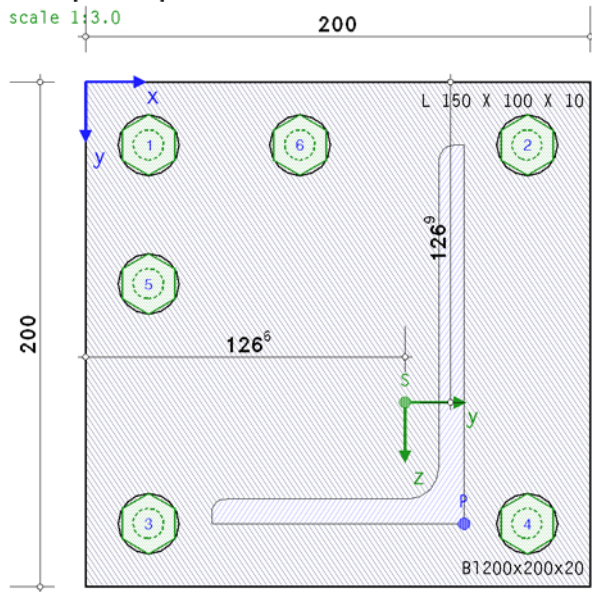


POS. 2: L

bolted end plate connection EC 3-1-8 (04.25), NA: Deutschland

1. input report



steel grade

steel grade S235

bolts

bolts have to be prestressed with with preloading $F_{p,c} = 37.8 \text{ kN} !!$

bolt class 8.8, bolt size M12

large wrench size (high strength bolt), preloaded (for info: preloading $F_{p,c}^* = 0.7 \cdot f_{yb} \cdot A_s = 37.8 \text{ kN}$)

thread included in the shear plane

connection

end plate (rectangular): thickness $t_p = 20.0 \text{ mm}$, width $b_p = 200.0 \text{ mm}$, length $l_p = 200.0 \text{ mm}$

beam: mirrored section L 150 X 100 X 10

beam-end plate: surrounding fillet weld, weld thickness $a = 7.0 \text{ mm}$

coordinates left top of the surrounding rectangle of beam section at $x_p = 150.0 \text{ mm}$, $y_p = 175.0 \text{ mm}$

coordinates of the beam centroid on end plate $x_s = 126.6 \text{ mm}$, $y_s = 126.9 \text{ mm}$

bolts:

coordinates of bolt axis:

$x_1 = 25.0 \text{ mm}$, $y_1 = 25.0 \text{ mm}$

$x_2 = 175.0 \text{ mm}$, $y_2 = 25.0 \text{ mm}$

$x_3 = 25.0 \text{ mm}$, $y_3 = 175.0 \text{ mm}$

$x_4 = 175.0 \text{ mm}$, $y_4 = 175.0 \text{ mm}$

$x_5 = 25.0 \text{ mm}$, $y_5 = 80.0 \text{ mm}$

$x_6 = 85.0 \text{ mm}$, $y_6 = 25.0 \text{ mm}$

calculation

verification:

calculation of internal forces and moments (FEM) and verifications of resistance

verification of end plate with the plastic method, verification of compression by contact

verification of beam section with the plastic method

verification of welds with the directional method

verification of bolts, check of distances

FEM-calculation:

bolts are plastically calculated, spring constant of bolts $c_f = 3210.0 \text{ kN/cm}$

plastic limit force $F_{t,f} = f_{t,f} \cdot F_{t,Rd} = 46.1 \text{ kN}$, $f_{t,f} = 0.950$, $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2} = 48.56 \text{ kN}$, $k_2 = 0.90$

effective elongation at failure $\varepsilon_{t,f} = f_{t,e} \cdot \varepsilon_{ub} = 3.0\%$, $f_{t,e} = 0.250$, $\varepsilon_{ub} = 12.0\%$

preload force of bolts $F_{p,c} = 37.8 \text{ kN} < F_{t,f}$ ok

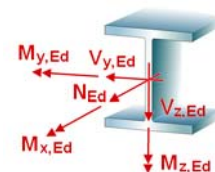
effective foundation modulus of end plate $c_b = 10500.0 \text{ kN/cm}^3$

number / dimension of finite elements each direction $n_x / \Delta x = 32 / 6.3 \text{ mm}$, $n_y / \Delta y = 32 / 6.3 \text{ mm}$

max. 50 iteration steps (tolerance limit 5%)

internal forces and moments referring to local axes of cross-section

LC	N_{Ed} kN	$M_{y,Ed}$ kNcm	$V_{z,Ed}$ kN	$M_{z,Ed}$ kNcm	$V_{y,Ed}$ kN	$M_{x,Ed}$ kNcm
1	-17.93	-88.20	16.35	-375.49	-1.70	-1.40
2	0.96	-29.92	0.62	-88.61	-0.36	111.34
3	-11.31	312.81	-0.14	-607.21	-2.90	78.95
4	-11.41	-722.87	24.36	424.73	2.24	-3.76
5	-5.17	-208.12	1.02	316.77	1.54	0.02
6	-14.33	-427.05	23.69	-191.51	-0.68	107.66
7	-11.20	-734.98	24.39	407.22	2.17	-4.79
8	-6.41	184.82	0.14	-398.30	-1.89	113.00



Lc	N _{Ed} kN	M _{y,Ed} kNm	V _{z,Ed} kN	M _{z,Ed} kNm	V _{y,Ed} kN	M _{x,Ed} kNm
9	-10.09	-751.73	24.41	318.09	1.80	106.69
10	-12.23	333.01	-0.18	-532.57	-2.59	1.63
11	-10.87	-629.33	17.55	473.84	2.43	-3.01

partial safety factors for material

resistance of cross-sections $\gamma_{M0} = 1.00$

resistance of bolts, welds, plates in bearing $\gamma_{M2} = 1.25$

local stresses especially of the beam and of welds are not considered !

utilizations

Lc	U _p	U _σ	U _b	U _{pl}	U _{pl,s}	U _{wt,s}	U _{t,s}	U _{vt,s}	U _{b,s}	U _q	U _{c/t}	U _w	U
1	0.278	0.278	0.156	0.081	0.076	0.076	0.159	0.677	0.029	0.757	0.498	0.494	0.757
2	0.123	0.106	0.123	0.032	---	0.071	0.152	0.635	0.019	1.039	0.231	0.108	1.039!
3	0.572	0.572	0.159	0.174	0.177	0.113	0.185	0.700	0.025	1.538	0.639	0.889	1.538*
4	0.302	0.302	0.168	0.210	0.080	0.080	0.166	0.779	0.054	1.188	0.163	0.879	1.188!
5	0.170	0.170	0.141	0.113	---	0.071	0.152	0.573	0.004	0.710	0.142	0.461	0.710
6	0.190	0.190	0.167	0.105	---	0.071	0.153	0.682	0.031	1.157	0.341	0.205	1.157!
7	0.311	0.311	0.172	0.215	0.081	0.081	0.167	0.782	0.055	1.175	0.162	0.869	1.175!
8	0.322	0.322	0.142	0.117	0.081	0.081	0.166	0.673	0.026	1.363	0.515	0.577	1.363!
9	0.328	0.328	0.176	0.223	0.082	0.082	0.168	0.707	0.036	1.494	0.153	0.793	1.494!
10	0.468	0.468	0.149	0.147	0.114	0.098	0.182	0.674	0.007	1.224	0.629	0.797	1.224!
11	0.248	0.248	0.153	0.181	0.076	0.076	0.159	0.712	0.038	1.177	0.170	0.866	1.177!

U_p: utilization of end plate; U_σ: utilization of end plate due to stress; U_b: utilization of end plate due to compression by contact

U_{pl}: min. plastic utilization of the connection; U_{pl,s}: plastic utilization of tensile forces of bolts; U_{wt,s}: utilization of bolts due to elongation

U_{t,s}: utilization of bolts due to tension; U_{vt,s}: utilization of bolts due to shear; U_{b,s}: utilization of bolts due to bearing resistance

U_q: stress utilization of the beam; U_{c/t}: c/t-utilization of the beam; U_w: utilization of welds

U: total utilization

*) maximum utilization

2. final result

maximum utilization of end plate due to 11 Lc: max U_p with corresponding values

node	x mm	y mm	u _z mm	b _z N/mm ²	m _{xx} kNm/m	m _{yy} kNm/m	m _{xy} kNm/m	q _x kN/m	q _y kN/m	U _p
292	50.0	168.8	0.052	0.00	-14.07	-9.34	0.66	572.62	-123.16	0.572

x,y: node coordinates; u_z: deformations (lifting off positive); b_z: compression by contact (compression positive); m_{xx},m_{yy},m_{xy}: moments

q_x,q_y: shear forces; q_x,q_y: shear forces; U_p: utilization of end plate

maximum utilization of bolts due to 11 Lc: max U_s with corresponding values

	x mm	y mm	F _t kN	U _{wt}	U _{vt}	U _b	U _s
1	25.0	25.0	37.77	0.071	0.685	0.032	0.685
2	175.0	25.0	41.56	0.081	0.750	0.034	0.750
3	25.0	175.0	46.00	0.113	0.700	0.006	0.700
4	175.0	175.0	37.77	0.071	0.782	0.055	0.782
5	25.0	80.0	37.77	0.071	0.686	0.020	0.686
6	85.0	25.0	38.15	0.071	0.700	0.033	0.700

x,y: bolt coordinates; F_t: bolt force; U_{wt}: utilization due to elongation; U_{vt}: utilization due to shear

U_b: utilization due to bearing resistance; U_s: utilization of bolts

maximum utilization of end plate [Lc 3]

maximum utilization of bolts due to elongation [Lc 3]

maximum utilization of bolts [Lc 7]

maximum utilization of the beam [Lc 3]

maximum utilization of welds [Lc 3]

maximum utilization [Lc 3]

max U_p = 0.572 < 1 ok

max U_{wt,s} = 0.113 < 1 ok

max U_s = 0.782 < 1 ok

max (U_q,U_{c/t}) = 1.538 > 1 not ok !!

max U_w = 0.889 < 1 ok

max U = 1.538 > 1 not ok !!

resistance not ensured !!

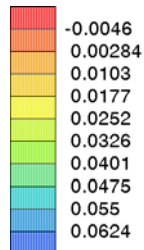
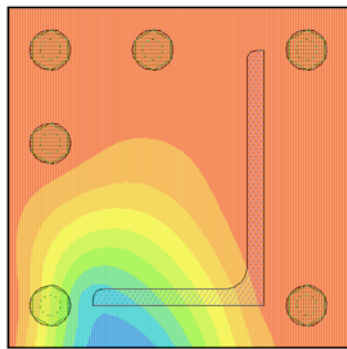
3. Lc 3 (decisive)

3.1. end plate

design values: N = -11.31 kN, M_y = 3.13 kNm, M_z = -6.07 kNm

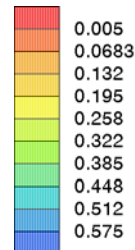
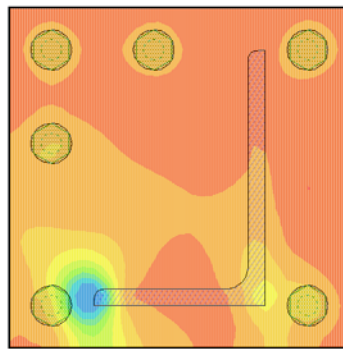
deformations u_z [mm]

min $u_z = -0.0046$ mm, max $u_z = 0.0627$ mm



utilization of end plate U_p

min $U_p = 0.005$, max $U_p = 0.572$



deformations lifting off positive

utilization of end plate

node	x mm	y mm	u_z mm	U_p
292	50.0	168.8	0.052	0.572
363	62.5	200.0	0.063	0.246

x,y: node coordinates; u_z : deformations (lifting off positive); U_p : utilization of end plate

utilization of bolts

	x mm	y mm	w_t mm	F_t kN	ϵ_{wt} %	U_{wt}
1	25.0	25.0	-0.000	37.77	0.213	0.071
2	175.0	25.0	-0.000	37.77	0.213	0.071
3	25.0	175.0	0.025	46.00	0.340	0.113
4	175.0	175.0	-0.000	37.77	0.213	0.071
5	25.0	80.0	-0.002	37.77	0.213	0.071
6	85.0	25.0	-0.000	37.77	0.213	0.071

x,y: bolt coordinates; w_t : deformation (tension positive); F_t : bolt force; ϵ_{wt} : elongation
 U_{wt} : utilization due to elongation

utilization of end plate [node 292] $U_{max} = 0.572 < 1$ ok

utilization of bolts due to elongation [bolt 3] $U_{s,max} = 0.113 < 1$ ok

minimum plastic utilization of the connection $U_{pl,min} = 0.174 < 1$ ok

plastic utilization of tensile forces of bolts $U_{pl,t,s} = 0.177 < 1$ ok

3.2. bolts

design values: min $F_t = 37.77$ kN, max $F_t = 46.00$ kN, $V_z = -0.14$ kN, $V_y = -2.90$ kN,
 $M_x = 0.79$ kNm

verification of bolts

U_{tp} utilization due to punching shear failure, U_{vt} utilization due to shear in tension, U_b utilization due to bearing resistance, U utilization of bolts

bolt 1	$U_{tp,1} = 0.152$	$U_{vt,1} = 0.603$	$U_{b,1} = 0.012$	$U_1 = 0.603$
bolt 2	$U_{tp,2} = 0.152$	$U_{vt,2} = 0.613$	$U_{b,2} = 0.014$	$U_2 = 0.613$
bolt 3	$U_{tp,3} = 0.185$	$U_{vt,3} = 0.700$	$U_{b,3} = 0.006$	$U_3 = 0.700$
bolt 4	$U_{tp,4} = 0.152$	$U_{vt,4} = 0.659$	$U_{b,4} = 0.025$	$U_4 = 0.659$
bolt 5	$U_{tp,5} = 0.152$	$U_{vt,5} = 0.607$	$U_{b,5} = 0.009$	$U_5 = 0.607$
bolt 6	$U_{tp,6} = 0.152$	$U_{vt,6} = 0.570$	$U_{b,6} = 0.003$	$U_6 = 0.570$
total:	$U_{tp} = 0.185$	$U_{vt} = 0.700$	$U_b = 0.025$	$U = 0.700 < 1$ ok

in utilization of bolts U_{max} ist minimum plastic utilization of the connection $U_{pl,min} = 0.174$
and plastic utilization of tensile forces of bolts $U_{pl,s} = 0.177$ is included.

utilization of bolts $U_{max} = 0.700 < 1$ ok

3.3. beam

calculation acc. to EC 3-1-1, 8.2 for dieses section not möglich !!

cross-section cannot be verified using plastic methods !!

elastic verification for $N = -11.31$ kN, $M_y = 3.13$ kNm, $V_z = -0.14$ kN, $M_z = -6.07$ kNm

$V_y = -2.90$ kN, $T_t = 0.79$ kNm

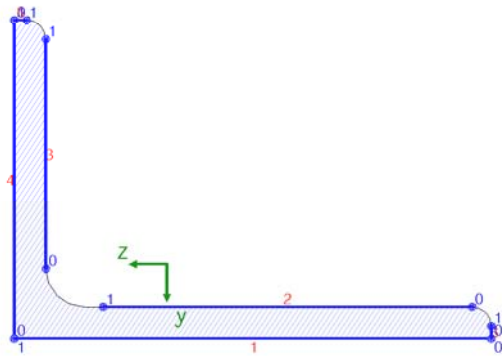
verification: $\sigma_v = 361.35$ N/mm² $> \sigma_{v,Rd} = 235.00$ N/mm² $\Rightarrow U_\sigma = 1.538 > 1$ not ok !!

c/t-verification: utilization $U_{c/t} = 0.639 < 1$ ok

utilization of the beam $\max(U_\sigma, U_{c/t}) = 1.538 > 1$ not ok !!

3.4. welds

design values: $N = -11.31 \text{ kN}$, $M_y = 3.13 \text{ kNm}$, $V_z = -0.14 \text{ kN}$, $M_z = -6.07 \text{ kNm}$,
 $V_y = -2.90 \text{ kN}$, $M_x = 0.79 \text{ kNm}$



weld 1:	$a_w = 7.0 \text{ mm}$	$l_w = 150.0 \text{ mm}$
weld 2:	$a_w = 7.0 \text{ mm}$	$l_w = 116.0 \text{ mm}$
weld 3:	$a_w = 7.0 \text{ mm}$	$l_w = 72.0 \text{ mm}$
weld 4:	$a_w = 7.0 \text{ mm}$	$l_w = 100.0 \text{ mm}$
weld 5:	$a_w = 7.0 \text{ mm}$	$l_w = 4.0 \text{ mm}$
weld 6:	$a_w = 7.0 \text{ mm}$	$l_w = 4.0 \text{ mm}$

Max: $\sigma_{1,w,Ed} = 319.94 \text{ N/mm}^2 < f_{1w,d} = 360.00 \text{ N/mm}^2$,
 $\sigma_{2,w,Ed} = 159.97 \text{ N/mm}^2 < f_{2w,d} = 259.20 \text{ N/mm}^2 \Rightarrow U_w = 0.889 < 1$ **ok**

utilization of welds $U_{max} = 0.889 < 1$ **ok**

3.5. total

utilization Lc 3 $U_{max} = 1.538 > 1$ **not ok !!**

4. Regulations

EN 1990, Eurocode 0: Grundlagen der Tragwerksplanung;

Deutsche Fassung EN 1990:2002 + A1:2005 + A1:2005/AC:2010, Ausgabe Dezember 2010

EN 1990/NA, Nationaler Anhang zur EN 1990, Ausgabe Dezember 2010

EN 1993-1-1, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -

Teil 1-1: Allgemeine Bemessungsregeln und Regeln für den Hochbau;

Deutsche Fassung EN 1993-1-1:2022, Ausgabe April 2025

EN 1993-1-1/NA, Nationaler Anhang zur EN 1993-1-1, Ausgabe April 2026

EN 1993-1-8, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -

Teil 1-8: Bemessung von Anschlüssen; Deutsche Fassung EN 1993-1-8:2024, Ausgabe April 2025

EN 1993-1-8/NA, Nationaler Anhang zur EN 1993-1-8, Ausgabe April 2026

prEN 1993-1-14, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -

Teil 1-14: Bemessung mithilfe von Finite-Element-Berechnung;

Deutsche und englische Fassung prEN 1993-1-14:2023, Ausgabe September 2023