1. **input report**

![Diagram with bolt layout](image)

**details (section A - A)**

- **top tension**
  - 1
  - 2
  - 3

- **bottom tension**
  - 1
  - 2
  - 3

**bolts**
- bolt class 10.9, bolt size M20
- large wrench size (high strength bolt), preloaded (for info: preloading \( F_{p,c} = 0.7 \cdot f_y \cdot A_2 = 154.3 \text{ kN} \))
- shear plane passes through the unthreaded portion of the bolt

**beam parameters**
- section HE260A, steel grade S235

**verification parameters**
- bolted end-plate connection:
  - thickness \( t_p = 20.0 \text{ mm} \), width \( b_p = 260.0 \text{ mm} \), length \( l_p = 340.0 \text{ mm} \), steel grade S355
  - projections \( h_{p,0} = 20.0 \text{ mm} \), \( h_{p,u} = 70.0 \text{ mm} \)

**bolts in connection:**
- 3 bolt-rows with 2 bolts
  - of these 1 bolt-row top in tension (row 1)
  - and 1 bolt-row for shear transfer top (row 3)
  - 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 \( e_2 = 65.0 \text{ mm} \)
- centre distance of the first bolt-row to the upper edge of the end-plate (end row) \( e_0 = 72.5 \text{ mm} \)
- centre distance of the last bolt-row to the bottom edge of the end-plate (end row) \( e_u = 30.0 \text{ mm} \)
- centre distance of the bolt-rows from each other \( p_{1-2} = 145.0 \text{ mm} \), \( p_{2-3} = 92.5 \text{ mm} \)

- welds at the connection point:
  - beam flange top: fillet weld, weld thickness \( a = 7.0 \text{ mm} \)
  - beam web: fillet weld, weld thickness \( a = 5.0 \text{ mm} \)
  - 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: \( M_{f,b,Ed} = 145.00 \) kNm, \( V_{f,b,Ed} = 100.00 \) 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 \( \gamma_{M7} = 1.10 \)

Check of data:

OK

Distances between bolt-rows at end-plate:
- Horizontal: \( e_2 = 65.0 \text{ mm} \) \( > 1.2 \cdot d_0 = 26.4 \text{ mm} \), \( e_2 = 65.0 \text{ mm} < 4 \cdot t + 40 \text{ mm} = 120.0 \text{ mm} \)
- Vertical: \( e_1 = 72.5 \text{ mm} \) \( > 1.2 \cdot d_0 = 26.4 \text{ mm} \), \( e_1 = 72.5 \text{ mm} < 4 \cdot t + 40 \text{ mm} = 120.0 \text{ mm} \)

Notes:

There are several basic components selected which perhaps do not ensure the total loading capacity of the joint.
No verification for welds within the connection.

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

\[
\begin{align*}
\text{Knotenschnittgrößen} & \quad \text{periphery connection} & \quad \text{periphery connection-sided} & \quad \text{partial internal forces and moments} \\
\text{intersectional forces and moments} & \quad \perp \text{to connection plane} & \quad \perp \text{to connection plane} & \quad \perp \text{to connection plane} \\
\end{align*}
\]

Slope angle: \( \alpha_{b} = \alpha_{V} = \alpha = 0^\circ \)

Internal forces and moments perpendicular to the connection planes:
- Periphery beam: \( M_{d} = -145.00 \) kNm, \( V_{d} = 100.00 \) kN
- Negative internal moment \( M_{d} \Rightarrow \text{mirrored model} \)
- \( M_{d} = 145.00 \) kNm, \( V_{d} = -100.00 \) kN

Partial internal forces and moments referring to the mirrored model:
- Internal forces and moments in the periphery end-plate-beam: \( M'_{d} = M_{d} \cdot V_{d,\text{top}} = 147.00 \text{ kN} \)
- \( N_{b,\text{top}} = -N_{d} \cdot z_{d} / z_{b} + M'_{d} / z_{b} = 618.95 \text{ kN}, \quad z_{b} = 237.5 \text{ mm}, \quad z_{b} = 118.8 \text{ mm} \)
- \( N_{b,\text{bottom}} = N_{d} \cdot z_{d} / z_{b} + M'_{d} / z_{b} = 618.95 \text{ kN}, \quad z_{b} = 237.5 \text{ mm}, \quad z_{b} = 118.8 \text{ mm} \)
- \( V_{b,\text{top}} = V_{d} = -100.00 \) kN

2.2. Resistance of cross-section:

Plastic cross-sectional check for \( M_{y} = -147.00 \) kNm, \( V_{z} = -100.00 \) kN
- Valid normal/shear stress: \( zul \cdot \sigma_{d} = 23.50 \text{ kN/cm}^2, \quad zul \cdot \tau_{d} = 13.57 \text{ kN/cm}^2 \)
- Top flange: resistance forces \( N_{\text{max},o} = 763.75 \text{ kN}, \quad N_{\text{min},o} = -763.75 \text{ kN} \)
- Bottom flange: resistance forces \( N_{\text{max},U} = 763.75 \text{ kN}, \quad N_{\text{min},U} = -763.75 \text{ kN} \)
- Web:
  - Shear force \( V_{S} = -100.00 \text{ kN}, \quad \text{Shear stress} \: \tau_{S} = 5.61 \) kN/cm² \( \Rightarrow U_{S} = 0.414 \)
  - Resistance forces \( N_{\text{max},S} = 381.08 \text{ kN}, \quad N_{\text{min},S} = -381.08 \) kN
- Main bending: moment \( M_{y} = -147.00 \text{ kNm}, \quad \text{Resistance moments} \: M_{y,\text{max}} = 204.02 \text{ kNm}, \quad M_{y,\text{min}} = -204.02 \text{ kNm} \Rightarrow U_{M} = 0.721 \)
- Total (possibly due to load increase): \( \max U = 0.732 < 1 \text{ OK} \)
- Utilisation: resistance \( U_{\text{r}} = 0.732 < 1 \text{ OK} \)
- C/t ratio \( U_{\text{ct}} = 0.501 < 1 \text{ OK} \)

2.3. Basic components
2.3.1. Gk 5: end-plate in bending

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

extended part of end-plate
In the extended part of the end-plate only one bolt-row is considered (n₀ = 1).

effective length of the T-stub flange (end-plate):
- in mode 1: $\sum \ell,1 = \ell,1 = \min(\ell,nc, \ell,cp) = 130.0 \text{ mm}$, \( \ell,cp = 201.6 \text{ mm} \)
- in mode 2: $\sum \ell,2 = \ell,2 = \ell,nc = \ell,cp = 130.0 \text{ mm}$

tension resistance of the T-stub flange:
- in mode 1+2: $M_{pl, Rd} = (0.25 \sum \ell,1^2 f_y) / \gamma_M = 4.62 \text{ kNm}$
- in mode 3: $\sum F_t, Rd = 2 n_b F_t, Rd = 352.80 \text{ kN}$

mode 1: complete yielding of the T-stub flange
$F_{T, Rd} = (4 M_{pl, Rd}) / m = 575.43 \text{ kN}$

mode 2: bolt failure simultaneously with yielding of the T-stub flange
$F_{T, Rd} = (2 M_{pl, Rd} + n \sum F_t, Rd) / (m + n) = 319.17 \text{ kN}$

mode 3: bolt failure
$F_{T, Rd} = \sum F_t, Rd = 352.80 \text{ kN}$

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

resistance of welds: $F_{w, Rd} = 2^{1/2} f_{w,d} a_{\text{eff}} = 463.30 \text{ kN}$ (≥ 319.17 kN, not decisive)

resistance and effective length of end-plate in bending (projection)
$F_{ep, Rd,1} = 319.17 \text{ kN}$, $\ell,1 = 130.0 \text{ mm}$

part of end-plate between beam flanges

equivalent T-stub flange (each individual bolt-row):
here: number of bolt-rows $n_0 = 1$

row 2

effective length of the T-stub flange (end-plate):
- in mode 1: $\sum \ell,1 = \ell,1 = \min(\ell,nc, \ell,cp) = 349.3 \text{ mm}$, \( \ell,cp = 386.2 \text{ mm} \)
- in mode 2: $\sum \ell,2 = \ell,2 = \ell,nc = 386.2 \text{ mm}$

tension resistance of the T-stub flange:
- in mode 1: $M_{pl,1, Rd} = (0.25 \sum \ell,1^2 f_y) / \gamma_M = 12.40 \text{ kNm}$
- in mode 2: $M_{pl,2, Rd} = (0.25 \sum \ell,2^2 f_y) / \gamma_M = 13.71 \text{ kNm}$

mode 3: complete yielding of the T-stub flange
$F_{T, Rd} = (4 M_{pl, Rd}) / m = 892.21 \text{ kN}$

mode 2: bolt failure simultaneously with yielding of the T-stub flange
$F_{T, Rd} = (2 M_{pl, Rd} + n \sum F_t, Rd) / (m + n) = 417.51 \text{ kN}$

mode 3: bolt failure
$F_{T, Rd} = \sum F_t, Rd = 352.80 \text{ kN}$

tension resistance of the T-stub flange: $F_{T, Rd} = \min(F_{T, Rd}, F_{T, Rd}, F_{T, Rd}) = 352.80 \text{ kN}$

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

tension resistance of welds: $F_{w, Rd} = 2^{1/2} f_{w,d} a_{\text{eff}} = 889.18 \text{ kN}$ (≥ 352.80 kN, not decisive)

resistances and effective lengths of end-plate in bending (per bolt-row):
$F_{ep, Rd,1} = 352.80 \text{ kN}$, $\ell,2 = 349.3 \text{ mm}$

2.4. verifications

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

tension force in the bolt-rows:
$N_{b,t} = (-N_{b,2bu} + M_d) / z = 610.53 \text{ kN}$, $z = z_{eq} = 237.5 \text{ mm}$, $z_{bu} = 118.8 \text{ mm}$

Gk 5: $F_{Rd} = \sum F_t, Rd, i = 665.4 \text{ kN}$, $F_{Ed} = N_{b,t} = 610.53 \text{ kN}$
$F_{Ed} = 610.53 \text{ kN} < F_{Rd} = 665.4 \text{ kN}$ \( \Rightarrow U = 0.918 \) \( \leq 1 \) \( \text{ok} \)

utilization partial internal forces and moments $U_{Gk} = 0.918 < 1 \text{ ok}$
2.4.2. verification result

maximum utilization: $\max U = 0.918 < 1 \text{ ok}$

3. final result

<table>
<thead>
<tr>
<th>$L_k$</th>
<th>$U_j$</th>
<th>Gleichgewicht</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>0.918</td>
<td>0.00 100.00 145.00</td>
</tr>
</tbody>
</table>

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

*) maximum utilization

maximum utilization: $\max U = 0.918 < 1 \text{ ok}$

verification succeeded