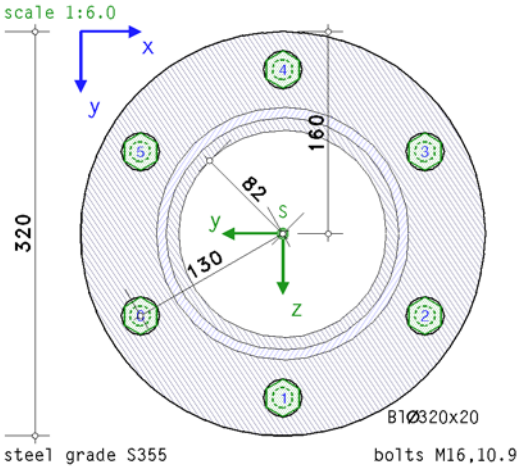
POS. 11: KREISPLATTE PIPEPROFIL

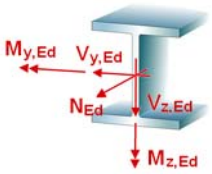
bolted end plate connection EC 3-1-8 (04.25), NA: Deutschland

1. input report



steel grade
steel grade S355
bolts
bolts have to be prestressed with with preloading $F_{p,C}$ = 98.7 kN !!
bolt class 10.9, bolt size M16
large wrench size (high strength bolt), preloaded (for info: preloading $F_{p,C}^* = 0.7 \cdot f_{yb} \cdot A_s$ = 98.7 kN)
thread included in the shear plane
connection
end plate (round): 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
cut out the end plate inside the hollow section
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 = 5448.2 kN/cm
plastic limit force $F_{t,f} = f_{t,f} \cdot F_{t,Rd}$ = 107.2 kN, $f_{t,f}$ = 0.950, $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2}$ = 112.82 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 $F_{p,C}$ = 98.7 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 / Δx = 43 / 7.4 mm, n_y / Δy = 43 / 7.4 mm
max. 50 iteration steps (tolerance limit 5‰)
internal forces and moments refering to local axes of cross-section

Lc	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 Lc 1
2	8.14	0.91	26.78	0.19	-0.10	import Lc 2
3	-26.48	-13.44	-7.36	25.35	-22.49	import Lc 3
4	4.28	-0.25	15.67	0.13	-0.07	import Lc 4
5	-25.83	-18.15	-10.20	4.62	-2.54	import Lc 5
6	8.11	2.52	27.17	0.17	-0.09	import Lc 6
7	-12.99	-11.48	9.05	3.27	-1.80	import Lc 7
8	-6.04	-2.89	-0.91	13.41	-12.51	import Lc 8
9	-25.81	-18.16	-10.15	4.64	-2.55	import Lc 9
10	-30.56	-18.15	-10.20	17.84	-14.94	import Lc 10
11	-25.83	-16.56	-9.76	4.62	-2.54	import Lc 11
12	-30.56	-16.56	-9.76	17.84	-14.94	import Lc 12



Lc	N_{Ed} kN	$M_{y,Ed}$ kNm	$V_{z,Ed}$ kN	$M_{z,Ed}$ kNm	$V_{y,Ed}$ kN	
13	-76.89	20.23	-5.06	-7.70	-1.92	import Lc 17
14	-3.62	0.73	-0.18	-0.28	-0.07	import Lc 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 !

utilizations

Lc	U_p	U_σ	U_b	U_{pl}	$U_{pl,s}$	$U_{wt,s}$	$U_{t,s}$	$U_{vt,s}$	$U_{b,s}$	U
1	0.296	0.296	0.172	0.132	0.168	0.168	0.252	0.696	0.012	0.696
2	0.165	0.107	0.165	0.023	---	0.133	0.236	0.696	0.021	0.696
3	0.304	0.304	0.172	0.216	0.212	0.212	0.256	0.710	0.015	0.710*
4	0.165	0.105	0.165	0.010	---	0.133	0.236	0.667	0.012	0.667
5	0.251	0.251	0.168	0.143	0.137	0.137	0.243	0.666	0.009	0.666
6	0.166	0.113	0.166	0.039	---	0.133	0.236	0.697	0.022	0.697
7	0.182	0.182	0.167	0.096	---	0.133	0.237	0.651	0.007	0.651
8	0.209	0.209	0.167	0.127	---	0.133	0.238	0.662	0.006	0.662
9	0.251	0.251	0.168	0.144	0.137	0.137	0.243	0.666	0.009	0.666
10	0.297	0.297	0.172	0.136	0.170	0.170	0.253	0.697	0.013	0.697
11	0.233	0.233	0.168	0.127	---	0.133	0.241	0.661	0.008	0.661
12	0.293	0.293	0.172	0.132	0.163	0.163	0.251	0.695	0.012	0.695
13	0.245	0.245	0.169	0.081	---	0.135	0.242	0.653	0.004	0.653
14	0.165	0.105	0.165	0.002	---	0.133	0.236	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}: min. plastic utilization of the connection; $U_{pl,s}$: 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 Lc: 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	0.202	0.00	1.14	-6.65	-1.27	181.79	862.10	0.304

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 Lc: 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	98.72	0.133	0.701	0.015	0.701
2	272.6	225.0	103.00	0.147	0.705	0.010	0.705
3	272.6	95.0	107.07	0.212	0.710	0.006	0.710
4	160.0	30.0	102.33	0.142	0.707	0.012	0.707
5	47.4	95.0	98.72	0.133	0.705	0.015	0.705
6	47.4	225.0	98.72	0.133	0.702	0.015	0.702

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 [Lc 3]	max U_p = 0.304 < 1 ok
maximum utilization of bolts due to elongation [Lc 3]	max $U_{wt,s}$ = 0.212 < 1 ok
maximum utilization of bolts [Lc 3]	max U_s = 0.710 < 1 ok
maximum utilization [Lc 3]	**max U = 0.710 < 1 ok**

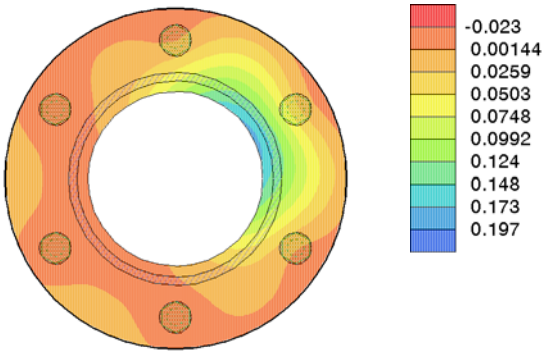
verification succeeded

3. Lc 3 (decisive)

3.1. end plate

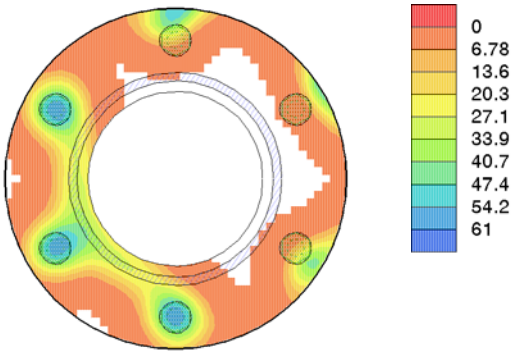
design values: N = -26.48 kN, M_y = -13.44 kNm, M_z = 25.35 kNm

deformations u_z [mm]
min u_z = -0.0225 mm, max u_z = 0.2018 mm



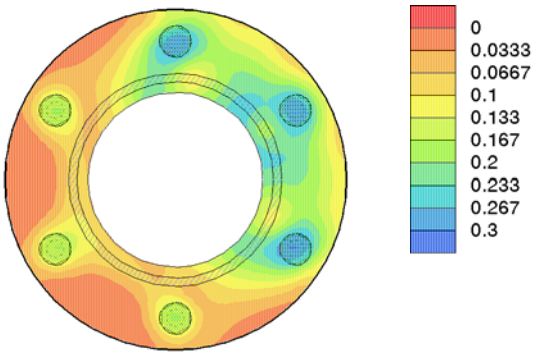
deformations lifting off positive

compression by contact b_z [N/mm²]
min b_z = 0.00 N/mm², max b_z = 61.06 N/mm²



compression by contact compression positive

utilization of end plate U_p
min U_p = 0.000, max U_p = 0.304



utilization of end plate

node	x mm	y mm	u_z mm	b_z N/mm²	U_p
322	52.1	96.7	-0.007	61.06	0.172
1384	230.7	141.4	0.202	0.00	0.304

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	98.72	0.300	0.133
2	272.6	225.0	0.006	103.00	0.330	0.147
3	272.6	95.0	0.035	107.07	0.477	0.212
4	160.0	30.0	0.004	102.33	0.320	0.142
5	47.4	95.0	-0.000	98.72	0.300	0.133
6	47.4	225.0	-0.000	98.72	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] $U_{max} = 0.304 < 1$ ok
utilization of bolts due to elongation [bolt 3] $U_{s,max} = 0.212 < 1$ ok
minimum plastic utilization of the connection $U_{pl,min} = 0.216 < 1$ ok
plastic utilization of tensile forces of bolts $U_{pl,t,s} = 0.212 < 1$ ok

3.2. bolts

design values: min F_t = 98.72 kN, max F_t = 107.07 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	$U_{tp,1} = 0.236$	$U_{vt,1} = 0.701$	$U_{b,1} = 0.015$	$U_1 = 0.701$
bolt 2	$U_{tp,2} = 0.246$	$U_{vt,2} = 0.705$	$U_{b,2} = 0.010$	$U_2 = 0.705$
bolt 3	$U_{tp,3} = 0.256$	$U_{vt,3} = 0.710$	$U_{b,3} = 0.006$	$U_3 = 0.710$
bolt 4	$U_{tp,4} = 0.245$	$U_{vt,4} = 0.707$	$U_{b,4} = 0.012$	$U_4 = 0.707$
bolt 5	$U_{tp,5} = 0.236$	$U_{vt,5} = 0.705$	$U_{b,5} = 0.015$	$U_5 = 0.705$
bolt 6	$U_{tp,6} = 0.236$	$U_{vt,6} = 0.702$	$U_{b,6} = 0.015$	$U_6 = 0.702$
total:	$U_{tp} = 0.256$	$U_{vt} = 0.710$	$U_b = 0.015$	$U = 0.710 < 1$ ok

in utilization of bolts U_{max} ist minimum plastic utilization of the connection $U_{pl,min} = 0.216$
and plastic utilization of tensile forces of bolts $U_{pl,s} = 0.212$ is included.

utilization of bolts $U_{max} = 0.710 < 1$ ok

3.3. total

utilization Lc 3 $U_{max} = 0.710 < 1$ ok

4. 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 1993-1-1:2022, Ausgabe April 2025
EN 1993-1-1/NA, Nationaler Anhang zur EN 1993-1-1, Ausgabe April 2026

EN 1993-1-8, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -
Teil 1-8: Bemessung von Anschlüssen; Deutsche Fassung EN 1993-1-8:2024, Ausgabe April 2025
EN 1993-1-8/NA, Nationaler Anhang zur EN 1993-1-8, Ausgabe April 2026

prEN 1993-1-14, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -
Teil 1-14: Bemessung mithilfe von Finite-Element-Berechnung;
Deutsche und englische Fassung prEN 1993-1-14:2023, Ausgabe September 2023