)^2\right] + \frac{\left(2\cdot 15\cdot\varepsilon\cdot t_2 + t_s\right)\cdot t_2^3}{12}$$

$$J_{st} = 2\cdot\left[\frac{8\cdot mm\cdot(89\cdot mm)^3}{12} + 8\cdot mm\cdot 89\cdot mm\cdot(0.5\cdot 89\cdot mm + 0.5\cdot 12\cdot mm)^2\right] + \frac{(2\cdot 15\cdot 12\cdot mm + 8\cdot mm)\cdot(12\cdot mm)^3}{12}$$

$$J_{st} = 4624506.67\cdot mm^4$$

Radius of inertia:

$$i_{st} = \sqrt{\frac{J_{st}}{A_{st}}} = \sqrt{\frac{4624506.67\cdot mm^4}{5840\cdot mm^2}} \qquad i_{st} = 28.14\cdot mm$$

5.7.2. Checking of bearing capacity of fillet under compression

$\frac{N_{Ed}}{N_{b.Rd}} \le 1.0$ - bearing capacity condition fillets under compression

$N_{Ed} = 260.36kN$

$l_w = 400\cdot mm$

$L_{cr} = 0.75\cdot l_w = 300\cdot mm$

$\lambda_1 = \pi\cdot\sqrt{\frac{E}{f_y}} = 86.815$

$i = i_{st} = 28.14\cdot mm$

$\lambda = \frac{L_{cr}}{i}\cdot\frac{1}{\lambda_1} = 0.123$

imperfection parameter → curve c → $\alpha = 0.49$

$$\phi = 0.5\cdot\left[1 + \alpha\cdot(\lambda - 0.2) + \lambda^2\right] = 0.5\cdot\left[1 + 0.49\cdot(0.123 - 0.2) + 0.123^2\right] \rightarrow \phi = 0.489$$

$$\chi = \frac{1}{\phi + \sqrt{\phi^2 - \lambda^2}} = \frac{1}{0.489 + \sqrt{0.489^2 - 0.123^2}} \rightarrow \chi = 1.039 \quad \text{but} \quad \chi \le 1.0$$

$$N_{b.Rd} = \frac{\chi\cdot A_{st}\cdot f_y}{\gamma_{M1}} = \frac{5840\cdot mm^2\cdot 275\cdot MPa}{1.0} \rightarrow N_{b.Rd} = 1606\cdot kN$$

$\frac{N_{Ed}}{N_{b.Rd}} = 0.162$ < 1.0 - condition satisfied

5.7.3. Check of press of fillet to sheet (t_1)

$\sigma_d = \dfrac{N_{Ed}}{A_d} \le f_d$ - press condition

Defined cut out in fillet: $c_s = 5mm$

Area of press:

$A_d = 2 \cdot (b_s - c_s) \cdot t_s = 2 \cdot (89 \cdot mm - 5 \cdot mm) \cdot 8 \cdot mm \rightarrow A_d = 1344 \cdot mm^2$

$N_{Ed} = 260.36 \cdot kN$

$\sigma_d = \dfrac{N_{Ed}}{A_d} = \dfrac{260.36 \cdot kN}{1344 \cdot mm^2} \rightarrow \sigma_d = 193.72 \cdot MPa$

$f_d = 1.25 \cdot \dfrac{f_y}{\gamma_{M0}} = 1.25 \cdot \dfrac{275 \cdot MPa}{1.0} \rightarrow f_d = 343.750 \cdot MPa$

$\sigma_d = 193.72 \cdot MPa$ < $f_d = 343.750 \cdot MPa$ - condition satisfied

5.7.4. Welds

Welds defined due to structures conditions:

$0.2 \cdot t_{max} \le a \le 0.7 \cdot t_{min}$ and $a \ge 3mm$

fillet - HEB: $a(t_s;t_w) = a(8;12) \rightarrow 2.4 \le a \le 5.6$

$a(t_s;t_f) = a(8;12) \rightarrow 2.4 \le a \le 5.6$

fillet - sheet node: $a(t_s;t_2) = a(8;12) \rightarrow 2.4 \le a \le 5.6$

fillet - sheet t_1: $a(t_s;t_1) = a(8;12) \rightarrow 2.4 \le a \le 5.6$

welds defined - **a = 4mm**.

5.8. Truss nodes

sheet node thickness: $t = 12mm$

welds ($a \geq 3mm$):

sheet node - IPE :	a(12;6) →	$2.4 \leq a \leq 4.2$	→	a = 3mm
sheet node - IPE:	a(12;11) →	$2.4 \leq a \leq 7.7$	→	a = 3mm
sheet node - HEB:	a(12;15) →	$3.0 \leq a \leq 8.4$	→	a = 3mm

Length of welds connecting truss bars to sheet node according to max. longitudinal force in bar:

Requirements of welds length:

$$l_w \geq 6 \cdot a \qquad \geq 30 \qquad \leq 150 \cdot a$$

for a = 3 mm

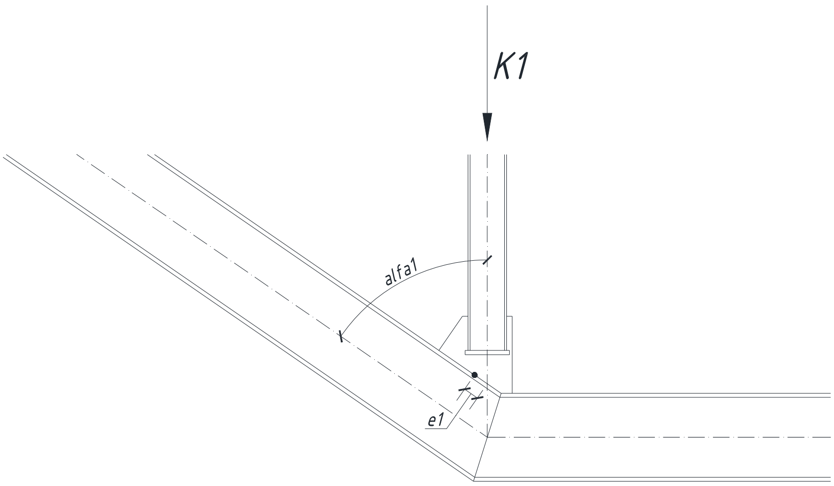
$$l_w \geq 6 \cdot 3mm = 18\,mm \qquad \geq 30mm \qquad \leq 150 \cdot 3mm = 450\,mm$$

Welds calculated due to formula:

$$l_w > \frac{N_{Ed} \cdot \sqrt{3} \cdot \beta_w \cdot \gamma_{M2}}{4 \cdot a \cdot f_u}$$

where $f_u = 430 \cdot MPa$ $\beta_w = 0.85$ $\gamma_{M2} = 1.25$

5.8.1. Check of node



$\alpha_1 = 52deg$

$K_1 = 200.96kN$

$K_{1.x} = K_1 \cdot \cos(\alpha_1) = 124\,kN$

$K_{1.y} = K_1 \cdot \sin(\alpha_1) = 158\,kN$

$e_1 = -20mm$

Weld Checking:

Welds connecting node steel plate with IPE beam:

$a = 5mm$

$L_s = 140mm$

$$\tau_1 = \frac{-K_{1.y} \cdot e_1}{\left(\frac{2 \cdot a \cdot L_s^2}{6}\right)} = 96.954 \cdot MPa$$

$$\tau_2 = \frac{K_{1.y}}{2 \cdot a \cdot L_s} = 113.113 \cdot MPa$$

$$\tau_3 = \frac{K_{1.x}}{2 \cdot a \cdot L_s} = 88.374 \cdot MPa$$

25	200,96	71,67	75	3	2220
26	221,72	79,08	80	3	3380
27	145,71	51,97	55	3	2450
28	139,10	49,61	50	3	3530
29	96,29	34,34	35	3	2670
30	71,04	25,34	30	3	3690
31	51,37	18,32	20	3	2890
32	23,66	8,44	10	3	3860
33	17,75	6,33	10	3	3120
34	49,54	17,67	20	3	4030
35	57,21	20,40	25	3	3340
36	49,54	17,67	20	3	4030
37	17,75	6,33	10	3	3120
38	23,66	8,44	10	3	3860
39	51,37	18,32	20	3	2890
40	71,04	25,34	30	3	3690
41	96,29	34,34	35	3	2670
42	139,10	49,61	50	3	3530
43	145,71	51,97	55	3	2450
44	221,72	79,08	80	3	3380
45	200,96	71,67	75	3	2220

$$\sqrt{\sigma_{pr}^2 + 3\cdot\left(\tau_{pr}^2 + \tau_{||}^2\right)} \le \frac{f_u}{\beta_w\cdot\gamma_{M2}} \qquad \sigma_{pr} \le \frac{0.9\cdot f_u}{\gamma_{M2}}$$

$\sigma_\perp$ - σ_{pr}
$\tau_\perp$ - τ_{pr}

$$\sigma_{pr} = \tau_{pr} = \frac{\tau_1 + \tau_2}{\sqrt{2}} \quad \rightarrow \quad \sigma_{pr} = \tau_{pr} = 148.54\cdot\text{MPa}$$

$$\tau_{||} = \tau_3 = 88.374\cdot\text{MPa}$$

$$\sqrt{\sigma_{pr}^2 + 3\cdot\left(\tau_{pr}^2 + \tau_{||}^2\right)} = 334.195\cdot\text{MPa} \quad < \quad \frac{f_u}{\beta_w\cdot\gamma_{M2}} = 404.706\cdot\text{MPa}$$ - condition satisfied

$$\sigma_{pr} = 148.54\cdot\text{MPa} \quad < \quad \frac{0.9\cdot f_u}{\gamma_{M2}} = 309.6\cdot\text{MPa}$$ - condition satisfied

<u>Checking of node steel plate:</u>

$$L_w = L_s = 140\,\text{mm}$$

$$\sigma = \frac{-K_{1.y}\cdot e_1}{\left(\frac{t\cdot L^2}{6}\right)} + \frac{K_{1.y}}{t\cdot L} = 175.056\cdot\text{MPa}$$

$$\tau = \frac{K_{1.x}}{t\cdot L} = 73.645\cdot\text{MPa}$$

<u>Conditions:</u> $\sigma \le f_y$ $\qquad \tau \le \frac{f_y}{\sqrt{3}}$ $\qquad \sigma_z \le f_y$

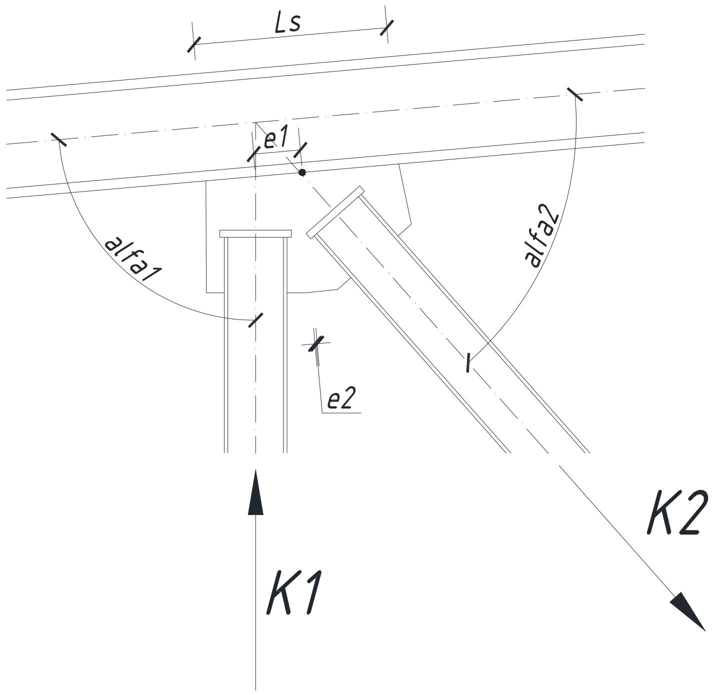
$$\sigma = 175.056\cdot\text{MPa} \quad < \quad f_y = 275\cdot\text{MPa}$$

$$\tau = 73.645\cdot\text{MPa} \quad < \quad \frac{f_y}{\sqrt{3}} = 158.771\cdot\text{MPa}$$

$$\sigma_z = \sqrt{\sigma^2 + 3\cdot\tau^2} = 216.6\cdot\text{MPa} \quad < \quad f_y = 275\cdot\text{MPa}$$

Conditions satisfied.

5.8.2. Check of node number 2



$\alpha_1 = 85deg$

$K_1 = 200.96kN$

$K_{1.x} = K_1 \cdot \cos(\alpha_1) = 18\,kN$

$K_{1.y} = K_1 \cdot \sin(\alpha_1) = 200\,kN$

$e_1 = 75mm$

$\alpha_2 = 46deg$

$K_2 = 221.27kN$

$K_{2.x} = K_2 \cdot \cos(\alpha_2) = 154\,kN$

$K_{2.y} = K_2 \cdot \sin(\alpha_2) = 159\,kN$

$e_2 = 8mm$

<u>Weld Checking:</u>

Weld connecting node steel plate with HEB beam:

$a = 5mm$

$L_s = 254mm$

$$\tau_1 = \frac{K_{1.y} \cdot e_1 + K_{2.y} \cdot e_2}{\left(\frac{2 \cdot a \cdot L_s^{\,2}}{6}\right)} = 151.479 \cdot MPa$$

$$\tau_2 = \frac{-K_{1.y} + K_{2.y}}{2 \cdot a \cdot L_s} = -16.152 \cdot MPa$$

$$\tau_3 = \frac{K_{1.x} + K_{2.x}}{2 \cdot a \cdot L_s} = 67.410 \cdot MPa$$

$\sqrt{\sigma_{pr}^2 + 3\cdot\left(\tau_{pr}^2 + \tau_{\parallel}^2\right)} \le \frac{f_u}{\beta_w\cdot\gamma_{M2}}$ $\sigma_{pr} \le \frac{0.9\cdot f_u}{\gamma_{M2}}$

$\sigma_{\perp}$ - σ_{pr}
$\tau_{\perp}$ - τ_{pr}

$\sigma_{pr} = \tau_{pr} = \frac{\tau_1 + \tau_2}{\sqrt{2}}$ → $\sigma_{pr} = \tau_{pr} = 95.690\cdot MPa$

$\tau_{\parallel} = \tau_3 = 67.410\cdot MPa$

$\sqrt{\sigma_{pr}^2 + 3\cdot\left(\tau_{pr}^2 + \tau_{\parallel}^2\right)} = 224.185\cdot MPa < \frac{f_u}{\beta_w\cdot\gamma_{M2}} = 404.706\cdot MPa$ **- condition satisfied**

$\sigma_{pr} = 95.690\cdot MPa < \frac{0.9\cdot f_u}{\gamma_{M2}} = 309.600\cdot MPa$ **- condition satisfied**

Checking node steel plate:

$L = L_s = 254\,mm$

$\sigma = \frac{K_{1.y}\cdot e_1 + K_{2.y}\cdot e_2}{\left(\frac{t\cdot L^2}{6}\right)} + \frac{-K_{1.y} + K_{2.y}}{t\cdot L} = 112.772\cdot MPa$

$\tau = \frac{K_{1.x} + K_{2.x}}{t\cdot L} = 56.175\cdot MPa$

Conditions: $\sigma \le f_y$ $\tau \le \frac{f_y}{\sqrt{3}}$ $\sigma_z \le f_y$

$\sigma = 112.772\cdot MPa < f_y = 275\cdot MPa$

$\tau = 56.175\cdot MPa < \frac{f_y}{\sqrt{3}} = 158.771\cdot MPa$

$\sigma_z = \sqrt{\sigma^2 + 3\cdot\tau^2} = 148.944\cdot MPa < f_y = 275\cdot MPa$ **Conditions satisfied.**

5.9. Checking Serviceability Limit State (SLS)

$w_{max} \le \frac{L}{250}$

$L = 31800mm$ - length of grinder

w_{max} - max. deflection ((node nr 1)

$w_{max} = 100mm < \frac{L}{250} = 127.2\,mm$ - condition satisfied