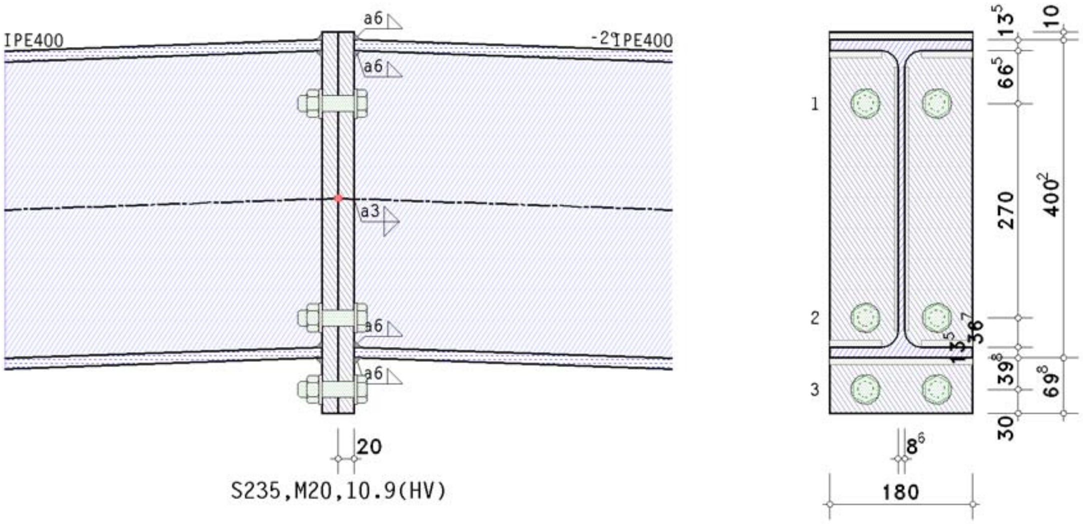
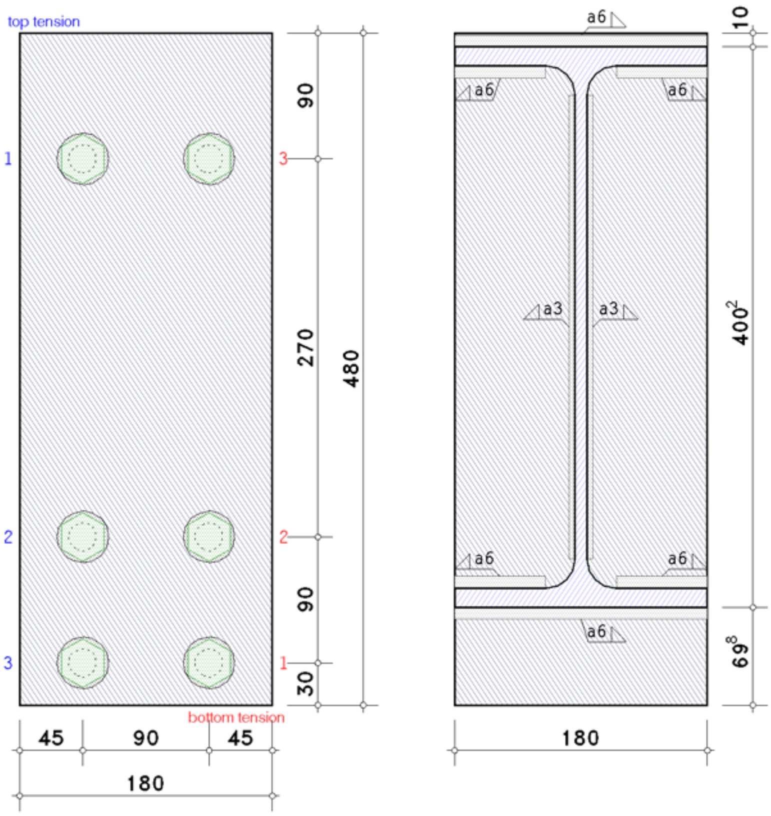
4H-ec3BT version: 4/2013-5I

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

## 1. input report




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 $F_{p,C}^* = 0.7 \cdot f_{yb} \cdot A_s = 154.3$ kN)

shear plane passes through the unthreaded portion of the bolt

**beam parameters**

section IPE400

slope angle of section about the horizontal axis $\alpha_b = -2.00°$

**verification parameters**

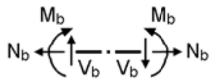
bolted end-plate connection:

thickness $t_p = 20.0$ mm, width $b_p = 180.0$ mm, length $l_p = 480.0$ mm

projections $h_{p,o} = 10.0$ mm, $h_{p,u} = 69.8$ 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 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 $e_2$ = 45.0 mm
  centre distance of the first bolt-row to the upper edge of the end-plate (end row) $e_o$ = 90.0 mm
  centre distance of the last bolt-row to the bottom edge of the end-plate (end row) $e_u$ = 30.0 mm
  centre distance of the bolt-rows from each other $p_{1\text{-}2}$ = 270.0 mm, $p_{2\text{-}3}$ = 90.0 mm
welds at the connection point:
  beam flange top: fillet weld, weld thickness a = 6.0 mm, angle $\varphi$ = 92°
  beam web: fillet weld, weld thickness a = 3.0 mm
  beam flange bottom: fillet weld, weld thickness a = 6.0 mm, angle $\varphi$ = 88°

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




Lk 1: $N_{j,b,Ed}$ = -30.10 kN $M_{j,b,Ed}$ = 184.50 kNm $V_{j,b,Ed}$ = 0.80 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: | $e_2$ = 45.0 mm > 1.2·$d_0$ = 26.4 mm, | $e_2$ = 45.0 mm < 4·t + 40 mm = 120.0 mm |
| horizontal: | $p_2$ = 90.0 mm > 2.4·$d_0$ = 52.8 mm, | $p_2$ = 90.0 mm < min(14·t, 200 mm) = 200.0 mm |
| vertical: | $e_1$ = 90.0 mm > 1.2·$d_0$ = 26.4 mm, | $e_1$ = 90.0 mm < 4·t + 40 mm = 120.0 mm |
| vertical: | $p_1$ = 270.0 mm > 2.2·$d_0$ = 48.4 mm, | $p_1$ = 270.0 mm > min(14·t, 200 mm) = 200.0 mm !! |
| vertical: | $p_1$ = 90.0 mm > 2.2·$d_0$ = 48.4 mm, | $p_1$ = 90.0 mm < min(14·t, 200 mm) = 200.0 mm |
| vertical: | $e_1$ = 30.0 mm > 1.2·$d_0$ = 26.4 mm, | $e_1$ = 30.0 mm < 4·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.

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 verfication for welds within the connection.

## 2. Lk 1

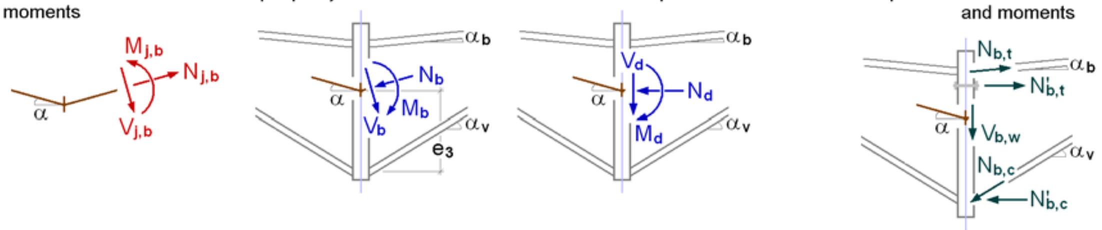
notes

connection is verified due to EC 3-1-8 regardless of preloading.
however, connections may be constructed with prestressed high strength bolts.

### 2.1. design values

Knotenschnittgrößen periphery connection⊥ zur connection plane partial internal forces and moments

intersectional forces and moments | periphery connection-sided | ⊥ to connection plane | partial internal forces and moments




sign definition of statics: a positive axial force means tension, a positive bending moment produces tension at the bottom
⇒ transformation to EC3: a positive axial force means compression, a positive bending moment produces tension at the top

slope angle: $\alpha_b = \alpha_v = \alpha$ = -2.00°

transformation sign convention of statics -> ec3-cos
  $N_{j,b,Ed}$ = 30.10 kN, $M_{j,b,Ed}$ = -184.50 kNm, $V_{j,b,Ed}$ = 0.80 kN
transformation node values -> joint values
  $N_{b,Ed}$ = 30.10 kN, $M_{b,Ed}$ = -184.50 kNm, $V_{b,Ed}$ = 0.80 kN
transformation joint values -> design values
  $N_d$ = 30.11 kN, $M_d$ = -184.50 kNm, $V_d$ = -0.25 kN

**internal forces and moments perpendicular to the connection planes**

  periphery beam
  $N_d$ = 30.11 kN, $M_d$ = -184.50 kNm, $V_d$ = -0.25 kN

**negative internal moment $M_d$** ⇒ mirrored model ($\alpha_b = \alpha_v = \alpha$ = 2.00°)
  $N_d$ = 30.11 kN, $M_d$ = 184.50 kNm, $V_d$ = 0.25 kN

**partial internal forces and moments refering to the mirrored model**

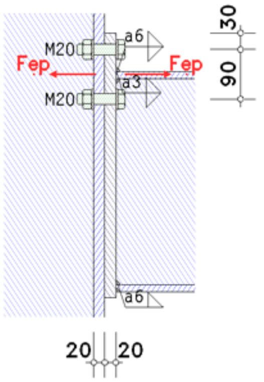
  internal forces and moments in the periphery end-plate-beam: $M'_d = M_d + N_d \cdot t_{ep} \cdot \tan(\alpha) - V_d \cdot t_{ep}$ = 184.52 kNm
  $N_{b,t} = (-N_d \cdot z_{bu}/z_b + M'_d/z_b) / \cos(\alpha_b)$ = 462.34 kN, $z_b$ = 386.7 mm, $z_{bu}$ = 193.4 mm

$N_{b,c} = (N_d \cdot z_{bo}/z_b + M'_d/z_b) / \cos(\alpha_b) = 492.47$ kN, $z_b = 386.7$ mm, $z_{bo} = 193.4$ mm
$V_{b,w} = V_d + N_{b,c} \cdot \sin(\alpha_v) = 1.30$ kN

### 2.2. basic components

beam splice w. end-plate:    selected basic component(s): 5

### 2.2.1. 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 ($n_b = 1$).

distance centre-line of the bolt to beam flange $m_1 = 33.0$ mm

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

$e_x = e_1 = 30.0$ mm, $m_x = m_1 = 33.0$ mm, $w = b_p - 2 \cdot e = 90.0$ mm with $b_p = 180.0$ mm, $e = 45.0$ mm

end bolt-row outside tension flange of beam

$l_{eff,cp,sa} = \min(2 \cdot \pi \cdot m_x,\ \pi \cdot m_x + w,\ \pi \cdot m_x + 2 \cdot e) = 193.6$ mm

$l_{eff,nc,sa} = \min(4 \cdot m_x + 1.25 \cdot e_x,\ e + 2 \cdot m_x + 0.625 \cdot e_x,\ 0.5 \cdot b_p,\ 0.5 \cdot w + 2 \cdot m_x + 0.625 \cdot e_x) = 90.0$ mm

in mode 1: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc},\ l_{eff,cp}) = 90.0$ mm

in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc} = 90.0$ mm

**tension resistance of the T-stub flange**

$n = \min(e_{min}, 1.25 \cdot m) = 30.0$ mm, $e_{min} = 30.0$ mm, $m = 33.0$ mm

resisting plastic moments:

in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 2.11$ kNm, $t_f = 20.0$ mm, $f_y = 235.0$ N/mm², $\gamma_{M0} = 1.00$

design value of tension resistance:

tension resistance of one bolt: $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2} = 176.40$ kN, $k_2 = 0.90$

in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 352.80$ kN, $n_b = 1$

prying forces always appear at preloaded bolts !

calculation with the alternative method

decisive diameter of the bolt $d_w = d_p = 37.00$ mm $\Rightarrow$ $e_w = d_w/4 = 9.3$ mm

mode 1: complete yielding of the T-stub flange

$F_{T,1,Rd} = ((8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}) / (2 \cdot m \cdot n - e_w \cdot (m+n)) = 335.61$ kN

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

$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 235.34$ kN

mode 3: bolt failure

$F_{T,3,Rd} = \Sigma F_{t,Rd} = 352.80$ kN

tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd},\ F_{T,2,Rd},\ F_{T,3,Rd}) = 235.34$ kN

resistance of a weld (req.1): $f_{1w,d} = f_u / (\beta_w \cdot \gamma_{M2}) = 360.0$ N/mm², $f_u = 360.0$ N/mm², $\beta_w = 0.80$

tension resistance of welds: $F_{T,w,Rd} = 2^{1/2} \cdot f_{1w,d} \cdot a \cdot l_{eff} = 274.92$ kN ($\geq 235.34$ kN, not decisive)

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

$F_{t,ep,Rd,1} = 235.34$ kN, $l_{eff,1} = 90.0$ 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**

distance centre-line of the bolt to the stiffener $m_2 = 29.9$ mm

distance centre-line of the bolt to the edge of flange $e = 45.0$ mm

distance centre-line of the bolt to the stub web $m = 37.3$ mm

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

inner bolt-row outside tension flange of beam

coefficient for stiffened column flanges and end-plates:

input values $\lambda_1 = m / (m+e) = 0.453$, $\lambda_2 = m_2 / (m+e) = 0.364$ $\Rightarrow$ $\alpha = 6.36$ (calculated)

$l_{eff,cp,si} = 2 \cdot \pi \cdot m = 234.4$ mm

$l_{eff,nc,si} = \alpha \cdot m = 237.4$ mm

in mode 1: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc},\ l_{eff,cp}) = 234.4$ mm

in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc} = 237.4$ mm

**tension resistance of the T-stub flange**

$n = \min(e_{min}, 1.25 \cdot m) = 45.0$ mm, $e_{min} = 45.0$ mm, $m = 37.3$ mm

resisting plastic moments:

in mode 1: $M_{pl,1,Rd} = (0.25 \cdot \Sigma l_{eff,1} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 5.51$ kNm, $t_f = 20.0$ mm, $f_y = 235.0$ N/mm², $\gamma_{M0} = 1.00$

in mode 2: $M_{pl,2,Rd} = (0.25 \cdot \Sigma l_{eff,2} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 5.58$ kNm

design value of tension resistance:

tension resistance of one bolt: $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2} = 176.40$ kN, $k_2 = 0.90$
in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 352.80$ kN, $n_b = 1$
prying forces always appear at preloaded bolts !
calculation with the alternative method
decisive diameter of the bolt $d_w = d_p = 37.00$ mm $\Rightarrow$ $e_w = d_w/4 = 9.3$ mm
mode 1: complete yielding of the T-stub flange
$F_{T,1,Rd} = ((8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}) / (2 \cdot m \cdot n - e_w \cdot (m+n)) = 724.57$ kN
mode 2: bolt failure simultaneously with yielding of the T-stub flange
$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 328.46$ kN
mode 3: bolt failure
$F_{T,3,Rd} = \Sigma F_{t,Rd} = 352.80$ kN
tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 328.46$ kN
resistance of a weld (req.1): $f_{1w,d} = f_u / (\beta_w \cdot \gamma_{M2}) = 360.0$ N/mm², $f_u = 360.0$ N/mm², $\beta_w = 0.80$
tension resistance of welds: $F_{T,w,Rd} = 2^{1/2} \cdot f_{1w,d} \cdot a \cdot l_{eff} = 358.01$ kN ($\geq 328.46$ kN, not decisive)

**resistances and effective lengths of end-plate in bending (per bolt-row):**
$F_{ep,Rd,2} = 328.46$ kN, $l_{eff,2} = 234.4$ mm

### 2.3. connection capacity

#### 2.3.1. moment resistance

distance of tension-bolt-rows from centre of compression: $h_1 = 433.2$ mm, $h_2 = 343.2$ mm

**resistances acc. to EC 3-1-8, 6.2.7.2(6) for bolt-rows considered individually**
row 1: $F_{tr,Rd} = 235.3$ kN
row 2: $F_{tr,Rd} = 328.5$ kN

**resistance per bolt-row** (tension)
row 1: $F_{tr,Rd} = 235.3$ kN
row 2: $F_{tr,Rd} = 328.5$ kN
$\Sigma F_{tr,Rd}^* = 563.8$ kN

**resistance per bolt-row** (bending)
row 1: $F_{tr,Rd} = 235.3$ kN
row 2: $F_{tr,Rd} = 328.5$ kN
$\Sigma F_{tr,Rd} = 563.8$ kN
potential failure by basic component 5

**resistance of flanges** (compression)
$\Sigma F_{c,Rd}^* = 0.0$ kN

**moment resistance** regarding the centre of compression
$M_{j,Rd} = \Sigma(F_{tr,Rd} \cdot h_r) = 214.7$ kNm
**tension resistance**
$N_{j,t,Rd} = \Sigma F_{tr,Rd}^* = 563.8$ kN

### 2.4. verifications

internal lever arm for a bolted end-plate joint with projection and 2 tension-bolt-rows:
$z = h_b + h_{po} - e_o - t_{b,fu}/2 - p_{1-2}/2 = 388.2$ mm

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

axial force: $N_{b,Ed} = |N_d \cdot \cos(\alpha) + V_d \cdot \sin(\alpha)| = 30.10$ kN $<$ 5%$\cdot N_{pl,Rd} = 99.30$ kN $\Rightarrow$ moment resistance
regarding beam axis with $N_{pl,Rd} = A_b \cdot f_{yb} / \gamma_{M0} = 1986.05$ kN
internal moment: $M_{Ed} = M_d - N_d \cdot z_{bu} = 178.70$ kNm, $z_{bu} = 192.7$ mm
bzgl. des centre of compressions

**moment resistance**
$M_{Ed}/M_{j,Rd} = 0.832 < 1$ ok

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

tension force in the bolt-rows:
$N'_{b,t} = (-N_d \cdot z_{bu} + M_d) / z = 460.27$ kN, $z = z_{eq} = 388.2$ mm, $z_{bu} = 192.7$ mm

Gk 5: $F_{Rd} = \Sigma F_{t,ep,Rd,i} = 553.0$ kN, $F_{Ed} = N'_{b,t} = 460.27$ kN
$F_{Ed} = 460.3$ kN $<$ $F_{Rd} = 553.0$ kN $\Rightarrow$ $U = 0.832 < 1$ ok

utilization partial internal forces and moments $U_{Gk} = 0.832 < 1$ ok

### 2.4.3. verification result

maximum utilization: max U = 0.832 < 1 ok

# 3. final result

### utilization of the connection

| Lk | $U_j$ | Gleichgewicht $\Sigma H$ | $\Sigma V$ | $\Sigma M$ | |
|---|---|---|---|---|---|
| -- | | kN | kN | kNm | |
| 1 | 0.832* | 30.11 | 0.25 | 184.50 | !! |

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

**maximum utilization:** max U = 0.832 < 1 ok

## verification succeeded