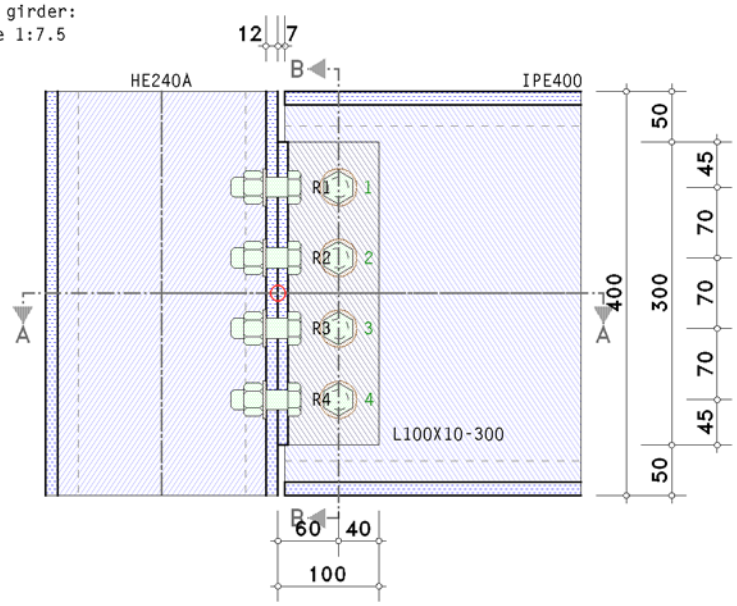
POS. 20: KAHLMEYER 1.1.3.1

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

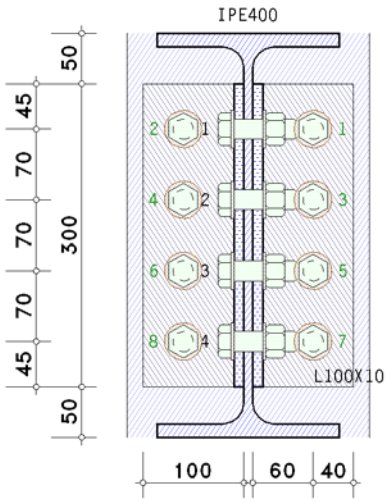
Simple Joint of Beams

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

main girder:
scale 1:7.5



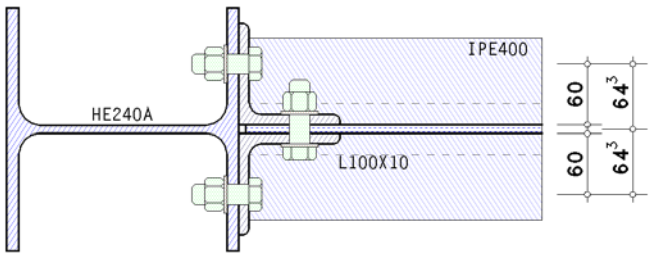
section B-B:



steel grade S 235

○ hinge

section A-A:



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

steel grade

steel grade S 235

bolts

bolt: bolt class 4.6,

dimensions:

shaft diameter d = 20.0 mm, clearance Δd = 1.0 mm $\Rightarrow$ hole diameter d_0 = 21.0 mm

gross cross-section area A = 3.142 cm²

tensile stress area A_s = 2.450 cm²

diameter of the bolt head (across flats dimension) d_s = 30.0 mm

diameter of the bolt head (across points dimension) d_e = 32.95 mm

thickness of the bolt head t_k = 12.5 mm

thickness of nut t_m = 19.0 mm

diameter of the plate under the bolt or the nut d_p = 37.0 mm

thickness of the plate under the bolt or the nut t_p = 3.0 mm

shear plane passes through the unthreaded portion of the bolt

geometry

main girder

section HE240A

supported beam

section IPE400

joint configuration

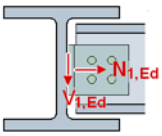
2 x angle: section L100X10

width of angles b_a = 300.0 mm

plate lengths: h_o = 0.0 mm, $\ddot{u}_o$ = 50.0 mm (h_u = 0.0 mm, $\ddot{u}_u$ = 50.0 mm), s = 7.0 mm

distances between bolts at main girder: $e_{z,0}$ = 45.0 mm, $p_{z,1\text{-}2}$ = 70.0 mm, $p_{z,2\text{-}3}$ = 70.0 mm, $p_{z,3\text{-}4}$ = 70.0 mm

$e_{x,0}$ = 40.0 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, $p_{z,3\text{-}4}$ = 70.0 mm
$e_{x,0}$ = 40.0 mm
design resistance
verification of welds with the directional method
internal forces and moments
Lk 1: $V_{1,Ed}$ = 200.00 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 = 25.2 mm,	e_2 = 40.0 mm < 4·t_{min} + 40 mm = 80.0 mm
pitch:	p_2 = 128.6 mm > 2.4·d_0 = 50.4 mm,	p_2 = 128.6 mm < min(14·t_{min}, 200 mm) = 140.0 mm
edge dist.:	e_1 = 45.0 mm > 1.2·d_0 = 25.2 mm,	e_1 = 45.0 mm < 4·t_1 + 40 mm = 88.0 mm
pitch:	p_1 = 70.0 mm > 2.2·d_0 = 46.2 mm,	p_1 = 70.0 mm < min(14·t_{min}, 200 mm) = 140.0 mm
pitch:	p_1 = 70.0 mm > 2.2·d_0 = 46.2 mm,	p_1 = 70.0 mm < min(14·t_{min}, 200 mm) = 140.0 mm
pitch:	p_1 = 70.0 mm > 2.2·d_0 = 46.2 mm,	p_1 = 70.0 mm < min(14·t_{min}, 200 mm) = 140.0 mm
edge dist.:	e_1 = 45.0 mm > 1.2·d_0 = 25.2 mm,	e_1 = 45.0 mm < 4·t_1 + 40 mm = 88.0 mm

distance of bolt rows at supported beam (right)

edge dist.:	e_2 = 53.0 mm > 1.2·d_0 = 25.2 mm,	e_2 = 53.0 mm < 4·t_{min} + 40 mm = 74.4 mm
edge dist.:	e_1 = 45.0 mm > 1.2·d_0 = 25.2 mm,	e_1 = 45.0 mm < 4·t_1 + 40 mm = 74.4 mm
pitch:	p_1 = 70.0 mm > 2.2·d_0 = 46.2 mm,	p_1 = 70.0 mm < min(14·t_{min}, 200 mm) = 120.4 mm
pitch:	p_1 = 70.0 mm > 2.2·d_0 = 46.2 mm,	p_1 = 70.0 mm < min(14·t_{min}, 200 mm) = 120.4 mm
pitch:	p_1 = 70.0 mm > 2.2·d_0 = 46.2 mm,	p_1 = 70.0 mm < min(14·t_{min}, 200 mm) = 120.4 mm
edge dist.:	e_1 = 45.0 mm > 1.2·d_0 = 25.2 mm,	e_1 = 45.0 mm < 4·t_1 + 40 mm = 74.4 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')

$M_{1,Ed}$ = $V_{j1,Ed}$·e_1 = -23.00 kNm, e_1 = -115.0 mm
$V_{1,Ed}$ = $V_{j1,Ed}$ = 200.00 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 = 13.8 mm, compression force in contact area D = 32.65 kN
check: D / (A_D·f_{yd}) = 0.502 < 1 **ok.** ⇒ compression by contact exists

calculation of the point section:
bolt 1 $T_{y,1}$ = 2.04 kN, $T_{z,1}$ = 25.00 kN, T_1 = 25.08 kN
bolt 2 $T_{y,2}$ = 6.12 kN, $T_{z,2}$ = 25.00 kN, T_2 = 25.74 kN
bolt 3 $T_{y,3}$ = 10.20 kN, $T_{z,3}$ = 25.00 kN, T_3 = 27.00 kN
bolt 4 $T_{y,4}$ = 14.29 kN, $T_{z,4}$ = 25.00 kN, T_4 = 28.79 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: $F_{v,Rd}$ = α_v·f_{ub}·A / γ_{M2} = 60.32 kN, α_v = 0.60

bolt 1:	U_1 = 0.416	$V_{Rd,1}$ = 480.9 kN
bolt 2:	U_2 = 0.427	$V_{Rd,2}$ = 468.7 kN
bolt 3:	U_3 = 0.448	$V_{Rd,3}$ = 446.8 kN
bolt 4:	U_4 = 0.477	$V_{Rd,4}$ = 419.0 kN

design shear resistance total: $V_{Rd,1}$ = 419.0 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:	$F_{b,z,1}$ = 102.86 kN	$F_{b,y,1}$ = 91.43 kN	U_1 = 0.281	$V_{Rd,1}$ = 711.1 kN
bolt 2:	$F_{b,z,2}$ = 124.00 kN	$F_{b,y,2}$ = 91.43 kN	U_2 = 0.202	$V_{Rd,2}$ = 992.0 kN

bolt 3: $F_{b,z,3}$ = 124.00 kN $F_{b,y,3}$ = 91.43 kN U_3 = 0.202 $V_{Rd,3}$ = 992.0 kN
bolt 4: $F_{b,z,4}$ = 102.86 kN $F_{b,y,4}$ = 91.43 kN U_4 = 0.281 $V_{Rd,4}$ = 711.1 kN
design bearing resistance total: $V_{Rd,2}$ = 711.1 kN

beam flange 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: $F_{b,z,1}$ = 148.80 kN $F_{b,y,1}$ = 152.78 kN U_1 = 0.168 $V_{Rd,1}$ = 1190.4 kN
bolt 2: $F_{b,z,2}$ = 148.80 kN $F_{b,y,2}$ = 152.78 kN U_2 = 0.168 $V_{Rd,2}$ = 1190.4 kN
bolt 3: $F_{b,z,3}$ = 148.80 kN $F_{b,y,3}$ = 152.78 kN U_3 = 0.168 $V_{Rd,3}$ = 1190.4 kN
bolt 4: $F_{b,z,4}$ = 148.80 kN $F_{b,y,4}$ = 152.78 kN U_4 = 0.168 $V_{Rd,4}$ = 1190.4 kN
design bearing resistance total: $V_{Rd,3}$ = 1190.4 kN

shear resistance: min $V_{Rd,a2}$ = $V_{Rd,1}$ = 419.0 kN

angle leg at supported beam:

calculation of the point section:
bolt 1 $T_{y,1}$ = 51.43 kN, $T_{z,1}$ = 50.00 kN, T_1 = 71.73 kN
bolt 2 $T_{y,2}$ = 17.14 kN, $T_{z,2}$ = 50.00 kN, T_2 = 52.86 kN
bolt 3 $T_{y,3}$ = -17.14 kN, $T_{z,3}$ = 50.00 kN, T_3 = 52.86 kN
bolt 4 $T_{y,4}$ = -51.43 kN, $T_{z,4}$ = 50.00 kN, T_4 = 71.73 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, α_v = 0.60
bolt 1: U_1 = 0.595 $V_{Rd,1}$ = 336.4 kN
bolt 2: U_2 = 0.438 $V_{Rd,2}$ = 456.5 kN
bolt 3: U_3 = 0.438 $V_{Rd,3}$ = 456.5 kN
bolt 4: U_4 = 0.595 $V_{Rd,4}$ = 336.4 kN
design shear resistance total: $V_{Rd,1}$ = 336.4 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: $F_{b,z,1}$ = 102.86 kN $F_{b,y,1}$ = 91.43 kN U_1 = 0.281 $V_{Rd,1}$ = 711.1 kN
bolt 2: $F_{b,z,2}$ = 124.00 kN $F_{b,y,2}$ = 91.43 kN U_2 = 0.202 $V_{Rd,2}$ = 992.0 kN
bolt 3: $F_{b,z,3}$ = 124.00 kN $F_{b,y,3}$ = 91.43 kN U_3 = 0.202 $V_{Rd,3}$ = 992.0 kN
bolt 4: $F_{b,z,4}$ = 102.86 kN $F_{b,y,4}$ = 91.43 kN U_4 = 0.281 $V_{Rd,4}$ = 711.1 kN
design bearing resistance total: $V_{Rd,2}$ = 711.1 kN

angle leg 1 in tension and shear (shear block):
shear resistance $V_{eff,Rd} = (0.5 \cdot A_{nt} \cdot f_u) / \gamma_{M2} + (A_{nv} \cdot f_y / 3^{1/3}) / \gamma_{M0}$ = 288.73 kN
shear resistance total: $V_{Rd,3}$ = 288.7 kN

angle leg 1 in bending and shear:
$(A_{f,net} \cdot 0.9 \cdot f_u)/\gamma_{M2}$ = 279.9 kN < $(A_f \cdot f_y)/\gamma_{M0}$ = 352.5 kN ⇒ der deduction of holes is respected.
shear resistance $V_{Rd} = f_y/\gamma_{M0} / ((b'/W_{el})^2 + 3 \cdot (1/A)^2)^{1/2}$ = 235.63 kN
shear resistance total: $V_{Rd,4}$ = 2·235.63 = 471.3 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: $F_{b,z,1}$ = 106.64 kN $F_{b,y,1}$ = 104.18 kN U_1 = 0.494 $V_{Rd,1}$ = 405.2 kN
bolt 2: $F_{b,z,2}$ = 106.64 kN $F_{b,y,2}$ = 104.18 kN U_2 = 0.469 $V_{Rd,2}$ = 426.6 kN
bolt 3: $F_{b,z,3}$ = 106.64 kN $F_{b,y,3}$ = 104.18 kN U_3 = 0.469 $V_{Rd,3}$ = 426.6 kN
bolt 4: $F_{b,z,4}$ = 106.64 kN $F_{b,y,4}$ = 104.18 kN U_4 = 0.494 $V_{Rd,4}$ = 405.2 kN
design bearing resistance total: $V_{Rd,5}$ = 405.2 kN

beam web in tension and shear (shear block):
shear resistance $V_{eff,Rd} = (0.5 \cdot A_{nt} \cdot f_u) / \gamma_{M2} + (A_{nv} \cdot f_y / 3^{1/3}) / \gamma_{M0}$ = 322.75 kN
shear resistance total: $V_{Rd,6}$ = 322.8 kN

shear resistance: min $V_{Rd,a1}$ = $V_{Rd,3}$ = 288.7 kN

design resistance: min V_{Rd} = 288.7 kN

verification of the connection

V_{Ed} = 200.0 kN: V_{Ed} / min V_{Rd} = 0.693 < 1 **ok.**

verification result

maximum utilization: max U = 0.693 < 1 **ok.**

Final Result

maximum utilization: design resistance max U = 0.693 < 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