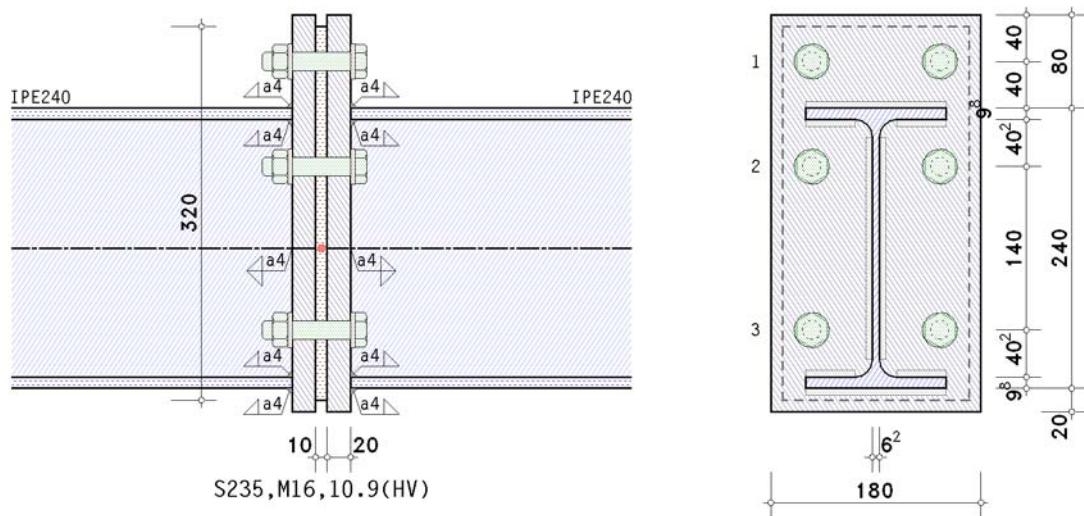


POS. 4: IMPORTBEISPIEL

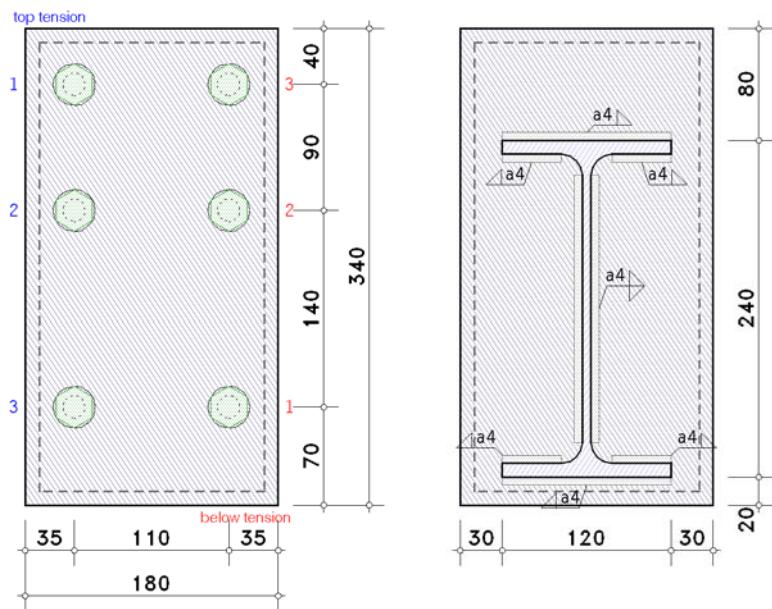
rigid splice with thermal separation layer EC 3-1-8 (12.10), NA: Deutschland

4H-EC3TT version: 3/2016-2r

1. input report



details



steel grade

steel grade S235

bolts

bolt class 10.9, bolt size M16

large wrench size (high strength bolt), preloaded (s. thermal separation layer parameters)
shaft included in the shear plane

beam parameters

section IPE240

verification parameters

bolted end-plate connection:

end-plate: thickness $t_p = 20.0$ mm, width $b_p = 180.0$ mm, length $l_p = 340.0$ mm

projections $h_{p,o} = 80.0$ mm, $h_{p,u} = 20.0$ mm

thermal separation layer (according to Kerncompactlager of Calenberg Ingenieure GmbH):

thickness $t_e = 10.0$ mm, width $b_e = 160.0$ mm, length $l_e = 320.0$ mm

edge distance $\bar{e}_e = 10.0$ mm, safety factor of material $\gamma_e = 1.00$, preload force per bolt $F_{p,C} = 0.0$ kN
bolts in connection:

3 bolt-rows with 2 bolts

all bolt-rows considered individually

all bolt-rows for shear transfer (rows 1-3)

bolt groups generated automatically, considering the decisive group

centre distance of the bolts to the lateral edge of the end-plate $e_2 = 35.0$ mm

centre distance of the first bolt-row to the upper edge of the end-plate (end row) $e_0 = 40.0$ mm
 centre distance of the last bolt-row to the bottom edge of the end-plate (end row) $e_u = 70.0$ mm
 centre distance of the bolt-rows from each other $p_{1-2} = 90.0$ mm, $p_{2-3} = 140.0$ mm

welds at the connection point:

beam flange top: fillet weld, weld thickness $a = 4.0$ mm

beam web: fillet weld, weld thickness $a = 4.0$ mm

beam flange below: fillet weld, weld thickness $a = 4.0$ mm

internal forces and moments in the intersection point of system axes

Ic 1: $N_{j,b,Ed} = -20.61$ kN $M_{j,b,Ed} = -16.76$ kNm $V_{j,b,Ed} = 8.68$ kN

Ic 2: $N_{j,b,Ed} = -15.77$ kN $M_{j,b,Ed} = -17.14$ kNm $V_{j,b,Ed} = -2.71$ kN

Ic 3: $N_{j,b,Ed} = -21.38$ kN $M_{j,b,Ed} = -16.72$ kNm $V_{j,b,Ed} = 16.60$ kN

partial safety factors for material

resistance of cross-sections $\gamma_{M0} = 1.00$

resistance of bolts, welds, plates in bearing $\gamma_{M2} = 1.25$

note

connection is verified due to EC 3-1-8 regardless of preloading.

however, connections may be constructed with prestressed high strength bolts.

check of data

ok

distances between bolts at end-plate

horizontal: $e_2 = 35.0$ mm $> 1.2 \cdot d_0 = 21.6$ mm,

horizontal: $p_2 = 110.0$ mm $> 2.4 \cdot d_0 = 43.2$ mm,

top-below: $e_1 = 40.0$ mm $> 1.2 \cdot d_0 = 21.6$ mm,

top-below: $p_1 = 90.0$ mm $> 2.2 \cdot d_0 = 39.6$ mm,

top-below: $p_1 = 140.0$ mm $> 2.2 \cdot d_0 = 39.6$ mm,

top-below: $e_1 = 70.0$ mm $> 1.2 \cdot d_0 = 21.6$ mm,

$e_2 = 35.0$ mm $< 4 \cdot t + 40$ mm $= 120.0$ mm

$p_2 = 110.0$ mm $< \min(14 \cdot t, 200)$ mm $= 200.0$ mm

$e_1 = 40.0$ mm $< 4 \cdot t + 40$ mm $= 120.0$ mm

$p_1 = 90.0$ mm $< \min(14 \cdot t, 200)$ mm $= 200.0$ mm

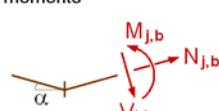
$p_1 = 140.0$ mm $< \min(14 \cdot t, 200)$ mm $= 200.0$ mm

$e_1 = 70.0$ mm $< 4 \cdot t + 40$ mm $= 120.0$ mm

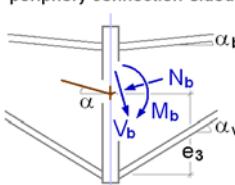
2. Ic 1

2.1. design values

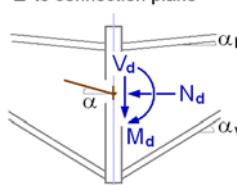
intersectional forces and moments



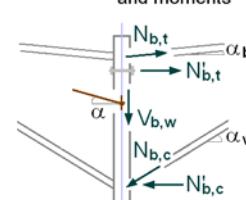
periphery connection-sided



periphery beam



partial internal forces and moments



slope angle: $\alpha_b = \alpha = \alpha_v = 0^\circ$

internal forces and moments perpendicular to the connection planes

periphery beam

$N_d = 20.61$ kN, $M_d = 16.71$ kNm, $V_d = 8.68$ kN

partial internal forces and moments

internal forces and moments in the periphery end-plate-beam: $M'_d = M_d - V_d \cdot t_p = 16.54$ kNm

$N_{b,t} = -N_d \cdot z_{bu}/z_b + M'_d/z_b = 61.54$ kN, $z_b = 230.2$ mm, $z_{bu} = 115.1$ mm

$N_{b,c} = N_d \cdot z_{bo}/z_b + M'_d/z_b = 82.15$ kN, $z_b = 230.2$ mm, $z_{bo} = 115.1$ mm

$V_{b,t} = -N_{b,t} \cdot \sin(\alpha_b) = 0.00$ kN, $V_{b,c} = N_{b,c} \cdot \sin(\alpha_v) = 0.00$ kN, $V_{b,w} = V_d - V_{b,t} - V_{b,c} = 8.68$ kN

2.2. resistance of cross-section in the periphery

plastic verification for $N = -20.61$ kN, $M_y = -16.54$ kNm, $V_z = 8.68$ kN

main bending: $N = -20.61$ kN, resistance forces $N_{max} = 887.78$ kN, $N_{min} = -887.78$ kN $\Rightarrow U_N = 0.023$

$M_y = -16.54$ kNm, resistance moments $M_{y,max} = 82.83$ kNm, $M_{y,min} = -82.83$ kNm $\Rightarrow U_{My} = 0.200$

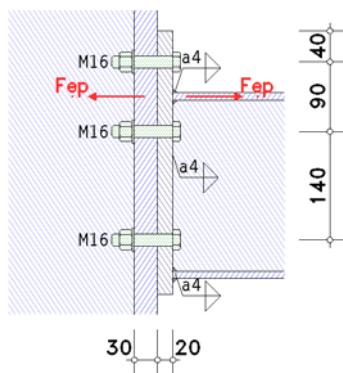
total (possibly due to load increase): max $U = 0.206 < 1$ **ok**

c/t-ratio: outstand flange: utilisation $U_{c/t} = 0.149 < 1$ **ok**

internal compression parts: utilisation $U_{c/t} = 0.134 < 1$ **ok**

2.3. basic components

2.3.1. bc 5: end-plate in bending



Only the essential sizes are sketched to scale.
The connection geometry is only hinted.

extended part of end-plate

in the extended part of the end-plate only one bolt-row is considered ($n_b = 1$).

effective length of the T-stub flange (end-plate):

in mode 1: $\Sigma_{\text{eff},1} = \text{leff},1 = \min(\text{leff},\text{nc}, \text{leff},\text{cp}) = 90.0 \text{ mm}$, $\text{leff},\text{cp} = 181.4 \text{ mm}$

in mode 2: $\Sigma_{\text{eff},2} = \text{leff},2 = \text{leff},\text{nc} = 90.0 \text{ mm}$

tension resistance of the T-stub flange:

in mode 1+2: $M_{\text{pl},\text{Rd}} = (0.25 \cdot \Sigma_{\text{eff}} \cdot t^2 \cdot f_y) / \gamma_{M0} = 2.11 \text{ kNm}$

$F_{t,\text{Rd}} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2} = 113.04 \text{ kN}$, $k_2 = 0.90$

in mode 3: $\Sigma F_{t,\text{Rd}} = 2 \cdot n_b \cdot F_{t,\text{Rd}} = 226.08 \text{ kN}$

$L_b = 66.0 \text{ mm} \leq 85.7 \text{ mm} = L_b^* \Rightarrow$ prying forces may develop !

mode 1: complete yielding of the T-stub flange

$F_{T,1,\text{Rd}} = ((8 \cdot n \cdot 2 \cdot e_w) \cdot M_{\text{pl},1,\text{Rd}}) / (2 \cdot m \cdot n \cdot e_w \cdot (m+n)) = 283.94 \text{ kN}$

mode 2: bolt failure simultaneously with yielding of the T-stub flange

$F_{T,2,\text{Rd}} = (2 \cdot M_{\text{pl},2,\text{Rd}} + n \cdot \Sigma F_{t,\text{Rd}}) / (m+n) = 175.86 \text{ kN}$

mode 3: bolt failure

$F_{T,3,\text{Rd}} = \Sigma F_{t,\text{Rd}} = 226.08 \text{ kN}$

tension resistance of the T-stub flange: $F_{T,\text{Rd}} = \min(F_{T,1,\text{Rd}}, F_{T,2,\text{Rd}}, F_{T,3,\text{Rd}}) = 175.86 \text{ kN}$

resistance of a weld (req.1): $f_{1w,d} = f_u / (\beta_w \cdot \gamma_{M2}) = 360.0 \text{ N/mm}^2$

tension resistance of welds: $F_{T,w,\text{Rd}} = 2^{1/2} \cdot f_{1w,d} \cdot a \cdot \text{leff} = 183.28 \text{ kN} (\geq 175.86 \text{ kN}, \text{not decisive})$

resistance and effective length of end-plate in bending (projection)

$F_{t,ep,\text{Rd},1} = 175.86 \text{ kN}$, $\text{leff},1 = 90.0 \text{ mm}$

part of end-plate between beam flanges

equivalent T-stub flange (each individual bolt-row):

here: number of bolt-rows $n_b = 1$

row 2

effective length of the T-stub flange (end-plate):

in mode 1: $\Sigma_{\text{eff},1} = \text{leff},1 = \min(\text{leff},\text{nc}, \text{leff},\text{cp}) = 256.8 \text{ mm}$, $\text{leff},\text{cp} = 297.7 \text{ mm}$

in mode 2: $\Sigma_{\text{eff},2} = \text{leff},2 = \text{leff},\text{nc} = 256.8 \text{ mm}$

tension resistance of the T-stub flange:

in mode 1+2: $M_{\text{pl},\text{Rd}} = (0.25 \cdot \Sigma_{\text{eff}} \cdot t^2 \cdot f_y) / \gamma_{M0} = 6.03 \text{ kNm}$

$F_{t,\text{Rd}} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2} = 113.04 \text{ kN}$, $k_2 = 0.90$

in mode 3: $\Sigma F_{t,\text{Rd}} = 2 \cdot n_b \cdot F_{t,\text{Rd}} = 226.08 \text{ kN}$

$L_b = 66.0 \text{ mm} \leq 71.5 \text{ mm} = L_b^* \Rightarrow$ prying forces may develop !

mode 1: complete yielding of the T-stub flange

$F_{T,1,\text{Rd}} = ((8 \cdot n \cdot 2 \cdot e_w) \cdot M_{\text{pl},1,\text{Rd}}) / (2 \cdot m \cdot n \cdot e_w \cdot (m+n)) = 592.66 \text{ kN}$

mode 2: bolt failure simultaneously with yielding of the T-stub flange

$F_{T,2,\text{Rd}} = (2 \cdot M_{\text{pl},2,\text{Rd}} + n \cdot \Sigma F_{t,\text{Rd}}) / (m+n) = 242.58 \text{ kN}$

mode 3: bolt failure

$F_{T,3,\text{Rd}} = \Sigma F_{t,\text{Rd}} = 226.08 \text{ kN}$

tension resistance of the T-stub flange: $F_{T,\text{Rd}} = \min(F_{T,1,\text{Rd}}, F_{T,2,\text{Rd}}, F_{T,3,\text{Rd}}) = 226.08 \text{ kN}$

resistance of a weld (req.1): $f_{1w,d} = f_u / (\beta_w \cdot \gamma_{M2}) = 360.0 \text{ N/mm}^2$

tension resistance of welds: $F_{T,w,\text{Rd}} = 2^{1/2} \cdot f_{1w,d} \cdot a \cdot \text{leff} = 522.97 \text{ kN} (\geq 226.08 \text{ kN}, \text{not decisive})$

row 3

effective length of the T-stub flange (end-plate):

in mode 1: $\Sigma_{\text{eff},1} = \text{leff},1 = \min(\text{leff},\text{nc}, \text{leff},\text{cp}) = 256.8 \text{ mm}$, $\text{leff},\text{cp} = 297.7 \text{ mm}$

in mode 2: $\Sigma_{\text{eff},2} = \text{leff},2 = \text{leff},\text{nc} = 256.8 \text{ mm}$

tension resistance of the T-stub flange:

in mode 1+2: $M_{\text{pl},\text{Rd}} = (0.25 \cdot \Sigma_{\text{eff}} \cdot t^2 \cdot f_y) / \gamma_{M0} = 6.03 \text{ kNm}$

$F_{t,\text{Rd}} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2} = 113.04 \text{ kN}$, $k_2 = 0.90$

in mode 3: $\Sigma F_{t,\text{Rd}} = 2 \cdot n_b \cdot F_{t,\text{Rd}} = 226.08 \text{ kN}$

$L_b = 66.0 \text{ mm} \leq 71.5 \text{ mm} = L_b^* \Rightarrow$ prying forces may develop !

mode 1: complete yielding of the T-stub flange

$F_{T,1,\text{Rd}} = ((8 \cdot n \cdot 2 \cdot e_w) \cdot M_{\text{pl},1,\text{Rd}}) / (2 \cdot m \cdot n \cdot e_w \cdot (m+n)) = 592.66 \text{ kN}$

mode 2: bolt failure simultaneously with yielding of the T-stub flange

$F_{T,2,\text{Rd}} = (2 \cdot M_{\text{pl},2,\text{Rd}} + n \cdot \Sigma F_{t,\text{Rd}}) / (m+n) = 242.58 \text{ kN}$

mode 3: bolt failure

$F_{T,3,\text{Rd}} = \Sigma F_{t,\text{Rd}} = 226.08 \text{ kN}$

tension resistance of the T-stub flange: $F_{T,\text{Rd}} = \min(F_{T,1,\text{Rd}}, F_{T,2,\text{Rd}}, F_{T,3,\text{Rd}}) = 226.08 \text{ kN}$

resistance of a weld (req.1): $f_{1w,d} = f_u / (\beta_w \cdot \gamma M_2) = 360.0 \text{ N/mm}^2$

tension resistance of welds: $F_{T,w,Rd} = 2^{1/2} \cdot f_{1w,d} \cdot a \cdot l_{eff} = 522.97 \text{ kN} \geq 226.08 \text{ kN}$, not decisive)

resistances and effective lengths of end-plate in bending (per bolt-row):

$F_{ep,Rd,2} = 226.08 \text{ kN}, l_{eff,2} = 256.8 \text{ mm}$

$F_{ep,Rd,3} = 226.08 \text{ kN}, l_{eff,3} = 256.8 \text{ mm}$

equivalent T-stub flange (group of bolts 1):

here: number of bolt-rows $n_b = 2$ ($R2+R3$)

effective length of the T-stub flange (end-plate):

in mode 1: $\Sigma l_{eff,1} = \min(\Sigma l_{eff,nc}, \Sigma l_{eff,cp}) = 420.4 \text{ mm}, \Sigma l_{eff,cp} = 577.7 \text{ mm}$

in mode 2: $\Sigma l_{eff,2} = \Sigma l_{eff,nc} = 420.4 \text{ mm}$

tension resistance of the T-stub flange:

in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma M_0 = 9.88 \text{ kNm}$

$F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma M_2 = 113.04 \text{ kN}, k_2 = 0.90$

in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 452.16 \text{ kN}$

$L_b = 66.0 \text{ mm} \leq 87.4 \text{ mm} = L_b^* \Rightarrow$ prying forces may develop !

mode 1: complete yielding of the T-stub flange

$F_{T,1,Rd} = ((8 \cdot n \cdot 2 \cdot e_w) \cdot M_{pl,1,Rd}) / (2 \cdot m \cdot n \cdot e_w \cdot (m+n)) = 970.12 \text{ kN}$

mode 2: bolt failure simultaneously with yielding of the T-stub flange

$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 431.96 \text{ kN}$

mode 3: bolt failure

$F_{T,3,Rd} = \Sigma F_{t,Rd} = 452.16 \text{ kN}$

tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 431.96 \text{ kN}$

resistance of a weld (req.1): $f_{1w,d} = f_u / (\beta_w \cdot \gamma M_2) = 360.0 \text{ N/mm}^2$

tension resistance of welds: $F_{T,w,Rd} = 2^{1/2} \cdot f_{1w,d} \cdot a \cdot l_{eff} = 856.05 \text{ kN} \geq 431.96 \text{ kN}$, not decisive)

resistance and effective length of end-plate in bending (decisive group of bolts)

$F_{t,ep,Rd} = 431.96 \text{ kN}, \Sigma l_{eff} = 420.4 \text{ mm}, 2 \text{ rows}$

2.3.2. bc 7: beam flange and web in compression

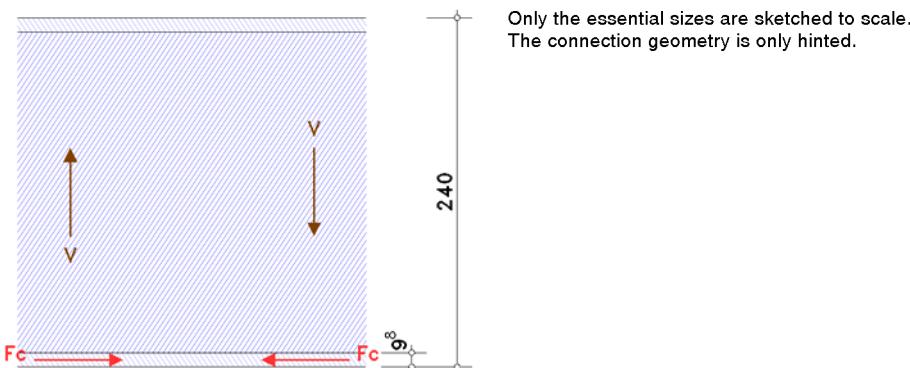
flange below: section class 1

web: section class 1

total: section class 1

section class of the beam: 1

taking into account the moment-shear force-interaction $V_{Ed} = 8.7 \text{ kN}$



stress due to bending with shear force: $V_{Ed} = 8.7 \text{ kN} \leq 129.9 \text{ kN} = V_{pl,Rd}/2 \Rightarrow$ no effect

resistance $M_{c,Rd} = M_{pl,Rd} = (W_{pl} \cdot f_y) / \gamma M_0 = 86.15 \text{ kNm}, W_{pl} = 366.61 \text{ cm}^3$

resistance of a flange (and web) with compression

$F_{c,f,Rd} = M_{c,Rd} / (h - t_f) = 374.25 \text{ kN}$

resistance of the upper beam flange:

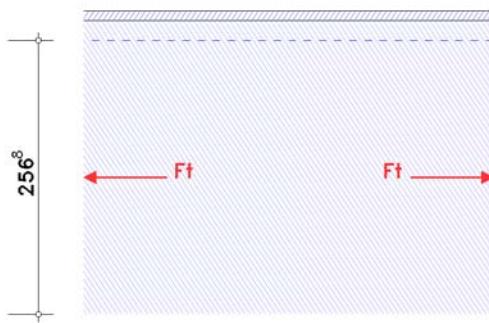
stress due to bending with shear force: $V_{Ed} = 8.7 \text{ kN} \leq 129.9 \text{ kN} = V_{pl,Rd}/2 \Rightarrow$ no effect

resistance $M_{c,Rd} = M_{pl,Rd} = (W_{pl} \cdot f_y) / \gamma M_0 = 86.15 \text{ kNm}, W_{pl} = 366.61 \text{ cm}^3$

resistance of a flange (and web) with compression

$F_{c,f,Rd} = M_{c,Rd} / (h - t_f) = 374.25 \text{ kN}$

2.3.3. bc 8: beam web in tension



Only the essential sizes are sketched to scale.
The connection geometry is only hinted.

each individual bolt-row:

row 2

effective width $b_{eff,t,wb} = 256.8 \text{ mm}$ (l_{eff} from bc 5)
resistance of a beam web in tension

$$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_y,wb / \gamma M_0 = 374.2 \text{ kN}$$

row 3

effective width $b_{eff,t,wb} = 256.8 \text{ mm}$ (l_{eff} from bc 5)
resistance of a beam web in tension

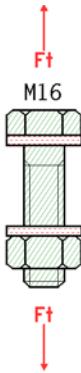
$$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_y,wb / \gamma M_0 = 374.2 \text{ kN}$$

eine group of bolt-rows decisive:

effective width $b_{eff,t,wb} = 420.4 \text{ mm}$ (l_{eff} from bc 5)
resistance of a beam web in tension

$$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_y,wb / \gamma M_0 = 612.5 \text{ kN}$$

2.3.4. bc 10: bolts in tension



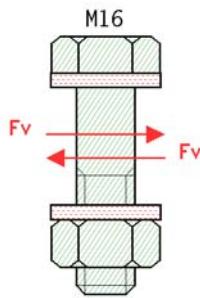
Only the essential sizes are sketched to scale.
The connection geometry is only hinted.

tension resistance of one bolt $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma M_2 = 113.04 \text{ kN}$, $k_2 = 0.90$

punching shear load capacity $B_p,Rd = (0.6 \cdot \pi \cdot d_m \cdot t_p \cdot f_u) / \gamma M_2 = 307.05 \text{ kN}$, $t_p = 20.0 \text{ mm}$

tension-/punching shear load capacity for 2 bolts: $\Sigma F_{tp,Rd} = 2 \cdot \min(F_{t,Rd}, B_p,Rd) = 226.08 \text{ kN}$

2.3.5. bc 11: bolts in shear

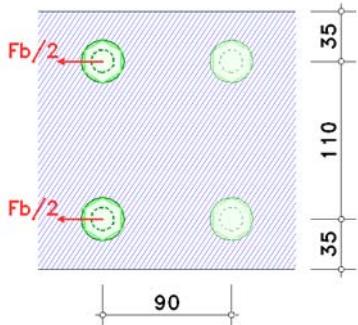


Only the essential sizes are sketched to scale.
The connection geometry is only hinted.

shear resistance per shear plane $F_{v,Rd} = \alpha_v \cdot f_{ub} \cdot A / \gamma M_2 = 96.51 \text{ kN}$, $\alpha_v = 0.60$
shear resistance of 2 bolts (1-shear): $\Sigma F_{v,Rd} = 2 \cdot F_{v,Rd} = 193.02 \text{ kN}$

2.3.6. bc 12: plate with bearing resistance

Only the essential sizes are sketched to scale.
The connection geometry is only hinted.



row 1

bolt 1: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma M_2 = 170.67 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 0.74$

bolt 2: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma M_2 = 170.67 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 0.74$

bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd} = 341.33 \text{ kN}$

shear block:

failure type 1: shear resistance $V_{eff,Rd} = (A_{nt} \cdot f_u) / \gamma M_2 + (A_{nv} \cdot f_y / 3^{1/2}) / \gamma M_0 = 698.16 \text{ kN}$

failure type 2: shear resistance $V_{eff,Rd} = (A_{nt} \cdot f_u) / \gamma M_2 + (A_{nv} \cdot f_y / 3^{1/2}) / \gamma M_0 = 467.76 \text{ kN}$

failure type 3: shear resistance $V_{eff,Rd} = (A_{nt} \cdot f_u) / \gamma M_2 + (A_{nv} \cdot f_y / 3^{1/2}) / \gamma M_0 = 829.44 \text{ kN}$

bearing resistance incl. shear block: $\min(\Sigma F_{b,Rd}, V_{eff,Rd}) = 341.3 \text{ kN}$

row 2

bolt 1: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma M_2 = 230.40 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 1.00$

bolt 2: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma M_2 = 230.40 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 1.00$

bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd} = 460.80 \text{ kN}$

row 3

bolt 1: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma M_2 = 230.40 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 1.00$

bolt 2: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma M_2 = 230.40 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 1.00$

bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd} = 460.80 \text{ kN}$

bearing resistance (3 rows)

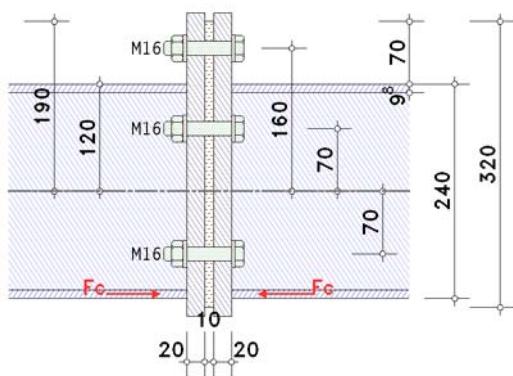
$\Sigma F_{b,Rd,1} = 341.33 \text{ kN}$

$\Sigma F_{b,Rd,2} = 460.80 \text{ kN}$

$\Sigma F_{b,Rd,3} = 460.80 \text{ kN}$

2.3.7. bc 15: end-plate with thermal separation layer

Only the essential sizes are sketched to scale.
The connection geometry is only hinted.



calculation is for structural bearings according to Kerncompactlager of Calenberg Ingenieure GmbH.
calculation method is also appropriate for the connection of a steel girder to a reinforced concrete column
bolts are verified with the thread in the shear plane.

effective length of separation layer $h_m = 74.6 \text{ mm}$

mean compressive stress $\sigma_m = 5.50 \text{ N/mm}^2$

verification of the separation layer:

shape factor $S = 1.962$ for 2 bolts in compression zone

permissible mean compressive stress $\sigma_{m,zul} = 9.73 \text{ N/mm}^2$

utilisation of the separation layer $0.565 < 1$ **ok**

verification of bolts:

shear force: $F_{Ed} = V_{Ed} / n_d = 4.3 \text{ kN}$

internal moment: $M_{Ed} = V_{Ed} \cdot t_e / n_d = 0.04 \text{ kNm}$

shear

shear resistance per shear plane $F_{v,Rd} = (0.5 \cdot f_{up} \cdot A) / \gamma M_2 = 62.80 \text{ kN}$

$F_{v,Ed} = F_{Ed} = 4.3 \text{ kN} < F_{v,Rd} = 62.80 \text{ kN} \Rightarrow U = 0.069 < 1$ **ok**

bending

bending resistance $M_{Rd} = (0.9 \cdot f_{yp} \cdot W_{el}) / \gamma M_0 = 0.225 \text{ kNm}$

$M_{Ed} = 0.04 \text{ kNm} < M_{Rd} = 0.225 \text{ kNm} \Rightarrow U = 0.193 < 1$ **ok**

combination of shear and bending

$(F_{v,Ed}/F_{v,Rd})^2 + (M_{Ed}/M_{Rd})^2 = 0.042 < 1$ **ok**

resistance of an end-plate connection with thermal separation layer:

$$F_{c,e,Rd} = A_{eff} \cdot f_e / \gamma_{Mn} = 86.3 \text{ kN}, \quad A_{eff} = 88.73 \text{ cm}^2, \quad f_e = \sigma_{m,zul} = 9.73 \text{ N/mm}^2, \quad \gamma_{Mn} = 1.00$$

2.4. connection capacity

2.4.1. moment resistance

distance of tension-bolt-rows from centre of compression: $h_1 = 275.1 \text{ mm}$, $h_2 = 185.1 \text{ mm}$, $h_3 = 45.1 \text{ mm}$

resistances acc. to EC 3-1-8, 6.2.7.2(6) for bolt-rows considered individually

decisive basic components: 5, 8

row 1: $F_{tr,Rd} = 175.9 \text{ kN}$

row 2: $F_{tr,Rd} = 226.1 \text{ kN}$

row 3: $F_{tr,Rd} = 226.1 \text{ kN}$

deductions acc. to EC 3-1-8, 6.2.7.2(8) for bolt-rows as part of a group (end-plate)

decisive basic components: 5, 8

row 2: $\Sigma F_{tr,Rd} = 0.0 \text{ kN}$

bc 5: $\Delta F_{tr,Rd} = F_{t,ep,Rd} - \Sigma F_{tr,Rd} = 432.0 \text{ kN}$

bc 8: $\Delta F_{tr,Rd} = F_{t,wb,Rd} - \Sigma F_{tr,Rd} = 612.5 \text{ kN}$

$F_{tr,Rd} = 226.1 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 226.1 \text{ kN}$

$F_{tr,Rd} = 226.1 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 226.1 \text{ kN}$

row 2: $F_{tr,Rd} = 226.1 \text{ kN}$

row 3: $\Sigma F_{tr,Rd} = 226.1 \text{ kN}$ (row 2)

bc 5: $\Delta F_{tr,Rd} = F_{t,ep,Rd} - \Sigma F_{tr,Rd} = 205.9 \text{ kN}$

bc 8: $\Delta F_{tr,Rd} = F_{t,wb,Rd} - \Sigma F_{tr,Rd} = 386.4 \text{ kN}$

$F_{tr,Rd} = 226.1 \text{ kN} > \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 205.9 \text{ kN}$

$F_{tr,Rd} = 205.9 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 205.9 \text{ kN}$

row 3: $F_{tr,Rd} = 205.9 \text{ kN}$

resistance per bolt-row (tension)

row 1: $F_{tr,Rd} = 175.9 \text{ kN}$

row 2: $F_{tr,Rd} = 226.1 \text{ kN}$

row 3: $F_{tr,Rd} = 205.9 \text{ kN}$

$\Sigma F_{tr,Rd}^* = 607.8 \text{ kN}$

deductions acc. to EC 3-1-8, 6.2.7.2(7)

decisive basic component: 7, 15

row 1: $\Sigma F_{tr,Rd} = 0.0 \text{ kN}$

bc 7: $\Delta F_{tr,Rd} = F_{c,f,Rd} - \Sigma F_{tr,Rd} = 374.3 \text{ kN}$

bc 15: $\Delta F_{tr,Rd} = F_{c,e,Rd} - \Sigma F_{tr,Rd} = 86.3 \text{ kN}$

$F_{tr,Rd} = 175.9 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 175.9 \text{ kN}$

$F_{tr,Rd} = 175.9 \text{ kN} > \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 86.3 \text{ kN}$

row 1: $F_{tr,Rd} = 86.3 \text{ kN}$

row 2: $\Sigma F_{tr,Rd} = 86.3 \text{ kN}$ (row 1)

bc 7: $\Delta F_{tr,Rd} = F_{c,f,Rd} - \Sigma F_{tr,Rd} = 287.9 \text{ kN}$

bc 15: $\Delta F_{tr,Rd} = F_{c,e,Rd} - \Sigma F_{tr,Rd} = 0.0 \text{ kN}$

$F_{tr,Rd} = 226.1 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 226.1 \text{ kN}$

$F_{tr,Rd} = 226.1 \text{ kN} > \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 0.0 \text{ kN}$

row 2: $F_{tr,Rd} = 0.0 \text{ kN}$

row 3: $\Sigma F_{tr,Rd} = 86.3 \text{ kN}$ (rows 1 to 2)

bc 7: $\Delta F_{tr,Rd} = F_{c,f,Rd} - \Sigma F_{tr,Rd} = 287.9 \text{ kN}$

bc 15: $\Delta F_{tr,Rd} = F_{c,e,Rd} - \Sigma F_{tr,Rd} = 0.0 \text{ kN}$

$F_{tr,Rd} = 205.9 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 205.9 \text{ kN}$

$F_{tr,Rd} = 205.9 \text{ kN} > \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 0.0 \text{ kN}$

row 3: $F_{tr,Rd} = 0.0 \text{ kN}$

check acc. to EC 3-1-8, 6.2.7.2(9)

decisive basic component: 10

row 1: $F_{tx,Rd} = 86.3 \text{ kN}$, $h_x = 275.1 \text{ mm} \Rightarrow F_{tx,Rd} \leq \lim F_{tx,Rd} = 214.8 \text{ kN}$, no deduction

row 1: $F_{tr,Rd} = 86.3 \text{ kN}$

resistance per bolt-row (bending)

row 1: $F_{tr,Rd} = 86.3 \text{ kN}$

row 2: $F_{tr,Rd} = 0.0 \text{ kN}$

row 3: $F_{tr,Rd} = 0.0 \text{ kN}$

$\Sigma F_{tr,Rd}^* = 86.3 \text{ kN}$

potential failure by basic component 5, 15

resistance of flanges

$\Sigma F_{c,Rd}^* = 172.7 \text{ kN}$

moment resistance

$M_{j,Rd} = \Sigma(F_{tr,Rd} \cdot h_r) = 23.7 \text{ kNm}$

tension resistance

$N_{j,t,Rd} = \Sigma F_{tr,Rd}^* = 607.8 \text{ kN}$

compression resistance

$N_{j,c,Rd} = \Sigma F_{c,Rd}^* = 172.7 \text{ kN}$

2.4.2. shear/bearing resistance

resistance per bolt-row

row 1: $F_{vr,Rd} = 140.4 \text{ kN}$

row 2: $F_{vr,Rd} = 193.0 \text{ kN}$

row 3: $F_{vr,Rd} = 193.0 \text{ kN}$

$\Sigma F_{vr,Rd} = 526.4 \text{ kN}$

shear/bearing resistance

$V_{j,Rd} = \Sigma F_{vr,Rd} = 526.4 \text{ kN}$

2.4.3. total

$M_{j,Rd} = 23.7 \text{ kNm}$ $N_{j,t,Rd} = 607.8 \text{ kN}$ $N_{j,c,Rd} = 172.7 \text{ kN}$ $V_{j,Rd} = 526.4 \text{ kN}$

2.5. verifications

2.5.1. verification of the connection capacity by means of the component method

axial force: $N_{b,Ed} = |N_d| = 20.61 \text{ kN} < 5\% \cdot N_{pl,Rd} = 45.96 \text{ kN} \Rightarrow$ moment resistance

internal moment: $M_{Ed} = M_d - N_d \cdot z_{bu} = 14.34 \text{ kNm}, z_{bu} = 115.1 \text{ mm}$

shear force: $V_{Ed} = |V_d| = 8.68 \text{ kN}$

shear force: $V_{b,w,Ed} = 8.68 \text{ kN}$

$M_{Ed}/M_{j,Rd} = 0.604 < 1$ **ok**

shear/bearing resistance at 60.4% utilisation of moment resistance $V_{j,Rd} = 547.3 \text{ kN}$

$V_{Ed}/V_{j,Rd} = 0.016 < 1$ **ok**

2.5.2. verification of welds at beam section

weld 1: beam flange in tension outer

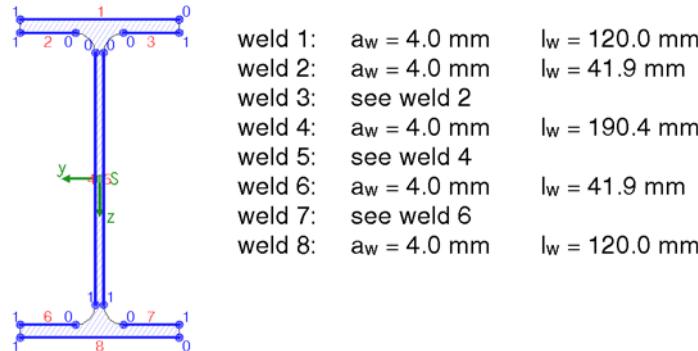
welds 2,3: beam flange in tension inner

welds 4,5: beam web double-sided

weld 8: beam flange in compression outer

welds 6,7: beam flange in compression inner

calculation section:



design values referring to centroid of the section:

$N_{Ed} = -20.61 \text{ kN}$, $M_{y,Ed} = -16.71 \text{ kNm}$, $V_{z,Ed} = 8.68 \text{ kN}$

cross-sectional properties referring to centroid of the line cross-section:

$\Sigma A_w = 31.54 \text{ cm}^2$, $A_{w,z} = 15.23 \text{ cm}^2$, $\Sigma l_w = 78.8 \text{ cm}$

$I_{w,y} = 2656.70 \text{ cm}^4$, $I_{w,z} = 228.70 \text{ cm}^4$, $\Delta z_w = 0.0 \text{ mm}$

distribution of internal forces and moments:

weld 1: $N_w = 33.10 \text{ kN}$

weld 2: $N_w = 10.52 \text{ kN}$

weld 3: see weld 2

weld 4: $N_w = -4.98 \text{ kN}$ $M_{y,w} = -1.45 \text{ kNm}$

weld 5: see weld 4

weld 6: $N_w = -12.71 \text{ kN}$

weld 7: see weld 6

weld 8: $N_w = -39.37 \text{ kN}$

from conventional distribution of shear force: $V_{z,w} = 8.68 \text{ kN}$

verifications in weld edges:

weld 1, pt. 0: $\sigma_{w,x} = 68.96 \text{ N/mm}^2$

$\Rightarrow U_w = 0.271 < 1$ **ok**

weld 2, pt. 0: $\sigma_{w,x} = 62.79 \text{ N/mm}^2$

$\Rightarrow U_w = 0.247 < 1$ **ok**

weld 4, pt. 0: $\sigma_{w,x} = 53.35 \text{ N/mm}^2$ $\tau_{w,z} = 5.70 \text{ N/mm}^2$

$\Rightarrow U_w = 0.211 < 1$ **ok**

pt. 1: $\sigma_{w,x} = -66.43 \text{ N/mm}^2$ $\tau_{w,z} = 5.70 \text{ N/mm}^2$

$\Rightarrow U_w = 0.262 < 1$ **ok**

weld 6, pt. 0: $\sigma_{w,x} = -75.86 \text{ N/mm}^2$

$\Rightarrow U_w = 0.298 < 1$ **ok**

weld 8, pt. 0: $\sigma_{w,x} = -82.03 \text{ N/mm}^2$

$\Rightarrow U_w = 0.322 < 1$ **ok**

Result:

weld 8, pt. 0: $\sigma_{w,x} = -82.03 \text{ N/mm}^2$

Max: $\sigma_{1,w,Ed} = 116.00 \text{ N/mm}^2 < f_{1w,d} = 360.00 \text{ N/mm}^2$,

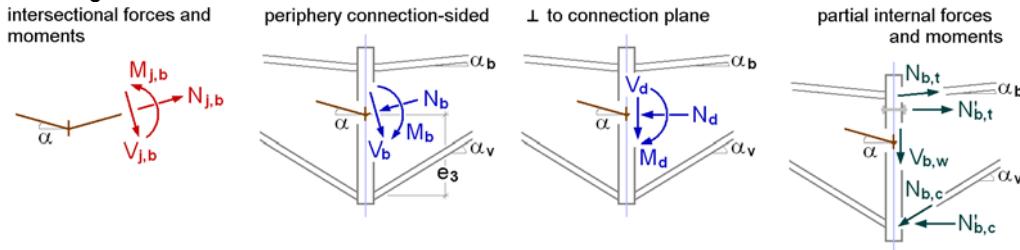
$\sigma_{2,w,Ed} = 58.00 \text{ N/mm}^2 < f_{2w,d} = 259.20 \text{ N/mm}^2 \Rightarrow U_w = 0.322 < 1$ **ok**

2.5.3. verification result

maximum utilisation: max $U = 0.604 < 1$ **ok**

3. Ic 2

3.1. design values



slope angle: $\alpha_b = \alpha = \alpha_v = 0^\circ$

internal forces and moments perpendicular to the connection planes

periphery beam

$N_d = 15.77 \text{ kN}$, $M_d = 17.16 \text{ kNm}$, $V_d = -2.71 \text{ kN}$

partial internal forces and moments

internal forces and moments in the periphery end-plate-beam: $M'd = M_d - V_d t_p = 17.21 \text{ kNm}$

$N_{b,t} = -N_d \cdot z_{bu}/z_b + M'd/z_b = 66.89 \text{ kN}$, $z_b = 230.2 \text{ mm}$, $z_{bu} = 115.1 \text{ mm}$

$N_{b,c} = N_d \cdot z_{bo}/z_b + M'd/z_b = 82.66 \text{ kN}$, $z_b = 230.2 \text{ mm}$, $z_{bo} = 115.1 \text{ mm}$

$V_{b,t} = -N_{b,t} \sin(\alpha_b) = 0.00 \text{ kN}$, $V_{b,c} = N_{b,c} \sin(\alpha_v) = 0.00 \text{ kN}$, $V_{b,w} = V_d - V_{b,t} - V_{b,c} = -2.71 \text{ kN}$

3.2. resistance of cross-section in the periphery

plastic verification for $N = -15.77 \text{ kN}$, $M_y = -17.21 \text{ kNm}$, $V_z = -2.71 \text{ kN}$

main bending: $N = -15.77 \text{ kN}$, resistance forces $N_{\max} = 888.09 \text{ kN}$, $N_{\min} = -888.09 \text{ kN} \Rightarrow U_N = 0.018$

$M_y = -17.21 \text{ kNm}$, resistance moments $M_{y,\max} = 82.88 \text{ kNm}$, $M_{y,\min} = -82.88 \text{ kNm} \Rightarrow U_{My} = 0.208$

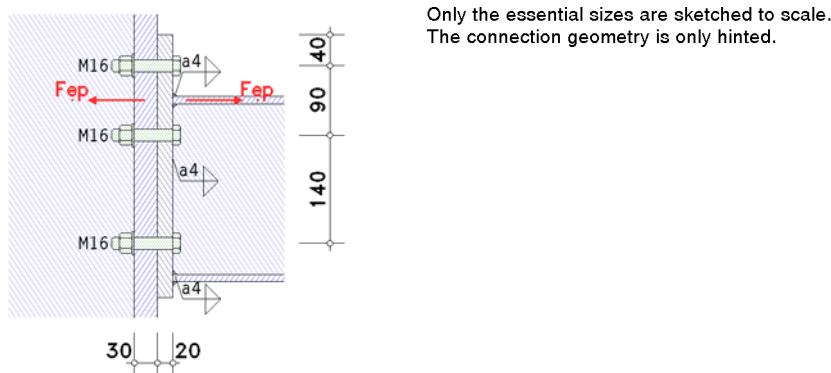
total (possibly due to load increase): max $U = 0.211 < 1$ **ok**

c/t-ratio: outstand flange: utilisation $U_{c/t} = 0.150 < 1$ **ok**

internal compression parts: utilisation $U_{c/t} = 0.129 < 1$ **ok**

3.3. basic components

3.3.1. bc 5: end-plate in bending



extended part of end-plate

in the extended part of the end-plate only one bolt-row is considered ($n_b = 1$).

effective length of the T-stub flange (end-plate):

in mode 1: $\Sigma_{\text{eff},1} = \text{eff}_{\text{left},1} = \min(\text{left}_{\text{eff},nc}, \text{left}_{\text{eff},cp}) = 90.0 \text{ mm}$, $\text{eff}_{\text{left},cp} = 181.4 \text{ mm}$

in mode 2: $\Sigma_{\text{eff},2} = \text{eff}_{\text{left},2} = \text{left}_{\text{eff},nc} = 90.0 \text{ mm}$

tension resistance of the T-stub flange:

in mode 1+2: $M_{\text{pl},Rd} = (0.25 \cdot \Sigma_{\text{eff}} \cdot t_f^2 \cdot f_y) / \gamma_M 0 = 2.11 \text{ kNm}$

$F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_M 2 = 113.04 \text{ kN}$, $k_2 = 0.90$

in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 226.08 \text{ kN}$

$L_b = 66.0 \text{ mm} \leq 85.7 \text{ mm} = L_b^* \Rightarrow$ prying forces may develop !

mode 1: complete yielding of the T-stub flange

$F_{t,1,Rd} = ((8 \cdot n \cdot 2 \cdot e_w) \cdot M_{\text{pl},1,Rd}) / (2 \cdot m \cdot n \cdot e_w \cdot (m+n)) = 283.94 \text{ kN}$

mode 2: bolt failure simultaneously with yielding of the T-stub flange

$F_{t,2,Rd} = (2 \cdot M_{\text{pl},2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 175.86 \text{ kN}$

mode 3: bolt failure

$F_{t,3,Rd} = \Sigma F_{t,Rd} = 226.08 \text{ kN}$

tension resistance of the T-stub flange: $F_{t,Rd} = \min(F_{t,1,Rd}, F_{t,2,Rd}, F_{t,3,Rd}) = 175.86 \text{ kN}$

resistance of a weld (req.1): $f_{1w,d} = f_u / (\beta_w \cdot \gamma_M 2) = 360.0 \text{ N/mm}^2$

tension resistance of welds: $F_{t,w,Rd} = 2^{1/2} \cdot f_{1w,d} \cdot a_{\text{eff}} = 183.28 \text{ kN} (\geq 175.86 \text{ kN}, \text{not decisive})$

resistance and effective length of end-plate in bending (projection)

$$F_{t,ep,Rd,1} = 175.86 \text{ kN}, \quad l_{eff,1} = 90.0 \text{ mm}$$

part of end-plate between beam flanges

equivalent T-stub flange (each individual bolt-row):

here: number of bolt-rows $n_b = 1$

row 2

effective length of the T-stub flange (end-plate):

$$\text{in mode 1: } \Sigma l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp}) = 256.8 \text{ mm}, \quad l_{eff,cp} = 297.7 \text{ mm}$$

$$\text{in mode 2: } \Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc} = 256.8 \text{ mm}$$

tension resistance of the T-stub flange:

$$\text{in mode 1+2: } M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma M_0 = 6.03 \text{ kNm}$$

$$F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma M_2 = 113.04 \text{ kN}, \quad k_2 = 0.90$$

$$\text{in mode 3: } \Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 226.08 \text{ kN}$$

$L_b = 66.0 \text{ mm} \leq 71.5 \text{ mm} = L_b^* \Rightarrow$ prying forces may develop !

mode 1: complete yielding of the T-stub flange

$$F_{t,1,Rd} = ((8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}) / (2 \cdot m \cdot n \cdot e_w \cdot (m+n)) = 592.66 \text{ kN}$$

mode 2: bolt failure simultaneously with yielding of the T-stub flange

$$F_{t,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 242.58 \text{ kN}$$

mode 3: bolt failure

$$F_{t,3,Rd} = \Sigma F_{t,Rd} = 226.08 \text{ kN}$$

tension resistance of the T-stub flange: $F_{t,Rd} = \min(F_{t,1,Rd}, F_{t,2,Rd}, F_{t,3,Rd}) = 226.08 \text{ kN}$

resistance of a weld (req.1): $f_{1w,d} = f_u / (\beta_w \cdot \gamma M_2) = 360.0 \text{ N/mm}^2$

tension resistance of welds: $F_{t,w,Rd} = 2^{1/2} \cdot f_{1w,d} \cdot a \cdot l_{eff} = 522.97 \text{ kN} (\geq 226.08 \text{ kN, not decisive})$

row 3

effective length of the T-stub flange (end-plate):

$$\text{in mode 1: } \Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp}) = 256.8 \text{ mm}, \quad l_{eff,cp} = 297.7 \text{ mm}$$

$$\text{in mode 2: } \Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc} = 256.8 \text{ mm}$$

tension resistance of the T-stub flange:

$$\text{in mode 1+2: } M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma M_0 = 6.03 \text{ kNm}$$

$$F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma M_2 = 113.04 \text{ kN}, \quad k_2 = 0.90$$

$$\text{in mode 3: } \Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 226.08 \text{ kN}$$

$L_b = 66.0 \text{ mm} \leq 71.5 \text{ mm} = L_b^* \Rightarrow$ prying forces may develop !

mode 1: complete yielding of the T-stub flange

$$F_{t,1,Rd} = ((8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}) / (2 \cdot m \cdot n \cdot e_w \cdot (m+n)) = 592.66 \text{ kN}$$

mode 2: bolt failure simultaneously with yielding of the T-stub flange

$$F_{t,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 242.58 \text{ kN}$$

mode 3: bolt failure

$$F_{t,3,Rd} = \Sigma F_{t,Rd} = 226.08 \text{ kN}$$

tension resistance of the T-stub flange: $F_{t,Rd} = \min(F_{t,1,Rd}, F_{t,2,Rd}, F_{t,3,Rd}) = 226.08 \text{ kN}$

resistance of a weld (req.1): $f_{1w,d} = f_u / (\beta_w \cdot \gamma M_2) = 360.0 \text{ N/mm}^2$

tension resistance of welds: $F_{t,w,Rd} = 2^{1/2} \cdot f_{1w,d} \cdot a \cdot l_{eff} = 522.97 \text{ kN} (\geq 226.08 \text{ kN, not decisive})$

resistances and effective lengths of end-plate in bending (per bolt-row):

$$F_{ep,Rd,2} = 226.08 \text{ kN}, \quad l_{eff,2} = 256.8 \text{ mm}$$

$$F_{ep,Rd,3} = 226.08 \text{ kN}, \quad l_{eff,3} = 256.8 \text{ mm}$$

equivalent T-stub flange (group of bolts 1):

here: number of bolt-rows $n_b = 2$ (R2+R3)

effective length of the T-stub flange (end-plate):

$$\text{in mode 1: } \Sigma l_{eff,1} = \min(\Sigma l_{eff,nc}, \Sigma l_{eff,cp}) = 420.4 \text{ mm}, \quad \Sigma l_{eff,cp} = 577.7 \text{ mm}$$

$$\text{in mode 2: } \Sigma l_{eff,2} = \Sigma l_{eff,nc} = 420.4 \text{ mm}$$

tension resistance of the T-stub flange:

$$\text{in mode 1+2: } M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma M_0 = 9.88 \text{ kNm}$$

$$F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma M_2 = 113.04 \text{ kN}, \quad k_2 = 0.90$$

$$\text{in mode 3: } \Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 452.16 \text{ kN}$$

$L_b = 66.0 \text{ mm} \leq 87.4 \text{ mm} = L_b^* \Rightarrow$ prying forces may develop !

mode 1: complete yielding of the T-stub flange

$$F_{t,1,Rd} = ((8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}) / (2 \cdot m \cdot n \cdot e_w \cdot (m+n)) = 970.12 \text{ kN}$$

mode 2: bolt failure simultaneously with yielding of the T-stub flange

$$F_{t,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 431.96 \text{ kN}$$

mode 3: bolt failure

$$F_{t,3,Rd} = \Sigma F_{t,Rd} = 452.16 \text{ kN}$$

tension resistance of the T-stub flange: $F_{t,Rd} = \min(F_{t,1,Rd}, F_{t,2,Rd}, F_{t,3,Rd}) = 431.96 \text{ kN}$

resistance of a weld (req.1): $f_{1w,d} = f_u / (\beta_w \cdot \gamma M_2) = 360.0 \text{ N/mm}^2$

tension resistance of welds: $F_{t,w,Rd} = 2^{1/2} \cdot f_{1w,d} \cdot a \cdot l_{eff} = 856.05 \text{ kN} (\geq 431.96 \text{ kN, not decisive})$

resistance and effective length of end-plate in bending (decisive group of bolts)

$$F_{t,ep,Rd} = 431.96 \text{ kN}, \quad \Sigma l_{eff} = 420.4 \text{ mm}, \quad 2 \text{ rows}$$

3.3.2. bc 7: beam flange and web in compression

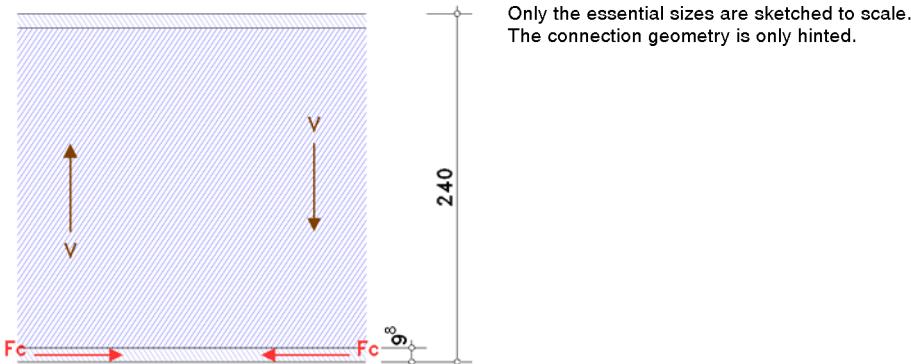
flange below: section class 1

web: section class 1

total: section class 1

section class of the beam: 1

taking into account the moment-shear force-interaction $V_{Ed} = 2.7 \text{ kN}$



stress due to bending with shear force: $V_{Ed} = 2.7 \text{ kN} \leq 129.9 \text{ kN} = V_{pl,Rd}/2 \Rightarrow$ no effect

resistance $M_{c,Rd} = M_{pl,Rd} = (W_{pl} \cdot f_y) / \gamma M_0 = 86.15 \text{ kNm}$, $W_{pl} = 366.61 \text{ cm}^3$

resistance of a flange (and web) with compression

$$F_{c,f,Rd} = M_{c,Rd} / (h - t_f) = 374.25 \text{ kN}$$

resistance of the upper beam flange:

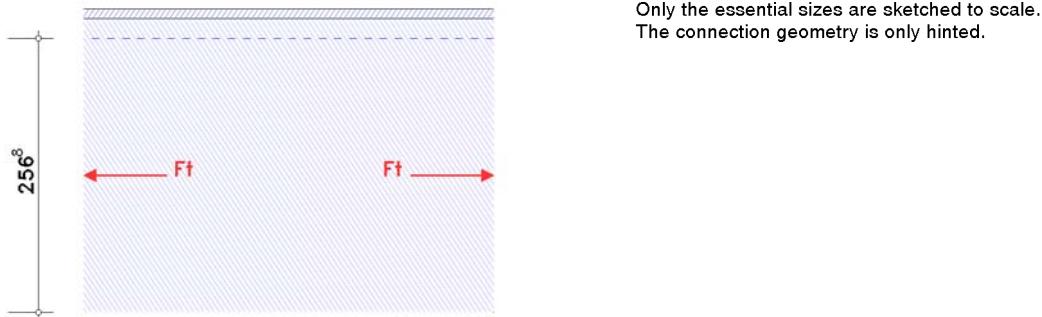
stress due to bending with shear force: $V_{Ed} = 2.7 \text{ kN} \leq 129.9 \text{ kN} = V_{pl,Rd}/2 \Rightarrow$ no effect

resistance $M_{c,Rd} = M_{pl,Rd} = (W_{pl} \cdot f_y) / \gamma M_0 = 86.15 \text{ kNm}$, $W_{pl} = 366.61 \text{ cm}^3$

resistance of a flange (and web) with compression

$$F_{c,f,Rd} = M_{c,Rd} / (h - t_f) = 374.25 \text{ kN}$$

3.3.3. bc 8: beam web in tension



each individual bolt-row:

row 2

effective width $b_{eff,t,wb} = 256.8 \text{ mm}$ (l_{eff} from bc 5)

resistance of a beam web in tension

$$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_y,wb / \gamma M_0 = 374.2 \text{ kN}$$

row 3

effective width $b_{eff,t,wb} = 256.8 \text{ mm}$ (l_{eff} from bc 5)

resistance of a beam web in tension

$$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_y,wb / \gamma M_0 = 374.2 \text{ kN}$$

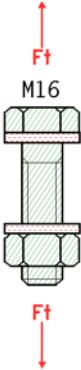
eine group of bolt-rows decisive:

effective width $b_{eff,t,wb} = 420.4 \text{ mm}$ (l_{eff} from bc 5)

resistance of a beam web in tension

$$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_y,wb / \gamma M_0 = 612.5 \text{ kN}$$

3.3.4. bc 10: bolts in tension



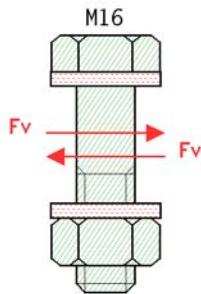
Only the essential sizes are sketched to scale.
The connection geometry is only hinted.

tension resistance of one bolt $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2} = 113.04 \text{ kN}$, $k_2 = 0.90$

punching shear load capacity $B_p,Rd = (0.6 \cdot \pi \cdot d_m \cdot t_p \cdot f_u) / \gamma_{M2} = 307.05 \text{ kN}$, $t_p = 20.0 \text{ mm}$

tension-/punching shear load capacity for 2 bolts: $\Sigma F_{tp,Rd} = 2 \cdot \min(F_{t,Rd}, B_p,Rd) = 226.08 \text{ kN}$

3.3.5. bc 11: bolts in shear



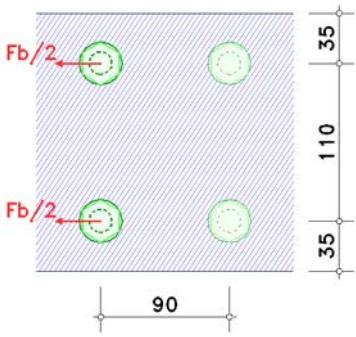
Only the essential sizes are sketched to scale.
The connection geometry is only hinted.

shear resistance per shear plane $F_{v,Rd} = \alpha_v \cdot f_{ub} \cdot A / \gamma_{M2} = 96.51 \text{ kN}$, $\alpha_v = 0.60$

shear resistance of 2 bolts (1-shear): $\Sigma F_{v,Rd} = 2 \cdot F_{v,Rd} = 193.02 \text{ kN}$

3.3.6. bc 12: plate with bearing resistance

Only the essential sizes are sketched to scale.
The connection geometry is only hinted.



row 1

bolt 1: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 230.40 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 1.00$

bolt 2: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 230.40 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 1.00$

bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd} = 460.80 \text{ kN}$

row 2

bolt 1: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 230.40 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 1.00$

bolt 2: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 230.40 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 1.00$

bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd} = 460.80 \text{ kN}$

row 3

bolt 1: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 230.40 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 1.00$

bolt 2: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 230.40 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 1.00$

bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd} = 460.80 \text{ kN}$

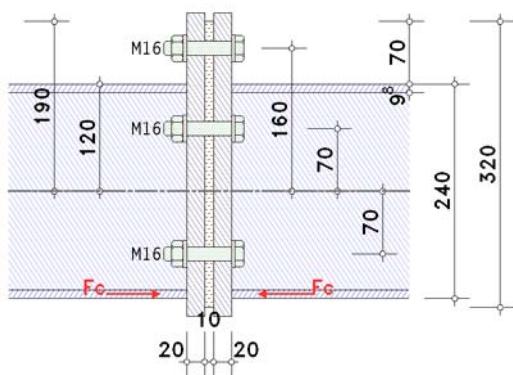
bearing resistance (3 rows)

$\Sigma F_{b,Rd,1} = 460.80 \text{ kN}$

$\Sigma F_{b,Rd,2} = 460.80 \text{ kN}$

$\Sigma F_{b,Rd,3} = 460.80 \text{ kN}$

3.3.7. bc 15: end-plate with thermal separation layer



Only the essential sizes are sketched to scale.
The connection geometry is only hinted.

calculation is for structural bearings according to Kerncompactlager of Calenberg Ingenieure GmbH.
calculation method is also appropriate for the connection of a steel girder to a reinforced concrete column
bolts are verified with the thread in the shear plane.

effective length of separation layer $h_m = 71.8 \text{ mm}$

mean compressive stress $\sigma_m = 5.64 \text{ N/mm}^2$

verification of the separation layer:

shape factor $S = 1.903$ for 2 bolts in compression zone

permissible mean compressive stress $\sigma_{m,zul} = 9.32 \text{ N/mm}^2$

utilisation of the separation layer $0.606 < 1$ **ok**

verification of bolts:

shear force: $F_{Ed} = V_{Ed} / n_d = 1.4 \text{ kN}$

internal moment: $M_{Ed} = V_{Ed} \cdot t_e / n_d = 0.01 \text{ kNm}$

shear

shear resistance per shear plane $F_{v,Rd} = (0.5 \cdot f_{yP} \cdot A) / \gamma_{M2} = 62.80 \text{ kN}$

$F_{v,Ed} = F_{Ed} = 1.4 \text{ kN} < F_{v,Rd} = 62.80 \text{ kN} \Rightarrow U = 0.022 < 1$ **ok**

bending

bending resistance $M_{Rd} = (0.9 \cdot f_{yP} \cdot W_{el}) / \gamma_{M0} = 0.225 \text{ kNm}$

$M_{Ed} = 0.01 \text{ kNm} < M_{Rd} = 0.225 \text{ kNm} \Rightarrow U = 0.060 < 1$ **ok**

combination of shear and bending

$(F_{v,Ed}/F_{v,Rd})^2 + (M_{Ed}/M_{Rd})^2 = 0.004 < 1$ **ok**

resistance of an end-plate connection with thermal separation layer:

$F_{c,e,Rd} = A_{eff} \cdot f_e / \gamma_{Me} = 82.7 \text{ kN}, A_{eff} = 88.73 \text{ cm}^2, f_e = \sigma_{m,zul} = 9.32 \text{ N/mm}^2, \gamma_{Me} = 1.00$

3.4. connection capacity

3.4.1. moment resistance

distance of tension-bolt-rows from centre of compression: $h_1 = 275.1 \text{ mm}, h_2 = 185.1 \text{ mm}, h_3 = 45.1 \text{ mm}$

resistances acc. to EC 3-1-8, 6.2.7.2(6) for bolt-rows considered individually

decisive basic components: 5, 8

row 1: $F_{tr,Rd} = 175.9 \text{ kN}$

row 2: $F_{tr,Rd} = 226.1 \text{ kN}$

row 3: $F_{tr,Rd} = 226.1 \text{ kN}$

deductions acc. to EC 3-1-8, 6.2.7.2(8) for bolt-rows as part of a group (end-plate)

decisive basic components: 5, 8

row 2: $\Sigma F_{tr,Rd} = 0.0 \text{ kN}$

bc 5: $\Delta F_{tr,Rd} = F_{t,ep,Rd} - \Sigma F_{tr,Rd} = 432.0 \text{ kN}$

$F_{tr,Rd} = 226.1 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 226.1 \text{ kN}$

bc 8: $\Delta F_{tr,Rd} = F_{t,wb,Rd} - \Sigma F_{tr,Rd} = 612.5 \text{ kN}$

$F_{tr,Rd} = 226.1 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 226.1 \text{ kN}$

row 2: $F_{tr,Rd} = 226.1 \text{ kN}$

row 3: $\Sigma F_{tr,Rd} = 226.1 \text{ kN}$ (row 2)

bc 5: $\Delta F_{tr,Rd} = F_{t,ep,Rd} - \Sigma F_{tr,Rd} = 205.9 \text{ kN}$

$F_{tr,Rd} = 226.1 \text{ kN} > \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 205.9 \text{ kN}$

bc 8: $\Delta F_{tr,Rd} = F_{t,wb,Rd} - \Sigma F_{tr,Rd} = 386.4 \text{ kN}$

$F_{tr,Rd} = 205.9 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 205.9 \text{ kN}$

row 3: $F_{tr,Rd} = 205.9 \text{ kN}$

resistance per bolt-row (tension)

row 1: $F_{tr,Rd} = 175.9 \text{ kN}$

row 2: $F_{tr,Rd} = 226.1 \text{ kN}$

row 3: $F_{tr,Rd} = 205.9 \text{ kN}$

$\Sigma F_{tr,Rd}^* = 607.8 \text{ kN}$

deductions acc. to EC 3-1-8, 6.2.7.2(7)

decisive basic component: 7, 15

row 1: $\Sigma F_{tr,Rd} = 0.0 \text{ kN}$

bc 7: $\Delta F_{tr,Rd} = F_{c,f,Rd} - \Sigma F_{tr,Rd} = 374.3 \text{ kN}$

$F_{tr,Rd} = 175.9 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 175.9 \text{ kN}$

bc 15: $\Delta F_{tr,Rd} = F_{c,e,Rd} - \Sigma F_{tr,Rd} = 82.7 \text{ kN}$

$F_{tr,Rd} = 175.9 \text{ kN} > \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 82.7 \text{ kN}$

row 1: $F_{tr,Rd} = 82.7 \text{ kN}$

row 2: $\Sigma F_{tr,Rd} = 82.7 \text{ kN}$ (row 1)

bc 7: $\Delta F_{tr,Rd} = F_{c,f,Rd} - \Sigma F_{tr,Rd} = 291.6 \text{ kN}$	$F_{tr,Rd} = 226.1 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 226.1 \text{ kN}$
bc 15: $\Delta F_{tr,Rd} = F_{c,e,Rd} - \Sigma F_{tr,Rd} = 0.0 \text{ kN}$	$F_{tr,Rd} = 226.1 \text{ kN} > \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 0.0 \text{ kN}$
row 2: $F_{tr,Rd} = 0.0 \text{ kN}$	
row 3: $\Sigma F_{tr,Rd} = 82.7 \text{ kN}$ (rows 1 to 2)	
bc 7: $\Delta F_{tr,Rd} = F_{c,f,Rd} - \Sigma F_{tr,Rd} = 291.6 \text{ kN}$	$F_{tr,Rd} = 205.9 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 205.9 \text{ kN}$
bc 15: $\Delta F_{tr,Rd} = F_{c,e,Rd} - \Sigma F_{tr,Rd} = 0.0 \text{ kN}$	$F_{tr,Rd} = 205.9 \text{ kN} > \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 0.0 \text{ kN}$
row 3: $F_{tr,Rd} = 0.0 \text{ kN}$	

check acc. to EC 3-1-8, 6.2.7.2(9)

decisive basic component: 10

row 1: $F_{tx,Rd} = 82.7 \text{ kN}, h_x = 275.1 \text{ mm} \Rightarrow F_{tx,Rd} \leq \lim F_{tx,Rd} = 214.8 \text{ kN}$, no deduction

row 1: $F_{tr,Rd} = 82.7 \text{ kN}$

resistance per bolt-row (bending)

row 1: $F_{tr,Rd} = 82.7 \text{ kN}$

row 2: $F_{tr,Rd} = 0.0 \text{ kN}$

row 3: $F_{tr,Rd} = 0.0 \text{ kN}$

$$\Sigma F_{tr,Rd} = 82.7 \text{ kN}$$

potential failure by basic component 5, 15

resistance of flanges

$$\Sigma F_{c,Rd}^* = 165.4 \text{ kN}$$

moment resistance

$$M_{j,Rd} = \Sigma(F_{tr,Rd} \cdot h_r) = 22.7 \text{ kNm}$$

tension resistance

$$N_{j,t,Rd} = \Sigma F_{tr,Rd} = 607.8 \text{ kN}$$

compression resistance

$$N_{j,c,Rd} = \Sigma F_{c,Rd}^* = 165.4 \text{ kN}$$

3.4.2. shear/bearing resistance

resistance per bolt-row

row 1: $F_{vr,Rd} = 142.6 \text{ kN}$

row 2: $F_{vr,Rd} = 193.0 \text{ kN}$

row 3: $F_{vr,Rd} = 193.0 \text{ kN}$

$$\Sigma F_{vr,Rd} = 528.6 \text{ kN}$$

shear/bearing resistance

$$V_{j,Rd} = \Sigma F_{vr,Rd} = 528.6 \text{ kN}$$

3.4.3. total

$$M_{j,Rd} = 22.7 \text{ kNm} \quad N_{j,t,Rd} = 607.8 \text{ kN} \quad N_{j,c,Rd} = 165.4 \text{ kN} \quad V_{j,Rd} = 528.6 \text{ kN}$$

3.5. verifications

3.5.1. verification of the connection capacity by means of the component method

axial force: $N_{b,Ed} = IN_d l = 15.77 \text{ kN} < 5\% \cdot N_{pl,Rd} = 45.96 \text{ kN} \Rightarrow$ moment resistance

internal moment: $M_{Ed} = M_d - N_d \cdot z_{bu} = 15.34 \text{ kNm}, z_{bu} = 115.1 \text{ mm}$

shear force: $V_{Ed} = |V_d| = 2.71 \text{ kN}$

shear force: $V_{b,w,Ed} = 2.71 \text{ kN}$

$M_{Ed}/M_{j,Rd} = 0.674 < 1$ **ok**

shear/bearing resistance at 67.4% utilisation of moment resistance $V_{j,Rd} = 545.0 \text{ kN}$

$V_{Ed}/V_{j,Rd} = 0.005 < 1$ **ok**

3.5.2. verification of welds at beam section

weld 1: beam flange in tension outer

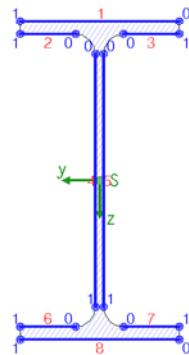
welds 2,3: beam flange in tension inner

weld 8: beam flange in compression outer

welds 4,5: beam web double-sided

welds 6,7: beam flange in compression inner

calculation section:



weld 1:	$a_w = 4.0 \text{ mm}$	$l_w = 120.0 \text{ mm}$
weld 2:	$a_w = 4.0 \text{ mm}$	$l_w = 41.9 \text{ mm}$
weld 3:	see weld 2	
weld 4:	$a_w = 4.0 \text{ mm}$	$l_w = 190.4 \text{ mm}$
weld 5:	see weld 4	
weld 6:	$a_w = 4.0 \text{ mm}$	$l_w = 41.9 \text{ mm}$
weld 7:	see weld 6	
weld 8:	$a_w = 4.0 \text{ mm}$	$l_w = 120.0 \text{ mm}$

design values referring to centroid of the section:

$$N_{Ed} = -15.77 \text{ kN}, M_{y,Ed} = -17.16 \text{ kNm}, V_{z,Ed} = -2.71 \text{ kN}$$

cross-sectional properties referring to centroid of the line cross-section:

$$\Sigma A_w = 31.54 \text{ cm}^2, A_{w,z} = 15.23 \text{ cm}^2, \Sigma l_w = 78.8 \text{ cm}$$

$$I_{w,y} = 2656.70 \text{ cm}^4, I_{w,z} = 228.70 \text{ cm}^4, \Delta z_w = 0.0 \text{ mm}$$

distribution of internal forces and moments:

weld 1:	$N_w = 34.80 \text{ kN}$
weld 2:	$N_w = 11.09 \text{ kN}$
weld 3:	see weld 2
weld 4:	$N_w = -3.81 \text{ kN} \quad M_{y,w} = -1.49 \text{ kNm}$
weld 5:	see weld 4
weld 6:	$N_w = -12.77 \text{ kN}$
weld 7:	see weld 6
weld 8:	$N_w = -39.60 \text{ kN}$

from conventionel distribution of shear force: $V_{z,w} = -2.71 \text{ kN}$

verifications in weld edges:

weld 1, pt. 0:	$\sigma_{w,x} = 72.50 \text{ N/mm}^2$	$\Rightarrow U_w = 0.285 < 1 \text{ ok}$
weld 2, pt. 0:	$\sigma_{w,x} = 66.17 \text{ N/mm}^2$	$\Rightarrow U_w = 0.260 < 1 \text{ ok}$
weld 4, pt. 0:	$\sigma_{w,x} = 56.48 \text{ N/mm}^2$	$\Rightarrow U_w = 0.222 < 1 \text{ ok}$
	$\tau_{w,z} = -1.78 \text{ N/mm}^2$	$\Rightarrow U_w = 0.261 < 1 \text{ ok}$
pt. 1:	$\sigma_{w,x} = -66.49 \text{ N/mm}^2$	$\tau_{w,z} = -1.78 \text{ N/mm}^2$
weld 6, pt. 0:	$\sigma_{w,x} = -76.17 \text{ N/mm}^2$	$\Rightarrow U_w = 0.299 < 1 \text{ ok}$
weld 8, pt. 0:	$\sigma_{w,x} = -82.50 \text{ N/mm}^2$	$\Rightarrow U_w = 0.324 < 1 \text{ ok}$

Result:

$$\text{weld 8, pt. 0: } \sigma_{w,x} = -82.50 \text{ N/mm}^2$$

$$\text{Max: } \sigma_{1,w,Ed} = 116.68 \text{ N/mm}^2 < f_{1w,d} = 360.00 \text{ N/mm}^2, \\ \sigma_{2,w,Ed} = 58.34 \text{ N/mm}^2 < f_{2w,d} = 259.20 \text{ N/mm}^2 \Rightarrow U_w = 0.324 < 1 \text{ ok}$$

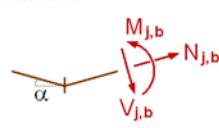
3.5.3. verification result

maximum utilisation: $\max U = 0.674 < 1 \text{ ok}$

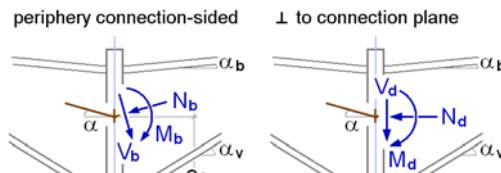
4. Ic 3

4.1. design values

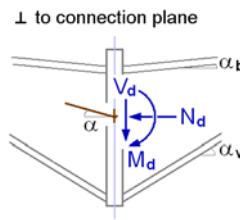
intersectional forces and moments



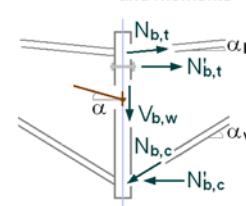
periphery connection-sided



perpendicular to connection plane



partial internal forces and moments



slope angle: $\alpha_b = \alpha = \alpha_v = 0^\circ$

internal forces and moments perpendicular to the connection planes

periphery beam

$$N_d = 21.38 \text{ kN}, M_d = 16.63 \text{ kNm}, V_d = 16.60 \text{ kN}$$

partial internal forces and moments

internal forces and moments in the periphery end-plate-beam: $M'_d = M_d - V_d \cdot t_p = 16.30 \text{ kNm}$

$$N_{b,t} = -N_d \cdot z_{bu}/z_b + M'_d/z_b = 60.12 \text{ kN}, z_b = 230.2 \text{ mm}, z_{bu} = 115.1 \text{ mm}$$

$$N_{b,c} = N_d \cdot z_{bo}/z_b + M'_d/z_b = 81.50 \text{ kN}, z_b = 230.2 \text{ mm}, z_{bo} = 115.1 \text{ mm}$$

$$V_{b,t} = -N_{b,t} \cdot \sin(\alpha_b) = 0.00 \text{ kN}, V_{b,c} = N_{b,c} \cdot \sin(\alpha_v) = 0.00 \text{ kN}, V_{b,w} = V_d - V_{b,t} - V_{b,c} = 16.60 \text{ kN}$$

4.2. resistance of cross-section in the periphery

plastic verification for $N = -21.38 \text{ kN}$, $M_y = -16.30 \text{ kNm}$, $V_z = 16.60 \text{ kN}$

main bending: $N = -21.38 \text{ kN}$, resistance forces $N_{\max} = 886.89 \text{ kN}$, $N_{\min} = -886.89 \text{ kN} \Rightarrow U_N = 0.024$

$M_y = -16.30 \text{ kNm}$, resistance moments $M_{y,\max} = 82.77 \text{ kNm}$, $M_{y,\min} = -82.77 \text{ kNm} \Rightarrow U_{M_y} = 0.197$

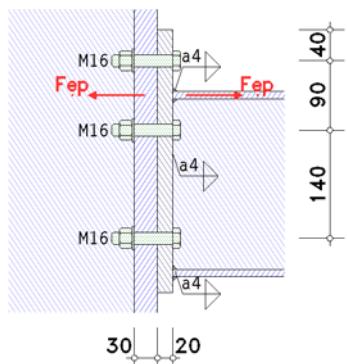
total (possibly due to load increase): max $U = 0.207 < 1 \text{ ok}$

c/t-ratio: outstand flange: utilisation $U_{c/t} = 0.148 < 1 \text{ ok}$

internal compression parts: utilisation $U_{c/t} = 0.135 < 1 \text{ ok}$

4.3. basic components

4.3.1. bc 5: end-plate in bending



Only the essential sizes are sketched to scale.
The connection geometry is only hinted.

extended part of end-plate

in the extended part of the end-plate only one bolt-row is considered ($n_b = 1$).

effective length of the T-stub flange (end-plate):

in mode 1: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp}) = 90.0 \text{ mm}$, $l_{eff,cp} = 181.4 \text{ mm}$

in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc} = 90.0 \text{ mm}$

tension resistance of the T-stub flange:

in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma_M 0 = 2.11 \text{ kNm}$

$F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_M 2 = 113.04 \text{ kN}$, $k_2 = 0.90$

in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 226.08 \text{ kN}$

$L_b = 66.0 \text{ mm} \leq 85.7 \text{ mm} = L_b^* \Rightarrow$ prying forces may develop !

mode 1: complete yielding of the T-stub flange

$F_{t,1,Rd} = ((8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}) / (2 \cdot m \cdot n \cdot e_w \cdot (m+n)) = 283.94 \text{ kN}$

mode 2: bolt failure simultaneously with yielding of the T-stub flange

$F_{t,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 175.86 \text{ kN}$

mode 3: bolt failure

$F_{t,3,Rd} = \Sigma F_{t,Rd} = 226.08 \text{ kN}$

tension resistance of the T-stub flange: $F_{t,Rd} = \min(F_{t,1,Rd}, F_{t,2,Rd}, F_{t,3,Rd}) = 175.86 \text{ kN}$

resistance of a weld (req.1): $f_{1w,d} = f_u / (\beta_w \cdot \gamma_M 2) = 360.0 \text{ N/mm}^2$

tension resistance of welds: $F_{t,w,Rd} = 2^{1/2} \cdot f_{1w,d} \cdot a \cdot l_{eff} = 183.28 \text{ kN} (\geq 175.86 \text{ kN}, \text{not decisive})$

resistance and effective length of end-plate in bending (projection)

$F_{t,ep,Rd,1} = 175.86 \text{ kN}$, $l_{eff,1} = 90.0 \text{ mm}$

part of end-plate between beam flanges

equivalent T-stub flange (each individual bolt-row):

here: number of bolt-rows $n_b = 1$

row 2

effective length of the T-stub flange (end-plate):

in mode 1: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp}) = 256.8 \text{ mm}$, $l_{eff,cp} = 297.7 \text{ mm}$

in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc} = 256.8 \text{ mm}$

tension resistance of the T-stub flange:

in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma_M 0 = 6.03 \text{ kNm}$

$F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_M 2 = 113.04 \text{ kN}$, $k_2 = 0.90$

in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 226.08 \text{ kN}$

$L_b = 66.0 \text{ mm} \leq 71.5 \text{ mm} = L_b^* \Rightarrow$ prying forces may develop !

mode 1: complete yielding of the T-stub flange

$F_{t,1,Rd} = ((8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}) / (2 \cdot m \cdot n \cdot e_w \cdot (m+n)) = 592.66 \text{ kN}$

mode 2: bolt failure simultaneously with yielding of the T-stub flange

$F_{t,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 242.58 \text{ kN}$

mode 3: bolt failure

$F_{t,3,Rd} = \Sigma F_{t,Rd} = 226.08 \text{ kN}$

tension resistance of the T-stub flange: $F_{t,Rd} = \min(F_{t,1,Rd}, F_{t,2,Rd}, F_{t,3,Rd}) = 226.08 \text{ kN}$

resistance of a weld (req.1): $f_{1w,d} = f_u / (\beta_w \cdot \gamma_M 2) = 360.0 \text{ N/mm}^2$

tension resistance of welds: $F_{t,w,Rd} = 2^{1/2} \cdot f_{1w,d} \cdot a \cdot l_{eff} = 522.97 \text{ kN} (\geq 226.08 \text{ kN}, \text{not decisive})$

row 3

effective length of the T-stub flange (end-plate):

in mode 1: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp}) = 256.8 \text{ mm}$, $l_{eff,cp} = 297.7 \text{ mm}$

in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc} = 256.8 \text{ mm}$

tension resistance of the T-stub flange:

in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma_{left} \cdot t_f^2 \cdot f_y) / \gamma M_0 = 6.03 \text{ kNm}$

$F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma M_2 = 113.04 \text{ kN}, k_2 = 0.90$

in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 226.08 \text{ kN}$

$L_b = 66.0 \text{ mm} \leq 71.5 \text{ mm} = L_b^* \Rightarrow \text{prying forces may develop !}$

mode 1: complete yielding of the T-stub flange

$F_{T,1,Rd} = ((8 \cdot n \cdot 2 \cdot e_w) \cdot M_{pl,1,Rd}) / (2 \cdot m \cdot n \cdot e_w \cdot (m+n)) = 592.66 \text{ kN}$

mode 2: bolt failure simultaneously with yielding of the T-stub flange

$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 242.58 \text{ kN}$

mode 3: bolt failure

$F_{T,3,Rd} = \Sigma F_{t,Rd} = 226.08 \text{ kN}$

tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 226.08 \text{ kN}$

resistance of a weld (req.1): $f_{1w,d} = f_u / (\beta_w \cdot \gamma M_2) = 360.0 \text{ N/mm}^2$

tension resistance of welds: $F_{T,w,Rd} = 2^{1/2} \cdot f_{1w,d} \cdot a \cdot l_{eff} = 522.97 \text{ kN} (\geq 226.08 \text{ kN, not decisive})$

resistances and effective lengths of end-plate in bending (per bolt-row):

$F_{ep,Rd,2} = 226.08 \text{ kN}, l_{eff,2} = 256.8 \text{ mm}$

$F_{ep,Rd,3} = 226.08 \text{ kN}, l_{eff,3} = 256.8 \text{ mm}$

equivalent T-stub flange (group of bolts 1):

here: number of bolt-rows $n_b = 2$ (R_2+R_3)

effective length of the T-stub flange (end-plate):

in mode 1: $\Sigma_{left,1} = \min(\Sigma_{left,nc}, \Sigma_{left,cp}) = 420.4 \text{ mm}, \Sigma_{left,cp} = 577.7 \text{ mm}$

in mode 2: $\Sigma_{left,2} = \Sigma_{left,nc} = 420.4 \text{ mm}$

tension resistance of the T-stub flange:

in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma_{left} \cdot t_f^2 \cdot f_y) / \gamma M_0 = 9.88 \text{ kNm}$

$F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma M_2 = 113.04 \text{ kN}, k_2 = 0.90$

in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 452.16 \text{ kN}$

$L_b = 66.0 \text{ mm} \leq 87.4 \text{ mm} = L_b^* \Rightarrow \text{prying forces may develop !}$

mode 1: complete yielding of the T-stub flange

$F_{T,1,Rd} = ((8 \cdot n \cdot 2 \cdot e_w) \cdot M_{pl,1,Rd}) / (2 \cdot m \cdot n \cdot e_w \cdot (m+n)) = 970.12 \text{ kN}$

mode 2: bolt failure simultaneously with yielding of the T-stub flange

$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 431.96 \text{ kN}$

mode 3: bolt failure

$F_{T,3,Rd} = \Sigma F_{t,Rd} = 452.16 \text{ kN}$

tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 431.96 \text{ kN}$

resistance of a weld (req.1): $f_{1w,d} = f_u / (\beta_w \cdot \gamma M_2) = 360.0 \text{ N/mm}^2$

tension resistance of welds: $F_{T,w,Rd} = 2^{1/2} \cdot f_{1w,d} \cdot a \cdot l_{eff} = 856.05 \text{ kN} (\geq 431.96 \text{ kN, not decisive})$

resistance and effective length of end-plate in bending (decisive group of bolts)

$F_{t,ep,Rd} = 431.96 \text{ kN}, \Sigma_{left} = 420.4 \text{ mm}, 2 \text{ rows}$

4.3.2. bc 7: beam flange and web in compression

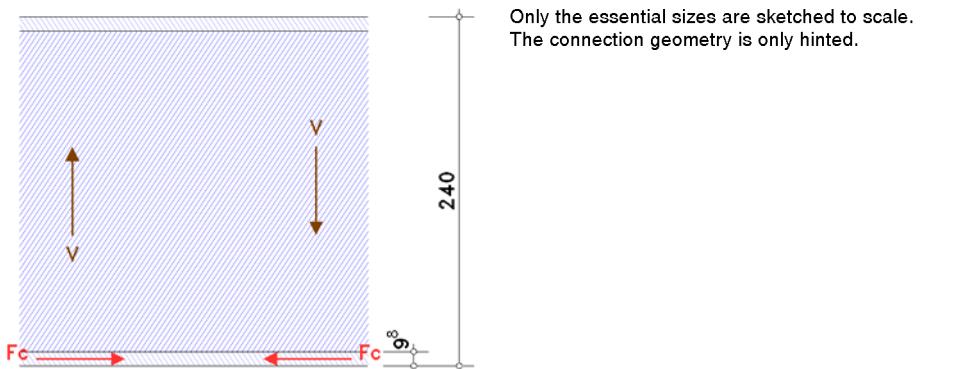
flange below: section class 1

web: section class 1

total: section class 1

section class of the beam: 1

taking into account the moment-shear force-interaction $V_{Ed} = 16.6 \text{ kN}$



stress due to bending with shear force: $V_{Ed} = 16.6 \text{ kN} \leq 129.9 \text{ kN} = V_{pl,Rd}/2 \Rightarrow \text{no effect}$

resistance $M_{c,Rd} = M_{pl,Rd} = (W_{pl} \cdot f_y) / \gamma M_0 = 86.15 \text{ kNm}, W_{pl} = 366.61 \text{ cm}^3$

resistance of a flange (and web) with compression

$F_{c,f,Rd} = M_{c,Rd} / (h - t_f) = 374.25 \text{ kN}$

resistance of the upper beam flange:

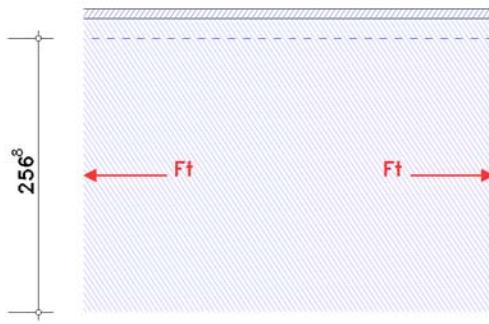
stress due to bending with shear force: $V_{Ed} = 16.6 \text{ kN} \leq 129.9 \text{ kN} = V_{pl,Rd}/2 \Rightarrow \text{no effect}$

resistance $M_{c,Rd} = M_{pl,Rd} = (W_{pl} \cdot f_y) / \gamma M_0 = 86.15 \text{ kNm}, W_{pl} = 366.61 \text{ cm}^3$

resistance of a flange (and web) with compression

$F_{c,f,Rd} = M_{c,Rd} / (h - t_f) = 374.25 \text{ kN}$

4.3.3. bc 8: beam web in tension



Only the essential sizes are sketched to scale.
The connection geometry is only hinted.

each individual bolt-row:

row 2

effective width $b_{eff,t,wb} = 256.8 \text{ mm}$ (l_{eff} from bc 5)
resistance of a beam web in tension

$$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_y,wb / \gamma M_0 = 374.2 \text{ kN}$$

row 3

effective width $b_{eff,t,wb} = 256.8 \text{ mm}$ (l_{eff} from bc 5)
resistance of a beam web in tension

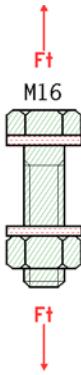
$$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_y,wb / \gamma M_0 = 374.2 \text{ kN}$$

eine group of bolt-rows decisive:

effective width $b_{eff,t,wb} = 420.4 \text{ mm}$ (l_{eff} from bc 5)
resistance of a beam web in tension

$$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_y,wb / \gamma M_0 = 612.5 \text{ kN}$$

4.3.4. bc 10: bolts in tension



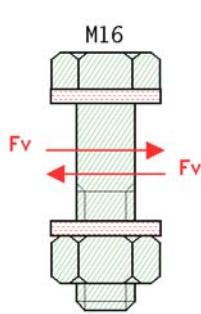
Only the essential sizes are sketched to scale.
The connection geometry is only hinted.

tension resistance of one bolt $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma M_2 = 113.04 \text{ kN}$, $k_2 = 0.90$

punching shear load capacity $B_p,Rd = (0.6 \cdot \pi \cdot d_m \cdot t_p \cdot f_u) / \gamma M_2 = 307.05 \text{ kN}$, $t_p = 20.0 \text{ mm}$

tension-/punching shear load capacity for 2 bolts: $\Sigma F_{tp,Rd} = 2 \cdot \min(F_{t,Rd}, B_p,Rd) = 226.08 \text{ kN}$

4.3.5. bc 11: bolts in shear

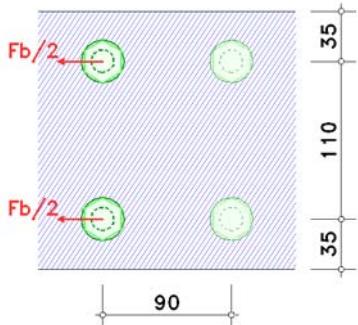


Only the essential sizes are sketched to scale.
The connection geometry is only hinted.

shear resistance per shear plane $F_{v,Rd} = \alpha_v \cdot f_{ub} \cdot A / \gamma M_2 = 96.51 \text{ kN}$, $\alpha_v = 0.60$
shear resistance of 2 bolts (1-shear): $\Sigma F_{v,Rd} = 2 \cdot F_{v,Rd} = 193.02 \text{ kN}$

4.3.6. bc 12: plate with bearing resistance

Only the essential sizes are sketched to scale.
The connection geometry is only hinted.



row 1

bolt 1: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma M_2 = 170.67 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 0.74$

bolt 2: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma M_2 = 170.67 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 0.74$

bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd} = 341.33 \text{ kN}$

shear block:

failure type 1: shear resistance $V_{eff,Rd} = (A_{nt} \cdot f_u) / \gamma M_2 + (A_{nv} \cdot f_y / 3^{1/2}) / \gamma M_0 = 698.16 \text{ kN}$

failure type 2: shear resistance $V_{eff,Rd} = (A_{nt} \cdot f_u) / \gamma M_2 + (A_{nv} \cdot f_y / 3^{1/2}) / \gamma M_0 = 467.76 \text{ kN}$

failure type 3: shear resistance $V_{eff,Rd} = (A_{nt} \cdot f_u) / \gamma M_2 + (A_{nv} \cdot f_y / 3^{1/2}) / \gamma M_0 = 829.44 \text{ kN}$

bearing resistance incl. shear block: $\min(\Sigma F_{b,Rd}, V_{eff,Rd}) = 341.3 \text{ kN}$

row 2

bolt 1: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma M_2 = 230.40 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 1.00$

bolt 2: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma M_2 = 230.40 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 1.00$

bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd} = 460.80 \text{ kN}$

row 3

bolt 1: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma M_2 = 230.40 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 1.00$

bolt 2: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma M_2 = 230.40 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 1.00$

bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd} = 460.80 \text{ kN}$

bearing resistance (3 rows)

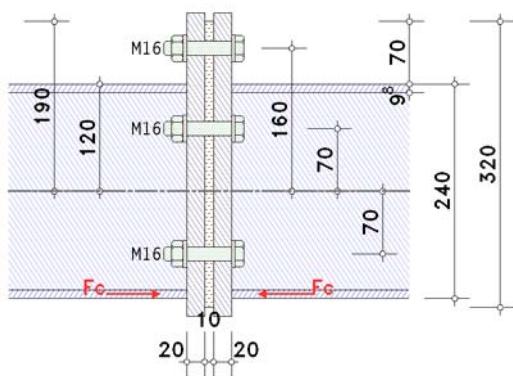
$\Sigma F_{b,Rd,1} = 341.33 \text{ kN}$

$\Sigma F_{b,Rd,2} = 460.80 \text{ kN}$

$\Sigma F_{b,Rd,3} = 460.80 \text{ kN}$

4.3.7. bc 15: end-plate with thermal separation layer

Only the essential sizes are sketched to scale.
The connection geometry is only hinted.



calculation is for structural bearings according to Kerncompactlager of Calenberg Ingenieure GmbH.
calculation method is also appropriate for the connection of a steel girder to a reinforced concrete column
bolts are verified with the thread in the shear plane.

effective length of separation layer $h_m = 75.0 \text{ mm}$

mean compressive stress $\sigma_m = 5.47 \text{ N/mm}^2$

verification of the separation layer:

shape factor $S = 1.971$ for 2 bolts in compression zone

permissible mean compressive stress $\sigma_{m,zul} = 9.80 \text{ N/mm}^2$

utilisation of the separation layer $0.559 < 1$ **ok**

verification of bolts:

shear force: $F_{Ed} = V_{Ed} / n_d = 8.3 \text{ kN}$

internal moment: $M_{Ed} = V_{Ed} \cdot t_e / n_d = 0.08 \text{ kNm}$

shear

shear resistance per shear plane $F_{v,Rd} = (0.5 \cdot f_{up} \cdot A) / \gamma M_2 = 62.80 \text{ kN}$

$F_{v,Ed} = 8.3 \text{ kN} < F_{v,Rd} = 62.80 \text{ kN} \Rightarrow U = 0.132 < 1$ **ok**

bending

bending resistance $M_{Rd} = (0.9 \cdot f_{yp} \cdot W_{el}) / \gamma M_0 = 0.225 \text{ kNm}$

$M_{Ed} = 0.08 \text{ kNm} < M_{Rd} = 0.225 \text{ kNm} \Rightarrow U = 0.369 < 1$ **ok**

combination of shear and bending

$(F_{v,Ed}/F_{v,Rd})^2 + (M_{Ed}/M_{Rd})^2 = 0.154 < 1$ **ok**

resistance of an end-plate connection with thermal separation layer:

$$F_{c,e,Rd} = A_{eff} \cdot f_e / \gamma_{M_e} = 86.9 \text{ kN}, \quad A_{eff} = 88.73 \text{ cm}^2, \quad f_e = \sigma_{m,zul} = 9.80 \text{ N/mm}^2, \quad \gamma_{M_e} = 1.00$$

4.4. connection capacity

4.4.1. moment resistance

distance of tension-bolt-rows from centre of compression: $h_1 = 275.1 \text{ mm}$, $h_2 = 185.1 \text{ mm}$, $h_3 = 45.1 \text{ mm}$

resistances acc. to EC 3-1-8, 6.2.7.2(6) for bolt-rows considered individually

decisive basic components: 5, 8

row 1: $F_{tr,Rd} = 175.9 \text{ kN}$

row 2: $F_{tr,Rd} = 226.1 \text{ kN}$

row 3: $F_{tr,Rd} = 226.1 \text{ kN}$

deductions acc. to EC 3-1-8, 6.2.7.2(8) for bolt-rows as part of a group (end-plate)

decisive basic components: 5, 8

row 2: $\Sigma F_{tr,Rd} = 0.0 \text{ kN}$

bc 5: $\Delta F_{tr,Rd} = F_{t,ep,Rd} - \Sigma F_{tr,Rd} = 432.0 \text{ kN}$

bc 8: $\Delta F_{tr,Rd} = F_{t,wb,Rd} - \Sigma F_{tr,Rd} = 612.5 \text{ kN}$

$F_{tr,Rd} = 226.1 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 226.1 \text{ kN}$

$F_{tr,Rd} = 226.1 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 226.1 \text{ kN}$

row 2: $F_{tr,Rd} = 226.1 \text{ kN}$

row 3: $\Sigma F_{tr,Rd} = 226.1 \text{ kN}$ (row 2)

bc 5: $\Delta F_{tr,Rd} = F_{t,ep,Rd} - \Sigma F_{tr,Rd} = 205.9 \text{ kN}$

bc 8: $\Delta F_{tr,Rd} = F_{t,wb,Rd} - \Sigma F_{tr,Rd} = 386.4 \text{ kN}$

$F_{tr,Rd} = 226.1 \text{ kN} > \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 205.9 \text{ kN}$

$F_{tr,Rd} = 205.9 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 205.9 \text{ kN}$

row 3: $F_{tr,Rd} = 205.9 \text{ kN}$

resistance per bolt-row (tension)

row 1: $F_{tr,Rd} = 175.9 \text{ kN}$

row 2: $F_{tr,Rd} = 226.1 \text{ kN}$

row 3: $F_{tr,Rd} = 205.9 \text{ kN}$

$\Sigma F_{tr,Rd}^* = 607.8 \text{ kN}$

deductions acc. to EC 3-1-8, 6.2.7.2(7)

decisive basic component: 7, 15

row 1: $\Sigma F_{tr,Rd} = 0.0 \text{ kN}$

bc 7: $\Delta F_{tr,Rd} = F_{c,f,Rd} - \Sigma F_{tr,Rd} = 374.3 \text{ kN}$

bc 15: $\Delta F_{tr,Rd} = F_{c,e,Rd} - \Sigma F_{tr,Rd} = 86.9 \text{ kN}$

$F_{tr,Rd} = 175.9 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 175.9 \text{ kN}$

$F_{tr,Rd} = 175.9 \text{ kN} > \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 86.9 \text{ kN}$

row 1: $F_{tr,Rd} = 86.9 \text{ kN}$

row 2: $\Sigma F_{tr,Rd} = 86.9 \text{ kN}$ (row 1)

bc 7: $\Delta F_{tr,Rd} = F_{c,f,Rd} - \Sigma F_{tr,Rd} = 287.3 \text{ kN}$

bc 15: $\Delta F_{tr,Rd} = F_{c,e,Rd} - \Sigma F_{tr,Rd} = 0.0 \text{ kN}$

$F_{tr,Rd} = 226.1 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 226.1 \text{ kN}$

$F_{tr,Rd} = 226.1 \text{ kN} > \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 0.0 \text{ kN}$

row 2: $F_{tr,Rd} = 0.0 \text{ kN}$

row 3: $\Sigma F_{tr,Rd} = 86.9 \text{ kN}$ (rows 1 to 2)

bc 7: $\Delta F_{tr,Rd} = F_{c,f,Rd} - \Sigma F_{tr,Rd} = 287.3 \text{ kN}$

bc 15: $\Delta F_{tr,Rd} = F_{c,e,Rd} - \Sigma F_{tr,Rd} = 0.0 \text{ kN}$

$F_{tr,Rd} = 205.9 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 205.9 \text{ kN}$

$F_{tr,Rd} = 205.9 \text{ kN} > \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 0.0 \text{ kN}$

row 3: $F_{tr,Rd} = 0.0 \text{ kN}$

check acc. to EC 3-1-8, 6.2.7.2(9)

decisive basic component: 10

row 1: $F_{tx,Rd} = 86.9 \text{ kN}, \quad h_x = 275.1 \text{ mm} \Rightarrow F_{tx,Rd} \leq \lim F_{tx,Rd} = 214.8 \text{ kN}$, no deduction

row 1: $F_{tr,Rd} = 86.9 \text{ kN}$

resistance per bolt-row (bending)

row 1: $F_{tr,Rd} = 86.9 \text{ kN}$

row 2: $F_{tr,Rd} = 0.0 \text{ kN}$

row 3: $F_{tr,Rd} = 0.0 \text{ kN}$

$\Sigma F_{tr,Rd} = 86.9 \text{ kN}$

potential failure by basic component 5, 15

resistance of flanges

$\Sigma F_{c,Rd}^* = 173.9 \text{ kN}$

moment resistance

$M_{j,Rd} = \Sigma(F_{tr,Rd} \cdot h_r) = 23.9 \text{ kNm}$

tension resistance

$N_{j,t,Rd} = \Sigma F_{tr,Rd}^* = 607.8 \text{ kN}$

compression resistance

$N_{j,c,Rd} = \Sigma F_{c,Rd}^* = 173.9 \text{ kN}$

4.4.2. shear/bearing resistance

resistance per bolt-row

row 1: $F_{vr,Rd} = 140.0 \text{ kN}$

row 2: $F_{vr,Rd} = 193.0 \text{ kN}$

row 3: $F_{vr,Rd} = 193.0 \text{ kN}$

$\Sigma F_{vr,Rd} = 526.0 \text{ kN}$

shear/bearing resistance

$V_{j,Rd} = \Sigma F_{vr,Rd} = 526.0 \text{ kN}$

4.4.3. total

$M_{j,Rd} = 23.9 \text{ kNm}$ $N_{j,t,Rd} = 607.8 \text{ kN}$ $N_{j,c,Rd} = 173.9 \text{ kN}$ $V_{j,Rd} = 526.0 \text{ kN}$

4.5. verifications

4.5.1. verification of the connection capacity by means of the component method

axial force: $N_{b,Ed} = |N_d| = 21.38 \text{ kN} < 5\% \cdot N_{pl,Rd} = 45.96 \text{ kN} \Rightarrow$ moment resistance

internal moment: $M_{Ed} = M_d - N_d \cdot z_{bu} = 14.17 \text{ kNm}, z_{bu} = 115.1 \text{ mm}$

shear force: $V_{Ed} = |V_d| = 16.60 \text{ kN}$

shear force: $V_{b,w,Ed} = 16.60 \text{ kN}$

$M_{Ed}/M_{j,Rd} = 0.593 < 1$ **ok**

shear/bearing resistance at 59.3% utilisation of moment resistance $V_{j,Rd} = 547.6 \text{ kN}$

$V_{Ed}/V_{j,Rd} = 0.030 < 1$ **ok**

4.5.2. verification of welds at beam section

weld 1: beam flange in tension outer

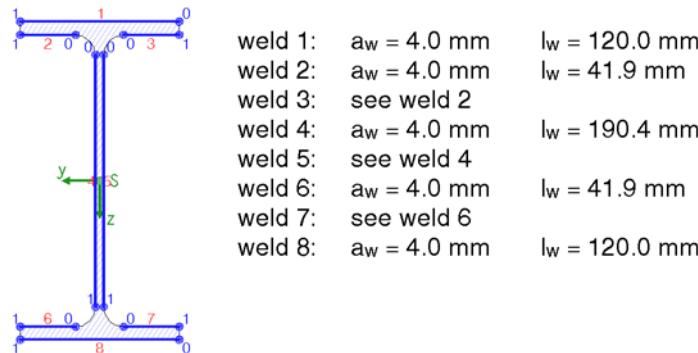
welds 2,3: beam flange in tension inner

welds 4,5: beam web double-sided

weld 8: beam flange in compression outer

welds 6,7: beam flange in compression inner

calculation section:



design values referring to centroid of the section:

$N_{Ed} = -21.38 \text{ kN}$, $M_{y,Ed} = -16.63 \text{ kNm}$, $V_{z,Ed} = 16.60 \text{ kN}$

cross-sectional properties referring to centroid of the line cross-section:

$\Sigma A_w = 31.54 \text{ cm}^2$, $A_{w,z} = 15.23 \text{ cm}^2$, $\Sigma l_w = 78.8 \text{ cm}$

$I_{w,y} = 2656.70 \text{ cm}^4$, $I_{w,z} = 228.70 \text{ cm}^4$, $\Delta z_w = 0.0 \text{ mm}$

distribution of internal forces and moments:

weld 1: $N_w = 32.81 \text{ kN}$

weld 2: $N_w = 10.43 \text{ kN}$

weld 3: see weld 2

weld 4: $N_w = -5.16 \text{ kN}$ $M_{y,w} = -1.44 \text{ kNm}$

weld 5: see weld 4

weld 6: $N_w = -12.70 \text{ kN}$

weld 7: see weld 6

weld 8: $N_w = -39.32 \text{ kN}$

from conventional distribution of shear force: $V_{z,w} = 16.60 \text{ kN}$

verifications in weld edges:

weld 1, pt. 0: $\sigma_{w,x} = 68.35 \text{ N/mm}^2$

$\Rightarrow U_w = 0.268 < 1$ **ok**

weld 2, pt. 0: $\sigma_{w,x} = 62.21 \text{ N/mm}^2$

$\Rightarrow U_w = 0.244 < 1$ **ok**

weld 4, pt. 0: $\sigma_{w,x} = 52.82 \text{ N/mm}^2$ $\tau_{w,z} = 10.90 \text{ N/mm}^2$

$\Rightarrow U_w = 0.214 < 1$ **ok**

pt. 1: $\sigma_{w,x} = -66.38 \text{ N/mm}^2$ $\tau_{w,z} = 10.90 \text{ N/mm}^2$

$\Rightarrow U_w = 0.266 < 1$ **ok**

weld 6, pt. 0: $\sigma_{w,x} = -75.77 \text{ N/mm}^2$

$\Rightarrow U_w = 0.298 < 1$ **ok**

weld 8, pt. 0: $\sigma_{w,x} = -81.91 \text{ N/mm}^2$

$\Rightarrow U_w = 0.322 < 1$ **ok**

Result:

weld 8, pt. 0: $\sigma_{w,x} = -81.91 \text{ N/mm}^2$

Max: $\sigma_{1,w,Ed} = 115.83 \text{ N/mm}^2 < f_{1w,d} = 360.00 \text{ N/mm}^2$,

$\sigma_{2,w,Ed} = 57.92 \text{ N/mm}^2 < f_{2w,d} = 259.20 \text{ N/mm}^2 \Rightarrow U_w = 0.322 < 1$ **ok**

4.5.3. verification result

maximum utilisation: max U = 0.593 < 1 **ok**

5. final result

thermal separation layer [lc 2]: max $U_e = 0.606 < 1$ **ok**
maximum utilisation [lc 2]: max U = 0.674 < 1 **ok**

verification succeeded

6. Regulations

EN 1990, Eurocode 0: Grundlagen der Tragwerksplanung;
Deutsche Fassung EN 1990:2002 + A1:2005 + A1:2005/AC:2010, Ausgabe Dezember 2010
EN 1990/NA, Nationaler Anhang zur EN 1990, Ausgabe Dezember 2010

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
EN 1993-1-1/A1, Ergänzungen zur EN 1993-1-1, Ausgabe Juli 2014
EN 1993-1-1/NA, Nationaler Anhang zur EN 1993-1-1, Ausgabe Dezember 2018

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
EN 1993-1-8/NA, Nationaler Anhang zur EN 1993-1-8, Ausgabe Dezember 2010

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