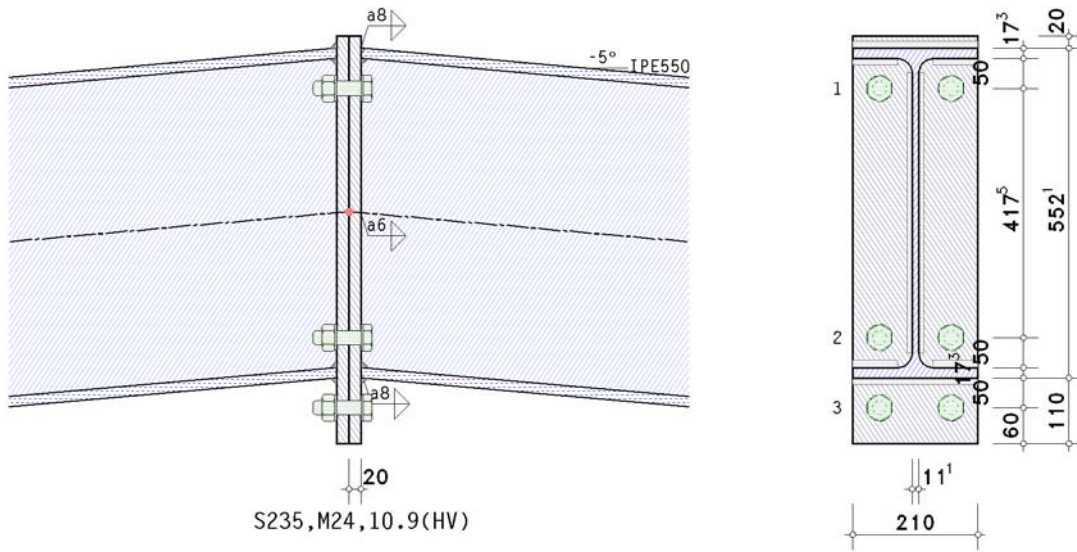
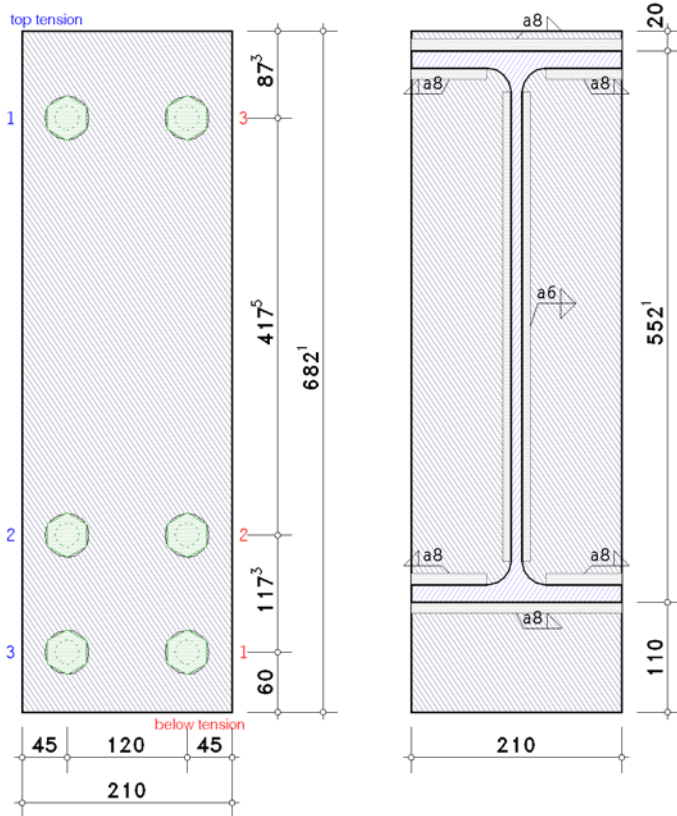


1. input report



details (section A - A)



steel grade

steel grade S235

bolts

bolt class 10.9, bolt size M24

large wrench size (high strength bolt), preloaded (for info: preloading $F_{p,c^*} = 0.7 \cdot f_{yb} \cdot A_s = 222.1$ kN)

shear plane passes through the unthreaded portion of the bolt

beam parameters

section IPE550

slope angle of section about the horizontal axis $\alpha_b = -5.00^\circ$

verification parameters

bolted end-plate connection

thickness $t_p = 20.0$ mm, width $b_p = 210.0$ mm, length $l_p = 682.1$ mm

projections $h_{p,o} = 20.0$ mm, $h_{p,u} = 110.0$ mm

bolts in connection:

3 bolt-rows with 2 bolts

of these 1 bolt-row top in tension (row 1)
 and 2 bolt-rows for shear transfer top (rows 2-3)
 of these 2 bolt-rows below in tension (rows 2-3)
 and 1 bolt-row for shear transfer below (row 3)
 bolt groups generated automatically, considering all groups reg. row 1
 centre distance of the bolts to the lateral edge of the end-plate $e_2 = 45.0$ mm
 centre distance of the first bolt-row to the upper edge of the end-plate (end row) $e_o = 87.3$ mm
 centre distance of the last bolt-row to the bottom edge of the end-plate (end row) $e_u = 60.0$ mm
 centre distance of the bolt-rows from each other $p_{1-2} = 417.5$ mm, $p_{2-3} = 117.3$ mm

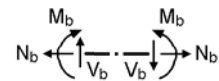
welds at the connection point:

beam flange top: fillet weld, weld thickness $a = 8.0$ mm, angle $\varphi = 95^\circ$
 beam web: fillet weld, weld thickness $a = 6.0$ mm
 beam flange below: fillet weld, weld thickness $a = 8.0$ mm, angle $\varphi = 85^\circ$

internal forces and moments in the intersection point of system axes

Lc 1: Ek 3 (reg. rightr frame corner)

$N_{j,b,Ed} = -50.10$ kN $M_{j,b,Ed} = 308.80$ kNm $V_{j,b,Ed} = 116.70$ kN



partial safety factors for material

resistance of cross-sections $\gamma_{M0} = 1.00$
 resistance of members in stability failure $\gamma_{M1} = 1.10$
 resistance of bolts, welds, plates in bearing $\gamma_{M2} = 1.25$
 prestressing of high strength bolts $\gamma_{M7} = 1.10$

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.
 the welds are not regarded by calculation the T-stub resistance.
 welds are not checked.
 calculation of T-stub-resistance with the standard method.

check of data

ok

distances between bolts at end-plate

horizontal:	$e_2 = 45.0$ mm	$> 1.2 \cdot d_0 = 31.2$ mm,	$e_2 = 45.0$ mm	$< 4 \cdot t + 40$ mm = 120.0 mm
horizontal:	$p_2 = 120.0$ mm	$> 2.4 \cdot d_0 = 62.4$ mm,	$p_2 = 120.0$ mm	$< \min(14 \cdot t, 200$ mm) = 200.0 mm
top-below:	$e_1 = 87.3$ mm	$> 1.2 \cdot d_0 = 31.2$ mm,	$e_1 = 87.3$ mm	$< 4 \cdot t + 40$ mm = 120.0 mm
top-below:	$e_1 = 65.4$ mm	$> 1.2 \cdot d_0 = 31.2$ mm,	$e_1 = 65.4$ mm	$< 4 \cdot t + 40$ mm = 120.0 mm
top-below:	$p_1 = 417.5$ mm	$> 2.2 \cdot d_0 = 57.2$ mm,	$p_1 = 417.5$ mm	$> \min(14 \cdot t, 200$ mm) = 200.0 mm !!
top-below:	$p_1 = 117.3$ mm	$> 2.2 \cdot d_0 = 57.2$ mm,	$p_1 = 117.3$ mm	$< \min(14 \cdot t, 200$ mm) = 200.0 mm
top-below:	$e_1 = 60.0$ mm	$> 1.2 \cdot d_0 = 31.2$ mm,	$e_1 = 60.0$ 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/rotation

Lc	U_m	U_v	U	$S_{j,ini}$	S_j	φ_j
--	---	---	---	MNm/rad	MNm/rad	°
1	0.897	0.258	0.897*	840.6	280.2	0.060

U_m : utilization due to bending; U_v : utilization due to shear/bearing resistance; U: utilization of the connection
 $S_{j,ini}$: initial rotational stiffness; S_j : rotational stiffness; φ_j : rotation
 *) maximum utilization

3. final result

maximum utilization: $\max U = 0.897 < 1$ ok
 minimum rotational stiffness: $\min S_j = 280.2$ MNm/rad, $S_{j,ini} = 840.6$ MNm/rad, $\varphi_j = 0.060^\circ$

verification succeeded

4. 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 1993-1-1:2022, Ausgabe April 2025
 EN 1993-1-1/NA, Nationaler appendix zur EN 1993-1-1, Ausgabe Oktober 2022

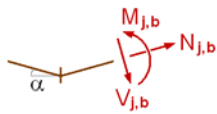
EN 1993-1-8, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -
 Teil 1-8: Bemessung von Anschlüssen;



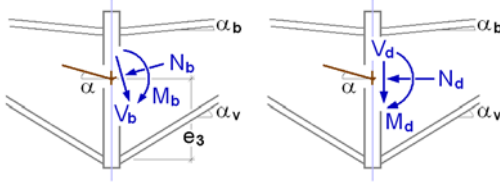
5. Lc 1 (decisive)

5.1. design values

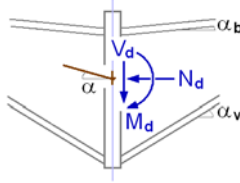
intersectional forces and moments



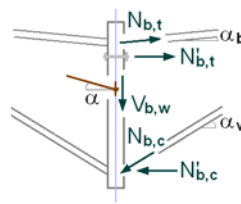
periphery connection-sided



⊥ to connection plane



partial internal forces and moments



slope angle: $\alpha_b = \alpha_v = \alpha = -5.00^\circ$

internal forces and moments perpendicular to the connection planes

periphery beam

$N_d = 60.08 \text{ kN}$, $M_d = -308.80 \text{ kNm}$, $V_d = 111.89 \text{ kN}$

negative internal moment $M_d \Rightarrow$ mirrored model ($\alpha_b = \alpha_v = \alpha = 5.00^\circ$)

$N_d = 60.08 \text{ kN}$, $M_d = 308.80 \text{ kNm}$, $V_d = -111.89 \text{ kN}$

partial internal forces and moments referring to the mirrored model

internal forces and moments in the periphery end-plate-beam: $M'_d = M_d + N_d \cdot t_p \cdot \tan(\alpha) - V_d \cdot t_p = 311.14 \text{ kNm}$

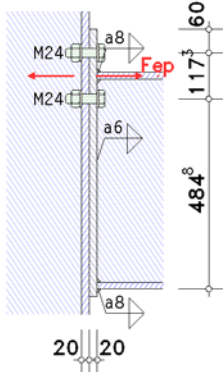
$N_{b,t} = (-N_d \cdot z_{bu} / z_b + M'_d / z_b) / \cos(\alpha_b) = 553.82 \text{ kN}$, $z_b = 534.8 \text{ mm}$, $z_{bu} = 267.4 \text{ mm}$

$N_{b,c} = (N_d \cdot z_{bo} / z_b + M'_d / z_b) / \cos(\alpha_b) = 614.13 \text{ kN}$, $z_b = 534.8 \text{ mm}$, $z_{bo} = 267.4 \text{ mm}$

$V_{b,t} = -N_{b,t} \cdot \sin(\alpha_b) = -48.27 \text{ kN}$, $V_{b,c} = N_{b,c} \cdot \sin(\alpha_v) = 53.53 \text{ kN}$, $V_{b,w} = V_d - V_{b,t} - V_{b,c} = -117.15 \text{ kN}$

5.2. basic components

5.2.1. 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: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp}) = 105.0 \text{ mm}$, $l_{eff,cp} = 218.6 \text{ mm}$

in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc} = 105.0 \text{ mm}$

tension resistance of the T-stub flange:

in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 2.47 \text{ kNm}$

$F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2} = 253.80 \text{ kN}$, $k_2 = 0.90$

in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 507.60 \text{ kN}$

mode 1: complete yielding of the T-stub flange

$F_{T,1,Rd} = (4 \cdot M_{pl,1,Rd}) / m = 241.04 \text{ kN}$

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

$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 335.56 \text{ kN}$

mode 3: bolt failure

$F_{T,3,Rd} = \Sigma F_{t,Rd} = 507.60 \text{ kN}$

tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 241.04 \text{ kN}$

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

$F_{t,ep,Rd,1} = 241.04 \text{ kN}$, $l_{eff,1} = 105.0 \text{ mm}$

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: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp}) = 273.8 \text{ mm}$, $l_{eff,cp} = 299.5 \text{ mm}$

in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc} = 273.8 \text{ mm}$

tension resistance of the T-stub flange:

in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 6.43 \text{ kNm}$

$$F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2} = 253.80 \text{ kN}, \quad k_2 = 0.90$$

$$\text{in mode 3: } \Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 507.60 \text{ kN}$$

mode 1: complete yielding of the T-stub flange

$$F_{T,1,Rd} = (4 \cdot M_{pl,1,Rd}) / m = 539.90 \text{ kN}$$

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

$$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 385.36 \text{ kN}$$

mode 3: bolt failure

$$F_{T,3,Rd} = \Sigma F_{t,Rd} = 507.60 \text{ kN}$$

$$\text{tension resistance of the T-stub flange: } F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 385.36 \text{ kN}$$

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

$$F_{ep,Rd,2} = 385.36 \text{ kN}, \quad l_{eff,2} = 273.8 \text{ mm}$$

5.2.2. bc 7: beam flange and web in compression

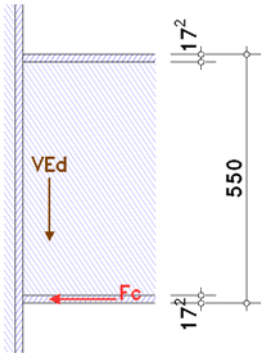
flange below: section class 1

web: section class 1

total: section class 1

section class of the beam: 1

taking into account the moment-shear force-interaction $V_{Ed} = 116.7 \text{ kN}$



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

stress due to bending with shear force: $V_{Ed} = 116.7 \text{ kN} \leq 490.8 \text{ kN} = 0.5 \cdot V_{pl,Rd}/2 \Rightarrow$ no effect

$$\text{resistance } M_{c,Rd} = M_{pl,Rd} = (W_{pl} \cdot f_y) / \gamma_{M0} = 654.87 \text{ kNm}, \quad W_{pl} = 2786.67 \text{ cm}^3$$

resistance of flange and web in compression

$$F_{c,f,Rd} = M_{c,Rd} / (h - t_f) = 1229.11 \text{ kN}$$

referring to aspect plane $F_{c,f,Rd} \cdot \cos(\alpha_b) = 1224.43 \text{ kN}$

resistance of the upper beam flange:

stress due to bending with shear force: $V_{Ed} = 116.7 \text{ kN} \leq 490.8 \text{ kN} = 0.5 \cdot V_{pl,Rd}/2 \Rightarrow$ no effect

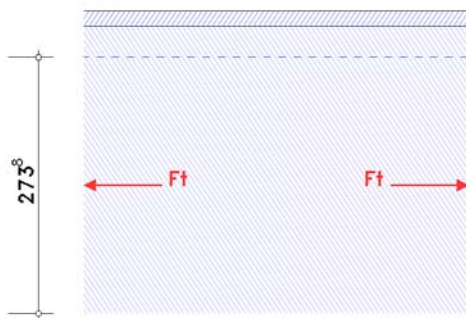
$$\text{resistance } M_{c,Rd} = M_{pl,Rd} = (W_{pl} \cdot f_y) / \gamma_{M0} = 654.87 \text{ kNm}, \quad W_{pl} = 2786.67 \text{ cm}^3$$

resistance of flange and web in compression

$$F_{c,f,Rd} = M_{c,Rd} / (h - t_f) = 1229.11 \text{ kN}$$

referring to aspect plane $F_{c,f,Rd} \cdot \cos(\alpha_b) = 1224.43 \text{ kN}$

5.2.3. 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 2

$$\text{effective width } b_{eff,t,wb} = 273.8 \text{ mm} \quad (l_{eff} \text{ from bc 5})$$

resistance of a beam web in tension

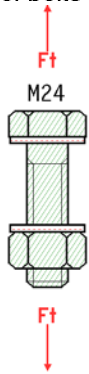
$$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_{y,wb} / \gamma_{M0} = 714.08 \text{ kN}$$

resistance of a beam web in tension (per bolt-row)

$$F_{t,wb,Rd,2} = 714.08 \text{ kN}, \quad b_{eff,t,wb} = 273.8 \text{ mm} \quad (\text{s. bc 5})$$

resistances of a beam web in tension (per bolt group):

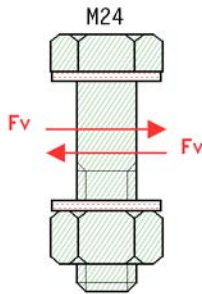
5.2.4. bc 10: bolts in tension



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

tension resistance of one bolt $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2} = 253.80 \text{ kN}$, $k_2 = 0.90$
 punching shear load capacity of a bolt $B_{p,Rd} = (0.6 \cdot \pi \cdot d_m \cdot t_p \cdot f_u) / \gamma_{M2} = 467.95 \text{ kN}$, $t_p = 20.0 \text{ mm}$
 tension-/punching shear load capacity for 2 bolts: $\Sigma F_{tp,Rd} = 2 \cdot \min(F_{t,Rd}, B_{p,Rd}) = 507.60 \text{ kN}$

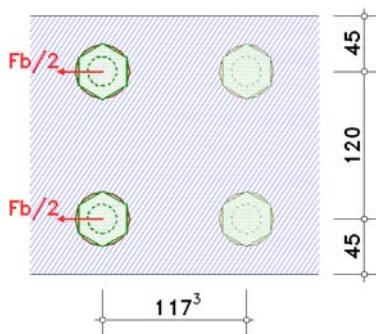
5.2.5. bc 11: bolts in shear



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

shear resistance $F_{v,Rd} = \alpha_v \cdot f_{ub} \cdot A / \gamma_{M2} = 217.15 \text{ kN}$, $\alpha_v = 0.60$
 shear resistance of 2 bolts (1-shear): $\Sigma F_{v,Rd} = 2 \cdot F_{v,Rd} = 434.29 \text{ kN}$

5.2.6. bc 12: plate with bearing resistance



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

row 3

bolt 1: bearing resistance $F_{b,Rd} = (k_m \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 414.72 \text{ kN}$, $k_m = 1.00$, $\alpha_b = 3.00$
 bolt 2: bearing resistance $F_{b,Rd} = (k_m \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 414.72 \text{ kN}$, $k_m = 1.00$, $\alpha_b = 3.00$
 bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd} = 737.28 \text{ kN}$

5.3. connection capacity

5.3.1. moment resistance

distance of tension-bolt-rows from centre of compression: $h_1 = 593.5 \text{ mm}$, $h_2 = 476.2 \text{ mm}$

resistances acc. to EC 3-1-8, B.3.2.2(6) for bolt-rows considered individually

decisive basic components: 5, 8

row 1: $F_{tr,Rd} = 241.0 \text{ kN}$

row 2: $F_{tr,Rd} = 385.4 \text{ kN}$

resistance per bolt-row (tension)

row 1: $F_{tr,Rd} = 241.0 \text{ kN}$

row 2: $F_{tr,Rd} = 385.4 \text{ kN}$

$\Sigma F_{tr,Rd}^* = 626.4 \text{ kN}$

deductions acc. to EC 3-1-8, B.3.2.2(7)

decisive basic component: 7

row 1: $F_{tr,Rd} = 241.0$ kN
row 2: $F_{tr,Rd} = 385.4$ kN

check acc. to EC 3-1-8, B.3.2.2(9)

decisive basic component: 10
row 1: $F_{tr,Rd} = 241.0$ kN

resistance per bolt-row (bending)

row 1: $F_{tr,Rd} = 241.0$ kN
row 2: $F_{tr,Rd} = 385.4$ kN
 $\Sigma F_{tr,Rd} = 626.4$ kN

potential failure by basic component 5

resistance of flanges (compression)

$\Sigma F_{c,Rd}^* = 2448.9$ kN

moment resistance

$M_{j,Rd} = \Sigma(F_{tr,Rd} \cdot h_r) = 326.5$ kNm

tension resistance

$N_{j,t,Rd} = \Sigma F_{tr,Rd}^* = 626.4$ kN

compression resistance

$N_{j,c,Rd} = \Sigma F_{c,Rd}^* = 2448.9$ kN

5.3.2. shear/bearing resistance

resistance per bolt-row

decisive basic components: 11, 12
row 3: $F_{vr,Rd} = 434.3$ kN

deductions depending on tension force (at full utilization of moment resistance)

decisive basic component: 10
row 3: $F_{vr,Rd} = 434.3$ kN

resistance per bolt-row (shear/bearing resistance)

row 3: $F_{vr,Rd} = 434.3$ kN
 $\Sigma F_{vr,Rd} = 434.3$ kN

shear/bearing resistance

$V_{j,Rd} = \Sigma F_{vr,Rd} = 434.3$ kN

5.3.3. total

$M_{j,Rd} = 326.5$ kNm $N_{j,t,Rd} = 626.4$ kN $N_{j,c,Rd} = 2448.9$ kN $V_{j,Rd} = 434.3$ kN

5.4. verifications

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

axial force: $N_{b,Ed} = |N_d \cdot \cos(\alpha) + V_d \cdot \sin(\alpha)| = 50.10$ kN < $5\% \cdot N_{pl,Rd} = 158.52$ kN \Rightarrow moment resistance
internal moment: $M_{Ed} = M_d - N_d \cdot z_{bu} = 292.84$ kNm, $z_{bu} = 265.7$ mm
shear force: $V_{Ed} = |V_d| = 111.89$ kN

$M_{Ed}/M_{j,Rd} = 0.897 < 1$ ok

5.4.2. verification result

maximum utilization: $\max U = 0.897 < 1$ ok

5.5. rotational stiffness

stiffness coefficients

equivalent stiffness coefficient for 2 tension-bolt-rows:

1: $k_s = 11.01$ mm $\Rightarrow k_{eff,1} = 1 / \Sigma(1/k_{i,1}) = 5.505$ mm

2: $k_s = 18.20$ mm $\Rightarrow k_{eff,2} = 1 / \Sigma(1/k_{i,2}) = 9.102$ mm

equivalent internal lever arm $z_{eq} = \Sigma(k_{eff,r} \cdot h_r^2) / \Sigma(k_{eff,r} \cdot h_r) = 526.59$ mm

äquivalenter stiffness coefficient $k_{eq} = \Sigma(k_{eff,r} \cdot h_r) / z_{eq} = 14.435$ mm

rotational stiffness

initial rotational stiffness: $S_{j,ini} = (E \cdot z^2) / \Sigma(1/k_i) = 840594.8$ kNm/rad, $z = z_{eq} = 526.6$ mm, $\Sigma(1/k_i) = 0.069$ mm⁻¹

$|N_{b,Ed}| = 50.10$ kN < $5\% \cdot N_{pl,Rd} = 158.52$ kN ok

$|M_{j,Ed}| = 292.84$ kNm > $2/3 M_{j,Rd} = 217.70$ kNm $\Rightarrow \mu = 3.0$

rotational stiffness: $S_{j,Rd} = S_{j,ini} / \mu = 280198.3$ kNm/rad

rotation: $\varphi_{j,Ed} = M_{j,Ed} / S_{j,Rd} = 0.060^\circ$