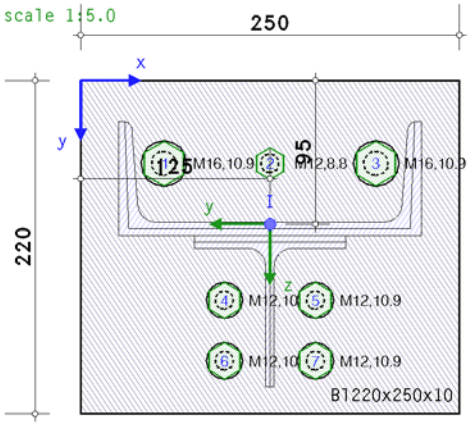
POS. 11: COMPOSITE U + T PROFILES

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

bolts have to be preloaded with $F_{p,C}$!!

thread included in the shear plane

--	FK	TP	Senk	Schlüss	--	FK	TP	Senk	Schlüss
1	10.9	M16	no	big	5	10.9	M12	no	big
2	8.8	M12	no	normal	6	10.9	M12	no	big
3	10.9	M16	no	big	7	10.9	M12	no	big
4	10.9	M12	no	big					

FK: bolt class; TP: bolt size; Senk: countersunk bolt; Schlüss: across flats dimension

connection

end-plate (rectangular): thickness t_p = 10.0 mm, width b_p = 250.0 mm, length l_p = 220.0 mm

beam: h = 175.0 mm, b = 200.0 mm, A = 46.45 cm², y_s = -100.0 mm, z_s = 67.9 mm, y_M = 0.0 mm, z_M = 26.6 mm

I_y = 445.06 cm⁴, I_z = 1983.90 cm⁴, I_T = 13.72 cm⁴, I_ω = 9245.50 cm⁶

beam-end-plate: surrounding fillet weld, weld thickness a = 4.0 mm

coordinates of centroid of beam section at x_p = 125.0 mm, y_p = 95.0 mm

coordinates of the beam centroid on end-plate x_s = 125.0 mm, y_s = 95.0 mm

bolts:

plastic limit force $F_{t,f} = f_{t,f} \cdot F_{t,Rd}$, $f_{t,f}$ = 0.950

effective elongation at failure $\varepsilon_{t,f} = f_{t,\varepsilon} \cdot \varepsilon_{ub}$, $f_{t,\varepsilon}$ = 0.250

	x mm	y mm	c_f kN/cm	$F_{t,f}$ kN	$\varepsilon_{t,f}$ %	$F_{p,C}$ kN		x mm	y mm	c_f kN/cm	$F_{t,f}$ kN	$\varepsilon_{t,f}$ %	$F_{p,C}$ kN
1	55.0	55.0	8346.8	107.4	2.25	98.9	5	155.0	145.0	5094.4	57.7	2.25	53.1
2	125.0	55.0	5472.3	46.1	3.00	--	6	95.0	185.0	5094.4	57.7	2.25	53.1
3	195.0	55.0	8346.8	107.4	2.25	98.9	7	155.0	185.0	5094.4	57.7	2.25	53.1
4	95.0	145.0	5094.4	57.7	2.25	53.1							

x,y: coordinates of bolt axis on end-plate; c_f: spring stiffness of bolt (FEM); $F_{t,f}$: plastic limit force of bolt (FEM)
$\varepsilon_{t,f}$: effective elongation at failure of bolt (FEM); $F_{p,C} \le F_{t,Rk}$: preload force of bolt (FEM)

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 bolts, check of distances

FEM-calculation:

bolts are plasticly calculated (c_f, $F_{t,Rk}$, $F_{t,f}$, $f_{t,f}$, $f_{t,\varepsilon}$, $F_{p,C}$ s. table)

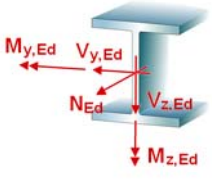
effective foundation modulus of end plate c_b = 21000.0 kN/cm³

number / dimension of finite elements each direction n_x / Δx = 62 / 4.0 mm, n_y / Δy = 55 / 4.0 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
1	-0.35	0.38	0.23	0.00	0.00
2	-2.36	11.22	-5.40	-0.03	-0.02
3	-7.50	7.51	4.45	0.04	0.02
4	-3.19	18.89	-9.28	0.02	0.01
5	-10.12	10.42	6.34	-0.02	-0.01
6	-0.88	0.29	0.17	0.04	0.02
7	-8.98	18.43	-1.12	-0.03	-0.02



Lk	N_{Ed} kN	$M_{y,Ed}$ kNm	$V_{z,Ed}$ kN	$M_{z,Ed}$ kNm	$V_{y,Ed}$ kN
8	-0.88	0.07	0.28	-0.03	-0.02
9	-10.20	10.47	6.31	0.00	0.00
10	-2.83	18.95	-9.25	0.00	0.00

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 !
4H-QUER-cross-sectione sind über ihre Mittellinien beschrieben.
edge- and distances between bolts sind daher separat zu überprüfen !!

minimum distances of bolts on end-plate

bolt 1: $e_1 = 55.0$ mm $> 1.2 \cdot d_0 = 21.6$ mm, $e_1 = 55.0$ mm $< 4 \cdot t + 40$ mm $= 80.0$ mm
bolt 1: $p_1 = 70.0$ mm $> 2.2 \cdot d_0 = 39.6$ mm, $p_1 = 70.0$ mm $< \min(14 \cdot t, 200$ mm$) = 140.0$ mm
bolt 2: $e_1 = 55.0$ mm $> 1.2 \cdot d_0 = 15.6$ mm, $e_1 = 55.0$ mm $< 4 \cdot t + 40$ mm $= 80.0$ mm
bolt 2: $p_1 = 70.0$ mm $> 2.2 \cdot d_0 = 28.6$ mm, $p_1 = 70.0$ mm $< \min(14 \cdot t, 200$ mm$) = 140.0$ mm
bolt 3: $e_1 = 55.0$ mm $> 1.2 \cdot d_0 = 21.6$ mm, $e_1 = 55.0$ mm $< 4 \cdot t + 40$ mm $= 80.0$ mm
bolt 3: $p_1 = 98.5$ mm $> 2.2 \cdot d_0 = 39.6$ mm, $p_1 = 98.5$ mm $< \min(14 \cdot t, 200$ mm$) = 140.0$ mm
bolt 4: $e_1 = 75.0$ mm $> 1.2 \cdot d_0 = 15.6$ mm, $e_1 = 75.0$ mm $< 4 \cdot t + 40$ mm $= 80.0$ mm
bolt 4: $p_1 = 40.0$ mm $> 2.2 \cdot d_0 = 28.6$ mm, $p_1 = 40.0$ mm $< \min(14 \cdot t, 200$ mm$) = 140.0$ mm
bolt 5: $e_1 = 75.0$ mm $> 1.2 \cdot d_0 = 15.6$ mm, $e_1 = 75.0$ mm $< 4 \cdot t + 40$ mm $= 80.0$ mm
bolt 5: $p_1 = 40.0$ mm $> 2.2 \cdot d_0 = 28.6$ mm, $p_1 = 40.0$ mm $< \min(14 \cdot t, 200$ mm$) = 140.0$ mm
bolt 6: $e_1 = 35.0$ mm $> 1.2 \cdot d_0 = 15.6$ mm, $e_1 = 35.0$ mm $< 4 \cdot t + 40$ mm $= 80.0$ mm
bolt 6: $p_1 = 60.0$ mm $> 2.2 \cdot d_0 = 28.6$ mm, $p_1 = 60.0$ mm $< \min(14 \cdot t, 200$ mm$) = 140.0$ mm
bolt 7: $e_1 = 35.0$ mm $> 1.2 \cdot d_0 = 15.6$ mm, $e_1 = 35.0$ mm $< 4 \cdot t + 40$ mm $= 80.0$ mm

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
1	0.354	0.109	0.354	0.007	0.133	0.133	0.473	0.625	---	0.625
2	0.484	0.484	0.360	0.221	0.135	0.135	0.473	0.651	0.024	0.651
3	0.355	0.304	0.355	0.137	0.133	0.133	0.473	0.638	0.019	0.638
4	0.923	0.923	0.366	0.374	0.228	0.228	0.473	0.678	0.044	0.923
5	0.440	0.440	0.357	0.191	0.133	0.133	0.473	0.649	0.028	0.649
6	0.354	0.109	0.354	0.004	0.133	0.133	0.473	0.625	---	0.625
7	0.890	0.890	0.364	0.354	0.217	0.217	0.473	0.668	0.005	0.890
8	0.355	0.110	0.355	---	---	0.133	0.473	0.626	0.001	0.626
9	0.443	0.443	0.357	0.191	0.133	0.133	0.473	0.649	0.028	0.649
10	0.927	0.927	0.366	0.376	0.229	0.229	0.473	0.678	0.043	0.927*

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: 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
1783	125.0	184.0	0.142	0.00	-9.21	-2.59	-0.00	0.22	-1.32	0.927

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	F_t kN	U_{wt}	U_{vt}	U_b	U_s
1	55.0	55.0	98.91	0.133	0.645	0.008	0.645
2	125.0	55.0	3.26	0.010	0.206	0.043	0.473
3	195.0	55.0	98.91	0.133	0.645	0.008	0.645
4	95.0	145.0	55.80	0.168	0.670	0.005	0.670
5	155.0	145.0	55.80	0.168	0.670	0.005	0.670
6	95.0	185.0	56.75	0.229	0.678	0.004	0.678
7	155.0	185.0	56.75	0.229	0.678	0.004	0.678

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 10] — max $U_p = 0.927 < 1$ ok
maximum utilization of bolts due to elongation [Lk 10] — max $U_{wt,s} = 0.229 < 1$ ok
maximum utilization of bolts [Lk 10] — max $U_s = 0.678 < 1$ ok
maximum utilization [Lk 10] — **max U = 0.927 < 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

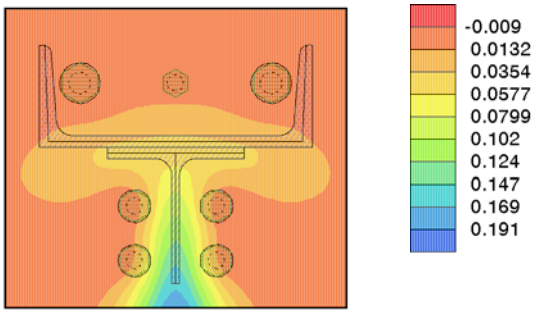
EN 1993-1-8, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -
Teil 1-8: Bemessung von Anschlüssen;
Deutsche Fassung EN 1993-1-8:2005 + AC:2009, Ausgabe Dezember 2010
EN 1993-1-8/NA, Nationaler Anhang zur EN 1993-1-8, Ausgabe Dezember 2010

4. Lk 10 (decisive)

4.1. end-plate

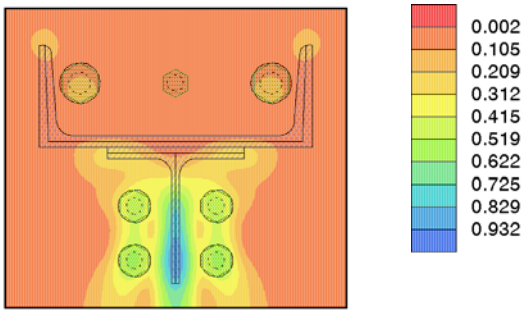
design values: N = -2.83 kN, M_y = 18.95 kNm

deformations u_z [mm]
min u_z = -0.0085 mm, max u_z = 0.1896 mm

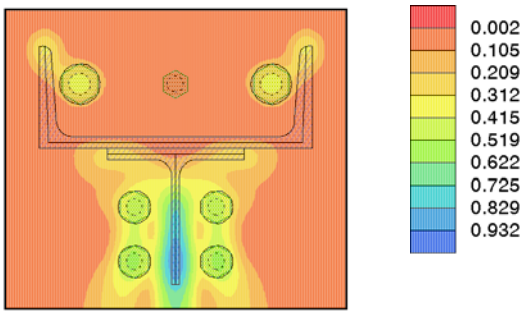


deformations lifting off positive

utilization due to stress U_σ
min U_σ = 0.002, max U_σ = 0.927



utilization of end-plate U_p
min U_p = 0.002, max U_p = 0.927



utilization of end-plate

node	x mm	y mm	u_z mm	U_σ	U_b	U_p
1783	125.0	184.0	0.142	0.927	---	0.927
1792	125.0	220.0	0.190	0.637	---	0.637

x,y: node coordinates; u_z: deformations (lifting off positive); U_σ: utilization due to moment with shear force; U_b: utilization due to compression by contact
U_p: utilization of end-plate

utilization of bolts

	x mm	y mm	w_t mm	F_t kN	ε_{wt} %	U_{wt}
1	55.0	55.0	-0.005	98.91	0.300	0.133
2	125.0	55.0	0.003	3.26	0.030	0.010
3	195.0	55.0	-0.005	98.91	0.300	0.133
4	95.0	145.0	0.008	55.80	0.379	0.168
5	155.0	145.0	0.008	55.80	0.379	0.168

	x mm	y mm	wt mm	Ft kN	εwt %	Uwt
6	95.0	185.0	0.022	56.75	0.516	0.229
7	155.0	185.0	0.022	56.75	0.516	0.229

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

FEM-calculation
number of iteration steps 10 of 50, accuracy 5.0‰
6 bolts preloaded, no bolt plastified
sum of forces due to external loads -2.8 kN
sum of bolt forces 426.2 kN
sum of bedding reactions 429.0 kN
compression area 82.7 cm² = 15.05% of end-plate area
rotational plane regarding the centroid of cross-section $u_{z,m}$ = 0.033 mm, φ_y = 0.056°, φ_z = -0.000°
rotational angle of end-plate connection $2\cdot\varphi_y$ = 0.113°, $2\cdot\varphi_z$ = -0.000°
lower limit of plastic utilization of bolts $U_{pl,min}$ = 0.376

utilization of end-plate [node 1783] U_{max} = 0.927 < 1 ok
utilization of bolts due to elongation [bolt 6] $U_{s,max}$ = 0.229 < 1 ok
minimum plastic utilization of bolts $U_{pl,s,min}$ = 0.376 < 1 ok
plastic utilization of tensile forces of bolts $U_{pl,t,s}$ = 0.229 < 1 ok

4.2. bolts

design values: min F_t = 3.26 kN, max F_t = 98.91 kN, V_z = -9.25 kN

cross-section of points
y_i,z_i coordinates refering to load application point (beam centroid), $F_{t,i}$ tension forces, $f_{vt,i}$ weighting factors

bolt 1	y_1 = 70.0 mm	z_1 = -40.0 mm	$F_{t,1}$ = 98.9 kN	$f_{vt,1}$ = 0.187
bolt 2	y_2 = 0.0 mm	z_2 = -40.0 mm	$F_{t,2}$ = 3.3 kN	$f_{vt,2}$ = 0.748
bolt 3	y_3 = -70.0 mm	z_3 = -40.0 mm	$F_{t,3}$ = 98.9 kN	$f_{vt,3}$ = 0.187
bolt 4	y_4 = 30.0 mm	z_4 = 50.0 mm	$F_{t,4}$ = 55.8 kN	$f_{vt,4}$ = 0.065
bolt 5	y_5 = -30.0 mm	z_5 = 50.0 mm	$F_{t,5}$ = 55.8 kN	$f_{vt,5}$ = 0.065
bolt 6	y_6 = 30.0 mm	z_6 = 90.0 mm	$F_{t,6}$ = 56.8 kN	$f_{vt,6}$ = 0.052
bolt 7	y_7 = -30.0 mm	z_7 = 90.0 mm	$F_{t,7}$ = 56.8 kN	$f_{vt,7}$ = 0.052

calculation of the point section
shear forces

point 1:	y_1' = 70.0 mm	z_1' = -18.6 mm	$T_{y,1}$ = 0.00 kN	$T_{z,1}$ = -1.27 kN	T_1 = 1.27 kN
point 2:	y_2' = -0.0 mm	z_2' = -18.6 mm	$T_{y,2}$ = 0.00 kN	$T_{z,2}$ = -5.10 kN	T_2 = 5.10 kN
point 3:	y_3' = -70.0 mm	z_3' = -18.6 mm	$T_{y,3}$ = 0.00 kN	$T_{z,3}$ = -1.27 kN	T_3 = 1.27 kN
point 4:	y_4' = 30.0 mm	z_4' = 71.4 mm	$T_{y,4}$ = -0.00 kN	$T_{z,4}$ = -0.44 kN	T_4 = 0.44 kN
point 5:	y_5' = -30.0 mm	z_5' = 71.4 mm	$T_{y,5}$ = -0.00 kN	$T_{z,5}$ = -0.44 kN	T_5 = 0.44 kN
point 6:	y_6' = 30.0 mm	z_6' = 111.4 mm	$T_{y,6}$ = -0.00 kN	$T_{z,6}$ = -0.36 kN	T_6 = 0.36 kN
point 7:	y_7' = -30.0 mm	z_7' = 111.4 mm	$T_{y,7}$ = -0.00 kN	$T_{z,7}$ = -0.36 kN	T_7 = 0.36 kN

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	$U_{tp,1}$ = 0.473	$U_{vt,1}$ = 0.645	$U_{b,1}$ = 0.008	U_1 = 0.645
bolt 2	$U_{tp,2}$ = 0.023	$U_{vt,2}$ = 0.206	$U_{b,2}$ = 0.043	U_2 = 0.206
bolt 3	$U_{tp,3}$ = 0.473	$U_{vt,3}$ = 0.645	$U_{b,3}$ = 0.008	U_3 = 0.645
bolt 4	$U_{tp,4}$ = 0.329	$U_{vt,4}$ = 0.670	$U_{b,4}$ = 0.005	U_4 = 0.670
bolt 5	$U_{tp,5}$ = 0.329	$U_{vt,5}$ = 0.670	$U_{b,5}$ = 0.005	U_5 = 0.670
bolt 6	$U_{tp,6}$ = 0.335	$U_{vt,6}$ = 0.678	$U_{b,6}$ = 0.004	U_6 = 0.678
bolt 7	$U_{tp,7}$ = 0.335	$U_{vt,7}$ = 0.678	$U_{b,7}$ = 0.004	U_7 = 0.678
total:	U_{tp} = 0.473	U_{vt} = 0.678	U_b = 0.043	U = 0.678 < 1 ok

in utilization of bolts max U_s the minimum plastic utilization of bolts min $U_{pl,s}$ = 0.376
and plastic utilization of tensile forces of bolts $U_{pl,t,s}$ = 0.229 is included.

utilization of bolts U_{max} = 0.678 < 1 ok

4.3. total

utilization Lk 10 U_{max} = 0.927 < 1 ok