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

1. input report

![Diagram of the splice connection with dimensions and bolt details.]

**steel grade**
steel grade S235

**bolts**
bolt class 10.9, bolt size M30
large wrench size (high strength bolt), preloaded (for info: preloading \( F_{pb,c^*} = 0.7 \cdot f_{yb} \cdot A_s = 353.4 \text{ kN} \))
shear plane passes through the unthreaded portion of the bolt

**beam parameters**
section HE700B

**verification parameters**
boiled end-plate connection:
thickness \( t_b = 45.0 \text{ mm} \), width \( b_p = 300.0 \text{ mm} \), length \( l_p = 855.0 \text{ mm} \)
projections \( h_{p,o} = 130.0 \text{ mm} \), \( h_{p,u} = 25.0 \text{ mm} \)
bolts in connection:
5 bolt-rows with 2 bolts
all bolt-rows considered individually
all bolt-rows for shear transfer (rows 1-5)
bolt groups generated automatically, considering all groups bzgl. row 1
verification with der Component method: MNV-interaction acc. to Cerfontaine (in Jaspar/Weynand)
centre distance of the bolts to the lateral edge of the end-plate $e_2 = 70.0$ mm
centre distance of the first bolt-row to the upper edge of the end-plate (end row) $e_0 = 65.0$ mm
centre distance of the last bolt-row to the bottom edge of the end-plate (end row) $e_6 = 125.0$ mm
centre distance of the bolt-rows from each other $p_{1-2} = 165.0$ mm, $p_{2-3} = 100.0$ mm, $p_{3-4} = 100.0$ mm
$p_{4-5} = 300.0$ mm
welds at the connection point:
beam flange top: fillet weld, weld thickness $a = 15.5$ mm
beam web: fillet weld, weld thickness $a = 8.0$ mm
beam flange bottom: fillet weld, weld thickness $a = 15.0$ mm

**Internal forces and moments in the intersection point of system axes**

Lk 1: $M_{b,b,Ed} = -1500.00$ kNm, $V_{b,b,Ed} = 900.00$ kN
Lk 2: $M_{b,b,Ed} = 600.00$ kNm, $V_{b,b,Ed} = 900.00$ kN
Lk 3: $N_{b,b,Ed} = 2000.00$ kN
Lk 4: $N_{b,b,Ed} = -5700.00$ kN

**Partial safety factors for material**
resistance of cross-sections $\gamma_M = 1.00$
resistance of members in stability failure $\gamma_M = 1.10$
resistance of bolts, welds, plates in bearing $\gamma_M = 1.25$
prestressing of high strength bolts $\gamma_M = 1.10$

**Check of data**

**Utilizations**

<table>
<thead>
<tr>
<th>Lk</th>
<th>$U_{sb,b}$</th>
<th>$U_{NNV}$</th>
<th>$U_{EP}$</th>
<th>$U_{sb}$</th>
<th>$U$</th>
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<td>0.953</td>
<td>0.465</td>
<td>0.977</td>
<td>0.977*</td>
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<td>0.799</td>
<td>---</td>
<td>0.309</td>
<td>0.799</td>
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<tr>
<td>4</td>
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<td>0.973</td>
<td>---</td>
<td>0.880</td>
<td>0.973</td>
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</table>

$U_{sb,b}$: stress utilization at the beam; $U_{NNV}$: utilization due to MNV-interaction; $U_{sb}$: utilization due to shear in end-plate

$U_{sb}$: utilization due to weld; $U$: utilization of the connection

*) maximum utilization

**2. Final result**

**Utilization/rotation of the connection**

<table>
<thead>
<tr>
<th>Lk</th>
<th>$S_{J,Int}$</th>
<th>$S_J$</th>
<th>$\varphi_J$</th>
<th>$U_J$</th>
<th>$\Sigma H$</th>
<th>$\Sigma V$</th>
<th>$\Sigma M$</th>
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<td>642.6</td>
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<tr>
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<td>0.0</td>
<td>0</td>
<td>0.973</td>
<td>700.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

$S_{J,Int}$: initial rotational stiffness; $S_J$: rotational stiffness; $\varphi_J$: rotation; $U_J$: utilization of the connection; tolerances of equilibrium 1 kN / 1 kNm

*) maximum utilization

**Maximum utilization [Lk 1]:**

$\max U = 0.997 < 1 \text{ ok}$

**Verification succeeded**

**3. Detailed edition of Lk 1 (decisive)**

Notes
connection is verified due to EC 3-1-8 regardless of preloading.
however, connections may be constructed with prestressed high strength bolts.
the welds are not regarded by calculation the T-stub resistance.
simplified calculation of shear force resistance takes all bolt-rows into account.

**3.1. Design values**
knotenschnittgrößen intersecional forces and moments

periphery connection zur connection plane

periphery connection-sided \( \perp \) to connection plane

partial internal forces and moments

slope angle: \( \alpha_b = \alpha_v = \alpha = 0^\circ \)

internal forces and moments perpendicular to the connection planes

periphery beam

\( M_d = 1500.00 \, \text{kNm} \), \( V_d = 900.00 \, \text{kN} \)

partial internal forces and moments

internal forces and moments in the periphery end-plate-beam: \( M_{d, \text{ep}} = 1459.50 \, \text{kNm} \)

\( N_{b,t} = -M_d \frac{z_{bu}}{z_b} + M_d \frac{z_{b}}{z_{b}} = 2184.88 \, \text{kN} \), \( z_{bu} = 688.0 \, \text{mm} \), \( z_b = 334.0 \, \text{mm} \)

\( N_{b,c} = N_{d} \frac{z_{bu}}{z_b} + M_d \frac{z_{b}}{z_{b}} = 2184.88 \, \text{kN} \), \( z_{bu} = 688.0 \, \text{mm} \), \( z_b = 334.0 \, \text{mm} \)

3.2. resistance of cross-section

plastic cross-sectional check for \( M_y = -1459.50 \, \text{kNm} \), \( V_z = 900.00 \, \text{kN} \)

valid normal/shear stress:

\( \text{zul} \sigma_{zd} = 23.50 \, \text{kN/cm}^2 \), \( \text{zul} \sigma_{zd} = 13.57 \, \text{kN/cm}^2 \)

top flange: resistance forces \( N_{\text{max},0} = 2256.00 \, \text{kN} \), \( N_{\text{min},0} = -2256.00 \, \text{kN} \)

bottom flange: resistance forces \( N_{\text{max},u} = 2256.00 \, \text{kN} \), \( N_{\text{min},u} = -2256.00 \, \text{kN} \)

web: shear force \( V_s = 900.00 \, \text{kN} \), shear stress \( \tau_s = 7.93 \, \text{kN/cm}^2 \) \( \Rightarrow U_s = 0.584 \)

resistance forces \( N_{\text{max},s} = 2166.04 \, \text{kN} \), \( N_{\text{min},s} = -2166.04 \, \text{kN} \)

main bending: moment \( M_y = -1459.50 \, \text{kNm} \), resistance moments \( M_{y, \text{max}} = 1668.74 \, \text{kNm} \), \( M_{y, \text{min}} = -1668.74 \, \text{kNm} \) \( \Rightarrow U_{My} = 0.781 \)

Overall (possibly due to load increase): max \( U = 0.807 < 1 \) \text{ok}

utilization: resistance \( U_{s} = 0.807 < 1 \) \text{ok}, \text{cratio} \( U_{c,t} = 0.233 < 1 \) \text{ok}

3.3. basic components

3.3.1. Gk 5: end-plate in bending

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

extended part of the 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: \( \Delta_{\text{eff},1} = \text{left},_1 = \min(\text{left},_{nc}, \text{left},_{cp}) = 150.0 \, \text{mm} \), \( \text{left},_{cp} = 289.1 \, \text{mm} \)
- in mode 2: \( \Delta_{\text{eff},2} = \text{left},_2 = \text{left},_{nc} = 150.0 \, \text{mm} \)

tension resistance of the T-stub flange:

- in mode 1 + 2: \( M_{p1,\text{RD}} = (0.25 \times \text{eff},_{TF} \times f_{y}) / \gamma_{M0} = 16.33 \, \text{kNm} \)
- in mode 3: \( \Delta_{\text{Fr1,rd}} = 2 \, n_b \, \text{Fr},_1 \text{rd} = 807.84 \, \text{kN} \)

mode 1: complete yielding of the T-stub flange

\( \text{Fr},_1 \text{rd} = \left[ (\sigma_{n} \times 2 \times f_{w}) \times M_{p1,1} \text{rd} \right] / (2 \times n_b \times \omega_{w} \times (m+n)) = 1762.68 \, \text{kN} \)

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

\( \text{Fr},_2 \text{rd} = (2 \times M_{p1,2} \times \text{rd} + n \times \Delta_{\text{Fr1,rd}} / (m+n)) = 754.56 \, \text{kN} \)

mode 3: bolt failure

\( \text{Fr},_3 \text{rd} = \Delta_{\text{Fr1,rd}} = 807.84 \, \text{kN} \)

friction stress of the T-stub flange: \( \text{Fr},_1 \text{rd} = \min(\text{Fr},_1 \text{rd}, \text{Fr},_2 \text{rd}, \text{Fr},_3 \text{rd}) = 754.56 \, \text{kN} \)

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

\( \text{Fr},_1 \text{rd} = 754.56 \, \text{kN} \), \( \text{left},_1 = 150.0 \, \text{mm} \)

part of end-plate between beam flanges

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

- number of bolt-rows \( n_b = 1 \)
- row 2

- in mode 1: \( \Delta_{\text{eff},1} = \text{left},_1 = \min(\text{left},_{nc}, \text{left},_{cp}) = 384.8 \, \text{mm} \), \( \text{left},_{cp} = 392.4 \, \text{mm} \)
- in mode 2: \( \Delta_{\text{eff},2} = \text{left},_2 = \text{left},_{nc} = 384.8 \, \text{mm} \)
tension resistance of the T-stub flange:
in mode 1+2: \( M_{pl,rd} = (0.25 \, \Delta_{left} t^2 f_y) / \gamma_{M0} = 41.89 \, \text{kNm} \)
in mode 3: \( \Sigma F_{t,rd} = 2 \, n_b \, F_{t,rd} = 807.84 \, \text{kN} \)

mode 1: complete yielding of the T-stub flange
\( F_{t,1,rd} = (8 - n - 2 \, \omega) \, M_{pl,1,rd} / (2 \, m - n \, \omega \, (m + n)) = 3235.01 \, \text{kN} \)
mode 2: bolt failure simultaneously with yielding of the T-stub flange
\( F_{t,2,rd} = (2 \, M_{pl,2,rd} + n \, \Sigma F_{t,rd}) / (m + n) = 1059.47 \, \text{kN} \)
mode 3: bolt failure
\( F_{t,3,rd} = \Sigma F_{t,rd} = 807.84 \, \text{kN} \)
tension resistance of the T-stub flange: \( F_{t,rd} = \min(F_{t,1,rd}, F_{t,2,rd}, F_{t,3,rd}) = 807.84 \, \text{kN} \)

row 3
effective length of the T-stub flange (end-plate):
in mode 1: \( \Delta_{left,1} = \Delta_{left,1} = \min(\Delta_{left,nc}, \Delta_{left,cp}) = 337.3 \, \text{mm}, \ \Delta_{left,cp} = 392.4 \, \text{mm} \)
in mode 2: \( \Delta_{left,2} = \Delta_{left,2} = \Delta_{left,nc} = 337.3 \, \text{mm} \)
tension resistance of the T-stub flange:
in mode 1+2: \( M_{pl,rd} = (0.25 \, \Delta_{left} t^2 f_y) / \gamma_{M0} = 36.71 \, \text{kNm} \)
in mode 3: \( \Sigma F_{t,rd} = 2 \, n_b \, F_{t,rd} = 807.84 \, \text{kN} \)
mode 1: complete yielding of the T-stub flange
\( F_{t,1,rd} = (8 - n - 2 \, \omega) \, M_{pl,1,rd} / (2 \, m - n \, \omega \, (m + n)) = 2835.29 \, \text{kN} \)
mode 2: bolt failure simultaneously with yielding of the T-stub flange
\( F_{t,2,rd} = (2 \, M_{pl,2,rd} + n \, \Sigma F_{t,rd}) / (m + n) = 981.31 \, \text{kN} \)
mode 3: bolt failure
\( F_{t,3,rd} = \Sigma F_{t,rd} = 807.84 \, \text{kN} \)
tension resistance of the T-stub flange: \( F_{t,rd} = \min(F_{t,1,rd}, F_{t,2,rd}, F_{t,3,rd}) = 807.84 \, \text{kN} \)

row 4
effective length of the T-stub flange (end-plate):
in mode 1: \( \Delta_{left,1} = \Delta_{left,1} = \min(\Delta_{left,nc}, \Delta_{left,cp}) = 337.3 \, \text{mm}, \ \Delta_{left,cp} = 392.4 \, \text{mm} \)
in mode 2: \( \Delta_{left,2} = \Delta_{left,2} = \Delta_{left,nc} = 337.3 \, \text{mm} \)
tension resistance of the T-stub flange:
in mode 1+2: \( M_{pl,rd} = (0.25 \, \Delta_{left} t^2 f_y) / \gamma_{M0} = 36.71 \, \text{kNm} \)
in mode 3: \( \Sigma F_{t,rd} = 2 \, n_b \, F_{t,rd} = 807.84 \, \text{kN} \)
mode 1: complete yielding of the T-stub flange
\( F_{t,1,rd} = (8 - n - 2 \, \omega) \, M_{pl,1,rd} / (2 \, m - n \, \omega \, (m + n)) = 2835.29 \, \text{kN} \)
mode 2: bolt failure simultaneously with yielding of the T-stub flange
\( F_{t,2,rd} = (2 \, M_{pl,2,rd} + n \, \Sigma F_{t,rd}) / (m + n) = 981.31 \, \text{kN} \)
mode 3: bolt failure
\( F_{t,3,rd} = \Sigma F_{t,rd} = 807.84 \, \text{kN} \)
tension resistance of the T-stub flange: \( F_{t,rd} = \min(F_{t,1,rd}, F_{t,2,rd}, F_{t,3,rd}) = 807.84 \, \text{kN} \)

row 5
effective length of the T-stub flange (end-plate):
in mode 1: \( \Delta_{left,1} = \Delta_{left,1} = \min(\Delta_{left,nc}, \Delta_{left,cp}) = 384.8 \, \text{mm}, \ \Delta_{left,cp} = 392.4 \, \text{mm} \)
in mode 2: \( \Delta_{left,2} = \Delta_{left,2} = \Delta_{left,nc} = 384.8 \, \text{mm} \)
tension resistance of the T-stub flange:
in mode 1+2: \( M_{pl,rd} = (0.25 \, \Delta_{left} t^2 f_y) / \gamma_{M0} = 41.89 \, \text{kNm} \)
in mode 3: \( \Sigma F_{t,rd} = 2 \, n_b \, F_{t,rd} = 807.84 \, \text{kN} \)
mode 1: complete yielding of the T-stub flange
\( F_{t,1,rd} = (8 - n - 2 \, \omega) \, M_{pl,1,rd} / (2 \, m - n \, \omega \, (m + n)) = 3235.01 \, \text{kN} \)
mode 2: bolt failure simultaneously with yielding of the T-stub flange
\( F_{t,2,rd} = (2 \, M_{pl,2,rd} + n \, \Sigma F_{t,rd}) / (m + n) = 1059.47 \, \text{kN} \)
mode 3: bolt failure
\( F_{t,3,rd} = \Sigma F_{t,rd} = 807.84 \, \text{kN} \)
tension resistance of the T-stub flange: \( F_{t,rd} = \min(F_{t,1,rd}, F_{t,2,rd}, F_{t,3,rd}) = 807.84 \, \text{kN} \)

resistances and effective lengths of end-plate in bending (per bolt-row):
\( F_{ep,rd,2} = 807.84 \, \text{kN}, \ \Delta_{left,2} = 384.8 \, \text{mm} \)
\( F_{ep,rd,3} = 807.84 \, \text{kN}, \ \Delta_{left,3} = 337.3 \, \text{mm} \)
\( F_{ep,rd,4} = 807.84 \, \text{kN}, \ \Delta_{left,4} = 337.3 \, \text{mm} \)
\( F_{ep,rd,5} = 807.84 \, \text{kN}, \ \Delta_{left,5} = 384.8 \, \text{mm} \)

equivalent T-stub flange (group of bolts 1):
here: number of bolt-rows \( n_b = 2 \)
effective length of the T-stub flange (end-plate):
in mode 1: \( \Delta_{left,1} = \min(\Delta_{left,nc}, \Delta_{left,cp}) = 484.8 \, \text{mm}, \ \Delta_{left,cp} = 592.4 \, \text{mm} \)
in mode 2: \( \Delta_{left,2} = \Delta_{left,2} = 484.8 \, \text{mm} \)
tension resistance of the T-stub flange:
in mode 1+2: \( M_{pl,rd} = (0.25 \, \Delta_{left} t^2 f_y) / \gamma_{M0} = 52.77 \, \text{kNm} \)
in mode 3: \( \Sigma F_{t,rd} = 2 \, n_b \, F_{t,rd} = 1615.68 \, \text{kN} \)
mode 1: complete yielding of the T-stub flange
\( F_{t,1,rd} = (8 - n - 2 \, \omega) \, M_{pl,1,rd} / (2 \, m - n \, \omega \, (m + n)) = 4075.80 \, \text{kN} \)
mode 2: bolt failure simultaneously with yielding of the T-stub flange
\( F_{t,2,rd} = (2 \, M_{pl,2,rd} + n \, \Sigma F_{t,rd}) / (m + n) = 1650.77 \, \text{kN} \)
mode 3: bolt failure
\( F_{t,3,rd} = \Sigma F_{t,rd} = 1615.68 \, \text{kN} \)
tension resistance of the T-stub flange: \( F_{t,rd} = \min(F_{t,1,rd}, F_{t,2,rd}, F_{t,3,rd}) = 1615.68 \, \text{kN} \)
equivalent T-stub flange (group of bolts 2):
here: number of bolt-rows \( n_r = 3 \)
effective length of the T-stub flange (end-plate):
in mode 1: \( \xi_{\text{eff},1} = \min(\xi_{\text{eff},\text{nc}}, \xi_{\text{eff},\text{cp}}) = 584.8 \text{ mm}, \ \xi_{\text{eff},\text{cp}} = 792.4 \text{ mm} \)
in mode 2: \( \xi_{\text{eff},2} = \xi_{\text{eff},\text{nc}} = 584.8 \text{ mm} \)
tension resistance of the T-stub flange:
in mode 1: \( M_{\text{T},Rd} = (0.25 \xi_{\text{eff}} h^2 f_y) / \gamma_M = 63.66 \text{ kNm} \)
in mode 3: \( \Sigma F_{T,Rd} = 2 n_b F_{T,Rd} = 2423.52 \text{ kN} \)
mode 1: complete yielding of the T-stub flange
\( F_{T,1,Rd} = \left( (8 \pi n - 2 \alpha_w) M_{\text{pl},1,Rd} / (2 \pi n - \alpha_w (m+n)) \right) = 4916.19 \text{ kN} \)
mode 2: bolt failure simultaneously with yielding of the T-stub flange
\( F_{T,2,Rd} = (2 M_{\text{pl},2,Rd} + n \Sigma F_{T,Rd}) / (m+n) = 2242.07 \text{ kN} \)
mode 3: bolt failure
\( F_{T,3,Rd} = \Sigma F_{T,Rd} = 2423.52 \text{ kN} \)
tension resistance of the T-stub flange: \( F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 2242.07 \text{ kN} \)

equivalent T-stub flange (group of bolts 3):
here: number of bolt-rows \( n_r = 4 \)
distance between bolt-rows too big (\( p_{4,3} = 100.0 \text{ mm}, p_{4,5} = 300.0 \text{ mm} \)) \( \Rightarrow \) group closed
resistances and effective lengths of end-plate in bending (per bolt group):
\( F_{\text{EP},Rd,2,3} = 1615.68 \text{ kN}, \ \xi_{\text{eff}} = 484.8 \text{ mm}, 2 \text{ rows} \)
\( F_{\text{EP},Rd,2,4} = 2242.07 \text{ kN}, \ \xi_{\text{eff}} = 584.8 \text{ mm}, 3 \text{ rows} \)

3.3.2. Gk 7: beam flange and web in compression

flange bottom: section class for \( \alpha/(c-t) = 3.58: 1 \)
web: section class for \( \alpha = 0.50 \) and \( \alpha/(c-t) = 34.24: 1 \)
section class of beam: 1

taking into account the moment-shear force-interaction \( V_{\text{Ed}} = 900.0 \text{ kN} \)

stress due to bending with shear force: \( V_{\text{Ed}} = 900.0 \text{ kN} \leq 930.1 \text{ kN} = V_{\text{pl},Rd} \) \( \Rightarrow \) no effect
resistance \( M_{\text{c,Rd}} = M_{\text{pl},Rd} = (W_{\text{pl},f_y}) / \gamma_M = 1956.84 \text{ kNm}, \ W_{\text{pl}} = 8327.00 \text{ cm}^2 \)
resistance of a flange (and web) with compression
\( F_{c,t,Rd} = M_{\text{c,Rd}} / (h - t) = 2929.41 \text{ kN} \)

resistance of upper beam flange:
stress due to bending with shear force: \( V_{\text{Ed}} = 900.0 \text{ kN} \leq 930.1 \text{ kN} = V_{\text{pl},Rd} \) \( \Rightarrow \) no effect
resistance \( M_{\text{c,Rd}} = M_{\text{pl},Rd} = (W_{\text{pl},f_y}) / \gamma_M = 1956.84 \text{ kNm}, \ W_{\text{pl}} = 8327.00 \text{ cm}^2 \)
resistance of a flange (and web) with compression
\( F_{c,t,Rd} = M_{\text{c,Rd}} / (h - t) = 2929.41 \text{ kN} \)

3.3.3. Gk 8: beam web in tension

row 2

effective width \( b_{\text{eff},t,\text{wb}} = 384.8 \text{ mm} \) (left from bc 5)
resistance of a beam web in tension
\( F_{t,\text{wb},Rd} = b_{\text{eff},t,\text{wb}} f_{\text{wb}} f_y / \gamma_M = 1537.5 \text{ kN} \)

row 3

Only the essential sizes are sketched to scale.
The connection geometry is only hinted.
effective width $b_{eff,t,wb} = 337.3 \text{ mm (left from bc 5)}$
resistance of a beam web in tension
$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_{y,wb} / \gamma_{M0} = 1347.5 \text{ kN}$

row 4

effective width $b_{eff,t,wb} = 337.3 \text{ mm (left from bc 5)}$
resistance of a beam web in tension
$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_{y,wb} / \gamma_{M0} = 1347.5 \text{ kN}$

row 5

effective width $b_{eff,t,wb} = 384.8 \text{ mm (left from bc 5)}$
resistance of a beam web in tension
$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_{y,wb} / \gamma_{M0} = 1537.5 \text{ kN}$

group of bolt-rows, group 1:
effective width $b_{eff,t,wb} = 484.8 \text{ mm (left from bc 5)}$
resistance of a beam web in tension
$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_{y,wb} / \gamma_{M0} = 1937.0 \text{ kN}$

group of bolt-rows, group 2:
effective width $b_{eff,t,wb} = 584.8 \text{ mm (left from bc 5)}$
resistance of a beam web in tension
$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_{y,wb} / \gamma_{M0} = 2336.5 \text{ kN}$

3.3.4. Gk 10: bolts in tension

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

3.3.5. Gk 11: bolts in shear

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

3.3.6. Gk 12: plate with bearing resistance

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

3.4.1. moment resistance

distance of tension-bolt-rows from centre of compression:
\[ h_1 = 749.0 \text{ mm}, \quad h_2 = 584.0 \text{ mm}, \quad h_3 = 484.0 \text{ mm}, \quad h_4 = 384.0 \text{ mm}, \quad h_5 = 84.0 \text{ mm} \]

resistance per bolt-row (MNV-interaction)

row 1: \[ F_{tr,Rd} = 754.6 \text{ kN} \]
row 2: \[ F_{tr,Rd} = 807.8 \text{ kN} \]
row 3: \[ F_{tr,Rd} = 669.5 \text{ kN} \]
row 4: \[ F_{tr,Rd} = 531.2 \text{ kN} \]
row 5: \[ F_{tr,Rd} = 116.2 \text{ kN} \]

resistance of flanges (MNV-interaction)

bottom: \[ F_{c,Rd} = 2879.3 \text{ kN} \]

moment resistance (MNV-interaction)
\[ M_{l,Rd} = \sum (F_{tr,Rd} \cdot h_i) = 1574.7 \text{ kNm} \]

shear force resistance (MNV-interaction)
\[ V_{l,Rd} = 944.8 \text{ kN} \]

3.4.2. shear resistance

shear resistance of end plate

end-plate: \[ V_{sp,Rd} = 3250.97 \text{ kN} \]
welds: \[ F_{w,Rd} = 1935.46 \text{ kN} \]
shear resistance of end plate: \[ V_{sp,Rd} = F_{w,Rd} = 1935.46 \text{ kN} \]

3.5. verifications

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

\[ U_{MNV} = 0.953 < 1 \quad \text{ok} \]
\[ V_{Es}/V_{sp,Rd} = 0.485 < 1 \quad \text{ok} \]

3.5.2. verification of welds at beam section

weld 1: beam flange in tension outer
welds 2,3: beam flange in tension inner
welds 4,6: 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:
\[ M_{y,Ed} = -1500.00 \text{ kNm}, \quad V_{z,Ed} = 900.00 \text{ kN} \]

cross-sectional properties referring to centroid of the line cross-section:
\[ \Delta A_w = 254.47 \text{ cm}^2, \quad A_{w,z} = 93.12 \text{ cm}^2, \quad I_{w} = 222.2 \text{ cm} \]
\[ I_{w,y} = 208971.47 \text{ cm}^4, \quad I_{w,z} = 13701.31 \text{ cm}^4, \quad W_{w,t} = 490.20 \text{ cm}^2, \quad \Delta z_{w} = -3.5 \text{ mm} \]

distribution of internal forces and moments:
weld 1: \[ N_w = 1156.56 \text{ kN} \]
weld 2: \[ N_w = 400.65 \text{ kN} \]
weld 3: siehe weld 2
weld 4: \[ N_w = -11.68 \text{ kN}, \quad M_{y,w} = -94.34 \text{ kNm} \]
weld 5: siehe weld 4
weld 6: \[ N_w = -396.35 \text{ kN} \]
weld 7: siehe weld 6
weld 8: \[ N_w = -1141.82 \text{ kN} \]
from conventional distribution of shear force: \[ V_{z,w} = 900.00 \text{ kN} \]

verifications in weld edges:
weld 1, pt. 0: \[ \sigma_{w,x} = 248.72 \text{ N/mm}^2 \]
\[ \Rightarrow U_w = 0.977 < 1 \quad \text{ok} \]
weld 2, pt. 0: \[ \sigma_{w,x} = 225.75 \text{ N/mm}^2 \]
\[ \Rightarrow U_w = 0.887 < 1 \quad \text{ok} \]
weld 4, pt. 0: \[ \sigma_{w,x} = 206.37 \text{ N/mm}^2, \quad \tau_{w,z} = 96.65 \text{ N/mm}^2 \]
\[ \Rightarrow U_w = 0.935 < 1 \quad \text{ok} \]
weld 6, pt. 1: \[ \sigma_{w,x} = -211.39 \text{ N/mm}^2, \quad \tau_{w,z} = 96.65 \text{ N/mm}^2 \]
\[ \Rightarrow U_w = 0.952 < 1 \quad \text{ok} \]
weld 8, pt. 0: \[ \sigma_{w,x} = -230.77 \text{ N/mm}^2 \]
\[ \Rightarrow U_w = 0.907 < 1 \quad \text{ok} \]

Result:
weld 8, pt. 0: \[ \sigma_{w,x} = -253.74 \text{ N/mm}^2 \]
Max: \[ \sigma_{1,w,Ed} = 35.88 \text{ kN/cm}^2 < f_{y,w,d} = 36.00 \text{ kN/cm}^2 \]
\[ \sigma_{2,w,Ed} = 17.94 \text{ kN/cm}^2 < f_{y,Ed} = 25.02 \text{ kN/cm}^2 \Rightarrow U_w = 0.997 < 1 \quad \text{ok} \]

3.5.3. verification result
maximum utilization: \[ \max U = 0.997 < 1 \quad \text{ok} \]

3.6. rotational stiffness

stiffness coefficients

equivalent stiffness coefficient for 5 tension-bolt-rows:
1: \[ k_s = 115.05 \text{ mm}, \quad k_{0} = 7.40 \text{ mm} \]
\[ \Rightarrow \text{keff,1} = 1 / \Sigma(1/k_i) = 6.554 \text{ mm} \]
2: \[ k_s = 129.60 \text{ mm}, \quad k_{0} = 7.40 \text{ mm} \]
\[ \Rightarrow \text{keff,2} = 1 / \Sigma(1/k_i) = 6.639 \text{ mm} \]
3: \[ k_s = 115.58 \text{ mm}, \quad k_{0} = 7.40 \text{ mm} \]
\[ \Rightarrow \text{keff,3} = 1 / \Sigma(1/k_i) = 6.544 \text{ mm} \]
4: \[ k_s = 115.58 \text{ mm}, \quad k_{0} = 7.40 \text{ mm} \]
\[ \Rightarrow \text{keff,4} = 1 / \Sigma(1/k_i) = 6.544 \text{ mm} \]
5: \[ k_s = 129.60 \text{ mm}, \quad k_{0} = 7.40 \text{ mm} \]
\[ \Rightarrow \text{keff,5} = 1 / \Sigma(1/k_i) = 6.639 \text{ mm} \]

\[ k_{eq} = (\text{keff,r}h) / z_{eq} = 26.600 \text{ mm}, \quad z_{eq} = (\Sigma(\text{keff,r}h^2)) / (\Sigma(\text{keff,r}h)) = 564.8 \text{ mm} \]

rotational stiffness

initial rotational stiffness: \[ S_{i,ini} = (Ez^2) / \Sigma(1/k_i) = 1782059.9 \text{ kNm/rad} \]
\[ z = z_{eq} = 564.8 \text{ mm}, \quad \Sigma(1/k_i) = 0.038 \text{ mm}^{-1} \]

rotational stiffness: \[ S_{i,Rd} = S_{i,ini} / \mu = 1782059.9 \text{ kNm/rad}, \quad \mu = 1 \]

rotation: \[ \phi_{L,Ed} = M_{l,Ed} / S_{i,Rd} = 0.048^\circ \]