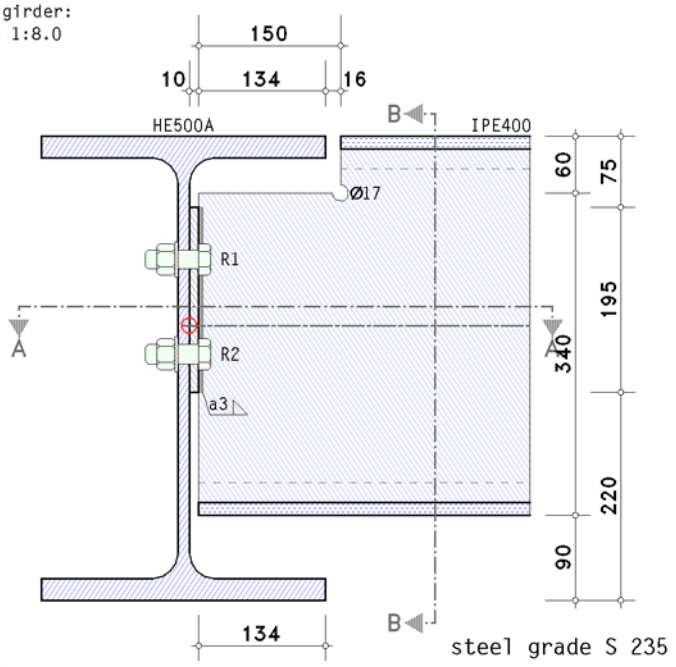
POS. 24: KAHLMEYER 1.5.3 AUS 1.2.3

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

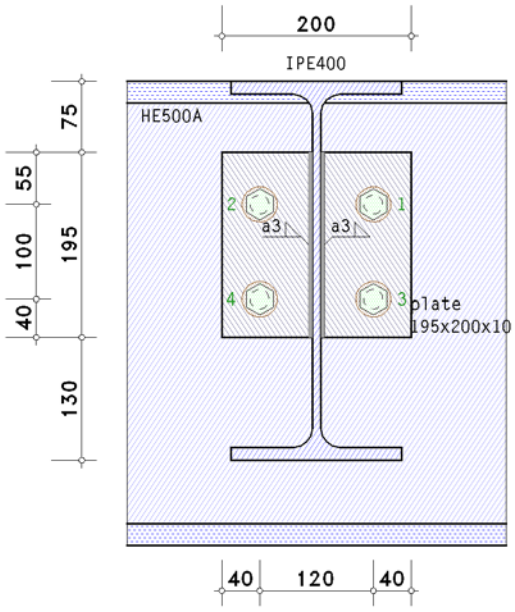
Simple Joint of Beams

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

main girder:
scale 1:8.0

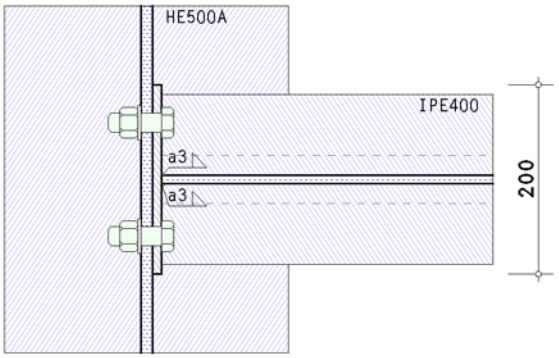


section B-B:



○ hinge

section A-A:



beam connection with end-plate, connected to the web 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

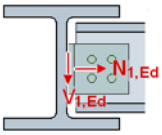
section HE500A

supported beam

section IPE400

joint configuration

end-plate: thickness t_p = 10.0 mm, length l_p = 195.0 mm, width b_p = 200.0 mm
plate lengths: h_o = 0.0 mm, $ü_o$ = 75.0 mm (h_u = 90.0 mm, $ü_u$ = 130.0 mm)
notch: a_o = 150.0 mm, e_o = 60.0 mm
notch with bore-hole (radius of bore-hole r_b = 8.5 mm)
distances between bolts at main girder: $e_{z,0}$ = 55.0 mm, $p_{z,1-2}$ = 100.0 mm, $e_{x,0}$ = 40.0 mm
thickness weld: a_w = 3.0 mm
design resistance
verification of welds with the directional method
elastic cross-sectional check der supported beam
internal forces and moments
Lk 1: $V_{1,Ed}$ = 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 = 120.0 mm > 2.4·d_0 = 50.4 mm,	p_2 = 120.0 mm < min(14·t_{min}, 200 mm) = 140.0 mm
edge dist.:	e_1 = 55.0 mm > 1.2·d_0 = 25.2 mm,	e_1 = 55.0 mm < 4·t_1 + 40 mm = 88.0 mm
pitch:	p_1 = 100.0 mm > 2.2·d_0 = 46.2 mm,	p_1 = 100.0 mm < min(14·t_{min}, 200 mm) = 140.0 mm
edge dist.:	e_1 = 40.0 mm > 1.2·d_0 = 25.2 mm,	e_1 = 40.0 mm < 4·t_1 + 40 mm = 88.0 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 = -1.20 kNm, e_1 = -6.0 mm
$V_{1,Ed}$ = $V_{j1,Ed}$ = 200.00 kN

design resistance of the connection

calculation of the point section:
bolt 1 T_1 = $T_{z,1}$ = 50.00 kN
bolt 2 T_2 = $T_{z,2}$ = 50.00 kN
bolt 3 T_3 = $T_{z,3}$ = 50.00 kN
bolt 4 T_4 = $T_{z,4}$ = 50.00 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 = 0.829	$V_{Rd,1}$ = 241.3 kN
bolt 2:	U_2 = 0.829	$V_{Rd,2}$ = 241.3 kN
bolt 3:	U_3 = 0.829	$V_{Rd,3}$ = 241.3 kN
bolt 4:	U_4 = 0.829	$V_{Rd,4}$ = 241.3 kN

design shear resistance total: $V_{Rd,1}$ = 241.3 kN

end-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 = max($U_{z,i}$, $U_{y,i}$), $V_{Rd,i}$ = $V_{1,Ed}$ / U_i, V_{Rd} = min $V_{Rd,i}$

bolt 1:	$F_{b,z,1}$ = 125.71 kN	U_1 = 0.398	$V_{Rd,1}$ = 502.9 kN
bolt 2:	$F_{b,z,2}$ = 125.71 kN	U_2 = 0.398	$V_{Rd,2}$ = 502.9 kN
bolt 3:	$F_{b,z,3}$ = 91.43 kN	U_3 = 0.547	$V_{Rd,3}$ = 365.7 kN
bolt 4:	$F_{b,z,4}$ = 91.43 kN	U_4 = 0.547	$V_{Rd,4}$ = 365.7 kN

design bearing resistance total: $V_{Rd,2}$ = 365.7 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:	$F_{b,z,1}$ = 172.80 kN	U_1 = 0.289	$V_{Rd,1}$ = 691.2 kN
bolt 2:	$F_{b,z,2}$ = 172.80 kN	U_2 = 0.289	$V_{Rd,2}$ = 691.2 kN
bolt 3:	$F_{b,z,3}$ = 172.80 kN	U_3 = 0.289	$V_{Rd,3}$ = 691.2 kN
bolt 4:	$F_{b,z,4}$ = 172.80 kN	U_4 = 0.289	$V_{Rd,4}$ = 691.2 kN

design bearing resistance total: $V_{Rd,3}$ = 691.2 kN

end-plate in tension and shear (shear block):
shear resistance $V_{eff,Rd} = (A_{nt} \cdot f_u) / \gamma_{M2} + (A_{nv} \cdot f_y / 3^{1/3}) / \gamma_{M0} = 432.33$ kN
shear resistance total: $V_{Rd,4} = 432.3$ kN

end-plate in bending and shear:
shear resistance $V_{Rd} = f_y / \gamma_{M0} / ((b'/W_{el})^2 + 3 \cdot (1/A)^2)^{1/2} = 147.23$ kN
shear resistance total: $V_{Rd,5} = 2 \cdot 147.23 = 294.5$ kN

beam web with shear (next to the weld):
shear resistance $V_{Rd} = (A_v \cdot f_y) / (3^{1/2} \cdot \gamma_{M0}) = 227.53$ kN
shear resistance total: $V_{Rd,6} = 227.5$ kN

shear resistance: min $V_{Rd,p} = V_{Rd,6} = 227.5$ kN

verification of the connection

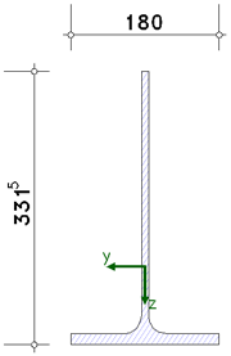
$V_{Ed} = 200.0$ kN: V_{Ed} / min $V_{Rd} = 0.879 < 1$ **ok.**

weld verification

$\sigma_{1,w,Ed} = 30.53$ kN/cm² $< f_{1,w,Rd} = 36.00$ kN/cm²,
$\sigma_{2,w,Ed} = 3.72$ kN/cm² $< f_{2,w,Rd} = 25.92$ kN/cm² $\Rightarrow U_w = 0.848 < 1$ **ok.**

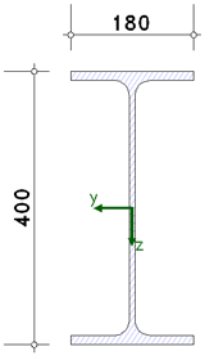
cross-sectional check of supported beam

verification at $\Delta x = 166.0$ mm with notch



elastic cross-sectional check for $M_{Ed} = 32.00$ kNm, $V_{Ed} = 200.00$ kN
elastic stresses: max $\sigma_x = 5.18$ kN/cm², min $\sigma_x = -12.98$ kN/cm², max $\tau = 9.61$ kN/cm², max $\sigma_v = 16.65$ kN/cm²
utilizations: design resistance $U_\sigma = 0.708 < 1$ **ok.**

verification at $\Delta x = 166.0$ mm



elastic cross-sectional check for $M_{Ed} = 32.00$ kNm, $V_{Ed} = 200.00$ kN
elastic stresses: max $\sigma_x = 2.77$ kN/cm², min $\sigma_x = -2.77$ kN/cm², max $\tau = 6.58$ kN/cm², max $\sigma_v = 11.39$ kN/cm²
utilizations: design resistance $U_\sigma = 0.485 < 1$ **ok.**, c/t-ratio $U_{c/t} = 0.117 < 1$ **ok.**

verification result

maximum utilization: max U = 0.879 < 1 **ok.**

Final Result

maximum utilization:	design resistance	max U = 0.879 < 1 **ok.**
	c/t-ratio	max U = 0.117 < 1 **ok.**

verification succeeded