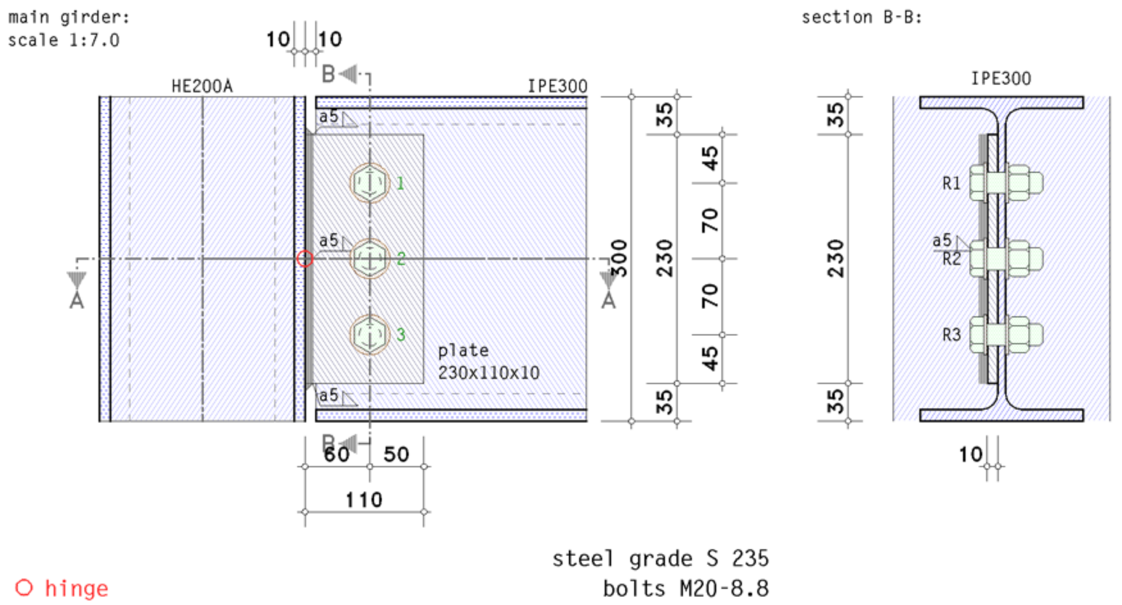
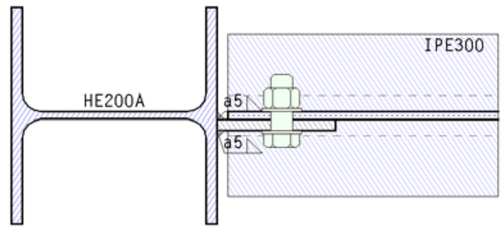
4H-EC3GT version: 6/2015-1c

Simple Joint of Beams

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



section A-A:



beam connection with fin plate, connected to the flange of the main girder

steel grade

steel grade S 235

bolts

bolt: bolt class 8.8, bolt size M20

thread in shear plane

geometry

main girder

section HE200A

supported beam

section IPE300

joint configuration

fin plate: thickness t_F = 10.0 mm, length l_F = 110.0 mm, width b_F = 230.0 mm

plate lengths: h_o = 0.0 mm, $ü_o$ = 35.0 mm (h_u = 0.0 mm, $ü_u$ = 35.0 mm), s = 10.0 mm

distances between bolts at supported beam: $e_{z,0}$ = 45.0 mm, $p_{z,1\text{-}2}$ = 70.0 mm, $p_{z,2\text{-}3}$ = 70.0 mm, $e_{x,0}$ = 50.0 mm

thickness weld: a_w = 5.0 mm

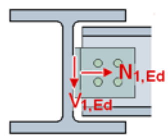
design resistance

design according to ECCS, 2009

verification of welds with the simplified method

internal forces and moments

Lk 1: $N_{1,Ed}$ = 100.00 kN $V_{1,Ed}$ = 100.00 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

resistance with tension loads γ_{Mu} = 1.10

Simple Joint of Beams

single shear connection with one bolt-row in direction of load transfer: washer on both sides !!

distance of bolt rows at supported beam (right)

edge dist.:	e_2 = 50.0 mm > 1.2·d_0 = 26.4 mm,	e_2 = 50.0 mm < 4·t_{min} + 40 mm = 68.4 mm
edge dist.:	e_1 = 45.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 45.0 mm < 4·t_1 + 40 mm = 68.4 mm
pitch:	p_1 = 70.0 mm > 2.2·d_0 = 48.4 mm,	p_1 = 70.0 mm < min(14·t_{min}, 200 mm) = 99.4 mm
pitch:	p_1 = 70.0 mm > 2.2·d_0 = 48.4 mm,	p_1 = 70.0 mm < min(14·t_{min}, 200 mm) = 99.4 mm
edge dist.:	e_1 = 45.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 45.0 mm < 4·t_1 + 40 mm = 68.4 mm

assumption: hinge is in the periphery to the flange of the main girder

Lk 1:

design values

transformation of member forces to the reference point (intersection point of beam axis')

$N_{1,Ed}$ = $N_{j1,Ed}$ = 100.00 kN
$M_{1,Ed}$ = $V_{j1,Ed}$·e_1 = -9.50 kNm, e_1 = -95.0 mm
$V_{1,Ed}$ = $V_{j1,Ed}$ = 100.00 kN

design resistance of the connection

shear force resistance
requirements to ensure the safety of the approach:
b_F = 230.0 mm < d_w = 248.6 mm **ok.**
lever arm z = 60.0 mm, $z_{lim} = ((z-s)^2 + (b_F/2+(ü_u-e_u)^2)^{1/2}$ = 158.1 mm
rotation capacity $\Phi_{vorh} = \arcsin(z/z_{lim}) - \arctan((z-s)/(b_F/2+(ü_u-e_u)))$ = 0.067
sufficient rotation capacity has to ensure ⇒ $\Phi_{vorh} = 0.067 \geq \Phi_{erf}$!!
a_w = 5.0 mm > $\beta_w/2^{1/2}\cdot f_{yF}/f_{uF}\cdot\gamma_{M2}/\gamma_{M0}\cdot t_F$ = 4.62 mm **ok.**

calculation of the point section for shear force:

bolt 1	$T_{y,1}$ = 42.86 kN, $T_{z,1}$ = 33.33 kN, T_1 = 54.29 kN
bolt 2	$T_{y,2}$ = -0.00 kN, $T_{z,2}$ = 33.33 kN, T_2 = 33.33 kN
bolt 3	$T_{y,3}$ = -42.86 kN, $T_{z,3}$ = 33.33 kN, T_3 = 54.29 kN

bolts in shear:
$U_i = T_i / (1\cdot F_{v,Rd})$, $V_{Rd,i} = V_{1,Ed} / U_i$, $V_{Rd} = \min V_{Rd,i}$
design shear resistance per shear plane: $F_{v,Rd} = \alpha_v\cdot f_{ub}\cdot A / \gamma_{M2}$ = 94.08 kN, α_v = 0.60

bolt 1:	U_1 = 0.577	$V_{Rd,1}$ = 173.3 kN
bolt 2:	U_2 = 0.354	$V_{Rd,2}$ = 282.2 kN
bolt 3:	U_3 = 0.577	$V_{Rd,3}$ = 173.3 kN

design shear resistance total: $V_{Rd,1}$ = 173.3 kN

fin plate with bearing resistance:
$U_{z,i} = T_{z,i} / F_{b,z,Rd}$, $U_{y,i} = T_{y,i} / F_{b,y,Rd}$, $U_i = (U_{z,i}^2 + U_{y,i}^2)^{1/2}$, $V_{Rd,i} = V_{1,Ed} / U_i$, $V_{Rd} = \min V_{Rd,i}$

bolt 1:	$F_{b,z,1}$ = 98.18 kN	$F_{b,y,1}$ = 109.09 kN	U_1 = 0.519	$V_{Rd,1}$ = 192.6 kN
bolt 2:	$F_{b,z,2}$ = 116.73 kN		U_2 = 0.286	$V_{Rd,2}$ = 350.2 kN
bolt 3:	$F_{b,z,3}$ = 98.18 kN	$F_{b,y,3}$ = 109.09 kN	U_3 = 0.519	$V_{Rd,3}$ = 192.6 kN

design bearing resistance total: $V_{Rd,2}$ = 192.6 kN

fin plate with shear (gross section):
shear resistance $V_{Rd} = (A_v\cdot f_y) / (3^{1/2}\cdot\gamma_{M0})$ = 312.06 kN
shear resistance total: $V_{Rd,3} = V_{Rd}/1.27$ = 245.7 kN

fin plate with shear (net section):
shear resistance $V_{Rd} = (A_{v,net}\cdot f_u) / (3^{1/2}\cdot\gamma_{M2})$ = 272.69 kN
shear resistance total: $V_{Rd,4}$ = 272.7 kN

fin plate in tension and shear (shear block):
shear resistance $V_{eff,Rd} = (0.5\cdot A_{nt}\cdot f_u) / \gamma_{M2} + (A_{nv}\cdot f_y/3^{1/3}) / \gamma_{M0}$ = 232.54 kN
shear resistance total: $V_{Rd,5}$ = 232.5 kN

fin plate in bending and shear:
b_F = 230.0 mm > 2.73·z = 163.8 mm:
shear resistance total: $V_{Rd,6} = \infty$

fin plate with buckling:

$z_F = 60.0$ mm $< t_F/0.15 = 66.7$ mm:
shear resistance total: $V_{Rd,7} = \infty$

beam web with bearing resistance:
$U_{z,i} = T_{z,i} / F_{b,z,Rd}$, $U_{y,i} = T_{y,i} / F_{b,y,Rd}$, $U_i = (U_{z,i}^2 + U_{y,i}^2)^{1/2}$, $V_{Rd,i} = V_{1,Ed} / U_i$, $V_{Rd} = \min V_{Rd,i}$

bolt 1:	$F_{b,z,1} = 82.88$ kN	$F_{b,y,1} = 77.45$ kN	$U_1 = 0.684$	$V_{Rd,1} = 146.2$ kN
bolt 2:	$F_{b,z,2} = 82.88$ kN		$U_2 = 0.402$	$V_{Rd,2} = 248.6$ kN
bolt 3:	$F_{b,z,3} = 82.88$ kN	$F_{b,y,3} = 77.45$ kN	$U_3 = 0.684$	$V_{Rd,3} = 146.2$ kN

design bearing resistance total: $V_{Rd,8} = 146.2$ kN

beam web with shear (gross section):
shear resistance $V_{Rd} = (A_v \cdot f_y) / (3^{1/2} \cdot \gamma_{M0}) = 348.44$ kN
shear resistance total: $V_{Rd,9} = 348.4$ kN

beam web with shear (net section):
shear resistance $V_{Rd} = (A_{v,net} \cdot f_u) / (3^{1/2} \cdot \gamma_{M2}) = 349.11$ kN
shear resistance total: $V_{Rd,10} = 349.1$ kN

beam web in tension and shear (shear block):
shear resistance $V_{eff,Rd} = (0.5 \cdot A_{nt} \cdot f_u) / \gamma_{M2} + (A_{nv} \cdot f_y / 3^{1/3}) / \gamma_{M0} = 198.82$ kN
shear resistance total: $V_{Rd,11} = 198.8$ kN

requirements to ensure sufficient rotation capacity:
$V_{Rd,F} = 146.2$ kN $< \min(V_{Rd,1}, V_{Rd,7}) = 173.3$ kN ok.
$V_{Rd,1,F} = 173.3$ mm $> \min(V_{Rd,2}, V_{Rd,8}) = 146.2$ kN ok.

shear resistance: min $V_{Rd,F} = V_{Rd,8}$ $= 146.2$ kN

tension force resistance
calculation of the point section for tension force:

bolt 1	$T_{y,1} = -33.33$ kN,	$T_{z,1} = 0.00$ kN,	$T_1 = 33.33$ kN
bolt 2	$T_{y,2} = -33.33$ kN,	$T_{z,2} = 0.00$ kN,	$T_2 = 33.33$ kN
bolt 3	$T_{y,3} = -33.33$ kN,	$T_{z,3} = 0.00$ kN,	$T_3 = 33.33$ kN

bolts in shear:
$U_i = T_i / (1 \cdot F_{v,Rd})$, $V_{Rd,i} = V_{1,Ed} / U_i$, $V_{Rd} = \min V_{Rd,i}$
design shear resistance per shear plane: $F_{v,Rd} = \alpha_v \cdot f_{ub} \cdot A / \gamma_{M2} = 106.91$ kN, $\alpha_v = 0.60$

bolt 1:	$U_1 = 0.312$	$V_{Rd,1} = 320.7$ kN
bolt 2:	$U_2 = 0.312$	$V_{Rd,2} = 320.7$ kN
bolt 3:	$U_3 = 0.312$	$V_{Rd,3} = 320.7$ kN

design shear resistance total: $N_{Rd,1} = 320.7$ kN

fin plate with bearing resistance:
$U_{z,i} = T_{z,i} / F_{b,z,Rd}$, $U_{y,i} = T_{y,i} / F_{b,y,Rd}$, $U_i = (U_{z,i}^2 + U_{y,i}^2)^{1/2}$, $V_{Rd,i} = V_{1,Ed} / U_i$, $V_{Rd} = \min V_{Rd,i}$

bolt 1:	$F_{b,y,1} = 123.97$ kN	$U_1 = 0.269$	$N_{Rd,1} = 371.9$ kN
bolt 2:	$F_{b,y,2} = 123.97$ kN	$U_2 = 0.269$	$N_{Rd,2} = 371.9$ kN
bolt 3:	$F_{b,y,3} = 123.97$ kN	$U_3 = 0.269$	$N_{Rd,3} = 371.9$ kN

design bearing resistance total: $N_{Rd,2} = 371.9$ kN

fin plate in tension (net section):
tension resistance $N_{Rd} = N_{u,Rd} = (0.9 \cdot A_{net} \cdot f_u) / \gamma_{M2} = 483.05$ kN
tension resistance total: $N_{Rd,3} = 483.1$ kN

beam web with bearing resistance:
$U_{z,i} = T_{z,i} / F_{b,z,Rd}$, $U_{y,i} = T_{y,i} / F_{b,y,Rd}$, $U_i = (U_{z,i}^2 + U_{y,i}^2)^{1/2}$, $V_{Rd,i} = V_{1,Ed} / U_i$, $V_{Rd} = \min V_{Rd,i}$

bolt 1:	$F_{b,y,1} = 88.02$ kN	$U_1 = 0.379$	$N_{Rd,1} = 264.0$ kN
bolt 2:	$F_{b,y,2} = 88.02$ kN	$U_2 = 0.379$	$N_{Rd,2} = 264.0$ kN
bolt 3:	$F_{b,y,3} = 88.02$ kN	$U_3 = 0.379$	$N_{Rd,3} = 264.0$ kN

design bearing resistance total: $N_{Rd,4} = 264.0$ kN

beam web in tension (net section):
tension resistance $N_{Rd} = N_{u,Rd} = (0.9 \cdot A_{net} \cdot f_u) / \gamma_{M2} = 342.97$ kN
tension resistance total: $N_{Rd,5} = 343.0$ kN

tension resistance: min $N_{Rd,F} = N_{Rd,4}$ $= 264.0$ kN

verification of the connection

$V_{Ed} = 100.0$ kN: $V_{Ed} / \min V_{Rd} = 0.684 < 1$ ok.
$N_{Ed} = 100.0$ kN: $N_{Ed} / \min N_{Rd} = 0.379 < 1$ ok.

weld verification

$F_{w,Ed}$ = 1.86 kN/cm < $F_{w,Rd}$ = 10.39 kN/cm ⇒ U_w = 0.388 < 1 ok.

verification result

maximum utilization: max U = 0.684 < 1 ok.

Final Result

maximum utilization: design resistance max U = 0.684 < 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

ECCS Document No. 126: European Recommendations for the Design of Simple Joints in Steel Structures.
ECCS TC10 - Structural Connections, 2009. J.P. Jaspart, J.F. Demonceau, S. Renkin, M.L. Guillaume