1. input report

**steel grade**

steel grade S235

**bolts**

bolt class 8.8, bolt size M16, normal wrench size

shear plane passes through the unthreaded portion of the bolt

**beam parameters**

section IPE240

slope angle of section about the horizontal axis $\alpha_b = -7.40^\circ$

**verification parameters**

bolted end-plate connection:

thickness $t_p = 20.0$ mm, width $b_p = 120.0$ mm, length $l_p = 327.0$ mm

projections $h_{p,o} = 10.0$ mm, $h_{p,u} = 75.0$ mm
bolts in connection:
3 bolt-rows with 2 bolts
d of these 1 bolt-row top in tension (row 1)
   and 3 bolt-rows for shear transfer top (rows 1-3)
d of these 2 bolt-rows bottom in tension (rows 2-3)
   and 1 bolt-row for shear transfer bottom (row 3)
centre distance of the bolts to the lateral edge of the end-plate \( e_2 = 26.0 \text{ mm} \)
centre distance of the first bolt-row to the upper edge of the end-plate (end row) \( e_0 = 60.0 \text{ mm} \)
centre distance of the last bolt-row to the bottom edge of the end-plate (end row) \( e_4 = 35.0 \text{ mm} \)
centre distance of the bolt-rows from each other \( p_{1.2} = 142.0 \text{ mm}, \ p_{2.3} = 90.0 \text{ mm} \)
welds at the connection point:
   beam flange top: fillet weld, weld thickness \( a = 5.0 \text{ mm}, \ \text{angle} \ \varphi = 97^\circ \)
   beam web: fillet weld, weld thickness \( a = 3.0 \text{ mm} \)
   beam flange bottom: fillet weld, weld thickness \( a = 5.0 \text{ mm}, \ \text{angle} \ \varphi = 83^\circ \)

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

\[ \begin{align*}
Lk 1: \quad N_{j,b,Ed} &= -24.30 \text{ kN} \quad M_{j,b,Ed} = 55.00 \text{ kNm} \quad V_{j,b,Ed} = 3.20 \text{ kN}
\end{align*} \]

**Partial safety factors for material**
resistance of cross-sections \( \gamma_{MO} = 1.00 \)
resistance of members in stability failure \( \gamma_{M1} = 1.10 \)
resistance of bolts, welds, plates in bearing \( \gamma_{M2} = 1.25 \)
presstress of high strength bolts \( \gamma_{M7} = 1.10 \)

**Check of data**

OK

distances between bolt-rows at end-plate

<table>
<thead>
<tr>
<th></th>
<th>( e_2 = 26.0 \text{ mm} )</th>
<th>( e_2 = 26.0 \text{ mm} &lt; 41 + 40 \text{ mm} = 120.0 \text{ mm} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>horizontal:</td>
<td>( p_2 = 68.0 \text{ mm} )</td>
<td>( p_2 = 68.0 \text{ mm} &lt; \min(141, 200) \text{ mm} = 200.0 \text{ mm} )</td>
</tr>
<tr>
<td>vertical:</td>
<td>( e_1 = 60.0 \text{ mm} )</td>
<td>( e_1 = 60.0 \text{ mm} &lt; 41 + 40 \text{ mm} = 120.0 \text{ mm} )</td>
</tr>
<tr>
<td>vertical:</td>
<td>( p_1 = 142.0 \text{ mm} )</td>
<td>( p_1 = 142.0 \text{ mm} &lt; \min(141, 200) \text{ mm} = 200.0 \text{ mm} )</td>
</tr>
<tr>
<td>vertical:</td>
<td>( e_1 = 35.0 \text{ mm} )</td>
<td>( e_1 = 35.0 \text{ mm} &lt; 41 + 40 \text{ mm} = 120.0 \text{ mm} )</td>
</tr>
</tbody>
</table>

**Notes**

there are several basic components selected which perhaps do not ensure the total loading capacity of the joint.
no verification for cross-sections.
no verification for welds within the connection.

2. Lk 1

**2.1. Design values**

Knotenschnittgrößen periphery connection\( \perp \) zur connection plane partial internal forces and moments

\[ \begin{align*}
N_{b,t} &= 24.51 \text{ kN}, \quad M_{b,t} = -55.00 \text{ kNm}, \quad V_{b,t} = 0.04 \text{ kN}
\end{align*} \]

negative internal moment \( M_d \Rightarrow \text{mirrored model (} \alpha_{b} = \alpha_{t} = \alpha = 7.40^\circ \)\)

\[ \begin{align*}
N_{b,t} &= 24.51 \text{ kN}, \quad M_{b,t} = 55.00 \text{ kNm}, \quad V_{b,t} = -0.04 \text{ kN}
\end{align*} \]

**Partial internal forces and moments referring to the mirrored model**

internal forces and moments in the end-plate beam: \( M_d = M_{b,t} + N_{b,t} \tan(\alpha) - V_{b,t} \tan(\alpha) = 55.06 \text{ kNm} \)

\[ \begin{align*}
N_{b,t} &= (-N_d z_{b} - M_d z_{b}^2) / \cos(\alpha_{b}) = 226.85 \text{ kN}, \quad z_{b} = 232.1 \text{ mm}, \quad z_{b} = 116.1 \text{ mm}
\end{align*} \]

\[ \begin{align*}
N_{b,c} &= (N_d z_{bo} + M_d z_{bo}^2) / \cos(\alpha_{b}) = 251.56 \text{ kN}, \quad z_{b} = 232.1 \text{ mm}, \quad z_{b} = 116.1 \text{ mm}
\end{align*} \]

**Slope angle:** \( \alpha_{b} = \alpha_{t} = \alpha = -7.40^\circ \)
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 \((m_0 - 1)\).

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

in mode 1: \(\ell_{eff,1} = \ell_{left,1} = \min(\ell_{left,nc, left,cp}) = 60.0\) mm, \(\ell_{left,cp} = 159.8\) mm

in mode 2: \(\ell_{eff,2} = \ell_{left,2} = \ell_{left,nc} = 60.0\) mm

tension resistance of the T-stub flange:

in mode 1+2: \(\Sigma F_{L,Rd} = \left(0.25 \cdot \ell_{eff,1} \cdot f_y \right) / \gamma_M = 1.41\) kNm

in mode 3: \(\Sigma F_{L,Rd} = 2 \cdot n_b \cdot F_{L,Rd} = 180.86\) kN

\(L_b = 56.0\) mm \(\leq 116.4\) mm \(\Rightarrow\) \(L_b^* = \) plying forces may develop

mode 1: complete yielding of the T-stub flange
\(F_{T,1,Rd} = \left(4 \cdot M_{p1,1,Rd} / \ell_{left,1,1,Rd} \right) / \gamma_M = 164.30\) kN

mode 2: bolt failure simultaneously with yielding of the T-stub flange
\(F_{T,2,Rd} = (2 \cdot M_{p1,2,Rd} + n \cdot \Sigma F_{T,Rd}) / (m + n) = 132.00\) kN

mode 3: bolt failure
\(F_{T,3,Rd} = \Sigma F_{T,Rd} = 180.86\) kN

tension resistance of the T-stub flange: \(F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}, 132.00\) kN

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

tension resistance of welds: \(F_{T,w,Rd} = 2f_{w,1,d} \cdot \ell_{left} = 152.74\) kN \((\geq 132.00\) kN, not decisive)

resistance and effective length of end-plate in bending (projection)
\(F_{T,eq,Rd,1} = 132.00\) kN, \(\ell_{left,1} = 60.0\) mm

part of end-plate between beam flanges

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

row 2:

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

in mode 1: \(\ell_{eff,1} = \ell_{left,1} = \min(\ell_{left,nc, left,cp}) = 147.7\) mm, \(\ell_{left,cp} = 172.8\) mm

in mode 2: \(\ell_{eff,2} = \ell_{left,2} = \ell_{left,nc} = 147.7\) mm

tension resistance of the T-stub flange:

in mode 1+2: \(\Sigma F_{L,Rd} = \left(0.25 \cdot \ell_{eff,1} \cdot f_y \right) / \gamma_M = 3.47\) kNm

in mode 3: \(\Sigma F_{L,Rd} = 2 \cdot n_b \cdot F_{L,Rd} = 180.86\) kN

\(L_b = 56.0\) mm \(> 24.3\) mm \(\Rightarrow\) no plying forces

mode 1 and 2: complete yielding of the T-stub flange and possibly coincident bolt failure
\(F_{T,1,2,Rd} = (2 \cdot M_{p1,1,Rd} / \ell_{left,1,1,Rd}) = 252.33\) kN

mode 3: bolt failure
\(F_{T,3,Rd} = \Sigma F_{T,Rd} = 180.86\) kN

tension resistance of the T-stub flange: \(F_{T,Rd} = \min(F_{T,1,2,Rd}, F_{T,3,Rd}) = 180.86\) kN

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

tension resistance of welds: \(F_{T,w,Rd} = 2f_{w,1,d} \cdot \ell_{left} = 225.55\) kN \((\geq 180.86\) kN, not decisive)

resistances and effective lengths of end-plate in bending (per bolt-row):
\(F_{eq,Rd,2} = 180.86\) kN, \(\ell_{left,2} = 147.7\) mm

2.3. verifications

2.3.1. verification of the connection capacity with partial internal forces and moments

tension force in the bolt-rows:
\(N_{b,t} = (-N_d \cdot z_{bu} + M_u) / z = 225.02\) kN, \(z = z_{eq} = 232.1\) mm, \(z_{bu} = 113.5\) mm

Gk 5: \(F_{Ed} = \Sigma F_{T,eq,Rd,i} = 303.4\) kN, \(F_{Ed} = N_{b,t} = 225.02\) kN
\(F_{Ed} = 225.0\) kN \(< F_{Rd} = 303.4\) kN \(\Rightarrow U = 0.742 < 1\) \(\text{ok}\)

utilization partial internal forces and moments \(U_{Gk} = 0.742 < 1\) \(\text{ok}\)
2.3.2. verification result

maximum utilization: max $U = 0.742 < 1 \text{ ok}$

3. final result

utilization of the connection

<table>
<thead>
<tr>
<th>$L_k$</th>
<th>$U_j$</th>
<th>$\text{Gleichgewicht}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.742*</td>
<td>24.51 kN 0.04 kN 55.00 kNm</td>
</tr>
</tbody>
</table>

$U_j$: utilization of the connection; tolerances of equilibrium 1 kN / 1 kNm

*) maximum utilization

maximum utilization: $\text{max } U = 0.742 < 1 \text{ ok}$

verification succeeded