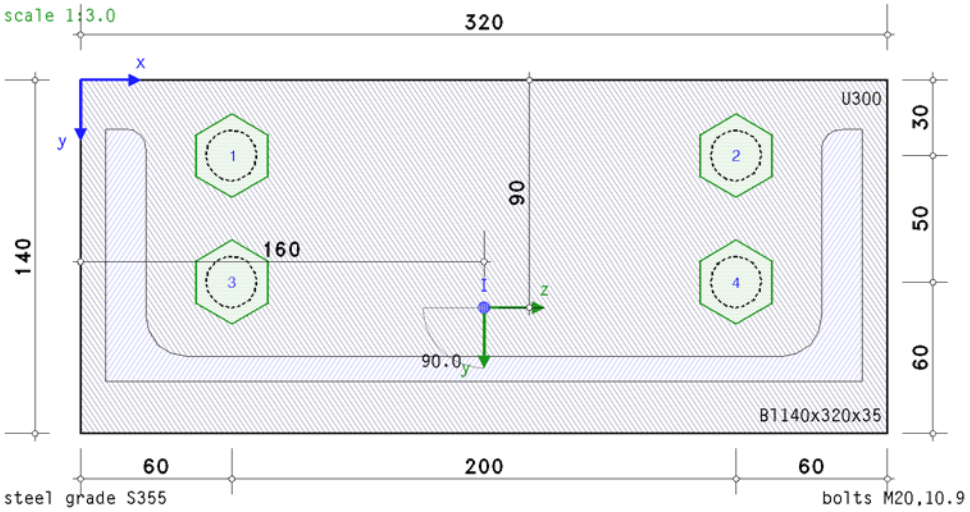
POS. 5: U-SECTION

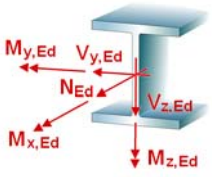
bolted end-plate connection EC 3-1-8 (12.10), NA: Deutschland 4H-EC3FS version: 2/2025-1b

1. input report



steel grade
steel grade S355
bolts
bolt class 10.9, bolt size M20, normal wrench size
thread included in the shear plane
connection
end-plate (rectangular): thickness t_p = 35.0 mm, width b_p = 320.0 mm, length l_p = 140.0 mm
beam: section U300
rotation of cross-section arround section centroid β = 90.0°
beam-end-plate: surrounding fillet weld, weld thickness a = 6.0 mm
coordinates of centroid of beam section at x_p = 160.0 mm, y_p = 90.0 mm
coordinates of the beam centroid on end-plate x_s = 160.0 mm, y_s = 90.0 mm
bolts:
uniform arrangement of bolts, 2 vertical and 2 horizontal rows
edge distances top e_o = 30.0 mm, below e_u = 60.0 mm
distances between bolts $p_{y,1\text{-}2}$ = 50.0 mm
edge distances left e_l = 60.0 mm, right e_r = 60.0 mm
distances between bolts $p_{x,1\text{-}2}$ = 200.0 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 = 5797.2 kN/cm
plastic limit force $F_{t,f} = f_{t,f} \cdot F_{t,Rd}$ = 167.6 kN, $f_{t,f}$ = 0.950, $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2}$ = 176.40 kN, k_2 = 0.90
effective elongation at failure $\varepsilon_{t,f} = f_{t,\varepsilon} \cdot \varepsilon_{ub}$ = 2.3%, $f_{t,\varepsilon}$ = 0.250, ε_{ub} = 9.0%
without preloading ($F_{p,C}$ = 0)
effective foundation modulus of end plate c_b = 6000.0 kN/cm³
number / dimension of finite elements each direction n_x / Δx = 98 / 3.3 mm, n_y / Δy = 43 / 3.3 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	-33.47	81.25	-21.16	-6.13	-4.35	-0.92
2	0.27	4.66	1.34	-5.73	2.40	-0.00
3	-33.24	80.85	-21.38	-5.83	-4.16	-0.89
4	0.11	4.94	1.50	-5.93	2.27	-0.02
5	-7.75	7.83	-5.09	14.00	5.80	-0.07
6	-28.26	69.16	-19.97	-7.69	-5.39	-0.93
7	-3.37	13.12	0.51	-4.63	3.13	0.00
8	-4.11	-0.63	-4.25	12.91	5.07	-0.07



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 !

FEM: the bolt distance from the free edge of the plate edge is too small (min e = 30.0 mm < 37.0 mm).
the accuracy of the results cannot be guaranteed !!

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	0.778	0.778	0.717	0.745	0.988	0.960	0.206	0.709	0.056	0.583	0.614	0.968	0.988*
2	0.168	0.114	0.168	0.163	0.152	0.054	0.061	0.208	0.004	0.148	0.614	0.321	0.614
3	0.759	0.759	0.707	0.741	0.979	0.931	0.206	0.710	0.056	0.573	0.614	0.950	0.979
4	0.174	0.118	0.174	0.169	0.158	0.057	0.063	0.217	0.005	0.154	0.614	0.334	0.614
5	0.276	0.276	0.143	0.250	0.271	0.082	0.092	0.315	0.013	0.340	0.750	0.753	0.753
6	0.572	0.572	0.534	0.634	0.865	0.659	0.206	0.694	0.047	0.554	0.614	0.947	0.947
7	0.116	0.111	0.116	0.124	0.182	0.073	0.081	0.275	0.005	0.169	0.614	0.336	0.614
8	0.248	0.248	0.111	0.233	0.251	0.065	0.073	0.257	0.012	0.281	0.750	0.644	0.750

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 8 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
300	19.6	113.9	0.010	19.27	29.46	27.42	21.45	-3604.13	2931.14	0.778

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 8 Lk: max U_s with corresponding values

	x mm	y mm	F_t kN	U_{wt}	U_{vt}	U_b	U_s
1	60.0	30.0	59.21	0.065	0.257	0.009	0.257
2	260.0	30.0	167.02	0.343	0.709	0.017	0.709
3	60.0	80.0	105.57	0.116	0.494	0.032	0.494
4	260.0	80.0	167.58	0.960	0.709	0.015	0.960

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 1]	max U_p = 0.778 < 1 ok
maximum utilization of bolts due to elongation [Lk 1]	max $U_{wt,s}$ = 0.960 < 1 ok
maximum utilization of bolts [Lk 1]	max U_s = 0.988 < 1 ok
maximum utilization of the beam [Lk 5]	max (U_q,U_{ct}) = 0.750 < 1 ok
maximum utilization of welds [Lk 1]	max U_w = 0.968 < 1 ok
maximum utilization [Lk 1]	**max U = 0.988 < 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

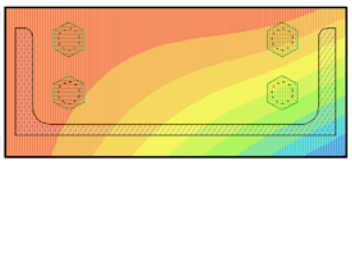
EN 1993-1-8, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -
Teil 1-8: Bemessung von Anschlüssen;
Deutsche Fassung EN 1993-1-8:2005 + AC:2009, Ausgabe Dezember 2010
EN 1993-1-8/NA, Nationaler Anhang zur EN 1993-1-8, Ausgabe Dezember 2010

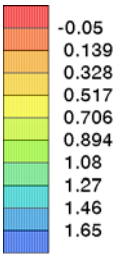
4. Lk 1 (decisive)

4.1. end-plate

design values: N = -33.47 kN, M_y = 81.25 kNm, M_z = -6.13 kNm

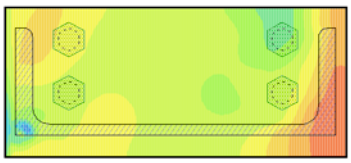
deformations u_z [mm]
min u_z = -0.0534 mm, max u_z = 1.6839 mm

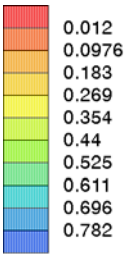




deformations lifting off positive

utilization of end-plate U_p
min U_p = 0.012, max U_p = 0.778





utilization of end-plate

node	x mm	y mm	u_z mm	U_p
300	19.6	113.9	0.010	0.778
4356	320.0	140.0	1.684	0.026

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	60.0	30.0	0.018	21.11	0.052	0.023
2	260.0	30.0	0.279	167.22	0.798	0.355
3	60.0	80.0	0.091	105.57	0.260	0.116
4	260.0	80.0	0.756	167.58	2.161	0.960

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 300] U_{max} = 0.778 < 1 ok
utilization of bolts due to elongation [bolt 4] $U_{s,max}$ = 0.960 < 1 ok
minimum plastic utilization of bolts $U_{pl,s,min}$ = 0.745 < 1 ok
plastic utilization of tensile forces of bolts $U_{pl,t,s}$ = 0.988 < 1 ok

4.2. bolts

design values: min F_t = 21.11 kN, max F_t = 167.58 kN, V_z = -21.16 kN, V_y = -4.35 kN,
M_x = -0.92 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	$U_{tp,1}$ = 0.026	$U_{vt,1}$ = 0.192	$U_{b,1}$ = 0.056	U_1 = 0.192
bolt 2	$U_{tp,2}$ = 0.205	$U_{vt,2}$ = 0.708	$U_{b,2}$ = 0.017	U_2 = 0.708
bolt 3	$U_{tp,3}$ = 0.130	$U_{vt,3}$ = 0.494	$U_{b,3}$ = 0.032	U_3 = 0.494
bolt 4	$U_{tp,4}$ = 0.206	$U_{vt,4}$ = 0.709	$U_{b,4}$ = 0.015	U_4 = 0.709
total:	U_{tp} = 0.206	U_{vt} = 0.709	U_b = 0.056	U = 0.709 < 1 ok

in utilization of bolts max U_s the minimum plastic utilization of bolts min $U_{pl,s}$ = 0.745
and plastic utilization of tensile forces of bolts $U_{pl,t,s}$ = 0.988 is included.

utilization of bolts U_{max} = 0.988 < 1 ok

4.3. beam

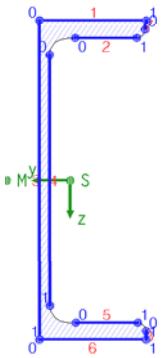
plastic verification for N = -33.47 kN, M_y = 81.25 kNm, V_z = -21.16 kN, M_z = -6.13 kNm
V_y = -4.35 kN, T_t = -0.92 kNm
internal forces and moments reg. yz-direction in kN, m: My = 81.25, Mz = -6.13, Vy = -4.35, Vz = -21.16
partial internal forces and moments of lines of cross-section in kN, m:
1: N = -299.69, My = -0.00, Mz = 0.00, Vy = -4.69, Vz = -0.19, T = -0.34
2: N = 50.67, My = 8.18, Mz = -0.00, Vy = 0.00, Vz = -20.96, T = -0.24
3: N = 215.55, My = -0.13, Mz = -3.24, Vy = 0.33, Vz = -0.01, T = -0.34
utilizations of lines of cross-section
1: U_σ = 0.562, U_τ = 0.154, U = 0.583
2: U_σ = 0.133, U_τ = 0.096, U = 0.164
3: U_σ = 0.552, U_τ = 0.153, U = 0.573
max. load factor (plastic): f_{pl} = 1.716
utilization: U_{pl} = 0.583

verification: $U_{pl} = 0.583 < 1$ ok
c/t-verification: utilization $U_{c/t} = 0.614 < 1$ ok

utilization of the beam $\max(U_\sigma, U_{c/t}) = 0.614 < 1$ ok

4.4. welds

design values: N = -33.47 kN, M_y = 81.25 kNm, V_z = -21.16 kN, M_z = -6.13 kNm, V_y = -4.35 kN, M_x = -0.92 kNm



weld 1:	a_w = 6.0 mm	l_w = 100.0 mm
weld 2:	a_w = 6.0 mm	l_w = 58.0 mm
weld 3:	a_w = 6.0 mm	l_w = 300.0 mm
weld 4:	a_w = 6.0 mm	l_w = 236.0 mm
weld 5:	a_w = 6.0 mm	l_w = 58.0 mm
weld 6:	a_w = 6.0 mm	l_w = 100.0 mm
weld 7:	a_w = 6.0 mm	l_w = 8.0 mm
weld 8:	a_w = 6.0 mm	l_w = 8.0 mm

Max: $\sigma_{1,w,Ed} = 421.53$ N/mm² $< f_{1w,d} = 435.56$ N/mm²,
$\sigma_{2,w,Ed} = 210.75$ N/mm² $< f_{2w,d} = 352.80$ N/mm² $\Rightarrow U_w = 0.968 < 1$ ok

utilization of welds $U_{max} = 0.968 < 1$ ok

4.5. total

utilization Lk 1 $U_{max} = 0.988 < 1$ ok