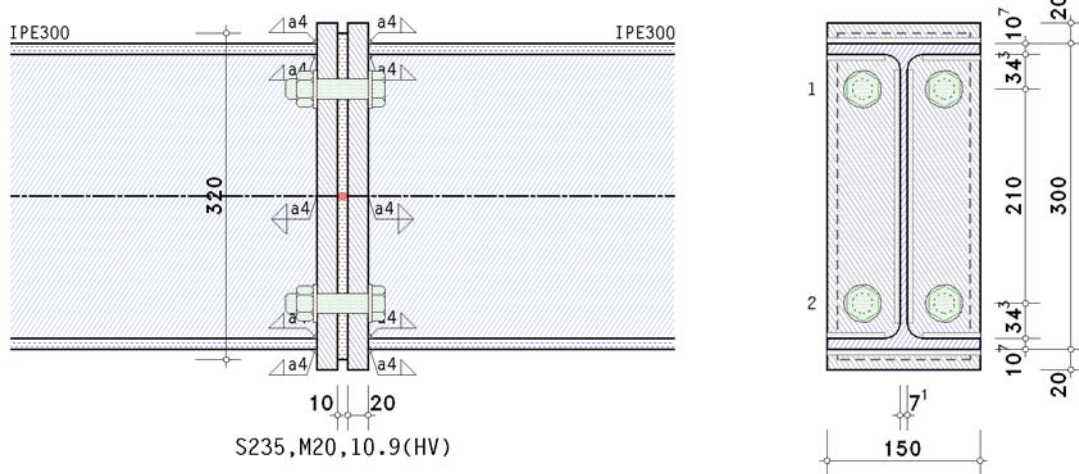
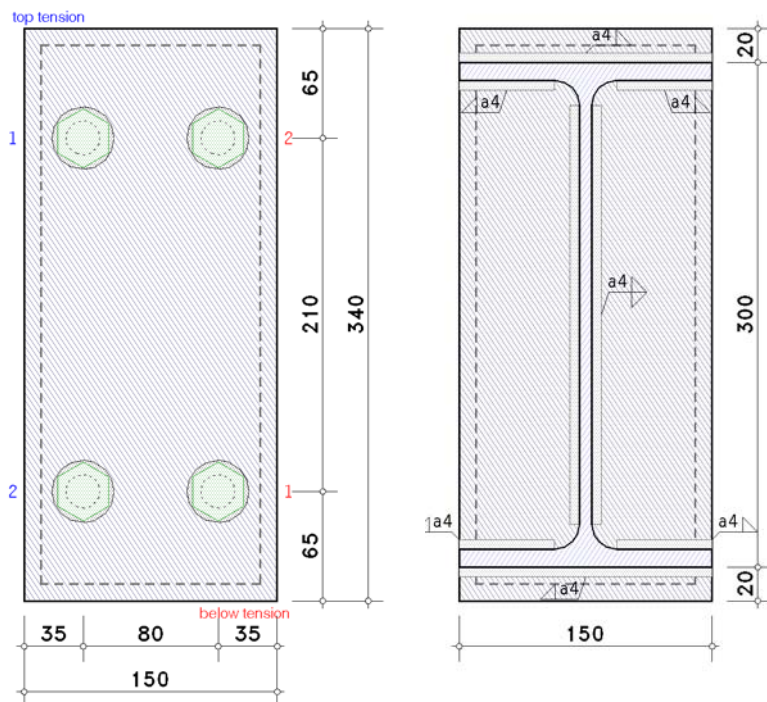


1. input report



details



steel grade

steel grade S235

bolts

bolt class 10.9, bolt size M20

large wrench size (high strength bolt), preloaded (for info: preloading $F_{p,c}^* = 0.7 \cdot f_{yb} \cdot A_s = 154.3$ kN)

shear plane passes through the unthreaded portion of the bolt

beam parameters

section IPE300

verification parameters

bolted end-plate connection

end-plate: thickness $t_p = 20.0$ mm, width $b_p = 150.0$ mm, length $l_p = 340.0$ mm

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

thermal separation layer (according to Kerncompactlager of Calenberg Ingenieure GmbH, approval until 2029):

thickness $t_e = 10.0$ mm, width $b_e = 130.0$ mm, length $l_e = 320.0$ mm

edge distance $\ddot{u}_e = 10.0$ mm, safety factor of material $\gamma_e = 1.00$, preload force per bolt $F_{p,c} = 160.0$ kN

bolts in connection:

2 bolt-rows with 2 bolts

all bolt-rows considered individually

all bolt-rows for shear transfer (rows 1-2)

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) $e_o = 65.0$ mm
 centre distance of the last bolt-row to the bottom edge of the end-plate (end row) $e_u = 65.0$ mm
 centre distance of the bolt-rows from each other $p_{1-2} = 210.0$ 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

Lc 1: Nr.4

$M_{j,b,Ed} = 14.00$ kNm

Lc 2: Nr.5

$M_{j,b,Ed} = 28.00$ kNm

Lc 3: Nr.6

$N_{j,b,Ed} = -28.00$ kN $M_{j,b,Ed} = 28.00$ kNm

partial safety factors for material

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

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

notes

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

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

no verification for cross-sections.

check of data

ok

distances between bolts at end-plate

horizontal: $e_2 = 35.0$ mm $> 1.2 \cdot d_o = 26.4$ mm,

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

horizontal: $p_2 = 80.0$ mm $> 2.4 \cdot d_o = 52.8$ mm,

$p_2 = 80.0$ mm $< \min(14 \cdot t, 200$ mm $) = 200.0$ mm

top-below: $e_1 = 65.0$ mm $> 1.2 \cdot d_o = 26.4$ mm,

$e_1 = 65.0$ mm $< 4 \cdot t + 40$ mm $= 120.0$ mm

top-below: $p_1 = 210.0$ mm $> 2.2 \cdot d_o = 48.4$ mm,

$p_1 = 210.0$ mm $> \min(14 \cdot t, 200$ mm $) = 200.0$ mm !!

top-below: $e_1 = 65.0$ mm $> 1.2 \cdot d_o = 26.4$ mm,

$e_1 = 65.0$ mm $< 4 \cdot t + 40$ mm $= 120.0$ mm

maximum values for spacings and edge distances should be in order to avoid local buckling and to prevent corrosion.

2. table of results

utilization

Lc	U_m	U	U_{tt}	
--	---	---	---	
1	0.274	0.611	0.611	---
2	0.510	0.637	0.637	---
3	0.436	0.652*	0.652	---

U_m : utilization due to bending; U: utilization of the connection; U_{tt} : utilization of thermal separation layer

*) maximum utilization

3. final result

thermal separation layer [Lc 3]: max $U_e = 0.652 < 1$ ok

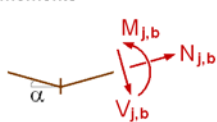
maximum utilization [Lc 3]: max U = 0.652 < 1 ok

verification succeeded

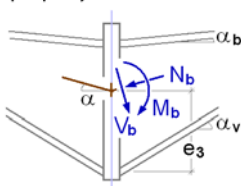
4. Lc 3 (decisive)

4.1. design values

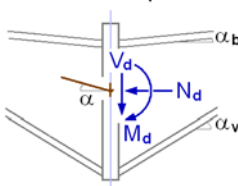
intersectional forces and moments



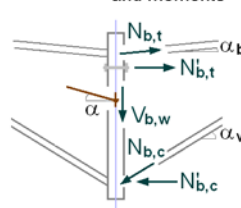
periphery connection-sided



⊥ 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

$N_d = 28.00$ kN, $M_d = -28.00$ kNm

negative internal moment $M_d \Rightarrow$ mirrored model

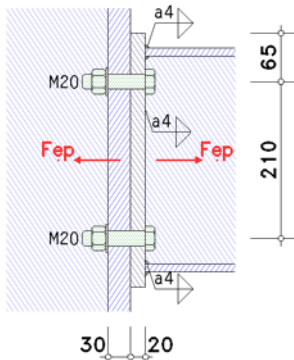
$N_d = 28.00$ kN, $M_d = 28.00$ kNm

partial internal forces and moments referring to the mirrored model

internal forces and moments in the periphery end-plate-beam: $M'_d = M_d - V_d \cdot t_p = 28.00 \text{ kNm}$
 $N_{b,t} = -N_d \cdot z_{bu}/z_b + M'_d/z_b = 82.79 \text{ kN}$, $z_b = 289.3 \text{ mm}$, $z_{bu} = 144.6 \text{ mm}$
 $N_{b,c} = N_d \cdot z_{bo}/z_b + M'_d/z_b = 110.79 \text{ kN}$, $z_b = 289.3 \text{ mm}$, $z_{bo} = 144.6 \text{ mm}$

4.2. basic components

4.2.1. bc 5: end-plate in bending



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

part of end-plate between beam flanges

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

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

row 1

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

in mode 1: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp}) = 188.8 \text{ mm}$, $l_{eff,cp} = 200.6 \text{ mm}$

in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc} = 188.8 \text{ mm}$

tension resistance of the T-stub flange:

in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 4.44 \text{ kNm}$

$F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2} = 176.40 \text{ kN}$, $k_2 = 0.90$

in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 352.80 \text{ kN}$

$L_b = 68.8 \text{ mm} > 46.5 \text{ mm} = L_b^* \Rightarrow$ no prying forces !

mode 1 and 2: complete yielding of the T-stub flange and possibly coincident bolt failure

$F_{T,1-2,Rd} = (2 \cdot M_{pl,1,Rd}) / m = 277.91 \text{ kN}$

mode 3: bolt failure

$F_{T,3,Rd} = \Sigma F_{t,Rd} = 352.80 \text{ kN}$

tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1-2,Rd}, F_{T,3,Rd}) = 277.91 \text{ kN}$

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: $F_{T,w,Rd} = 2^{1/2} \cdot f_{1w,d} \cdot a \cdot l_{eff} = 384.42 \text{ kN}$ ($\geq 277.91 \text{ kN}$, not decisive)

row 2

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

in mode 1: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp}) = 188.8 \text{ mm}$, $l_{eff,cp} = 200.6 \text{ mm}$

in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc} = 188.8 \text{ mm}$

tension resistance of the T-stub flange:

in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 4.44 \text{ kNm}$

$F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2} = 176.40 \text{ kN}$, $k_2 = 0.90$

in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 352.80 \text{ kN}$

$L_b = 68.8 \text{ mm} > 46.5 \text{ mm} = L_b^* \Rightarrow$ no prying forces !

mode 1 and 2: complete yielding of the T-stub flange and possibly coincident bolt failure

$F_{T,1-2,Rd} = (2 \cdot M_{pl,1,Rd}) / m = 277.91 \text{ kN}$

mode 3: bolt failure

$F_{T,3,Rd} = \Sigma F_{t,Rd} = 352.80 \text{ kN}$

tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1-2,Rd}, F_{T,3,Rd}) = 277.91 \text{ kN}$

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: $F_{T,w,Rd} = 2^{1/2} \cdot f_{1w,d} \cdot a \cdot l_{eff} = 384.42 \text{ kN}$ ($\geq 277.91 \text{ kN}$, not decisive)

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

$F_{ep,Rd,1} = 277.91 \text{ kN}$, $l_{eff,1} = 188.8 \text{ mm}$

$F_{ep,Rd,2} = 277.91 \text{ kN}$, $l_{eff,2} = 188.8 \text{ mm}$

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

here: number of bolt-rows $n_b = 2$ ($R1+R2$)

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

in mode 1: $\Sigma l_{eff,1} = \min(\Sigma l_{eff,nc}, \Sigma l_{eff,cp}) = 416.1 \text{ mm}$, $\Sigma l_{eff,cp} = 620.6 \text{ mm}$

in mode 2: $\Sigma l_{eff,2} = \Sigma l_{eff,nc} = 416.1 \text{ mm}$

tension resistance of the T-stub flange:

in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 9.78 \text{ kNm}$

$F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2} = 176.40 \text{ kN}$, $k_2 = 0.90$

in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 705.60 \text{ kN}$

$L_b = 68.8 \text{ mm} > 42.1 \text{ mm} = L_b^* \Rightarrow$ no prying forces !

mode 1 and 2: complete yielding of the T-stub flange and possibly coincident bolt failure

$F_{T,1-2,Rd} = (2 \cdot M_{pl,1,Rd}) / m = 612.58 \text{ kN}$

mode 3: bolt failure

$F_{T,3,Rd} = \Sigma F_{t,Rd} = 705.60 \text{ kN}$

tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1-2,Rd}, F_{T,3,Rd}) = 612.58 \text{ kN}$

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: $F_{T,w,Rd} = 2^{1/2} \cdot f_{1w,d} \cdot a \cdot l_{eff} = 847.35 \text{ kN}$ ($\geq 612.58 \text{ kN}$, not decisive)

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

$F_{t,ep,Rd} = 612.58 \text{ kN}$, $\Sigma l_{eff} = 416.1 \text{ mm}$, 2 rows

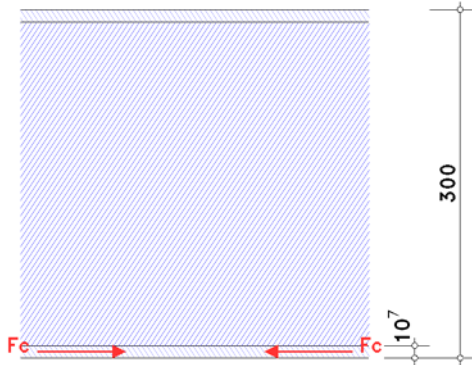
4.2.2. bc 7: beam flange and web in compression

flange below: section class 1

web: section class 1

total: section class 1

section class of the beam: 1



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

resistance $M_{c,Rd} = M_{pl,Rd} = (W_{pl} \cdot f_y) / \gamma_{M0} = 147.65 \text{ kNm}$, $W_{pl} = 628.29 \text{ cm}^3$

resistance of a flange (and web) with compression

$F_{c,f,Rd} = M_{c,Rd} / (h - t_f) = 510.36 \text{ kN}$

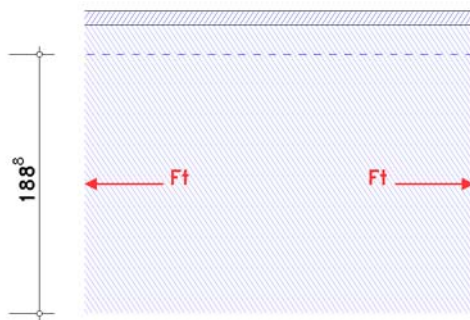
resistance of the upper beam flange:

resistance $M_{c,Rd} = M_{pl,Rd} = (W_{pl} \cdot f_y) / \gamma_{M0} = 147.65 \text{ kNm}$, $W_{pl} = 628.29 \text{ cm}^3$

resistance of a flange (and web) with compression

$F_{c,f,Rd} = M_{c,Rd} / (h - t_f) = 510.36 \text{ kN}$

4.2.3. 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 1

effective width $b_{eff,t,wb} = 188.8 \text{ mm}$ (l_{eff} from bc 5)

resistance of a beam web in tension

$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_{y,wb} / \gamma_{M0} = 315.0 \text{ kN}$

row 2

effective width $b_{eff,t,wb} = 188.8 \text{ mm}$ (l_{eff} from bc 5)

resistance of a beam web in tension

$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_{y,wb} / \gamma_{M0} = 315.0 \text{ kN}$

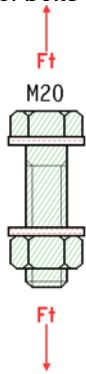
one group of bolt-rows decisive:

effective width $b_{eff,t,wb} = 416.1 \text{ mm}$ (l_{eff} from bc 5)

resistance of a beam web in tension

$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_{y,wb} / \gamma_{M0} = 694.2 \text{ kN}$

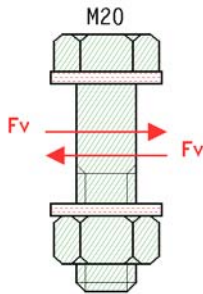
4.2.4. bc 10: bolts in tension



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

tension resistance of one bolt $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2} = 176.40 \text{ kN}$, $k_2 = 0.90$
punching shear load capacity $B_{p,Rd} = (0.6 \cdot \pi \cdot d_m \cdot t_p \cdot f_u) / \gamma_{M2} = 363.88 \text{ kN}$, $t_p = 20.0 \text{ mm}$
tension-/punching shear load capacity for 2 bolts: $\Sigma F_{tp,Rd} = 2 \cdot \min(F_{t,Rd}, B_{p,Rd}) = 352.80 \text{ kN}$

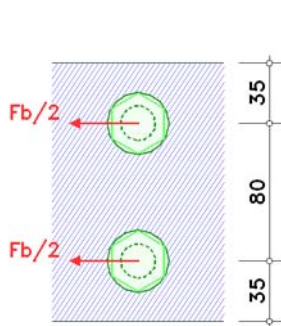
4.2.5. bc 11: bolts in shear



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

shear resistance per shear plane $F_{v,Rd} = \alpha_v \cdot f_{ub} \cdot A / \gamma_{M2} = 150.80 \text{ kN}$, $\alpha_v = 0.60$
shear resistance of 2 bolts (1-shear): $\Sigma F_{v,Rd} = 2 \cdot F_{v,Rd} = 301.59 \text{ kN}$

4.2.6. 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 $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 288.00 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 1.00$

bolt 2: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 288.00 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 1.00$

bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd} = 576.00 \text{ kN}$

row 2

bolt 1: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 288.00 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 1.00$

bolt 2: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 288.00 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 1.00$

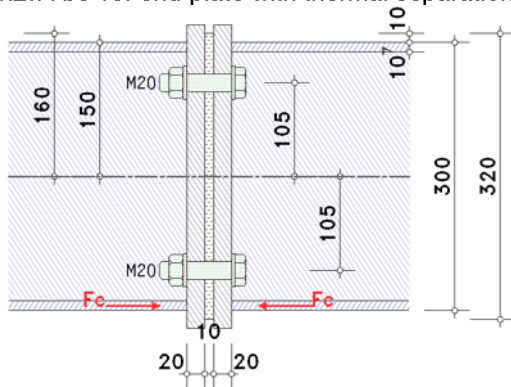
bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd} = 576.00 \text{ kN}$

bearing resistance (2 rows)

$\Sigma F_{b,Rd,1} = 576.00 \text{ kN}$

$\Sigma F_{b,Rd,2} = 576.00 \text{ kN}$

4.2.7. 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,
approval as structural bearings until 2029.

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 joint.

a preload force of the bolts of $F_{p,C} = 160.0$ kN is taken into account in the calculation.

effective length of separation layer $h_m = 259.4$ mm

mean compressive stress $\sigma_m = 19.57$ N/mm²

verification of the separation layer

shape factor $S = 3.594$ for 2 bolts in compression zone

permissible mean compressive stress $\sigma_{md,zul} = 42.00$ N/mm²

utilization of the separation layer $0.652 < 1$ **ok**

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

$$F_{c,e,Rd} = A_{eff} \cdot f_e / \gamma_{Me} = 219.8 \text{ kN}, \quad A_{eff} = 73.26 \text{ cm}^2, \quad f_e = \sigma_{m,zul} = 30.00 \text{ N/mm}^2, \quad \gamma_{Me} = 1.00$$

4.3. connection capacity

4.3.1. moment resistance

distance of tension-bolt-rows from centre of compression: $h_1 = 249.6$ mm, $h_2 = 39.6$ 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: $F_{tr,Rd} = 277.9$ kN

row 2: $F_{tr,Rd} = 277.9$ 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 1: $\Sigma F_{tr,Rd} = 0.0$ kN

bc 5: $\Delta F_{tr,Rd} = F_{t,ep,Rd} - \Sigma F_{tr,Rd} = 612.6$ kN

$F_{tr,Rd} = 277.9 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 277.9 \text{ kN}$

bc 8: $\Delta F_{tr,Rd} = F_{t,wb,Rd} - \Sigma F_{tr,Rd} = 694.2$ kN

$F_{tr,Rd} = 277.9 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 277.9 \text{ kN}$

row 1: $F_{tr,Rd} = 277.9$ kN

row 2: $\Sigma F_{tr,Rd} = 277.9$ kN (row 1)

bc 5: $\Delta F_{tr,Rd} = F_{t,ep,Rd} - \Sigma F_{tr,Rd} = 334.7$ kN

$F_{tr,Rd} = 277.9 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 277.9 \text{ kN}$

bc 8: $\Delta F_{tr,Rd} = F_{t,wb,Rd} - \Sigma F_{tr,Rd} = 416.3$ kN

$F_{tr,Rd} = 277.9 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 277.9 \text{ kN}$

row 2: $F_{tr,Rd} = 277.9$ kN

resistance per bolt-row (tension)

row 1: $F_{tr,Rd} = 277.9$ kN

row 2: $F_{tr,Rd} = 277.9$ kN

$\Sigma F_{tr,Rd}^* = 555.8$ kN

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

decisive basic component: 7, 15

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

bc 7: $\Delta F_{tr,Rd} = F_{c,f,Rd} - \Sigma F_{tr,Rd} = 510.4$ kN

$F_{tr,Rd} = 277.9 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 277.9 \text{ kN}$

bc 15: $\Delta F_{tr,Rd} = F_{c,e,Rd} - \Sigma F_{tr,Rd} = 219.8$ kN

$F_{tr,Rd} = 277.9 \text{ kN} > \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 219.8 \text{ kN}$

row 1: $F_{tr,Rd} = 219.8$ kN

row 2: $\Sigma F_{tr,Rd} = 219.8$ kN (row 1)

bc 7: $\Delta F_{tr,Rd} = F_{c,f,Rd} - \Sigma F_{tr,Rd} = 290.6$ kN

$F_{tr,Rd} = 277.9 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 277.9 \text{ kN}$

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

$F_{tr,Rd} = 277.9 \text{ kN} > \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 0.0 \text{ kN}$

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

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

decisive basic component: 10

row 1: $F_{tx,Rd} = 219.8$ kN, $h_x = 249.6$ mm $\Rightarrow F_{tx,Rd} \leq \lim F_{tx,Rd} = 335.2$ kN, no deduction

row 1: $F_{tr,Rd} = 219.8$ kN

resistance per bolt-row (bending)

row 1: $F_{tr,Rd} = 219.8$ kN

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

$$\Sigma F_{tr,Rd} = 219.8 \text{ kN}$$

potential failure by basic component 5, 15

resistance of flanges

$$\Sigma F_{c,Rd}^* = 439.6 \text{ kN}$$

moment resistance

$$M_{j,Rd} = \Sigma(F_{tr,Rd} \cdot h_r) = 54.9 \text{ kNm}$$

tension resistance

$$N_{j,t,Rd} = \Sigma F_{tr,Rd}^* = 555.8 \text{ kN}$$

compression resistance

$$N_{j,c,Rd} = \Sigma F_{c,Rd}^* = 439.6 \text{ kN}$$

4.3.2. shear/bearing resistance

resistance per bolt-row

row 1: $F_{vr,Rd} = 167.4 \text{ kN}$

row 2: $F_{vr,Rd} = 301.6 \text{ kN}$

$$\Sigma F_{vr,Rd} = 469.0 \text{ kN}$$

shear/bearing resistance

$$V_{j,Rd} = \Sigma F_{vr,Rd} = 469.0 \text{ kN}$$

4.3.3. total

$$M_{j,Rd} = 54.9 \text{ kNm} \quad N_{j,t,Rd} = 555.8 \text{ kN} \quad N_{j,c,Rd} = 439.6 \text{ kN} \quad V_{j,Rd} = 469.0 \text{ kN}$$

4.4. verifications

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

axial force: $N_{b,Ed} = |N_d| = 28.00 \text{ kN} < 5\% \cdot N_{pl,Rd} = 63.23 \text{ kN} \Rightarrow$ moment resistance

internal moment: $M_{Ed} = M_d - N_d \cdot z_{bu} = 23.95 \text{ kNm}, \quad z_{bu} = 144.6 \text{ mm}$

$$M_{Ed}/M_{j,Rd} = 0.436 < 1 \quad \text{ok}$$

4.4.2. verification result

maximum utilization: $\max U = 0.652 < 1 \quad \text{ok}$