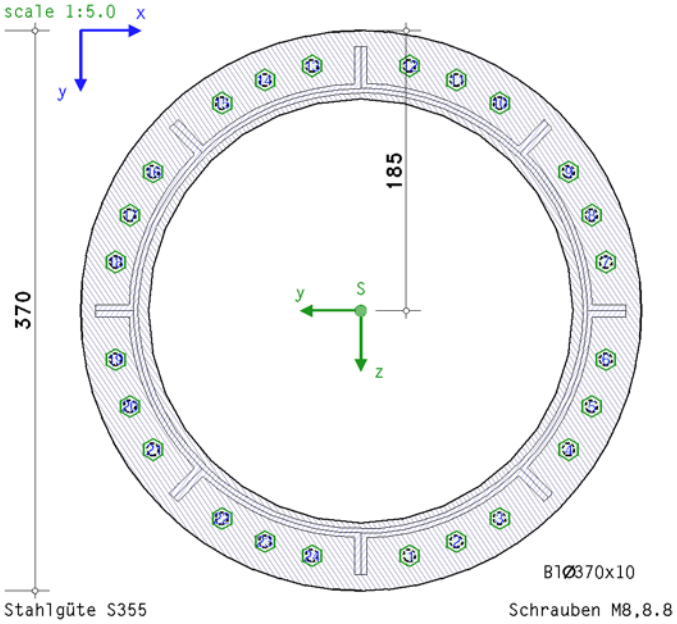
POS. 9: PIPE FLANGE WITH STIFFENERS

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

1. input report

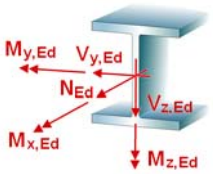


steel grade
steel grade S355
bolts
bolt class 8.8, bolt size M8, normal wrench size
thread included in the shear plane
connection
end-plate (rund): thickness t_p = 10.0 mm, diameter $Ø_p$ = 370.0 mm
beam: h = 349.0 mm, b = 350.0 mm, A = 71.02 cm², y_s = -175.0 mm, z_s = 174.5 mm
I_y = 8091.70 cm⁴, I_z = 8174.31 cm⁴, I_T = 12252.59 cm⁴, I_ω = 41.49 cm⁶
recess in of end-plate (rund): Mittelpunkt x_{of} = 185.0 mm, y_{of} = 185.0 mm, wheelius r_{of} = 140.0 mm
beam-end-plate: surrounding fillet weld, weld thickness a = 4.0 mm
beam section centric on end-plate (beam centroid in plate centre)
coordinates of the beam centroid on end-plate x_s = 185.0 mm, y_s = 185.0 mm
bolts:
coordinates of bolt axis:

x_1 = 217.2 mm, y_1 = 346.8 mm	x_2 = 248.1 mm, y_2 = 337.4 mm	x_3 = 276.7 mm, y_3 = 322.2 mm
x_4 = 322.2 mm, y_4 = 276.7 mm	x_5 = 337.4 mm, y_5 = 248.1 mm	x_6 = 346.8 mm, y_6 = 217.2 mm
x_7 = 346.8 mm, y_7 = 152.8 mm	x_8 = 337.4 mm, y_8 = 121.9 mm	x_9 = 322.2 mm, y_9 = 93.3 mm
x_{10} = 276.7 mm, y_{10} = 47.8 mm	x_{11} = 248.1 mm, y_{11} = 32.6 mm	x_{12} = 217.2 mm, y_{12} = 23.2 mm
x_{13} = 152.8 mm, y_{13} = 23.2 mm	x_{14} = 121.9 mm, y_{14} = 32.6 mm	x_{15} = 93.3 mm, y_{15} = 47.8 mm
x_{16} = 47.8 mm, y_{16} = 93.3 mm	x_{17} = 32.6 mm, y_{17} = 121.9 mm	x_{18} = 23.2 mm, y_{18} = 152.8 mm
x_{19} = 23.2 mm, y_{19} = 217.2 mm	x_{20} = 32.6 mm, y_{20} = 248.1 mm	x_{21} = 47.8 mm, y_{21} = 276.7 mm
x_{22} = 93.3 mm, y_{22} = 322.2 mm	x_{23} = 121.9 mm, y_{23} = 337.4 mm	x_{24} = 152.8 mm, y_{24} = 346.8 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 beam section with the elastic method
verification of bolts, check of distances
FEM-calculation:
bolts are plasticly calculated, spring constant of bolts c_f = 2725.5 kN/cm
plastic limit force $F_{t,f} = f_{t,f} \cdot F_{t,Rd}$ = 20.0 kN, $f_{t,f}$ = 0.950, $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2}$ = 21.08 kN, k_2 = 0.90
effective elongation at failure $\varepsilon_{t,f} = f_{t,\varepsilon} \cdot \varepsilon_{ub}$ = 3.0%, $f_{t,\varepsilon}$ = 0.250, ε_{ub} = 12.0%
without preloading ($F_{p,C}$ = 0)
effective foundation modulus of end plate c_b = 21000.0 kN/cm³
number / dimension of finite elements each direction n_x / Δx = 174 / 2.1 mm, n_y / Δy = 174 / 2.1 mm
max. 50 iteration steps (tolerance limit 5‰)
internal forces and moments refering to local axes of cross-section

Lk 1: N_{Ed} = -75.63 kN, $M_{y,Ed}$ = 20.01 kNm, $V_{z,Ed}$ = -4.97 kN
$M_{z,Ed}$ = -7.59 kNm, $V_{y,Ed}$ = -1.89 kN, $M_{x,Ed}$ = -0.00 kNm
Lk 2: N_{Ed} = -76.89 kN, $M_{y,Ed}$ = 20.26 kNm, $V_{z,Ed}$ = -5.04 kN
$M_{z,Ed}$ = -7.69 kNm, $V_{y,Ed}$ = -1.91 kN, $M_{x,Ed}$ = -0.00 kNm
Lk 3: N_{Ed} = -16.41 kN, $M_{y,Ed}$ = -41.41 kNm, $V_{z,Ed}$ = 26.17 kN
$M_{z,Ed}$ = -7.60 kNm, $V_{y,Ed}$ = -1.90 kN, $M_{x,Ed}$ = -0.45 kNm
Lk 4: N_{Ed} = -17.52 kN, $M_{y,Ed}$ = -41.70 kNm, $V_{z,Ed}$ = 26.19 kN
$M_{z,Ed}$ = -7.69 kNm, $V_{y,Ed}$ = -1.92 kN, $M_{x,Ed}$ = -0.45 kNm



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

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
1	0.172	0.172	0.053	0.071	0.273	0.055	0.089	0.315	0.004	0.153	0.106	0.315
2	0.174	0.174	0.054	0.071	0.276	0.056	0.090	0.318	0.004	0.155	0.106	0.318
3	0.598	0.598	0.089	0.454	0.792	0.378	0.199	0.685	0.025	0.259	0.137	0.792
4	0.605	0.605	0.089	0.455	0.798	0.390	0.199	0.685	0.025	0.261	0.138	0.798*

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: total utilization
*) maximum utilization

2. final result

maximum utilization of end-plate due to 4 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
15226	185.0	0.0	0.259	0.00	-5.76	-0.92	-0.05	2.13	-53.04	0.605

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 4 Lk: max U_s with corresponding values

	x mm	y mm	Ft kN	U_{wt}	U_{vt}	U_b	U_s
1	217.2	346.8	8.18	0.050	0.288	0.002	0.288
2	248.1	337.4	0.33	0.002	0.135	0.023	0.199
3	276.7	322.2	0.35	0.002	0.137	0.024	0.199
4	322.2	276.7	0.27	0.002	0.138	0.024	0.199
5	337.4	248.1	0.02	---	0.132	0.025	0.199
6	346.8	217.2	0.51	0.003	0.146	0.024	0.199
7	346.8	152.8	3.13	0.019	0.219	0.021	0.219
8	337.4	121.9	5.64	0.034	0.288	0.018	0.288
9	322.2	93.3	12.61	0.077	0.480	0.010	0.480
10	276.7	47.8	18.06	0.122	0.631	0.004	0.631
11	248.1	32.6	19.71	0.175	0.676	0.002	0.676
12	217.2	23.2	20.03	0.352	0.685	0.001	0.685
13	152.8	23.2	20.03	0.390	0.685	0.001	0.685
14	121.9	32.6	20.03	0.243	0.685	0.001	0.685
15	93.3	47.8	20.03	0.228	0.685	0.001	0.685
16	47.8	93.3	19.75	0.156	0.676	0.001	0.676
17	32.6	121.9	13.35	0.082	0.494	0.008	0.494
18	23.2	152.8	8.41	0.051	0.353	0.013	0.353
19	23.2	217.2	2.99	0.018	0.198	0.018	0.199
20	32.6	248.1	0.00	---	0.113	0.021	0.199
21	47.8	276.7	7.87	0.048	0.278	0.002	0.278
22	93.3	322.2	8.86	0.054	0.311	0.002	0.311
23	121.9	337.4	7.76	0.047	0.274	0.002	0.274
24	152.8	346.8	9.08	0.056	0.318	0.002	0.318

x,y: bolt coordinates; Ft: 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]	max U_p = 0.605 < 1 ok
maximum utilization of bolts due to elongation [Lk 4]	max $U_{wt,s}$ = 0.390 < 1 ok
maximum utilization of bolts [Lk 4]	max U_s = 0.798 < 1 ok
maximum utilization of the beam [Lk 4]	max (U_q,U_{ct}) = 0.261 < 1 ok
maximum utilization [Lk 4]	**max U = 0.798 < 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

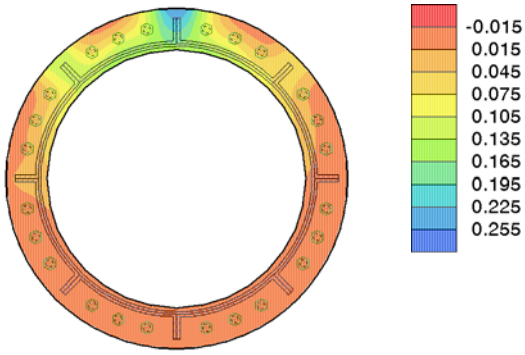
EN 1993-1-8, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -
Teil 1-8: Bemessung von Anschlüssen;
Deutsche Fassung EN 1993-1-8:2005 + AC:2009, Ausgabe Dezember 2010
EN 1993-1-8/NA, Nationaler Anhang zur EN 1993-1-8, Ausgabe Dezember 2010

4. Lk 4 (decisive)

4.1. end-plate

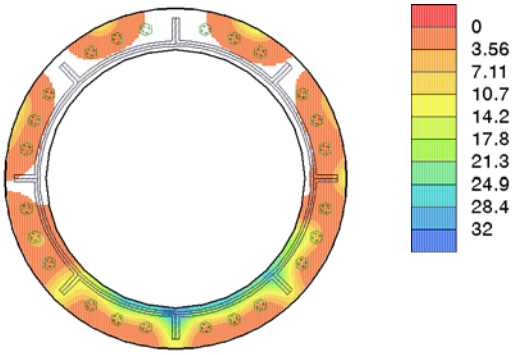
design values: N = -17.52 kN, M_y = -41.70 kNm, M_z = -7.69 kNm

deformations u_z [mm]
min u_z = -0.0149 mm, max u_z = 0.2593 mm



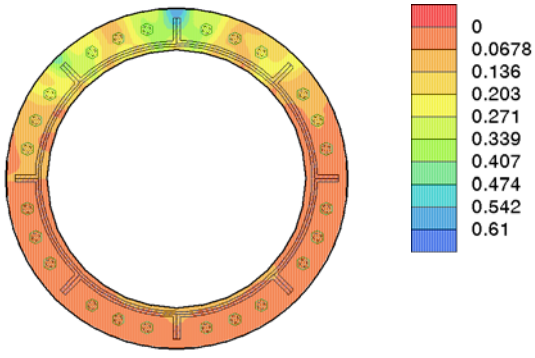
deformations lifting off positive

compression by contact b_z [N/mm²]
min b_z = 0.00 N/mm², max b_z = 31.74 N/mm²



compression by contact compression positive

utilization of end-plate U_p
min U_p = 0.000, max U_p = 0.605



utilization of end-plate

node	x mm	y mm	u_z mm	b_z N/mm²	U_p
15051	182.9	0.0	0.259	0.00	0.600
15226	185.0	0.0	0.259	0.00	0.605
15379	185.0	325.3	-0.002	31.74	0.089

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	wt mm	Ft kN	εwt %	Uwt
1	217.2	346.8	0.001	0.40	0.007	0.002
2	248.1	337.4	0.001	0.33	0.006	0.002
3	276.7	322.2	0.001	0.35	0.006	0.002
4	322.2	276.7	0.000	0.27	0.005	0.002
5	337.4	248.1	-0.000	0.02	0.000	---
6	346.8	217.2	0.001	0.51	0.009	0.003
7	346.8	152.8	0.006	3.13	0.057	0.019
8	337.4	121.9	0.010	5.64	0.103	0.034
9	322.2	93.3	0.023	12.61	0.231	0.077
10	276.7	47.8	0.037	18.06	0.367	0.122
11	248.1	32.6	0.053	19.71	0.525	0.175
12	217.2	23.2	0.106	20.03	1.057	0.352
13	152.8	23.2	0.117	20.03	1.170	0.390
14	121.9	32.6	0.073	20.03	0.729	0.243
15	93.3	47.8	0.069	20.03	0.685	0.228
16	47.8	93.3	0.047	19.75	0.467	0.156
17	32.6	121.9	0.025	13.35	0.247	0.082
18	23.2	152.8	0.015	8.41	0.154	0.051
19	23.2	217.2	0.005	3.00	0.055	0.018
20	32.6	248.1	-0.000	0.00	0.000	---
21	47.8	276.7	0.000	0.05	0.001	0.000
22	93.3	322.2	0.001	0.30	0.005	0.002
23	121.9	337.4	0.001	0.30	0.005	0.002
24	152.8	346.8	0.001	0.41	0.008	0.003

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 15226] $U_{max} = 0.605 < 1$ ok
utilization of bolts due to elongation [bolt 13] $U_{s,max} = 0.390 < 1$ ok
minimum plastic utilization of bolts $U_{pl,s,min} = 0.455 < 1$ ok
plastic utilization of tensile forces of bolts $U_{pl,t,s} = 0.798 < 1$ ok

4.2. bolts

design values: max $F_t = 20.03$ kN, $V_z = 26.19$ kN, $V_y = -1.92$ kN, $M_x = -0.45$ 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	$U_{tp,1} = 0.004$	$U_{vt,1} = 0.136$	$U_{b,1} = 0.025$	$U_1 = 0.136$
bolt 2	$U_{tp,2} = 0.003$	$U_{vt,2} = 0.136$	$U_{b,2} = 0.024$	$U_2 = 0.136$
bolt 3	$U_{tp,3} = 0.004$	$U_{vt,3} = 0.138$	$U_{b,3} = 0.024$	$U_3 = 0.138$
bolt 4	$U_{tp,4} = 0.003$	$U_{vt,4} = 0.138$	$U_{b,4} = 0.024$	$U_4 = 0.138$
bolt 5	$U_{tp,5} = 0.000$	$U_{vt,5} = 0.133$	$U_{b,5} = 0.025$	$U_5 = 0.133$
bolt 6	$U_{tp,6} = 0.005$	$U_{vt,6} = 0.147$	$U_{b,6} = 0.025$	$U_6 = 0.147$
bolt 7	$U_{tp,7} = 0.031$	$U_{vt,7} = 0.219$	$U_{b,7} = 0.021$	$U_7 = 0.219$
bolt 8	$U_{tp,8} = 0.056$	$U_{vt,8} = 0.288$	$U_{b,8} = 0.018$	$U_8 = 0.288$
bolt 9	$U_{tp,9} = 0.125$	$U_{vt,9} = 0.480$	$U_{b,9} = 0.010$	$U_9 = 0.480$
bolt 10	$U_{tp,10} = 0.180$	$U_{vt,10} = 0.631$	$U_{b,10} = 0.004$	$U_{10} = 0.631$
bolt 11	$U_{tp,11} = 0.196$	$U_{vt,11} = 0.676$	$U_{b,11} = 0.002$	$U_{11} = 0.676$
bolt 12	$U_{tp,12} = 0.199$	$U_{vt,12} = 0.685$	$U_{b,12} = 0.001$	$U_{12} = 0.685$
bolt 13	$U_{tp,13} = 0.199$	$U_{vt,13} = 0.685$	$U_{b,13} = 0.001$	$U_{13} = 0.685$
bolt 14	$U_{tp,14} = 0.199$	$U_{vt,14} = 0.685$	$U_{b,14} = 0.001$	$U_{14} = 0.685$
bolt 15	$U_{tp,15} = 0.199$	$U_{vt,15} = 0.685$	$U_{b,15} = 0.001$	$U_{15} = 0.685$
bolt 16	$U_{tp,16} = 0.197$	$U_{vt,16} = 0.676$	$U_{b,16} = 0.001$	$U_{16} = 0.676$
bolt 17	$U_{tp,17} = 0.133$	$U_{vt,17} = 0.494$	$U_{b,17} = 0.008$	$U_{17} = 0.494$
bolt 18	$U_{tp,18} = 0.084$	$U_{vt,18} = 0.353$	$U_{b,18} = 0.013$	$U_{18} = 0.353$
bolt 19	$U_{tp,19} = 0.030$	$U_{vt,19} = 0.198$	$U_{b,19} = 0.018$	$U_{19} = 0.198$
bolt 20	$U_{tp,20} = 0.000$	$U_{vt,20} = 0.113$	$U_{b,20} = 0.021$	$U_{20} = 0.113$
bolt 21	$U_{tp,21} = 0.000$	$U_{vt,21} = 0.116$	$U_{b,21} = 0.022$	$U_{21} = 0.116$
bolt 22	$U_{tp,22} = 0.003$	$U_{vt,22} = 0.125$	$U_{b,22} = 0.022$	$U_{22} = 0.125$
bolt 23	$U_{tp,23} = 0.003$	$U_{vt,23} = 0.127$	$U_{b,23} = 0.022$	$U_{23} = 0.127$
bolt 24	$U_{tp,24} = 0.004$	$U_{vt,24} = 0.132$	$U_{b,24} = 0.025$	$U_{24} = 0.132$
total:	$U_{tp} = 0.199$	$U_{vt} = 0.685$	$U_b = 0.025$	$U = 0.685 < 1$ ok

in utilization of bolts max U_s the minimum plastic utilization of bolts min $U_{pl,s} = 0.455$
and plastic utilization of tensile forces of bolts $U_{pl,t,s} = 0.798$ is included.

utilization of bolts $U_{max} = 0.798 < 1$ ok

4.3. beam

elastic verification for $N = -17.52$ kN, $M_y = -41.70$ kNm, $V_z = 26.19$ kN, $M_z = -7.69$ kNm
$V_y = -1.92$ kN, $T_t = -0.45$ kNm
verification: $\sigma_v = 92.77$ N/mm² $<$ $\sigma_{v,Rd} = 355.00$ N/mm² $\Rightarrow$ $U_\sigma = 0.261 < 1$ ok
c/t-verification: utilization $U_{c/t} = 0.138 < 1$ ok

utilization of the beam $\max(U_\sigma, U_{c/t}) = 0.261 < 1$ ok

4.4. total

utilization Lk 4 $U_{max} = 0.798 < 1$ ok