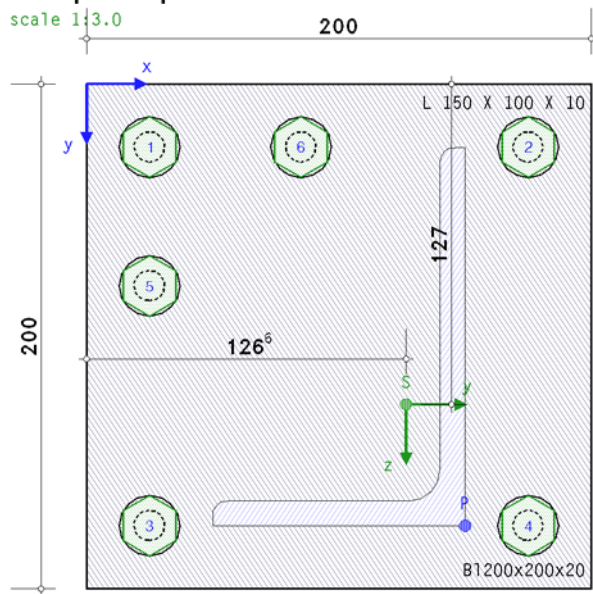


POS. 2: L-SECTION

bolted end-plate connection EC 3-1-8 (12.10), NA: Deutschland

4H-EC3FS version: 2/2025-1b

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 $x_s = 126.6 \text{ mm}$, $y_s = 127.0 \text{ mm}$

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 $c_f = 3233.4 \text{ kN/cm}$

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**

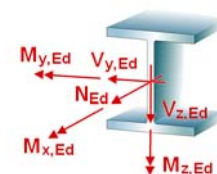
effective foundation modulus of end plate $c_b = 10500.0 \text{ kN/cm}^3$

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

Lk	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



Lk	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

in utilization of bolts due to tension $U_{t,s}$ ist minimum plastic utilization of the connection U_{pl} and plastic utilization of tensile forces of bolts $U_{pl,s}$ is included.

Lk	U _p	U _σ	U _b	U _{pl,s}	U _{pl,t,s}	U _{wt,s}	U _{t,s}	U _{vt,s}	U _{b,s}	U _q	U _{c/t}	U _w	U
1	0.277	0.277	0.156	0.081	0.076	0.076	0.159	0.677	0.035	0.397	0.750	0.494	0.750
2	0.123	0.105	0.123	0.032	---	0.071	0.152	0.635	0.023	0.721	0.750	0.108	0.750
3	0.571	0.571	0.159	0.174	0.178	0.113	0.185	0.700	0.030	0.863	0.750	0.888	0.888
4	0.302	0.302	0.168	0.210	0.080	0.080	0.166	0.779	0.065	0.689	0.585	0.894	0.894
5	0.170	0.170	0.141	0.113	---	0.071	0.152	0.573	0.005	0.372	0.674	0.460	0.674
6	0.190	0.190	0.167	0.105	---	0.071	0.153	0.682	0.037	0.728	1.000	0.206	1.000*
7	0.310	0.310	0.172	0.215	0.081	0.081	0.167	0.782	0.066	0.682	0.580	0.885	0.885
8	0.322	0.322	0.142	0.117	0.081	0.081	0.166	0.673	0.031	0.855	0.750	0.576	0.855
9	0.327	0.327	0.176	0.223	0.082	0.082	0.169	0.707	0.043	0.919	0.557	0.807	0.919
10	0.466	0.466	0.149	0.147	0.115	0.098	0.182	0.674	0.008	0.632	0.750	0.796	0.796
11	0.247	0.247	0.153	0.181	0.076	0.076	0.159	0.712	0.046	0.681	0.607	0.881	0.881

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,s}: minimum plastic utilization of the connection; U_{pl,t,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_{ct}: 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 Lk: 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	-14.03	-9.31	0.65	573.50	-127.03	0.571

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 Lk: 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	0.038	0.685
2	175.0	25.0	41.57	0.081	0.750	0.041	0.750
3	25.0	175.0	46.00	0.113	0.700	0.007	0.700
4	175.0	175.0	37.77	0.071	0.782	0.066	0.782
5	25.0	80.0	37.77	0.071	0.686	0.024	0.686
6	85.0	25.0	38.15	0.071	0.700	0.040	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 [Lk 3]

maximum utilization of bolts due to elongation [Lk 3]

maximum utilization of bolts [Lk 7]

maximum utilization of the beam [Lk 6]

maximum utilization of welds [Lk 4]

maximum utilization [Lk 6]

max U_p = 0.571 < 1 ok

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

max U_s = 0.782 < 1 ok

max (U_q,U_{ct}) = 1.000 ≤ 1 ok

max U_w = 0.894 < 1 ok

max U = 1.000 ≤ 1 ok

verification succeeded

3. 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 1993-1-1:2005 + AC:2009, Ausgabe Dezember 2010

EN 1993-1-1/A1, Ergänzungen zur EN 1993-1-1, Ausgabe Juli 2014

EN 1993-1-1/NA, Nationaler Anhang zur EN 1993-1-1, Ausgabe Dezember 2018

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

4. Lk 6 (decisive)

4.1. end-plate

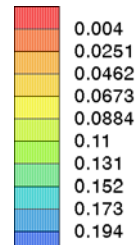
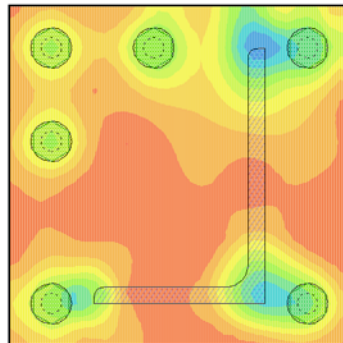
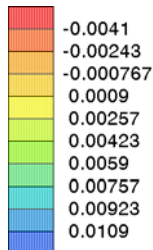
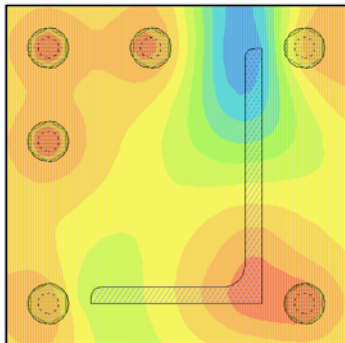
design values: $N = -14.33$ kN, $M_y = -4.27$ kNm, $M_z = -1.92$ kNm

deformations u_z [mm]

min $u_z = -0.0041$ mm, max $u_z = 0.0109$ mm

utilization of end-plate U_p

min $U_p = 0.004$, max $U_p = 0.190$



deformations lifting off positive

utilization of end-plate

node	x mm	y mm	u_z mm	U_p
697	131.2	18.8	0.010	0.132
797	150.0	25.0	0.009	0.190

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	38.06	0.213	0.071
3	25.0	175.0	-0.001	37.80	0.213	0.071
4	175.0	175.0	-0.000	37.77	0.213	0.071
5	25.0	80.0	-0.000	37.77	0.213	0.071
6	85.0	25.0	-0.002	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 797] $U_{max} = 0.190 < 1$ ok

utilization of bolts due to elongation [bolt 1] $U_{s,max} = 0.071 < 1$ ok

minimum plastic utilization of bolts $U_{pl,s,min} = 0.105 < 1$ ok

4.2. bolts

design values: min $F_t = 37.77$ kN, max $F_t = 38.06$ kN, $V_z = 23.69$ kN, $V_y = -0.68$ kN,
 $M_x = 1.08$ kNm

verification of bolts

U_{lp} 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	$U_{tp,1} = 0.152$	$U_{vt,1} = 0.682$	$U_{b,1} = 0.037$	$U_1 = 0.682$
bolt 2	$U_{tp,2} = 0.153$	$U_{vt,2} = 0.674$	$U_{b,2} = 0.033$	$U_2 = 0.674$
bolt 3	$U_{tp,3} = 0.152$	$U_{vt,3} = 0.682$	$U_{b,3} = 0.037$	$U_3 = 0.682$
bolt 4	$U_{tp,4} = 0.152$	$U_{vt,4} = 0.673$	$U_{b,4} = 0.034$	$U_4 = 0.673$
bolt 5	$U_{tp,5} = 0.152$	$U_{vt,5} = 0.682$	$U_{b,5} = 0.024$	$U_5 = 0.682$
bolt 6	$U_{tp,6} = 0.152$	$U_{vt,6} = 0.678$	$U_{b,6} = 0.036$	$U_6 = 0.678$
total:	$U_{tp} = 0.153$	$U_{vt} = 0.682$	$U_b = 0.037$	$U = 0.682 < 1$ ok

in utilization of bolts max U_s the minimum plastic utilization of bolts min $U_{pl,s} = 0.105$ is included.

utilization of bolts $U_{max} = 0.682 < 1$ ok

4.3. beam

plastic verification for $N = -14.33$ kN, $M_y = -4.27$ kNm, $V_z = 23.69$ kN, $M_z = -1.92$ kNm

$V_y = -0.68$ kN, $T_t = 1.08$ kNm

internal forces and moments reg. yz-direction in kN, m: $M_y = -4.27$, $M_z = -1.92$, $V_y = -0.68$, $V_z = 23.69$

partial internal forces and moments of lines of cross-section in kN, m:

1: $N = 34.67$, $M_y = -1.18$, $M_z = 0.00$, $V_y = 0.00$, $V_z = 23.69$, $T = 0.65$

2: $N = -49.00$, $M_y = -0.00$, $M_z = 0.10$, $V_y = -0.68$, $V_z = 0.00$, $T = 0.43$

utilizations of lines of cross-section

1: $U_\sigma = 0.159$, $U_\tau = 0.702$, $U = 0.719$

2: $U_\sigma = 0.227$, $U_\tau = 0.692$, $U = 0.728$

max. load factor (plastic): $f_{pl} = 1.373$

no equilibrium of warping at limit state: $\Delta B = -0.000$ kNm²

utilization (without equilibrium of warping): $U_{pl} = 0.728$

verification: $U_{pl} = 0.728 < 1$ ok

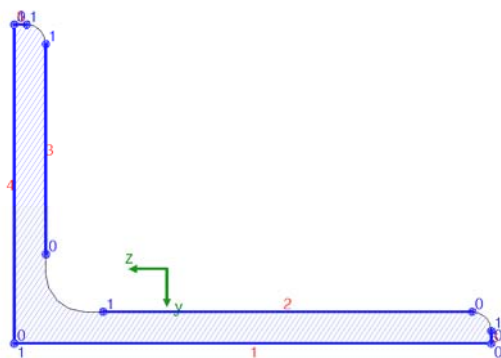
c/t-verification: utilization $U_{c/t} = 1.000 \leq 1$ ok

utilization of the beam $\max(U_\sigma, U_{c/t}) = 1.000 \leq 1$ ok

4.4. welds

design values: $N = -14.33$ kN, $M_y = -4.27$ kNm, $V_z = 23.69$ kN, $M_z = -1.92$ kNm,

$V_y = -0.68$ kN, $M_x = 1.08$ kNm



weld 1:	$a_w = 7.0$ mm	$l_w = 150.0$ mm
weld 2:	$a_w = 7.0$ mm	$l_w = 116.0$ mm
weld 3:	$a_w = 7.0$ mm	$l_w = 66.0$ mm
weld 4:	$a_w = 7.0$ mm	$l_w = 100.0$ mm
weld 5:	$a_w = 7.0$ mm	$l_w = 4.0$ mm
weld 6:	$a_w = 7.0$ mm	$l_w = 4.0$ mm

Max: $\sigma_{1,w,Ed} = 74.01$ N/mm² $< f_{1w,d} = 360.00$ N/mm²,
 $\sigma_{2,w,Ed} = 35.33$ N/mm² $< f_{2w,d} = 259.20$ N/mm² $\Rightarrow U_w = 0.206 < 1$ ok

utilization of welds $U_{max} = 0.206 < 1$ ok

4.5. total

utilization Lk 6 $U_{max} = 1.000 \leq 1$ ok