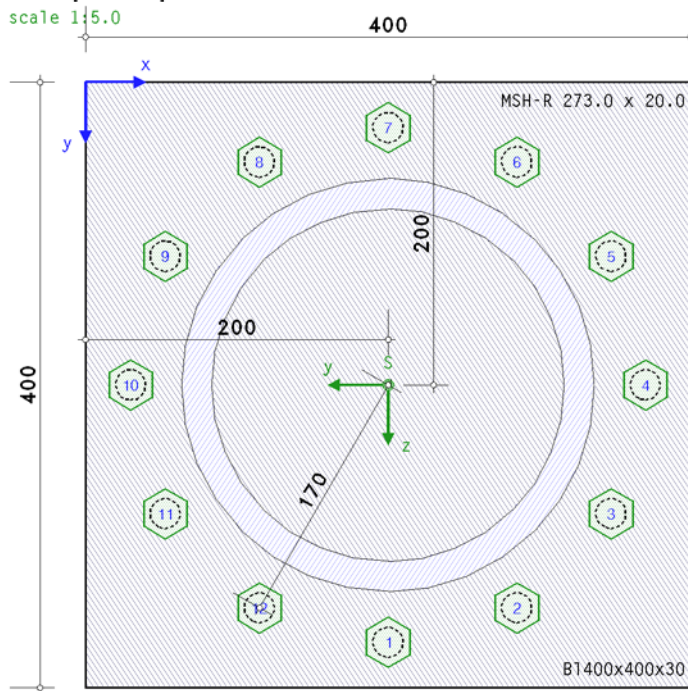


POS. 7: ROUND TUBE

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

bolt class 10.9, bolt size M20, normal wrench size

thread included in the shear plane

connection

end-plate (rectangular): thickness $t_p = 30.0$ mm, width $b_p = 400.0$ mm, length $l_p = 400.0$ mm

beam: section MSH-R 273.0 x 20.0

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:

circular arrangement of 12 bolts with radius $r = 170.0$ mm around centroid of beam section

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 plastic method

verification of welds with the directional method

verification of bolts, check of distances

FEM-calculation:

bolts are plastically calculated, spring constant of bolts $c_f = 6533.3$ kN/cm

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

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

without preloading ($F_{p,c} = 0$)

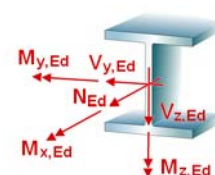
effective foundation modulus of end plate $c_b = 7000.0$ kN/cm³

number / dimension of finite elements each direction $n_x / \Delta x = 53 / 7.5$ mm, $n_y / \Delta y = 53 / 7.5$ 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	-169.42	-183.86	-36.77	91.74	-18.35	50.10
2	60.30	22.74	4.55	-184.49	18.15	-83.61
3	-143.32	-138.74	-27.75	127.81	-25.56	63.40
4	23.41	-40.87	-8.17	-182.80	17.81	-87.44
5	-106.43	-75.13	-15.03	126.12	-25.22	67.22
6	-168.10	-175.68	-35.14	89.63	-17.93	54.78
7	59.38	17.02	3.40	-183.00	17.85	-86.89



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 $e = 30.0 \text{ mm} < 37.0 \text{ mm}$).
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 $U_{pl,t,s}$ 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_{ct}	U_w	U
1	0.816	0.816	0.262	0.392	0.897	0.624	0.240	0.733	0.115	0.483	0.295	0.525	0.897
2	0.801	0.801	0.224	0.514	0.939	0.715	0.240	1.030	0.220	0.476	0.295	0.460	1.030!
3	0.720	0.720	0.301	0.288	0.780	0.406	0.240	0.772	0.129	0.461	0.295	0.480	0.780
4	0.791	0.791	0.239	0.490	0.888	0.614	0.240	1.082	0.248	0.485	0.295	0.457	1.082*
5	0.523	0.523	0.185	0.274	0.602	0.214	0.230	0.722	0.118	0.380	0.295	0.373	0.722
6	0.764	0.764	0.280	0.371	0.849	0.505	0.240	0.742	0.118	0.470	0.295	0.505	0.849
7	0.788	0.788	0.232	0.510	0.928	0.654	0.240	1.056	0.223	0.477	0.295	0.455	1.056!

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 7 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
1795	249.1	90.6	0.643	0.00	-58.68	-68.43	6.63	-16.51	-84.84	0.816

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 7 Lk: max U_s with corresponding values

	x mm	y mm	F_t kN	U_{wt}	U_{vt}	U_b	U_s
1	200.0	370.0	20.36	0.023	1.082	0.248	1.082 > 1
2	285.0	347.2	5.76	0.006	0.994	0.162	0.994
3	347.2	285.0	76.39	0.087	0.772	0.078	0.772
4	370.0	200.0	149.35	0.198	0.744	0.029	0.744
5	347.2	115.0	167.58	0.391	0.726	0.009	0.726
6	285.0	52.8	15.18	0.017	0.976	0.152	0.976
7	200.0	30.0	38.51	0.044	1.056	0.223	1.056 > 1
8	115.0	52.8	155.31	0.203	0.796	0.032	0.796
9	52.8	115.0	167.58	0.606	0.758	0.014	0.758
10	30.0	200.0	167.58	0.654	0.760	0.016	0.760
11	52.8	285.0	167.58	0.569	0.759	0.014	0.759
12	115.0	347.2	131.03	0.152	0.884	0.068	0.884

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 1]

maximum utilization of bolts due to elongation [Lk 2]

maximum utilization of bolts [Lk 4]

maximum utilization of the beam [Lk 4]

maximum utilization of welds [Lk 1]

maximum utilization [Lk 4]

max $U_p = 0.816 < 1$ ok

max $U_{wt,s} = 0.715 < 1$ ok

max $U_s = 1.082 > 1$ not ok !!

max $(U_q, U_{ct}) = 0.485 < 1$ ok

max $U_w = 0.525 < 1$ ok

max $U = 1.082 > 1$ not ok !!

resistance not ensured !!

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;

4. Lk 4 (decisive)

4.1. end-plate

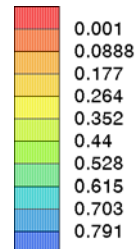
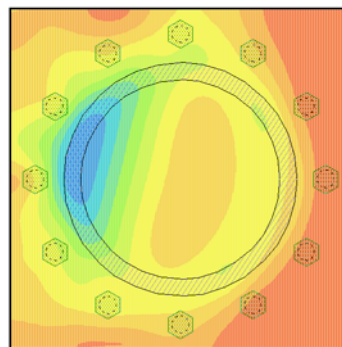
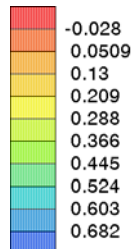
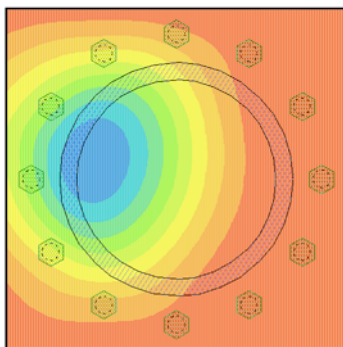
design values: $N = 23.41$ kN, $M_y = -40.87$ kNm, $M_z = -182.80$ kNm

deformations u_z [mm]

min $u_z = -0.0277$ mm, max $u_z = 0.6783$ mm

utilization of end-plate U_p

min $U_p = 0.001$, max $U_p = 0.791$



deformations lifting off positive

utilization of end-plate

node	x mm	y mm	u_z mm	U_p
619	83.0	181.1	0.660	0.791
726	98.1	173.6	0.678	0.746

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	200.0	370.0	0.016	20.36	0.052	0.023
2	285.0	347.2	-0.003	0.01	0.000	---
3	347.2	285.0	0.001	2.06	0.002	0.001
4	370.0	200.0	0.001	2.31	0.003	0.001
5	347.2	115.0	-0.003	0.06	0.000	---
6	285.0	52.8	0.012	15.18	0.039	0.017
7	200.0	30.0	0.071	92.27	0.236	0.105
8	115.0	52.8	0.227	167.58	0.755	0.336
9	52.8	115.0	0.409	167.58	1.363	0.606
10	30.0	200.0	0.415	167.58	1.382	0.614
11	52.8	285.0	0.263	167.58	0.875	0.389
12	115.0	347.2	0.103	131.03	0.342	0.152

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 619] $U_{max} = 0.791 < 1$ ok

utilization of bolts due to elongation [bolt 10] $U_{s,max} = 0.614 < 1$ ok

minimum plastic utilization of bolts $U_{pl,s,min} = 0.490 < 1$ ok

plastic utilization of tensile forces of bolts $U_{pl,t,s} = 0.888 < 1$ ok

4.2. bolts

design values: min $F_t = 0.01$ kN, max $F_t = 167.58$ kN, $V_z = -8.17$ kN, $V_y = 17.81$ kN,
 $M_x = -87.44$ 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	$U_{tp,1} = 0.029$	$U_{vt,1} = 1.082$	$U_{b,1} = 0.248$	$U_1 = 1.082$
bolt 2	$U_{tp,2} = 0.000$	$U_{vt,2} = 0.846$	$U_{b,2} = 0.141$	$U_2 = 0.846$
bolt 3	$U_{tp,3} = 0.003$	$U_{vt,3} = 0.591$	$U_{b,3} = 0.112$	$U_3 = 0.591$
bolt 4	$U_{tp,4} = 0.003$	$U_{vt,4} = 0.525$	$U_{b,4} = 0.104$	$U_4 = 0.525$
bolt 5	$U_{tp,5} = 0.000$	$U_{vt,5} = 0.716$	$U_{b,5} = 0.142$	$U_5 = 0.716$
bolt 6	$U_{tp,6} = 0.022$	$U_{vt,6} = 0.976$	$U_{b,6} = 0.152$	$U_6 = 0.976$
bolt 7	$U_{tp,7} = 0.132$	$U_{vt,7} = 0.979$	$U_{b,7} = 0.144$	$U_7 = 0.979$
bolt 8	$U_{tp,8} = 0.240$	$U_{vt,8} = 0.752$	$U_{b,8} = 0.014$	$U_8 = 0.752$
bolt 9	$U_{tp,9} = 0.240$	$U_{vt,9} = 0.758$	$U_{b,9} = 0.014$	$U_9 = 0.758$
bolt 10	$U_{tp,10} = 0.240$	$U_{vt,10} = 0.759$	$U_{b,10} = 0.016$	$U_{10} = 0.759$

bolt 11	$U_{tp,11} = 0.240$	$U_{vt,11} = 0.756$	$U_{b,11} = 0.013$	$U_{11} = 0.756$
bolt 12	$U_{tp,12} = 0.188$	$U_{vt,12} = 0.884$	$U_{b,12} = 0.068$	$U_{12} = 0.884$
total:	$U_{tp} = 0.240$	$U_{vt} = 1.082$	$U_b = 0.248$	$U = 1.082 > 1$ not ok !!

in utilization of bolts max U_s the minimum plastic utilization of bolts $U_{pl,s} = 0.490$
and plastic utilization of tensile forces of bolts $U_{pl,t,s} = 0.888$ is included.

utilization of bolts $U_{max} = 1.082 > 1$ **not ok !!**

4.3. beam

plastic verification for $N = 23.41$ kN, $M_y = -40.87$ kNm, $V_z = -8.17$ kN, $M_z = -182.80$ kNm

$V_y = 17.81$ kN, $T_t = -87.44$ kNm

internal forces and moments reg. yz-direction in kN, m: $M_y = -40.87$, $M_z = -182.80$, $V_y = 17.81$, $V_z = -8.17$

partial internal forces and moments of lines of cross-section in kN, m:

- 1: $N = -143.67$, $M_y = 0.00$, $M_z = -0.00$, $V_y = 45.15$, $V_z = 8.98$, $T = -0.05$
- 2: $N = -144.88$, $M_y = 0.00$, $M_z = -0.00$, $V_y = 37.69$, $V_z = 25.18$, $T = -0.05$
- 3: $N = -146.43$, $M_y = 0.00$, $M_z = -0.00$, $V_y = 24.69$, $V_z = 36.95$, $T = -0.05$
- 4: $N = -148.08$, $M_y = 0.00$, $M_z = -0.00$, $V_y = 8.48$, $V_z = 42.64$, $T = -0.05$
- 5: $N = -149.58$, $M_y = 0.00$, $M_z = 0.00$, $V_y = -8.31$, $V_z = 41.79$, $T = -0.05$
- 6: $N = -150.70$, $M_y = 0.00$, $M_z = 0.00$, $V_y = -23.31$, $V_z = 34.89$, $T = -0.05$
- 7: $N = -151.28$, $M_y = 0.00$, $M_z = 0.00$, $V_y = -34.61$, $V_z = 23.13$, $T = -0.05$
- 8: $N = 34.41$, $M_y = -0.31$, $M_z = -1.57$, $V_y = -40.86$, $V_z = 8.13$, $T = -0.05$
- 9: $N = -1.14$, $M_y = -0.34$, $M_z = -1.72$, $V_y = 45.54$, $V_z = -9.06$, $T = -0.05$
- 10: $N = 142.92$, $M_y = 0.00$, $M_z = 0.00$, $V_y = 38.63$, $V_z = -25.81$, $T = -0.05$
- 11: $N = 143.49$, $M_y = 0.00$, $M_z = 0.00$, $V_y = 25.63$, $V_z = -38.36$, $T = -0.05$
- 12: $N = 144.61$, $M_y = 0.00$, $M_z = 0.00$, $V_y = 8.87$, $V_z = -44.61$, $T = -0.05$
- 13: $N = 146.11$, $M_y = 0.00$, $M_z = -0.00$, $V_y = -8.70$, $V_z = -43.76$, $T = -0.05$
- 14: $N = 147.77$, $M_y = 0.00$, $M_z = -0.00$, $V_y = -24.26$, $V_z = -36.30$, $T = -0.05$
- 15: $N = 149.31$, $M_y = 0.00$, $M_z = -0.00$, $V_y = -35.56$, $V_z = -23.76$, $T = -0.05$
- 16: $N = 150.52$, $M_y = 0.00$, $M_z = -0.00$, $V_y = -41.25$, $V_z = -8.21$, $T = -0.05$

utilizations of lines of cross-section

- 1: $U_\sigma = 0.410$, $U_\tau = 0.243$, $U = 0.476$
- 2: $U_\sigma = 0.413$, $U_\tau = 0.239$, $U = 0.478$
- 3: $U_\sigma = 0.418$, $U_\tau = 0.235$, $U = 0.479$
- 4: $U_\sigma = 0.423$, $U_\tau = 0.230$, $U = 0.481$
- 5: $U_\sigma = 0.427$, $U_\tau = 0.226$, $U = 0.483$
- 6: $U_\sigma = 0.430$, $U_\tau = 0.222$, $U = 0.484$
- 7: $U_\sigma = 0.432$, $U_\tau = 0.221$, $U = 0.485$
- 8: $U_\sigma = 0.395$, $U_\tau = 0.221$, $U = 0.453$
- 9: $U_\sigma = 0.406$, $U_\tau = 0.244$, $U = 0.474$
- 10: $U_\sigma = 0.408$, $U_\tau = 0.245$, $U = 0.476$
- 11: $U_\sigma = 0.409$, $U_\tau = 0.243$, $U = 0.476$
- 12: $U_\sigma = 0.413$, $U_\tau = 0.240$, $U = 0.477$
- 13: $U_\sigma = 0.417$, $U_\tau = 0.236$, $U = 0.479$
- 14: $U_\sigma = 0.422$, $U_\tau = 0.231$, $U = 0.481$
- 15: $U_\sigma = 0.426$, $U_\tau = 0.226$, $U = 0.482$
- 16: $U_\sigma = 0.430$, $U_\tau = 0.223$, $U = 0.484$

max. load factor (plastic): $f_{pl} = 2.062$

no equilibrium of warping at limit state: $\Delta B = -0.039$ kNm²

utilization (without equilibrium of warping): $U_{pl} = 0.485$

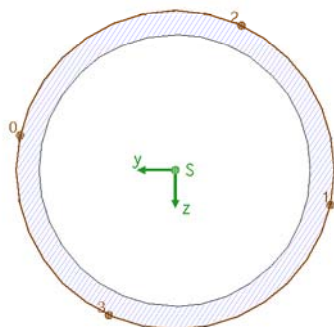
verification: $U_{pl} = 0.485 < 1$ **ok**

c/t-verification: utilization $U_{c/t} = 0.295 < 1$ **ok**

utilization of the beam $\max(U_\sigma, U_{c/t}) = 0.485 < 1$ **ok**

4.4. welds

design values: $N = 23.41$ kN, $M_y = -40.87$ kNm, $V_z = -8.17$ kN, $M_z = -182.80$ kNm,
 $V_y = 17.81$ kN, $M_x = -87.44$ kNm



weld 1: $a_w = 20.0$ mm $l_w = 857.7$ mm

Max: $\sigma_{1,w,Ed} = 174.15$ N/mm² $< f_{1w,d} = 435.56$ N/mm²,

$$\sigma_{2,w,Ed} = 161.36 \text{ N/mm}^2 < f_{2w,d} = 352.80 \text{ N/mm}^2 \Rightarrow U_w = 0.457 < 1 \text{ ok}$$

utilization of welds $U_{\max} = 0.457 < 1$ ok

4.5. total

utilization Lk 4 $U_{\max} = 1.082 > 1$ not ok !!