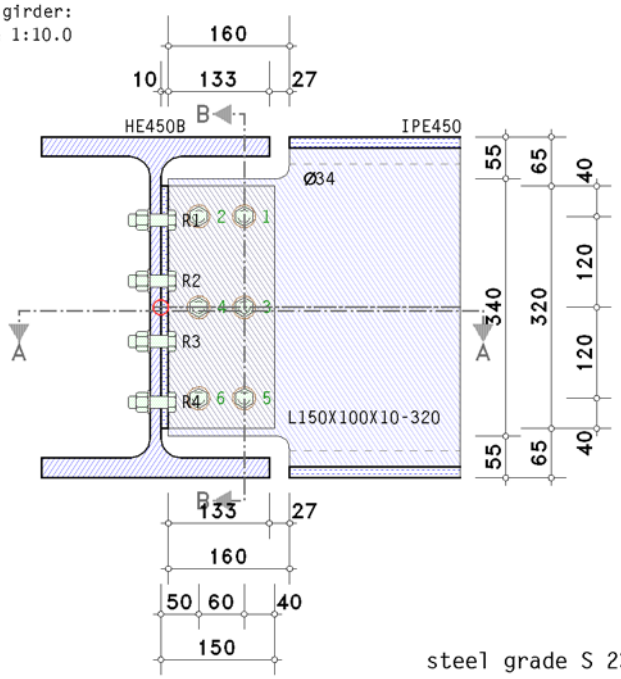
POS. 30: KINDMANN T.1, 8.3.6

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

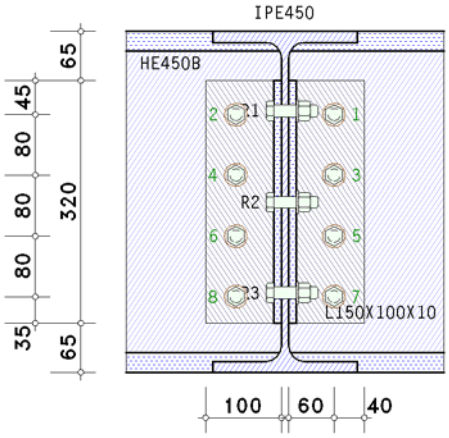
Simple Joint of Beams

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

main girder:
scale 1:10.0



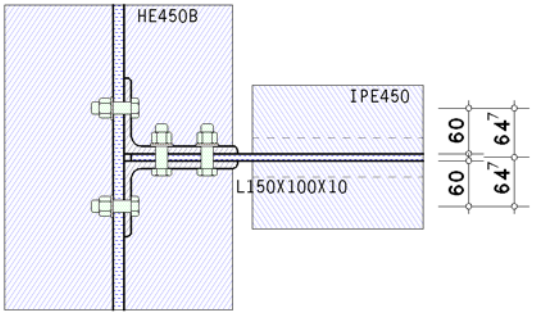
section B-B:



steel grade S 235
bolts M16-5.6

○ hinge

section A-A:



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

steel grade

steel grade S 235

bolts

bolt: bolt class 5.6, bolt size M16

shear plane passes through the unthreaded portion of the bolt

geometry

main girder

section HE450B

supported beam

section IPE450

joint configuration

2 x angle: section L150X100X10

width of angles b_a = 320.0 mm

plate lengths: h_o = 0.0 mm, $ü_o$ = 65.0 mm (h_u = 0.0 mm, $ü_u$ = 65.0 mm), s = 10.0 mm

notchs: a_o = 160.0 mm, e_o = 55.0 mm, a_u = 160.0 mm, e_u = 55.0 mm

rounded notchs (root radius r_a = 17.0 mm)

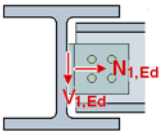
distances between bolts at main girder: $e_{z,0}$ = 45.0 mm, $p_{z,1-2}$ = 80.0 mm, $p_{z,2-3}$ = 80.0 mm, $p_{z,3-4}$ = 80.0 mm
$e_{x,0}$ = 40.0 mm

distances between bolts at supported beam: $e_{z,0}$ = 40.0 mm, $p_{z,1-2}$ = 120.0 mm, $p_{z,2-3}$ = 120.0 mm, $e_{x,0}$ = 40.0 mm
$p_{x,1-2}$ = 60.0 mm

design resistance

verification of welds with the directional method

elastic cross-sectional check der supported beam
internal forces and moments
Lk 1: $V_{1,Ed}$ = 260.00 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 = 21.6 mm,	e_2 = 40.0 mm < 4·t_{min} + 40 mm = 80.0 mm
pitch:	p_2 = 129.4 mm > 2.4·d_0 = 43.2 mm,	p_2 = 129.4 mm < min(14·t_{min}, 200 mm) = 140.0 mm
edge dist.:	e_1 = 45.0 mm > 1.2·d_0 = 21.6 mm,	e_1 = 45.0 mm < 4·t_1 + 40 mm = 96.0 mm
pitch:	p_1 = 80.0 mm > 2.2·d_0 = 39.6 mm,	p_1 = 80.0 mm < min(14·t_{min}, 200 mm) = 140.0 mm
pitch:	p_1 = 80.0 mm > 2.2·d_0 = 39.6 mm,	p_1 = 80.0 mm < min(14·t_{min}, 200 mm) = 140.0 mm
pitch:	p_1 = 80.0 mm > 2.2·d_0 = 39.6 mm,	p_1 = 80.0 mm < min(14·t_{min}, 200 mm) = 140.0 mm
edge dist.:	e_1 = 35.0 mm > 1.2·d_0 = 21.6 mm,	e_1 = 35.0 mm < 4·t_1 + 40 mm = 96.0 mm

distance of bolt rows at supported beam (right)

edge dist.:	e_2 = 40.0 mm > 1.2·d_0 = 21.6 mm,	e_2 = 40.0 mm < 4·t_{min} + 40 mm = 77.6 mm
pitch:	p_2 = 60.0 mm > 2.4·d_0 = 43.2 mm,	p_2 = 60.0 mm < min(14·t_{min}, 200 mm) = 131.6 mm
edge dist.:	e_2 = 40.0 mm > 1.2·d_0 = 21.6 mm,	e_2 = 40.0 mm < 4·t_{min} + 40 mm = 77.6 mm
edge dist.:	e_1 = 40.0 mm > 1.2·d_0 = 21.6 mm,	e_1 = 40.0 mm < 4·t_1 + 40 mm = 77.6 mm
pitch:	p_1 = 120.0 mm > 2.2·d_0 = 39.6 mm,	p_1 = 120.0 mm < min(14·t_{min}, 200 mm) = 131.6 mm
pitch:	p_1 = 120.0 mm > 2.2·d_0 = 39.6 mm,	p_1 = 120.0 mm < min(14·t_{min}, 200 mm) = 131.6 mm
edge dist.:	e_1 = 40.0 mm > 1.2·d_0 = 21.6 mm,	e_1 = 40.0 mm < 4·t_1 + 40 mm = 77.6 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 = -1.82 kNm, e_1 = -7.0 mm
$V_{1,Ed}$ = $V_{j1,Ed}$ = 260.00 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 = 11.3 mm, compression force in contact area D = 37.75 kN
check: D / (A_D·f_{yd}) = 0.713 < 1 **ok.** ⇒ compression by contact exists

calculation of the point section:
bolt 1 $T_{y,1}$ = 2.13 kN, $T_{z,1}$ = 32.50 kN, T_1 = 32.57 kN
bolt 2 $T_{y,2}$ = 7.00 kN, $T_{z,2}$ = 32.50 kN, T_2 = 33.25 kN
bolt 3 $T_{y,3}$ = 11.87 kN, $T_{z,3}$ = 32.50 kN, T_3 = 34.60 kN
bolt 4 $T_{y,4}$ = 16.74 kN, $T_{z,4}$ = 32.50 kN, T_4 = 36.56 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: $F_{v,Rd} = \alpha_v \cdot f_{ub} \cdot A / \gamma_{M2}$ = 48.25 kN, α_v = 0.60

bolt 1:	U_1 = 0.675	$V_{Rd,1}$ = 385.2 kN
bolt 2:	U_2 = 0.689	$V_{Rd,2}$ = 377.4 kN
bolt 3:	U_3 = 0.717	$V_{Rd,3}$ = 362.6 kN
bolt 4:	U_4 = 0.758	$V_{Rd,4}$ = 343.2 kN

design shear resistance total: $V_{Rd,1}$ = 343.2 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:	$F_{b,z,1}$ = 96.00 kN	$F_{b,y,1}$ = 85.33 kN	U_1 = 0.343	$V_{Rd,1}$ = 758.5 kN
bolt 2:	$F_{b,z,2}$ = 115.20 kN	$F_{b,y,2}$ = 85.33 kN	U_2 = 0.282	$V_{Rd,2}$ = 921.6 kN
bolt 3:	$F_{b,z,3}$ = 115.20 kN	$F_{b,y,3}$ = 85.33 kN	U_3 = 0.282	$V_{Rd,3}$ = 921.6 kN
bolt 4:	$F_{b,z,4}$ = 74.67 kN	$F_{b,y,4}$ = 85.33 kN	U_4 = 0.435	$V_{Rd,4}$ = 597.3 kN

design bearing resistance total: $V_{Rd,2}$ = 597.3 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:	$F_{b,z,1} = 161.28$ kN	$F_{b,y,1} = 161.28$ kN	$U_1 = 0.202$	$V_{Rd,1} = 1290.2$ kN
bolt 2:	$F_{b,z,2} = 161.28$ kN	$F_{b,y,2} = 161.28$ kN	$U_2 = 0.202$	$V_{Rd,2} = 1290.2$ kN
bolt 3:	$F_{b,z,3} = 161.28$ kN	$F_{b,y,3} = 161.28$ kN	$U_3 = 0.202$	$V_{Rd,3} = 1290.2$ kN
bolt 4:	$F_{b,z,4} = 161.28$ kN	$F_{b,y,4} = 161.28$ kN	$U_4 = 0.202$	$V_{Rd,4} = 1290.2$ kN

design bearing resistance total: $V_{Rd,3} = 1290.2$ kN

shear resistance: min $V_{Rd,a2} = V_{Rd,1} = 343.2$ kN

angle leg at supported beam:

calculation of the point section:

bolt 1	$T_{y,1} = 39.62$ kN, $T_{z,1} = 33.43$ kN, $T_1 = 51.84$ kN
bolt 2	$T_{y,2} = 39.62$ kN, $T_{z,2} = 53.24$ kN, $T_2 = 66.36$ kN
bolt 3	$T_{y,3} = -0.00$ kN, $T_{z,3} = 33.43$ kN, $T_3 = 33.43$ kN
bolt 4	$T_{y,4} = -0.00$ kN, $T_{z,4} = 53.24$ kN, $T_4 = 53.24$ kN
bolt 5	$T_{y,5} = -39.62$ kN, $T_{z,5} = 33.43$ kN, $T_5 = 51.84$ kN
bolt 6	$T_{y,6} = -39.62$ kN, $T_{z,6} = 53.24$ kN, $T_6 = 66.36$ 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: $F_{v,Rd} = \alpha_v \cdot f_{ub} \cdot A / \gamma_{M2} = 48.25$ kN, $\alpha_v = 0.60$

bolt 1:	$U_1 = 0.537$	$V_{Rd,1} = 484.1$ kN
bolt 2:	$U_2 = 0.688$	$V_{Rd,2} = 378.1$ kN
bolt 3:	$U_3 = 0.346$	$V_{Rd,3} = 750.6$ kN
bolt 4:	$U_4 = 0.552$	$V_{Rd,4} = 471.3$ kN
bolt 5:	$U_5 = 0.537$	$V_{Rd,5} = 484.1$ kN
bolt 6:	$U_6 = 0.688$	$V_{Rd,6} = 378.1$ kN

design shear resistance total: $V_{Rd,1} = 378.1$ 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:	$F_{b,z,1} = 85.33$ kN	$F_{b,y,1} = 85.33$ kN	$U_1 = 0.232$	$V_{Rd,1} = 1120.0$ kN
bolt 2:	$F_{b,z,2} = 85.33$ kN	$F_{b,y,2} = 85.33$ kN	$U_2 = 0.312$	$V_{Rd,2} = 833.5$ kN
bolt 3:	$F_{b,z,3} = 115.20$ kN		$U_3 = 0.145$	$V_{Rd,3} = 1792.0$ kN
bolt 4:	$F_{b,z,4} = 115.20$ kN		$U_4 = 0.231$	$V_{Rd,4} = 1125.2$ kN
bolt 5:	$F_{b,z,5} = 85.33$ kN	$F_{b,y,5} = 85.33$ kN	$U_5 = 0.232$	$V_{Rd,5} = 1120.0$ kN
bolt 6:	$F_{b,z,6} = 85.33$ kN	$F_{b,y,6} = 85.33$ kN	$U_6 = 0.312$	$V_{Rd,6} = 833.5$ kN

design bearing resistance total: $V_{Rd,2} = 833.5$ kN

angle leg 1 in tension and shear (shear block):
shear resistance $V_{eff,Rd} = (0.5 \cdot A_{nt} \cdot f_u) / \gamma_{M2} + (A_{nv} \cdot f_y / 3^{1/3}) / \gamma_{M0} = 399.54$ kN
shear resistance total: $V_{Rd,3} = 399.5$ kN

angle leg 1 in bending and shear:
$(A_{f,net} \cdot 0.9 \cdot f_u)/\gamma_{M2} = 368.1$ kN $<$ $(A_f \cdot f_y)/\gamma_{M0} = 376.0$ kN $\Rightarrow$ der deduction of holes is respected.
shear resistance $V_{Rd} = f_y/\gamma_{M0} / ((b'/W_{el})^2 + 3 \cdot (1/A)^2)^{1/2} = 240.38$ kN
shear resistance total: $V_{Rd,4} = 2 \cdot 240.38 = 480.8$ 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:	$F_{b,z,1} = 100.27$ kN	$F_{b,y,1} = 80.21$ kN	$U_1 = 0.494$	$V_{Rd,1} = 526.4$ kN
bolt 2:	$F_{b,z,2} = 100.27$ kN	$F_{b,y,2} = 80.21$ kN	$U_2 = 0.531$	$V_{Rd,2} = 489.7$ kN
bolt 3:	$F_{b,z,3} = 108.29$ kN		$U_3 = 0.309$	$V_{Rd,3} = 842.2$ kN
bolt 4:	$F_{b,z,4} = 108.29$ kN		$U_4 = 0.492$	$V_{Rd,4} = 528.8$ kN
bolt 5:	$F_{b,z,5} = 100.27$ kN	$F_{b,y,5} = 80.21$ kN	$U_5 = 0.494$	$V_{Rd,5} = 526.4$ kN
bolt 6:	$F_{b,z,6} = 100.27$ kN	$F_{b,y,6} = 80.21$ kN	$U_6 = 0.531$	$V_{Rd,6} = 489.7$ kN

design bearing resistance total: $V_{Rd,5} = 489.7$ kN

beam web in tension and shear (shear block):
shear resistance $V_{eff,Rd} = (0.5 \cdot A_{nt} \cdot f_u) / \gamma_{M2} + (A_{nv} \cdot f_y / 3^{1/3}) / \gamma_{M0} = 411.28$ kN
shear resistance total: $V_{Rd,6} = 411.3$ kN

shear resistance: min $V_{Rd,a1} = V_{Rd,1} = 378.1$ kN

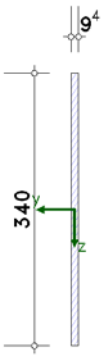
design resistance: min $V_{Rd} = 343.2$ kN

verification of the connection

V_{Ed} = 260.0 kN: V_{Ed} / min V_{Rd} = 0.758 < 1 ok.

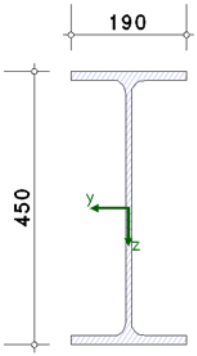
cross-sectional check of supported beam

verification at Δx = 160.0 mm with 2 notchs



elastic cross-sectional check for M_{Ed} = 39.78 kNm, V_{Ed} = 260.00 kN
elastic stresses: max σ_x = 21.96 kN/cm², min σ_x = -21.96 kN/cm², max τ = 12.20 kN/cm², max σ_v = 30.48 kN/cm²
utilizations: design resistance U_σ = 1.297 > 1 not ok. !!

verification at Δx = 177.0 mm



elastic cross-sectional check for M_{Ed} = 44.20 kNm, V_{Ed} = 260.00 kN
elastic stresses: max σ_x = 2.95 kN/cm², min σ_x = -2.95 kN/cm², max τ = 6.98 kN/cm², max σ_v = 12.09 kN/cm²
utilizations: design resistance U_σ = 0.514 < 1 ok., c/t-ratio $U_{c/t}$ = 0.120 < 1 ok.

fault at calcualation of resistance of cross section !!

verification result

maximum utilization: max U = 1.297 > 1 not ok. !!
failure at cross-sectional check (right): U = 1.297, $U_{c/t}$ = 0.120

Final Result

maximum utilization: design resistance max U = 1.297 > 1 not ok. !!
c/t-ratio max U = 0.120 < 1 ok.

design resistance not ensured !!

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