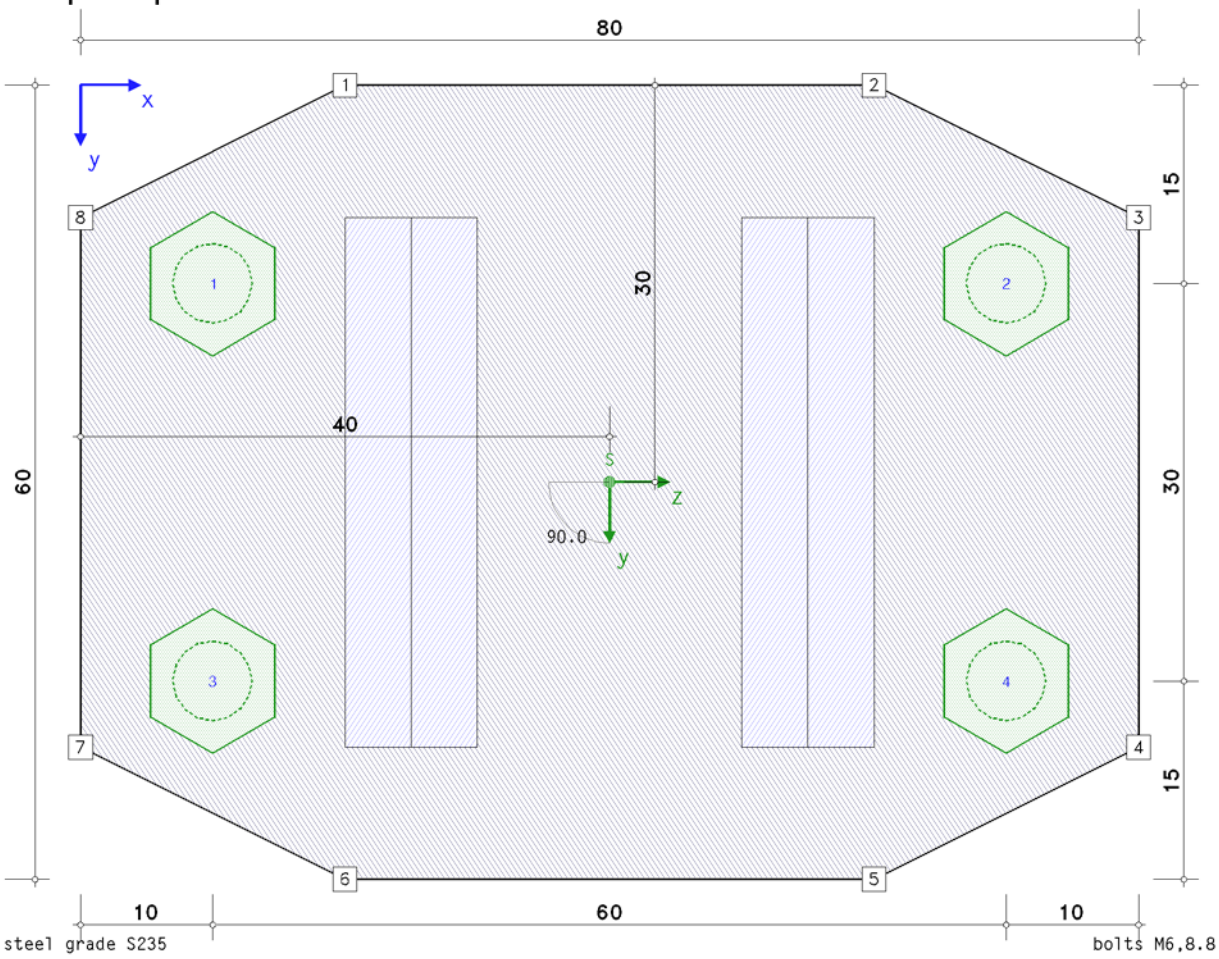
POS. 9: POLYPLATTE DOPPELBLECH

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

1. input report

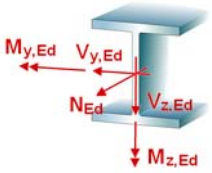


steel grade
steel grade S235
bolts
bolt class 8.8, bolt size M6, normal wrench size
shear plane passes through the unthreaded portion of the bolt
connection
end plate (polygonal):

pt.	x_p mm	y_p mm	pt.	x_p mm	y_p mm
1	20.0	0.0	5	60.0	60.0
2	60.0	0.0	6	20.0	60.0
3	80.0	10.0	7	0.0	50.0
4	80.0	50.0	8	0.0	10.0

thickness t_p = 8.0 mm
beam: h = 40.0 mm, b = 40.0 mm, A = 8.00 cm², y_s = -20.0 mm, z_s = 20.0 mm
I_y = 18.67 cm⁴, I_z = 10.67 cm⁴, I_T = 2.67 cm⁴, I_ω = 24.00 cm⁶
rotation of cross-section arround section centroid β = 90.0°
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 = 40.0 mm, y_s = 30.0 mm
bolts:
uniform arrangement of bolts, 2 vertical and 2 horizontal rows
edge distances top e_o = 15.0 mm, below e_u = 15.0 mm
distances between bolts $p_{y,1\text{-}2}$ = 30.0 mm
edge distances left e_l = 10.0 mm, right e_r = 10.0 mm
distances between bolts $p_{x,1\text{-}2}$ = 60.0 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 welds with the simplified method
verification of bolts, check of distances
FEM-calculation:
bolts are plasticly calculated, spring constant of bolts c_f = 1863.6 kN/cm
plastic limit force $F_{t,f} = f_{t,f} \cdot F_{t,Rd}$ = 11.0 kN, $f_{t,f}$ = 0.950, $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2}$ = 11.58 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 = 26250.0 kN/cm³
number / dimension of finite elements each direction n_x / Δx = 35 / 2.3 mm, n_y / Δy = 26 / 2.3 mm
max. 50 iteration steps (tolerance limit 5‰)
internal forces and moments refering to local axes of cross-section
Lc 1: N_{Ed} = -0.35 kN, $M_{y,Ed}$ = 0.38 kNm, $V_{z,Ed}$ = 0.23 kN
$M_{z,Ed}$ = 0.00 kNm, $V_{y,Ed}$ = 0.00 kN
Lc 2: N_{Ed} = -0.88 kN, $M_{y,Ed}$ = 0.29 kNm, $V_{z,Ed}$ = 0.17 kN
$M_{z,Ed}$ = 0.04 kNm, $V_{y,Ed}$ = 0.02 kN
Lc 3: N_{Ed} = -0.88 kN, $M_{y,Ed}$ = 0.07 kNm, $V_{z,Ed}$ = 0.28 kN
$M_{z,Ed}$ = -0.03 kNm, $V_{y,Ed}$ = -0.02 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-sections are described by their centre lines.
edge- and distances between bolts must therefore be checked separately !!

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_w	U
1	0.331	0.331	0.100	0.220	0.361	0.044	0.088	0.249	0.003	0.176	0.199	0.361*
2	0.263	0.263	0.081	0.153	0.264	0.036	0.071	0.203	0.003	0.165	0.186	0.264
3	0.076	0.076	0.029	0.023	0.087	0.011	0.021	0.065	0.004	0.066	0.075	0.087

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_w: utilization of welds; U: total utilization
*) maximum utilization

2. final result

maximum utilization of end plate due to 3 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
656	54.9	16.1	0.025	0.00	-1.40	-0.44	0.01	18.35	-1.70	0.331

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 3 Lc: max U_s with corresponding values

	x mm	y mm	F_t kN	U_{wt}	U_{vt}	U_b	U_s
1	10.0	15.0	0.01	---	0.007	0.003	0.088
2	70.0	15.0	3.97	0.044	0.249	0.002	0.249
3	10.0	45.0	0.01	---	0.007	0.003	0.088
4	70.0	45.0	3.97	0.044	0.249	0.002	0.249

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]	max U_p = 0.331 < 1 ok
maximum utilization of bolts due to elongation [Lc 1]	max $U_{wt,s}$ = 0.044 < 1 ok
maximum utilization of bolts [Lc 1]	max U_s = 0.361 < 1 ok
maximum utilization of the beam [Lc 1]	max (U_q,U_{ct}) = 0.176 < 1 ok
maximum utilization of welds [Lc 1]	max U_w = 0.199 < 1 ok
maximum utilization [Lc 1]	**max U = 0.361 < 1 ok**

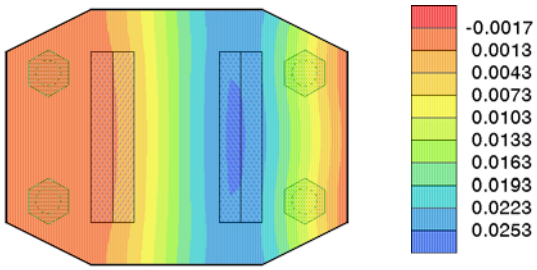
verification succeeded

3. Lc 1 (decisive)

3.1. end plate

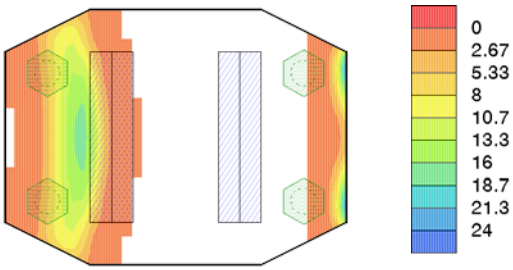
design values: N = -0.35 kN, M_y = 0.38 kNm

deformations u_z [mm]
min u_z = -0.0017 mm, max u_z = 0.0256 mm



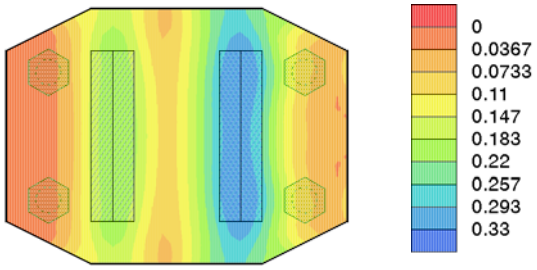
deformations lifting off positive

compression by contact b_z [N/mm²]
min b_z = 0.00 N/mm², max b_z = 23.58 N/mm²



compression by contact compression positive

utilization of end plate U_p
min U_p = 0.000, max U_p = 0.331



utilization of end plate

node	x mm	y mm	u_z mm	b_z N/mm²	U_p
602	50.3	16.1	0.025	0.00	0.292
656	54.9	16.1	0.025	0.00	0.331
952	80.0	13.8	-0.002	23.58	0.100

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	10.0	15.0	-0.000	0.01	0.000	---
2	70.0	15.0	0.011	3.97	0.133	0.044
3	10.0	45.0	-0.000	0.01	0.000	---
4	70.0	45.0	0.011	3.97	0.133	0.044

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 656] $U_{max} = 0.331 < 1$ ok
utilization of bolts due to elongation [bolt 2] $U_{s,max} = 0.044 < 1$ ok
minimum plastic utilization of the connection $U_{pl,min} = 0.220 < 1$ ok
plastic utilization of tensile forces of bolts $U_{pl,t,s} = 0.361 < 1$ ok

3.2. bolts

design values: min F_t = 0.01 kN, max F_t = 3.97 kN, V_z = 0.23 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	$U_{tp,1} = 0.000$	$U_{vt,1} = 0.007$	$U_{b,1} = 0.003$	$U_1 = 0.007$
bolt 2	$U_{tp,2} = 0.088$	$U_{vt,2} = 0.249$	$U_{b,2} = 0.002$	$U_2 = 0.249$
bolt 3	$U_{tp,3} = 0.000$	$U_{vt,3} = 0.007$	$U_{b,3} = 0.003$	$U_3 = 0.007$
bolt 4	$U_{tp,4} = 0.088$	$U_{vt,4} = 0.249$	$U_{b,4} = 0.002$	$U_4 = 0.249$
total:	$U_{tp} = 0.088$	$U_{vt} = 0.249$	$U_b = 0.003$	$U = 0.249 < 1$ ok

in utilization of bolts U_{max} ist minimum plastic utilization of the connection $U_{pl,min}$ = 0.220
and plastic utilization of tensile forces of bolts $U_{pl,s}$ = 0.361 is included.

utilization of bolts $U_{max} = 0.361 < 1$ ok

3.3. beam

elastic verification for $N = -0.35$ kN, $M_y = 0.38$ kNm, $V_z = 0.23$ kN
verification: $\sigma_v = 41.38$ N/mm² $<$ $\sigma_{v,Rd} = 235.00$ N/mm² $\Rightarrow$ $U_\sigma = 0.176 < 1$ ok

utilization of the beam $\max(U_\sigma, U_{c/t}) = 0.176 < 1$ ok

3.4. welds

design values: $N = -0.35$ kN, $M_y = 0.38$ kNm, $V_z = 0.23$ kN
$U_w = 0.199 < 1$ ok

utilization of welds $U_{max} = 0.199 < 1$ ok

3.5. total

utilization Lc 1 $U_{max} = 0.361 < 1$ 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