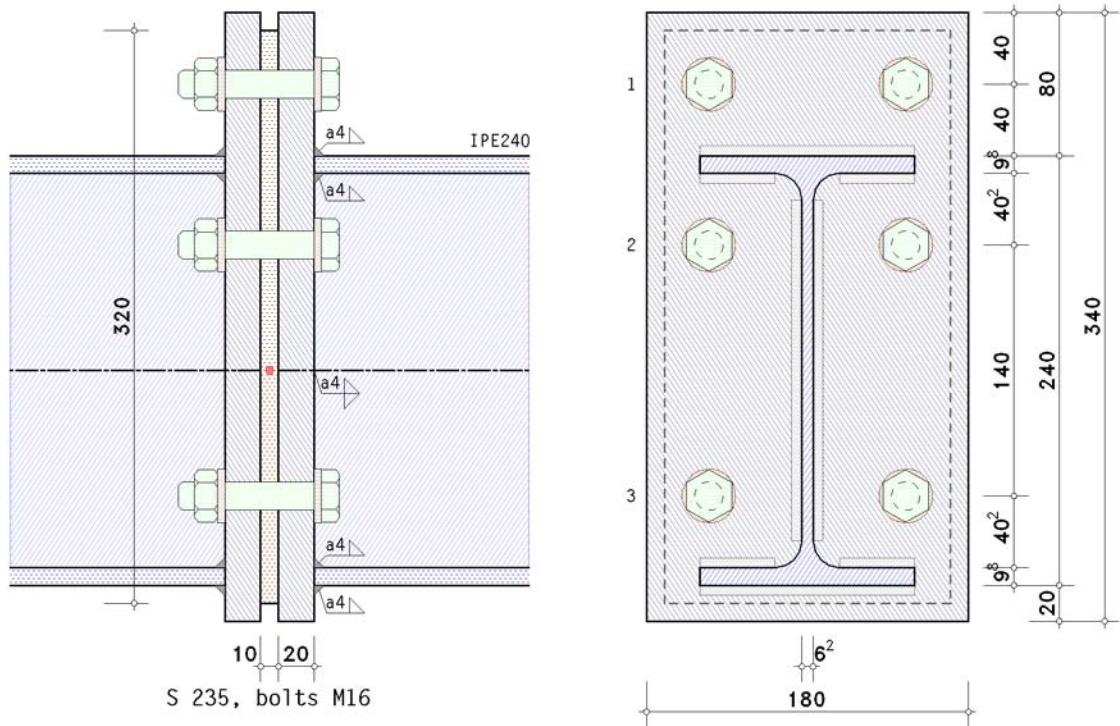
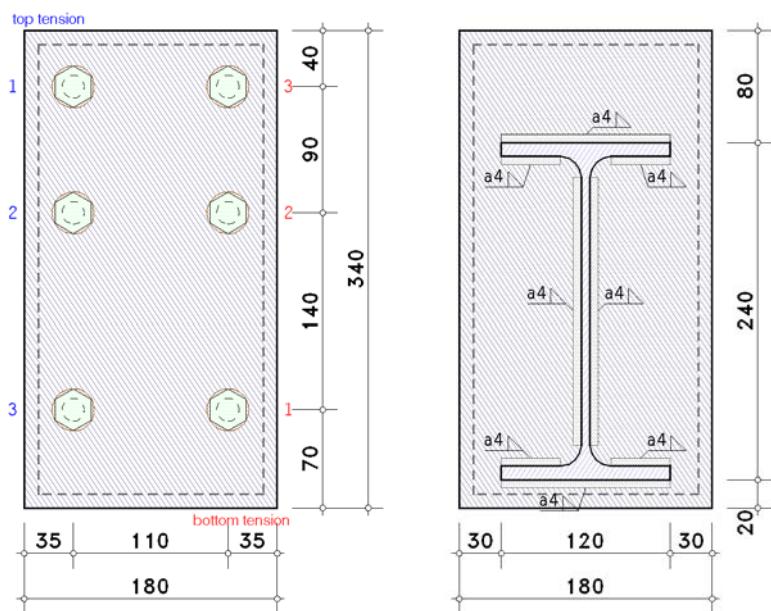


POS. 4: IMPORTBEISPIEL

rigid joint with thermal separation layer
EC 3-1-8 (12.10), NA: Deutschland



details



steel grade

steel grade S 235

beam parameters

section IPE240

bolts

bolt: bolt class 10.9, bolt size M16

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 $b_p = 180.0$ mm

projections $h_{p,o} = 80.0$ mm, $h_{p,u} = 20.0$ mm



thermal separation layer (Kerncompactlager of Calenberg Ingenieure GmbH):

thickness $t_e = 10.0 \text{ mm}$, length $l_e = 320.0 \text{ mm}$, width $b_e = 160.0 \text{ mm}$

safety factor of material $\gamma_e = 1.00$

bolts at the connection point:

3 bolt-row(s) with 2 bolts each

all bolt rows are considered individually

max. 2 bolt-rows top (M^+) in a group of bolts (rows 1-2)

and all bolt rows for shear transfer at tension top (rows 1-3)

no bolt rows bottom (M^-) in a group of bolts

and all bolt rows for shear transfer at tension bottom (rows 1-3)

centre distance of the bolts to the lateral edge of the end-plate $e_2 = 35.0 \text{ mm}$

centre distance of the first bolt-row to the upper edge of the end-plate (end row) $e_o = 40.0 \text{ mm}$

centre distance of the last bolt-row to the bottom edge of the end-plate (end row) $e_u = 70.0 \text{ mm}$

centre distance of the bolt-rows from each other $p_{1-2} = 90.0 \text{ mm}$, $p_{2-3} = 140.0 \text{ mm}$

welds at the connection point:

beam flange top: fillet weld, weld thickness $a = 4.0 \text{ mm}$

beam web: fillet weld, weld thickness $a = 4.0 \text{ mm}$

beam flange bottom: fillet weld, weld thickness $a = 4.0 \text{ mm}$

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

Lk 1: $N_{j,b1,Ed} = -20.61 \text{ kN}$ $M_{j,b1,Ed} = -16.76 \text{ kNm}$ $V_{j,b1,Ed} = 8.68 \text{ kN}$

Lk 2: $N_{j,b1,Ed} = -15.77 \text{ kN}$ $M_{j,b1,Ed} = -17.14 \text{ kNm}$ $V_{j,b1,Ed} = -2.71 \text{ kN}$

Lk 3: $N_{j,b1,Ed} = -21.38 \text{ kN}$ $M_{j,b1,Ed} = -16.72 \text{ kNm}$ $V_{j,b1,Ed} = 16.60 \text{ kN}$

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 $\gamma_{M7} = 1.10$

Component method

notes

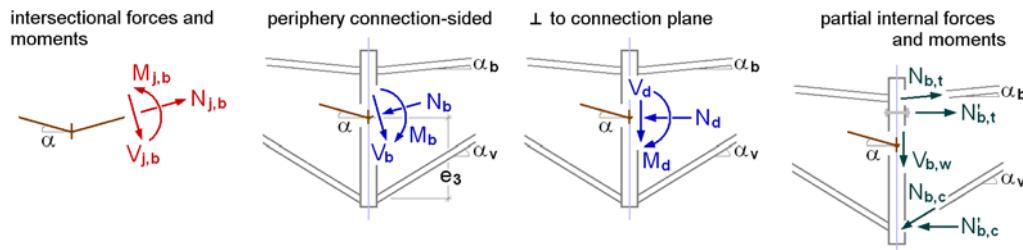
high strength bolts have to be controlled prestressed, bolt category D (tension), A (shear).

distances between bolt-rows at end-plate

| | |
|---|--|
| edge dist.: $e_2 = 35.0 \text{ mm} > 1.2 \cdot d_0 = 21.6 \text{ mm}$, | $e_2 = 35.0 \text{ mm} < 4 \cdot t_{min} + 40 \text{ mm} = 120.0 \text{ mm}$ |
| pitch: $p_2 = 110.0 \text{ mm} > 2.4 \cdot d_0 = 43.2 \text{ mm}$, | $p_2 = 110.0 \text{ mm} < \min(14 \cdot t_{min}, 200 \text{ mm}) = 200.0 \text{ mm}$ |
| edge dist.: $e_1 = 40.0 \text{ mm} > 1.2 \cdot d_0 = 21.6 \text{ mm}$, | $e_1 = 40.0 \text{ mm} < 4 \cdot t_1 + 40 \text{ mm} = 120.0 \text{ mm}$ |
| pitch: $p_1 = 90.0 \text{ mm} > 2.2 \cdot d_0 = 39.6 \text{ mm}$, | $p_1 = 90.0 \text{ mm} < \min(14 \cdot t_{min}, 200 \text{ mm}) = 200.0 \text{ mm}$ |
| pitch: $p_1 = 140.0 \text{ mm} > 2.2 \cdot d_0 = 39.6 \text{ mm}$, | $p_1 = 140.0 \text{ mm} < \min(14 \cdot t_{min}, 200 \text{ mm}) = 200.0 \text{ mm}$ |
| edge dist.: $e_1 = 70.0 \text{ mm} > 1.2 \cdot d_0 = 21.6 \text{ mm}$, | $e_1 = 70.0 \text{ mm} < 4 \cdot t_1 + 40 \text{ mm} = 120.0 \text{ mm}$ |

Lk 1:

design values



internal forces and moments in the periphery

$$N_{b,Ed} = -N_{j,b,Ed} = 20.61 \text{ kN}$$

$$M_{b,Ed} = -M_{j,b,Ed} - V_{j,b,Ed} \cdot e_1 = 16.71 \text{ kNm}, \quad e_1 = 5.0 \text{ mm}$$

$$V_{b,Ed} = V_{j,b,Ed} = 8.68 \text{ kN}$$

internal forces and moments perpendicular to the connection plane

$$N_d = N_{b,Ed} = 20.61 \text{ kN}$$

$$M_d = M_{b,Ed} = 16.71 \text{ kNm}$$

$$V_d = V_{b,Ed} = 8.68 \text{ kN}$$

partial internal forces and moments

internal forces and moments in the periphery end-plate-beam: $M'd = M_d - V_d \cdot t_{ep} = 16.54 \text{ kNm}$

$$N_{b,t} = -N_d \cdot z_{bu}/z_b + M'd/z_b = 61.54 \text{ kN}, \quad z_b = 230.2 \text{ mm}, \quad z_{bu} = 115.1 \text{ mm}$$

$$N_{b,c} = N_d \cdot z_{bo}/z_b + M'd/z_b = 82.15 \text{ kN}, \quad z_b = 230.2 \text{ mm}, \quad z_{bo} = 115.1 \text{ mm}$$

resistance of cross section

elastic cross-sectional check for $N = -20.61 \text{ kN}$, $M_y = -16.54 \text{ kNm}$, $V_z = 8.68 \text{ kN}$

valid normal-/shear stress: zul $\sigma_{Rd} = 23.50 \text{ kN/cm}^2$, zul $\tau_{Rd} = 13.57 \text{ kN/cm}^2$

top flange: design resistance forces $N_{max,O} = 276.36 \text{ kN}$, $N_{min,O} = -276.36 \text{ kN}$

bottom flange: design resistance forces $N_{max,U} = 276.36 \text{ kN}$, $N_{min,U} = -276.36 \text{ kN}$

web: shear force $V_s = 8.68 \text{ kN}$, shear stress $\tau_s = 0.61 \text{ kN/cm}^2 \Rightarrow U_{t,s} = 0.045$

design resistance forces $N_{max,S} = 335.06 \text{ kN}$, $N_{min,S} = -335.06 \text{ kN}$

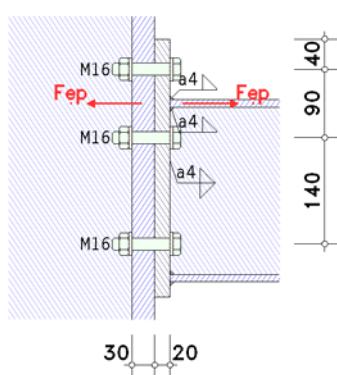
main bending: axial force $N = -20.61 \text{ kN}$, design resistance forces $N_{max} = 887.78 \text{ kN}$, $N_{min} = -887.78 \text{ kN} \Rightarrow U_N = 0.023$

moment $M_y = -16.54 \text{ kNm}$, design resistance moments $M_{y,max} = 82.83 \text{ kNm}$, $M_{y,min} = -82.83 \text{ kNm} \Rightarrow U_{My} = 0.200$

total (possibly due to load increase): max $U = 0.206 < 1$ **ok.**

basic components

basic component 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: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp}) = 90.0 \text{ mm}$, $l_{eff,cp} = 181.4 \text{ mm}$

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

design tension resistance of the T-stub flange:

in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma_M0 = 2.11 \text{ kNm}$

in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 226.08 \text{ kN}$

mode 1: complete yielding of the T-stub flange

$F_{T,1,Rd} = (8 \cdot n \cdot 2 \cdot e_w) \cdot M_{pl,1,Rd} / (2 \cdot m \cdot n \cdot e_w \cdot (m+n)) = 283.94 \text{ kN}$

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

$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 175.86 \text{ kN}$

mode 3: bolt failure

$F_{T,3,Rd} = \Sigma F_{t,Rd} = 226.08 \text{ kN}$

tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 175.86 \text{ kN}$

design resistances of welds: $f_{1,w,Rd} = 36.00 \text{ kN/cm}^2$, $f_{2,w,Rd} = 25.92 \text{ kN/cm}^2$

tension resistance of welds: $F_{T,w,Rd} = 2 \cdot f_{2,w,Rd} \cdot a \cdot l_{eff} = 186.62 \text{ kN}$ (not decisive)

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

$F_{t,ep,Rd,1} = 175.9 \text{ kN}$, ass. $l_{eff,1} = 90.0 \text{ mm}$

part of end-plate between beam flanges

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

here: number of bolt rows $n_b = 1$

row 2

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

in mode 1: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp}) = 260.6 \text{ mm}$, $l_{eff,cp} = 297.7 \text{ mm}$

in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc} = 260.6 \text{ mm}$

design tension resistance of the T-stub flange:

in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma_M0 = 6.12 \text{ kNm}$

in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 226.08 \text{ kN}$

mode 1: complete yielding of the T-stub flange

$F_{T,1,Rd} = (8 \cdot n \cdot 2 \cdot e_w) \cdot M_{pl,1,Rd} / (2 \cdot m \cdot n \cdot e_w \cdot (m+n)) = 601.33 \text{ kN}$

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

$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 244.73 \text{ kN}$

mode 3: bolt failure

$F_{T,3,Rd} = \Sigma F_{t,Rd} = 226.08 \text{ kN}$

tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 226.08 \text{ kN}$

design resistances of welds: $f_{1,w,Rd} = 36.00 \text{ kN/cm}^2$, $f_{2,w,Rd} = 25.92 \text{ kN/cm}^2$

tension resistance of welds: $F_{T,w,Rd} = 2 \cdot f_{2,w,Rd} \cdot a \cdot l_{eff} = 540.30 \text{ kN}$ (not decisive)

row 3

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



in mode 1: $\Sigma l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp}) = 260.6$ mm, $l_{eff,cp} = 297.7$ mm
 in mode 2: $\Sigma l_{eff,2} = l_{eff,nc} = 260.6$ mm

design tension resistance of the T-stub flange:

in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 6.12$ kNm

in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 226.08$ kN

mode 1: complete yielding of the T-stub flange

$F_{T,1,Rd} = (8 \cdot n \cdot 2 \cdot e_w) \cdot M_{pl,1,Rd} / (2 \cdot m \cdot n \cdot e_w \cdot (m+n)) = 601.33$ kN

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

$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 244.73$ kN

mode 3: bolt failure

$F_{T,3,Rd} = \Sigma F_{t,Rd} = 226.08$ kN

tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 226.08$ 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: $F_{T,w,Rd} = 2 \cdot f_{2,w,Rd} \cdot a \cdot l_{eff} = 540.30$ kN (not decisive)

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

$F_{ep,Rd,2} = 226.1$ kN, ass. $l_{eff,1} = 260.6$ mm

$F_{ep,Rd,3} = 226.1$ kN, ass. $l_{eff,1} = 260.6$ mm

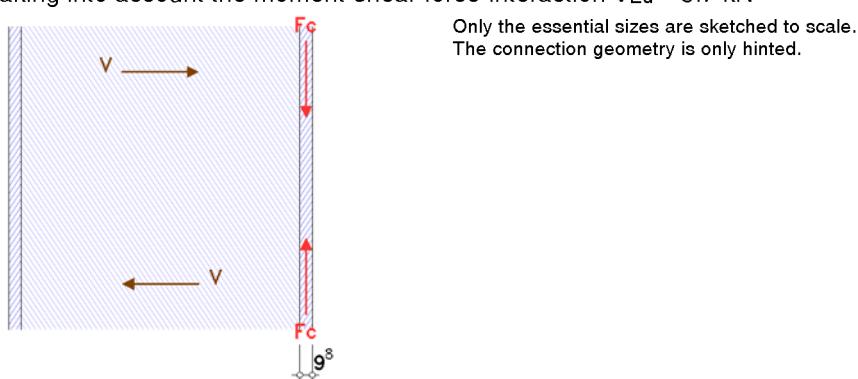
basic component 7: beam flange and web in compression

flange bottom: section class for $c/(s \cdot t) = 4.28$: 1

web: section class for $\alpha = 0.56$ and $c/(s \cdot t) = 30.71$: 1

section class of the beam in connection plane: 1

taking into account the moment-shear force-interaction $V_{Ed} = 8.7$ kN



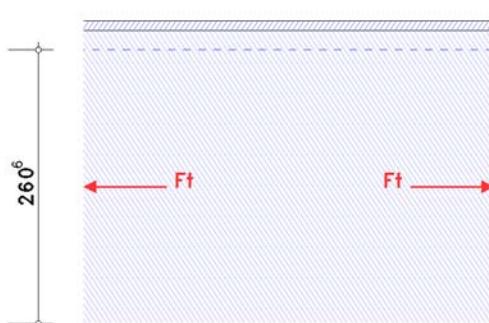
stress due to bending with shear force: $V_{Ed} = 8.7$ kN ≤ 129.9 kN $= V_{pl,Rd}/2 \Rightarrow$ no effect

moment resistance $M_{c,Rd} = M_{pl,Rd} = (W_{pl} \cdot f_y) / \gamma_{M0} = 86.24$ kNm

design resistance of flange and web in compression

$F_{c,f,Rd} = M_{c,Rd} / (h - t_f) = 374.65$ 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 2

effective width $b_{eff,t,wb} = 260.6$ mm (l_{eff} from bc 5)

design resistance of a beam web in tension

$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_y,wb / \gamma_{M0} = 379.6$ kN

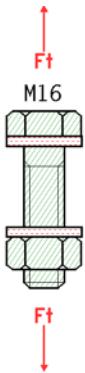
row 3

effective width $b_{eff,t,wb} = 260.6$ mm (l_{eff} from bc 5)

design resistance of a beam web in tension

$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_y,wb / \gamma_{M0} = 379.6$ kN

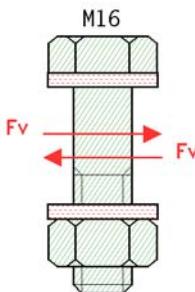
basic component 10: bolts in tension



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

tension resistance of one bolt: $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2} = 113.04 \text{ kN}$, $k_2 = 0.90$
p. sh. load capacity: $B_{p,Rd} = (0.6 \cdot \pi \cdot d_m \cdot t_p \cdot f_u) / \gamma_{M2} = 307.05 \text{ kN}$, $t_p = 20.0 \text{ mm}$
tension-/punching shear load capacity for 2 bolts: $\Sigma F_{tp,Rd} = 2 \cdot \min(F_{t,Rd}, B_{p,Rd}) = 226.08 \text{ kN}$

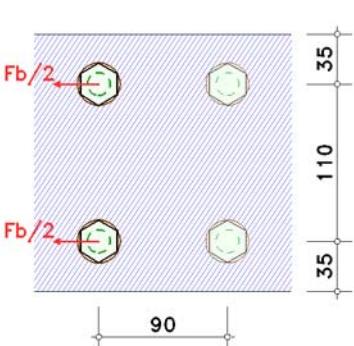
basic component 11: bolts in shear



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

design shear resistance per shear plane: $F_{v,Rd} = \alpha_v \cdot f_{ub} \cdot A / \gamma_{M2} = 96.51 \text{ kN}$, $\alpha_v = 0.60$
design shear resistance of 2 bolts (1-shear): $\Sigma F_{v,Rd} = 2 \cdot 1 \cdot F_{v,Rd} = 193.02 \text{ kN}$

basic component 12: bolts in bearing



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

row 1

bearing resistance: $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 170.67 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 0.74$

bearing resistance: $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 170.67 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 0.74$

design bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd} = 341.33 \text{ kN}$

shear block:

Versagensform 1: shear resistance $V_{eff,Rd} = (A_{nt} \cdot f_u) / \gamma_{M2} + (A_{nv} \cdot f_y / 3^{1/2}) / \gamma_{M0} = 698.16 \text{ kN}$

Versagensform 2: shear resistance $V_{eff,Rd} = (A_{nt} \cdot f_u) / \gamma_{M2} + (A_{nv} \cdot f_y / 3^{1/2}) / \gamma_{M0} = 467.76 \text{ kN}$

Versagensform 3: shear resistance $V_{eff,Rd} = (A_{nt} \cdot f_u) / \gamma_{M2} + (A_{nv} \cdot f_y / 3^{1/2}) / \gamma_{M0} = 829.44 \text{ kN}$

design bearing resistance einschl. shear block: $\min(\Sigma F_{b,Rd}, V_{eff,Rd}) = 341.3 \text{ kN}$

row 2

bearing resistance: $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 230.40 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 1.00$

bearing resistance: $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 230.40 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 1.00$

design bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd} = 460.80 \text{ kN}$

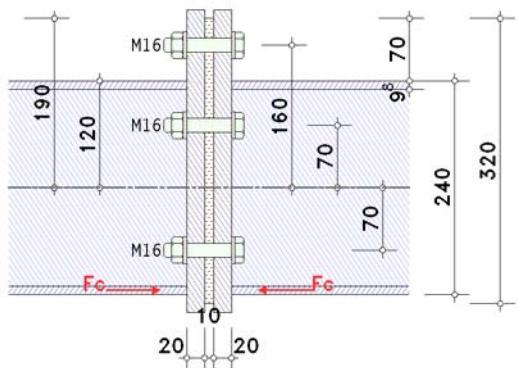
row 3

bearing resistance: $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 230.40 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 1.00$

bearing resistance: $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 230.40 \text{ kN}$, $k_1 = 2.50$, $\alpha_b = 1.00$

design bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd} = 460.80 \text{ kN}$

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 $h_m = 74.6 \text{ mm}$

mean compressive stress $\sigma_m = 5.50 \text{ N/mm}^2$

verification of the separation layer

shape factor $S = 1.962$ for 2 bolts in compression zone

permissible mean compressive stress $\sigma_{m,zul} = 9.73 \text{ N/mm}^2$

utilization of the separation layer $0.565 < 1$ **ok.**

verification of bolts:

shear force: $F_{Ed} = V_{Ed} / n_d = 4.3 \text{ kN}$

internal moment: $M_{Ed} = V_{Ed} \cdot t_e / n_d = 0.04 \text{ kNm}$

bolts have to be executed as threaded rods.

shear

design shear resistance per shear plane: $F_{v,Rd} = (0.5 \cdot f_{up} \cdot A) / \gamma_{M2} = 62.80 \text{ kN}$

$F_{v,Ed} = F_{Ed} = 4.3 \text{ kN} < F_{v,Rd} = 62.80 \text{ kN} \Rightarrow$ utilization $U = 0.069 < 1$ **ok.**

bending

bending resistance: $M_{Rd} = (0.9 \cdot f_{yp} \cdot W_{el}) / \gamma_{M0} = 0.225 \text{ kNm}$

$M_{Ed} = 0.04 \text{ kNm} < M_{Rd} = 0.225 \text{ kNm} \Rightarrow$ utilization $U = 0.193 < 1$ **ok.**

combination of shear and bending

$(F_{v,Ed}/F_{v,Rd})^2 + (M_{Ed}/M_{Rd})^2 = 0.042 < 1$ **ok.**

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

$F_{c,e,Rd} = A_{eff} \cdot f_e / \gamma_{Me} = 77.5 \text{ kN}, A_{eff} = 79.68 \text{ cm}^2, f_e = \sigma_{m,zul} = 9.73 \text{ N/mm}^2, \gamma_{Me} = 1.00$

connection design capacity

moment resistance

distance of tension-bolt-rows from centre of compression: $h_1 = 275.1 \text{ mm}, h_2 = 185.1 \text{ mm}, h_3 = 45.1 \text{ mm}$

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: $F_{tr,Rd} = 175.9 \text{ kN}$

row 2: $F_{tr,Rd} = 226.1 \text{ kN}$

row 3: $F_{tr,Rd} = 226.1 \text{ kN}$

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

decisive basic component: 7, 15

row 1: $\Sigma F_{tr,Rd} = 0.0 \text{ kN}$

Gk 7: $\Delta F_{tr,Rd} = F_{c,f,Rd} - \Sigma F_{tr,Rd} = 374.7 \text{ kN}$

Gk 15: $\Delta F_{tr,Rd} = F_{c,e,Rd} - \Sigma F_{tr,Rd} = 77.5 \text{ kN}$

row 2: $\Sigma F_{tr,Rd} = 77.5 \text{ kN}$ (row 1)

Gk 7: $\Delta F_{tr,Rd} = F_{c,f,Rd} - \Sigma F_{tr,Rd} = 297.1 \text{ kN}$

Gk 15: $\Delta F_{tr,Rd} = F_{c,e,Rd} - \Sigma F_{tr,Rd} = 0.0 \text{ kN}$

row 3: $\Sigma F_{tr,Rd} = 77.5 \text{ kN}$ (rows 1 bis 2)

Gk 7: $\Delta F_{tr,Rd} = F_{c,f,Rd} - \Sigma F_{tr,Rd} = 297.1 \text{ kN}$

Gk 15: $\Delta F_{tr,Rd} = F_{c,e,Rd} - \Sigma F_{tr,Rd} = 0.0 \text{ kN}$

$F_{tr,Rd} = 175.9 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 175.9 \text{ kN}$

$F_{tr,Rd} = 175.9 \text{ kN} > \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 77.5 \text{ kN}$

$F_{tr,Rd} = 226.1 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 226.1 \text{ kN}$

$F_{tr,Rd} = 226.1 \text{ kN} > \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 0.0 \text{ kN}$

$F_{tr,Rd} = 226.1 \text{ kN} < \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 226.1 \text{ kN}$

$F_{tr,Rd} = 226.1 \text{ kN} > \Delta F_{tr,Rd} \Rightarrow F_{tr,Rd} = 0.0 \text{ kN}$

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

decisive basic component: 10

row 1: $F_{tx,Rd} = 77.5 \text{ kN}, h_x = 275.1 \text{ mm} \Rightarrow F_{tx,Rd} \leq 0.95 \cdot \Sigma F_{tr,Rd} = 214.8 \text{ kN}$, no deduction

design resistance per bolt-row (finally)

row 1: $F_{tr,Rd} = 77.5 \text{ kN}$

row 2: $F_{tr,Rd} = 0.0 \text{ kN}$

row 3: $F_{tr,Rd} = 0.0 \text{ kN}$

potential failure by basic component 5, 15

moment resistance

$$M_{j,Rd} = \sum(F_{tr,Rd} \cdot h_r) = 21.3 \text{ kNm}$$

tension resistance

$$N_{j,Rd} = \sum F_{tr,Rd} = 77.5 \text{ kN}$$

compression resistance

$$N_{j,c,Rd} = \min F_{c,Rd} = 77.5 \text{ kN}$$

shear/design bearing resistance

design resistance per bolt-row

decisive basic components: 11, 12

row 1: $F_{vr,Rd} = 193.0 \text{ kN}$

row 2: $F_{vr,Rd} = 193.0 \text{ kN}$

row 3: $F_{vr,Rd} = 193.0 \text{ kN}$

deductions depending on tension force (at 100% utilization of moment resistance)

decisive basic component: 10

$$\Sigma F_{t,Rd} = 226.1 \text{ kN}$$

row 1: $F_{vr,Rd} = f_v \cdot 193.0 \text{ kN} = 145.7 \text{ kN}$ with $f_v = 1 - F_{tr,Rd} / (1.4 \cdot \Sigma F_{t,Rd}) = 0.755$

row 2: $F_{vr,Rd} = f_v \cdot 193.0 \text{ kN} = 193.0 \text{ kN}$ with $f_v = 1 - F_{tr,Rd} / (1.4 \cdot \Sigma F_{t,Rd}) = 1.000$

row 3: $F_{vr,Rd} = f_v \cdot 193.0 \text{ kN} = 193.0 \text{ kN}$ with $f_v = 1 - F_{tr,Rd} / (1.4 \cdot \Sigma F_{t,Rd}) = 1.000$

design resistance per bolt-row (finally)

row 1: $F_{vr,Rd} = 145.7 \text{ kN}$

row 2: $F_{vr,Rd} = 193.0 \text{ kN}$

row 3: $F_{vr,Rd} = 193.0 \text{ kN}$

shear/design bearing resistance

$$V_{j,Rd} = \Sigma F_{vr,Rd} = 531.8 \text{ kN}$$

total

$$N_{j,Rd} = 77.5 \text{ kN} \quad N_{j,c,Rd} = 77.5 \text{ kN} \quad M_{j,Rd} = 21.3 \text{ kNm} \quad V_{j,Rd} = 531.8 \text{ kN}$$

verifications

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

axial force: $N_{b,Ed} = |N|d = 20.61 \text{ kN} < 5\% \cdot N_{pl,Rd} = 45.96 \text{ kN} \Rightarrow$ moment resistance

internal moment: $M_{Ed} = M_d - N_d \cdot z_{bu} = 14.34 \text{ kNm}, z_{bu} = 115.1 \text{ mm}$

shear force: $V_{Ed} = |V|d = 8.68 \text{ kN}$

$M_{Ed}/M_{j,Rd} = 0.672 < 1$ **ok.**

$V_{Ed}/V_{j,Rd} = 0.016 < 1$ **ok.**

shear/design bearing resistance at 67.2% utilization of moment resistance $V_{j,Rd} = 547.3 \text{ kN}$

$V_{Ed}/V_{j,Rd} = 0.016 < 1$ **ok.**

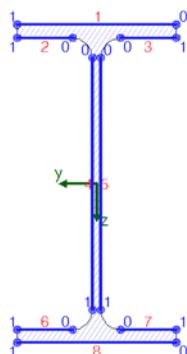
verification of welds at beam section

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: | $a_w = 4.0 \text{ mm}$ | $l_w = 120.0 \text{ mm}$ |
| weld 2: | $a_w = 4.0 \text{ mm}$ | $l_w = 41.9 \text{ mm}$ |
| weld 3: | siehe weld 2 | |
| weld 4: | $a_w = 4.0 \text{ mm}$ | $l_w = 190.4 \text{ mm}$ |
| weld 5: | siehe weld 4 | |
| weld 6: | $a_w = 4.0 \text{ mm}$ | $l_w = 41.9 \text{ mm}$ |
| weld 7: | siehe weld 6 | |
| weld 8: | $a_w = 4.0 \text{ mm}$ | $l_w = 120.0 \text{ mm}$ |

design values:

$$N_{Ed} = -20.61 \text{ kN}, M_{y,Ed} = -16.71 \text{ kNm}, V_{z,Ed} = 8.68 \text{ kN}$$

cross-sectional properties referring to centroid of the line cross section:

$$\Sigma A_w = 31.54 \text{ cm}^2, A_{w,z} = 15.23 \text{ cm}^2, \Sigma l_w = 78.8 \text{ cm}$$

$$I_{w,y} = 2656.70 \text{ cm}^4, I_{w,z} = 228.70 \text{ cm}^4, \Delta z_w = 0.0 \text{ mm}$$

member forces distributed to the individual welds:

weld 1: $N_w = 33.10 \text{ kN}$



weld 2: $N_w = 10.52 \text{ kN}$
weld 4: $N_w = -4.98 \text{ kN}$ $M_{y,w} = -1.45 \text{ kNm}$
weld 6: $N_w = -12.71 \text{ kN}$
weld 8: $N_w = -39.37 \text{ kN}$

verifications in the edge points of the individual welds:

| | |
|---|--|
| weld 1, pt. 0: $\sigma_{w,x} = 68.96 \text{ N/mm}^2$ | $\Rightarrow U_w = 0.271 < 1$ ok. |
| weld 2, pt. 0: $\sigma_{w,x} = 62.79 \text{ N/mm}^2$ | $\Rightarrow U_w = 0.247 < 1$ ok. |
| weld 4, pt. 0: $\sigma_{w,x} = 53.35 \text{ N/mm}^2$ $\tau_{w,z} = 5.70 \text{ N/mm}^2$ | $\Rightarrow U_w = 0.211 < 1$ ok. |
| pt. 1: $\sigma_{w,x} = -66.43 \text{ N/mm}^2$ $\tau_{w,z} = 5.70 \text{ N/mm}^2$ | $\Rightarrow U_w = 0.262 < 1$ ok. |
| weld 6, pt. 0: $\sigma_{w,x} = -75.86 \text{ N/mm}^2$ | $\Rightarrow U_w = 0.298 < 1$ ok. |
| weld 8, pt. 0: $\sigma_{w,x} = -82.03 \text{ N/mm}^2$ | $\Rightarrow U_w = 0.322 < 1$ ok. |

Result:

weld 8, pt. 0: $\sigma_{w,x} = -82.03 \text{ N/mm}^2$
Max: $\sigma_{1,w,Ed} = 11.60 \text{ kN/cm}^2 < f_{1,w,Rd} = 36.00 \text{ kN/cm}^2$,
 $\sigma_{2,w,Ed} = 5.80 \text{ kN/cm}^2 < f_{2,w,Rd} = 25.92 \text{ kN/cm}^2 \Rightarrow U_w = 0.322 < 1$ **ok.**

verification result

maximum utilization: max $U = 0.672 < 1$ **ok.**

Lk 2:

reduced output, calculation process see Lk 1

design values

$$\begin{aligned} N_d &= N_b,Ed = 15.77 \text{ kN} \\ M_d &= M_b,Ed = 17.16 \text{ kNm} \\ V_d &= V_b,Ed = -2.71 \text{ kN} \\ N_{b,t} &= -N_d \cdot z_{bu}/z_b + M'd/z_b = 66.89 \text{ kN} \\ N_{b,c} &= N_d \cdot z_{bo}/z_b + M'd/z_b = 82.66 \text{ kN} \end{aligned}$$

resistance of cross section

total (possibly due to load increase): max $U = 0.211 < 1$ **ok.**

basic components

Gk 5: end-plate in bending

design resistances of welds: $f_{1,w,Rd} = 36.00 \text{ kN/cm}^2$, $f_{2,w,Rd} = 25.92 \text{ kN/cm}^2$
design resistance and effective length of end-plate in bending (projection)

$$F_{t,ep,Rd,1} = 175.9 \text{ kN}, \text{ ass. } l_{eff,1} = 90.0 \text{ mm}$$

design resistances of welds: $f_{1,w,Rd} = 36.00 \text{ kN/cm}^2$, $f_{2,w,Rd} = 25.92 \text{ kN/cm}^2$

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

$$F_{ep,Rd,2} = 226.1 \text{ kN}, \text{ ass. } l_{eff,1} = 260.6 \text{ mm}$$

$$F_{ep,Rd,3} = 226.1 \text{ kN}, \text{ ass. } l_{eff,1} = 260.6 \text{ mm}$$

Gk 7: beam flange and web in compression

$V_{Ed} = 2.7 \text{ kN} \leq 129.9 \text{ kN} = V_{pl,Rd}/2 \Rightarrow$ no effect

design resistance of flange and web in compression

$$F_{c,f,Rd} = M_{c,Rd} / (h - t_f) = 374.65 \text{ kN}$$

Gk 8: beam web in tension

design resistance of a beam web in tension (per bolt-row)

$$F_{t,wb,Rd,1} = 379.6 \text{ kN}, \text{ b}_{eff,t} = 90.0 \text{ mm (s. Gk 5)}$$

$$F_{t,wb,Rd,2} = 379.6 \text{ kN}, \text{ b}_{eff,t} = 260.6 \text{ mm (s. Gk 5)}$$

$$F_{t,wb,Rd,3} = 379.6 \text{ kN}, \text{ b}_{eff,t} = 260.6 \text{ mm (s. Gk 5)}$$

Gk 10: bolts in tension

tension resistance of one bolt-row: $\Sigma F_{t,Rd} = 226.1 \text{ kN}$

Gk 11: bolts in shear

design shear resistance of one bolt-row: $\Sigma F_{v,Rd} = 193.0 \text{ kN}$

Gk 12: bolts in bearing

$$\Sigma F_{b,Rd} = 460.8 \text{ kN}$$

$$\Sigma F_{b,Rd} = 460.8 \text{ kN}$$

$$\Sigma F_{b,Rd} = 460.8 \text{ kN}$$

Gk 15: end-plate with Trennschicht

calculation is for Kerncompactlager of Calenberg Ingenieure GmbH.

$\sigma_m/\sigma_{m,zul} = 0.606 < 1$ **ok.**

verification of bolts:

bolts have to be executed as threaded rods.

shear

$F_{v,Ed} = F_{Ed} = 1.4 \text{ kN} < F_{v,Rd} = 62.80 \text{ kN} \Rightarrow \text{utilization } U = 0.022 < 1$ **ok.**

bending

$M_{Ed} = 0.01 \text{ kNm} < M_{Rd} = 0.225 \text{ kNm} \Rightarrow \text{utilization } U = 0.060 < 1$ **ok.**

combination of shear and bending

$(F_{v,Ed}/F_{v,Rd})^2 + (M_{Ed}/M_{Rd})^2 = 0.004 < 1$ **ok.**

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

$F_{c,e,Rd} = A_{eff} \cdot f_e / \gamma_{Me} = 74.3 \text{ kN}$

connection design capacity

moment resistance

$M_{j,Rd} = \sum(F_{tr,Rd} \cdot h_r) = 20.4 \text{ kNm}$

tension resistance

$N_{j,Rd} = \sum F_{tr,Rd} = 74.3 \text{ kN}$

compression resistance

$N_{j,c,Rd} = \min F_{c,Rd} = 74.3 \text{ kN}$

shear/design bearing resistance

$V_{j,Rd} = \sum F_{vr,Rd} = 533.8 \text{ kN}$

total

$N_{j,Rd} = 74.3 \text{ kN} \quad N_{j,c,Rd} = 74.3 \text{ kN} \quad M_{j,Rd} = 20.4 \text{ kNm} \quad V_{j,Rd} = 533.8 \text{ kN}$

verifications

verification of connection design capacity

$N_{b,Ed} = 15.77 \text{ kN} < 5\% \cdot N_{pl,Rd}$

$M_{Ed} = M_d - N_d \cdot z_{bu} = 15.34 \text{ kNm}$

$V_{Ed} = |V_d| = 2.71 \text{ kN}$

$M_{Ed}/M_{j,Rd} = 0.751 < 1$ **ok.**

$V_{Ed}/V_{j,Rd} = 0.005 < 1$ **ok.**

shear/design bearing resistance at 75.1% utilization of moment resistance $V_{j,Rd} = 545.0 \text{ kN}$

$V_{Ed}/V_{j,Rd} = 0.005 < 1$ **ok.**

verification of welds at beam section

Max: $\sigma_{1,w,Ed} = 11.67 \text{ kN/cm}^2 < f_{1,w,Rd} = 36.00 \text{ kN/cm}^2$,

$\sigma_{2,w,Ed} = 5.83 \text{ kN/cm}^2 < f_{2,w,Rd} = 25.92 \text{ kN/cm}^2 \Rightarrow U_w = 0.324 < 1$ **ok.**

verification result

maximum utilization: max $U = 0.751 < 1$ **ok.**

Lk 3:

reduced output, calculation process see Lk 1

design values

$N_d = N_{b,Ed} = 21.38 \text{ kN}$

$M_d = M_{b,Ed} = 16.63 \text{ kNm}$

$V_d = V_{b,Ed} = 16.60 \text{ kN}$

$N_{b,t} = -N_d \cdot z_{bu}/z_b + M_d/z_b = 60.12 \text{ kN}$

$N_{b,c} = N_d \cdot z_{bo}/z_b + M_d/z_b = 81.50 \text{ kN}$

resistance of cross section

total (possibly due to load increase): max $U = 0.207 < 1$ **ok.**



basic components

Gk 5: end-plate in bending

design resistances of welds: $f_{1,w,Rd} = 36.00 \text{ kN/cm}^2$, $f_{2,w,Rd} = 25.92 \text{ kN/cm}^2$

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

$F_{t,ep,Rd,1} = 175.9 \text{ kN}$, ass. $l_{eff,1} = 90.0 \text{ mm}$

design resistances of welds: $f_{1,w,Rd} = 36.00 \text{ kN/cm}^2$, $f_{2,w,Rd} = 25.92 \text{ kN/cm}^2$

design resistances of welds: $f_{1,w,Rd} = 36.00 \text{ kN/cm}^2$, $f_{2,w,Rd} = 25.92 \text{ kN/cm}^2$

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

$F_{ep,Rd,2} = 226.1 \text{ kN}$, ass. $l_{eff,1} = 260.6 \text{ mm}$

$F_{ep,Rd,3} = 226.1 \text{ kN}$, ass. $l_{eff,1} = 260.6 \text{ mm}$

Gk 7: beam flange and web in compression

$V_{Ed} = 16.6 \text{ kN} \leq 129.9 \text{ kN} = V_{pl,Rd}/2 \Rightarrow \text{no effect}$

design resistance of flange and web in compression

$F_{c,f,Rd} = M_{c,Rd} / (h - t_f) = 374.65 \text{ kN}$

Gk 8: beam web in tension

design resistance of a beam web in tension (per bolt-row)

$F_{t,wb,Rd,1} = 379.6 \text{ kN}$, $b_{eff,t} = 90.0 \text{ mm}$ (s. Gk 5)

$F_{t,wb,Rd,2} = 379.6 \text{ kN}$, $b_{eff,t} = 260.6 \text{ mm}$ (s. Gk 5)

$F_{t,wb,Rd,3} = 379.6 \text{ kN}$, $b_{eff,t} = 260.6 \text{ mm}$ (s. Gk 5)

Gk 10: bolts in tension

tension resistance of one bolt-row: $\Sigma F_{t,Rd} = 226.1 \text{ kN}$

Gk 11: bolts in shear

design shear resistance of one bolt-row: $\Sigma F_{v,Rd} = 193.0 \text{ kN}$

Gk 12: bolts in bearing

$\Sigma F_{b,Rd} = 341.3 \text{ kN}$

$\Sigma F_{b,Rd} = 460.8 \text{ kN}$

$\Sigma F_{b,Rd} = 460.8 \text{ kN}$

Gk 15: end-plate with Trennschicht

calculation is for Kerncompactlager of Calenberg Ingenieure GmbH.

$\sigma_m/\sigma_{m,zul} = 0.559 < 1$ **ok.**

verification of bolts:

bolts have to be executed as threaded rods.

shear

$F_{v,Ed} = F_{Ed} = 8.3 \text{ kN} < F_{v,Rd} = 62.80 \text{ kN} \Rightarrow \text{utilization } U = 0.132 < 1$ **ok.**

bending

$M_{Ed} = 0.08 \text{ kNm} < M_{Rd} = 0.225 \text{ kNm} \Rightarrow \text{utilization } U = 0.369 < 1$ **ok.**

combination of shear and bending

$(F_{v,Ed}/F_{v,Rd})^2 + (M_{Ed}/M_{Rd})^2 = 0.154 < 1$ **ok.**

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

$F_{c,e,Rd} = A_{eff} \cdot f_e / \gamma_{Me} = 78.1 \text{ kN}$

connection design capacity

moment resistance

$M_{j,Rd} = \Sigma (F_{tr,Rd} \cdot h_r) = 21.5 \text{ kNm}$

tension resistance

$N_{j,Rd} = \Sigma F_{tr,Rd} = 78.1 \text{ kN}$

compression resistance

$N_{j,c,Rd} = \min F_{c,Rd} = 78.1 \text{ kN}$

shear/design bearing resistance

$V_{j,Rd} = \Sigma F_{vr,Rd} = 531.5 \text{ kN}$

total

$N_{j,Rd} = 78.1 \text{ kN}$ $N_{j,c,Rd} = 78.1 \text{ kN}$ $M_{j,Rd} = 21.5 \text{ kNm}$ $V_{j,Rd} = 531.5 \text{ kN}$

verifications

verification of connection design capacity

$N_{b,Ed} = 21.38 \text{ kN} < 5\% \cdot N_{pl,Rd}$

$M_{Ed} = M_d - N_d \cdot z_{bu} = 14.17 \text{ kNm}$

$V_{Ed} = |V_d| = 16.60 \text{ kN}$

$M_{Ed}/M_{j,Rd} = 0.660 < 1$ **ok.**

$V_{Ed}/V_{j,Rd} = 0.031 < 1$ **ok.**

shear/design bearing resistance at 66.0% utilization of moment resistance $V_{j,Rd} = 547.6 \text{ kN}$

$V_{Ed}/V_{j,Rd} = 0.030 < 1$ **ok.**

verification of welds at beam section



Max: $\sigma_{1,w,Ed} = 11.58 \text{ kN/cm}^2 < f_{1,w,Rd} = 36.00 \text{ kN/cm}^2$,
 $\sigma_{2,w,Ed} = 5.79 \text{ kN/cm}^2 < f_{2,w,Rd} = 25.92 \text{ kN/cm}^2 \Rightarrow U_w = 0.322 < 1 \text{ ok.}$

verification result

maximum utilization: max $U = 0.660 < 1 \text{ ok.}$

Final Result

maximum utilization [Lk 2]: max $U = 0.751 < 1 \text{ ok.}$

verification succeeded

Regulations

DIN EN 1990, Eurocode 0: Grundlagen der Tragwerksplanung;
Deutsche Fassung EN 1990:2002 + A1:2005 + A1:2005/AC:2010, Ausgabe Dezember 2010
DIN EN 1990/NA, Nationaler Anhang zur DIN EN 1990, Ausgabe Dezember 2010

DIN EN 1993-1-1, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -
Teil 1-1: Allgemeine Bemessungsregeln und Regeln für den Hochbau;
Deutsche Fassung EN 1993-1-1:2005 + AC:2009, Ausgabe Dezember 2010
DIN EN 1993-1-1/NA, Nationaler Anhang zur DIN EN 1993-1-1, Ausgabe Dezember 2010

DIN EN 1993-1-8, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -
Teil 1-8: Bemessung von Anschlüssen;
Deutsche Fassung EN 1993-1-8:2005 + AC:2009, Ausgabe Dezember 2010
DIN EN 1993-1-8/NA, Nationaler Anhang zur DIN EN 1993-1-8, Ausgabe Dezember 2010

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