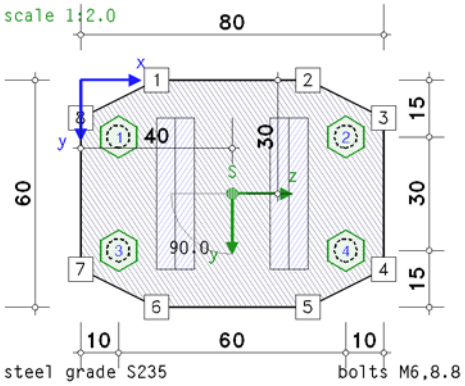
POS. 10: POLYPLATE DOUBLE SHEET

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

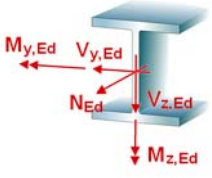
1. input report



steel grade
steel grade S235
bolts
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 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
Lk 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
Lk 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
Lk 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-sectione sind über ihre Mittellinien beschrieben.
edge- and distances between bolts sind daher separat zu überprüfen !!

FEM: the bolt distance from the free edge of the plate edge is too small (min e = 8.9 mm < 12.0 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 $U_{pl,s}$ 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
1	0.331	0.331	0.100	0.220	0.361	0.044	0.088	0.250	0.003	0.176	0.361*
2	0.263	0.263	0.081	0.153	0.264	0.036	0.071	0.203	0.002	0.165	0.264
3	0.076	0.076	0.029	0.023	0.087	0.011	0.021	0.065	0.003	0.066	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
$U_{pl,s}$: 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: total utilization
*) maximum utilization

2. final result

maximum utilization of end-plate due to 3 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
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 Lk: 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	---	0.006	0.003	0.088
2	70.0	15.0	3.97	0.044	0.250	0.002	0.250
3	10.0	45.0	0.01	---	0.006	0.003	0.088
4	70.0	45.0	3.97	0.044	0.250	0.002	0.250

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

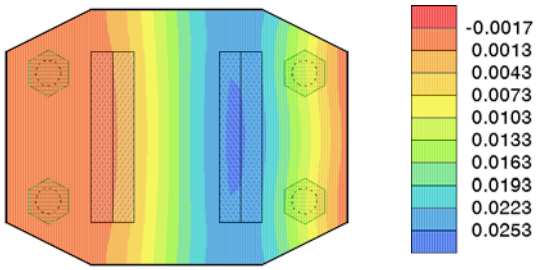
EN 1993-1-8, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -
Teil 1-8: Bemessung von Anschlüssen;
Deutsche Fassung EN 1993-1-8:2005 + AC:2009, Ausgabe Dezember 2010
EN 1993-1-8/NA, Nationaler Anhang zur EN 1993-1-8, Ausgabe Dezember 2010

4. Lk 1 (decisive)

4.1. end-plate

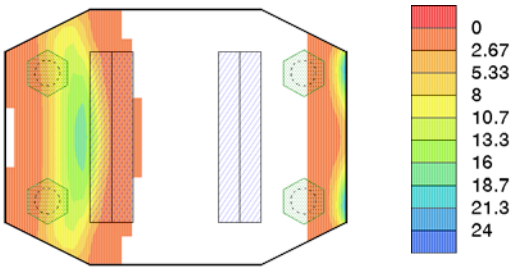
design values: N = -0.35 kN, M_y = 0.38 kNm

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



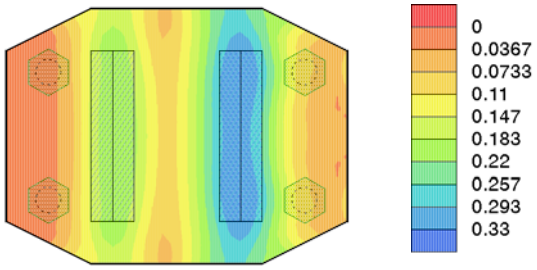
deformations lifting off positive

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 bolts $U_{pl,s,min} = 0.220 < 1$ ok
plastic utilization of tensile forces of bolts $U_{pl,t,s} = 0.361 < 1$ ok

4.2. 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	$U_{tp,1} = 0.000$	$U_{vt,1} = 0.006$	$U_{b,1} = 0.003$	$U_1 = 0.006$
bolt 2	$U_{tp,2} = 0.088$	$U_{vt,2} = 0.250$	$U_{b,2} = 0.002$	$U_2 = 0.250$
bolt 3	$U_{tp,3} = 0.000$	$U_{vt,3} = 0.006$	$U_{b,3} = 0.003$	$U_3 = 0.006$
bolt 4	$U_{tp,4} = 0.088$	$U_{vt,4} = 0.250$	$U_{b,4} = 0.002$	$U_4 = 0.250$
total:	$U_{tp} = 0.088$	$U_{vt} = 0.250$	$U_b = 0.003$	$U = 0.250 < 1$ ok

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

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

4.3. 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

4.4. total

utilization Lk 1 $U_{max} = 0.361 < 1$ ok