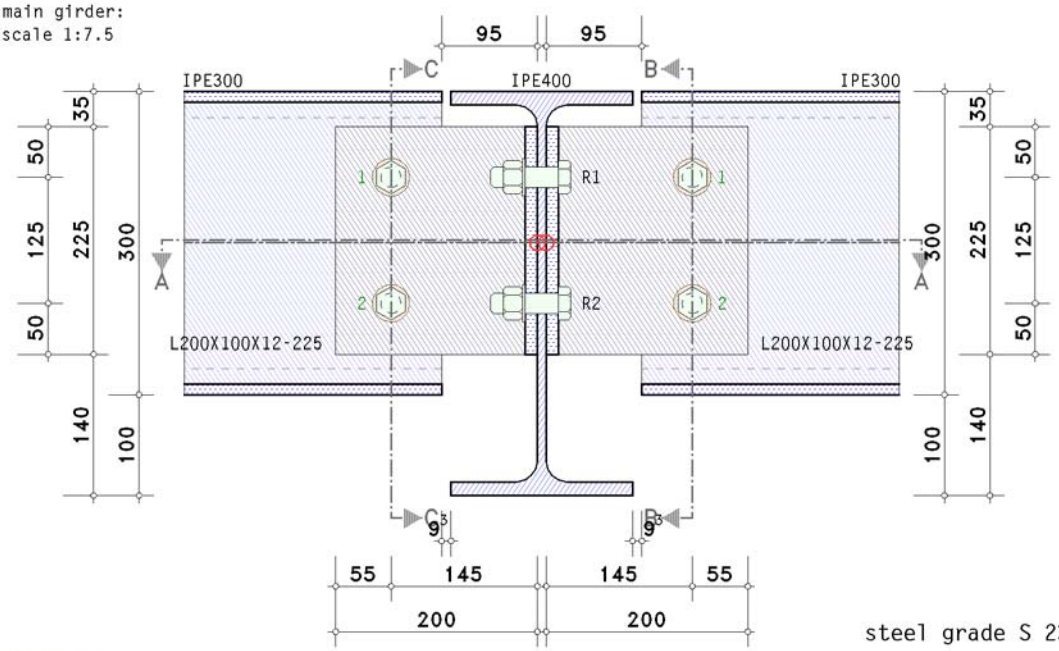
POS. 11: WAGENKNECHT 5.8.2

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

Simple Joint of Beams

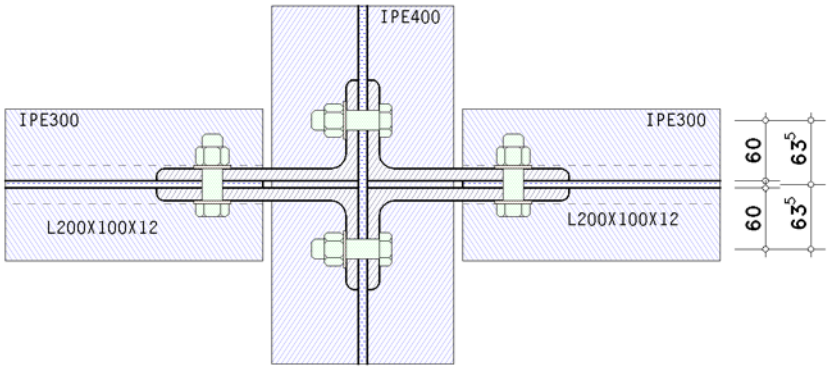
EC 3-1-8 (12.10), NA: Deutschland

main girder:
scale 1:7.5

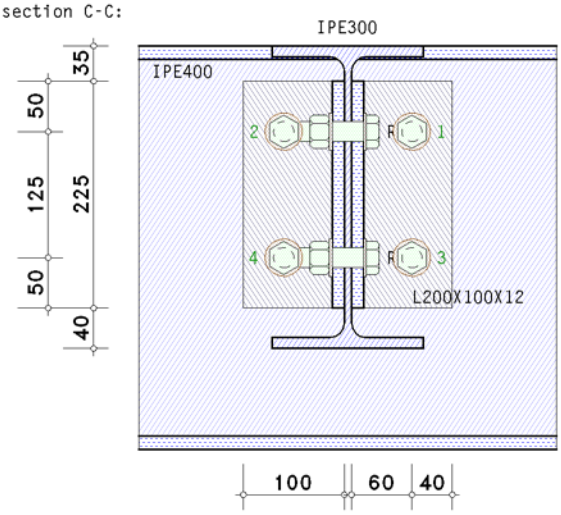


○ hinge

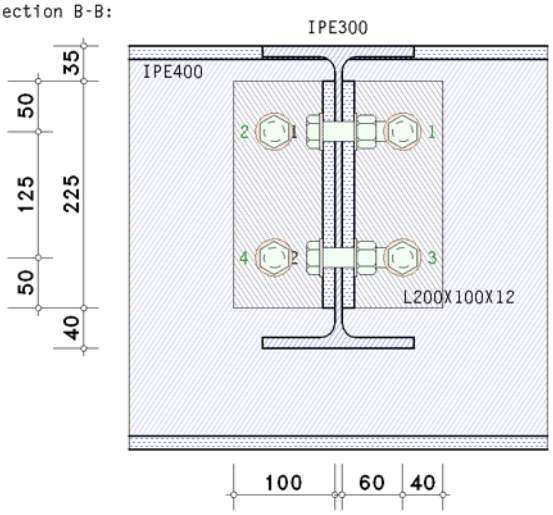
section A-A:



section C-C:



section B-B:



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 left

section IPE300

joint configuration left

2 x angle: section L200X100X12

width of angles b_a = 225.0 mm

plate lengths: h_o = 0.0 mm, $ü_o$ = 35.0 mm (h_u = 100.0 mm, $ü_u$ = 40.0 mm), s = 95.0 mm

distances between bolts at main girder: $e_{z,0}$ = 50.0 mm, $p_{z,1-2}$ = 125.0 mm, $e_{x,0}$ = 40.0 mm

distances between bolts at supported beam: $e_{z,0}$ = 50.0 mm, $p_{z,1-2}$ = 125.0 mm, $e_{x,0}$ = 55.0 mm

supported beam right

section IPE300

joint configuration right

2 x angle: section L200X100X12

width of angles b_a = 225.0 mm

plate lengths: h_o = 0.0 mm, $ü_o$ = 35.0 mm (h_u = 100.0 mm, $ü_u$ = 40.0 mm), s = 95.0 mm

distances between bolts at main girder: $e_{z,0}$ = 50.0 mm, $p_{z,1-2}$ = 125.0 mm, $e_{x,0}$ = 40.0 mm

distances between bolts at supported beam: $e_{z,0}$ = 50.0 mm, $p_{z,1-2}$ = 125.0 mm, $e_{x,0}$ = 55.0 mm

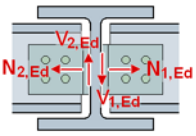
design resistance

verification of welds with the directional method

elastic cross-sectional check der supported beam

internal forces and moments

Lk 1: $V_{1,Ed}$ = 55.00 kN $V_{2,Ed}$ = 55.00 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 (left)

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 = 50.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 50.0 mm < 4·t_1 + 40 mm = 74.4 mm
pitch:	p_1 = 125.0 mm > 2.2·d_0 = 48.4 mm,	p_1 = 125.0 mm > min(14·t_{min}, 200 mm) = 120.4 mm !!
edge dist.:	e_1 = 50.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 50.0 mm < 4·t_1 + 40 mm = 74.4 mm

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
edge dist.:	e_1 = 50.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 50.0 mm < 4·t_1 + 40 mm = 74.4 mm
edge dist.:	e_1 = 50.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 50.0 mm < 4·t_1 + 40 mm = 74.4 mm

distance of bolt rows at supported beam (left)

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 = 50.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 50.0 mm < 4·t_1 + 40 mm = 68.4 mm
pitch:	p_1 = 125.0 mm > 2.2·d_0 = 48.4 mm,	p_1 = 125.0 mm > min(14·t_{min}, 200 mm) = 99.4 mm !!
edge dist.:	e_1 = 50.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 50.0 mm < 4·t_1 + 40 mm = 68.4 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 = 50.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 50.0 mm < 4·t_1 + 40 mm = 68.4 mm
pitch:	p_1 = 125.0 mm > 2.2·d_0 = 48.4 mm,	p_1 = 125.0 mm > min(14·t_{min}, 200 mm) = 99.4 mm !!
edge dist.:	e_1 = 50.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 50.0 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')

connection left:
$M_{2,Ed} = V_{j2,Ed} \cdot e_2 = 0.24$ kNm, $e_2 = 4.3$ mm
$V_{2,Ed} = V_{j2,Ed} = 55.00$ kN

connection right:
$M_{1,Ed} = V_{j1,Ed} \cdot e_1 = -0.24$ kNm, $e_1 = -4.3$ mm
$V_{1,Ed} = V_{j1,Ed} = 55.00$ kN

design resistance of the connection

connection left:

angle leg at main girder:

calculation of the point section:
bolt 1 $T_{y,1} = -13.20$ kN, $T_{z,1} = 13.75$ kN, $T_1 = 19.06$ kN
bolt 2 $T_{y,2} = 13.20$ kN, $T_{z,2} = 13.75$ kN, $T_2 = 19.06$ kN

shear force resistance
bolts in shear:
$U_i = T_i / F_{v,Rd}$, $V_{Rd,i} = V_{2,Ed} / U_i$, $V_{Rd} = \min V_{Rd,i}$
design shear resistance per shear plane: $F_{v,Rd} = \alpha_v \cdot f_{ub} \cdot A / \gamma_{M2} = 60.32$ kN, $\alpha_v = 0.60$
bolt 1: $U_1 = 0.316$ $V_{Rd,1} = 174.1$ kN
bolt 2: $U_2 = 0.316$ $V_{Rd,2} = 174.1$ kN
design shear resistance total: $V_{Rd,1} = 174.1$ kN

angle leg 2 with bearing resistance:
$U_{z,i} = T_{z,i} / F_{b,z,Rd}$, $U_{y,i} = T_{y,i} / F_{b,y,Rd}$, $U_i = \max(U_{z,i}, U_{y,i})$, $V_{Rd,i} = V_{2,Ed} / U_i$, $V_{Rd} = \min V_{Rd,i}$

bolt 1:	$F_{b,z,1} = 130.91$ kN	$F_{b,y,1} = 104.73$ kN	$U_1 = 0.126$	$V_{Rd,1} = 436.4$ kN
bolt 2:	$F_{b,z,2} = 130.91$ kN	$F_{b,y,2} = 104.73$ kN	$U_2 = 0.126$	$V_{Rd,2} = 436.4$ kN

design bearing resistance total: $V_{Rd,2} = 436.4$ kN

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

bolt 1:	$F_{b,z,1} = 123.84$ kN	$F_{b,y,1} = 123.84$ kN	$U_1 = 0.111$	$V_{Rd,1} = 495.4$ kN
bolt 2:	$F_{b,z,2} = 123.84$ kN	$F_{b,y,2} = 123.84$ kN	$U_2 = 0.111$	$V_{Rd,2} = 495.4$ kN

design bearing resistance total: $V_{Rd,3} = 495.4$ kN

shear resistance: min $V_{Rd,a2} = V_{Rd,1} = 174.1$ kN

angle leg at supported beam:

calculation of the point section:
bolt 1 $T_{y,1} = 67.58$ kN, $T_{z,1} = 27.50$ kN, $T_1 = 72.96$ kN
bolt 2 $T_{y,2} = -67.58$ kN, $T_{z,2} = 27.50$ kN, $T_2 = 72.96$ kN

shear force resistance
bolts in shear:
$U_i = T_i / (2 \cdot F_{v,Rd})$, $V_{Rd,i} = V_{2,Ed} / U_i$, $V_{Rd} = \min V_{Rd,i}$
design shear resistance per shear plane: $F_{v,Rd} = \alpha_v \cdot f_{ub} \cdot A / \gamma_{M2} = 60.32$ kN, $\alpha_v = 0.60$
bolt 1: $U_1 = 0.605$ $V_{Rd,1} = 90.9$ kN
bolt 2: $U_2 = 0.605$ $V_{Rd,2} = 90.9$ kN
design shear resistance total: $V_{Rd,1} = 90.9$ kN

angle leg 1 with bearing resistance:
$U_{z,i} = T_{z,i} / F_{b,z,Rd}$, $U_{y,i} = T_{y,i} / F_{b,y,Rd}$, $U_i = \max(U_{z,i}, U_{y,i})$, $V_{Rd,i} = V_{2,Ed} / U_i$, $V_{Rd} = \min V_{Rd,i}$

bolt 1:	$F_{b,z,1} = 130.91$ kN	$F_{b,y,1} = 144.00$ kN	$U_1 = 0.235$	$V_{Rd,1} = 234.4$ kN
bolt 2:	$F_{b,z,2} = 130.91$ kN	$F_{b,y,2} = 144.00$ kN	$U_2 = 0.235$	$V_{Rd,2} = 234.4$ kN

design bearing resistance total: $V_{Rd,2} = 234.4$ kN

angle leg 1 in tension and shear (shear block):
shear resistance $V_{eff,Rd} = (0.5 \cdot A_{nt} \cdot f_u) / \gamma_{M2} + (A_{nv} \cdot f_y / 3^{1/3}) / \gamma_{M0} = 307.23$ kN
shear resistance total: $V_{Rd,3} = 307.2$ kN

angle leg 1 in bending and shear:
$(A_{f,net} \cdot 0.9 \cdot f_u)/\gamma_{M2} = 281.5$ kN $<$ $(A_f \cdot f_y)/\gamma_{M0} = 317.3$ kN $\Rightarrow$ der deduction of holes is respected.
shear resistance $V_{Rd} = f_y/\gamma_{M0} / ((b'/W_{el})^2 + 3 \cdot (1/A)^2)^{1/2} = 120.87$ kN

shear resistance total: $V_{Rd,4} = 2 \cdot 120.87 = 241.7$ kN

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

bolt 1:	$F_{b,z,1} = 102.24$ kN	$F_{b,y,1} = 77.45$ kN	$U_1 = 0.873$	$V_{Rd,1} = 63.0$ kN
bolt 2:	$F_{b,z,2} = 102.24$ kN	$F_{b,y,2} = 77.45$ kN	$U_2 = 0.873$	$V_{Rd,2} = 63.0$ kN

design bearing resistance total: $V_{Rd,5} = 63.0$ kN

beam web in tension and shear (shear block):
shear resistance $V_{eff,Rd} = (0.5 \cdot A_{nt} \cdot f_u) / \gamma_{M2} + (A_{nv} \cdot f_y / 3^{1/3}) / \gamma_{M0} = 215.20$ kN
shear resistance total: $V_{Rd,6} = 215.2$ kN

shear resistance: min $V_{Rd,a1} = V_{Rd,5} = 63.0$ kN

design resistance: min $V_{Rd} = 63.0$ kN

connection right:

angle leg at main girder:

calculation of the point section:
bolt 1 $T_{y,1} = -13.20$ kN, $T_{z,1} = 13.75$ kN, $T_1 = 19.06$ kN
bolt 2 $T_{y,2} = 13.20$ kN, $T_{z,2} = 13.75$ kN, $T_2 = 19.06$ 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, $\alpha_v = 0.60$

bolt 1:	$U_1 = 0.316$	$V_{Rd,1} = 174.1$ kN
bolt 2:	$U_2 = 0.316$	$V_{Rd,2} = 174.1$ kN

design shear resistance total: $V_{Rd,1} = 174.1$ 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:	$F_{b,z,1} = 130.91$ kN	$F_{b,y,1} = 104.73$ kN	$U_1 = 0.126$	$V_{Rd,1} = 436.4$ kN
bolt 2:	$F_{b,z,2} = 130.91$ kN	$F_{b,y,2} = 104.73$ kN	$U_2 = 0.126$	$V_{Rd,2} = 436.4$ kN

design bearing resistance total: $V_{Rd,2} = 436.4$ 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:	$F_{b,z,1} = 123.84$ kN	$F_{b,y,1} = 123.84$ kN	$U_1 = 0.111$	$V_{Rd,1} = 495.4$ kN
bolt 2:	$F_{b,z,2} = 123.84$ kN	$F_{b,y,2} = 123.84$ kN	$U_2 = 0.111$	$V_{Rd,2} = 495.4$ kN

design bearing resistance total: $V_{Rd,3} = 495.4$ kN

shear resistance: min $V_{Rd,a2} = V_{Rd,1} = 174.1$ kN

angle leg at supported beam:

calculation of the point section:
bolt 1 $T_{y,1} = 63.80$ kN, $T_{z,1} = 27.50$ kN, $T_1 = 69.47$ kN
bolt 2 $T_{y,2} = -63.80$ kN, $T_{z,2} = 27.50$ kN, $T_2 = 69.47$ kN

shear force resistance
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, $\alpha_v = 0.60$

bolt 1:	$U_1 = 0.576$	$V_{Rd,1} = 95.5$ kN
bolt 2:	$U_2 = 0.576$	$V_{Rd,2} = 95.5$ kN

design shear resistance total: $V_{Rd,1} = 95.5$ 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:	$F_{b,z,1} = 130.91$ kN	$F_{b,y,1} = 144.00$ kN	$U_1 = 0.222$	$V_{Rd,1} = 248.3$ kN
bolt 2:	$F_{b,z,2} = 130.91$ kN	$F_{b,y,2} = 144.00$ kN	$U_2 = 0.222$	$V_{Rd,2} = 248.3$ kN

design bearing resistance total: $V_{Rd,2} = 248.3$ kN

angle leg 1 in tension and shear (shear block):
shear resistance $V_{eff,Rd} = (0.5 \cdot A_{nt} \cdot f_u) / \gamma_{M2} + (A_{nv} \cdot f_y / 3^{1/3}) / \gamma_{M0} = 307.23$ kN
shear resistance total: $V_{Rd,3} = 307.2$ kN

angle leg 1 in bending and shear:
$(A_{f,net} \cdot 0.9 \cdot f_u) / \gamma_{M2} = 281.5$ kN $<$ $(A_f \cdot f_y) / \gamma_{M0} = 317.3$ kN $\Rightarrow$ der deduction of holes is respected.
shear resistance $V_{Rd} = f_y / \gamma_{M0} / ((b'/W_{el})^2 + 3 \cdot (1/A)^2)^{1/2} = 120.87$ kN
shear resistance total: $V_{Rd,4} = 2 \cdot 120.87 = 241.7$ 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:	$F_{b,z,1} = 102.24$ kN	$F_{b,y,1} = 77.45$ kN	$U_1 = 0.824$	$V_{Rd,1} = 66.8$ kN
bolt 2:	$F_{b,z,2} = 102.24$ kN	$F_{b,y,2} = 77.45$ kN	$U_2 = 0.824$	$V_{Rd,2} = 66.8$ kN

design bearing resistance total: $V_{Rd,5} = 66.8$ kN

beam web in tension and shear (shear block):
shear resistance $V_{eff,Rd} = (0.5 \cdot A_{nt} \cdot f_u) / \gamma_{M2} + (A_{nv} \cdot f_y / 3^{1/3}) / \gamma_{M0} = 215.20$ kN
shear resistance total: $V_{Rd,6} = 215.2$ kN

shear resistance: min $V_{Rd,a1} = V_{Rd,5} = 66.8$ kN

design resistance: min $V_{Rd} = 66.8$ kN

verification of the connection

connection left:
$V_{Ed} = 55.0$ kN: $V_{Ed} / \min V_{Rd} = 0.824 < 1$ **ok.**

connection right:
$V_{Ed} = 55.0$ kN: $V_{Ed} / \min V_{Rd} = 0.824 < 1$ **ok.**

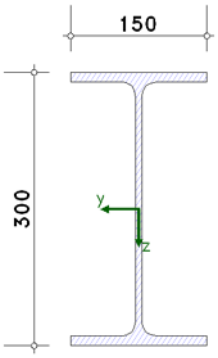
angle leg at main girder, double-sided connection:
beam web with bearing resistance:

bolt 1:	$U_{b,z,1} = 0.222$	$U_{b,y,1} = 0.213$
bolt 2:	$U_{b,z,2} = 0.222$	$U_{b,y,2} = 0.213$

verifications: $\max U_b = 0.222 < 1$ **ok.**

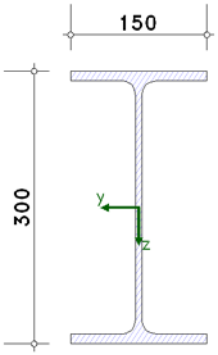
cross-sectional check of supported beam

beam left:
verification at $\Delta x = 99.3$ mm



elastic cross-sectional check for $M_{Ed} = -5.22$ kNm, $V_{Ed} = 55.00$ kN
elastic stresses: max $\sigma_x = 0.94$ kN/cm², min $\sigma_x = -0.94$ kN/cm², max $\tau = 2.91$ kN/cm², max $\sigma_v = 5.05$ kN/cm²
utilizations: design resistance $U_\sigma = 0.215 < 1$ **ok.**, c/t-ratio $U_{c/t} = 0.075 < 1$ **ok.**

beam right:
verification at $\Delta x = 99.3$ mm



elastic cross-sectional check for $M_{Ed} = 5.22$ kNm, $V_{Ed} = 55.00$ kN
elastic stresses: max $\sigma_x = 0.94$ kN/cm², min $\sigma_x = -0.94$ kN/cm², max $\tau = 2.91$ kN/cm², max $\sigma_v = 5.05$ kN/cm²
utilizations: design resistance $U_\sigma = 0.215 < 1$ **ok.**, c/t-ratio $U_{c/t} = 0.075 < 1$ **ok.**

verification result

maximum utilization: max U = 0.873 < 1 ok.

Final Result

maximum utilization: design resistance max U = 0.873 < 1 ok.
c/t-ratio max U = 0.075 < 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