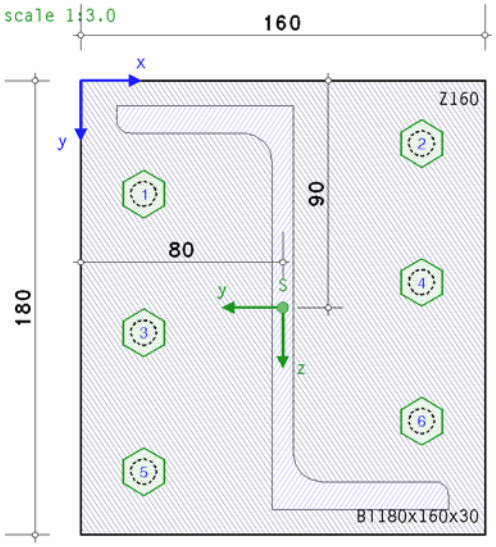
POS. 4: Z-SECTION

bolted end-plate connection EC 3-1-8 (12.10), NA: Deutschland 4H-EC3FS version: 2/2025-1b

1. input report

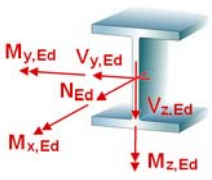


steel grade
steel grade S355
bolts
bolt class 8.8, bolt size M10, normal wrench size
thread included in the shear plane
connection
end-plate (rectangular): thickness t_p = 30.0 mm, width b_p = 160.0 mm, length l_p = 180.0 mm
beam: section Z160
beam-end-plate: surrounding fillet weld, weld thickness a = 10.0 mm
beam section centric on end-plate (beam centroid in plate centre)
coordinates of the beam centroid on end-plate x_s = 80.0 mm, y_s = 90.0 mm
bolts:
coordinates of bolt axis:

x_1 = 25.0 mm, y_1 = 45.0 mm	x_2 = 135.0 mm, y_2 = 25.0 mm	x_3 = 25.0 mm, y_3 = 100.0 mm
x_4 = 135.0 mm, y_4 = 80.0 mm	x_5 = 25.0 mm, y_5 = 155.0 mm	x_6 = 135.0 mm, y_6 = 135.0 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 plasticly calculated, spring constant of bolts c_f = 1741.2 kN/cm
plastic limit force $F_{t,f} = f_{t,f} \cdot F_{t,Rd}$ = 31.7 kN, $f_{t,f}$ = 0.950, $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2}$ = 33.41 kN, k_2 = 0.90
effective elongation at failure $\varepsilon_{t,f} = f_{t,\varepsilon} \cdot \varepsilon_{ub}$ = 3.0%, $f_{t,\varepsilon}$ = 0.250, ε_{ub} = 12.0%
without preloading ($F_{p,C}$ = 0)
effective foundation modulus of end plate c_b = 7000.0 kN/cm³
number / dimension of finite elements each direction n_x / Δx = 26 / 6.2 mm, n_y / Δy = 30 / 6.0 mm
max. 50 iteration steps (tolerance limit 5‰)
internal forces and moments refering to local axes of cross-section

Lk	N_{Ed} kN	$M_{y,Ed}$ kNm	$V_{z,Ed}$ kN	$M_{z,Ed}$ kNm	$V_{y,Ed}$ kN	$M_{x,Ed}$ kNm
1	-9.61	-0.50	0.78	2.58	1.37	0.80
2	8.45	2.97	23.13	10.43	5.10	0.05
3	-3.69	0.01	0.58	-5.59	-2.87	0.78
4	2.96	2.77	23.19	12.14	6.00	0.05
5	-8.86	-0.02	0.69	3.28	1.68	0.01
6	5.44	2.39	23.19	6.24	3.00	1.17
7	-2.93	0.49	0.49	-4.90	-2.55	-0.01
8	1.88	2.08	23.32	11.15	5.55	1.18
9	-3.92	1.30	16.64	9.57	4.80	0.83
10	-3.17	1.78	16.55	10.26	5.12	0.04



partial safety factors for material

resistance of cross-sections γ_{M0} = 1.00
resistance of bolts, welds, plates in bearing γ_{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	0.146	0.146	0.097	0.125	0.136	0.023	0.018	0.237	0.010	0.389	0.460	0.204	0.460
2	0.537	0.537	0.396	0.767	0.663	0.224	0.082	0.711	0.035	0.695	0.479	0.747	0.767
3	0.309	0.309	0.205	0.366	0.327	0.061	0.050	0.463	0.011	0.529	0.462	0.419	0.529
4	0.657	0.657	0.490	0.856	0.746	0.294	0.082	0.741	0.046	0.820	0.476	0.874	0.874
5	0.181	0.181	0.121	0.177	0.179	0.032	0.026	0.227	0.002	0.235	0.469	0.250	0.469
6	0.289	0.289	0.216	0.462	0.414	0.091	0.074	0.626	0.030	0.648	0.487	0.440	0.648
7	0.276	0.276	0.178	0.322	0.291	0.052	0.042	0.359	0.002	0.355	0.455	0.372	0.455
8	0.607	0.607	0.420	0.781	0.708	0.199	0.082	0.690	0.034	0.916	0.473	0.807	0.916*
9	0.520	0.520	0.350	0.640	0.594	0.128	0.082	0.685	0.023	0.749	0.471	0.700	0.749
10	0.558	0.558	0.378	0.692	0.649	0.155	0.082	0.698	0.024	0.701	0.474	0.746	0.746

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 10 Lk: max U_p with corresponding values

node	x mm	y mm	u_z mm	b_z N/mm²	m_{xx} kNm/m	m_{yy} kNm/m	m_{xy} kNm/m	q_x kN/m	q_y kN/m	U_p
431	80.0	162.0	0.122	0.00	33.15	11.11	14.81	-2685.97	403.43	0.657

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 10 Lk: max U_s with corresponding values

	x mm	y mm	Ft kN	U_{wt}	U_{vt}	U_b	U_s
1	25.0	45.0	19.18	0.061	0.463	0.004	0.463
2	135.0	25.0	29.95	0.096	0.741	0.010	0.741
3	25.0	100.0	5.96	0.019	0.415	0.023	0.415
4	135.0	80.0	31.74	0.161	0.725	0.004	0.725
5	25.0	155.0	4.16	0.013	0.550	0.046	0.550
6	135.0	135.0	31.74	0.294	0.727	0.004	0.727

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 4]	max U_p = 0.657 < 1 ok
maximum utilization of bolts due to elongation [Lk 4]	max $U_{wt,s}$ = 0.294 < 1 ok
maximum utilization of bolts [Lk 4]	max U_s = 0.856 < 1 ok
maximum utilization of the beam [Lk 8]	max (U_q,U_{ct}) = 0.916 < 1 ok
maximum utilization of welds [Lk 4]	max U_w = 0.874 < 1 ok
maximum utilization [Lk 8]	**max U = 0.916 < 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

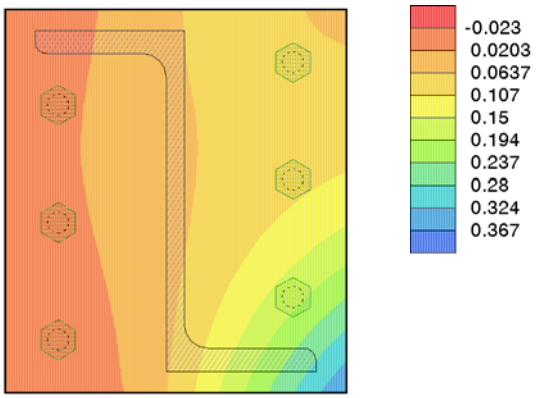
EN 1993-1-8, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -
Teil 1-8: Bemessung von Anschlüssen;
Deutsche Fassung EN 1993-1-8:2005 + AC:2009, Ausgabe Dezember 2010
EN 1993-1-8/NA, Nationaler Anhang zur EN 1993-1-8, Ausgabe Dezember 2010

4. Lk 8 (decisive)

4.1. end-plate

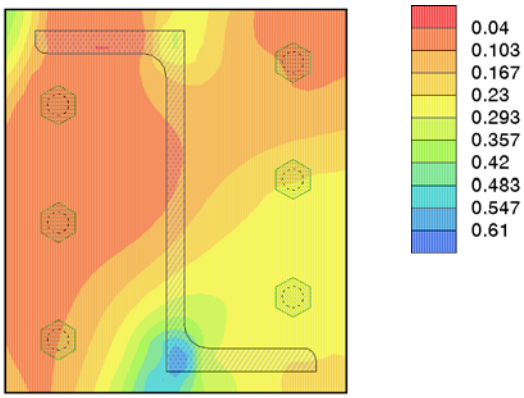
design values: N = 1.88 kN, M_y = 2.08 kNm, M_z = 11.15 kNm

deformations u_z [mm]
min u_z = -0.0234 mm, max u_z = 0.3640 mm



deformations lifting off positive

utilization of end-plate U_p
min U_p = 0.039, max U_p = 0.607



utilization of end-plate

node	x mm	y mm	u_z mm	U_p
431	80.0	162.0	0.069	0.607
837	160.0	180.0	0.364	0.200

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

utilization of bolts

	x mm	y mm	wt mm	F_t kN	ε_{wt} %	U_{wt}
1	25.0	45.0	0.010	3.39	0.032	0.011
2	135.0	25.0	0.068	23.60	0.226	0.075
3	25.0	100.0	0.010	3.43	0.033	0.011
4	135.0	80.0	0.095	31.40	0.315	0.105
5	25.0	155.0	0.002	0.76	0.007	0.002
6	135.0	135.0	0.179	31.74	0.598	0.199

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 431] $U_{max} = 0.607 < 1$ ok
utilization of bolts due to elongation [bolt 6] $U_{s,max} = 0.199 < 1$ ok
minimum plastic utilization of bolts $U_{pl,s,min} = 0.781 < 1$ ok
plastic utilization of tensile forces of bolts $U_{pl,t,s} = 0.708 < 1$ ok

4.2. bolts

design values: min F_t = 0.76 kN, max F_t = 31.74 kN, V_z = 23.32 kN, V_y = 5.55 kN,
M_x = 1.18 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	$U_{tp,1} = 0.009$	$U_{vt,1} = 0.401$	$U_{b,1} = 0.026$	$U_1 = 0.401$
bolt 2	$U_{tp,2} = 0.061$	$U_{vt,2} = 0.586$	$U_{b,2} = 0.008$	$U_2 = 0.586$
bolt 3	$U_{tp,3} = 0.009$	$U_{vt,3} = 0.388$	$U_{b,3} = 0.024$	$U_3 = 0.388$
bolt 4	$U_{tp,4} = 0.082$	$U_{vt,4} = 0.686$	$U_{b,4} = 0.001$	$U_4 = 0.686$
bolt 5	$U_{tp,5} = 0.002$	$U_{vt,5} = 0.352$	$U_{b,5} = 0.034$	$U_5 = 0.352$
bolt 6	$U_{tp,6} = 0.082$	$U_{vt,6} = 0.690$	$U_{b,6} = 0.000$	$U_6 = 0.690$
total:	$U_{tp} = 0.082$	$U_{vt} = 0.690$	$U_b = 0.034$	$U = 0.690 < 1$ ok

in utilization of bolts max U_s the minimum plastic utilization of bolts min $U_{pl,s} = 0.781$
and plastic utilization of tensile forces of bolts $U_{pl,t,s} = 0.708$ is included.

utilization of bolts $U_{max} = 0.781 < 1$ ok

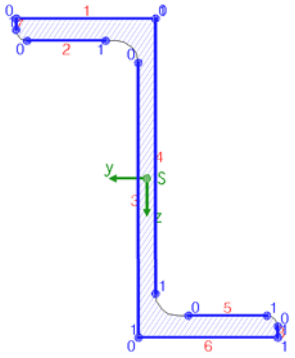
4.3. beam

plastic verification for N = 1.88 kN, M_y = 2.08 kNm, V_z = 23.32 kN, M_z = 11.15 kNm
V_y = 5.55 kN, T_t = 1.18 kNm
internal forces and moments reg. yz-direction in kN, m: My = 2.08, Mz = 11.15, Vy = 5.55, Vz = 23.32
partial internal forces and moments of lines of cross-section in kN, m:
1: N = -108.54, My = 0.00, Mz = 2.06, Vy = 2.77, Vz = 0.00, T = 0.39
2: N = 0.50, My = -14.20, Mz = 0.00, Vy = 0.00, Vz = 23.32, T = 0.41
3: N = 109.92, My = -0.00, Mz = 2.05, Vy = 2.77, Vz = 0.00, T = 0.39
utilizations of lines of cross-section
1: U_σ = 0.728, U_τ = 0.518, U = 0.894
2: U_σ = 0.828, U_τ = 0.390, U = 0.916
3: U_σ = 0.731, U_τ = 0.518, U = 0.896
max. load factor (plastic): f_{pl} = 1.092
utilization: U_{pl} = 0.916
verification: U_{pl} = 0.916 < 1 ok
c/t-verification: utilization $U_{c/t}$ = 0.473 < 1 ok

utilization of the beam max(U_σ,$U_{c/t}$) = 0.916 < 1 ok

4.4. welds

design values: N = 1.88 kN, M_y = 2.08 kNm, V_z = 23.32 kN, M_z = 11.15 kNm,
V_y = 5.55 kN, M_x = 1.18 kNm
weld 1: weld thickness a = 10.0 mm > a_{max} = 0.7·t_{min} = 7.7 mm (welding technology, s. DIN 18800) !!
weld 3: weld thickness a = 10.0 mm > a_{max} = 0.7·t_{min} = 5.9 mm (welding technology, s. DIN 18800) !!
weld 4: weld thickness a = 10.0 mm > a_{max} = 0.7·t_{min} = 5.9 mm (welding technology, s. DIN 18800) !!
weld 6: weld thickness a = 10.0 mm > a_{max} = 0.7·t_{min} = 7.7 mm (welding technology, s. DIN 18800) !!



weld 1:	a_w = 10.0 mm	l_w = 70.0 mm
weld 2:	a_w = 10.0 mm	l_w = 39.5 mm
weld 3:	a_w = 10.0 mm	l_w = 138.0 mm
weld 4:	a_w = 10.0 mm	l_w = 138.0 mm
weld 5:	a_w = 10.0 mm	l_w = 39.5 mm
weld 6:	a_w = 10.0 mm	l_w = 70.0 mm
weld 7:	a_w = 10.0 mm	l_w = 5.5 mm
weld 8:	a_w = 10.0 mm	l_w = 5.5 mm

Max: $\sigma_{1,w,Ed}$ = 351.39 N/mm² < $f_{1w,d}$ = 435.56 N/mm²,
$\sigma_{2,w,Ed}$ = 175.70 N/mm² < $f_{2w,d}$ = 352.80 N/mm² ⇒ U_w = 0.807 < 1 ok

utilization of welds U_{max} = 0.807 < 1 ok

4.5. total

utilization Lk 8 U_{max} = 0.916 < 1 ok