1. input report

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

![Diagram of a beam splice](image)

**details (section A - A)**

**steel grade**
steel grade S235

**bolts**
bolt class 10.9, bolt size M20
large wrench size (high strength bolt), preloaded (for info: preloading $F_{p,c} = 0.7f_{yb}A_s = 154.3 \text{ kN}$)
shear plane passes through the unthreaded portion of the bolt

**beam parameters**
section HE280A

**verification parameters**
boiled end-plate connection:
thickness $t_p = 20.0 \text{ mm}$, width $b_p = 280.0 \text{ mm}$, length $l_p = 360.0 \text{ mm}$
projections $h_{p,o} = 70.0 \text{ mm}$, $h_{p,u} = 20.0 \text{ mm}$
bolts in connection:
3 bolt-rows with 2 bolts
of these 2 bolt-rows top in tension (rows 1-2)
and 1 bolt-row for shear transfer top (row 3)
of these 1 bolt-row bottom in tension (row 3)
and 1 bolt-row for shear transfer bottom (row 3)
centre distance of the bolts to the lateral edge of the end-plate $e_2 = 70.0 \text{ mm}$
centre distance of the first bolt-row to the upper edge of the end-plate (end row) $e_o = 30.0 \text{ mm}$
centre distance of the last bolt-row to the bottom edge of the end-plate (end row) $e_u = 75.0 \text{ mm}$
centre distance of the bolt-rows from each other $p_{1,2} = 95.0 \text{ mm}$, $p_{2,3} = 160.0 \text{ mm}$
welds at the connection point:
beam flange top: fillet weld, weld thickness $a = 7.0 \text{ mm}$
beam web: fillet weld, weld thickness $a = 4.0 \text{ mm}$
beam flange bottom: fillet weld, weld thickness $a = 7.0 \text{ mm}$
internal forces and moments in the intersection point of system axes
Lk 1: \( M_{j,b,Ed} = -145.00 \text{ kNm} \quad V_{j,b,Ed} = 120.00 \text{ kN} \)

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 \( \gamma_{M2} = 1.25 \)
presstressing of high strength bolts \( \gamma_{M7} = 1.10 \)

check of data
ok
distances between bolt-rows at end-plate
horizontal: \( e_2 = 70.0 \text{ mm} < 2 \cdot d_0 = 26.4 \text{ mm} \), \( e_2 = 70.0 \text{ mm} < 4 \cdot t = 40 \text{ mm} = 120.0 \text{ mm} \)
horizontal: \( p_2 = 140.0 \text{ mm} > 2.4 \cdot d_0 = 52.8 \text{ mm} \)
vertical: \( e_1 = 30.0 \text{ mm} > 1.2 \cdot d_0 = 26.4 \text{ mm} \)
vertical: \( p_1 = 95.0 \text{ mm} > 2.2 \cdot d_0 = 48.4 \text{ mm} \)
vertical: \( e_1 = 75.0 \text{ mm} > 1.2 \cdot d_0 = 26.4 \text{ mm} \)

notes
no verification for cross-sections.

2. Lk 1
notes
connection is verified due to EC 3-1-8 regardless of preloading.
however, connections may be constructed with prestressed high strength bolts.
calculation of T-stub-resistance with the standard method.

2.1. design values
Knotenschnittgrößen
interseccional forces and moments
Knotenschnittgrößen
periphery connection⊥ zur connection plane
partial internal forces and moments
periphery connection⊥ to connection plane

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

internal forces and moments perpendicular to the connection planes
periphery beam
\( M_d = 145.00 \text{ kNm} \quad V_d = 120.00 \text{ kN} \)

partial internal forces and moments
internal forces and moments in the periphery end-plate-beam: \( M_d' = M_d - V_d t_{ep} = 142.60 \text{ kNm} \)
\( N_b,t = -N_d z_{bu}/z_b + M_d'/z_b = 554.86 \text{ kN} \quad z_b = 257.0 \text{ mm} \quad z_{bu} = 128.5 \text{ mm} \)
\( N_{b,c} = N_d z_{bo}/z_b + M_d'/z_b = 554.86 \text{ kN} \quad z_b = 257.0 \text{ mm} \quad z_{bo} = 128.5 \text{ mm} \)

2.2. basic components
2.2.1. Gk 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: \( \Sigma_{eff,1} = \text{left,1} = \min(\text{left,nc}, \text{left,cp}) = 140.0 \text{ mm} \quad \text{left,cp} = 201.6 \text{ mm} \)
in mode 2: \( \Sigma_{eff,2} = \text{left,2} = \text{left,nc} = 140.0 \text{ mm} \)
tension resistance of the T-stub flange:
in mode 1+2: \( M_{\text{pl,rd}} = (0.25 \cdot \Sigma_{eff} t_2^2 t_{2y}) / \gamma_{M0} = 3.29 \text{ kNm} \)
in mode 3: \( \Sigma_{\text{Fl,rd}} = 2 \cdot n_b \cdot \text{Fl,rd} = 352.80 \text{ kN} \)
mode 1: complete yielding of the T-stub flange
\[ F_{T,1,Rd} = \left( 4 M_{pl,1,Rd} / m \right) = 410.22 \text{kN} \]
mode 2: bolt failure simultaneously with yielding of the T-stub flange
\[ F_{T,2,Rd} = \left( 2 M_{pl,2,Rd} + n \Sigma F_{Rd} \right) / (m+n) = 276.48 \text{kN} \]
mode 3: bolt failure
\[ F_{T,3,Rd} = \Sigma F_{Rd} = 352.80 \text{kN} \]

tension resistance of the T-stub flange: \[ F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 276.48 \text{kN} \]
shear strength: \[ f_{w,d} = \left( f_w / (\gamma_M) \right) = 207.8 \text{N/mm}^2 \]
tension resistance of welds: \[ F_{w,Rd} = 2 f_{w,d} a \cdot \text{left} = 407.38 \text{kN} \] (not decisive)
résistance and effective length of end-plate in bending (projection)
\[ F_{e,Rd,1} = 276.48 \text{kN}, \text{left,1} = 140.0 \text{mm} \]

depart or end-plate between beam flangles

<table>
<thead>
<tr>
<th>equivalent T-stub flange (each individual bolt-row):</th>
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<tbody>
<tr>
<td>here: number of bolt-rows ( n_0 = 1 )</td>
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<table>
<thead>
<tr>
<th>row 2</th>
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</thead>
<tbody>
<tr>
<td>effective length of the T-stub flange (end-plate):</td>
</tr>
<tr>
<td>in mode 1: [ \Sigma \text{left,1} = \text{left,1} = \min(\text{left,nc, left,cp}) = 386.3 \text{mm}, \text{left,cp} = 386.3 \text{mm} ]</td>
</tr>
<tr>
<td>in mode 2: [ \Sigma \text{left,2} = \text{left,2} = \text{left,nc} = 427.4 \text{mm} ]</td>
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</table>

tension resistance of the T-stub flange: |
| in mode 1: \[ M_{pl,1,Rd} = \left( 0.25 \Sigma \text{left,1} h_1^2 f_y / \gamma_M \right) = 9.08 \text{kNm} \] |
| in mode 2: \[ M_{pl,2,Rd} = \left( 0.25 \Sigma \text{left,2} h_1^2 f_y / \gamma_M \right) = 10.04 \text{kNm} \] |
| in mode 3: \[ \Sigma F_{Rd} = 2 n_0 F_{pl,Rd} = 352.80 \text{kN} \] |
| mode 1: complete yielding of the T-stub flange |
\[ F_{T,1,Rd} = \left( 4 M_{pl,1,Rd} / m \right) = 590.62 \text{kN} \]
mode 2: bolt failure simultaneously with yielding of the T-stub flange
\[ F_{T,2,Rd} = \left( 2 M_{pl,2,Rd} + n \Sigma F_{Rd} \right) / (m+n) = 340.64 \text{kN} \]
mode 3: bolt failure
\[ F_{T,3,Rd} = \Sigma F_{Rd} = 352.80 \text{kN} \]
tension resistance of the T-stub flange: \[ F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 340.64 \text{kN} \]
shear strength: \[ f_{w,d} = \left( f_w / (\gamma_M) \right) = 207.8 \text{N/mm}^2 \]
tension resistance of welds: \[ F_{w,Rd} = 2 f_{w,d} a \cdot \text{left} = 642.25 \text{kN} \] (not decisive)
résistances et effective lengths of end-plate in bending (per bolt-row):
\[ F_{e,Rd,2} = 340.64 \text{kN}, \text{left,2} = 386.3 \text{mm} \]

2.2.2. Gk 7: beam flange and web in compression

<table>
<thead>
<tr>
<th>flange bottom: section class for ( f'(c-t) = 8.62: 1 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>web: section class for ( \alpha = 0.50 ) and ( f'(c-t) = 24.50: 1 )</td>
</tr>
<tr>
<td>section class of beam: 1</td>
</tr>
<tr>
<td>taking into account the moment-shear force-connection ( V_{Ed} = 120.0 \text{kN} )</td>
</tr>
</tbody>
</table>

![Diagram of beam flange and web](image)

<table>
<thead>
<tr>
<th>Only the essential sizes are sketched to scale. The connection geometry is only hinted.</th>
</tr>
</thead>
</table>

stress due to bending with shear force: \[ V_{Ed} = 120.0 \text{kN} \leq 215.3 \text{kN} = V_{pl,Rd} / 2 \Rightarrow \text{no effect} \]
résistance of a flange (and web) with compression
\[ F_{c,t,Rd} = M_{c,Rd} / (h-t) = 1016.81 \text{kN} \]

<table>
<thead>
<tr>
<th>resistance of upper beam flange:</th>
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| stress due to bending with shear force: \[ V_{Ed} = 120.0 \text{kN} \leq 215.3 \text{kN} = V_{pl,Rd} / 2 \Rightarrow \text{no effect} \]
résistance of a flange (and web) with compression
\[ F_{c,t,Rd} = M_{c,Rd} / (h-t) = 1016.81 \text{kN} \]

2.2.3. Gk 8: beam web in tension
2.2.4. Gk 10: bolts in tension

\[ F_{t,Rd} = \left( k_2 \cdot f_{ub} \cdot A_{s} \right) / \gamma_{M2} = 176.40 \text{ kN}, \quad k_2 = 0.90 \]

2.2.5. Gk 11: bolts in shear

\[ F_{v,Rd} = \alpha_{v} \cdot f_{ub} \cdot A / \gamma_{M2} = 150.80 \text{ kN}, \quad \alpha_{v} = 0.60 \]

2.2.6. Gk 12: plate with bearing resistance

\[ F_{b,Rd} = \left( k_1 \cdot \alpha_{b} \cdot f_{ub} \cdot d \cdot t \right) / \gamma_{M2} = 288.00 \text{ kN}, \quad k_1 = 2.50, \quad \alpha_{b} = 1.00 \]
2.3. connection capacity
2.3.1. moment resistance
distance of tension-bolt-rows from centre of compression: \( h_1 = 303.5 \text{ mm} \), \( h_2 = 208.5 \text{ mm} \)

resistance per bolt-row
row 1: \( F_{tr,Rd} = 276.5 \text{ kN} \)
row 2: \( F_{tr,Rd} = 340.6 \text{ kN} \)
\( \Sigma F_{tr,Rd} = 617.1 \text{ kN} \)
potential failure by basic component 5

resistance of flanges
\( \Sigma F_{c,Rd} = 2033.6 \text{ kN} \)

moment resistance
\( M_{j,Rd} = \Sigma (F_{tr,Rd} h) = 154.9 \text{ kNmm} \)
tension resistance
\( N_{j,t,Rd} = \Sigma F_{tr,Rd} = 617.1 \text{ kN} \)
compression resistance
\( N_{j,c,Rd} = \Sigma F_{c,Rd} = 2033.6 \text{ kN} \)

2.3.2. shear/bearing resistance

resistance per bolt-row
row 3: \( F_{vr,Rd} = 301.6 \text{ kN} \)
\( \Sigma F_{vr,Rd} = 301.6 \text{ kN} \)

shear/bearing resistance
\( V_{j,Rd} = \Sigma F_{vr,Rd} = 301.6 \text{ kN} \)

2.3.3. total
\( M_{j,Rd} = 154.9 \text{ kNmm} \)
\( N_{j,t,Rd} = 617.1 \text{ kN} \)
\( N_{j,c,Rd} = 2033.6 \text{ kN} \)
\( V_{j,Rd} = 301.6 \text{ kN} \)

2.4. verifications

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

internal moment: \( M_{Ed} = M_{d} = 145.00 \text{ kNmm} \)
shear force: \( V_{Ed} = |V_{d}| = 120.00 \text{ kN} \)

\( M_{Ed}/M_{j,Rd} = 0.936 < 1 \text{ ok} \)
\( V_{Ed}/V_{j,Rd} = 0.398 < 1 \text{ ok} \)

2.4.2. verification of welds at beam section

weld 1: beam flange in tension outer
weld 8: beam flange in compression outer
calculation section:

weld 1: \( a_w = 7.0 \text{ mm} \), \( l_w = 280.0 \text{ mm} \)
weld 2: \( a_w = 7.0 \text{ mm} \), \( l_w = 112.0 \text{ mm} \)
weld 3: siehe weld 2
weld 4: \( a_w = 4.0 \text{ mm} \), \( l_w = 196.0 \text{ mm} \)
weld 5: siehe weld 4
weld 6: \( a_w = 7.0 \text{ mm} \), \( l_w = 112.0 \text{ mm} \)
weld 7: siehe weld 6
weld 8: \( a_w = 7.0 \text{ mm} \), \( l_w = 280.0 \text{ mm} \)

design values referring to centroid of the section:
\( M_{y,Ed} = -145.00 \text{ kNmm} \), \( V_{z,Ed} = 120.00 \text{ kN} \)
cross-sectional properties referring to centroid of the line cross-section:
\( \Sigma A_w = 86.24 \text{ cm}^2 \), \( A_{w,x} = 15.68 \text{ cm}^2 \), \( \Sigma I_w = 140.0 \text{ cm}^4 \)
\( I_{w,y} = 12913.79 \text{ cm}^4 \), \( I_{w,z} = 5104.15 \text{ cm}^4 \), \( W_{w,t} = 77.81 \text{ cm}^3 \), \( \Delta z_w = 0.0 \text{ mm} \)
distribution of internal forces and moments:
weld 1: \( N_w = 311.58 \text{ kN} \)
weld 2: \( N_w = 112.63 \text{ kN} \)
weld 3: siehe weld 2
weld 4: \( M_{y,w} = -2.96 \text{ kNm} \)
weld 5: siehe weld 4
weld 6: \( N_w = -112.63 \text{ kN} \)
weld 7: siehe weld 6
weld 8: \( N_w = -311.58 \text{ kN} \)

from conventional distribution of shear force: \( V_{z,w} = 120.00 \text{ kN} \)

verifications in weld edges:

weld 1, pt. 0: \( \sigma_{w,x} = 158.97 \text{ N/mm}^2 \) \( \Rightarrow U_w = 0.765 < 1 \text{ ok} \)
weld 2, pt. 0: \( \sigma_{w,x} = 143.66 \text{ N/mm}^2 \) \( \Rightarrow U_w = 0.691 < 1 \text{ ok} \)
weld 4, pt. 0: \( \sigma_{w,x} = 115.40 \text{ N/mm}^2 \) \( \tau_{w,z} = 76.53 \text{ N/mm}^2 \) \( \Rightarrow U_w = 0.666 < 1 \text{ ok} \)
weld 4, pt. 1: \( \sigma_{w,x} = -115.40 \text{ N/mm}^2 \) \( \tau_{w,z} = 76.53 \text{ N/mm}^2 \) \( \Rightarrow U_w = 0.666 < 1 \text{ ok} \)
weld 6, pt. 0: \( \sigma_{w,x} = -143.66 \text{ N/mm}^2 \) \( \Rightarrow U_w = 0.691 < 1 \text{ ok} \)
weld 8, pt. 0: \( \sigma_{w,x} = -158.97 \text{ N/mm}^2 \) \( \Rightarrow U_w = 0.765 < 1 \text{ ok} \)

Result:

weld 8, pt. 0: \( \sigma_{w,x} = -158.97 \text{ N/mm}^2 \)
Max: \( F_{w,Ed} = 11.13 \text{ kN/cm} < F_{w,Rd} = 14.55 \text{ kN/cm} \) \( \Rightarrow U_w = 0.765 < 1 \text{ ok} \)

2.4.3. verification result

maximum utilization: \( \max U = 0.936 < 1 \text{ ok} \)

3. final result

utilization of the connection

<table>
<thead>
<tr>
<th>Lk</th>
<th>( U_j )</th>
<th>( \Sigma H )</th>
<th>( \Sigma V )</th>
<th>( \Sigma M )</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>0.936*</td>
<td>0.00</td>
<td>120.00</td>
<td>145.00</td>
</tr>
</tbody>
</table>

\( U_j \): utilization of the connection; \( \Sigma H, \Sigma V, \Sigma M \): tolerances of equilibrium 1 kN / 1 kNm

*) maximum utilization

maximum utilization: \( \max U = 0.936 < 1 \text{ ok} \)

verification succeeded