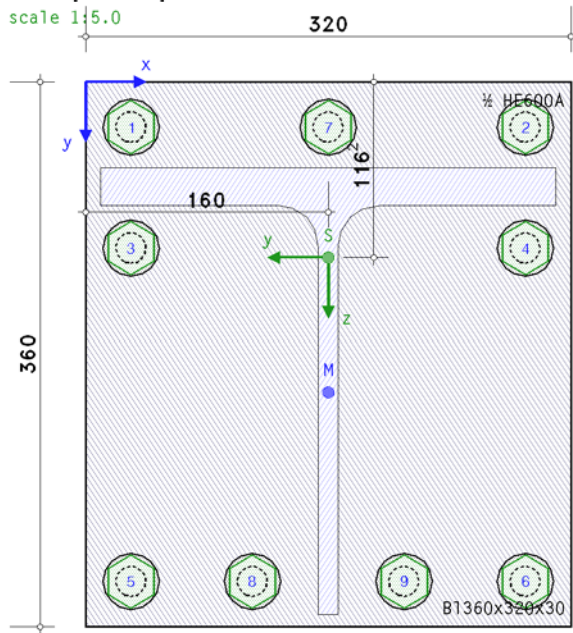


POS. 3: T-SECTION

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

bolts have to be prestressed with with preloading $F_{p,c} = 154.3 \text{ kN} !!$

bolt class 10.9, bolt size M20

large wrench size (high strength bolt), preloaded (for info: preloading $F_{p,c}^* = 0.7 \cdot f_{yb} \cdot A_s = 154.3 \text{ kN}$)

thread included in the shear plane

connection

end-plate (rectangular): thickness $t_p = 30.0 \text{ mm}$, width $b_p = 320.0 \text{ mm}$, length $l_p = 360.0 \text{ mm}$

beam: section 1/2 HE600A

beam-end-plate: surrounding fillet weld, weld thickness $a = 10.0 \text{ mm}$

surrounding welds: short welds are neglected

coordinates of the beam centroid on end-plate $x_s = 160.0 \text{ mm}$, $y_s = 116.2 \text{ mm}$

bolts:

coordinates of bolt axis:

$x_1 = 30.0 \text{ mm}$, $y_1 = 30.0 \text{ mm}$

$x_2 = 290.0 \text{ mm}$, $y_2 = 30.0 \text{ mm}$

$x_3 = 30.0 \text{ mm}$, $y_3 = 110.0 \text{ mm}$

$x_4 = 290.0 \text{ mm}$, $y_4 = 110.0 \text{ mm}$

$x_5 = 30.0 \text{ mm}$, $y_5 = 330.0 \text{ mm}$

$x_6 = 290.0 \text{ mm}$, $y_6 = 330.0 \text{ mm}$

$x_7 = 160.0 \text{ mm}$, $y_7 = 30.0 \text{ mm}$

$x_8 = 110.0 \text{ mm}$, $y_8 = 330.0 \text{ mm}$

$x_9 = 210.0 \text{ mm}$, $y_9 = 330.0 \text{ mm}$

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 bolts, check of distances

FEM-calculation:

bolts are plastically calculated, spring constant of bolts $c_f = 6255.3 \text{ kN/cm}$

plastic limit force $F_{t,f} = f_{t,f} \cdot F_{t,Rd} = 167.6 \text{ kN}$, $f_{t,f} = 0.950$, $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2} = 176.40 \text{ kN}$, $k_2 = 0.90$

effective elongation at failure $\epsilon_{t,f} = f_{t,e} \cdot \epsilon_{ub} = 2.3\%$, $f_{t,e} = 0.250$, $\epsilon_{ub} = 9.0\%$

preload force of bolts $F_{p,c} = 154.3 \text{ kN} < F_{t,f}$ **ok**

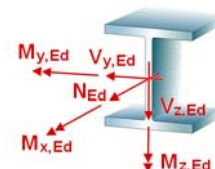
effective foundation modulus of end plate $c_b = 7000.0 \text{ kN/cm}^3$

number / dimension of finite elements each direction $n_x / \Delta x = 46 / 7.0 \text{ mm}$, $n_y / \Delta y = 52 / 6.9 \text{ mm}$

max. 50 iteration steps (tolerance limit 5%)

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

Lk	N_{Ed} kN	$M_{y,Ed}$ kNm	$V_{z,Ed}$ kN	$M_{z,Ed}$ kNm	$V_{y,Ed}$ kN	$M_{x,Ed}$ kNm
1	-45.81	-178.34	125.70	-24.25	-9.67	10.34
2	3.62	17.74	0.37	89.86	39.12	-3.27
3	-15.63	-76.27	43.37	-49.85	-17.49	2.27
4	-14.97	-39.91	48.47	93.76	39.76	3.08
5	-8.00	-44.37	36.57	90.43	38.31	-3.65
6	-29.22	-89.61	73.99	-25.08	-8.51	10.88
7	-4.02	-14.16	7.17	-50.43	-16.68	2.65



Lk	N _{Ed} kN	M _{y,Ed} kNm	V _{z,Ed} kN	M _{z,Ed} kNm	V _{y,Ed} kN	M _{x,Ed} kNm
8	-45.53	-173.45	125.19	-24.94	-8.68	10.62
9	3.42	14.32	0.73	90.34	38.43	-3.46

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 !

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
1	0.747	0.747	0.428	0.652	0.801	0.508	0.226	0.912	0.124	0.912*
2	0.532	0.532	0.400	0.394	0.182	0.182	0.226	0.699	0.022	0.699
3	0.504	0.504	0.245	0.283	0.176	0.176	0.226	0.707	0.033	0.707
4	0.748	0.748	0.582	0.398	0.568	0.402	0.226	0.771	0.063	0.771
5	0.746	0.746	0.560	0.389	0.541	0.392	0.226	0.709	0.035	0.746
6	0.322	0.322	0.190	0.322	0.141	0.141	0.216	0.794	0.073	0.794
7	0.281	0.281	0.212	0.217	0.135	0.135	0.212	0.658	0.014	0.658
8	0.740	0.740	0.398	0.633	0.584	0.416	0.226	0.912	0.124	0.912
9	0.549	0.549	0.406	0.396	0.188	0.188	0.226	0.698	0.023	0.698

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 9 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
2449	320.0	69.2	0.267	0.00	-5.60	-60.90	-0.46	1009.43	21.67	0.748

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 9 Lk: max U_s with corresponding values

	x mm	y mm	F_t kN	U_{wt}	U_{vt}	U_b	U_s
1	30.0	30.0	167.58	0.385	0.796	0.051	0.796
2	290.0	30.0	159.41	0.138	0.767	0.053	0.767
3	30.0	110.0	167.58	0.496	0.791	0.024	0.791
4	290.0	110.0	160.04	0.140	0.746	0.023	0.746
5	30.0	330.0	154.35	0.133	0.912	0.124	0.912
6	290.0	330.0	154.35	0.133	0.773	0.064	0.773
7	160.0	30.0	167.58	0.364	0.769	0.031	0.769
8	110.0	330.0	154.35	0.133	0.868	0.086	0.868
9	210.0	330.0	154.35	0.133	0.814	0.066	0.814

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]

maximum utilization of bolts due to elongation [Lk 1]

maximum utilization of bolts [Lk 1]

maximum utilization [Lk 1]

max $U_p = 0.748 < 1$ ok

max $U_{wt,s} = 0.508 < 1$ ok

max $U_s = 0.912 < 1$ ok

max U = 0.912 < 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 1 (decisive)

4.1. end-plate

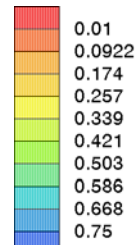
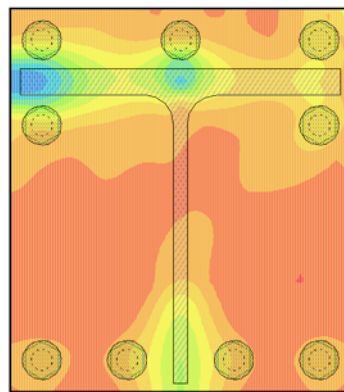
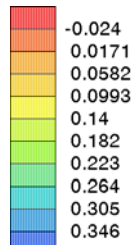
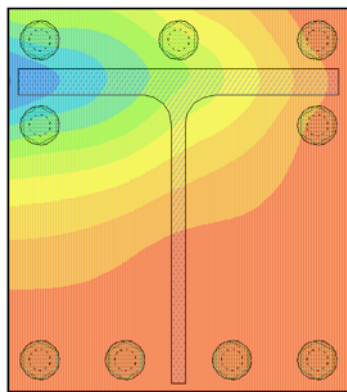
design values: $N = -45.81$ kN, $M_y = -178.34$ kNm, $M_z = -24.25$ kNm

deformations u_z [mm]

min $u_z = -0.0236$ mm, max $u_z = 0.3497$ mm

utilization of end-plate U_p

min $U_p = 0.010$, max $U_p = 0.747$



deformations lifting off positive

utilization of end-plate

node	x mm	y mm	u_z mm	U_p
11	0.0	69.2	0.350	0.747

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	30.0	30.0	0.253	167.58	1.144	0.508
2	290.0	30.0	0.008	161.55	0.326	0.145
3	30.0	110.0	0.245	167.58	1.115	0.496
4	290.0	110.0	0.008	161.98	0.328	0.146
5	30.0	330.0	-0.000	154.35	0.300	0.133
6	290.0	330.0	-0.000	154.35	0.300	0.133
7	160.0	30.0	0.156	167.58	0.819	0.364
8	110.0	330.0	-0.000	154.35	0.300	0.133
9	210.0	330.0	-0.000	154.35	0.300	0.133

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 11] $U_{max} = 0.747 < 1$ ok

utilization of bolts due to elongation [bolt 1] $U_{s,max} = 0.508 < 1$ ok

minimum plastic utilization of bolts $U_{pl,s,min} = 0.652 < 1$ ok

plastic utilization of tensile forces of bolts $U_{pl,t,s} = 0.801 < 1$ ok

4.2. bolts

design values: min $F_t = 154.35$ kN, max $F_t = 167.58$ kN, $V_z = 125.70$ kN, $V_y = -9.67$ kN,
 $M_x = 10.34$ 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	$U_{tp,1} = 0.226$	$U_{vt,1} = 0.796$	$U_{b,1} = 0.051$	$U_1 = 0.796$
bolt 2	$U_{tp,2} = 0.217$	$U_{vt,2} = 0.763$	$U_{b,2} = 0.047$	$U_2 = 0.763$
bolt 3	$U_{tp,3} = 0.226$	$U_{vt,3} = 0.791$	$U_{b,3} = 0.024$	$U_3 = 0.791$
bolt 4	$U_{tp,4} = 0.218$	$U_{vt,4} = 0.746$	$U_{b,4} = 0.021$	$U_4 = 0.746$
bolt 5	$U_{tp,5} = 0.208$	$U_{vt,5} = 0.912$	$U_{b,5} = 0.124$	$U_5 = 0.912$
bolt 6	$U_{tp,6} = 0.208$	$U_{vt,6} = 0.773$	$U_{b,6} = 0.064$	$U_6 = 0.773$
bolt 7	$U_{tp,7} = 0.226$	$U_{vt,7} = 0.769$	$U_{b,7} = 0.031$	$U_7 = 0.769$
bolt 8	$U_{tp,8} = 0.208$	$U_{vt,8} = 0.868$	$U_{b,8} = 0.086$	$U_8 = 0.868$
bolt 9	$U_{tp,9} = 0.208$	$U_{vt,9} = 0.814$	$U_{b,9} = 0.066$	$U_9 = 0.814$
total:	$U_{tp} = 0.226$	$U_{vt} = 0.912$	$U_b = 0.124$	$U = 0.912 < 1$ ok

in utilization of bolts max U_s the minimum plastic utilization of bolts min $U_{pl,s} = 0.652$

and plastic utilization of tensile forces of bolts $U_{pl,t,s} = 0.801$ is included.

utilization of bolts $U_{max} = 0.912 < 1$ **ok**

4.3. total

utilization Lk 1 $U_{max} = 0.912 < 1$ **ok**