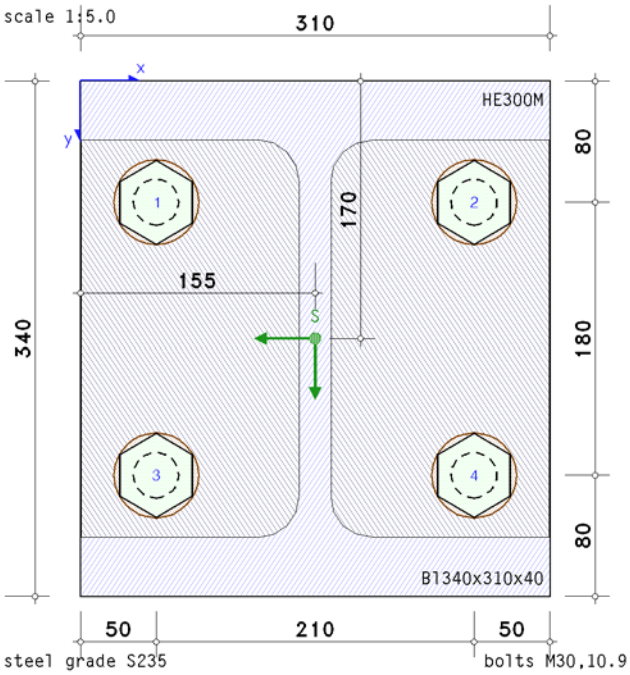
4H-EC3FS version: 2/2017-1d

bolted end-plate connection

EC 3-1-8 (12.10), NA: Deutschland



steel grade

steel grade S235

bolts

bolts with big width across flats have to be preloaded with $F_{p,C}$!!

bolt class 10.9, bolt size M30

large width across flats (high strength bolt), controlled preloaded

preloading $F_{p,C}^* = 0.7 \cdot f_{yb} \cdot A_s = 353.4$ kN, thread included in the shear plane

connection

end-plate: 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 fillet weld, weld thickness a = 8.0 mm

beam section centric on end-plate (coinciding centroids)

coordinates of 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, bottom $e_o = e_u = 80.0$ mm, distances between bolts $p_x = 210.0$ mm

edge distances left, right $e_l = e_r = 50.0$ mm, distances between bolts $p_y = 180.0$ mm

calculation

verification:

calculation and verification of internal forces and moments (FEM)

verification of end-plate with the plastic method

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 $c_f = 13331.0$ kN/cm

plastic limit force $F_{t,f} = f_{t,f} \cdot F_{t,Rd} = 383.7$ kN, $f_{t,f} = 0.950$, $F_{t,Rd} = 403.9$ kN, effective elongation at failure $\varepsilon_{t,f} = 4.5\%$

preload force $F_{p,C} = 353.4$ kN

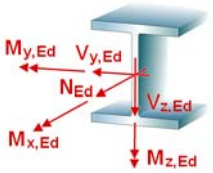
effective foundation modulus of end plate $c_b = 10500.0$ kN/cm³

number / dimension of finite elements each direction $n_x / \Delta x = 20 / 15.5$ mm, $n_y / \Delta y = 20 / 17.0$ mm

max. 50 iteration steps (tolerance limit 5‰)

internal forces and moments

Lk	N_{Ed} kN	$M_{y,Ed}$ kNm	$V_{z,Ed}$ kN	$M_{z,Ed}$ kNm	$V_{y,Ed}$ kN	$M_{x,Ed}$ kNm
1	-190.6	227.5	45.5	57.3	-11.5	0.1
2	21.5	28.0	5.6	-66.9	-5.4	-0.1
3	-98.5	100.9	20.2	67.5	-13.5	0.1
4	-75.4	88.7	17.7	0.8	-0.2	0.0
5	-24.7	-1.4	-0.3	47.1	-9.4	0.0
6	-162.9	245.2	49.0	-11.1	-9.0	0.0



Lk	N_{Ed} kN	$M_{y,Ed}$ kNm	$V_{z,Ed}$ kN	$M_{z,Ed}$ kNm	$V_{y,Ed}$ kN	$M_{x,Ed}$ kNm
7	-26.6	84.0	16.8	-67.2	-5.3	-0.1
8	-122.0	147.5	29.5	57.7	-11.5	0.1
9	-161.6	237.5	47.5	-13.0	-8.7	0.0
10	-25.6	3.9	0.8	48.4	-9.7	0.0

partial safety factors for material
resistance of cross-sections γ_{M0} = 1.00
resistance of bolts, welds, plates in bearing γ_{M2} = 1.25

Calculation

parts of fillet weld outside of end plate !

utilizations

Lk	U_p	U_σ	U_b	U_{wt}	$U_{t,s}$	$U_{vt,s}$	$U_{b,s}$	U_q	$U_{c/t}$	U_w	U
1	0.927	0.927	0.729	0.559	0.950	0.725	0.024	0.308	0.145	0.988	0.988*
2	0.310	0.226	0.310	0.054	0.890	0.644	0.004	0.153	0.101	0.455	0.890
3	0.394	0.394	0.325	0.072	0.936	0.685	0.012	0.199	0.123	0.677	0.936
4	0.167	0.139	0.167	0.053	0.878	0.647	0.006	0.096	0.072	0.265	0.878
5	0.222	0.102	0.222	0.053	0.876	0.636	0.005	0.107	0.081	0.274	0.876
6	0.699	0.644	0.699	0.378	0.950	0.727	0.023	0.272	0.124	0.770	0.950
7	0.370	0.370	0.305	0.069	0.929	0.677	0.008	0.183	0.117	0.608	0.929
8	0.526	0.526	0.365	0.112	0.950	0.697	0.016	0.227	0.128	0.754	0.950
9	0.630	0.630	0.606	0.317	0.950	0.721	0.023	0.266	0.123	0.759	0.950
10	0.228	0.109	0.228	0.053	0.876	0.637	0.006	0.110	0.083	0.288	0.876

U_p: utilization of end-plate; U_σ: utilization of end-plate due to stress; U_p: utilization of end-plate due to compression by contact
$U_{wt,s}$: utilization of bolts due to elongation; $U_{t,s}$: utilization of bolts due to tension; $U_{vt,s}$: utilization of bolts due to shear in tension
$U_{b,s}$: utilization of bolts due to bearing resistance; U_q: stress utilization of beam; U_{ct}: c/t-utilization of beam
U_w: utilization of welds; U: total utilization
*) maximum utilization

Final Result

maximum utilization [Lk 1] max U = 0.988 < 1 ok.

verification succeeded

Regulations

DIN EN 1990, Eurocode 0: Grundlagen der Tragwerksplanung;
Deutsche Fassung EN 1990:2002 + A1:2005 + A1:2005/AC:2010, Ausgabe Dezember 2010
DIN EN 1990/NA, Nationaler Anhang zur DIN EN 1990, Ausgabe Dezember 2010

DIN 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
DIN EN 1993-1-1/NA, Nationaler Anhang zur DIN EN 1993-1-1, Ausgabe Dezember 2010

DIN 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
DIN EN 1993-1-8/NA, Nationaler Anhang zur DIN EN 1993-1-8, Ausgabe Dezember 2010

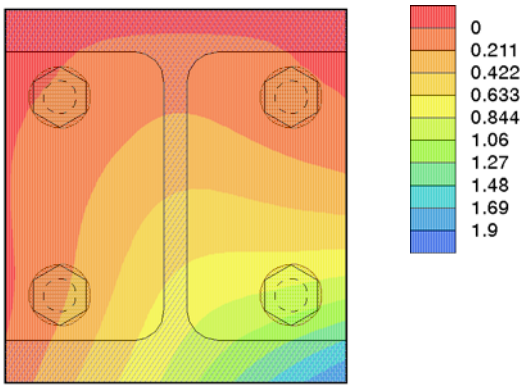
Detailed edition of Lk 1 (decisive)

Lk 1: N_{Ed} = -190.6 kN, $M_{y,Ed}$ = 227.5 kNm , $V_{z,Ed}$ = 45.5 kN, $M_{z,Ed}$ = 57.3 kNm , V

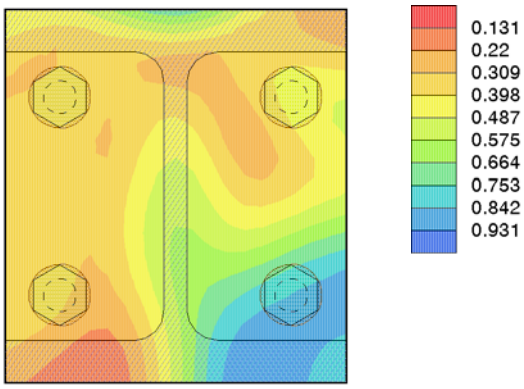
end-plate

design values: N = -190.57 kN, M_y = 227.47 kNm, M_z = 57.30 kNm

deformations u_z [mm], lifting off positive
min u_z = -0.05 mm, max u_z = 1.93 mm



utilization of end-plate U_p
min U_p = 0.131, max U_p = 0.927



utilization of end-plate

Kno	x mm	y mm	u_z mm	U_σ	U_b	U_p
336	232.5	340.0	1.438	0.927	---	0.927
441	310.0	340.0	1.929	0.757	---	0.757

x,y: node coordinates; u_z: deformations (lifting off positive); U_σ: utilization due to moment with shear force; U_b: utilization due to compression by contact
U_p: utilization of end-plate

tension force of bolts

	x mm	y mm	wt mm	F_t kN	ε_{wt} %	U_{wt}
1	50.0	80.0	0.020	370.16	0.288	0.064
2	260.0	80.0	0.045	378.19	0.351	0.078
3	50.0	260.0	0.183	383.72	0.695	0.154
4	260.0	260.0	0.911	383.72	2.515	0.559

x,y: bolt coordinates; wt: deformation (tension positive); F_t: bolt force; ε_{wt}: elongation
U_{wt}: utilization due to elongation

utilization of end-plate [node 336] U_{max} = 0.927 < 1 ok.
utilization of bolts due to elongation [bolt 4] U_{max} = 0.559 < 1 ok.

bolts

design values: max F_t = 383.72 kN, V_z = 45.49 kN, V_y = -11.46 kN, M_x = 0.08 kNm

verification of bolts
U_{tp} utilization due to tension/punching shear failure, U_{vt} utilization due to shear in tension, U_b utilization due to bearing resistance, U utilization of bolts

bolt 1	$U_{tp,1}$ = 0.916	$U_{vt,1}$ = 0.725	$U_{b,1}$ = 0.024	U_1 = 0.916
bolt 2	$U_{tp,2}$ = 0.936	$U_{vt,2}$ = 0.723	$U_{b,2}$ = 0.018	U_2 = 0.936
bolt 3	$U_{tp,3}$ = 0.950	$U_{vt,3}$ = 0.720	$U_{b,3}$ = 0.014	U_3 = 0.950
bolt 4	$U_{tp,4}$ = 0.950	$U_{vt,4}$ = 0.721	$U_{b,4}$ = 0.014	U_4 = 0.950
total Max:	U_{tp} = 0.950	U_{vt} = 0.725	U_b = 0.024	U = 0.950 < 1 ok.

utilization of bolts [bolt 3] U_{max} = 0.950 < 1 ok.

beam

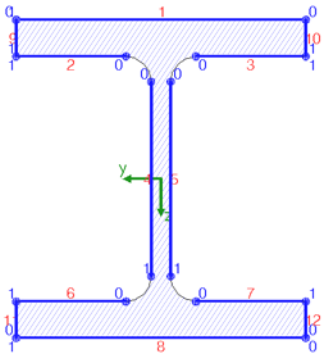
plastic cross-sectional check for N = -190.57 kN, M_y = 227.47 kNm, V_z = 45.49 kN,
M_z = 57.30 kNm, V_y = -11.46 kN, M_x = 0.08 kNm
valid normal-/shear stress: zul σ_{Rd} = 23.50 kN/cm², zul τ_{Rd} = 13.57 kN/cm²
top flange: shear force V_O = -5.73 kN, torsion T_{pO} = 0.04 kNm, shear stress τ_O = 0.06 kN/cm² ⇒ $U_{\tau,O}$ = 0.004
flange bending $M_{\sigma,O}$ = 28.65 kNm, bending stress σ_O = 3.06 kN/cm² ⇒ $U_{\sigma,O}$ = 0.130
design resistance forces $N_{max,O}$ = 2649.85 kN, $N_{min,O}$ = -2649.85 kN
bottom flange: shear force V_U = -5.73 kN, torsion T_{pU} = 0.04 kNm, shear stress τ_O = 0.06 kN/cm² ⇒ $U_{\tau,U}$ = 0.004
flange bending $M_{\sigma,U}$ = 28.65 kNm, bending stress σ_U = 3.06 kN/cm² ⇒ $U_{\sigma,U}$ = 0.130
design resistance forces $N_{max,U}$ = 2649.85 kN, $N_{min,U}$ = -2649.85 kN
web: shear force V_S = 45.49 kN, torsion T_{pS} = 0.01 kNm, shear stress τ_S = 0.72 kN/cm² ⇒ $U_{\tau,S}$ = 0.053
design resistance forces $N_{max,S}$ = 1483.32 kN, $N_{min,S}$ = -1483.32 kN
main bending: axial force N = -190.57 kN, design resistance forces N_{max} = 6783.02 kN, N_{min} = -6783.02 kN ⇒ U_N = 0.028
moment M_y = 227.47 kNm, design resistance moments $M_{y,max}$ = 907.38 kNm, $M_{y,min}$ = -907.38 kNm ⇒ U_{My} = 0.25

total (possibly due to load increase): max U = 0.308 < 1 **ok.**
utilizations: design resistance U_σ = 0.308 < 1 **ok.**, c/t-ratio $U_{c/t}$ = 0.145 < 1 **ok.**

utilization of beam max(U_σ,$U_{c/t}$) = 0.308 < 1 **ok.**

welds

design values: N = -190.57 kN, M_y = 227.47 kNm, V_z = 45.49 kN, M_z = 57.30 kNm,
V_y = -11.46 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: $\sigma_{1,w,Ed}$ = 35.55 kN/cm² < $f_{1,w,Rd}$ = 36.00 kN/cm²,
$\sigma_{2,w,Ed}$ = 17.78 kN/cm² < $f_{2,w,Rd}$ = 25.92 kN/cm² ⇒ U_w = 0.988 < 1 **ok.**

utilization of welds U_{max} = 0.988 < 1 **ok.**

utilization Lk 1 U_{max} = 0.988 < 1 **ok.**