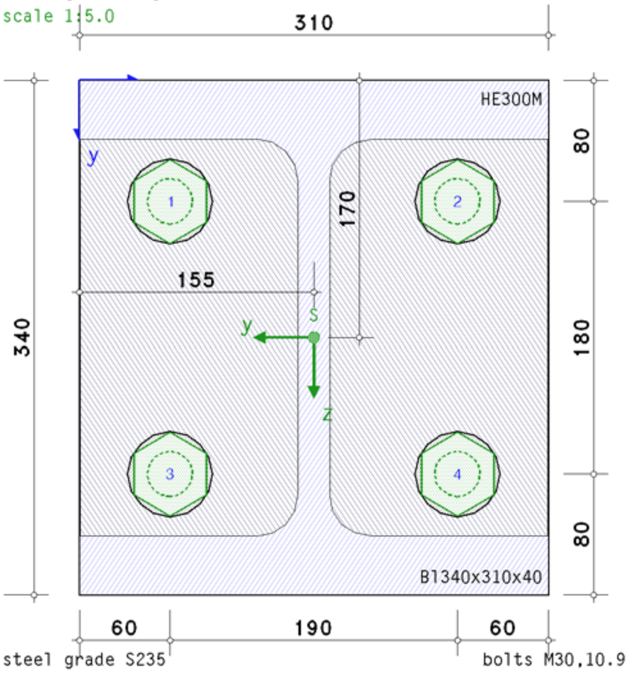
POS. 1: 2T

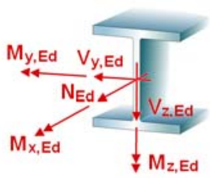
bolted end plate connection EC 3-1-8 (04.25), NA: Deutschland

1. input report



steel grade
steel grade S235
bolts
bolts have to be prestressed with with preloading $F_{p,C}$ = 353.2 kN !!
bolt class 10.9, bolt size M30
large wrench size (high strength bolt), preloaded (for info: preloading $F_{p,C}^* = 0.7 \cdot f_{yb} \cdot A_s$ = 353.2 kN)
thread included in the shear plane
connection
end plate (rectangular): thickness t_p = 40.0 mm, width b_p = 310.0 mm, length l_p = 340.0 mm
beam: section HE300M
beam-end plate: surrounding butt weld (partial penetrated, weld thickness a = 8.0 mm), weld thickness a = 8.0 mm
beam section centric on end plate (beam centroid in plate centre)
coordinates of the beam centroid on end plate x_s = 155.0 mm, y_s = 170.0 mm
bolts:
uniform arrangement of bolts, 2 vertical and 2 horizontal rows
edge distances top, below $e_o = e_u$ = 80.0 mm, distances between bolts p_y = 180.0 mm
edge distances left, right $e_l = e_r$ = 60.0 mm, distances between bolts p_x = 190.0 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 plastic method
verification of welds with the directional method
verification of bolts, check of distances
FEM-calculation:
bolts are plasticly calculated, spring constant of bolts c_f = 10497.2 kN/cm
plastic limit force $F_{t,f} = f_{t,f} \cdot F_{t,Rd}$ = 383.5 kN, $f_{t,f}$ = 0.950, $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2}$ = 403.63 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 $F_{p,C}$ = 353.2 kN < $F_{t,f}$ ok
effective foundation modulus of end plate c_b = 5250.0 kN/cm³
number / dimension of finite elements each direction n_x / Δx = 30 / 10.3 mm, n_y / Δy = 33 / 10.3 mm
max. 50 iteration steps (tolerance limit 5‰)
internal forces and moments refering 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	21.46	28.05	5.61	-66.94	-5.36	-0.05
2	-98.50	100.88	20.18	67.50	-13.50	0.08
3	-75.42	88.74	17.75	0.76	-0.15	0.00
4	-24.68	-1.45	-0.29	47.12	-9.42	0.03
5	-26.57	84.02	16.80	-67.21	-5.31	-0.06
6	-121.96	147.51	29.50	57.68	-11.54	0.08



Lc	N_{Ed} kN	$M_{y,Ed}$ kNm	$V_{z,Ed}$ kN	$M_{z,Ed}$ kNm	$V_{y,Ed}$ kN	$M_{x,Ed}$ kNm
7	-25.61	3.94	0.79	48.40	-9.68	0.04

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 !

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	0.486	0.486	0.472	0.311	---	0.134	0.316	0.647	0.003	0.150	0.301	0.455	0.647
2	0.687	0.687	0.513	0.339	0.180	0.180	0.334	0.690	0.010	0.161	0.301	0.677	0.690
3	0.358	0.358	0.267	0.306	---	0.133	0.309	0.646	0.005	0.014	0.301	0.265	0.646
4	0.297	0.297	0.271	0.192	---	0.133	0.309	0.636	0.004	0.105	0.301	0.274	0.636
5	0.664	0.664	0.507	0.320	0.170	0.170	0.332	0.684	0.007	0.157	0.301	0.608	0.684
6	0.766	0.766	0.438	0.511	0.360	0.284	0.335	0.697	0.013	0.152	0.301	0.754	0.766*
7	0.308	0.308	0.283	0.197	---	0.133	0.309	0.636	0.004	0.108	0.301	0.288	0.636

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_{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 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
876	258.3	257.6	0.122	0.00	47.30	75.77	15.83	-361.50	-116.27	0.766

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	60.0	80.0	353.18	0.133	0.672	0.013	0.672
2	250.0	80.0	353.18	0.133	0.669	0.012	0.669
3	60.0	260.0	370.72	0.148	0.688	0.009	0.688
4	250.0	260.0	383.45	0.284	0.697	0.005	0.697

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 6]	max U_p = 0.766 < 1 ok
maximum utilization of bolts due to elongation [Lc 6]	max $U_{wt,s}$ = 0.284 < 1 ok
maximum utilization of bolts [Lc 6]	max U_s = 0.697 < 1 ok
maximum utilization of the beam [Lc 1]	max (U_q,U_{ct}) = 0.301 < 1 ok
maximum utilization of welds [Lc 6]	max U_w = 0.754 < 1 ok
maximum utilization [Lc 6]	**max U = 0.766 < 1** ok

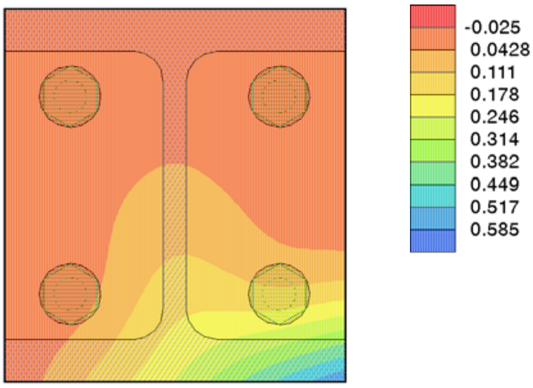
verification succeeded

3. Lc 6 (decisive)

3.1. end plate

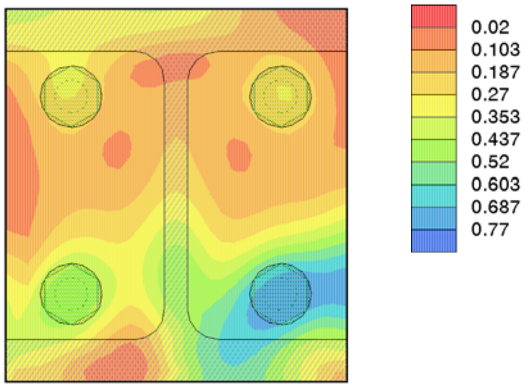
design values: N = -121.96 kN, M_y = 147.51 kNm, M_z = 57.68 kNm

deformations u_z [mm]
min u_z = -0.0254 mm, max u_z = 0.5808 mm



deformations lifting off positive

utilization of end plate U_p
min U_p = 0.020, max U_p = 0.766



utilization of end plate

node	x	y	u_z	U_p
	mm	mm	mm	
876	258.3	257.6	0.122	0.766
1054	310.0	340.0	0.581	0.160

x,y: node coordinates; u_z: deformations (lifting off positive); U_p: utilization of end plate

utilization of bolts

	x	y	w_t	F_t	ε_{wt}	U_{wt}
	mm	mm	mm	kN	%	
1	60.0	80.0	-0.000	353.18	0.300	0.133
2	250.0	80.0	-0.000	353.18	0.300	0.133
3	60.0	260.0	0.013	370.72	0.333	0.148
4	250.0	260.0	0.135	383.45	0.638	0.284

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 876] U_{max} = 0.766 < 1 ok
utilization of bolts due to elongation [bolt 4] $U_{s,max}$ = 0.284 < 1 ok
minimum plastic utilization of the connection $U_{pl,min}$ = 0.511 < 1 ok
plastic utilization of tensile forces of bolts $U_{pl,t,s}$ = 0.360 < 1 ok

3.2. bolts

design values: min F_t = 353.18 kN, max F_t = 383.45 kN, V_z = 29.50 kN, V_y = -11.54 kN, M_x = 0.08 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	$U_{tp,1}$ = 0.309	$U_{vt,1}$ = 0.672	$U_{b,1}$ = 0.013	U_1 = 0.672
bolt 2	$U_{tp,2}$ = 0.309	$U_{vt,2}$ = 0.669	$U_{b,2}$ = 0.012	U_2 = 0.669
bolt 3	$U_{tp,3}$ = 0.324	$U_{vt,3}$ = 0.688	$U_{b,3}$ = 0.009	U_3 = 0.688
bolt 4	$U_{tp,4}$ = 0.335	$U_{vt,4}$ = 0.697	$U_{b,4}$ = 0.005	U_4 = 0.697
total:	U_{tp} = 0.335	U_{vt} = 0.697	U_b = 0.013	U = 0.697 < 1 ok

in utilization of bolts U_{max} ist minimum plastic utilization of the connection $U_{pl,min}$ = 0.511 and plastic utilization of tensile forces of bolts $U_{pl,s}$ = 0.360 is included.

utilization of bolts U_{max} = 0.697 < 1 ok

3.3. beam

plastic verification for N_{Ed} = -121.96 kN, $M_{y,Ed}$ = 147.51 kNm, $V_{z,Ed}$ = 29.50 kN, $M_{z,Ed}$ = 57.68 kNm
$V_{y,Ed}$ = -11.54 kN, $T_{t,Ed}$ = 0.08 kNm
section class of the cross-section 1 ≤ 2 ok
shear buckling: $h_p/t_p = 12.48 \le 72 \cdot \varepsilon/\eta = 60.00$ ok
plastic values: $N_{pl,Rd} = A \cdot f_y/\gamma_{M0}$ = 7122.33 kN, $M_{pl,y,Rd} = W_{pl,y} \cdot f_y/\gamma_{M0}$ = 958.12 kNm
$V_{pl,z,Rd} = A_{vz} \cdot f_y/(3^{1/2} \cdot \gamma_{M0})$ = 1228.26 kN, $M_{pl,z,Rd} = W_{pl,z} \cdot f_y/\gamma_{M0}$ = 449.41 kNm, $V_{pl,y,Rd} = A_{vy} \cdot f_y/(3^{1/2} \cdot \gamma_{M0})$ = 3280.68 kN

torsion
$\tau_{t,Ed} = |T_{t,Ed}|/\min W_t$ = 0.25 N/mm²
verification: $\tau_{t,Ed}/\tau_{Rd}$ = 0.002 < 1 ok

shear force and torsion
deduction V_z: $f_{T,z} = (1 - \tau_{t,z,Ed}/(1.25 \cdot \tau_{Rd}))^{1/2}$ = 1.000 ⇒ $V_{pl,T,z,Rd} = V_{pl,z,Rd} \cdot f_{T,z}$ = 1227.77 kNm
deduction V_y: $f_{T,y} = (1 - \tau_{t,y,Ed}/\tau_{Rd})^{1/2}$ = 0.999 ⇒ $V_{pl,T,y,Rd} = V_{pl,y,Rd} \cdot f_{T,y}$ = 3277.67 kNm

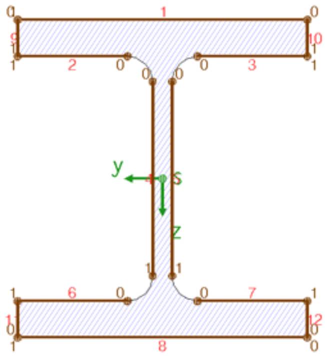
shear force
verification: $|V_{z,Ed}|/V_{pl,T,z,Rd}$ = 0.024 < 1 ok

verification: $|V_{y,Ed}|/V_{pl,T,y,Rd} = 0.004 < 1$ ok
reduction factors:
web: $0.5 \cdot V_{pl,T,z,Rd} = 613.89$ kN $> |V_{z,Ed}| = 29.50$ kN: $\rho_z = 0$ (no deduction)
flanges: $0.5 \cdot V_{pl,T,y,Rd} = 1638.83$ kN $> |V_{y,Ed}| = 11.54$ kN: $\rho_y = 0$ (no deduction)
axial force
verification: $|N_{Ed}|/N_{pl,Rd} = 0.017 < 1$ ok
bending and axial force
deduction M_y: $M_{pl,y,Rd} = M_{pl,y,Rd} \cdot f_{N,y} = 958.12$ kNm, $f_{N,y} = 1.000$
deduction M_z: $M_{pl,z,Rd} = M_{pl,z,Rd} \cdot f_{N,z} = 449.41$ kNm, $f_{N,z} = 1.000$
bending
verification: $(|M_{y,Ed}|/M_{pl,y,Rd})^{\alpha} + (|M_{z,Ed}|/M_{pl,z,Rd})^{\beta} = 0.024 + 0.128 = 0.152 < 1$ ok
with $\alpha = 2.00$, $\beta = 1.00 = 5 \cdot n \geq 1$
c/t-verification: utilization $U_{c/t} = 0.301 < 1$ ok

utilization of the beam $\max(U_{\sigma}, U_{c/t}) = 0.301 < 1$ ok

3.4. welds

design values: $N = -121.96$ kN, $M_y = 147.51$ kNm, $V_z = 29.50$ kN, $M_z = 57.68$ kNm,
$V_y = -11.54$ kN, $M_x = 0.08$ kNm



weld 1:	$a_w = 8.0$ mm	$l_w = 310.0$ mm
weld 2:	$a_w = 8.0$ mm	$l_w = 117.5$ mm
weld 3:	$a_w = 8.0$ mm	$l_w = 117.5$ mm
weld 4:	$a_w = 8.0$ mm	$l_w = 208.0$ mm
weld 5:	$a_w = 8.0$ mm	$l_w = 208.0$ mm
weld 6:	$a_w = 8.0$ mm	$l_w = 117.5$ mm
weld 7:	$a_w = 8.0$ mm	$l_w = 117.5$ mm
weld 8:	$a_w = 8.0$ mm	$l_w = 310.0$ mm
weld 9:	$a_w = 8.0$ mm	$l_w = 39.0$ mm
weld 10:	$a_w = 8.0$ mm	$l_w = 39.0$ mm
weld 11:	$a_w = 8.0$ mm	$l_w = 39.0$ mm
weld 12:	$a_w = 8.0$ mm	$l_w = 39.0$ mm

Max: $\sigma_{1,w,Ed} = 271.56$ N/mm² $< f_{1w,d} = 360.00$ N/mm²,
$\sigma_{2,w,Ed} = 135.77$ N/mm² $< f_{2w,d} = 259.20$ N/mm² $\Rightarrow U_w = 0.754 < 1$ ok

utilization of welds $U_{max} = 0.754 < 1$ ok

3.5. total

utilization Lc 6 $U_{max} = 0.766 < 1$ 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