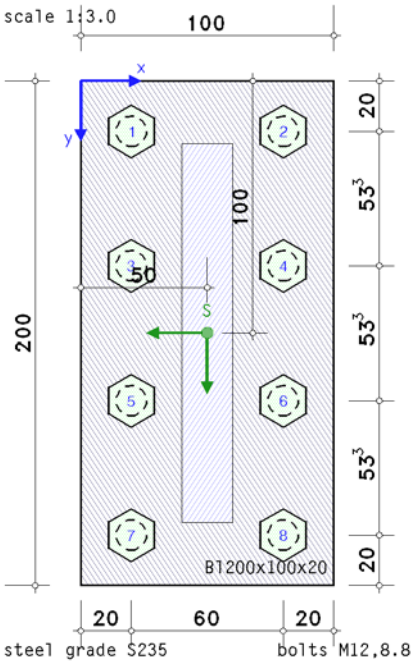
4H-EC3FS version: 2/2017-1d

bolted end-plate connection

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



steel grade

steel grade S235

bolts

bolt class 8.8, bolt size M12, thread included in the shear plane

connection

end-plate: thickness t_p = 20.0 mm, width b_p = 100.0 mm, length l_p = 200.0 mm

beam: section parameters (flat steel):

h = 150.0 mm, t = 20.0 mm

beam-end-plate: surrounding butt weld (full penetrated)

beam section centric on end-plate (coinciding centroids)

coordinates of beam centroid on end-plate x_s = 50.0 mm, y_s = 100.0 mm

bolts:

uniform arrangement of bolts, 2 vertical and 4 horizontal rows

edge distances top, bottom $e_o = e_u$ = 20.0 mm, distances between bolts p_x = 60.0 mm

edge distances left, right $e_l = e_r$ = 20.0 mm, distances between bolts p_y = 53.3 mm

calculation

verification:

calculation and verification of internal forces and moments (FEM)

verification of end-plate 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 = 4536.9 kN/cm

plastic limit force $F_{t,f} = f_{t,f} \cdot F_{t,Rd}$ = 46.1 kN, $f_{t,f}$ = 0.950, $F_{t,Rd}$ = 48.6 kN, effective elongation at failure $\varepsilon_{t,f}$ = 6.0%

without preloading ($F_{p,C}$ = 0)

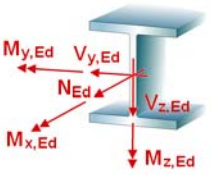
effective foundation modulus of end plate c_b = 21000.0 kN/cm³

number / dimension of finite elements each direction n_x / Δx = 20 / 5.0 mm, n_y / Δy = 20 / 10.0 mm

max. 50 iteration steps (tolerance limit 5‰)

internal forces and moments

Lk	N_{Ed} kN	$M_{y,Ed}$ kNcm	$V_{z,Ed}$ kN	$M_{z,Ed}$ kNcm	$V_{y,Ed}$ kN	$M_{x,Ed}$ kNcm
1	-12.3	-93.5	0.9	70.9	0.2	-0.1
2	7.1	-2244.9	25.9	-347.7	-0.8	129.0
3	1.1	-28.7	0.5	-152.6	-0.3	-7.6
4	-1.0	-2283.8	26.1	-213.6	-0.5	133.5
5	-1.7	-2283.9	26.1	-183.1	-0.4	16.9
6	1.6	-28.6	0.5	-174.0	-0.4	74.1
7	-1.8	-2281.8	26.1	-178.2	-0.4	12.3
8	1.7	-30.1	0.6	-177.4	-0.4	77.2
9	6.4	-2267.7	26.0	-258.6	-0.6	132.0



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

utilizations

Lk	U_p	U_σ	U_b	U_{wt}	$U_{t,s}$	$U_{vt,s}$	$U_{b,s}$	U_w	U
1	0.016	0.005	0.016	---	0.006	0.008	0.001	0.069	0.069
2	0.466	0.466	0.327	0.090	0.917	0.692	0.110	0.646	0.917
3	0.007	0.007	0.004	0.001	0.015	0.019	0.003	0.102	0.102
4	0.461	0.461	0.333	0.089	0.912	0.691	0.111	0.565	0.912
5	0.460	0.460	0.333	0.088	0.910	0.668	0.070	0.543	0.910
6	0.008	0.008	0.004	0.001	0.017	0.066	0.021	0.119	0.119
7	0.459	0.459	0.333	0.088	0.909	0.667	0.069	0.540	0.909
8	0.009	0.009	0.004	0.002	0.018	0.069	0.022	0.122	0.122
9	0.469	0.469	0.331	0.092	0.921	0.695	0.113	0.595	0.921*

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

Final Result

maximum utilization [Lk 9] max U = 0.921 < 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

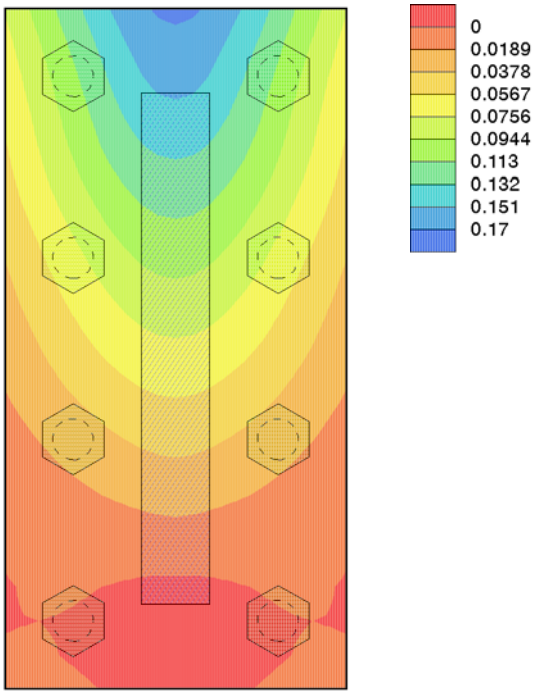
Detailed edition of Lk 9 (decisive)

Lk 9: N_{Ed} = 6.4 kN, $M_{y,Ed}$ = -2267.7 kNcm, $V_{z,Ed}$ = 26.0 kN, $M_{z,Ed}$ = -258.6 kNcm, V

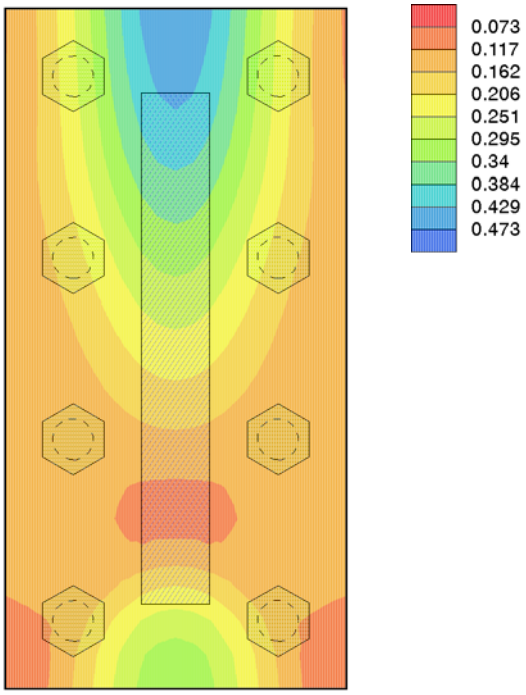
end-plate

design values: N = 6.45 kN, M_y = -22.68 kNm, M_z = -2.59 kNm

deformations u_z [mm], lifting off positive
min u_z = -0.01 mm, max u_z = 0.17 mm



utilization of end-plate U_p
min U_p = 0.073, max U_p = 0.469



utilization of end-plate

Kno	x mm	y mm	u_z mm	U_σ	U_b	U_p
211	50.0	0.0	0.174	0.469	---	0.469

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	w_t mm	F_t kN	ε_{wt} %	U_{wt}
1	20.0	20.0	0.110	44.74	0.550	0.092
2	80.0	20.0	0.110	44.74	0.550	0.092
3	20.0	73.3	0.070	31.63	0.349	0.058
4	80.0	73.3	0.070	31.63	0.349	0.058
5	20.0	126.7	0.027	12.29	0.135	0.023
6	80.0	126.7	0.027	12.29	0.135	0.023
7	20.0	180.0	-0.001	0.10	---	---
8	80.0	180.0	-0.001	0.10	---	---

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 211] U_{max} = 0.469 < 1 **ok.**
utilization of bolts due to elongation [bolt 1] U_{max} = 0.092 < 1 **ok.**

bolts

design values: max F_t = 44.74 kN, V_z = 26.00 kN, V_y = -0.58 kN, M_x = 1.32 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

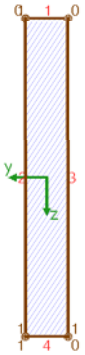
bolt 1	$U_{tp,1}$ = 0.921	$U_{vt,1}$ = 0.695	$U_{b,1}$ = 0.013	U_1 = 0.921
bolt 2	$U_{tp,2}$ = 0.921	$U_{vt,2}$ = 0.688	$U_{b,2}$ = 0.011	U_2 = 0.921
bolt 3	$U_{tp,3}$ = 0.651	$U_{vt,3}$ = 0.585	$U_{b,3}$ = 0.032	U_3 = 0.651
bolt 4	$U_{tp,4}$ = 0.651	$U_{vt,4}$ = 0.542	$U_{b,4}$ = 0.026	U_4 = 0.651
bolt 5	$U_{tp,5}$ = 0.253	$U_{vt,5}$ = 0.391	$U_{b,5}$ = 0.040	U_5 = 0.391
bolt 6	$U_{tp,6}$ = 0.253	$U_{vt,6}$ = 0.253	$U_{b,6}$ = 0.016	U_6 = 0.253
bolt 7	$U_{tp,7}$ = 0.002	$U_{vt,7}$ = 0.311	$U_{b,7}$ = 0.113	U_7 = 0.311
bolt 8	$U_{tp,8}$ = 0.002	$U_{vt,8}$ = 0.163	$U_{b,8}$ = 0.059	U_8 = 0.163
total Max:	U_{tp} = 0.921	U_{vt} = 0.695	U_b = 0.113	U = 0.921 < 1 **ok.**

utilization of bolts [bolt 1] U_{max} = 0.921 < 1 **ok.**

welds

design values: N = 6.45 kN, M_y = -22.68 kNm, V_z = 26.00 kN, M_z = -2.59 kNm,

V_y = -0.58 kN, M_x = 1.32 kNm



weld 1: a_w = 20.0 mm l_w = 20.0 mm
weld 2: a_w = 20.0 mm l_w = 150.0 mm
weld 3: a_w = 20.0 mm l_w = 150.0 mm
weld 4: a_w = 20.0 mm l_w = 20.0 mm

Max: $\sigma_{1,w,Ed}$ = 21.41 kN/cm² < $f_{1,w,Rd}$ = 36.00 kN/cm²,
$\sigma_{2,w,Ed}$ = 10.62 kN/cm² < $f_{2,w,Rd}$ = 25.92 kN/cm² ⇒ U_w = 0.595 < 1 **ok.**

utilization of welds U_{max} = 0.595 < 1 **ok.**

utilization Lk 9 U_{max} = 0.921 < 1 **ok.**