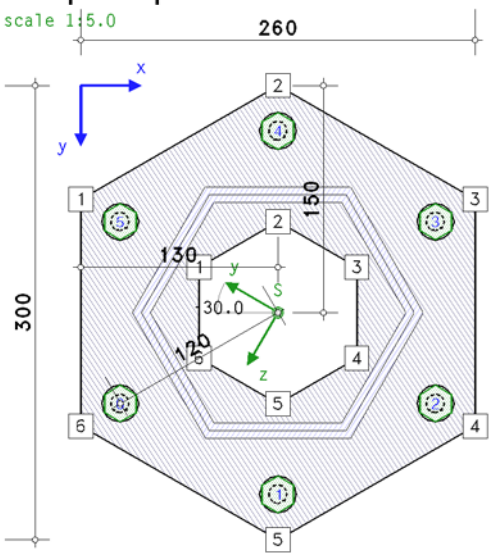
POS. 16: POLYPLATE POLYPROFILE

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 S235
bolts
bolts have to be prestressed with with preloading $F_{p,C}$ = 53.1 kN !!
bolt class 10.9, bolt size M12
large wrench size (high strength bolt), preloaded (for info: preloading $F_{p,C}^* = 0.7 \cdot f_{yb} \cdot A_s$ = 53.1 kN)
thread included in the shear plane
connection
end-plate (polygonal):

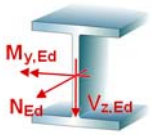
pt.	x_p mm	y_p mm	pt.	x_p mm	y_p mm
1	0.0	75.0	4	260.0	225.0
2	130.0	0.0	5	130.0	300.0
3	260.0	75.0	6	0.0	225.0

thickness t_p = 20.0 mm
beam: h = 191.5 mm, b = 166.0 mm, A = 54.02 cm², y_s = -83.0 mm, z_s = 95.8 mm
I_y = 1830.95 cm⁴, I_z = 1833.11 cm⁴, I_T = 3302.15 cm⁴
rotation of cross-section arround section centroid β = -30.0°
recess in of end-plate (polygonal):

pt.	x_{of} mm	y_{of} mm	pt.	x_{of} mm	y_{of} mm
1	78.0	120.0	4	182.0	180.0
2	130.0	90.0	5	130.0	210.0
3	182.0	120.0	6	78.0	180.0

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 = 130.0 mm, y_s = 150.0 mm
bolts:
circular arrangement of 6 bolts with radius r = 120.0 mm arround 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 bolts, check of distances
FEM-calculation:
bolts are plasticly calculated, spring constant of bolts c_f = 3233.4 kN/cm
plastic limit force $F_{t,f} = f_{t,f} \cdot F_{t,Rd}$ = 57.7 kN, $f_{t,f}$ = 0.950, $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2}$ = 60.70 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 $F_{p,C}$ = 53.1 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 = 40 / 6.5 mm, n_y / Δy = 46 / 6.5 mm
max. 50 iteration steps (tolerance limit 5‰)
internal forces and moments refering to local axes of cross-section

Lk 1: N_{Ed} = 260.00 kN
Lk 2: N_{Ed} = -1200.00 kN
partial safety factors for material
resistance of cross-sections γ_{M0} = 1.00
resistance of bolts, welds, plates in bearing γ_{M2} = 1.25



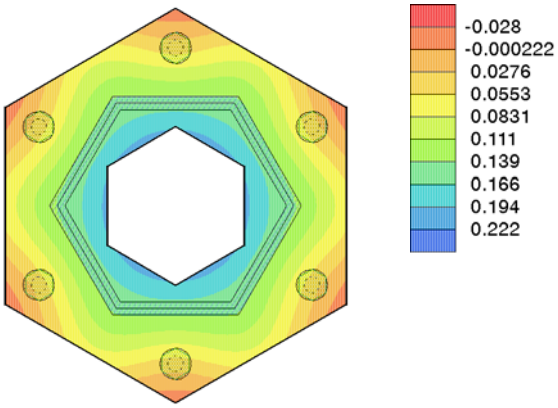
local stresses especially of the beam and of welds are not considered !
4H-QUER-cross-sectione sind über ihre Mittellinien beschrieben.
edge- and distances between bolts sind daher separat zu überprüfen !!

2. Lk 1

2.1. end-plate

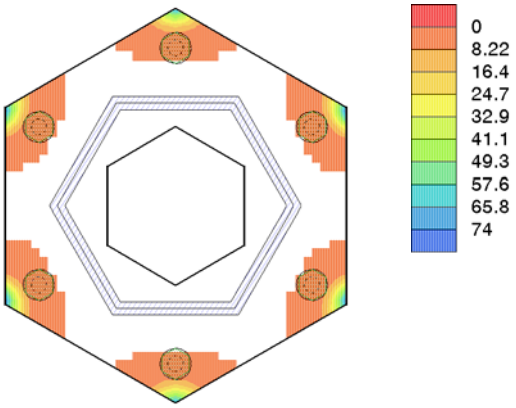
design values: N = 260.00 kN

deformations u_z [mm]
min u_z = -0.0284 mm, max u_z = 0.2206 mm



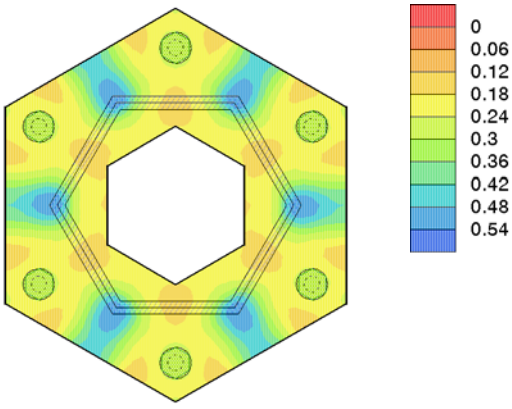
deformations lifting off positive

compression by contact b_z [N/mm²]
min b_z = 0.00 N/mm², max b_z = 73.69 N/mm²



compression by contact compression positive

utilization of end-plate U_p
min U_p = 0.000, max U_p = 0.540



utilization of end-plate

node	x mm	y mm	u_z mm	b_z N/mm²	m_1 kNm/m	m_2 kNm/m	U_p
11	0.0	65.2	-0.028	44.12	1.36	-0.13	0.188
12	0.0	71.7	-0.023	64.36	1.18	0.47	0.274
35	0.0	221.7	-0.017	73.69	1.67	0.98	0.314
647	84.5	228.3	0.144	0.00	12.38	6.80	0.540
817	110.5	110.9	0.221	0.00	3.67	-1.29	0.247
1917	260.0	234.8	-0.028	44.12	1.36	-0.13	0.188

x,y: node coordinates; u_z: deformations (lifting off positive); b_z: compression by contact (compression positive); : Hauptschnittgrößen
U_p: utilization of end-plate

utilization of bolts

	x mm	y mm	w_t mm	F_t kN	ε_{wt} %	U_{wt}
1	130.0	270.0	0.043	57.66	0.517	0.230
2	233.9	210.0	0.042	57.66	0.512	0.227
3	233.9	90.0	0.042	57.66	0.510	0.227
4	130.0	30.0	0.043	57.66	0.517	0.230
5	26.1	90.0	0.042	57.66	0.512	0.227

	x	y	wt	Ft	εwt	Uwt
	mm	mm	mm	kN	%	
6	26.1	210.0	0.042	57.66	0.510	0.227

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 647] $U_{max} = 0.540 < 1$ ok
utilization of bolts due to elongation [bolt 1] $U_{s,max} = 0.230 < 1$ ok
minimum plastic utilization of bolts $U_{pl,s,min} = 0.791 < 1$ ok
plastic utilization of tensile forces of bolts $U_{pl,t,s} = 0.239 < 1$ ok

2.2. bolts

design values: min $F_t = 57.66$ kN, max $F_t = 57.66$ kN

verification of bolts
U_{tp} utilization due to punching shear failure, U utilization of bolts

bolt 1	$U_{tp,1} = 0.231$	$U_1 = 0.231$
bolt 2	$U_{tp,2} = 0.231$	$U_2 = 0.231$
bolt 3	$U_{tp,3} = 0.231$	$U_3 = 0.231$
bolt 4	$U_{tp,4} = 0.231$	$U_4 = 0.231$
bolt 5	$U_{tp,5} = 0.231$	$U_5 = 0.231$
bolt 6	$U_{tp,6} = 0.231$	$U_6 = 0.231$
total:	$U_{tp} = 0.231$	$U = 0.231 < 1$ ok

in utilization of bolts max U_s the minimum plastic utilization of bolts min $U_{pl,s} = 0.791$
and plastic utilization of tensile forces of bolts $U_{pl,t,s} = 0.239$ is included.

utilization of bolts $U_{max} = 0.791 < 1$ ok

2.3. beam

plastic verification for N = 260.00 kN
internal forces and moments reg. yz-direction in kN, m: My = 0.00, Mz = 0.00, Vy = 0.00, Vz = 0.00
partial internal forces and moments of lines of cross-section in kN, m:
1: N = 43.34, My = 0.00, Mz = 0.00, Vy = 0.00, Vz = 0.00, T = 0.00
2: N = 43.34, My = -0.00, Mz = 0.00, Vy = 0.00, Vz = 0.00, T = 0.00
3: N = 43.32, My = -0.00, Mz = 0.00, Vy = 0.00, Vz = 0.00, T = 0.00
4: N = 43.34, My = -0.00, Mz = -0.00, Vy = 0.00, Vz = 0.00, T = 0.00
5: N = 43.34, My = 0.00, Mz = -0.00, Vy = 0.00, Vz = 0.00, T = 0.00
6: N = 43.32, My = 0.00, Mz = 0.00, Vy = 0.00, Vz = 0.00, T = 0.00
utilizations of lines of cross-section
1: $U_\sigma = 0.205$, $U_\tau = 0.000$, U = 0.205
2: $U_\sigma = 0.205$, $U_\tau = 0.000$, U = 0.205
3: $U_\sigma = 0.205$, $U_\tau = 0.000$, U = 0.205
4: $U_\sigma = 0.205$, $U_\tau = 0.000$, U = 0.205
5: $U_\sigma = 0.205$, $U_\tau = 0.000$, U = 0.205
6: $U_\sigma = 0.205$, $U_\tau = 0.000$, U = 0.205
max. load factor (plastic): $f_{pl} = 4.883$
no equilibrium of warping at limit state: $\Delta B = 0.000$ kNm²
utilization (without equilibrium of warping): $U_{pl} = 0.205$
verification: $U_{pl} = 0.205 < 1$ ok

utilization of the beam $\max(U_\sigma, U_{c/t}) = 0.205 < 1$ ok

2.4. total

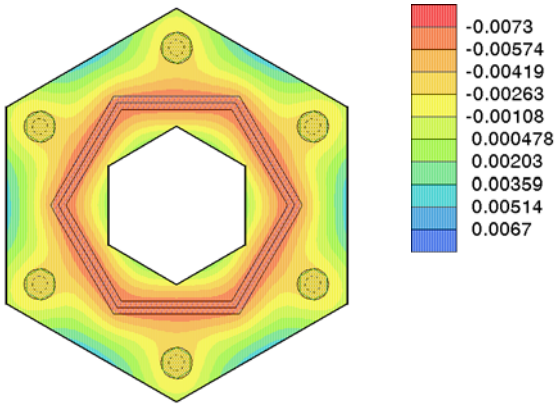
utilization Lk 1 $U_{max} = 0.791 < 1$ ok

3. Lk 2

3.1. end-plate

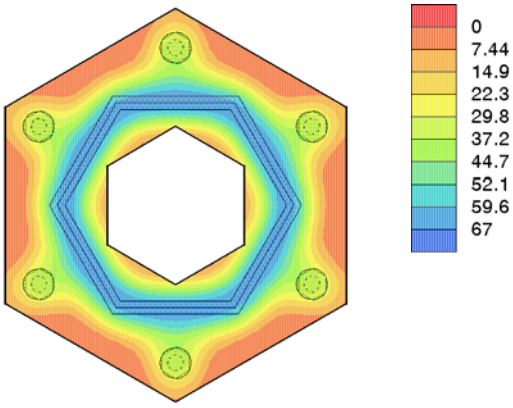
design values: N = -1200.00 kN

deformations u_z [mm]
min u_z = -0.0073 mm, max u_z = 0.0064 mm



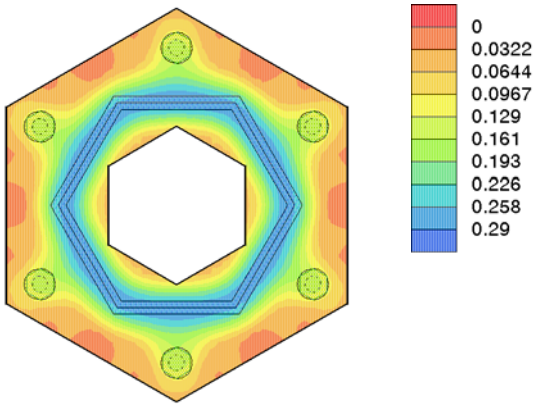
deformations lifting off positive

compression by contact b_z [N/mm²]
min b_z = 0.00 N/mm², max b_z = 67.09 N/mm²



compression by contact compression positive

utilization of end-plate U_p
min U_p = 0.000, max U_p = 0.286



utilization of end-plate

node	x mm	y mm	u_z mm	b_z N/mm²	m_1 kNm/m	m_2 kNm/m	U_p
11	0.0	65.2	0.001	1.93	0.84	-0.28	0.061
13	0.0	78.3	-0.000	7.50	1.08	0.05	0.056
37	0.0	234.8	0.001	1.94	0.84	-0.28	0.061
336	45.5	39.1	0.006	0.00	0.46	-0.15	0.034
501	65.0	195.7	-0.007	67.09	3.93	1.34	0.286
1427	195.0	104.4	-0.007	67.09	3.93	1.34	0.286

x,y: node coordinates; u_z: deformations (lifting off positive); b_z: compression by contact (compression positive); : Hauptschnittgrößen
U_p: utilization of end-plate

utilization of bolts

	x mm	y mm	F_t kN	ε_{wt} %	U_{wt}		x mm	y mm	F_t kN	ε_{wt} %	U_{wt}
1	130.0	270.0	53.11	0.300	0.133	4	130.0	30.0	53.11	0.300	0.133
2	233.9	210.0	53.11	0.300	0.133	5	26.1	90.0	53.11	0.300	0.133
3	233.9	90.0	53.11	0.300	0.133	6	26.1	210.0	53.11	0.300	0.133

x,y: bolt coordinates; F_t: bolt force; ε_{wt}: elongation; U_{wt}: utilization due to elongation

utilization of end-plate [node 501] $U_{max} = 0.286 < 1$ ok
utilization of bolts due to elongation [bolt 1] $U_{s,max} = 0.133 < 1$ ok

3.2. bolts

design values: min F_t = 53.11 kN, max F_t = 53.11 kN

verification of bolts
U_{tp} utilization due to punching shear failure, U utilization of bolts

bolt 1	$U_{tp,1} = 0.213$	$U_1 = 0.213$
bolt 2	$U_{tp,2} = 0.213$	$U_2 = 0.213$
bolt 3	$U_{tp,3} = 0.213$	$U_3 = 0.213$
bolt 4	$U_{tp,4} = 0.213$	$U_4 = 0.213$
bolt 5	$U_{tp,5} = 0.213$	$U_5 = 0.213$
bolt 6	$U_{tp,6} = 0.213$	$U_6 = 0.213$
total:	$U_{tp} = 0.213$	$U = 0.213 < 1$ ok

utilization of bolts $U_{max} = 0.213 < 1$ ok

3.3. beam

plastic verification for N = -1200.00 kN
internal forces and moments reg. yz-direction in kN, m: My = 0.00, Mz = 0.00, Vy = 0.00, Vz = 0.00
partial internal forces and moments of lines of cross-section in kN, m:
1: N = -200.04, My = 0.00, Mz = 0.00, Vy = 0.00, Vz = 0.00, T = 0.00
2: N = -200.04, My = -0.00, Mz = 0.00, Vy = 0.00, Vz = 0.00, T = 0.00
3: N = -199.93, My = -0.00, Mz = 0.00, Vy = 0.00, Vz = 0.00, T = 0.00
4: N = -200.04, My = -0.00, Mz = -0.00, Vy = 0.00, Vz = 0.00, T = 0.00
5: N = -200.04, My = 0.00, Mz = -0.00, Vy = 0.00, Vz = 0.00, T = 0.00
6: N = -199.93, My = 0.00, Mz = 0.00, Vy = 0.00, Vz = 0.00, T = 0.00
utilizations of lines of cross-section
1: $U_\sigma = 0.945$, $U_\tau = 0.000$, U = 0.945
2: $U_\sigma = 0.945$, $U_\tau = 0.000$, U = 0.945
3: $U_\sigma = 0.945$, $U_\tau = 0.000$, U = 0.945
4: $U_\sigma = 0.945$, $U_\tau = 0.000$, U = 0.945
5: $U_\sigma = 0.945$, $U_\tau = 0.000$, U = 0.945
6: $U_\sigma = 0.945$, $U_\tau = 0.000$, U = 0.945
max. load factor (plastic): $f_{pl} = 1.058$
no equilibrium of warping at limit state: $\Delta B = -0.000$ kNm²
utilization (without equilibrium of warping): $U_{pl} = 0.945$
verification: $U_{pl} = 0.945 < 1$ ok
c/t-verification: utilization $U_{c/t} = 0.222 < 1$ ok

utilization of the beam $\max(U_\sigma, U_{c/t}) = 0.945 < 1$ ok

3.4. total

utilization Lk 2 $U_{max} = 0.945 < 1$ ok

4. final result

maximum utilization of end-plate due to 2 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
647	84.5	228.3	0.144	0.00	-11.05	-8.12	-2.37	414.46	-660.46	0.540

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 2 Lk: max U_s with corresponding values

	x mm	y mm	F_t kN	U_{wt}	U_{vt}	U_b	U_s
1	130.0	270.0	57.66	0.230	---	---	0.231
2	233.9	210.0	57.66	0.227	---	---	0.231
3	233.9	90.0	57.66	0.227	---	---	0.231
4	130.0	30.0	57.66	0.230	---	---	0.231
5	26.1	90.0	57.66	0.227	---	---	0.231
6	26.1	210.0	57.66	0.227	---	---	0.231

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]	max $U_p = 0.540 < 1$ ok
maximum utilization of bolts due to elongation [Lk 1]	max $U_{wt,s} = 0.230 < 1$ ok
maximum utilization of bolts [Lk 1]	max $U_s = 0.791 < 1$ ok
maximum utilization of the beam [Lk 2]	max $(U_q, U_{ct}) = 0.945 < 1$ ok
maximum utilization [Lk 2]	**max U = 0.945 < 1** ok

verification succeeded

5. 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;