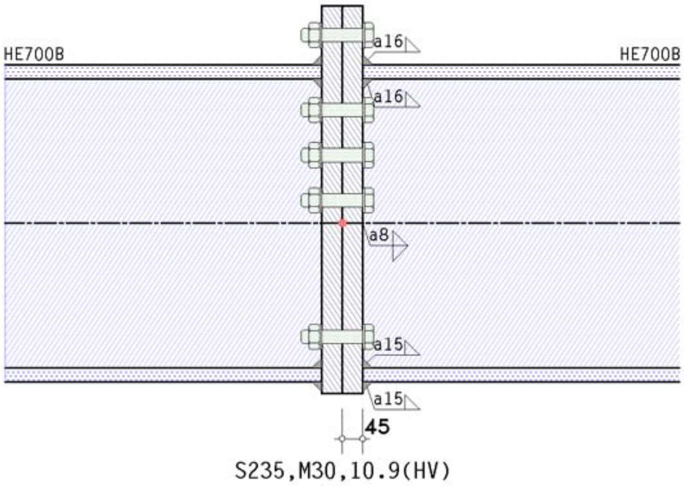
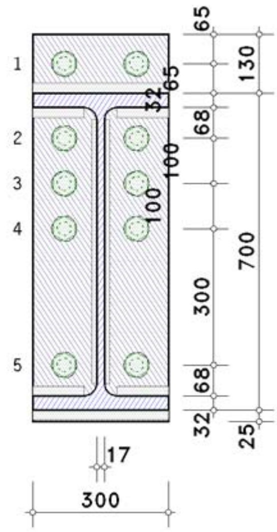
POS. 78: DAST IM 11436

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

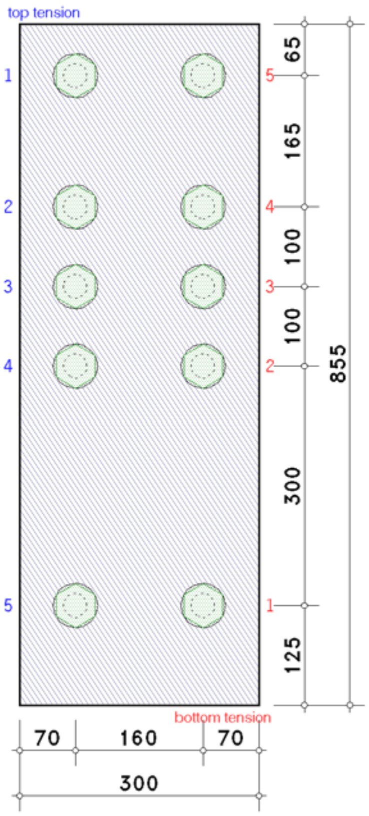
Rigid beam splice EC 3-1-8 (12.10), NA: Deutschland

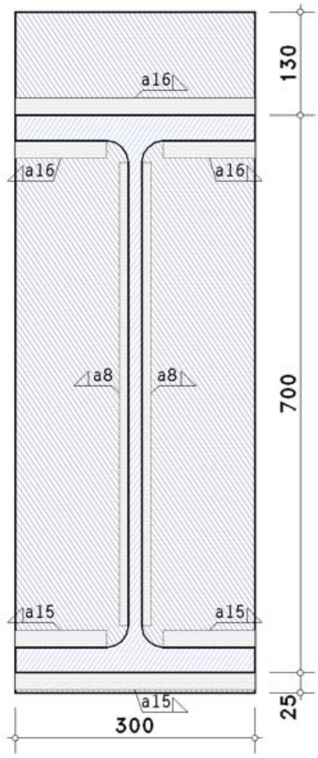
1. input report





details (section A - A)



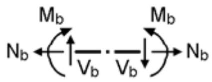


steel grade
steel grade S235
bolts
bolt class 10.9, bolt size M30
large wrench size (high strength bolt), preloaded (for info: preloading $F_{p,C}^{*} = 0.7 \cdot f_{yb} \cdot A_s = 353.4$ kN)
shear plane passes through the unthreaded portion of the bolt
beam parameters
section HE700B
verification parameters
bolted end-plate connection:
thickness $t_p = 45.0$ mm, width $b_p = 300.0$ mm, length $l_p = 855.0$ mm
projections $h_{p,o} = 130.0$ mm, $h_{p,u} = 25.0$ mm
bolts in connection:

5 bolt-rows with 2 bolts
all bolt-rows considered individually
all bolt-rows for shear transfer (rows 1-5)
bolt groups generated automatically, considering all groups bzgl. row 1
verification with der Component method: MNV-interaction acc. to Cerfontaine (in Jaspart/Weynand)
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 = 65.0 mm
centre distance of the last bolt-row to the bottom edge of the end-plate (end row) e_u = 125.0 mm
centre distance of the bolt-rows from each other $p_{1\text{-}2}$ = 165.0 mm, $p_{2\text{-}3}$ = 100.0 mm, $p_{3\text{-}4}$ = 100.0 mm
$p_{4\text{-}5}$ = 300.0 mm

welds at the connection point:
beam flange top: fillet weld, weld thickness a = 15.5 mm
beam web: fillet weld, weld thickness a = 8.0 mm
beam flange bottom: fillet weld, weld thickness a = 15.0 mm

internal forces and moments in the intersection point of system axes



Lk 1: $M_{j,b,Ed}$ = -1500.00 kNm $V_{j,b,Ed}$ = 900.00 kN
Lk 2: $M_{j,b,Ed}$ = 600.00 kNm $V_{j,b,Ed}$ = 900.00 kN
Lk 3: $N_{j,b,Ed}$ = 2000.00 kN
Lk 4: $N_{j,b,Ed}$ = -5700.00 kN

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

check of data
ok

utilizations

Lk	$U_{\sigma,b}$	U_{MNV}	U_{ep}	U_{sb}	U
--	---	---	---	---	---
1	0.807	0.953	0.465	0.997	0.997*
2	0.587	0.938	0.465	0.571	0.938
3	0.279	0.799	---	0.309	0.799
4	0.794	0.973	---	0.880	0.973

$U_{\sigma,b}$: stress utilization at the beam; U_{MNV}: utilization due to MNV-interaction; U_{pl}: utilization due to shear in end-plate
U_{sb}: utilization due to weld; U: utilization of the connection
*) maximum utilization

2. final result

utilization/rotation of the connection

Lk	$S_{j,ini}$	S_j	φ_j	U_j	Gleichgewicht			
					ΣH	ΣV	ΣM	
--	MNm/rad	MNm/rad	°		kN	kN	kNm	
1	1782.1	1782.1	0.048	0.997*	0.00	900.00	1500.00	!!
2	642.6	642.6	0.053	0.938	0.00	900.00	600.00	!!
3	0.0	0.0	0	0.799	2000.00	0.00	0.00	!!
4	0.0	0.0	0	0.973	5700.00	0.00	0.00	!!

$S_{j,ini}$: initial rotational stiffness; S_j: rotational stiffness; φ_j: rotation; U_j: utilization of the connection; tolerances of equilibrium 1 kN / 1 kNm
*) maximum utilization

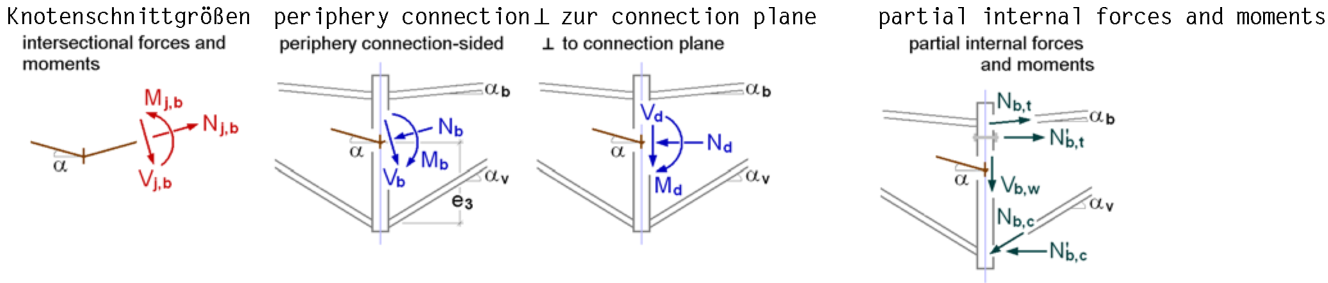
maximum utilization [Lk 1]: max U = 0.997 < 1 ok

verification succeeded

3. Detailed edition of Lk 1 (decisive)

notes
connection is verified due to EC 3-1-8 regardless of preloading.
however, connections may be constructed with prestressed high strength bolts.
the welds are not regarded by calculation the T-stub resistance.
simplified calculation of shear force resistance takes all bolt-rows into account.

3.1. design values



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

internal forces and moments perpendicular to the connection planes

periphery beam

M_d = 1500.00 kNm, V_d = 900.00 kN

partial internal forces and moments

internal forces and moments in the periphery end-plate-beam: $M'_d = M_d - V_d \cdot t_{ep}$ = 1459.50 kNm

$N_{b,t} = -N_d \cdot z_{bu}/z_b + M'_d/z_b$ = 2184.88 kN, z_b = 668.0 mm, z_{bu} = 334.0 mm

$N_{b,c} = N_d \cdot z_{bo}/z_b + M'_d/z_b$ = 2184.88 kN, z_b = 668.0 mm, z_{bo} = 334.0 mm

3.2. resistance of cross-section

plastic cross-sectional check for M_y = -1459.50 kNm, V_z = 900.00 kN

valid normal/shear stress: zul σ_{Rd} = 23.50 kN/cm², zul τ_{Rd} = 13.57 kN/cm²

top flange: resistance forces $N_{max,O}$ = 2256.00 kN, $N_{min,O}$ = -2256.00 kN

bottom flange: resistance forces $N_{max,U}$ = 2256.00 kN, $N_{min,U}$ = -2256.00 kN

web: shear force V_S = 900.00 kN, shear stress τ_S = 7.93 kN/cm² $\Rightarrow$ $U_{\tau,S}$ = 0.584

resistance forces $N_{max,S}$ = 2166.04 kN, $N_{min,S}$ = -2166.04 kN

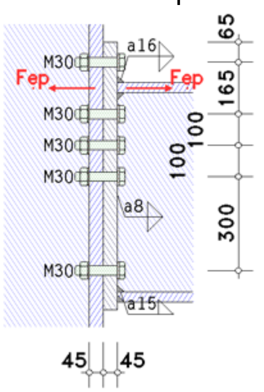
main bending: moment M_y = -1459.50 kNm, resistance moments $M_{y,max}$ = 1868.74 kNm, $M_{y,min}$ = -1868.74 kNm $\Rightarrow$ U_{My} = 0.781

total (possibly due to load increase): max U = 0.807 $<$ 1 ok

utilizations: resistance U_σ = 0.807 $<$ 1 ok, c/t-ratio $U_{c/t}$ = 0.233 $<$ 1 ok

3.3. basic components

3.3.1. 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 (n_b = 1).

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

in mode 1: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp})$ = 150.0 mm, $l_{eff,cp}$ = 289.1 mm

in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc}$ = 150.0 mm

tension resistance of the T-stub flange:

in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma_{M0}$ = 16.33 kNm

in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd}$ = 807.84 kN

mode 1: complete yielding of the T-stub flange

$F_{T,1,Rd} = ((8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}) / (2 \cdot m \cdot n - e_w \cdot (m+n))$ = 1762.68 kN

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

$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n)$ = 754.56 kN

mode 3: bolt failure

$F_{T,3,Rd} = \Sigma F_{t,Rd}$ = 807.84 kN

tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd})$ = 754.56 kN

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

$F_{t,ep,Rd,1}$ = 754.56 kN, $l_{eff,1}$ = 150.0 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: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp})$ = 384.8 mm, $l_{eff,cp}$ = 392.4 mm

in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc}$ = 384.8 mm tension resistance of the T-stub flange:

in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 41.89$ kNm

in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 807.84$ kN

mode 1: complete yielding of the T-stub flange

$F_{T,1,Rd} = ((8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}) / (2 \cdot m \cdot n - e_w \cdot (m+n)) = 3235.01$ kN

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

$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 1059.47$ kN

mode 3: bolt failure

$F_{T,3,Rd} = \Sigma F_{t,Rd} = 807.84$ kN

tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 807.84$ kN

row 3

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

in mode 1: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp}) = 337.3$ mm, $l_{eff,cp} = 392.4$ mm

in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc} = 337.3$ mm

tension resistance of the T-stub flange:

in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 36.71$ kNm

in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 807.84$ kN

mode 1: complete yielding of the T-stub flange

$F_{T,1,Rd} = ((8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}) / (2 \cdot m \cdot n - e_w \cdot (m+n)) = 2835.29$ kN

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

$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 981.31$ kN

mode 3: bolt failure

$F_{T,3,Rd} = \Sigma F_{t,Rd} = 807.84$ kN

tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 807.84$ kN

row 4

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

in mode 1: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp}) = 337.3$ mm, $l_{eff,cp} = 392.4$ mm

in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc} = 337.3$ mm

tension resistance of the T-stub flange:

in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 36.71$ kNm

in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 807.84$ kN

mode 1: complete yielding of the T-stub flange

$F_{T,1,Rd} = ((8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}) / (2 \cdot m \cdot n - e_w \cdot (m+n)) = 2835.29$ kN

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

$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 981.31$ kN

mode 3: bolt failure

$F_{T,3,Rd} = \Sigma F_{t,Rd} = 807.84$ kN

tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 807.84$ kN

row 5

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

in mode 1: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp}) = 384.8$ mm, $l_{eff,cp} = 392.4$ mm

in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc} = 384.8$ mm

tension resistance of the T-stub flange:

in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 41.89$ kNm

in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 807.84$ kN

mode 1: complete yielding of the T-stub flange

$F_{T,1,Rd} = ((8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}) / (2 \cdot m \cdot n - e_w \cdot (m+n)) = 3235.01$ kN

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

$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 1059.47$ kN

mode 3: bolt failure

$F_{T,3,Rd} = \Sigma F_{t,Rd} = 807.84$ kN

tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 807.84$ kN

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

$F_{ep,Rd,2} = 807.84$ kN, $l_{eff,2} = 384.8$ mm

$F_{ep,Rd,3} = 807.84$ kN, $l_{eff,3} = 337.3$ mm

$F_{ep,Rd,4} = 807.84$ kN, $l_{eff,4} = 337.3$ mm

$F_{ep,Rd,5} = 807.84$ kN, $l_{eff,5} = 384.8$ mm

equivalent T-stub flange (group of bolts 1):

here: number of bolt-rows $n_b = 2$

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

in mode 1: $\Sigma l_{eff,1} = \min(\Sigma l_{eff,nc}, \Sigma l_{eff,cp}) = 484.8$ mm, $\Sigma l_{eff,cp} = 592.4$ mm

in mode 2: $\Sigma l_{eff,2} = \Sigma l_{eff,nc} = 484.8$ mm

tension resistance of the T-stub flange:

in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 52.77$ kNm

in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 1615.68$ kN

mode 1: complete yielding of the T-stub flange

$F_{T,1,Rd} = ((8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}) / (2 \cdot m \cdot n - e_w \cdot (m+n)) = 4075.60$ kN

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

$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 1650.77$ kN

mode 3: bolt failure

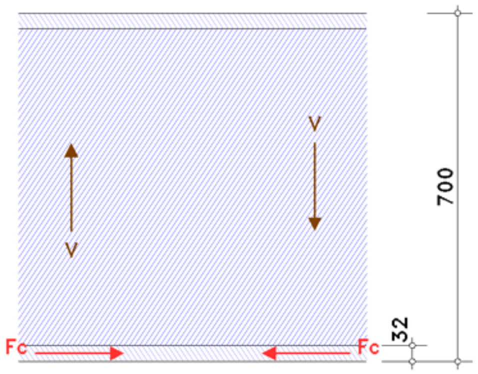
$F_{T,3,Rd} = \Sigma F_{t,Rd} = 1615.68$ kN

tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 1615.68$ kN

equivalent T-stub flange (group of bolts 2):
here: number of bolt-rows $n_b = 3$
effective length of the T-stub flange (end-plate):
in mode 1: $\Sigma l_{eff,1} = \min(\Sigma l_{eff,nc}, \Sigma l_{eff,cp}) = 584.8$ mm, $\Sigma l_{eff,cp} = 792.4$ mm
in mode 2: $\Sigma l_{eff,2} = \Sigma l_{eff,nc} = 584.8$ mm
tension resistance of the T-stub flange:
in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 63.66$ kNm
in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 2423.52$ kN
mode 1: complete yielding of the T-stub flange
$F_{T,1,Rd} = ((8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}) / (2 \cdot m \cdot n - e_w \cdot (m+n)) = 4916.19$ kN
mode 2: bolt failure simultaneously with yielding of the T-stub flange
$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 2242.07$ kN
mode 3: bolt failure
$F_{T,3,Rd} = \Sigma F_{t,Rd} = 2423.52$ kN
tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 2242.07$ kN
equivalent T-stub flange (group of bolts 3):
here: number of bolt-rows $n_b = 4$
distance between bolt-rows too big ($p_{4\text{-}3} = 100.0$ mm, $p_{4\text{-}5} = 300.0$ mm) $\Rightarrow$ group closed
resistances and effective lengths of end-plate in bending (per bolt group):
$F_{ep,Rd,2\text{-}3} = 1615.68$ kN, $\Sigma l_{eff} = 484.8$ mm, 2 rows
$F_{ep,Rd,2\text{-}4} = 2242.07$ kN, $\Sigma l_{eff} = 584.8$ mm, 3 rows

3.3.2. Gk 7: beam flange and web in compression

flange bottom: section class for $c/(\varepsilon \cdot t) = 3.58$: 1
web: section class for $\alpha = 0.50$ and $c/(\varepsilon \cdot t) = 34.24$: 1
section class of beam: 1
taking into account the moment-shear force-interaction $V_{Ed} = 900.0$ kN

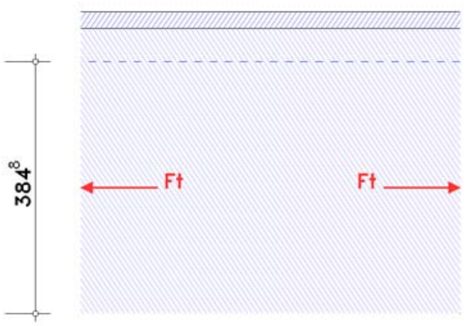


Only the essential sizes are sketched to scale.
The connection geometry is only hinted.

stress due to bending with shear force: $V_{Ed} = 900.0$ kN ≤ 930.1 kN $= V_{pl,Rd}/2$ $\Rightarrow$ no effect
resistance $M_{c,Rd} = M_{pl,Rd} = (W_{pl} \cdot f_y) / \gamma_{M0} = 1956.84$ kNm, $W_{pl} = 8327.00$ cm^3
resistance of a flange (and web) with compression
$F_{c,f,Rd} = M_{c,Rd} / (h - t_f) = 2929.41$ kN

resistance of upper beam flange:
stress due to bending with shear force: $V_{Ed} = 900.0$ kN ≤ 930.1 kN $= V_{pl,Rd}/2$ $\Rightarrow$ no effect
resistance $M_{c,Rd} = M_{pl,Rd} = (W_{pl} \cdot f_y) / \gamma_{M0} = 1956.84$ kNm, $W_{pl} = 8327.00$ cm^3
resistance of a flange (and web) with compression
$F_{c,f,Rd} = M_{c,Rd} / (h - t_f) = 2929.41$ kN

3.3.3. 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 $b_{eff,t,wb} = 384.8$ mm (l_{eff} from bc 5)
resistance of a beam web in tension
$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_{y,wb} / \gamma_{M0} = 1537.5$ kN
row 3

effective width $b_{eff,t,wb}$ = 337.3 mm (l_{eff} from bc 5)
resistance of a beam web in tension
$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_{y,wb} / \gamma_{M0}$ = 1347.5 kN

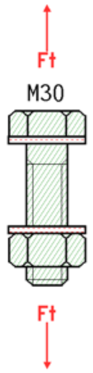
row 4
effective width $b_{eff,t,wb}$ = 337.3 mm (l_{eff} from bc 5)
resistance of a beam web in tension
$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_{y,wb} / \gamma_{M0}$ = 1347.5 kN

row 5
effective width $b_{eff,t,wb}$ = 384.8 mm (l_{eff} from bc 5)
resistance of a beam web in tension
$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_{y,wb} / \gamma_{M0}$ = 1537.5 kN

group of bolt-rows, group 1:
effective width $b_{eff,t,wb}$ = 484.8 mm (l_{eff} from bc 5)
resistance of a beam web in tension
$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_{y,wb} / \gamma_{M0}$ = 1937.0 kN

group of bolt-rows, group 2:
effective width $b_{eff,t,wb}$ = 584.8 mm (l_{eff} from bc 5)
resistance of a beam web in tension
$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_{y,wb} / \gamma_{M0}$ = 2336.5 kN

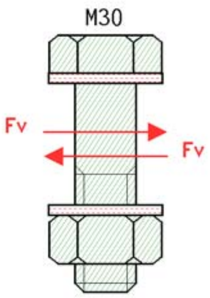
3.3.4. Gk 10: bolts in tension



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

tension resistance of one bolt $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2}$ = 403.92 kN, k_2 = 0.90
punching shear load capicity $B_{p,Rd} = (0.6 \cdot \pi \cdot d_m \cdot t_p \cdot f_u)) / \gamma_{M2}$ = 1287.04 kN, t_p = 45.0 mm
tension-/punching shear load capicity for 2 bolts: $\Sigma F_{tp,Rd} = 2 \cdot \min(F_{t,Rd}, B_{p,Rd})$ = 807.84 kN

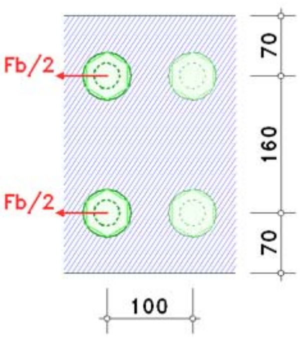
3.3.5. Gk 11: bolts in shear



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

shear resistance per shear plane $F_{v,Rd} = \alpha_v \cdot f_{ub} \cdot A / \gamma_{M2}$ = 339.29 kN, α_v = 0.60
shear resistance of 2 bolts (1-shear): $\Sigma F_{v,Rd} = 2 \cdot F_{v,Rd}$ = 678.58 kN

3.3.6. Gk 12: plate with bearing resistance



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

row 1
bolt 1: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2}$ = 638.18 kN, k_1 = 2.50, α_b = 0.66
bolt 2: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2}$ = 638.18 kN, k_1 = 2.50, α_b = 0.66
bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd}$ = 1276.36 kN
row 2
bolt 1: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2}$ = 972.00 kN, k_1 = 2.50, α_b = 1.00
bolt 2: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2}$ = 972.00 kN, k_1 = 2.50, α_b = 1.00
bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd}$ = 1944.00 kN
row 3
bolt 1: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2}$ = 738.82 kN, k_1 = 2.50, α_b = 0.76
bolt 2: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2}$ = 738.82 kN, k_1 = 2.50, α_b = 0.76
bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd}$ = 1477.64 kN
row 4
bolt 1: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2}$ = 738.82 kN, k_1 = 2.50, α_b = 0.76
bolt 2: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2}$ = 738.82 kN, k_1 = 2.50, α_b = 0.76
bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd}$ = 1477.64 kN
row 5
bolt 1: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2}$ = 972.00 kN, k_1 = 2.50, α_b = 1.00
bolt 2: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2}$ = 972.00 kN, k_1 = 2.50, α_b = 1.00
bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd}$ = 1944.00 kN

bearing resistance (5 rows)
$\Sigma F_{b,Rd,1}$ = 1276.36 kN
$\Sigma F_{b,Rd,2}$ = 1944.00 kN
$\Sigma F_{b,Rd,3}$ = 1477.64 kN
$\Sigma F_{b,Rd,4}$ = 1477.64 kN
$\Sigma F_{b,Rd,5}$ = 1944.00 kN

3.4. connection capacity

3.4.1. moment resistance

distance of tension-bolt-rows from centre of compression:
h_1 = 749.0 mm, h_2 = 584.0 mm, h_3 = 484.0 mm, h_4 = 384.0 mm, h_5 = 84.0 mm

resistance per bolt-row (MNV-interaction)
row 1: $F_{tr,Rd}$ = 754.6 kN
row 2: $F_{tr,Rd}$ = 807.8 kN
row 3: $F_{tr,Rd}$ = 669.5 kN
row 4: $F_{tr,Rd}$ = 531.2 kN
row 5: $F_{tr,Rd}$ = 116.2 kN

resistance of flanges (MNV-interaction)
bottom: $F_{c,Rd}$ = 2879.3 kN

moment resistance (MNV-interaction)
$M_{j,Rd} = \Sigma(F_{tr,Rd} \cdot h_r)$ = 1574.7 kNm

shear force resistance (MNV-interaction)
$V_{j,Rd}$ = 944.8 kN

3.4.2. shear resistance

shear resistance of end plate
end-plate: $V_{ep,Rd}$ = 3250.97 kN
welds: $F_{w,Rd}$ = 1935.46 kN
shear resistance of end plate: $V_{ep,Rd} = F_{w,Rd}$ = 1935.46 kN

3.5. verifications

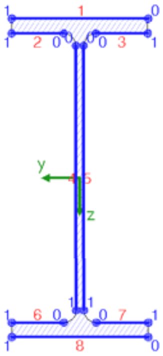
3.5.1. verification of the connection capacity by means of the component method

U_{MNV} = 0.953 < 1 ok
$V_{Ed}/V_{ep,Rd}$ = 0.465 < 1 ok

3.5.2. 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 = 15.5 mm l_w = 300.0 mm
weld 2: a_w = 15.5 mm l_w = 114.5 mm
weld 3: siehe weld 2
weld 4: a_w = 8.0 mm l_w = 582.0 mm
weld 5: siehe weld 4
weld 6: a_w = 15.0 mm l_w = 114.5 mm
weld 7: siehe weld 6
weld 8: a_w = 15.0 mm l_w = 300.0 mm

design values refering to centroid of the section:
$M_{y,Ed}$ = -1500.00 kNm, $V_{z,Ed}$ = 900.00 kN
cross-sectional properties refering to centroid of the line cross-section:
ΣA_w = 254.47 cm², $A_{w,z}$ = 93.12 cm², Σl_w = 222.2 cm
$I_{w,y}$ = 208971.47 cm⁴, $I_{w,z}$ = 13701.31 cm⁴, $W_{w,t}$ = 490.20 cm³, Δz_w = -3.5 mm
distribution of internal forces and moments:
weld 1: N_w = 1156.56 kN
weld 2: N_w = 400.65 kN
weld 3: siehe weld 2
weld 4: N_w = -11.68 kN $M_{y,w}$ = -94.34 kNm
weld 5: siehe weld 4
weld 6: N_w = -396.35 kN
weld 7: siehe weld 6
weld 8: N_w = -1141.82 kN
from conventionel distribution of shear force: $V_{z,w}$ = 900.00 kN
verifications in weld edges:

weld 1,	pt. 0:	$\sigma_{w,x}$ = 248.72 N/mm²		$\Rightarrow U_w = 0.977 < 1$ ok
weld 2,	pt. 0:	$\sigma_{w,x}$ = 225.75 N/mm²		$\Rightarrow U_w = 0.887 < 1$ ok
weld 4,	pt. 0:	$\sigma_{w,x}$ = 206.37 N/mm²	$\tau_{w,z}$ = 96.65 N/mm²	$\Rightarrow U_w = 0.935 < 1$ ok
	pt. 1:	$\sigma_{w,x}$ = -211.39 N/mm²	$\tau_{w,z}$ = 96.65 N/mm²	$\Rightarrow U_w = 0.952 < 1$ ok
weld 6,	pt. 0:	$\sigma_{w,x}$ = -230.77 N/mm²		$\Rightarrow U_w = 0.907 < 1$ ok
weld 8,	pt. 0:	$\sigma_{w,x}$ = -253.74 N/mm²		$\Rightarrow U_w = 0.997 < 1$ ok

Result:
weld 8, pt. 0: $\sigma_{w,x}$ = -253.74 N/mm²
Max: $\sigma_{1,w,Ed}$ = 35.88 kN/cm² < $f_{1w,d}$ = 36.00 kN/cm²,
$\sigma_{2,w,Ed}$ = 17.94 kN/cm² < $f_{2w,d}$ = 25.92 kN/cm² $\Rightarrow U_w = 0.997 < 1$ ok

3.5.3. verification result

maximum utilization: max U = 0.997 < 1 ok

3.6. rotational stiffness

stiffness coefficients
equivalent stiffness coefficient for 5 tension-bolt-rows:
1: k_5 = 115.05 mm, k_{10} = 7.40 mm $\Rightarrow$ $k_{eff,1} = 1 / \Sigma(1/k_{i,1})$ = 6.554 mm
2: k_5 = 129.60 mm, k_{10} = 7.40 mm $\Rightarrow$ $k_{eff,2} = 1 / \Sigma(1/k_{i,2})$ = 6.639 mm
3: k_5 = 113.58 mm, k_{10} = 7.40 mm $\Rightarrow$ $k_{eff,3} = 1 / \Sigma(1/k_{i,3})$ = 6.544 mm
4: k_5 = 113.58 mm, k_{10} = 7.40 mm $\Rightarrow$ $k_{eff,4} = 1 / \Sigma(1/k_{i,4})$ = 6.544 mm
5: k_5 = 129.60 mm, k_{10} = 7.40 mm $\Rightarrow$ $k_{eff,5} = 1 / \Sigma(1/k_{i,5})$ = 6.639 mm
$k_{eq} = \Sigma(k_{eff,r} \cdot h_r) / z_{eq}$ = 26.600 mm, $z_{eq} = \Sigma(k_{eff,r} \cdot h_r^2) / \Sigma(k_{eff,r} \cdot h_r)$ = 564.8 mm
rotational stiffness
initial rotational stiffness: $S_{j,ini} = (E \cdot z^2) / \Sigma(1/k_i)$ = 1782059.9 kNm/rad, $z = z_{eq}$ = 564.8 mm, $\Sigma(1/k_i)$ = 0.038 mm⁻¹
rotational stiffness: $S_{j,Rd} = S_{j,ini} / \mu$ = 1782059.9 kNm/rad, $\mu = 1$
rotation: $\varphi_{j,Ed} = M_{j,Ed} / S_{j,Rd}$ = 0.048°