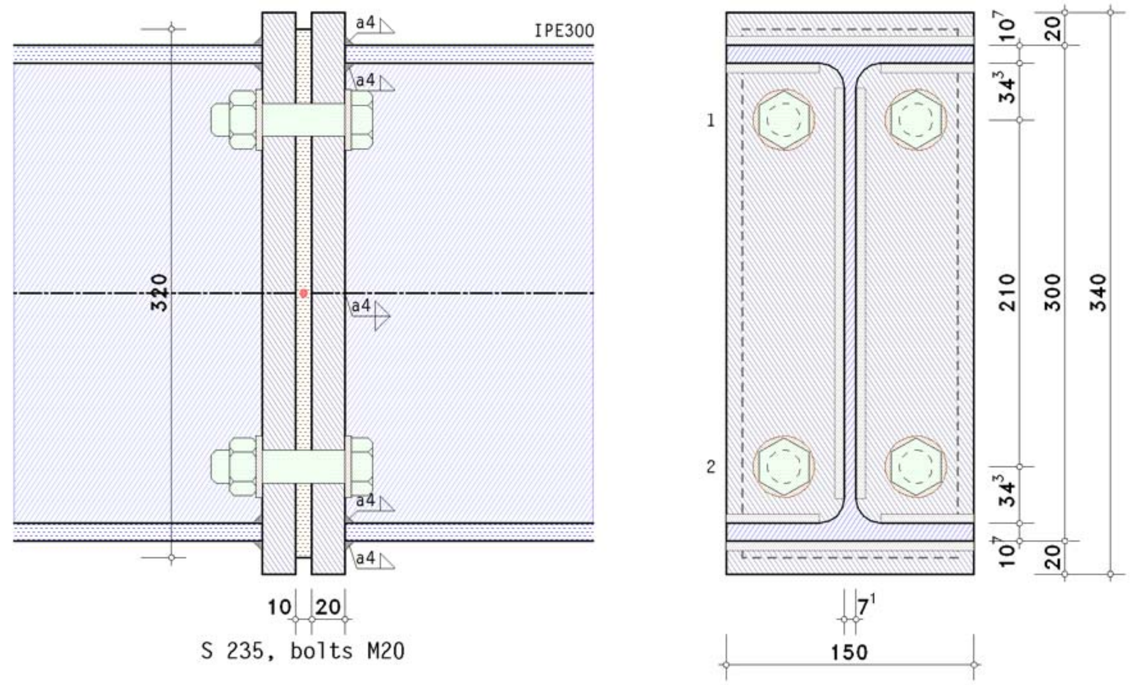
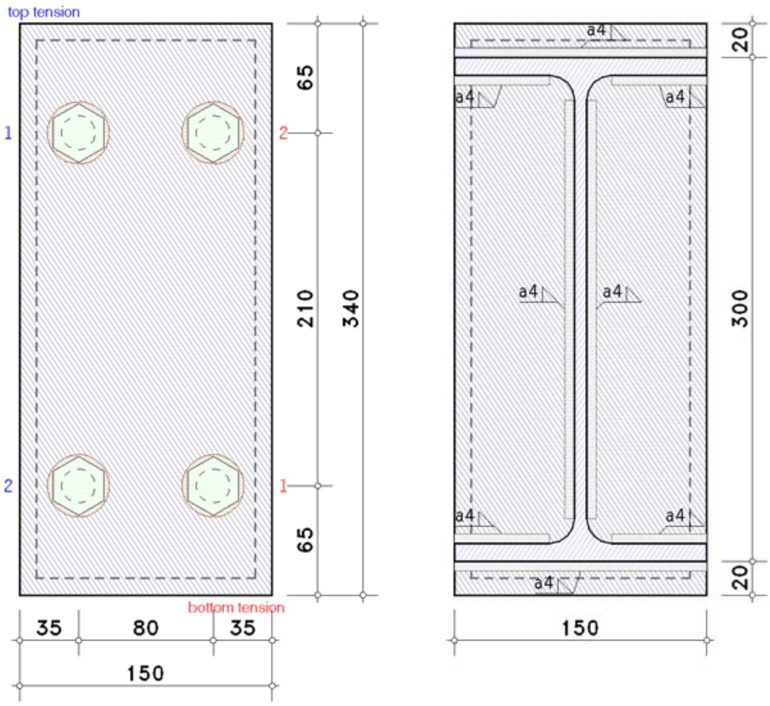
POS. 2: NASDALA 4-6

rigid joint with thermal separation layer

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



details



steel grade

steel grade S 235

beam parameters

section IPE300

bolts

bolt: bolt class 10.9, bolt size M20

large width across flats (high strength bolt)

shear plane passes through the unthreaded portion of the bolt

verification parameters

bolted end-plate joint:

end-plate: thickness t_p = 20.0 mm, length l_p = 340.0 mm, width b_p = 150.0 mm

projections $h_{p,o}$ = 20.0 mm, $h_{p,u}$ = 20.0 mm
thermal separation layer (Kerncompactlager of Calenberg Ingenieure GmbH):
thickness t_e = 10.0 mm, length l_e = 320.0 mm, width b_e = 130.0 mm
safety factor of material γ_e = 1.00, preload force per bolt $F_{p,C}$ = 160.0 kN

bolts at the connection point:
2 bolt-row(s) with 2 bolts each
all bolt rows are considered individually
no bolt rows top (M^+) in a group of bolts
and all bolt rows for shear transfer at tension top (rows 1-2)
no bolt rows bottom (M^-) in a group of bolts
and all bolt rows for shear transfer at tension bottom (rows 1-2)
centre distance of the bolts to the lateral edge of the end-plate e_2 = 35.0 mm
centre distance of the first bolt-row to the upper edge of the end-plate (end row) e_o = 65.0 mm
centre distance of the last bolt-row to the bottom edge of the end-plate (end row) e_u = 65.0 mm
centre distance of the bolt-rows from each other p_{1-2} = 210.0 mm

welds at the connection point:
beam flange top: fillet weld, weld thickness a = 4.0 mm
beam web: fillet weld, weld thickness a = 4.0 mm
beam flange bottom: fillet weld, weld thickness a = 4.0 mm

internal forces and moments in the intersection point of system axes (sign convention of statics)

Lk 1: $M_{j,b1,Ed}$ = 14.00 kNm
Lk 2: $M_{j,b1,Ed}$ = 28.00 kNm
Lk 3: $N_{j,b1,Ed}$ = -28.00 kN $M_{j,b1,Ed}$ = 28.00 kNm

partial safety factors for material

resistance of cross sections γ_{M0} = 1.00
resistance of members in stability failure γ_{M1} = 1.10
resistance of bolts, welds, plates in bearing γ_{M2} = 1.25
prestressing of high strength bolts γ_{M7} = 1.10

Component method

notes

high strength bolts have to be controlled prestressed, bolt category D (tension), A (shear).
no verification for cross sections within the connection area.
no verfication for welds within the connection.

distances between bolt-rows at end-plate

edge dist.:	e_2 = 35.0 mm > 1.2·d_0 = 26.4 mm,	e_2 = 35.0 mm < 4·t_{min} + 40 mm = 120.0 mm
pitch:	p_2 = 80.0 mm > 2.4·d_0 = 52.8 mm,	p_2 = 80.0 mm < min(14·t_{min}, 200 mm) = 200.0 mm
edge dist.:	e_1 = 65.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 65.0 mm < 4·t_1 + 40 mm = 120.0 mm
pitch:	p_1 = 210.0 mm > 2.2·d_0 = 48.4 mm,	p_1 = 210.0 mm > min(14·t_{min}, 200 mm) = 200.0 mm !!
edge dist.:	e_1 = 65.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 65.0 mm < 4·t_1 + 40 mm = 120.0 mm

maximum values for spacings and edge distances only in order to avoid local buckling and to prevent corrosion.

utilizations

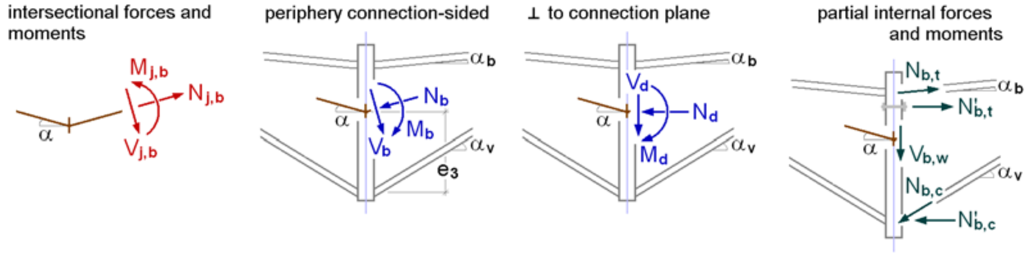
Lk	U
1	0.406
2	0.684
3	0.582

Final Result

maximum utilization [Lk 2]: max U = 0.684 < 1 ok.

verification succeeded

design values



internal forces and moments in the periphery

$M_{b,Ed}$ = $-M_{j,b,Ed} - V_{j,b,Ed} \cdot e_1$ = -28.00 kNm, e_1 = 5.0 mm

internal forces and moments perpendicular to the connection plane

$M_d = M_{b,Ed}$ = -28.00 kNm

negative internal moment M_d ⇒ mirrored joint model

M_d = 28.00 kNm

partial internal forces and moments refering to the mirrored model

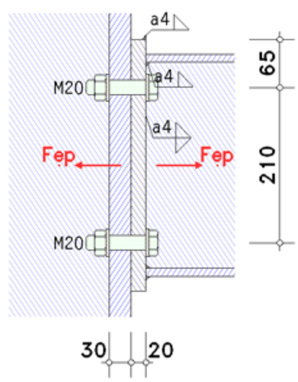
internal forces and moments in the periphery end-plate-beam: $M'_d = M_d - V_d \cdot t_{ep}$ = 28.00 kNm

$N_{b,t}$ = $-N_d \cdot z_{bu}/z_b + M'_d/z_b$ = 96.79 kN, z_b = 289.3 mm, z_{bu} = 144.6 mm

$N_{b,c}$ = $N_d \cdot z_{bo}/z_b + M'_d/z_b$ = 96.79 kN, z_b = 289.3 mm, z_{bo} = 144.6 mm

basic components

basic component 5: end-plate in bending



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

part of end-plate between beam flanges

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

here: number of bolt rows n_b = 1

row 1

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

in mode 1: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp})$ = 193.0 mm, $l_{eff,cp}$ = 200.6 mm

in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc}$ = 193.0 mm

design tension resistance of the T-stub flange:

in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma_{M0}$ = 4.54 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

$F_{T,1,Rd} = (8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}) / (2 \cdot m \cdot n - e_w \cdot (m+n))$ = 734.08 kN

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

$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n)$ = 320.05 kN

mode 3: bolt failure

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

tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd})$ = 320.05 kN

design resistances of welds: $f_{1,w,Rd}$ = 36.00 kN/cm², $f_{2,w,Rd}$ = 25.92 kN/cm²

tension resistance of welds: $F_{T,w,Rd} = 2 \cdot f_{2,w,Rd} \cdot a \cdot l_{eff}$ = 400.21 kN (not decisive)

row 2

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

in mode 1: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp})$ = 193.0 mm, $l_{eff,cp}$ = 200.6 mm

in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc}$ = 193.0 mm

design tension resistance of the T-stub flange:

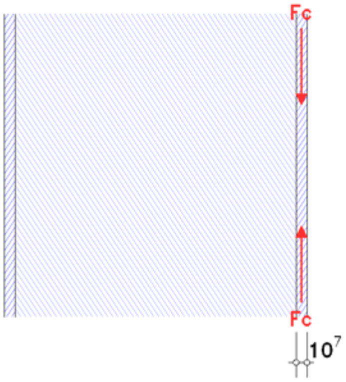
in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma_{M0}$ = 4.54 kNm

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
$F_{T,1,Rd} = (8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}) / (2 \cdot m \cdot n - e_w \cdot (m+n)) = 734.08$ kN
mode 2: bolt failure simultaneously with yielding of the T-stub flange
$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 320.05$ kN
mode 3: bolt failure
$F_{T,3,Rd} = \Sigma F_{t,Rd} = 352.80$ kN
tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 320.05$ kN
design resistances of welds: $f_{1,w,Rd} = 36.00$ kN/cm², $f_{2,w,Rd} = 25.92$ kN/cm²
tension resistance of welds: $F_{T,w,Rd} = 2 \cdot f_{2,w,Rd} \cdot a \cdot l_{eff} = 400.21$ kN (not decisive)

design resistances and effective lengths of end-plate in bending (per bolt-row):
$F_{ep,Rd,1} = 320.0$ kN, ass. $l_{eff,1} = 193.0$ mm
$F_{ep,Rd,2} = 320.0$ kN, ass. $l_{eff,1} = 193.0$ mm

basic component 7: beam flange and web in compression

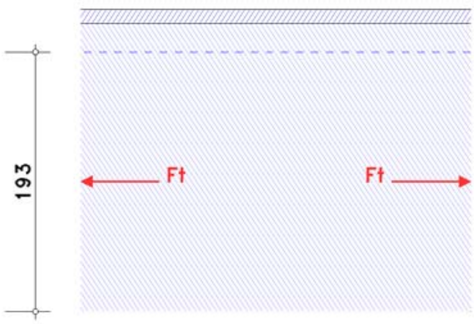
flange bottom: section class for $c/(\varepsilon \cdot t) = 5.28$: 1
web: section class for $\alpha = 0.50$ and $c/(\varepsilon \cdot t) = 35.01$: 1
section class of the beam in connection plane: 1



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

moment resistance $M_{c,Rd} = M_{pl,Rd} = (W_{pl} \cdot f_y) / \gamma_{M0} = 147.58$ kNm
design resistance of flange and web in compression
$F_{c,f,Rd} = M_{c,Rd} / (h - t_f) = 510.13$ kN

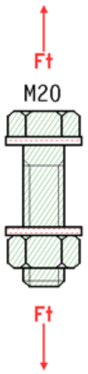
basic component 8: beam web in tension



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

each bolt-row decisive:
row 1
effective width $b_{eff,t,wb} = 193.0$ mm (l_{eff} from bc 5)
design resistance of a beam web in tension
$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_{y,wb} / \gamma_{M0} = 322.0$ kN
row 2
effective width $b_{eff,t,wb} = 193.0$ mm (l_{eff} from bc 5)
design resistance of a beam web in tension
$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_{y,wb} / \gamma_{M0} = 322.0$ kN

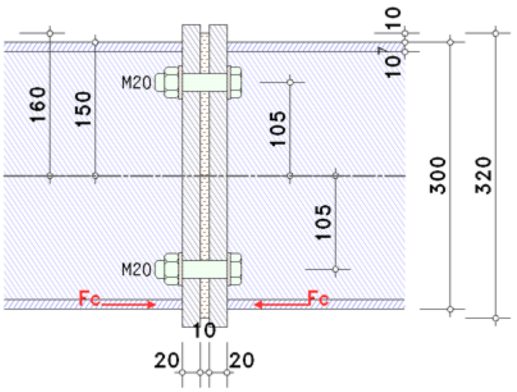
basic component 10: bolts in tension



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, $k_2 = 0.90$
p. sh. 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

basic component 15: end-plate with thermal separation layer



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

calculation is for Kerncompactlager of Calenberg Ingenieure GmbH.
effective length of separation layer $h_m = 257.5$ mm
mean compressive stress $\sigma_m = 19.12$ N/mm²

verification of the separation layer

shape factor S = 3.582 for 2 bolts in compression zone
permissible mean compressive stress $\sigma_{m,zul} = 24.88$ N/mm²
utilization of the separation layer 0.768 < 1 ok.

design resistance of an end-plate splice with thermal separation layer:

$F_{c,e,Rd} = A_{eff} \cdot f_e / \gamma_{Me} = 164.0$ kN, $A_{eff} = 65.91$ cm², $f_e = \sigma_{m,zul} = 24.88$ N/mm², $\gamma_{Me} = 1.00$

connection design capacity

moment resistance

distance of tension-bolt-rows from centre of compression: $h_1 = 249.6$ mm, $h_2 = 39.6$ mm

design resistances acc. to EC 3-1-8, 6.2.7.2(6) for bolt-rows considered individually

decisive basic components: 5, 8
row 1: $F_{tr,Rd} = 320.0$ kN
row 2: $F_{tr,Rd} = 320.0$ kN

deductions acc. to EC 3-1-8, 6.2.7.2(7)

decisive basic component: 7, 15
row 1: $\Sigma F_{tr,Rd} = 0.0$ kN
Gk 7: $\Delta F_{tr,Rd} = F_{c,f,Rd} - \Sigma F_{tr,Rd} = 510.1$ kN $F_{tr,Rd} = 320.0$ kN $< \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 320.0$ kN
Gk 15: $\Delta F_{tr,Rd} = F_{c,e,Rd} - \Sigma F_{tr,Rd} = 164.0$ kN $F_{tr,Rd} = 320.0$ kN $> \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 164.0$ kN
row 2: $\Sigma F_{tr,Rd} = 164.0$ kN (row 1)
Gk 7: $\Delta F_{tr,Rd} = F_{c,f,Rd} - \Sigma F_{tr,Rd} = 346.2$ kN $F_{tr,Rd} = 320.0$ kN $< \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 320.0$ kN
Gk 15: $\Delta F_{tr,Rd} = F_{c,e,Rd} - \Sigma F_{tr,Rd} = 0.0$ kN $F_{tr,Rd} = 320.0$ kN $> \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 0.0$ kN

check acc. to EC 3-1-8, 6.2.7.2(9)

decisive basic component: 10
row 1: $F_{tx,Rd} = 164.0$ kN, $h_x = 249.6$ mm $\Rightarrow F_{tx,Rd} \leq 0.95 \cdot \Sigma F_{t,Rd} = 335.2$ kN, no deduction

design resistance per bolt-row (finally)

row 1: $F_{tr,Rd} = 164.0$ kN
row 2: $F_{tr,Rd} = 0.0$ kN

potential failure by basic component 5, 15

moment resistance
$M_{j,Rd} = \Sigma(F_{tr,Rd} \cdot h_r) = 40.9$ kNm
tension resistance
$N_{j,Rd} = \Sigma F_{tr,Rd} = 164.0$ kN
compression resistance
$N_{j,c,Rd} = \min F_{c,Rd} = 164.0$ kN

verifications

verification of the connection design capacity by means of the component method

internal moment: $M_{Ed} = M_d = 28.00$ kNm

$M_{Ed}/M_{j,Rd} = 0.684 < 1$ **ok.**

verification result

maximum utilization: max $U = 0.684 < 1$ **ok.**