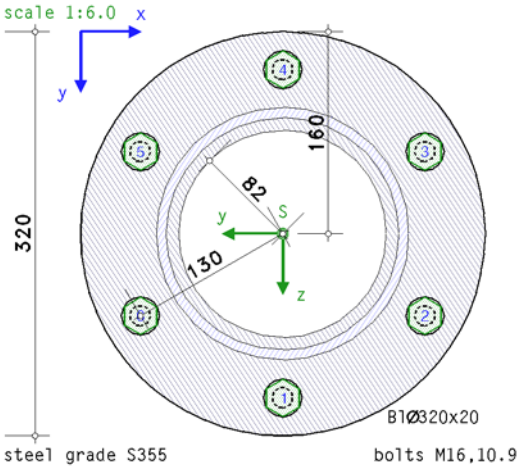
POS. 14: CIRCULAR PLATE TUBULAR PROFILE WITH HOLE

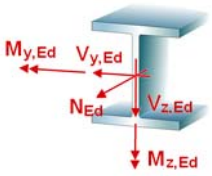
bolted end-plate connection EC 3-1-8 (12.10), NA: Deutschland 4H-EC3FS version: 2/2025-1b

1. input report



steel grade
steel grade S355
bolts
bolts have to be prestressed with with preloading $F_{p,C}$ = 98.9 kN !!
bolt class 10.9, bolt size M16
large wrench size (high strength bolt), preloaded (for info: preloading $F_{p,C}^* = 0.7 \cdot f_{yb} \cdot A_s$ = 98.9 kN)
thread included in the shear plane
connection
end-plate (rund): thickness t_p = 20.0 mm, diameter $Ø_p$ = 320.0 mm
beam: section parameters (pipe):
d = 200.0 mm, t = 8.0 mm, hot-finished
end-plate im Inneren des hollow sections due toschneiden
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 = 160.0 mm, y_s = 160.0 mm
bolts:
circular arrangement of 6 bolts with radius r = 130.0 mm arround centroid of beam section
calculation
verification:
calculation of internal forces and moments (FEM) and verifications of resistance plastic
verification of compression by contact
verification of bolts, check of distances
FEM-calculation:
plastic calculation of end-plate:
plastic limit stress $f_{y,pl} = f_{y,f} \cdot f_{yd}$ = 337.3 N/mm², $f_{y,f}$ = 0.950, f_{yd} = 355.0 N/mm²
max. edge strain max ε_{pl} = 50‰
plastic calculation of bolts:
spring constant of bolts c_f = 5541.2 kN/cm
plastic limit force $F_{t,f} = f_{t,f} \cdot F_{t,Rd}$ = 107.4 kN, $f_{t,f}$ = 0.950, $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2}$ = 113.04 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%
preload force of bolts $F_{p,C}$ = 98.9 kN < $F_{t,f}$ ok
effective foundation modulus of end plate c_b = 10500.0 kN/cm³
number / dimension of finite elements each direction $n_x / \Delta x$ = 43 / 7.4 mm, $n_y / \Delta y$ = 43 / 7.4 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	-30.59	-17.62	-10.10	17.81	-14.93	Import Lk 1
2	8.14	0.91	26.78	0.19	-0.10	Import Lk 2
3	-26.48	-13.44	-7.36	25.35	-22.49	Import Lk 3
4	4.28	-0.25	15.67	0.13	-0.07	Import Lk 4
5	-25.83	-18.15	-10.20	4.62	-2.54	Import Lk 5
6	8.11	2.52	27.17	0.17	-0.09	Import Lk 6
7	-12.99	-11.48	9.05	3.27	-1.80	Import Lk 7
8	-6.04	-2.89	-0.91	13.41	-12.51	Import Lk 8
9	-25.81	-18.16	-10.15	4.64	-2.55	Import Lk 9
10	-30.56	-18.15	-10.20	17.84	-14.94	Import Lk 10
11	-25.83	-16.56	-9.76	4.62	-2.54	Import Lk 11



Lk	N_{Ed} kN	$M_{y,Ed}$ kNm	$V_{z,Ed}$ kN	$M_{z,Ed}$ kNm	$V_{y,Ed}$ kN	
12	-30.56	-16.56	-9.76	17.84	-14.94	Import Lk 12
13	-76.89	20.23	-5.06	-7.70	-1.92	Import Lk 17
14	-3.62	0.73	-0.18	-0.28	-0.07	Import Lk 19

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 = 29.3 mm < 30.0 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	0.382	0.382	0.208	0.132	0.211	0.211	0.257	0.702	0.015	0.702
2	0.167	0.109	0.167	0.023	---	0.133	0.237	0.696	0.026	0.696
3	0.509	0.509	0.206	0.216	0.346	0.294	0.257	0.713	0.019	0.713*
4	0.167	0.106	0.167	0.010	---	0.133	0.237	0.667	0.015	0.667
5	0.299	0.299	0.171	0.143	0.148	0.148	0.247	0.674	0.011	0.674
6	0.168	0.117	0.168	0.039	---	0.133	0.237	0.697	0.026	0.697
7	0.213	0.213	0.168	0.096	---	0.133	0.238	0.653	0.009	0.653
8	0.247	0.247	0.169	0.127	---	0.133	0.240	0.665	0.008	0.665
9	0.300	0.300	0.171	0.143	0.148	0.148	0.247	0.674	0.011	0.674
10	0.395	0.395	0.217	0.135	0.217	0.217	0.257	0.702	0.015	0.702
11	0.279	0.279	0.170	0.127	0.140	0.140	0.244	0.667	0.010	0.667
12	0.360	0.360	0.191	0.132	0.201	0.201	0.256	0.701	0.014	0.701
13	0.293	0.293	0.171	0.081	0.145	0.145	0.246	0.661	0.005	0.661
14	0.167	0.106	0.167	0.001	---	0.133	0.237	0.626	---	0.626

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 14 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
1384	230.7	141.4	0.351	0.00	1.19	-11.41	-2.95	134.72	1431.34	0.509

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 14 Lk: max U_s with corresponding values

	x mm	y mm	F_t kN	U_{wt}	U_{vt}	U_b	U_s
1	160.0	290.0	98.91	0.133	0.706	0.018	0.706
2	272.6	225.0	105.60	0.172	0.710	0.010	0.710
3	272.6	95.0	107.39	0.294	0.712	0.008	0.712
4	160.0	30.0	104.85	0.162	0.713	0.011	0.713
5	47.4	95.0	98.91	0.133	0.711	0.019	0.711
6	47.4	225.0	98.91	0.133	0.708	0.019	0.708

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 = 0.509 < 1 ok
maximum utilization of bolts due to elongation [Lk 3]	max $U_{wt,s}$ = 0.294 < 1 ok
maximum utilization of bolts [Lk 3]	max U_s = 0.713 < 1 ok
maximum utilization [Lk 3]	**max U = 0.713 < 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

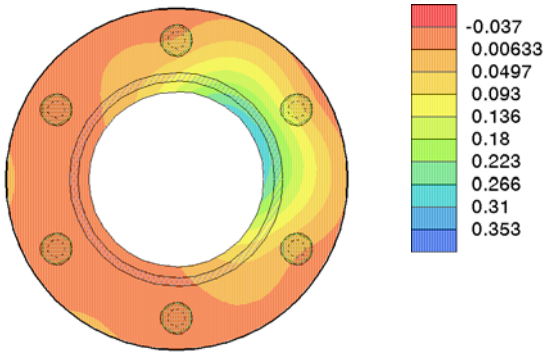
EN 1993-1-8, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -
Teil 1-8: Bemessung von Anschlüssen;
Deutsche Fassung EN 1993-1-8:2005 + AC:2009, Ausgabe Dezember 2010
EN 1993-1-8/NA, Nationaler Anhang zur EN 1993-1-8, Ausgabe Dezember 2010

4. Lk 3 (decisive)

4.1. end-plate

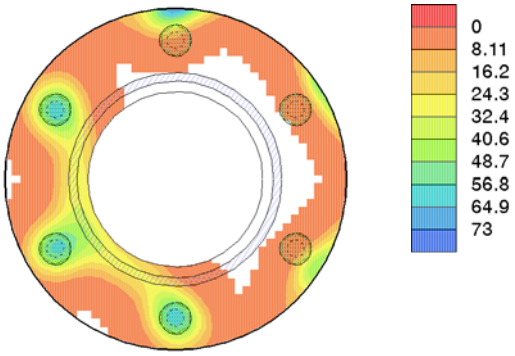
design values: N = -26.48 kN, M_y = -13.44 kNm, M_z = 25.35 kNm

deformations u_z [mm]
min u_z = -0.0369 mm, max u_z = 0.3508 mm



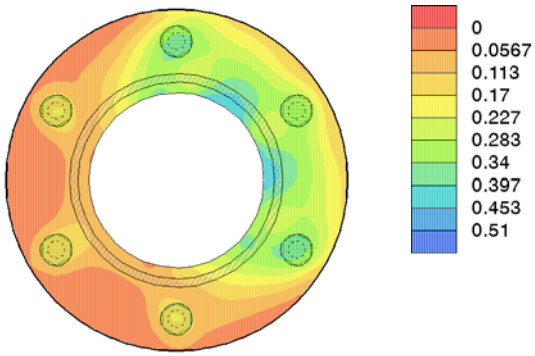
deformations lifting off positive

compression by contact b_z [N/mm²]
min b_z = 0.00 N/mm², max b_z = 73.00 N/mm²



compression by contact compression positive

utilization of end-plate U_p
min U_p = 0.000, max U_p = 0.509



utilization of end-plate

node	x mm	y mm	u_z mm	b_z N/mm²	U_p
969	163.7	0.0	-0.009	73.00	0.206
1384	230.7	141.4	0.351	0.00	0.509

x,y: node coordinates; u_z: deformations (lifting off positive); b_z: compression by contact (compression 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	160.0	290.0	-0.000	98.91	0.300	0.133
2	272.6	225.0	0.017	105.60	0.387	0.172
3	272.6	95.0	0.072	107.39	0.662	0.294
4	160.0	30.0	0.013	104.85	0.365	0.162
5	47.4	95.0	-0.000	98.91	0.300	0.133
6	47.4	225.0	-0.000	98.91	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 1384] $U_{max} = 0.509 < 1$ ok
utilization of bolts due to elongation [bolt 3] $U_{s,max} = 0.294 < 1$ ok
minimum plastic utilization of bolts $U_{pl,s,min} = 0.216 < 1$ ok
plastic utilization of tensile forces of bolts $U_{pl,t,s} = 0.346 < 1$ ok

4.2. bolts

design values: min F_t = 98.91 kN, max F_t = 107.39 kN, V_z = -7.36 kN, V_y = -22.49 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	$U_{tp,1}$ = 0.237	$U_{vt,1}$ = 0.706	$U_{b,1}$ = 0.018	U_1 = 0.706
bolt 2	$U_{tp,2}$ = 0.253	$U_{vt,2}$ = 0.710	$U_{b,2}$ = 0.010	U_2 = 0.710
bolt 3	$U_{tp,3}$ = 0.257	$U_{vt,3}$ = 0.712	$U_{b,3}$ = 0.008	U_3 = 0.712
bolt 4	$U_{tp,4}$ = 0.251	$U_{vt,4}$ = 0.713	$U_{b,4}$ = 0.011	U_4 = 0.713
bolt 5	$U_{tp,5}$ = 0.237	$U_{vt,5}$ = 0.711	$U_{b,5}$ = 0.019	U_5 = 0.711
bolt 6	$U_{tp,6}$ = 0.237	$U_{vt,6}$ = 0.708	$U_{b,6}$ = 0.019	U_6 = 0.708
total:	U_{tp} = 0.257	U_{vt} = 0.713	U_b = 0.019	U = 0.713 < 1 ok

in utilization of bolts max U_s the minimum plastic utilization of bolts min $U_{pl,s}$ = 0.216
and plastic utilization of tensile forces of bolts $U_{pl,t,s}$ = 0.346 is included.

utilization of bolts U_{max} = 0.713 < 1 ok

4.3. total

utilization Lk 3 U_{max} = 0.713 < 1 ok