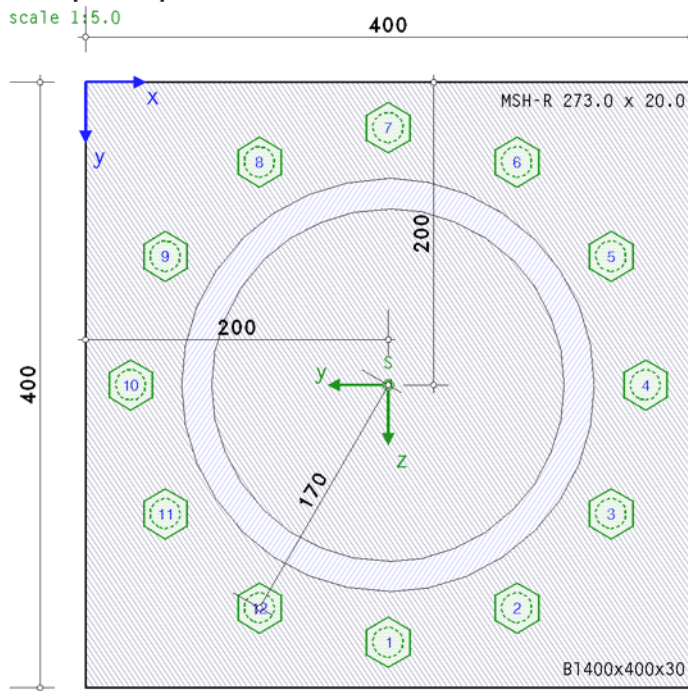


POS. 6: MSH

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

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 $c_f = 6528.0$ kN/cm

plastic limit force $F_{t,f} = f_{t,f} \cdot F_{t,Rd} = 167.4$ kN, $f_{t,f} = 0.950$, $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2} = 176.26$ 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 ($F_{p,c} = 0$)

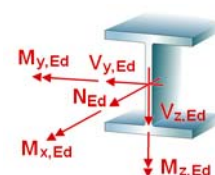
effective foundation modulus of end plate $c_b = 7000.0$ kN/cm³

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

Lc	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 !

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_q	$U_{c/t}$	U_w	U
1	0.660	0.660	0.266	0.392	0.854	0.509	0.240	0.724	0.106	0.455	0.295	0.536	0.854
2	0.647	0.647	0.228	0.514	0.893	0.566	0.240	1.005	0.207	0.410	0.295	0.492	1.005!
3	0.582	0.582	0.253	0.288	0.744	0.340	0.240	0.752	0.122	0.417	0.295	0.498	0.752
4	0.636	0.636	0.233	0.491	0.840	0.490	0.240	1.033	0.231	0.413	0.295	0.494	1.033!
5	0.441	0.441	0.187	0.274	0.562	0.193	0.221	0.713	0.117	0.324	0.295	0.399	0.713
6	0.622	0.622	0.255	0.372	0.803	0.411	0.240	0.732	0.110	0.436	0.295	0.518	0.803
7	0.640	0.640	0.225	0.510	0.880	0.518	0.240	1.037	0.210	0.406	0.295	0.490	1.037*

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_q : stress utilization of the beam; $U_{c/t}$: 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 Lc: 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
1848	256.6	83.0	0.496	0.00	-45.93	-55.30	7.10	89.63	-135.19	0.660

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 Lc: 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	60.86	0.069	1.037	0.187	1.037 > 1
2	285.0	347.2	5.19	0.006	0.949	0.129	0.949
3	347.2	285.0	69.21	0.079	0.752	0.066	0.752
4	370.0	200.0	142.09	0.176	0.743	0.037	0.743
5	347.2	115.0	167.44	0.328	0.724	0.007	0.724
6	285.0	52.8	13.73	0.016	0.933	0.122	0.933
7	200.0	30.0	34.20	0.039	1.012	0.210	1.012 > 1
8	115.0	52.8	142.86	0.172	0.827	0.040	0.827
9	52.8	115.0	167.44	0.486	0.754	0.011	0.754
10	30.0	200.0	167.44	0.518	0.755	0.017	0.755
11	52.8	285.0	167.44	0.453	0.754	0.011	0.754
12	115.0	347.2	116.31	0.133	0.912	0.071	0.912

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 1]

maximum utilization of bolts due to elongation [Lc 2]

maximum utilization of bolts [Lc 7]

maximum utilization of the beam [Lc 1]

maximum utilization of welds [Lc 1]

maximum utilization [Lc 7]

max $U_p = 0.660 < 1$ ok

max $U_{wt,s} = 0.566 < 1$ ok

max $U_s = 1.037 > 1$ not ok !!

max $(U_q, U_{ct}) = 0.455 < 1$ ok

max $U_w = 0.536 < 1$ ok

max $U = 1.037 > 1$ not ok !!

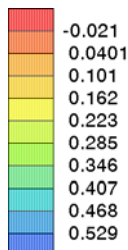
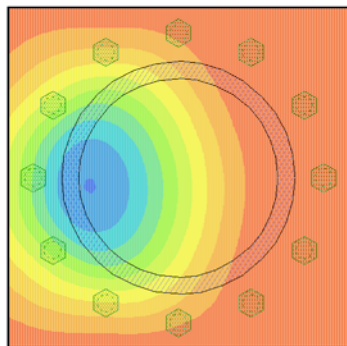
resistance not ensured !!

3. Lc 7 (decisive)

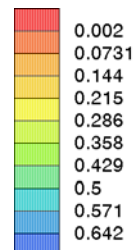
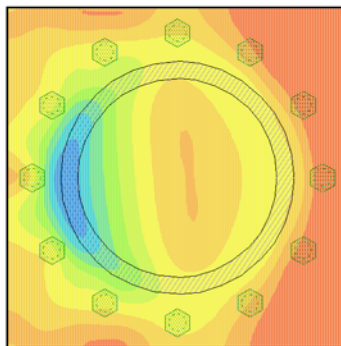
3.1. end plate

design values: $N = 59.38$ kN, $M_y = 17.02$ kNm, $M_z = -183.00$ kNm

deformations u_z [mm]
min $u_z = -0.0212$ mm, max $u_z = 0.5307$ mm



utilization of end plate U_p
min $U_p = 0.001$, max $U_p = 0.640$



deformations lifting off positive

utilization of end plate

node	x mm	y mm	u_z mm	U_p
514	67.9	203.8	0.498	0.640
730	98.1	203.8	0.530	0.498

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	0.047	60.86	0.155	0.069
2	285.0	347.2	0.004	5.19	0.013	0.006
3	347.2	285.0	-0.002	0.37	0.000	---
4	370.0	200.0	0.001	2.70	0.004	0.002
5	347.2	115.0	-0.000	1.39	0.000	---
6	285.0	52.8	-0.002	0.01	0.000	---
7	200.0	30.0	0.026	34.20	0.087	0.039
8	115.0	52.8	0.116	142.86	0.387	0.172
9	52.8	115.0	0.257	167.44	0.858	0.381
10	30.0	200.0	0.349	167.44	1.165	0.518
11	52.8	285.0	0.306	167.44	1.019	0.453
12	115.0	347.2	0.157	163.80	0.523	0.232

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 514] $U_{max} = 0.640 < 1$ ok

utilization of bolts due to elongation [bolt 10] $U_{s,max} = 0.518 < 1$ ok

minimum plastic utilization of the connection $U_{pl,min} = 0.510 < 1$ ok

plastic utilization of tensile forces of bolts $U_{pl,t,s} = 0.880 < 1$ ok

3.2. bolts

design values: min $F_t = 0.01$ kN, max $F_t = 167.44$ kN, $V_z = 3.40$ kN, $V_y = 17.85$ kN,
 $M_x = -86.89$ 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	$U_{tp,1} = 0.087$	$U_{vt,1} = 1.037$	$U_{b,1} = 0.187$	$U_1 = 1.037$
bolt 2	$U_{tp,2} = 0.007$	$U_{vt,2} = 0.949$	$U_{b,2} = 0.129$	$U_2 = 0.949$
bolt 3	$U_{tp,3} = 0.001$	$U_{vt,3} = 0.693$	$U_{b,3} = 0.113$	$U_3 = 0.693$
bolt 4	$U_{tp,4} = 0.004$	$U_{vt,4} = 0.522$	$U_{b,4} = 0.113$	$U_4 = 0.522$
bolt 5	$U_{tp,5} = 0.002$	$U_{vt,5} = 0.584$	$U_{b,5} = 0.092$	$U_5 = 0.584$
bolt 6	$U_{tp,6} = 0.000$	$U_{vt,6} = 0.819$	$U_{b,6} = 0.114$	$U_6 = 0.819$
bolt 7	$U_{tp,7} = 0.049$	$U_{vt,7} = 1.012$	$U_{b,7} = 0.210$	$U_7 = 1.012$
bolt 8	$U_{tp,8} = 0.205$	$U_{vt,8} = 0.827$	$U_{b,8} = 0.040$	$U_8 = 0.827$
bolt 9	$U_{tp,9} = 0.240$	$U_{vt,9} = 0.752$	$U_{b,9} = 0.010$	$U_9 = 0.752$
bolt 10	$U_{tp,10} = 0.240$	$U_{vt,10} = 0.755$	$U_{b,10} = 0.017$	$U_{10} = 0.755$
bolt 11	$U_{tp,11} = 0.240$	$U_{vt,11} = 0.754$	$U_{b,11} = 0.011$	$U_{11} = 0.754$
bolt 12	$U_{tp,12} = 0.235$	$U_{vt,12} = 0.763$	$U_{b,12} = 0.016$	$U_{12} = 0.763$
total:	$U_{tp} = 0.240$	$U_{vt} = 1.037$	$U_b = 0.210$	$U = 1.037 > 1$ not ok !!

in utilization of bolts U_{max} ist minimum plastic utilization of the connection $U_{pl,min} = 0.510$
and plastic utilization of tensile forces of bolts $U_{pl,s} = 0.880$ is included.

utilization of bolts $U_{max} = 1.037 > 1$ not ok !!

3.3. beam

circular hollow section: $V = (V_y^2 + V_z^2)^{1/2} = 18.17 \text{ kN}$, $M = (M_y^2 + M_z^2)^{1/2} = 183.79 \text{ kNm}$
plastic verification for $N_{Ed} = 59.38 \text{ kN}$, $M_{Ed} = 183.79 \text{ kNm}$, $V_{Ed} = 18.17 \text{ kN}$, $T_{t,Ed} = -86.89 \text{ kNm}$
plastic values: $N_{pl,Rd} = A \cdot f_y / \gamma_{M0} = 5643.24 \text{ kN}$, $M_{pl,Rd} = W_{pl} \cdot f_y / \gamma_{M0} = 453.10 \text{ kNm}$
 $V_{pl,Rd} = A_v \cdot f_y / (3^{1/2} \cdot \gamma_{M0}) = 2074.19 \text{ kN}$

torsion

$\tau_{t,Ed} = |T_{t,Ed}| / W_t = 43.21 \text{ N/mm}^2$

verification: $\tau_{t,Ed} / \tau_{Rd} = 0.211 < 1$ **ok**

shear force and torsion

deduction: $V_{pl,T,Rd} = V_{pl,Rd} \cdot f_T = 1636.93 \text{ kNm}$

shear force

verification: $V_{Ed} / V_{pl,T,Rd} = 0.011 < 1$ **ok**

reduction factor for $0.5 \cdot V_{pl,T,Rd} = 818.46 \text{ kN} > V_{Ed} = 18.17 \text{ kN}$: $\rho = 0$ (no deduction)

axial force

verification: $|N_{Ed}| / N_{pl,Rd} = 0.011 < 1$ **ok**

bending and axial force

deduction M_y : $M_{pl,N,y,Rd} = M_{pl,y,Rd} \cdot f_{N,y} = 452.90 \text{ kNm}$, $f_{N,y} = 1.000$

bending

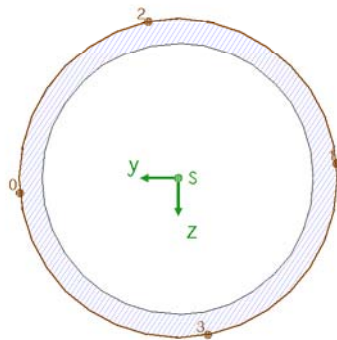
verification: $|M_{y,Ed}| / M_{pl,N,y,Rd} = 0.406 < 1$ **ok**

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

utilization of the beam $\max(U_\sigma, U_{c/t}) = 0.406 < 1$ **ok**

3.4. welds

design values: $N = 59.38 \text{ kN}$, $M_y = 17.02 \text{ kNm}$, $V_z = 3.40 \text{ kN}$, $M_z = -183.00 \text{ kNm}$,
 $V_y = 17.85 \text{ kN}$, $M_x = -86.89 \text{ kNm}$



weld 1: $a_w = 20.0 \text{ mm}$ $l_w = 857.7 \text{ mm}$

Max: $F_{w,Ed} = 3454.40 \text{ kN/m} < F_{w,Rd} = 7056.00 \text{ kN/m} \Rightarrow U_w = 0.490 < 1$ **ok**

utilization of welds $U_{max} = 0.490 < 1$ **ok**

3.5. total

utilization Lc 7 $U_{max} = 1.037 > 1$ **not 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