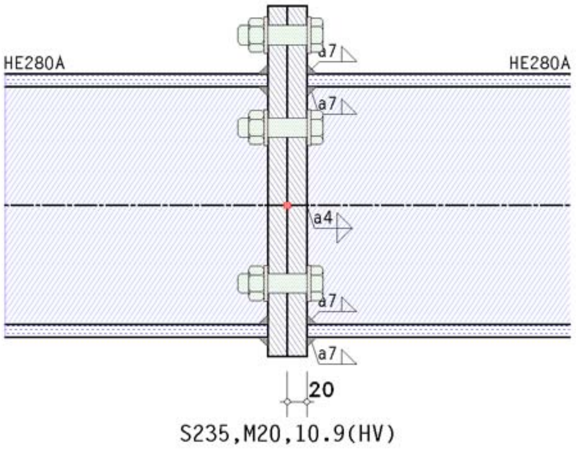
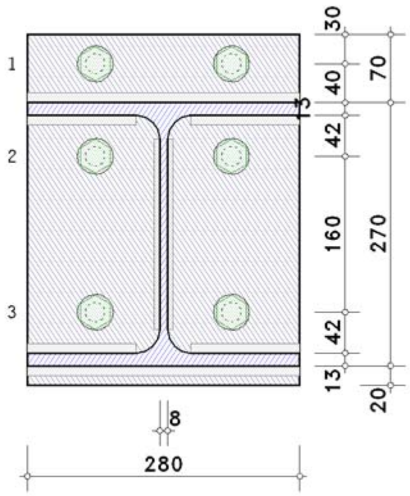
POS. 161: WAGENKNECHT 6.8.2

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

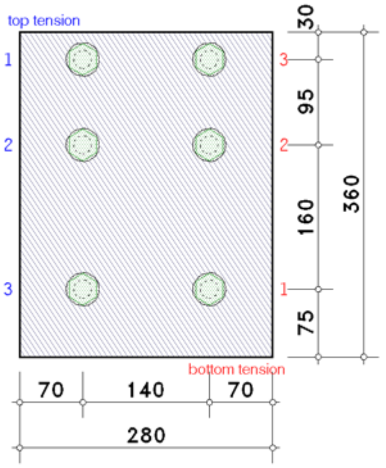
Rigid beam splice EC 3-1-8 (12.10), NA: Deutschland

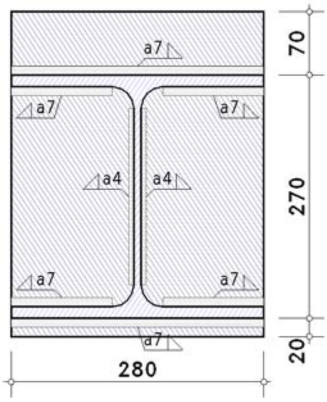
1. input report





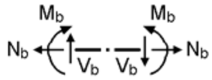
details (section A - A)





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 HE280A
verification parameters
bolted end-plate connection:
thickness t_p = 20.0 mm, width b_p = 280.0 mm, length l_p = 360.0 mm
projections $h_{p,o}$ = 70.0 mm, $h_{p,u}$ = 20.0 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 mm
centre distance of the first bolt-row to the upper edge of the end-plate (end row) e_o = 30.0 mm
centre distance of the last bolt-row to the bottom edge of the end-plate (end row) e_u = 75.0 mm
centre distance of the bolt-rows from each other p_{1-2} = 95.0 mm, p_{2-3} = 160.0 mm
welds at the connection point:
beam flange top: fillet weld, weld thickness a = 7.0 mm
beam web: fillet weld, weld thickness a = 4.0 mm
beam flange bottom: fillet weld, weld thickness a = 7.0 mm

internal forces and moments in the intersection point of system axes



Lk 1: $M_{j,b,Ed} = -145.00$ kNm $V_{j,b,Ed} = 120.00$ 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:	$e_2 = 70.0$ mm > $1.2 \cdot d_0 = 26.4$ mm,	$e_2 = 70.0$ mm < $4 \cdot t + 40$ mm $= 120.0$ mm
horizontal:	$p_2 = 140.0$ mm > $2.4 \cdot d_0 = 52.8$ mm,	$p_2 = 140.0$ mm < min(14·t, 200 mm) = 200.0 mm
vertical:	$e_1 = 30.0$ mm > $1.2 \cdot d_0 = 26.4$ mm,	$e_1 = 30.0$ mm < $4 \cdot t + 40$ mm $= 120.0$ mm
vertical:	$p_1 = 95.0$ mm > $2.2 \cdot d_0 = 48.4$ mm,	$p_1 = 95.0$ mm < min(14·t, 200 mm) = 200.0 mm
vertical:	$p_1 = 160.0$ mm > $2.2 \cdot d_0 = 48.4$ mm,	$p_1 = 160.0$ mm < min(14·t, 200 mm) = 200.0 mm
vertical:	$e_1 = 75.0$ mm > $1.2 \cdot d_0 = 26.4$ mm,	$e_1 = 75.0$ mm < $4 \cdot t + 40$ mm $= 120.0$ mm

notes

no verification for cross-sections.

2. Lk 1

notes

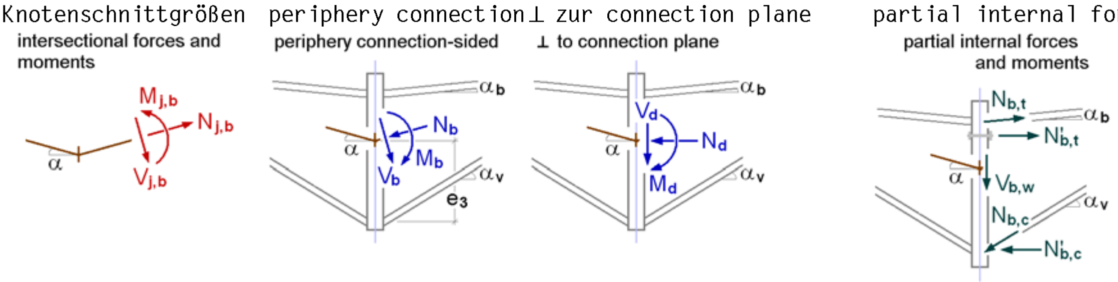
connection is verified due to EC 3-1-8 regardless of preloading.

however, connections may be constructed with prestressed high strength bolts.

calculation of T-stub-resistance with the standard method.

2.1. design values

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



slope angle: $\alpha_b = \alpha_v = \alpha = 0°$

internal forces and moments perpendicular to the connection planes

periphery beam

$M_d = 145.00$ kNm, $V_d = 120.00$ kN

partial internal forces and moments

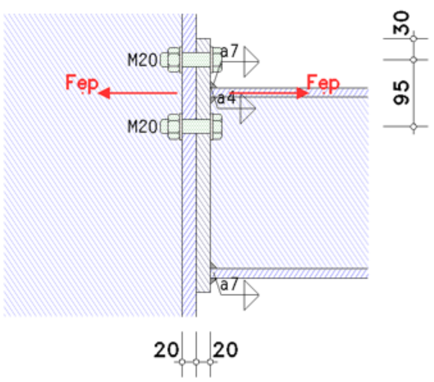
internal forces and moments in the periphery end-plate-beam: $M'_d = M_d - V_d \cdot t_{ep} = 142.60$ kNm

$N_{b,t} = -N_d \cdot z_{bu}/z_b + M'_d/z_b = 554.86$ kN, $z_b = 257.0$ mm, $z_{bu} = 128.5$ mm

$N_{b,c} = N_d \cdot z_{bo}/z_b + M'_d/z_b = 554.86$ kN, $z_b = 257.0$ mm, $z_{bo} = 128.5$ mm

2.2. basic components

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 ($n_b = 1$).

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

in mode 1: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp}) = 140.0$ mm, $l_{eff,cp} = 201.6$ mm

in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc} = 140.0$ mm

tension resistance of the T-stub flange:

in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 3.29$ kNm

in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 352.80$ kN mode 1: complete yielding of the T-stub flange

$F_{T,1,Rd} = (4 \cdot M_{pl,1,Rd}) / m = 410.22$ kN

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

$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 276.48$ kN

mode 3: bolt failure

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

tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 276.48$ kN

shear strength: $f_{vw,d} = (f_u/3^{1/2}) / (\beta_w \cdot \gamma_{M2}) = 207.8$ N/mm²

tension resistance of welds: $F_{T,w,Rd} = 2 \cdot f_{vw,d} \cdot a \cdot l_{eff} = 407.38$ kN ($\geq$ 276.48 kN, not decisive)

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

$F_{t,ep,Rd,1} = 276.48$ kN, $l_{eff,1} = 140.0$ 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

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

in mode 1: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp}) = 386.3$ mm, $l_{eff,cp} = 386.3$ mm

in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc} = 427.4$ mm

tension resistance of the T-stub flange:

in mode 1: $M_{pl,1,Rd} = (0.25 \cdot \Sigma l_{eff,1} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 9.08$ kNm

in mode 2: $M_{pl,2,Rd} = (0.25 \cdot \Sigma l_{eff,2} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 10.04$ kNm

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

mode 1: complete yielding of the T-stub flange

$F_{T,1,Rd} = (4 \cdot M_{pl,1,Rd}) / m = 590.62$ kN

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

$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 340.64$ kN

mode 3: bolt failure

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

tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 340.64$ kN

shear strength: $f_{vw,d} = (f_u/3^{1/2}) / (\beta_w \cdot \gamma_{M2}) = 207.8$ N/mm²

tension resistance of welds: $F_{T,w,Rd} = 2 \cdot f_{vw,d} \cdot a \cdot l_{eff} = 642.25$ kN ($\geq$ 340.64 kN, not decisive)

resistances and effective lengths of end-plate in bending (per bolt-row):

$F_{ep,Rd,2} = 340.64$ kN, $l_{eff,2} = 386.3$ mm

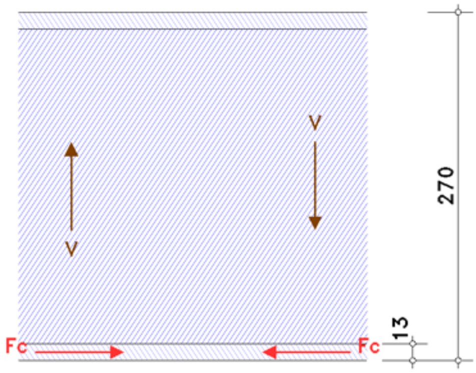
2.2.2. Gk 7: beam flange and web in compression

flange bottom: section class for $c/(\varepsilon \cdot t) = 8.62$: 1

web: section class for $\alpha = 0.50$ and $c/(\varepsilon \cdot t) = 24.50$: 1

section class of beam: 1

taking into account the moment-shear force-interaction $V_{Ed} = 120.0$ kN



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

stress due to bending with shear force: $V_{Ed} = 120.0 \text{ kN} \leq 215.3 \text{ kN} = V_{pl,Rd}/2 \Rightarrow$ no effect

resistance $M_{c,Rd} = M_{pl,Rd} = (W_{pl} \cdot f_y) / \gamma_{M0} = 261.32$ kNm, $W_{pl} = 1112.00$ cm³

resistance of a flange (and web) with compression

$F_{c,f,Rd} = M_{c,Rd} / (h - t_f) = 1016.81$ kN

resistance of upper beam flange:

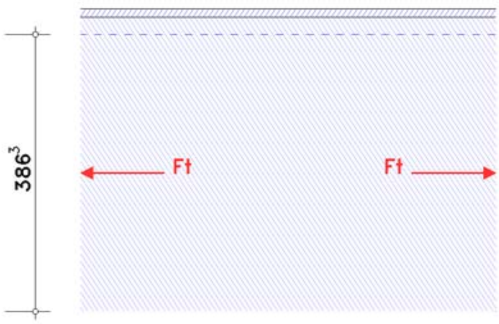
stress due to bending with shear force: $V_{Ed} = 120.0 \text{ kN} \leq 215.3 \text{ kN} = V_{pl,Rd}/2 \Rightarrow$ no effect

resistance $M_{c,Rd} = M_{pl,Rd} = (W_{pl} \cdot f_y) / \gamma_{M0} = 261.32$ kNm, $W_{pl} = 1112.00$ cm³

resistance of a flange (and web) with compression

$F_{c,f,Rd} = M_{c,Rd} / (h - t_f) = 1016.81$ kN

2.2.3. Gk 8: beam web in tension



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

each individual bolt-row:

row 2

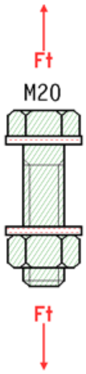
effective width $b_{eff,t,wb}$ = 386.3 mm (l_{eff} from bc 5)

resistance of a beam web in tension

$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_{y,wb} / \gamma_{M0}$ = 726.2 kN

2.2.4. Gk 10: bolts in tension

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



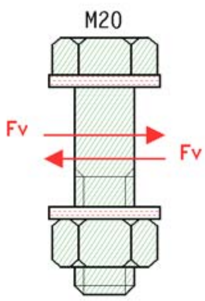
tension resistance of one bolt $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2}$ = 176.40 kN, k_2 = 0.90

punching shear load capicity $B_{p,Rd} = (0.6 \cdot \pi \cdot d_m \cdot t_p \cdot f_u)) / \gamma_{M2}$ = 363.88 kN, t_p = 20.0 mm

tension-/punching shear load capicity for 2 bolts: $\Sigma F_{tp,Rd} = 2 \cdot \min(F_{t,Rd}, B_{p,Rd})$ = 352.80 kN

2.2.5. Gk 11: bolts in shear

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

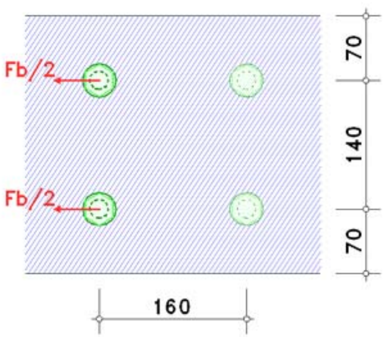


shear resistance per shear plane $F_{v,Rd} = \alpha_v \cdot f_{ub} \cdot A / \gamma_{M2}$ = 150.80 kN, α_v = 0.60

shear resistance of 2 bolts (1-shear): $\Sigma F_{v,Rd} = 2 \cdot F_{v,Rd}$ = 301.59 kN

2.2.6. Gk 12: plate with bearing resistance

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



row 3

bolt 1: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2}$ = 288.00 kN, k_1 = 2.50, α_b = 1.00

bolt 2: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2}$ = 288.00 kN, k_1 = 2.50, α_b = 1.00

bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd}$ = 576.00 kN

2.3. connection capacity

2.3.1. moment resistance

distance of tension-bolt-rows from centre of compression: h_1 = 303.5 mm, h_2 = 208.5 mm

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

resistance of flanges
$\Sigma F_{c,Rd}^*$ = 2033.6 kN

moment resistance
$M_{j,Rd} = \Sigma(F_{tr,Rd} \cdot h_r)$ = 154.9 kNm
tension resistance
$N_{j,t,Rd} = \Sigma F_{tr,Rd}^*$ = 617.1 kN
compression resistance
$N_{j,c,Rd} = \Sigma F_{c,Rd}^*$ = 2033.6 kN

2.3.2. shear/bearing resistance

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

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

2.3.3. total

$M_{j,Rd}$ = 154.9 kNm $N_{j,t,Rd}$ = 617.1 kN $N_{j,c,Rd}$ = 2033.6 kN $V_{j,Rd}$ = 301.6 kN

2.4. verifications

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

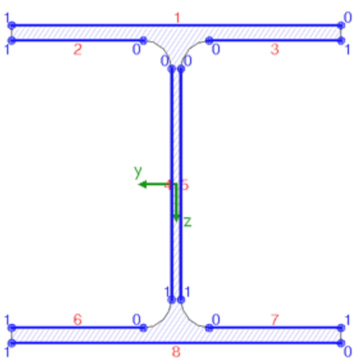
internal moment: $M_{Ed} = M_d$ = 145.00 kNm
shear force: $V_{Ed} = |V_d|$ = 120.00 kN

$M_{Ed}/M_{j,Rd} = 0.936 < 1$ ok
$V_{Ed}/V_{j,Rd} = 0.398 < 1$ ok

2.4.2. verification of welds at beam section

weld 1: beam flange in tension outer
welds 2,3: beam flange in tension inner
welds 4,5: beam web double-sided
weld 8: beam flange in compression outer
welds 6,7: beam flange in compression inner

calculation section:



weld 1:	a_w = 7.0 mm	l_w = 280.0 mm
weld 2:	a_w = 7.0 mm	l_w = 112.0 mm
weld 3:	siehe weld 2	
weld 4:	a_w = 4.0 mm	l_w = 196.0 mm
weld 5:	siehe weld 4	
weld 6:	a_w = 7.0 mm	l_w = 112.0 mm
weld 7:	siehe weld 6	
weld 8:	a_w = 7.0 mm	l_w = 280.0 mm

design values refering to centroid of the section:
$M_{y,Ed}$ = -145.00 kNm, $V_{z,Ed}$ = 120.00 kN
cross-sectional properties refering to centroid of the line cross-section:
ΣA_w = 86.24 cm², $A_{w,z}$ = 15.68 cm², Σl_w = 140.0 cm
$I_{w,y}$ = 12313.79 cm⁴, $I_{w,z}$ = 5104.15 cm⁴, $W_{w,t}$ = 77.81 cm³, Δz_w = 0.0 mm
distribution of internal forces and moments:
weld 1: N_w = 311.58 kN
weld 2: N_w = 112.63 kN

weld 3: siehe weld 2
weld 4: $M_{y,w}$ = -2.96 kNm
weld 5: siehe weld 4
weld 6: N_w = -112.63 kN
weld 7: siehe weld 6
weld 8: N_w = -311.58 kN
from conventionel distribution of shear force: $V_{z,w}$ = 120.00 kN

verifications in weld edges:

weld 1,	pt. 0:	$\sigma_{w,x}$ = 158.97 N/mm²		⇒ U_w = 0.765 < 1 ok
weld 2,	pt. 0:	$\sigma_{w,x}$ = 143.66 N/mm²		⇒ U_w = 0.691 < 1 ok
weld 4,	pt. 0:	$\sigma_{w,x}$ = 115.40 N/mm²	$\tau_{w,z}$ = 76.53 N/mm²	⇒ U_w = 0.666 < 1 ok
	pt. 1:	$\sigma_{w,x}$ = -115.40 N/mm²	$\tau_{w,z}$ = 76.53 N/mm²	⇒ U_w = 0.666 < 1 ok
weld 6,	pt. 0:	$\sigma_{w,x}$ = -143.66 N/mm²		⇒ U_w = 0.691 < 1 ok
weld 8,	pt. 0:	$\sigma_{w,x}$ = -158.97 N/mm²		⇒ U_w = 0.765 < 1 ok

Result:

weld 8, pt. 0: $\sigma_{w,x}$ = -158.97 N/mm²
Max: $F_{w,Ed}$ = 11.13 kN/cm < $F_{w,Rd}$ = 14.55 kN/cm ⇒ U_w = 0.765 < 1 ok

2.4.3. verification result

maximum utilization: max U = 0.936 < 1 ok

3. final result

utilization of the connection

Lk	U_j	Gleichgewicht			
		ΣH	ΣV	ΣM	
--		kN	kN	kNm	
1	0.936*	0.00	120.00	145.00	!!

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

maximum utilization: max U = 0.936 < 1 ok

verification succeeded