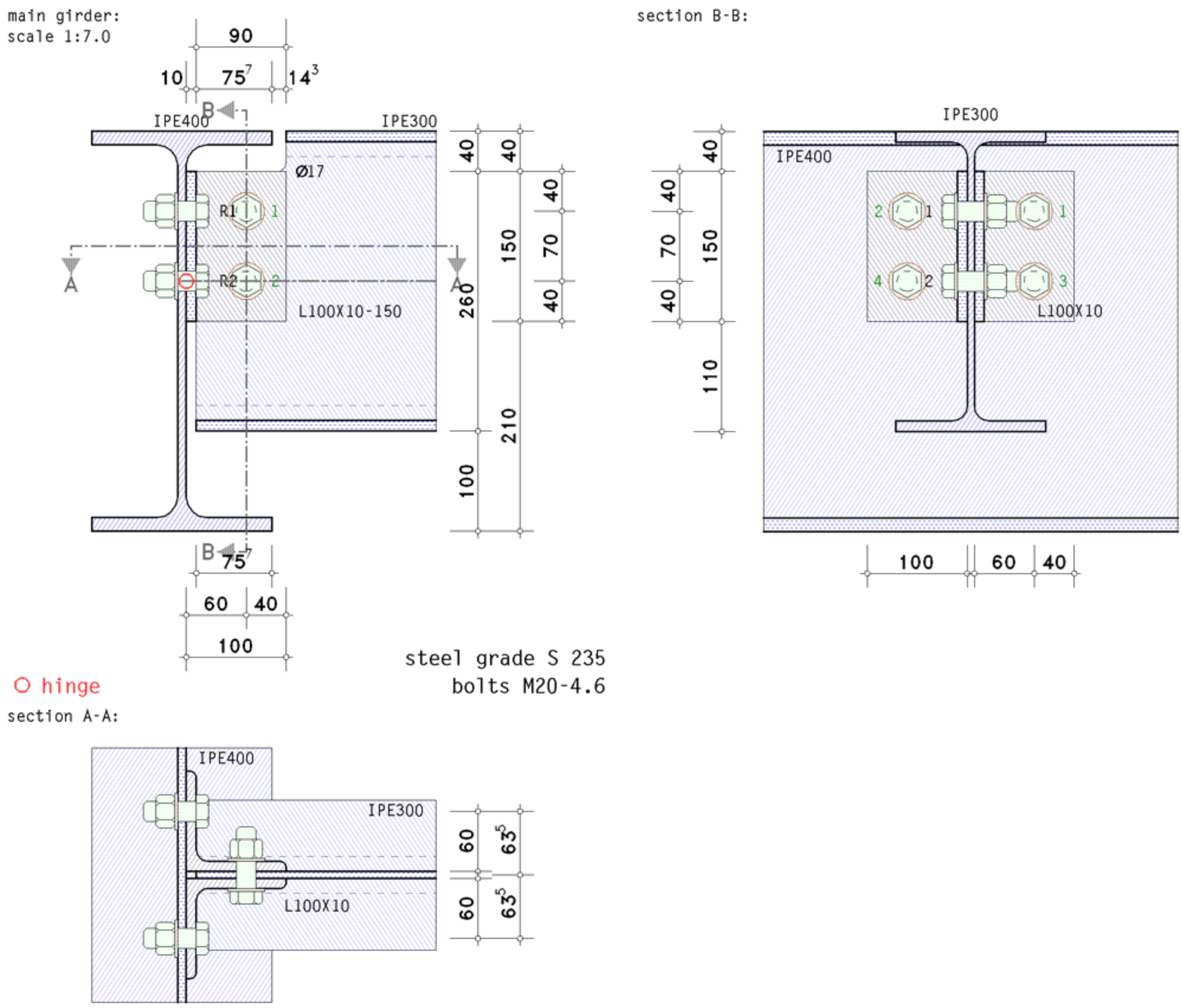
4H-EC3GT version: 6/2015-1c

Simple Joint of Beams

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



beam connection with two bolted angles, connected to the web of the main girder

steel grade

steel grade S 235

bolts

bolt: bolt class 4.6, bolt size M20

shear plane passes through the unthreaded portion of the bolt

geometry

main girder

section IPE400

supported beam

section IPE300

joint configuration

2 x angle: section L100X10

width of angles b_a = 150.0 mm

plate lengths: h_o = 0.0 mm, $ü_o$ = 40.0 mm (h_u = 100.0 mm, $ü_u$ = 110.0 mm), s = 10.0 mm

notch: a_o = 90.0 mm, e_o = 40.0 mm

rounded notch (root radius r_a = 8.5 mm)

distances between bolts at main girder: $e_{z,0}$ = 40.0 mm, $p_{z,1-2}$ = 70.0 mm, $e_{x,0}$ = 40.0 mm

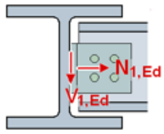
distances between bolts at supported beam: $e_{z,0}$ = 40.0 mm, $p_{z,1-2}$ = 70.0 mm, $e_{x,0}$ = 40.0 mm

design resistance

verification of welds with the directional method

elastic cross-sectional check der supported beam

internal forces and moments
Lk 1: $V_{1,Ed}$ = 75.00 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

Simple Joint of Beams

distance of bolt rows at main girder (right)

edge dist.:	e_2 = 40.0 mm > 1.2·d_0 = 26.4 mm,	e_2 = 40.0 mm < 4·t_{min} + 40 mm = 74.4 mm
pitch:	p_2 = 127.1 mm > 2.4·d_0 = 52.8 mm,	p_2 = 127.1 mm > min(14·t_{min}, 200 mm) = 120.4 mm !!
edge dist.:	e_1 = 40.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 40.0 mm < 4·t_1 + 40 mm = 74.4 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) = 120.4 mm
edge dist.:	e_1 = 40.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 40.0 mm < 4·t_1 + 40 mm = 74.4 mm

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 = 40.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 40.0 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
edge dist.:	e_1 = 40.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 40.0 mm < 4·t_1 + 40 mm = 68.4 mm

assumption: hinge is in the periphery to main girder web

Lk 1:

design values

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

$M_{1,Ed}$ = $V_{j1,Ed}$·e_1 = -0.32 kNm, e_1 = -4.3 mm
$V_{1,Ed}$ = $V_{j1,Ed}$ = 75.00 kN

design resistance of the connection

angle leg at main girder:

compression by contact
dimensions of contact area h_D = 20.0 mm, b_D = 10.8 mm, compression force in contact area D = 26.83 kN
check: D / (A_D·f_{yd}) = 0.526 < 1 ok. ⇒ compression by contact exists

calculation of the point section:
bolt 1 $T_{y,1}$ = 6.19 kN, $T_{z,1}$ = 18.75 kN, T_1 = 19.75 kN
bolt 2 $T_{y,2}$ = 20.64 kN, $T_{z,2}$ = 18.75 kN, T_2 = 27.89 kN

shear force resistance
bolts in shear:
$U_i = T_i / F_{v,Rd}$, $V_{Rd,i} = V_{1,Ed} / U_i$, V_{Rd} = min $V_{Rd,i}$
design shear resistance per shear plane: $F_{v,Rd} = \alpha_v \cdot f_{ub} \cdot A / \gamma_{M2}$ = 60.32 kN, α_v = 0.60

bolt 1:	U_1 = 0.327	$V_{Rd,1}$ = 229.1 kN
bolt 2:	U_2 = 0.462	$V_{Rd,2}$ = 162.2 kN

design shear resistance total: $V_{Rd,1}$ = 162.2 kN

angle leg 2 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 = max($U_{z,i}$, $U_{y,i}$), $V_{Rd,i} = V_{1,Ed} / U_i$, V_{Rd} = min $V_{Rd,i}$

bolt 1:	$F_{b,z,1}$ = 87.27 kN	$F_{b,y,1}$ = 87.27 kN	U_1 = 0.368	$V_{Rd,1}$ = 203.6 kN
bolt 2:	$F_{b,z,2}$ = 87.27 kN	$F_{b,y,2}$ = 87.27 kN	U_2 = 0.368	$V_{Rd,2}$ = 203.6 kN

design bearing resistance total: $V_{Rd,2}$ = 203.6 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 = max($U_{z,i}$, $U_{y,i}$), $V_{Rd,i} = V_{1,Ed} / U_i$, V_{Rd} = min $V_{Rd,i}$

bolt 1:	$F_{b,z,1}$ = 100.39 kN	$F_{b,y,1}$ = 123.84 kN	U_1 = 0.187	$V_{Rd,1}$ = 401.5 kN
bolt 2:	$F_{b,z,2}$ = 100.39 kN	$F_{b,y,2}$ = 123.84 kN	U_2 = 0.187	$V_{Rd,2}$ = 401.5 kN

design bearing resistance total: $V_{Rd,3}$ = 401.5 kN

shear resistance: min $V_{Rd,a2}$ = $V_{Rd,1}$ = 162.2 kN

angle leg at supported beam:

calculation of the point section:
bolt 1 $T_{y,1}$ = 64.29 kN, $T_{z,1}$ = 37.50 kN, T_1 = 74.42 kN

bolt 2 $T_{y,2}$ = -64.29 kN, $T_{z,2}$ = 37.50 kN, T_2 = 74.42 kN

<u>shear force resistance</u>

bolts in shear:

$U_i = T_i / (2 \cdot F_{v,Rd})$, $V_{Rd,i} = V_{1,Ed} / U_i$, $V_{Rd} = \min V_{Rd,i}$

design shear resistance per shear plane: $F_{v,Rd} = \alpha_v \cdot f_{ub} \cdot A / \gamma_{M2}$ = 60.32 kN, α_v = 0.60

bolt 1: U_1 = 0.617 $V_{Rd,1}$ = 121.6 kN

bolt 2: U_2 = 0.617 $V_{Rd,2}$ = 121.6 kN

design shear resistance total: $V_{Rd,1}$ = 121.6 kN

angle leg 1 with bearing resistance:

$U_{z,i} = T_{z,i} / F_{b,z,Rd}$, $U_{y,i} = T_{y,i} / F_{b,y,Rd}$, $U_i = \max(U_{z,i}, U_{y,i})$, $V_{Rd,i} = V_{1,Ed} / U_i$, $V_{Rd} = \min V_{Rd,i}$

bolt 1: $F_{b,z,1}$ = 87.27 kN $F_{b,y,1}$ = 87.27 kN U_1 = 0.368 $V_{Rd,1}$ = 203.6 kN

bolt 2: $F_{b,z,2}$ = 87.27 kN $F_{b,y,2}$ = 87.27 kN U_2 = 0.368 $V_{Rd,2}$ = 203.6 kN

design bearing resistance total: $V_{Rd,2}$ = 203.6 kN

angle leg 1 in tension and shear (shear block):

shear resistance $V_{eff,Rd} = (0.5 \cdot A_{nt} \cdot f_u) / \gamma_{M2} + (A_{nv} \cdot f_y / 3^{1/3}) / \gamma_{M0}$ = 146.23 kN

shear resistance total: $V_{Rd,3}$ = 146.2 kN

angle leg 1 in bending and shear:

$(A_{f,net} \cdot 0.9 \cdot f_u)/\gamma_{M2}$ = 137.4 kN < $(A_f \cdot f_y)/\gamma_{M0}$ = 176.3 kN ⇒ der deduction of holes is respected.

shear resistance $V_{Rd} = f_y/\gamma_{M0} / ((b'/W_{el})^2 + 3 \cdot (1/A)^2)^{1/2}$ = 90.00 kN

shear resistance total: $V_{Rd,4}$ = 2·90.00 = 180.0 kN

beam web with bearing resistance:

$U_{z,i} = T_{z,i} / F_{b,z,Rd}$, $U_{y,i} = T_{y,i} / F_{b,y,Rd}$, $U_i = \max(U_{z,i}, U_{y,i})$, $V_{Rd,i} = V_{1,Ed} / U_i$, $V_{Rd} = \min V_{Rd,i}$

bolt 1: $F_{b,z,1}$ = 61.96 kN $F_{b,y,1}$ = 77.45 kN U_1 = 0.830 $V_{Rd,1}$ = 90.4 kN

bolt 2: $F_{b,z,2}$ = 82.88 kN $F_{b,y,2}$ = 77.45 kN U_2 = 0.830 $V_{Rd,2}$ = 90.4 kN

design bearing resistance total: $V_{Rd,5}$ = 90.4 kN

beam web in tension and shear (shear block):

shear resistance $V_{eff,Rd} = (0.5 \cdot A_{nt} \cdot f_u) / \gamma_{M2} + (A_{nv} \cdot f_y / 3^{1/3}) / \gamma_{M0}$ = 220.01 kN

shear resistance total: $V_{Rd,6}$ = 220.0 kN

shear resistance: min $V_{Rd,a1}$ = $V_{Rd,5}$ = 90.4 kN

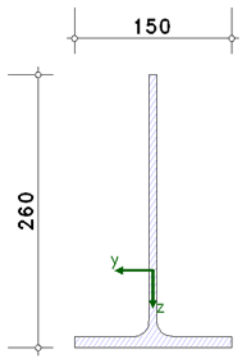
design resistance: min V_{Rd} = 90.4 kN

verification of the connection

V_{Ed} = 75.0 kN: V_{Ed} / min V_{Rd} = 0.830 < 1 ok.

cross-sectional check of supported beam

verification at Δx = 95.8 mm with notch

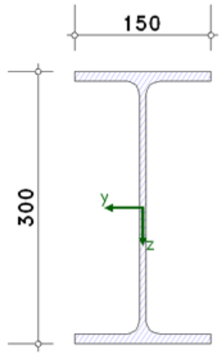


elastic cross-sectional check for M_{Ed} = 6.86 kNm, V_{Ed} = 75.00 kN

elastic stresses: max σ_x = 2.16 kN/cm², min σ_x = -5.47 kN/cm², max τ = 5.57 kN/cm², max σ_v = 9.64 kN/cm²

utilizations: design resistance U_σ = 0.410 < 1 ok.

verification at Δx = 104.3 mm



elastic cross-sectional check for M_{Ed} = 7.50 kNm, V_{Ed} = 75.00 kN
elastic stresses: max σ_x = 1.35 kN/cm², min σ_x = -1.35 kN/cm², max τ = 3.97 kN/cm², max σ_v = 6.88 kN/cm²
utilizations: design resistance U_σ = 0.293 < 1 ok., c/t-ratio $U_{c/t}$ = 0.090 < 1 ok.

verification result

maximum utilization: max U = 0.830 < 1 ok.

Final Result

maximum utilization: design resistance max U = 0.830 < 1 ok.
c/t-ratio max U = 0.090 < 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