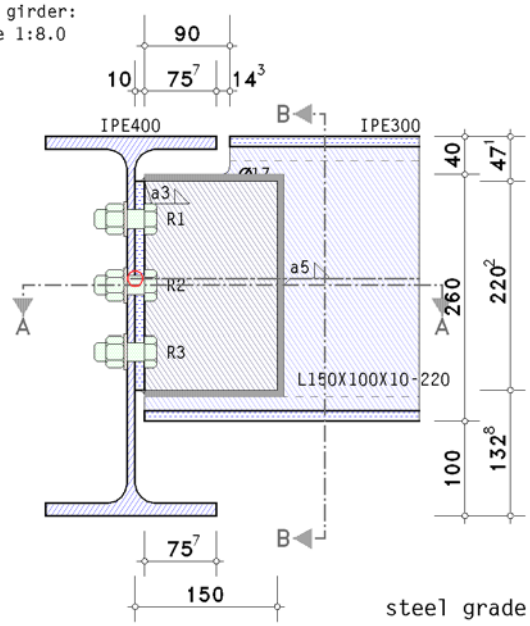
# POS. 50: ANGLE BOLTED/WELDED EC3

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

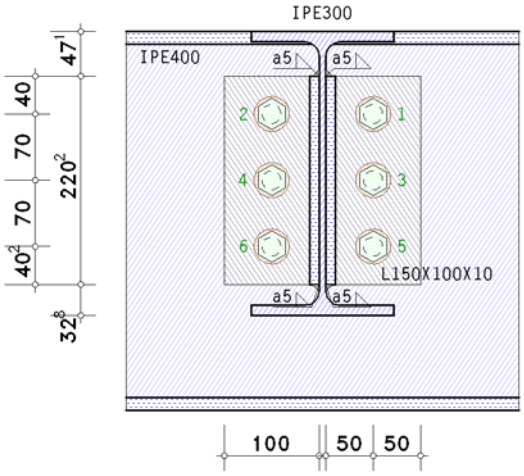
## Simple Joint of Beams

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

main girder:
scale 1:8.0



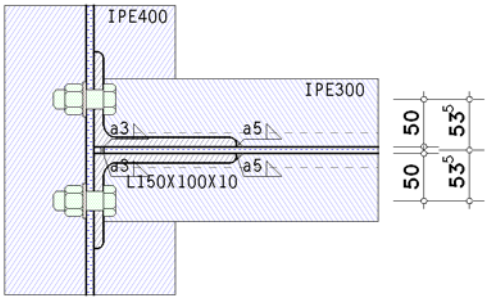

section B-B:




○ hinge

steel grade S 235
bolts M20-4.6

section A-A:




beam connection with two bolted/welded 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 L150X100X10

width of angles $b_a$ = 220.2 mm

plate lengths: $h_o$ = 0.0 mm, $ü_o$ = 47.1 mm ($h_u$ = 100.0 mm, $ü_u$ = 32.8 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, $p_{z,2-3}$ = 70.0 mm, $e_{x,0}$ = 50.0 mm

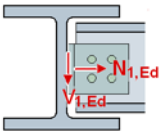
thickness weld: $a_w$ = 5.0 mm (at angle leg), $a_{w,s}$ = 3.0 mm (end weld)

**design resistance**

verification of welds with the simplified method

elastic cross-sectional check der supported beam

**internal forces and moments**
Lk 1: $V_{1,Ed}$ = 200.00 kN
Lk 2: $V_{1,Ed}$ = 160.00 kN




**partial safety factors for material**
resistance of cross sections $\gamma_{M0}$ = 1.00
resistance of bolts, welds, plates in bearing $\gamma_{M2}$ = 1.25

## Simple Joint of Beams

distance of bolt rows at main girder (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 = 74.4 mm |
| pitch: | $p_2$ = 107.1 mm > 2.4·$d_0$ = 52.8 mm, | $p_2$ = 107.1 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 |
| 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.: | $e_1$ = 40.2 mm > 1.2·$d_0$ = 26.4 mm, | $e_1$ = 40.2 mm < 4·$t_1$ + 40 mm = 74.4 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')

$M_{1,Ed}$ = $V_{j1,Ed}$·$e_1$ = -0.86 kNm, $e_1$ = -4.3 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, $b_D$ = 11.3 mm, compression force in contact area D = 37.69 kN
check: D / ($A_D$·$f_{yd}$) = 0.712 < 1 **ok.** ⇒ compression by contact exists

calculation of the point section:
bolt 1 $T_{y,1}$ = 3.77 kN, $T_{z,1}$ = 33.33 kN, $T_1$ = 33.55 kN
bolt 2 $T_{y,2}$ = 12.56 kN, $T_{z,2}$ = 33.33 kN, $T_2$ = 35.62 kN
bolt 3 $T_{y,3}$ = 21.36 kN, $T_{z,3}$ = 33.33 kN, $T_3$ = 39.59 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: $U_1$ = 0.556 $V_{Rd,1}$ = 359.6 kN
bolt 2: $U_2$ = 0.591 $V_{Rd,2}$ = 338.7 kN
bolt 3: $U_3$ = 0.656 $V_{Rd,3}$ = 304.7 kN
design shear resistance total: $V_{Rd,1}$ = 304.7 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 | $F_{b,y,1}$ = 109.09 kN | $U_1$ = 0.382 | $V_{Rd,1}$ = 523.6 kN |
| bolt 2: | $F_{b,z,2}$ = 116.73 kN | | $U_2$ = 0.286 | $V_{Rd,2}$ = 700.4 kN |
| bolt 3: | $F_{b,z,3}$ = 87.62 kN | $F_{b,y,3}$ = 109.09 kN | $U_3$ = 0.380 | $V_{Rd,3}$ = 525.7 kN |

design bearing resistance total: $V_{Rd,2}$ = 523.6 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 | $U_1$ = 0.332 | $V_{Rd,1}$ = 602.3 kN |
| bolt 2: | $F_{b,z,2}$ = 100.39 kN | $F_{b,y,2}$ = 123.84 kN | $U_2$ = 0.332 | $V_{Rd,2}$ = 602.3 kN |
| bolt 3: | $F_{b,z,3}$ = 100.39 kN | $F_{b,y,3}$ = 123.84 kN | $U_3$ = 0.332 | $V_{Rd,3}$ = 602.3 kN |

design bearing resistance total: $V_{Rd,3}$ = 602.3 kN

**shear resistance: min $V_{Rd,a2}$ = $V_{Rd,1}$** = 304.7 kN

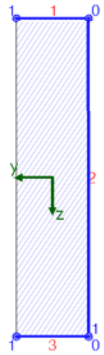
**angle leg at supported beam:**

s. weld verification

## verification of the connection

$V_{Ed}$ = 200.0 kN: $V_{Ed}$ / min $V_{Rd}$ = 0.656 < 1 **ok.**

## weld verification



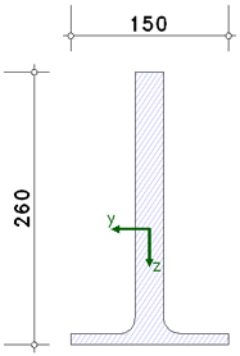

weld 1: $a_w$ = 5.0 mm $l_w$ = 50.0 mm
weld 2: $a_w$ = 5.0 mm $l_w$ = 220.2 mm
weld 3: $a_w$ = 5.0 mm $l_w$ = 50.0 mm

$F_{w,Ed}$ = 6.81 kN/cm < $F_{w,Rd}$ = 10.39 kN/cm ⇒ $U_w$ = 0.656 < 1 **ok.**

end weld:
$F_{w,Ed}$ = 2.00 kN/cm < $F_{w,Rd}$ = 6.24 kN/cm ⇒ $U_w$ = 0.321 < 1 **ok.**

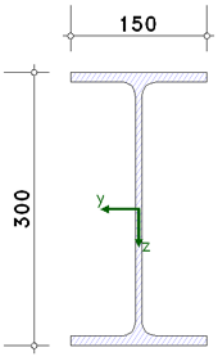
## cross-sectional check of supported beam

verification at Δx = 95.8 mm with notch




elastic cross-sectional check for $M_{Ed}$ = 18.30 kNm, $V_{Ed}$ = 200.00 kN
elastic stresses: max $\sigma_x$ = 3.55 kN/cm², min $\sigma_x$ = -4.81 kN/cm², max $\tau$ = 3.92 kN/cm², max $\sigma_v$ = 6.79 kN/cm²
utilizations: design resistance $U_\sigma$ = 0.289 < 1 **ok.**

verification at Δx = 104.3 mm




elastic cross-sectional check for $M_{Ed}$ = 20.00 kNm, $V_{Ed}$ = 200.00 kN
elastic stresses: max $\sigma_x$ = 3.59 kN/cm², min $\sigma_x$ = -3.59 kN/cm², max $\tau$ = 10.59 kN/cm², max $\sigma_v$ = 18.35 kN/cm²
utilizations: design resistance $U_\sigma$ = 0.781 < 1 **ok.**, c/t-ratio $U_{c/t}$ = 0.147 < 1 **ok.**

**verification result**

maximum utilization: max U = 0.781 < 1 **ok.**

Lk 2:

## design values

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

$M_{1,Ed} = V_{j1,Ed} \cdot e_1 = -0.69$ kNm, $e_1 = -4.3$ mm
$V_{1,Ed} = V_{j1,Ed} = 160.00$ 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 $D = 30.15$ kN
check: $D / (A_D \cdot f_{yd}) = 0.569 < 1$ **ok.** $\Rightarrow$ compression by contact exists

calculation of the point section:
bolt 1 $T_{y,1} = 3.02$ kN, $T_{z,1} = 26.67$ kN, $T_1 = 26.84$ kN
bolt 2 $T_{y,2} = 10.05$ kN, $T_{z,2} = 26.67$ kN, $T_2 = 28.50$ kN
bolt 3 $T_{y,3} = 17.09$ kN, $T_{z,3} = 26.67$ kN, $T_3 = 31.67$ 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: $U_1 = 0.445$ $V_{Rd,1} = 359.6$ kN
bolt 2: $U_2 = 0.472$ $V_{Rd,2} = 338.7$ kN
bolt 3: $U_3 = 0.525$ $V_{Rd,3} = 304.7$ kN
design shear resistance total: $V_{Rd,1} = 304.7$ 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 | $F_{b,y,1} = 109.09$ kN | $U_1 = 0.306$ | $V_{Rd,1} = 523.6$ kN |
| bolt 2: | $F_{b,z,2} = 116.73$ kN | | $U_2 = 0.228$ | $V_{Rd,2} = 700.4$ kN |
| bolt 3: | $F_{b,z,3} = 87.62$ kN | $F_{b,y,3} = 109.09$ kN | $U_3 = 0.304$ | $V_{Rd,3} = 525.7$ kN |

design bearing resistance total: $V_{Rd,2} = 523.6$ 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 | $U_1 = 0.266$ | $V_{Rd,1} = 602.3$ kN |
| bolt 2: | $F_{b,z,2} = 100.39$ kN | $F_{b,y,2} = 123.84$ kN | $U_2 = 0.266$ | $V_{Rd,2} = 602.3$ kN |
| bolt 3: | $F_{b,z,3} = 100.39$ kN | $F_{b,y,3} = 123.84$ kN | $U_3 = 0.266$ | $V_{Rd,3} = 602.3$ kN |

design bearing resistance total: $V_{Rd,3} = 602.3$ kN

**shear resistance: min $V_{Rd,a2} = V_{Rd,1} = 304.7$ kN**

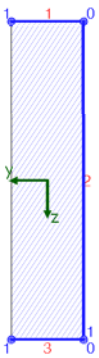
**angle leg at supported beam:**

s. weld verification

## verification of the connection

$V_{Ed} = 160.0$ kN: $V_{Ed} / \min V_{Rd} = 0.525 < 1$ **ok.**

## weld verification




weld 1: $a_w = 5.0$ mm $l_w = 50.0$ mm
weld 2: $a_w = 5.0$ mm $l_w = 220.2$ mm
weld 3: $a_w = 5.0$ mm $l_w = 50.0$ mm

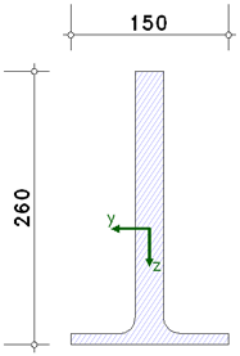
$F_{w,Ed} = 5.45$ kN/cm $< F_{w,Rd} = 10.39$ kN/cm $\Rightarrow U_w = 0.524 < 1$ **ok.**

end weld:

$F_{w,Ed}$ = 1.60 kN/cm < $F_{w,Rd}$ = 6.24 kN/cm ⇒ $U_w$ = 0.257 < 1 ok.

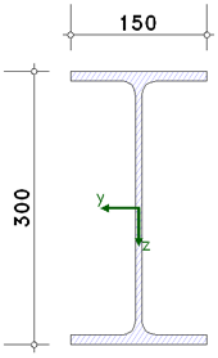
## cross-sectional check of supported beam

verification at Δx = 95.8 mm with notch




elastic cross-sectional check for $M_{Ed}$ = 14.64 kNm, $V_{Ed}$ = 160.00 kN
elastic stresses: max $\sigma_x$ = 2.84 kN/cm², min $\sigma_x$ = -3.85 kN/cm², max $\tau$ = 3.14 kN/cm², max $\sigma_v$ = 5.43 kN/cm²
utilizations: design resistance $U_\sigma$ = 0.231 < 1 ok.

verification at Δx = 104.3 mm




elastic cross-sectional check for $M_{Ed}$ = 16.00 kNm, $V_{Ed}$ = 160.00 kN
elastic stresses: max $\sigma_x$ = 2.87 kN/cm², min $\sigma_x$ = -2.87 kN/cm², max $\tau$ = 8.47 kN/cm², max $\sigma_v$ = 14.68 kN/cm²
utilizations: design resistance $U_\sigma$ = 0.625 < 1 ok., c/t-ratio $U_{c/t}$ = 0.131 < 1 ok.

**verification result**

maximum utilization: max U = 0.625 < 1 ok.

## Final Result

**maximum utilization [Lk 1]:** design resistance max U = 0.781 < 1 ok.
c/t-ratio max U = 0.147 < 1 ok.

**verification succeeded**

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## 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