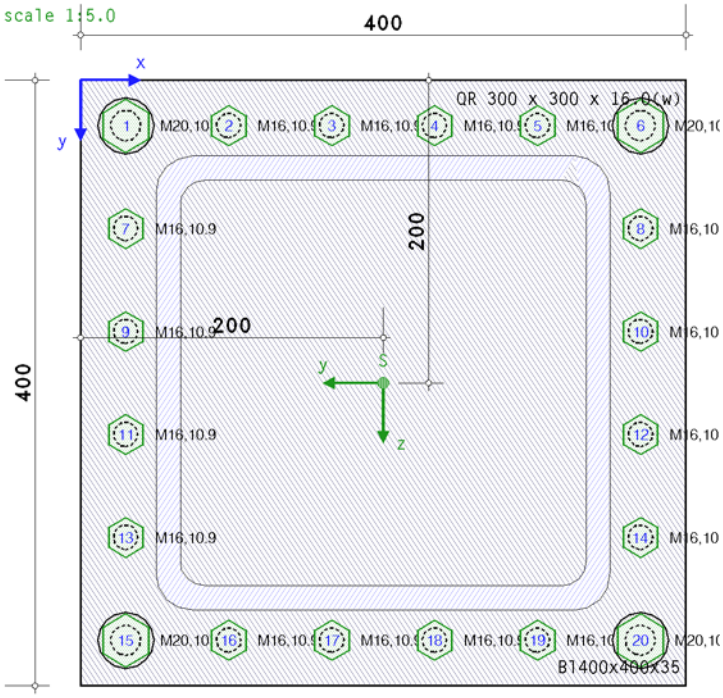
POS. 6: SQUARE TUBE

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	--	FK	TP	Senk	Schlüss
1	10.9	M20	no	big	8	10.9	M16	no	normal	15	10.9	M20	no	big
2	10.9	M16	no	normal	9	10.9	M16	no	normal	16	10.9	M16	no	normal
3	10.9	M16	no	normal	10	10.9	M16	no	normal	17	10.9	M16	no	normal
4	10.9	M16	no	normal	11	10.9	M16	no	normal	18	10.9	M16	no	normal
5	10.9	M16	no	normal	12	10.9	M16	no	normal	19	10.9	M16	no	normal
6	10.9	M20	no	big	13	10.9	M16	no	normal	20	10.9	M20	no	big
7	10.9	M16	no	normal	14	10.9	M16	no	normal					

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

connection

end-plate (rectangular): thickness t_p = 35.0 mm, width b_p = 400.0 mm, length l_p = 400.0 mm

beam: section QR 300 x 300 x 16.0(w)

beam-end-plate: surrounding butt weld (full penetrated)

beam section centric on end-plate (beam centroid in plate centre)

coordinates of the beam centroid on end-plate x_s = 200.0 mm, y_s = 200.0 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	30.0	30.0	5577.2	167.6	2.25	154.3	11	30.0	234.0	3836.0	107.4	2.25	--
2	98.0	30.0	3836.0	107.4	2.25	--	12	370.0	234.0	3836.0	107.4	2.25	--
3	166.0	30.0	3836.0	107.4	2.25	--	13	30.0	302.0	3836.0	107.4	2.25	--
4	234.0	30.0	3836.0	107.4	2.25	--	14	370.0	302.0	3836.0	107.4	2.25	--
5	302.0	30.0	3836.0	107.4	2.25	--	15	30.0	370.0	5577.2	167.6	2.25	154.3
6	370.0	30.0	5577.2	167.6	2.25	154.3	16	98.0	370.0	3836.0	107.4	2.25	--
7	30.0	98.0	3836.0	107.4	2.25	--	17	166.0	370.0	3836.0	107.4	2.25	--
8	370.0	98.0	3836.0	107.4	2.25	--	18	234.0	370.0	3836.0	107.4	2.25	--
9	30.0	166.0	3836.0	107.4	2.25	--	19	302.0	370.0	3836.0	107.4	2.25	--
10	370.0	166.0	3836.0	107.4	2.25	--	20	370.0	370.0	5577.2	167.6	2.25	154.3

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); $F_{p,C} \leq F_{t,Rk}$: preload force of bolt (FEM)

calculation

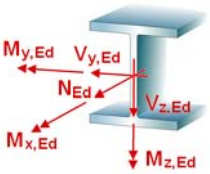
verification:

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 beam section with the elastic method
verification of welds with the directional method
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 = 6000.0 kN/cm³
number / dimension of finite elements each direction n_x / Δx = 80 / 5.0 mm, n_y / Δy = 80 / 5.0 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	-171.66	-199.41	-44.31	-130.93	29.10	10.62
2	33.33	6.55	1.45	103.02	-12.77	22.46
3	-160.29	-156.01	-34.67	-189.96	42.21	-13.55
4	-70.53	-30.08	-6.69	-169.52	37.67	-36.39
5	-109.35	-177.44	-39.43	32.59	-1.17	45.93



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	0.498	0.338	0.498	0.363	0.670	0.227	0.193	0.686	0.026	0.586	0.248	0.550	0.686
2	0.264	0.157	0.264	0.241	0.297	0.133	0.181	0.657	0.022	0.203	0.175	0.183	0.657
3	0.500	0.355	0.500	0.347	0.682	0.233	0.193	0.688	0.033	0.610	0.241	0.571	0.688
4	0.383	0.234	0.383	0.342	0.450	0.155	0.188	0.686	0.040	0.364	0.230	0.332	0.686
5	0.390	0.240	0.390	0.342	0.461	0.159	0.188	0.699	0.055	0.387	0.238	0.355	0.699*

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 5 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
1	0.0	0.0	-0.050	177.59	-0.89	-0.49	5.37	79.52	136.39	0.500

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 5 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	167.49	0.204	0.688	0.004	0.688
2	98.0	30.0	106.96	0.206	0.684	---	0.684
3	166.0	30.0	107.39	0.227	0.686	---	0.686
4	234.0	30.0	95.94	0.159	0.665	0.007	0.665
5	302.0	30.0	70.90	0.117	0.611	0.024	0.611
6	370.0	30.0	163.03	0.150	0.699	0.014	0.699
7	30.0	98.0	107.37	0.223	0.688	0.001	0.688
8	370.0	98.0	49.66	0.082	0.558	0.037	0.558
9	30.0	166.0	107.39	0.233	0.688	0.001	0.688
10	370.0	166.0	41.95	0.069	0.504	0.031	0.504
11	30.0	234.0	85.36	0.141	0.614	0.009	0.614
12	370.0	234.0	58.25	0.096	0.436	0.008	0.436
13	30.0	302.0	51.06	0.085	0.508	0.027	0.508
14	370.0	302.0	0.01	---	0.371	0.046	0.371
15	30.0	370.0	158.58	0.136	0.682	0.015	0.682
16	98.0	370.0	25.54	0.042	0.417	0.040	0.417
17	166.0	370.0	17.71	0.029	0.352	0.032	0.352
18	234.0	370.0	2.06	0.003	0.271	0.030	0.271
19	302.0	370.0	0.00	---	0.324	0.055	0.324
20	370.0	370.0	154.35	0.133	0.677	0.019	0.677

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]	max U_p = 0.500 < 1 ok
maximum utilization of bolts due to elongation [Lk 3]	max $U_{wt,s}$ = 0.233 < 1 ok
maximum utilization of bolts [Lk 5]	max U_s = 0.699 < 1 ok
maximum utilization of the beam [Lk 3]	max (U_q,U_{ct}) = 0.610 < 1 ok
maximum utilization of welds [Lk 3]	max U_w = 0.571 < 1 ok
maximum utilization [Lk 5]	**max U = 0.699 < 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

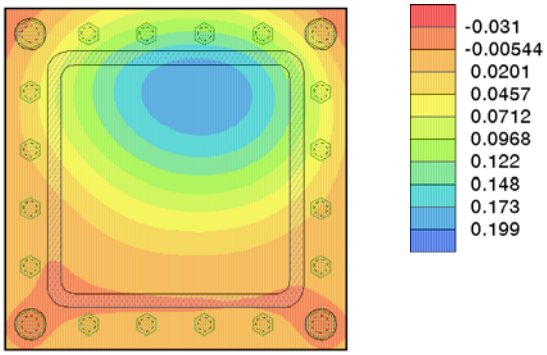
EN 1993-1-8, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -
Teil 1-8: Bemessung von Anschlüssen;
Deutsche Fassung EN 1993-1-8:2005 + AC:2009, Ausgabe Dezember 2010
EN 1993-1-8/NA, Nationaler Anhang zur EN 1993-1-8, Ausgabe Dezember 2010

4. Lk 5 (decisive)

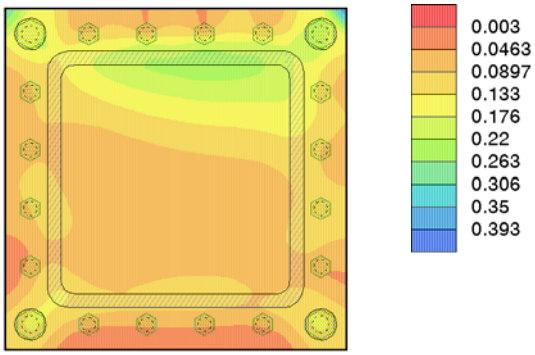
4.1. end-plate

design values: N = -109.35 kN, M_y = -177.44 kNm, M_z = 32.59 kNm

deformations u_z [mm]
min u_z = -0.0306 mm, max u_z = 0.1972 mm



utilization of end-plate U_p
min U_p = 0.003, max U_p = 0.390



deformations lifting off positive

utilization of end-plate

node	x mm	y mm	u_z mm	U_p
3504	215.0	100.0	0.196	0.187
6481	400.0	0.0	-0.031	0.390

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	Ft kN	εwt %	U_{wt}
1	30.0	30.0	0.002	158.67	0.306	0.136
2	98.0	30.0	0.068	52.00	0.194	0.086
3	166.0	30.0	0.114	87.33	0.325	0.145
4	234.0	30.0	0.126	95.94	0.359	0.159
5	302.0	30.0	0.092	70.90	0.264	0.117
6	370.0	30.0	0.013	163.03	0.337	0.150
7	30.0	98.0	0.033	25.36	0.094	0.042
8	370.0	98.0	0.065	49.66	0.185	0.082
9	30.0	166.0	0.022	17.01	0.063	0.028
10	370.0	166.0	0.055	41.95	0.156	0.069
11	30.0	234.0	0.002	1.58	0.006	0.003

	x	y	w_t	F_t	ε_{wt}	U_{wt}
	mm	mm	mm	kN	%	
12	370.0	234.0	0.018	13.55	0.050	0.022
13	30.0	302.0	-0.000	0.00	-0.000	---
14	370.0	302.0	-0.002	0.01	0.000	---
15	30.0	370.0	-0.000	154.35	0.300	0.133
16	98.0	370.0	-0.000	0.00	-0.000	---
17	166.0	370.0	-0.000	0.00	-0.000	---
18	234.0	370.0	-0.000	0.00	-0.000	---
19	302.0	370.0	-0.000	0.00	-0.000	---
20	370.0	370.0	-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 6481] $U_{max} = 0.390 < 1$ ok
utilization of bolts due to elongation [bolt 4] $U_{s,max} = 0.159 < 1$ ok
minimum plastic utilization of bolts $U_{pl,s,min} = 0.342 < 1$ ok
plastic utilization of tensile forces of bolts $U_{pl,t,s} = 0.461 < 1$ ok

4.2. bolts

design values: max $F_t = 163.03$ kN, $V_z = -39.43$ kN, $V_y = -1.17$ kN, $M_x = 45.93$ 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	$U_{tp,1} = 0.183$	$U_{vt,1} = 0.686$	$U_{b,1} = 0.016$	$U_1 = 0.686$
bolt 2	$U_{tp,2} = 0.080$	$U_{vt,2} = 0.535$	$U_{b,2} = 0.026$	$U_2 = 0.535$
bolt 3	$U_{tp,3} = 0.135$	$U_{vt,3} = 0.635$	$U_{b,3} = 0.010$	$U_3 = 0.635$
bolt 4	$U_{tp,4} = 0.148$	$U_{vt,4} = 0.665$	$U_{b,4} = 0.007$	$U_4 = 0.665$
bolt 5	$U_{tp,5} = 0.109$	$U_{vt,5} = 0.611$	$U_{b,5} = 0.024$	$U_5 = 0.611$
bolt 6	$U_{tp,6} = 0.188$	$U_{vt,6} = 0.699$	$U_{b,6} = 0.014$	$U_6 = 0.699$
bolt 7	$U_{tp,7} = 0.039$	$U_{vt,7} = 0.421$	$U_{b,7} = 0.045$	$U_7 = 0.421$
bolt 8	$U_{tp,8} = 0.077$	$U_{vt,8} = 0.558$	$U_{b,8} = 0.037$	$U_8 = 0.558$
bolt 9	$U_{tp,9} = 0.026$	$U_{vt,9} = 0.330$	$U_{b,9} = 0.032$	$U_9 = 0.330$
bolt 10	$U_{tp,10} = 0.065$	$U_{vt,10} = 0.504$	$U_{b,10} = 0.031$	$U_{10} = 0.504$
bolt 11	$U_{tp,11} = 0.002$	$U_{vt,11} = 0.233$	$U_{b,11} = 0.026$	$U_{11} = 0.233$
bolt 12	$U_{tp,12} = 0.021$	$U_{vt,12} = 0.400$	$U_{b,12} = 0.036$	$U_{12} = 0.400$
bolt 13	$U_{tp,13} = 0.000$	$U_{vt,13} = 0.247$	$U_{b,13} = 0.033$	$U_{13} = 0.247$
bolt 14	$U_{tp,14} = 0.000$	$U_{vt,14} = 0.371$	$U_{b,14} = 0.046$	$U_{14} = 0.371$
bolt 15	$U_{tp,15} = 0.178$	$U_{vt,15} = 0.664$	$U_{b,15} = 0.014$	$U_{15} = 0.664$
bolt 16	$U_{tp,16} = 0.000$	$U_{vt,16} = 0.242$	$U_{b,16} = 0.033$	$U_{16} = 0.242$
bolt 17	$U_{tp,17} = 0.000$	$U_{vt,17} = 0.217$	$U_{b,17} = 0.025$	$U_{17} = 0.217$
bolt 18	$U_{tp,18} = 0.000$	$U_{vt,18} = 0.250$	$U_{b,18} = 0.036$	$U_{18} = 0.250$
bolt 19	$U_{tp,19} = 0.000$	$U_{vt,19} = 0.324$	$U_{b,19} = 0.055$	$U_{19} = 0.324$
bolt 20	$U_{tp,20} = 0.178$	$U_{vt,20} = 0.677$	$U_{b,20} = 0.019$	$U_{20} = 0.677$
total:	$U_{tp} = 0.188$	$U_{vt} = 0.699$	$U_b = 0.055$	$U = 0.699 < 1$ ok

in utilization of bolts max U_s the minimum plastic utilization of bolts min $U_{pl,s} = 0.342$
and plastic utilization of tensile forces of bolts $U_{pl,t,s} = 0.461$ is included.

utilization of bolts $U_{max} = 0.699 < 1$ ok

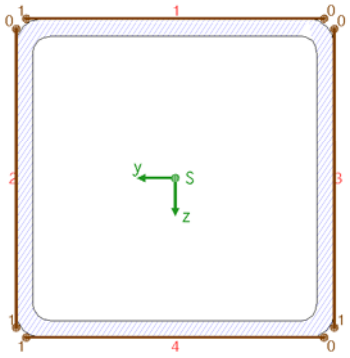
4.3. beam

elastic verification for $N = -109.35$ kN, $M_y = -177.44$ kNm, $V_z = -39.43$ kN, $M_z = 32.59$ kNm
$V_y = -1.17$ kN, $T_t = 45.93$ kNm
verification: $\sigma_v = 137.39$ N/mm² $< \sigma_{v,Rd} = 355.00$ N/mm² $\Rightarrow U_\sigma = 0.387 < 1$ ok
c/t-verification: utilization $U_{c/t} = 0.238 < 1$ ok

utilization of the beam $\max(U_\sigma, U_{c/t}) = 0.387 < 1$ ok

4.4. welds

design values: $N = -109.35$ kN, $M_y = -177.44$ kNm, $V_z = -39.43$ kN, $M_z = 32.59$ kNm,
$V_y = -1.17$ kN, $M_x = 45.93$ kNm



weld 1: a_w = 16.0 mm l_w = 281.2 mm
weld 2: a_w = 16.0 mm l_w = 281.2 mm
weld 3: a_w = 16.0 mm l_w = 281.2 mm
weld 4: a_w = 16.0 mm l_w = 281.2 mm

Max: $\sigma_{1,w,Ed}$ = 128.35 N/mm² < $f_{1w,d}$ = 435.56 N/mm²,
$\sigma_{2,w,Ed}$ = 125.29 N/mm² < $f_{2w,d}$ = 352.80 N/mm² ⇒ U_w = 0.355 < 1 ok

utilization of welds U_{max} = 0.355 < 1 ok

4.5. total

utilization Lk 5 U_{max} = 0.699 < 1 ok