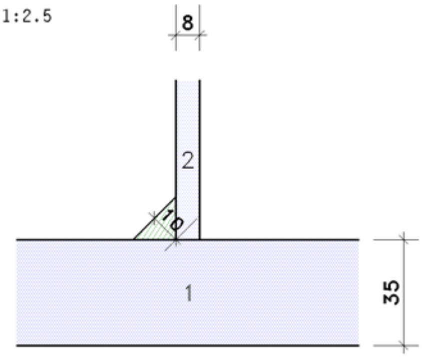
POS. 26: BAUFORUM S.78 (WELD)

4H-EC3BV version: 1/2012-1i

welded connection

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

scale 1:2.5



connection device

fillet weld, weld thickness a = 10.0 mm, weld length l_w = 100.0 mm, single sided weld, angle φ = 90°

connection plates

plate 1 with thickness t = 35.0 mm
plate 2 with thickness t = 8.0 mm
steel grade S 355

verifications

directional method
design load of axial force in connection plate N_{Ed} = 284.0 kN

partial safety factors

resistance of bolts, welds, plates bearing γ_{M2} = 1.25

design resistance

effective weld length $l_{eff} = l_w - a$ = 90.0 mm

forces on the design area of the weld: $F_{Ed}(\sigma_\perp)$ = 22.31 kN/cm $F_{Ed}(\tau_\perp)$ = 22.31 kN/cm
stresses on the design area of the weld: $\sigma_\perp$ = 22.31 kN/cm² $\tau_\perp$ = 22.31 kN/cm²
$\sigma_{1,w,Ed} = (\sigma_\perp^2 + 3\cdot(\tau_\perp^2 + \tau_{||}^2))^{1/2}$ = 44.63 kN/cm²
design resistance of the weld (req.1) $f_{1,w,Rd} = f_u / (\beta_w \cdot \gamma_{M2})$ = 43.56 kN/cm²
$\sigma_{1,w,Ed}$ = 44.63 kN/cm² > $f_{1,w,Rd}$ = 43.56 kN/cm² ⇒ utilization U = 1.025 > 1 **not ok. !!**
$\sigma_{2,w,Ed} = \sigma_\perp$ = 22.31 kN/cm²
design resistance of the weld (req.2) $f_{2,w,Rd} = 0.9 \cdot f_u / \gamma_{M2}$ = 35.28 kN/cm²
$\sigma_{2,w,Ed}$ = 22.31 kN/cm² < $f_{2,w,Rd}$ = 35.28 kN/cm² ⇒ utilization U = 0.632 < 1 **ok.**
maximum utilization: U_{max} = 1.025
design resistance not ensured !!

selected design parameters of National Annex

Germany

DIN EN 1993-1-1 (EC 3)

chapter	value	definition
6.1(1)		partial factors for structural steel
	γ_{M0} = 1.00	collapse of cross-sections
	γ_{M1} = 1.10	instability
	γ_{M2} = 1.25	fracture cross-sections in tension

DIN EN 1993-1-8 (EC 3, connections)

chapter	value	definition
2.2(2)		partial safety factors for connections
	γ_{M3} = 1.25	slip resistance (cat.C, ULS)
	$\gamma_{M3,ser}$ = 1.10	slip resistance (cat.B, SLS)
	γ_{M4} = 1.00	injection bolts

chapter	value	definition
	$\gamma_{M6,ser}$ = 1.00	pins (SLS)

regulations

DIN EN 1990, Eurocode 0: Basis of structural design;
German version EN 1990:2002 + A1:2005 + A1:2005/AC:2010, edition December 2010
DIN EN 1990/NA, National Annex DIN EN 1990, edition December 2010

DIN EN 1993-1-1, Eurocode 3: Design of steel structures - part 1-1:
General rules and rules for buildings;
German version EN 1993-1-1:2005 + AC:2009, edition December 2010
DIN EN 1993-1-1/NA, National Annex DIN EN 1993-1-1, edition December 2010

DIN EN 1993-1-8, Eurocode 3: Design of steel structures - part 1-8:
Design of joints; German version EN 1993-1-8:2005 + AC:2009, edition December 2010
DIN EN 1993-1-8/NA, National Annex DIN EN 1993-1-8, edition December 2010

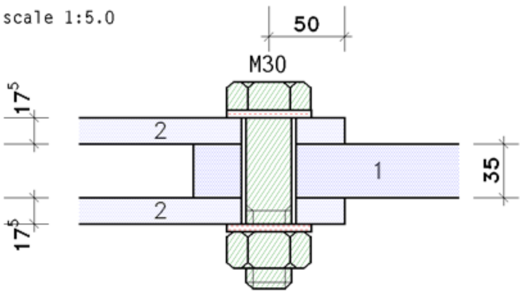
POS. 31: BAUFORUM S.77 (BOLT)

4H-EC3BV version: 1/2012-1i

bolted connection

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

scale 1:5.0



connection device
bolt, property class 10.9, bolt size M30
large width across flats (high tensile bolt), preloaded, normal clearance
connection plates
plate 1 with thickness t = 35.0 mm
plate 2 with thickness t = 17.5 mm
steel grade S 355
verifications
double shear connection
tension connection category E (tension, punching):
design value of the applied tensile force per bolt $F_{t,Edr}$ = 336.3 kN
partial safety factors
resistance of bolts, welds, plates bearing γ_{M2} = 1.25

design resistance

tension connection category E: preloaded
tensile failure
design value of tension resistance:
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, f_{ub} = 1000.0 N/mm²
$F_{t,Ed}$ = 336.3 kN < $F_{t,Rd}$ = 403.92 kN ⇒ utilization U = 0.833 < 1 **ok.**
punching shear failure
design value of punching shear load capicity:
p. sh. load capicity: $B_{p,Rd} = (0.6 \cdot \pi \cdot d_m \cdot t_p \cdot f_u)) / \gamma_{M2}$ = 681.26 kN, d_m = 52.7 mm, t_p = 17.5 mm, f_u = 490.0 N/mm²
$F_{t,Ed}$ = 336.3 kN < $B_{p,Rd}$ = 681.26 kN ⇒ utilization U = 0.494 < 1 **ok.**
maximum utilization: U_{max} = 0.833

selected design parameters of National Annex
Germany

DIN EN 1993-1-1 (EC 3)

chapter	value	definition
6.1(1)		partial factors for structural steel
	γ_{M0} = 1.00	collapse of cross-sections
	γ_{M1} = 1.10	instability
	γ_{M2} = 1.25	fracture cross-sections in tension

DIN EN 1993-1-8 (EC 3, connections)

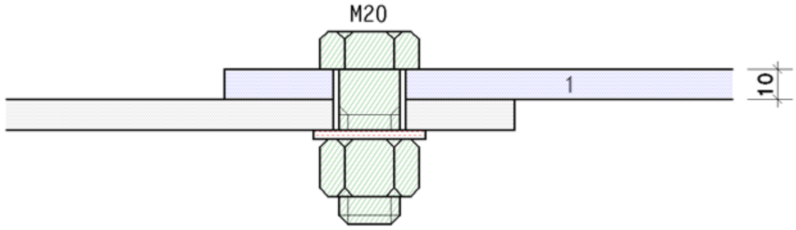
chapter	value	definition
2.2(2)		partial safety factors for connections
	γ_{M3} = 1.25	slip resistance (cat.C, ULS)
	$\gamma_{M3,ser}$ = 1.10	slip resistance (cat.B, SLS)
	γ_{M4} = 1.00	injection bolts
	$\gamma_{M6,ser}$ = 1.00	pins (SLS)

POS. 34: WAGENKNECHT S.17 (BOLT)

4H-EC3BV version: 1/2012-1i

bolted connection
EC 3-1-8 (12.10), NA: Germany

scale 1:2.5



connection device
bolt, property class 4.6, bolt size M20, normal clearance
connection plates
plate 1 with thickness t = 10.0 mm
plate 2 (without verification) with thickness t = 10.0 mm
steel grade S 235
verifications
single shear connection
shear connection category A (shear, bearing failure):
shear: shear plane passes through the unthreaded portion of the bolt
bearing resistance in direction of load transfer (inner bolt):
pitch p_1 = 60.0 mm
bearing resistance perpendicular to direction of load transfer (inner bolt):
pitch p_2 = 70.0 mm
tension connection category D
partial safety factors
resistance of bolts, welds, plates bearing γ_{M2} = 1.25

design resistance

pitch: p_1 = 60.0 mm > 2.2 d_0 = 48.4 mm, p_1 = 60.0 mm < min(14·t_{min}, 200 mm) = 140.0 mm
pitch: p_2 = 70.0 mm > 2.4 d_0 = 52.8 mm, p_2 = 70.0 mm < min(14·t_{min}, 200 mm) = 140.0 mm

shear connection category A: shear/bearing resistance
shear

design value of shear resistance per shear plane:
shear plane passes through the unthreaded portion of the bolt: $\alpha_v = 0.6$, $A = 3.14\ cm^2$
shear resistance: $F_{v,Rd} = \alpha_v \cdot f_{ub} \cdot A / \gamma_{M2} = 60.32$ kN, $f_{ub} = 400.0\ N/mm^2$

bearing resistance

design value of bearing resistance:
in the direction of load transfer: $\alpha_d = p_1/(3 \cdot d_0) - 1/4 = 0.66$ (inner bolt)
$\Rightarrow$ $\alpha_b = 0.66$ (smallest value of α_d or $f_{ub}/f_u = 1.11$ or 1.0)
perpendicular to the direction of load transfer: $k_1 = 2.50$ (inner bolt)
(smallest value of $1.4 \cdot p_2/d_0 - 1.7 = 2.75$ or 2.5)
bearing resistance: $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 94.91$ kN, $f_u = 360.0\ N/mm^2$

tension connection category D: not preloaded

tensile failure

design value of tension resistance:
tension resistance of one bolt: $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2} = 70.56$ kN, $k_2 = 0.90$, $f_{ub} = 400.0\ N/mm^2$

punching shear failure

design value of punching shear load capicity:
p. sh. load capicity: $B_{p,Rd} = (0.6 \cdot \pi \cdot d_m \cdot t_p \cdot f_u)) / \gamma_{M2} = 170.87$ kN, $d_m = 31.5$ mm, $t_p = 10.0$ mm, $f_u = 360.0\ N/mm^2$

selected design parameters of National Annex

Germany

DIN EN 1993-1-1 (EC 3)

chapter	value	definition
6.1(1)		partial factors for structural steel
	γ_{M0} = 1.00	collapse of cross-sections
	γ_{M1} = 1.10	instability
	γ_{M2} = 1.25	fracture cross-sections in tension

DIN EN 1993-1-8 (EC 3, connections)

chapter	value	definition
2.2(2)		partial safety factors for connections
	γ_{M3} = 1.25	slip resistance (cat.C, ULS)
	$\gamma_{M3,ser}$ = 1.10	slip resistance (cat.B, SLS)
	γ_{M4} = 1.00	injection bolts
	$\gamma_{M6,ser}$ = 1.00	pins (SLS)

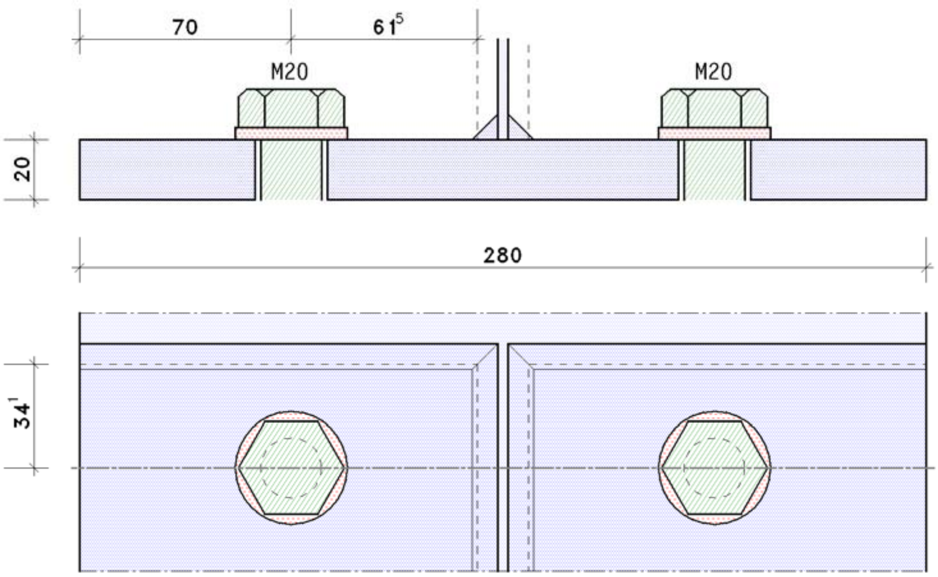
POS. 39: WAGENKNECHT S.194 (T-STUB 2)

4H-EC3BV version: 1/2012-1i

T-stub in tension

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

scale 1:2.5



T-stub flange with thickness t = 20.0 mm, width b = 280.0 mm
steel grade S 235

connection device
bolt, property class 10.9, bolt size M20
large width across flats (high tensile bolt), preloaded, normal clearance

verification parameters
verification of the connection plate (end-plate) between the flanges of the beam
application of method 1
calculation effective length l_{eff} of T-stub flange:
distance centre-line of the bolt to the free end of the connection plate e = 70.0 mm
to the web of the beam m = 61.5 mm
distance centre-line of the bolt to the flange of the beam m_2 = 34.1 mm
bolt-row considered individually (n_b = 1)
inner bolt-row outside tension flange of beam

partial safety factors
resistance of cross-sections γ_{M0} = 1.00

design resistance

effective length of T-stub flange (end-plate)
bolt-row considered individually
tab. 6.6: end-plate:
inner bolt-row outside tension flange of beam
coefficient for stiffened column flanges and end-plates (figure 6.11):
input values $\lambda_1 = m / (m+e) = 0.47$, $\lambda_2 = m_2 / (m+e) = 0.26$
from figure 6.11: $\alpha = 6.95$
$l_{eff,cp,si} = 2 \cdot \pi \cdot m = 386.4$ mm
$l_{eff,nc,si} = \alpha \cdot m = 427.4$ mm
in mode 1: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp}) = 386.4$ mm
in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc} = 427.4$ mm

minimum distance centre-line of the bolt to the edge of flange $e_{min} = e = 70.0$ mm

design tension resistance of the T-stub flange
$n = e_{min} \leq 1.25 \cdot m = 70.0$ mm
resisting plastic moment:
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, $f_y = 235.0$ N/mm²
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, $f_y = 235.0$ N/mm²
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, $k_2 = 0.90$
tension resistance of all bolts: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 352.80$ kN
bolt elongation length $L_b = t_{ges} + 2 \cdot t_p + 0.5 \cdot (t_k + t_m) = 62.3$ mm
max. bolt elongation length $L_b^* = (8.8 \cdot m^3 \cdot A_s \cdot n_b) / (\Sigma l_{eff,1} \cdot t_f^3) = 162.2$ mm
$L_b \leq L_b^*$ $\Rightarrow$ prying forces may develop:
mode 1: complete yielding of the T-stub flange
method 1: $F_{T,1,Rd} = (4 \cdot M_{pl,1,Rd}) / m = 590.62$ kN
mode 2: bolt failure with yielding of the T-stub flange
method 1: $F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 340.57$ kN
mode 3: bolt failure
method 1: $F_{T,3,Rd} = \Sigma F_{t,Rd} = 352.80$ kN
tension resistance of T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 340.57$ kN

selected design parameters of National Annex
Germany

DIN EN 1993-1-1 (EC 3)

chapter	value	definition
6.1(1)		partial factors for structural steel
	γ_{M0} = 1.00	collapse of cross-sections
	γ_{M1} = 1.10	instability
	γ_{M2} = 1.25	fracture cross-sections in tension

DIN EN 1993-1-8 (EC 3, connections)

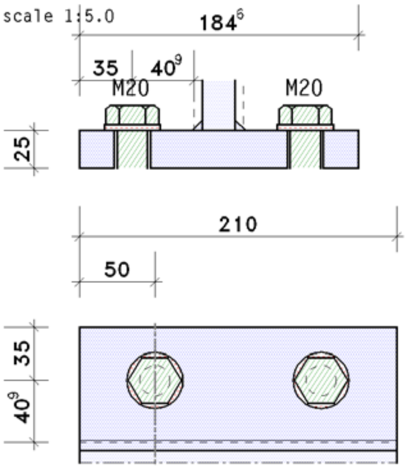
chapter	value	definition
2.2(2)		partial safety factors for connections
	γ_{M3} = 1.25	slip resistance (cat.C, ULS)
	$\gamma_{M3,ser}$ = 1.10	slip resistance (cat.B, SLS)
	γ_{M4} = 1.00	injection bolts
	$\gamma_{M6,ser}$ = 1.00	pins (SLS)

POS. 40: WAGENKNECHT S.201 (T-STUB 1)

4H-EC3BV version: 1/2012-1i

T-stub in tension

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



T-stub flange with thickness t = 25.0 mm, length l = 184.6 mm, width b = 210.0 mm
steel grade S 235

connection device
bolt, property class 10.9, bolt size M20
large width across flats (high tensile bolt), preloaded, normal clearance

loading
design value of the tensile force per bolt $F_{t,Ed}$ = 133.0 kN

verification parameters
verification of the extended part of the connection plate (end-plate)
application of method 1
calculation effective length l_{eff} of T-stub flange:
distance centre-line of the bolt to the free end of the connection plate e = 50.0 mm
distance centre-line of the bolt to the tension flange of beam m_1 = 40.9 mm
distance centre-line of the bolt to the tensile edge of connection plate e_1 = 35.0 mm

partial safety factors
resistance of cross-sections γ_{M0} = 1.00

design resistance

effective length of T-stub flange (end-plate)
$e_x = e_1$, $m_x = m_1$, $w = b_p\text{-}2\cdot e$ = 110.0 mm
bolt-row considered individually
tab. 6.6: end-plate:
bolt-row outside tension flange of beam
$l_{eff,cp,sa} = \min(2\cdot\pi\cdot m_x,\ \pi\cdot m_x+w,\ \pi\cdot m_x+2\cdot e)$ = 228.5 mm
$l_{eff,nc,sa} = \min(4\cdot m_x+1.25\cdot e_x,\ e+2\cdot m_x+0.625\cdot e_x,\ 0.5\cdot b_p,\ 0.5\cdot w+2\cdot m_x+0.625\cdot e_x)$ = 105.0 mm
in mode 1: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc},\ l_{eff,cp})$ = 105.0 mm
in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc}$ = 105.0 mm
minimum distance centre-line of the bolt to the edge of flange $e_{min} = e_1$ = 35.0 mm
$m = m_1$ = 40.9 mm

design tension resistance of the T-stub flange
$n = e_{min} \leq 1.25\cdot m$ = 35.0 mm
resisting plastic moment:
in mode 1: $M_{pl,1,Rd} = (0.25\cdot\Sigma l_{eff,1}\cdot t_f^2\cdot f_y) / \gamma_{M0}$ = 3.86 kNm, f_y = 235.0 N/mm²
in mode 2: $M_{pl,2,Rd} = (0.25\cdot\Sigma l_{eff,2}\cdot t_f^2\cdot f_y) / \gamma_{M0}$ = 3.86 kNm, f_y = 235.0 N/mm²
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
tension resistance of all bolts: $\Sigma F_{t,Rd} = 2\cdot n_b\cdot F_{t,Rd}$ = 352.80 kN
bolt elongation length $L_b = t_{ges} + 2\cdot t_p + 0.5\cdot(t_k+t_m)$ = 72.3 mm
max. bolt elongation length $L_b^* = (8.8\cdot m^3\cdot A_s\cdot n_b) / (\Sigma l_{eff,1}\cdot t_f^3)$ = 89.9 mm
$L_b \leq L_b^*$ ⇒ prying forces may develop:
mode 1: complete yielding of the T-stub flange

method 1: $F_{T,1,Rd} = (4 \cdot M_{pl,1,Rd}) / m$ = 377.06 kN
mode 2: bolt failure with yielding of the T-stub flange
method 1: $F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n)$ = 264.28 kN
mode 3: bolt failure
method 1: $F_{T,3,Rd} = \Sigma F_{t,Rd}$ = 352.80 kN
tension resistance of T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd})$ = 264.28 kN

verification

$F_{T,Ed} = 2 \cdot F_{t,Ed}$ = 266.0 kN $>$ $F_{T,Rd}$ = 264.28 kN $\Rightarrow$ utilization U = 1.007 $>$ 1 **not ok. !!**

maximum utilization: U_{max} = 1.007
design resistance not ensured !!

selected design parameters of National Annex

Germany

DIN EN 1993-1-1 (EC 3)

chapter	value	definition
6.1(1)		partial factors for structural steel
	γ_{M0} = 1.00	collapse of cross-sections
	γ_{M1} = 1.10	instability
	γ_{M2} = 1.25	fracture cross-sections in tension

DIN EN 1993-1-8 (EC 3, connections)

chapter	value	definition
2.2(2)		partial safety factors for connections
	γ_{M3} = 1.25	slip resistance (cat.C, ULS)
	$\gamma_{M3,ser}$ = 1.10	slip resistance (cat.B, SLS)
	γ_{M4} = 1.00	injection bolts
	$\gamma_{M6,ser}$ = 1.00	pins (SLS)

regulations

DIN EN 1990, Eurocode 0: Basis of structural design;
German version EN 1990:2002 + A1:2005 + A1:2005/AC:2010, edition December 2010
DIN EN 1990/NA, National Annex DIN EN 1990, edition December 2010

DIN EN 1993-1-1, Eurocode 3: Design of steel structures - part 1-1:
General rules and rules for buildings;
German version EN 1993-1-1:2005 + AC:2009, edition December 2010
DIN EN 1993-1-1/NA, National Annex DIN EN 1993-1-1, edition December 2010

DIN EN 1993-1-8, Eurocode 3: Design of steel structures - part 1-8:
Design of joints; German version EN 1993-1-8:2005 + AC:2009, edition December 2010
DIN EN 1993-1-8/NA, National Annex DIN EN 1993-1-8, edition December 2010

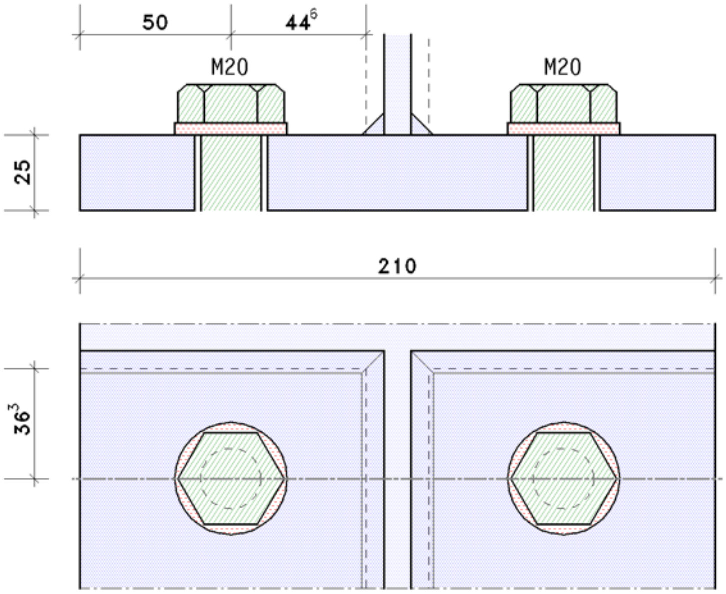
POS. 44: WAGENKNECHT S.201 (T-STUB 2)

4H-EC3BV version: 1/2012-1i

T-stub in tension

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

scale 1:2.5



T-stub flange with thickness t = 25.0 mm, width b = 210.0 mm
steel grade S 235
connection device
bolt, property class 10.9, bolt size M20
large width across flats (high tensile bolt), preloaded, normal clearance
loading
design value of the tensile force per bolt $F_{t,Ed}$ = 133.0 kN
verification parameters
verification of the connection plate (end-plate) between the flanges of the beam
application of method 1
calculation effective length l_{eff} of T-stub flange:
distance centre-line of the bolt to the free end of the connection plate e = 50.0 mm
to the web of the beam m = 44.6 mm
distance centre-line of the bolt to the flange of the beam m_2 = 36.3 mm
bolt-row considered individually (n_b = 1)
inner bolt-row outside tension flange of beam
partial safety factors
resistance of cross-sections γ_{M0} = 1.00

<u>design resistance</u>

effective length of T-stub flange (end-plate)
bolt-row considered individually
tab. 6.6: end-plate:
inner bolt-row outside tension flange of beam
coefficient for stiffened column flanges and end-plates (figure 6.11):
input values $\lambda_1 = m / (m+e) = 0.47$, $\lambda_2 = m_2 / (m+e) = 0.38$
from figure 6.11: $\alpha = 6.15$
$l_{eff,cp,si} = 2 \cdot \pi \cdot m = 280.2$ mm
$l_{eff,nc,si} = \alpha \cdot m = 274.4$ mm
in mode 1: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp}) = 274.4$ mm
in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc} = 274.4$ mm
minimum distance centre-line of the bolt to the edge of flange $e_{min} = e = 50.0$ mm
design tension resistance of the T-stub flange
$n = e_{min} \leq 1.25 \cdot m = 50.0$ mm
resisting plastic moment:

in mode 1: $M_{pl,1,Rd} = (0.25 \cdot \Sigma l_{eff,1} \cdot t_f^2 \cdot f_y) / \gamma_{M0}$ = 10.08 kNm, f_y = 235.0 N/mm²
in mode 2: $M_{pl,2,Rd} = (0.25 \cdot \Sigma l_{eff,2} \cdot t_f^2 \cdot f_y) / \gamma_{M0}$ = 10.08 kNm, f_y = 235.0 N/mm²

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
tension resistance of all bolts: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd}$ = 352.80 kN

bolt elongation length $L_b = t_{ges} + 2 \cdot t_p + 0.5 \cdot (t_k + t_m)$ = 72.3 mm
max. bolt elongation length $L_b^* = (8.8 \cdot m^3 \cdot A_s \cdot n_b) / (\Sigma l_{eff,1} \cdot t_f^3)$ = 44.6 mm
$L_b > L_b^*$ ⇒ no prying forces:

mode 1 and 2: complete yielding of the T-stub flange and possibly coincident bolt failure
$F_{T,1\text{-}2,Rd} = (2 \cdot M_{pl,1,Rd}) / m$ = 451.86 kN

mode 3: bolt failure
$F_{T,3,Rd} = \Sigma F_{t,Rd}$ = 352.80 kN

tension resistance of T-stub flange: $F_{T,Rd} = \min(F_{T,1\text{-}2,Rd}, F_{T,3,Rd})$ = 352.80 kN

verification

$F_{T,Ed} = 2 \cdot F_{t,Ed}$ = 266.0 kN < $F_{T,Rd}$ = 352.80 kN ⇒ utilization U = 0.754 < 1 **ok.**

maximum utilization: U_{max} = 0.754

selected design parameters of National Annex

Germany

DIN EN 1993-1-1 (EC 3)

chapter	value	definition
6.1(1)		partial factors for structural steel
	γ_{M0} = 1.00	collapse of cross-sections
	γ_{M1} = 1.10	instability
	γ_{M2} = 1.25	fracture cross-sections in tension

DIN EN 1993-1-8 (EC 3, connections)

chapter	value	definition
2.2(2)		partial safety factors for connections
	γ_{M3} = 1.25	slip resistance (cat.C, ULS)
	$\gamma_{M3,ser}$ = 1.10	slip resistance (cat.B, SLS)
	γ_{M4} = 1.00	injection bolts
	$\gamma_{M6,ser}$ = 1.00	pins (SLS)

regulations

DIN EN 1990, Eurocode 0: Basis of structural design;
German version EN 1990:2002 + A1:2005 + A1:2005/AC:2010, edition December 2010
DIN EN 1990/NA, National Annex DIN EN 1990, edition December 2010

DIN EN 1993-1-1, Eurocode 3: Design of steel structures - part 1-1:
General rules and rules for buildings;
German version EN 1993-1-1:2005 + AC:2009, edition December 2010
DIN EN 1993-1-1/NA, National Annex DIN EN 1993-1-1, edition December 2010

DIN EN 1993-1-8, Eurocode 3: Design of steel structures - part 1-8:
Design of joints; German version EN 1993-1-8:2005 + AC:2009, edition December 2010
DIN EN 1993-1-8/NA, National Annex DIN EN 1993-1-8, edition December 2010

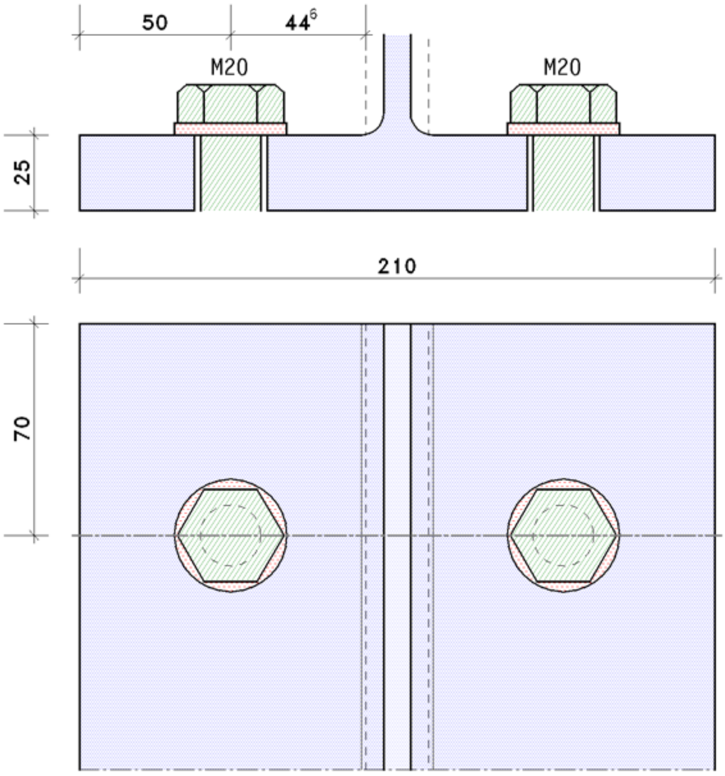
POS. 45: WAGENKNECHT S.201 (T-STUB 3)

4H-EC3BV version: 1/2012-1i

T-stub in tension

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

scale 1:2.5



T-stub flange with thickness t = 25.0 mm, width b = 210.0 mm
steel grade S 235

connection device
bolt, property class 10.9, bolt size M20
large width across flats (high tensile bolt), preloaded, normal clearance

loading
design value of the tensile force per bolt $F_{t,Ed}$ = 133.0 kN

verification parameters
verification of the column flange
application of method 1
calculation effective length l_{eff} of T-stub flange:
distance centre-line of the bolt to the edge of the column flange e = 50.0 mm
distance centre-line of the bolt to the free edge of the column flange (end row) e_1 = 70.0 mm
distance centre-line of the bolt to the web of the column m = 44.6 mm
bolt-row considered individually (n_b = 1)
end bolt-row

partial safety factors
resistance of cross-sections γ_{M0} = 1.00

design resistance

effective length of T-stub flange (flange of column)
bolt-row considered individually
tab. 6.4: unstiffened flange of column:
(other) end bolt-row
$l_{eff,cp,a} = \min(2\cdot\pi\cdot m,\ \pi\cdot m+2\cdot e_1)$ = 280.1 mm
$l_{eff,nc,a} = \min(4\cdot m+1.25\cdot e,\ 2\cdot m+0.625\cdot e+e_1)$ = 190.4 mm
in mode 1: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp})$ = 190.4 mm
in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc}$ = 190.4 mm
minimum distance centre-line of the bolt to the edge of flange e_{min} = e = 50.0 mm

design tension resistance of the T-stub flange

$n = e_{min} \le 1.25 \cdot m = 50.0$ mm

resisting plastic moment:

in mode 1: $M_{pl,1,Rd} = (0.25 \cdot \Sigma l_{eff,1} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 6.99$ kNm, $f_y = 235.0$ N/mm²

in mode 2: $M_{pl,2,Rd} = (0.25 \cdot \Sigma l_{eff,2} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 6.99$ kNm, $f_y = 235.0$ N/mm²

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, $k_2 = 0.90$

tension resistance of all bolts: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 352.80$ kN

bolt elongation length $L_b = t_{ges} + 2 \cdot t_p + 0.5 \cdot (t_k + t_m) = 72.3$ mm

max. bolt elongation length $L_b^* = (8.8 \cdot m^3 \cdot A_s \cdot n_b) / (\Sigma l_{eff,1} \cdot t_f^3) = 64.3$ mm

$L_b > L_b^*$ $\Rightarrow$ no prying forces:

mode 1 and 2: complete yielding of the T-stub flange and possibly coincident bolt failure

$F_{T,1\text{-}2,Rd} = (2 \cdot M_{pl,1,Rd}) / m = 313.59$ kN

mode 3: bolt failure

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

tension resistance of T-stub flange: $F_{T,Rd} = \min(F_{T,1\text{-}2,Rd}, F_{T,3,Rd}) = 313.59$ kN

verification

$F_{T,Ed} = 2 \cdot F_{t,Ed} = 266.0$ kN $<$ $F_{T,Rd} = 313.59$ kN $\Rightarrow$ utilization U = 0.848 $<$ 1 **ok.**

maximum utilization: $U_{max} = 0.848$

selected design parameters of National Annex

Germany

DIN EN 1993-1-1 (EC 3)

chapter	value	definition
6.1(1)		partial factors for structural steel
	γ_{M0} = 1.00	collapse of cross-sections
	γ_{M1} = 1.10	instability
	γ_{M2} = 1.25	fracture cross-sections in tension

DIN EN 1993-1-8 (EC 3, connections)

chapter	value	definition
2.2(2)		partial safety factors for connections
	γ_{M3} = 1.25	slip resistance (cat.C, ULS)
	$\gamma_{M3,ser}$ = 1.10	slip resistance (cat.B, SLS)
	γ_{M4} = 1.00	injection bolts
	$\gamma_{M6,ser}$ = 1.00	pins (SLS)

regulations

DIN EN 1990, Eurocode 0: Basis of structural design;
German version EN 1990:2002 + A1:2005 + A1:2005/AC:2010, edition December 2010
DIN EN 1990/NA, National Annex DIN EN 1990, edition December 2010

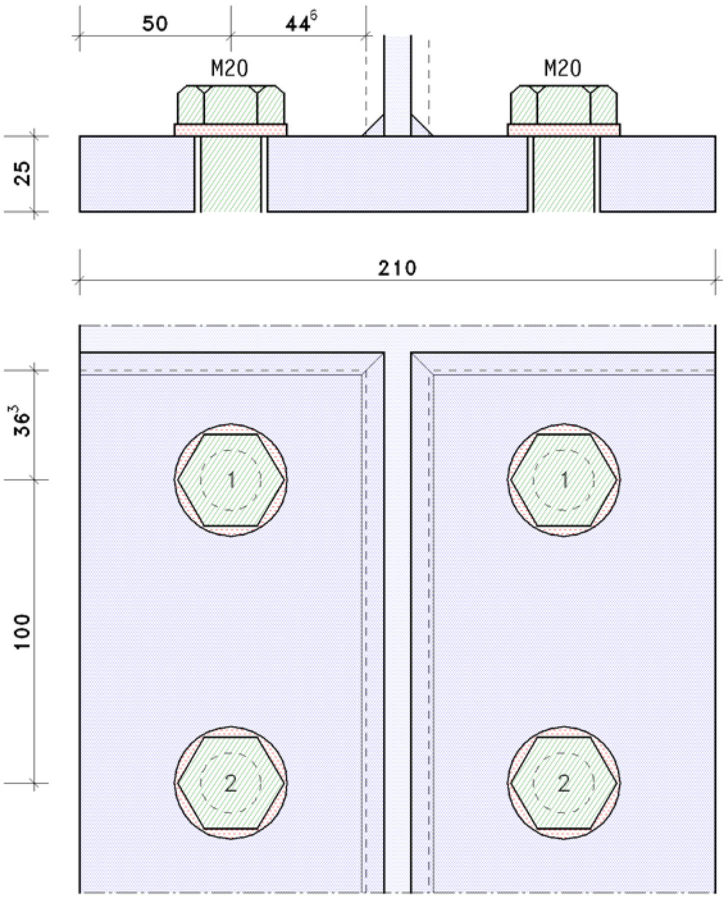
DIN EN 1993-1-1, Eurocode 3: Design of steel structures - part 1-1:
General rules and rules for buildings;
German version EN 1993-1-1:2005 + AC:2009, edition December 2010
DIN EN 1993-1-1/NA, National Annex DIN EN 1993-1-1, edition December 2010

DIN EN 1993-1-8, Eurocode 3: Design of steel structures - part 1-8:
Design of joints; German version EN 1993-1-8:2005 + AC:2009, edition December 2010
DIN EN 1993-1-8/NA, National Annex DIN EN 1993-1-8, edition December 2010

POS. 46: WAGENKNECHT S.201 (T-STUB 4)

T-stub in tension

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



T-stub flange with thickness t = 25.0 mm, width b = 210.0 mm
steel grade S 235

connection device
bolt, property class 10.9, bolt size M20
large width across flats (high tensile bolt), preloaded, normal clearance

loading
design value of tensile force bolt in row 1 $F_{t,Ed}$ = 133.0 kN
design value of tensile force bolt in row 2 $F_{t,Ed}$ = 0.0 kN

verification parameters
verification of the connection plate (end-plate) between the flanges of the beam
application of method 1
calculation effective length l_{eff} of T-stub flange:
distance centre-line of the bolt seitlichen Rand des connection plates e = 50.0 mm
to the web of the beam m = 44.6 mm
distance centre-line of the bolt to the flange of the beam m_2 = 36.3 mm
number of bolt rows (2 bolts per row) n_b = 2
distance between bolt rows p = 100.0 mm
bolt-row considered as part of a group of bolt rows
one (inner) bolt-row outside tension flange of beam

partial safety factors
resistance of cross-sections γ_{M0} = 1.00

design resistance

effective length of T-stub flange (end-plate)
bolt-row considered as part of a group of bolt rows
tab. 6.6: end-plate:
(other) inner bolt-row
$l_{eff,cp,i} = 2 \cdot p$ = 200.0 mm
$l_{eff,nc,i} = p$ = 100.0 mm
(other) end bolt-row

$l_{eff,cp,a} = \pi \cdot m+p = 240.1$ mm
$l_{eff,nc,a} = 2 \cdot m+0.625 \cdot e+0.5 \cdot p = 170.4$ mm
inner bolt-row outside tension flange of beam
coefficient for stiffened column flanges and end-plates (figure 6.11):
input values $\lambda_1 = m / (m+e) = 0.47$, $\lambda_2 = m_2 / (m+e) = 0.38$
from figure 6.11: $\alpha = 6.15$
$l_{eff,cp,si} = \pi \cdot m+p = 240.1$ mm
$l_{eff,nc,si} = 0.5 \cdot p+\alpha \cdot m-(2 \cdot m+0.625 \cdot e) = 204.0$ mm
bolt-row outside tension flange of beam
$l_{eff,cp,sa}$, $l_{eff,nc,sa}$ not relevant
group of 2 bolt rows:
assumption: one inner bolt-row is adjacent to the tension flange of beam
$\Rightarrow \Sigma l_{eff,cp} = l_{eff,cp,a} + l_{eff,cp,si} = 480.2$ mm
$\Rightarrow \Sigma l_{eff,nc} = l_{eff,nc,a} + l_{eff,nc,si} = 374.4$ mm
in mode 1: $\Sigma l_{eff,1} = \min(\Sigma l_{eff,nc}, \Sigma l_{eff,cp}) = 374.4$ mm
in mode 2: $\Sigma l_{eff,2} = \Sigma l_{eff,nc} = 374.4$ mm
minimum distance centre-line of the bolt to the edge of flange $e_{min} = e = 50.0$ mm
design tension resistance of the T-stub flange
$n = e_{min} \leq 1.25 \cdot m = 50.0$ mm
resisting plastic moment:
in mode 1: $M_{pl,1,Rd} = (0.25 \cdot \Sigma l_{eff,1} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 13.75$ kNm, $f_y = 235.0$ N/mm²
in mode 2: $M_{pl,2,Rd} = (0.25 \cdot \Sigma l_{eff,2} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 13.75$ kNm, $f_y = 235.0$ N/mm²
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, $k_2 = 0.90$
tension resistance of all bolts: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd} = 705.60$ kN
bolt elongation length $L_b = t_{ges} + 2 \cdot t_p + 0.5 \cdot (t_k+t_m) = 72.3$ mm
max. bolt elongation length $L_b^* = (8.8 \cdot m^3 \cdot A_s \cdot n_b) / (\Sigma l_{eff,1} \cdot t_f^3) = 65.4$ mm
$L_b > L_b^*$ $\Rightarrow$ no prying forces:
mode 1 and 2: complete yielding of the T-stub flange and possibly coincident bolt failure
$F_{T,1\text{-}2,Rd} = (2 \cdot M_{pl,1,Rd}) / m = 616.52$ kN
mode 3: bolt failure
$F_{T,3,Rd} = \Sigma F_{t,Rd} = 705.60$ kN
tension resistance of T-stub flange: $F_{T,Rd} = \min(F_{T,1\text{-}2,Rd}, F_{T,3,Rd}) = 616.52$ kN
verification
$F_{T,Ed} = 2 \cdot \Sigma F_{t,Ed} = 266.0$ kN $<$ $F_{T,Rd} = 616.52$ kN $\Rightarrow$ utilization U = 0.431 $<$ 1 **ok.**

maximum utilization: $U_{max} = 0.431$

selected design parameters of National Annex
Germany

DIN EN 1993-1-1 (EC 3)

chapter	value	definition
6.1(1)		partial factors for structural steel
	γ_{M0} = 1.00	collapse of cross-sections
	γ_{M1} = 1.10	instability
	γ_{M2} = 1.25	fracture cross-sections in tension

DIN EN 1993-1-8 (EC 3, connections)

chapter	value	definition
2.2(2)		partial safety factors for connections
	γ_{M3} = 1.25	slip resistance (cat.C, ULS)
	$\gamma_{M3,ser}$ = 1.10	slip resistance (cat.B, SLS)
	γ_{M4} = 1.00	injection bolts
	$\gamma_{M6,ser}$ = 1.00	pins (SLS)

regulations

DIN EN 1990, Eurocode 0: Basis of structural design;
German version EN 1990:2002 + A1:2005 + A1:2005/AC:2010, edition December 2010
DIN EN 1990/NA, National Annex DIN EN 1990, edition December 2010

DIN EN 1993-1-1, Eurocode 3: Design of steel structures - part 1-1:
General rules and rules for buildings;

German version EN 1993-1-1:2005 + AC:2009, edition December 2010
DIN EN 1993-1-1/NA, National Annex DIN EN 1993-1-1, edition December 2010

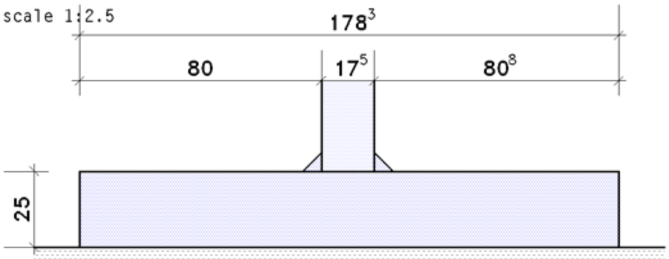
DIN EN 1993-1-8, Eurocode 3: Design of steel structures - part 1-8:
Design of joints; German version EN 1993-1-8:2005 + AC:2009, edition December 2010
DIN EN 1993-1-8/NA, National Annex DIN EN 1993-1-8, edition December 2010

POS. 49: WAGENKNECHT S.278 (T-STUB DRUCK 1)

4H-EC301 version: 1/2012-1f

T-stub in compression

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



T-stub flange with thickness t = 25.0 mm, width b = 340.0 mm
steel grade S 235

loading
design value of compression force $F_{C,Ed}$ = 428.5 kN

verification parameters
joint coefficient β_j = 0.6667
load expansion coefficient A_{c1}/A_{c0} = 1.00
concrete/mortar compressive strength f_{ck} = 20.0 N/mm²
expansion width c_{left} = 80.0 mm, c_{right} = 80.8 mm, web thickness t_s = 17.5 mm

partial safety factors
resistance of cross-sections γ_{M0} = 1.00

design resistance

design compression resistance of the T-sub flange
effective length/width of the T-stub flange l_{eff} = 340.0 mm, $b_{eff} = c_l+c_r+t_s$ = 178.3 mm
design value of max. compression strength of concrete $f_{cd} = \alpha_c \cdot f_{ck}/\gamma_c$ = 11.33 N/mm², α_c = 0.85, γ_c = 1.5
maximum partial distributed load $F_{Rd,u} = A_{c0} \cdot f_{cd} \cdot (A_{c1}/A_{c0})^{1/2}$ = 687.05 kN with $A_{c0} = l_{eff} \cdot b_{eff}$ = 606.2 cm²
design value of concrete compression $f_{jd} = \beta_j \cdot F_{Rd,u}/(b_{eff} \cdot l_{eff})$ = 0.76 kN/cm²
allowable bearing width $c_{max} = t \cdot (f_y/(3 \cdot f_{jd} \cdot \gamma_{M0}))^{1/2}$ = 80.5 mm, f_y = 235.0 N/mm²
c_{left} = 80.0 mm < c_{max} = 80.50 mm **ok.**
compression capacity of the T-sub flange $F_{C,Rd} = f_{jd} \cdot b_{eff} \cdot l_{eff}$ = 458.06 kN

verifications
$F_{C,Ed}$ = 428.5 kN < $F_{C,Rd}$ = 458.06 kN ⇒ utilization U = 0.935 < 1 **ok.**

maximum utilization: U_{max} = 0.935

selected design parameters of National Annex
Germany

DIN EN 1993-1-1 (EC 3)

chapter	value	definition
6.1(1)		partial factors for structural steel
	γ_{M0} = 1.00	collapse of cross-sections
	γ_{M1} = 1.10	instability
	γ_{M2} = 1.25	fracture cross-sections in tension

DIN EN 1993-1-8 (EC 3, connections)

chapter	value	definition
2.2(2)		partial safety factors for connections
	γ_{M3} = 1.25	slip resistance (cat.C, ULS)
	$\gamma_{M3,ser}$ = 1.10	slip resistance (cat.B, SLS)
	γ_{M4} = 1.00	injection bolts
	$\gamma_{M6,ser}$ = 1.00	pins (SLS)

DIN EN 1992-1-1 (EC 2)

chapter	value	definition
2.4.2.4(1)		Partial safety factor for concrete and reinforcement
	γ_c = 1.50 γ_s = 1.15	permanent and transient design situation
3.1.6(1)P	α_{cc} = 0.85	Coeff. to consider the long-term influence of compression strength of concrete and the unfavourable effect due to the kind of action effect

regulations

DIN EN 1990, Eurocode 0: Basis of structural design;
German version EN 1990:2002 + A1:2005 + A1:2005/AC:2010, edition December 2010
DIN EN 1990/NA, National Annex DIN EN 1990, edition December 2010

DIN EN 1992-1-1, Eurocode 2: Design of concrete structures -
part 1-1: General rules and rules for buildings;
German version EN 1992-1-1:2004 + AC:2010, edition January 2011
DIN EN 1992-1-1/NA, National Annex DIN EN 1992-1-1, edition January 2011

DIN EN 1993-1-1, Eurocode 3: Design of steel structures - part 1-1:
General rules and rules for buildings;
German version EN 1993-1-1:2005 + AC:2009, edition December 2010
DIN EN 1993-1-1/NA, National Annex DIN EN 1993-1-1, edition December 2010

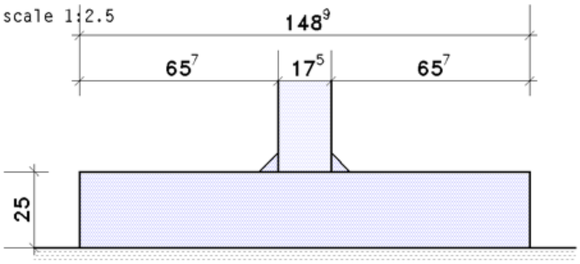
DIN EN 1993-1-8, Eurocode 3: Design of steel structures - part 1-8:
Design of joints; German version EN 1993-1-8:2005 + AC:2009, edition December 2010
DIN EN 1993-1-8/NA, National Annex DIN EN 1993-1-8, edition December 2010

POS. 51: WAGENKNECHT S.278 (T-STUB DRUCK 2)

4H-EC301 version: 1/2012-1f

T-stub in compression

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



T-stub flange with thickness t = 25.0 mm, width b = 280.0 mm
steel grade S 235

loading
design value of compression force $F_{C,Ed}$ = 410.1 kN

verification parameters
joint coefficient β_j = 1.0000
load expansion coefficient A_{c1}/A_{c0} = 1.00
concrete/mortar compressive strength f_{ck} = 20.0 N/mm²
expansion width c_{left} = 65.7 mm, c_{right} = 65.7 mm, web thickness t_s = 17.5 mm

partial safety factors
resistance of cross-sections γ_{M0} = 1.00

design resistance

design compression resistance of the T-sub flange
effective length/width of the T-stub flange l_{eff} = 280.0 mm, $b_{eff} = c_l+c_r+t_s$ = 148.9 mm
design value of max. compression strength of concrete $f_{cd} = \alpha_c \cdot f_{ck}/\gamma_c$ = 11.33 N/mm², α_c = 0.85, γ_c = 1.5
maximum partial distributed load $F_{Rd,u} = A_{c0} \cdot f_{cd} \cdot (A_{c1}/A_{c0})^{1/2}$ = 472.51 kN with $A_{c0} = l_{eff} \cdot b_{eff}$ = 416.9 cm²
design value of concrete compression $f_{jd} = \beta_j \cdot F_{Rd,u}/(b_{eff} \cdot l_{eff})$ = 1.13 kN/cm²
allowable bearing width $c_{max} = t \cdot (f_y/(3 \cdot f_{jd} \cdot \gamma_{M0}))^{1/2}$ = 65.7 mm, f_y = 235.0 N/mm²
c_{left} = 65.7 mm < c_{max} = 65.73 mm, c_{right} = 65.7 mm < c_{max} = 65.73 mm **ok.**
compression capacity of the T-sub flange $F_{C,Rd} = f_{jd} \cdot b_{eff} \cdot l_{eff}$ = 472.51 kN

verifications
$F_{C,Ed}$ = 410.1 kN < $F_{C,Rd}$ = 472.51 kN ⇒ utilization U = 0.868 < 1 **ok.**

maximum utilization: U_{max} = 0.868

selected design parameters of National Annex

Germany

DIN EN 1993-1-1 (EC 3)

chapter	value	definition
6.1(1)		partial factors for structural steel
	γ_{M0} = 1.00	collapse of cross-sections
	γ_{M1} = 1.10	instability
	γ_{M2} = 1.25	fracture cross-sections in tension

DIN EN 1993-1-8 (EC 3, connections)

chapter	value	definition
2.2(2)		partial safety factors for connections
	γ_{M3} = 1.25	slip resistance (cat.C, ULS)
	$\gamma_{M3,ser}$ = 1.10	slip resistance (cat.B, SLS)
	γ_{M4} = 1.00	injection bolts
	$\gamma_{M6,ser}$ = 1.00	pins (SLS)

DIN EN 1992-1-1 (EC 2)

chapter	value	definition
2.4.2.4(1)	γ_C = 1.50 γ_S = 1.15	Partial safety factor for concrete and reinforcement permanent and transient design situation
3.1.6(1)P	α_{CC} = 0.85	Coeff. to consider the long-term influence of compression strength of concrete and the unfavourable effect due to the kind of action effect

regulations

DIN EN 1990, Eurocode 0: Basis of structural design;
German version EN 1990:2002 + A1:2005 + A1:2005/AC:2010, edition December 2010
DIN EN 1990/NA, National Annex DIN EN 1990, edition December 2010

DIN EN 1992-1-1, Eurocode 2: Design of concrete structures -
part 1-1: General rules and rules for buildings;
German version EN 1992-1-1:2004 + AC:2010, edition January 2011
DIN EN 1992-1-1/NA, National Annex DIN EN 1992-1-1, edition January 2011

DIN EN 1993-1-1, Eurocode 3: Design of steel structures - part 1-1:
General rules and rules for buildings;
German version EN 1993-1-1:2005 + AC:2009, edition December 2010
DIN EN 1993-1-1/NA, National Annex DIN EN 1993-1-1, edition December 2010

DIN EN 1993-1-8, Eurocode 3: Design of steel structures - part 1-8:
Design of joints; German version EN 1993-1-8:2005 + AC:2009, edition December 2010
DIN EN 1993-1-8/NA, National Annex DIN EN 1993-1-8, edition December 2010

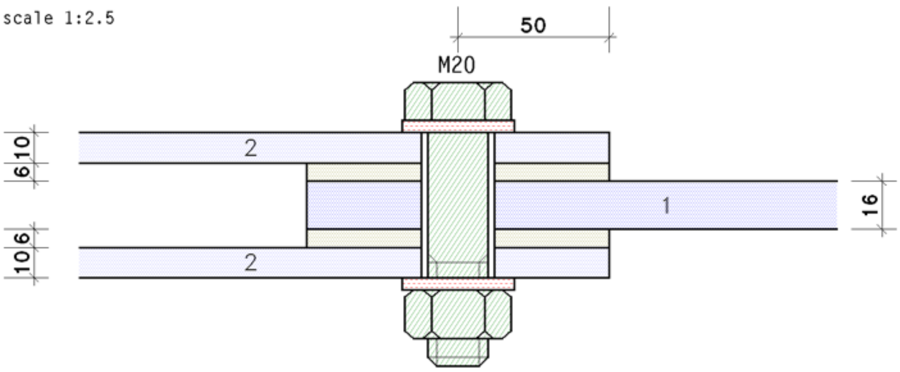
POS. 55: BASICAL CONNECTIONS

4H-EC301 version: 1/2012-1f

bolted connection

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

scale 1:2.5



connection device
bolt, property class 8.8, bolt size M20
large width across flats (high tensile bolt), preloaded, normal clearance
connection plates
plate 1 with thickness t = 16.0 mm, steel grade S 275
plate 2 with thickness t = 10.0 mm, steel grade S 275
packing with thickness t = 6.0 mm
verifications
double shear connection
shear connection category B (shear, bearing failure, slip):
design ultimate shear load per bolt $F_{v,Ed}$ = 23.0 kN
design ultimate shear load (SLS) per bolt $F_{v,Ed,ser}$ = 20.0 kN
shear: shear plane passes through the unthreaded portion of the bolt
bearing resistance in direction of load transfer (end bolt):
edge distance e_1 = 50.0 mm
bearing resistance perpendicular to direction of load transfer (end bolt):

edge distance e_2 = 40.0 mm   pitch p_2 = 80.0 mm
slip: class of friction surfaces B (slip factor μ = 0.40)
tension connection category D (tension, punching):
design value of the applied tensile force per bolt $F_{t,Edr}$ = 65.0 kN
design value of the applied tensile force (SLS) per bolt $F_{t,Ed,ser}$ = 50.0 kN

partial safety factors
resistance of bolts, welds, plates bearing γ_{M2} = 1.25
slip resistance at serviceability limit state (category B) $\gamma_{M3,ser}$ = 1.10

design resistance

edge distance: e_1 = 50.0 mm > 1.2 d_0 = 26.4 mm, e_1 = 50.0 mm < $4 \cdot t_{min}+40$ = 80.0 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) = 140.0 mm
edge distance: e_2 = 40.0 mm > 1.2 d_0 = 26.4 mm, e_2 = 40.0 mm < $4 \cdot t_{min}+40$ = 80.0 mm

shear connection category B: slip-resistant connection in SLS

shear (with $F_{v,Ed}/2$)
shear resistance: $F_{v,Rd} = \alpha_v \cdot f_{ub} \cdot A / \gamma_{M2}$ = 120.64 kN, α_v = 0.60
$F_{v,Ed}/2$ = 11.5 kN < $F_{v,Rd}$ = 120.64 kN ⇒ utilization U = 0.095 < 1 **ok.**

bearing resistance of plate 1 and bolt
bearing resistance: $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2}$ = 275.20 kN, k_1 = 2.50, α_b = 1.00
$F_{v,Ed}$ = 23.0 kN < $F_{b,Rd}$ = 275.20 kN ⇒ utilization U = 0.084 < 1 **ok.**

bearing resistance of plate 2 and bolt (with $F_{v,Ed}/2$)
bearing resistance: $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2}$ = 172.00 kN, k_1 = 2.50, α_b = 1.00
$F_{v,Ed}/2$ = 11.5 kN < $F_{b,Rd}$ = 172.00 kN ⇒ utilization U = 0.067 < 1 **ok.**

slip
preload force $F_{p,C} = 0.7 \cdot f_{yb} \cdot A_s$ = 109.8 kN
slip resistance in SLS (combined shear and tensile load):
$F_{s,Rd,ser} = (k_s \cdot n \cdot \mu \cdot (F_{p,C} - 0.8 \cdot F_{t,Ed,ser})) / \gamma_{M3,ser}$ = 50.73 kN, k_s = 1.00, n = 2
$F_{v,Ed,ser}$ = 20.0 kN < $F_{s,Rd,ser}$ = 50.73 kN ⇒ utilization U = 0.394 < 1 **ok.**

tension connection category D: not preloaded

tensile failure
tension resistance of one bolt: $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2}$ = 141.12 kN, k_2 = 0.90
$F_{t,Ed}$ = 65.0 kN < $F_{t,Rd}$ = 141.12 kN ⇒ utilization U = 0.461 < 1 **ok.**

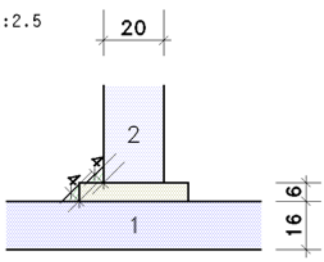
punching shear failure
p. sh. load capicity: $B_{p,Rd} = (0.6 \cdot \pi \cdot d_m \cdot t_p \cdot f_u)) / \gamma_{M2}$ = 217.32 kN, t_p = 10.0 mm
$F_{t,Ed}$ = 65.0 kN < $B_{p,Rd}$ = 217.32 kN ⇒ utilization U = 0.299 < 1 **ok.**

combination of Scher-/bearing resistance and Zug
$(F_{v,Ed}/2)/F_{v,Rd} + F_{t,Ed}/(1.4 \cdot F_{t,Rd})$ = 0.424 < 1 **ok.**
maximum utilization: U_{max} = 0.461

welded connection

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

scale 1:2.5



connection device
fillet weld, weld thickness a = 4.0 mm, weld length l_w = 250.0 mm, single sided weld, angle φ = 90°

connection plates
plate 1 with thickness t = 16.0 mm, steel grade S 275
plate 2 with thickness t = 20.0 mm, steel grade S 275
packing with thickness t = 6.0 mm

verifications
simplified method
design load along the weld $F_{w,Ed}$ = 15.61 kN/cm

partial safety factors
resistance of bolts, welds, plates bearing γ_{M2} = 1.25

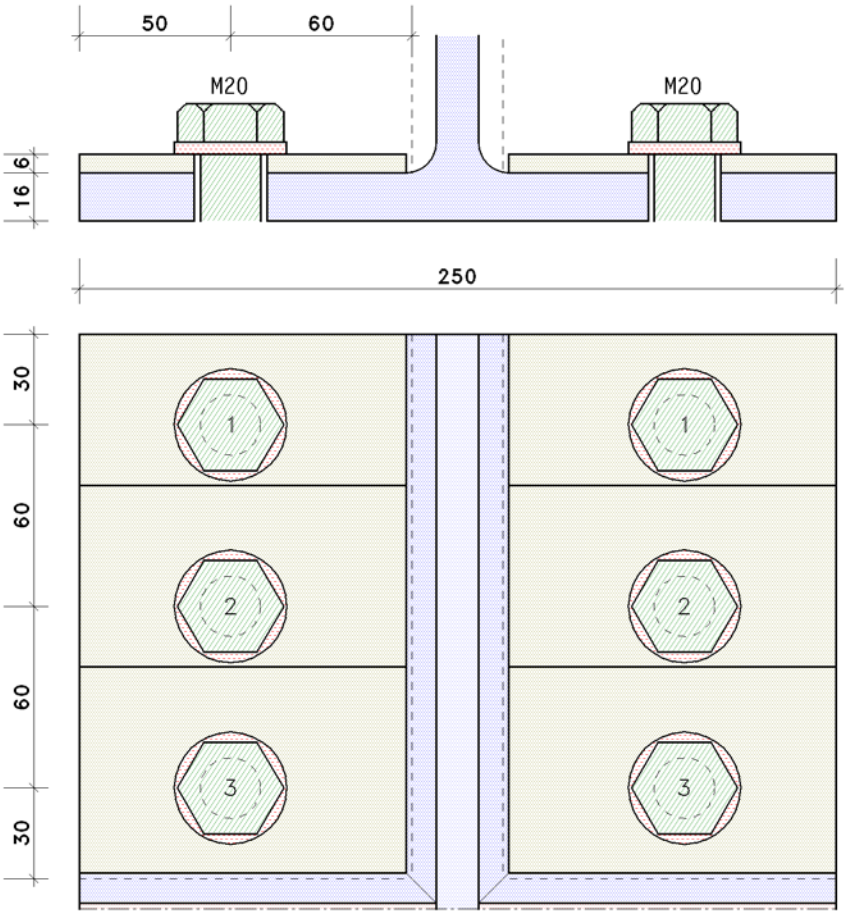
design resistance

shear strength: $f_{vw,d} = (f_u/3^{1/2}) / (\beta_w \cdot \gamma_{M2}) = 233.66$ N/mm²
design resistance: $F_{w,Rd} = f_{vw,d} \cdot a \cdot l_w = 233.66$ kN
$F_{w,Ed} = 15.61$ kN/cm $>$ $F_{w,Rd} = 2.34$ kN/cm $\Rightarrow$ utilization U = 6.681 $>$ 1 **not ok. !!**
welding with packings
required weld thickness $a_{erf} = (a_1+t_p) \cdot \cos(\varphi/2) = 31.0$ mm
weld thickness a = 4.0 mm $<$ $a_{erf} = 31.0$ mm **not ok. !!**
maximum utilization: $U_{max} = 6.681$
design resistance not ensured !!

T-stub in tension

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

scale 1:2.5



T-stub flange with thickness t = 16.0 mm, width b = 250.0 mm
steel grade S 275
flange reinforcement with thickness t = 6.0 mm, steel grade S 275
connection device
bolt, property class 8.8, bolt size M20
large width across flats (high tensile bolt), preloaded, normal clearance
loading
design value of tensile force bolt in row 1 $F_{t,Ed} = 134.0$ kN
design value of tensile force bolt in row 2 $F_{t,Ed} = 135.0$ kN
design value of tensile force bolt in row 3 $F_{t,Ed} = 136.0$ kN
verification parameters
verification of the column flange
application of method 1
calculation effective length l_{eff} of T-stub flange:
distance centre-line of the bolt to the edge of the column flange e = 50.0 mm
distance centre-line of the bolt to the free edge of the column flange (end row) $e_1 = 30.0$ mm
distance centre-line of the bolt to the web of the column m = 60.0 mm
distance centre-line of the bolt to the next web stiffener $m_2 = 30.0$ mm
number of bolt rows (2 bolts per row) $n_b = 3$
distance between bolt rows p = 60.0 mm

bolt-row considered individually
one (inner) bolt-row adjacent to a stiffener

partial safety factors

resistance of cross-sections γ_{M0} = 1.00

design resistance

effective length of T-stub flange (column flange):

in mode 1: $\Sigma l_{eff,1} = \min(\Sigma l_{eff,nc}, \Sigma l_{eff,cp})$ = 374.2 mm

in mode 2: $\Sigma l_{eff,2} = \Sigma l_{eff,nc}$ = 374.2 mm

design tension resistance of the T-stub flange:

in mode 1: $M_{pl,1,Rd} = (0.25 \cdot \Sigma l_{eff,1} \cdot t_f^2 \cdot f_y) / \gamma_{M0}$ = 6.59 kNm

in mode 2: $M_{pl,2,Rd} = (0.25 \cdot \Sigma l_{eff,2} \cdot t_f^2 \cdot f_y) / \gamma_{M0}$ = 6.59 kNm

flange reinforcement: $M_{bp,Rd} = (0.25 \cdot \Sigma l_{eff,1} \cdot t_{bp}^2 \cdot f_{y,bp}) / \gamma_{M0}$ = 0.93 kNm

tension resistance of one bolt: $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2}$ = 141.12 kN, k_2 = 0.90

tension resistance of all bolts: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd}$ = 846.72 kN

$F_{T,1,Rd} = (4 \cdot M_{pl,1,Rd} + 2 \cdot M_{bp,Rd}) / m$ = 469.88 kN

$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n)$ = 504.60 kN, n = 50.0 mm

$F_{T,3,Rd} = \Sigma F_{t,Rd}$ = 846.72 kN

tension resistance of T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd})$ = 469.88 kN

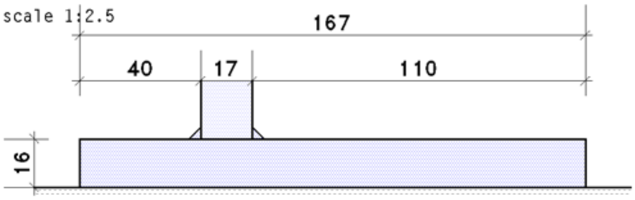
verification

$F_{T,Ed} = 2 \cdot \Sigma F_{t,Ed}$ = 810.0 kN $>$ $F_{T,Rd}$ = 469.88 kN $\Rightarrow$ utilization U = 1.724 $>$ 1 **not ok. !!**

maximum utilization: U_{max} = 1.724
design resistance not ensured !!

T-stub in compression

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



T-stub flange with thickness t = 16.0 mm, width b = 250.0 mm

steel grade S 275

loading

design value of compression force $F_{C,Ed}$ = 254.0 kN

verification parameters

joint coefficient β_j = 0.6667

load expansion coefficient A_{c1}/A_{c0} = 2.80

concrete/mortar compressive strength f_{ck} = 20.0 N/mm²

expansion width c_{left} = 40.0 mm, c_{right} = 110.0 mm, web thickness t_s = 17.0 mm

partial safety factors

resistance of cross-sections γ_{M0} = 1.00

design resistance

design compression resistance of the T-sub flange

maximum partial distributed load $F_{Rd,u} = A_{c0} \cdot f_{cd} \cdot (A_{c1}/A_{c0})^{1/2}$ = 791.76 kN

design value of concrete compression $f_{jd} = \beta_j \cdot F_{Rd,u} / (b_{eff} \cdot l_{eff})$ = 1.26 kN/cm²

allowable bearing width $c_{max} = t \cdot (f_y / (3 \cdot f_{jd} \cdot \gamma_{M0}))^{1/2}$ = 43.1 mm

c_{left} = 40.0 mm $<$ c_{max} = 43.08 mm **ok.**

compression capacity of the T-sub flange $F_{C,Rd} = f_{jd} \cdot b_{eff} \cdot l_{eff}$ = 527.84 kN

verifications

$F_{C,Ed}$ = 254.0 kN $<$ $F_{C,Rd}$ = 527.84 kN $\Rightarrow$ utilization U = 0.481 $<$ 1 **ok.**

maximum utilization: U_{max} = 0.481

result

maximum utilization: U_{max} = 6.681
fault - design resistance of welded connection not ensured !!
fault - design resistance of T-stub in tension not ensured !!

selected design parameters of National Annex
Germany

DIN EN 1993-1-1 (EC 3)

chapter	value	definition
6.1(1)		partial factors for structural steel
	γ_{M0} = 1.00	collapse of cross-sections
	γ_{M1} = 1.10	instability
	γ_{M2} = 1.25	fracture cross-sections in tension

DIN EN 1993-1-8 (EC 3, connections)

chapter	value	definition
2.2(2)		partial safety factors for connections
	γ_{M3} = 1.25	slip resistance (cat.C, ULS)
	$\gamma_{M3,ser}$ = 1.10	slip resistance (cat.B, SLS)
	γ_{M4} = 1.00	injection bolts
	$\gamma_{M6,ser}$ = 1.00	pins (SLS)

DIN EN 1992-1-1 (EC 2)

chapter	value	definition
2.4.2.4(1)		Partial safety factor for concrete and reinforcement
	γ_c = 1.50 γ_s = 1.15	permanent and transient design situation
3.1.6(1)P	α_{cc} = 0.85	Coeff. to consider the long-term influence of compression strength of concrete and the unfavourable effect due to the kind of action effect

regulations

DIN EN 1990, Eurocode 0: Basis of structural design;
German version EN 1990:2002 + A1:2005 + A1:2005/AC:2010, edition December 2010
DIN EN 1990/NA, National Annex DIN EN 1990, edition December 2010

DIN EN 1992-1-1, Eurocode 2: Design of concrete structures -
part 1-1: General rules and rules for buildings;
German version EN 1992-1-1:2004 + AC:2010, edition January 2011
DIN EN 1992-1-1/NA, National Annex DIN EN 1992-1-1, edition January 2011

DIN EN 1993-1-1, Eurocode 3: Design of steel structures - part 1-1:
General rules and rules for buildings;
German version EN 1993-1-1:2005 + AC:2009, edition December 2010
DIN EN 1993-1-1/NA, National Annex DIN EN 1993-1-1, edition December 2010

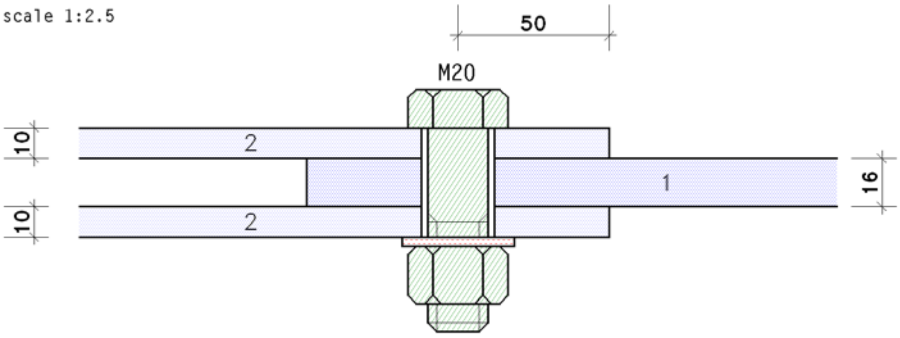
DIN EN 1993-1-8, Eurocode 3: Design of steel structures - part 1-8:
Design of joints; German version EN 1993-1-8:2005 + AC:2009, edition December 2010
DIN EN 1993-1-8/NA, National Annex DIN EN 1993-1-8, edition December 2010

POS. 60: BEISPIEL

4H-EC301 version: 1/2012-1f

bolted connection

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



connection device
bolt, property class 8.8, bolt size M20, normal clearance
connection plates
plate 1 with thickness t = 16.0 mm
plate 2 with thickness t = 10.0 mm
steel grade S 275
verifications
double shear connection
shear connection category A (shear, bearing failure):
design ultimate shear load per bolt $F_{v,Ed}$ = 23.0 kN
shear: shear plane passes through the unthreaded portion of the bolt
bearing resistance in direction of load transfer (end bolt):
edge distance e_1 = 50.0 mm
bearing resistance perpendicular to direction of load transfer (end bolt):
edge distance e_2 = 40.0 mm pitch p_2 = 80.0 mm
tension connection category D (tension, punching):
design value of the applied tensile force per bolt $F_{t,Edr}$ = 65.0 kN
partial safety factors
resistance of bolts, welds, plates bearing γ_{M2} = 1.25

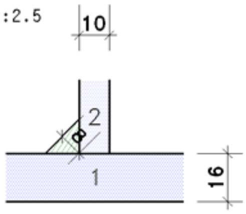
design resistance

edge distance: e_1 = 50.0 mm > 1.2 d_0 = 26.4 mm, e_1 = 50.0 mm < $4 \cdot t_{min}+40$ = 80.0 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) = 140.0 mm
edge distance: e_2 = 40.0 mm > 1.2 d_0 = 26.4 mm, e_2 = 40.0 mm < $4 \cdot t_{min}+40$ = 80.0 mm

shear connection category A: shear/bearing resistance
shear (with $F_{v,Ed}/2$)
shear resistance: $F_{v,Rd} = \alpha_v \cdot f_{ub} \cdot A / \gamma_{M2}$ = 120.64 kN, α_v = 0.60
$F_{v,Ed}/2$ = 11.5 kN < $F_{v,Rd}$ = 120.64 kN ⇒ utilization U = 0.095 < 1 **ok.**
bearing resistance of plate 1 and bolt
bearing resistance: $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2}$ = 275.20 kN, k_1 = 2.50, α_b = 1.00
$F_{v,Ed}$ = 23.0 kN < $F_{b,Rd}$ = 275.20 kN ⇒ utilization U = 0.084 < 1 **ok.**
bearing resistance of plate 2 and bolt (with $F_{v,Ed}/2$)
bearing resistance: $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2}$ = 172.00 kN, k_1 = 2.50, α_b = 1.00
$F_{v,Ed}/2$ = 11.5 kN < $F_{b,Rd}$ = 172.00 kN ⇒ utilization U = 0.067 < 1 **ok.**
tension connection category D: not preloaded
tensile failure
tension resistance of one bolt: $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2}$ = 141.12 kN, k_2 = 0.90
$F_{t,Ed}$ = 65.0 kN < $F_{t,Rd}$ = 141.12 kN ⇒ utilization U = 0.461 < 1 **ok.**
punching shear failure
p. sh. load capicity: $B_{p,Rd} = (0.6 \cdot \pi \cdot d_m \cdot t_p \cdot f_u)) / \gamma_{M2}$ = 204.09 kN, t_p = 10.0 mm
$F_{t,Ed}$ = 65.0 kN < $B_{p,Rd}$ = 204.09 kN ⇒ utilization U = 0.318 < 1 **ok.**
combination of Scher-/bearing resistance and Zug
$(F_{v,Ed}/2)/F_{v,Rd} + F_{t,Ed}/(1.4 \cdot F_{t,Rd})$ = 0.424 < 1 **ok.**
maximum utilization: U_{max} = 0.461

welded connection
EC 3-1-8 (12.10), NA: Germany

scale 1:2.5



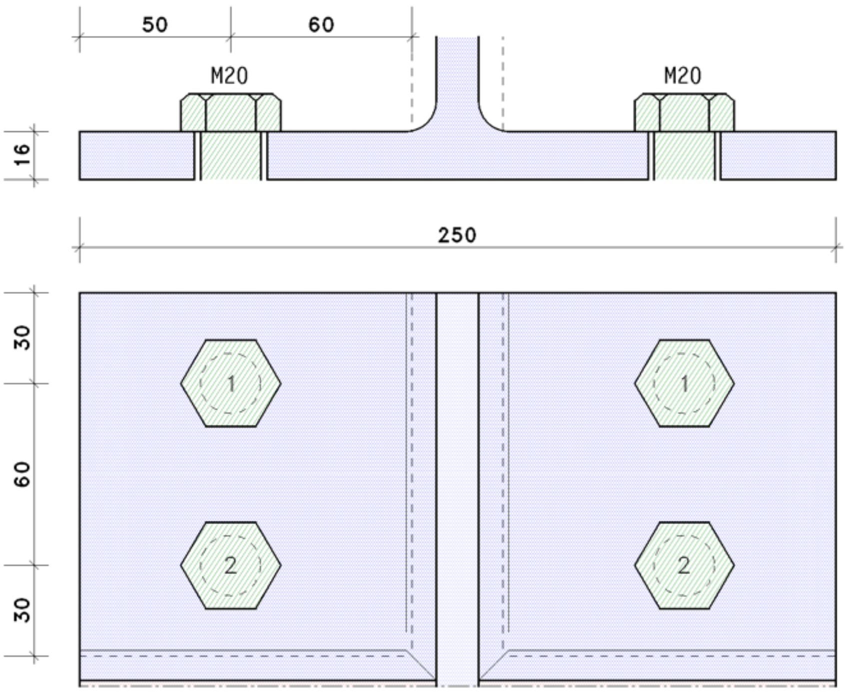
connection device
fillet weld, weld thickness a = 8.0 mm, weld length l_w = 250.0 mm, single sided weld, angle φ = 90°
connection plates
plate 1 with thickness t = 16.0 mm
plate 2 with thickness t = 10.0 mm
steel grade S 275
verifications
simplified method
design load of axial force in connection plate N_{Ed} = 71.6 kN
design load of bending moment in connection plate M_{Ed} = 12.9 kNm
design load of shear force parallel to the axis of the weld $V_{II,Ed}$ = 83.5 kN
partial safety factors
resistance of bolts, welds, plates bearing γ_{M2} = 1.25

design resistance

forces on the design area of the weld: $F_{Ed}(\sigma_\perp)$ = 10.78 kN/cm $F_{Ed}(\tau_\perp)$ = 10.78 kN/cm $F_{Ed}(\tau_{II})$ = 3.34 kN/cm
Resultierende Nahtkraft: $F_{w,Ed} = (F_{Ed}(\sigma_\perp)^2 + F_{Ed}(\tau_\perp)^2 + F_{Ed}(\tau_{II})^2)^{1/2}$ = 15.61 kN/cm
shear strength: $f_{vw,d} = (f_u/3^{1/2}) / (\beta_w \cdot \gamma_{M2})$ = 233.66 N/mm²
design resistance: $F_{w,Rd} = f_{vw,d} \cdot a \cdot l_w$ = 467.31 kN
$F_{w,Ed}$ = 15.61 kN/cm > $F_{w,Rd}$ = 4.67 kN/cm ⇒ utilization U = 3.340 > 1 **not ok. !!**
maximum utilization: U_{max} = 3.340
design resistance not ensured !!

T-stub in tension
EC 3-1-8 (12.10), NA: Germany

scale 1:2.5



T-stub flange with thickness t = 16.0 mm, width b = 250.0 mm
steel grade S 275
connection device

bolt, property class 8.8, bolt size M20, normal clearance

loading

design value of tensile force bolt in row 1 $F_{t,Ed}$ = 94.0 kN

design value of tensile force bolt in row 2 $F_{t,Ed}$ = 0.0 kN

verification parameters

verification of the column flange

application of method 1

calculation effective length l_{eff} of T-stub flange:

distance centre-line of the bolt to the edge of the column flange e = 50.0 mm

distance centre-line of the bolt to the free edge of the column flange (end row) e_1 = 30.0 mm

distance centre-line of the bolt to the web of the column m = 60.0 mm

distance centre-line of the bolt to the next web stiffener m_2 = 30.0 mm

number of bolt rows (2 bolts per row) n_b = 2

distance between bolt rows p = 60.0 mm

bolt-row considered as part of a group of bolt rows

one (inner) bolt-row adjacent to a stiffener

partial safety factors

resistance of cross-sections γ_{M0} = 1.00

design resistance

effective length of T-stub flange (column flange):

in mode 1: $\Sigma l_{eff,1} = \min(\Sigma l_{eff,nc}, \Sigma l_{eff,cp})$ = 368.5 mm

in mode 2: $\Sigma l_{eff,2} = \Sigma l_{eff,nc}$ = 464.2 mm

design tension resistance of the T-stub flange:

in mode 1: $M_{pl,1,Rd} = (0.25 \cdot \Sigma l_{eff,1} \cdot t_f^2 \cdot f_y) / \gamma_{M0}$ = 6.49 kNm

in mode 2: $M_{pl,2,Rd} = (0.25 \cdot \Sigma l_{eff,2} \cdot t_f^2 \cdot f_y) / \gamma_{M0}$ = 8.17 kNm

tension resistance of one bolt: $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2}$ = 141.12 kN, k_2 = 0.90

tension resistance of all bolts: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd}$ = 564.48 kN

$F_{T,1,Rd} = (4 \cdot M_{pl,1,Rd}) / m$ = 432.37 kN

$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n)$ = 405.11 kN, n = 50.0 mm

$F_{T,3,Rd} = \Sigma F_{t,Rd}$ = 564.48 kN

tension resistance of T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd})$ = 405.11 kN

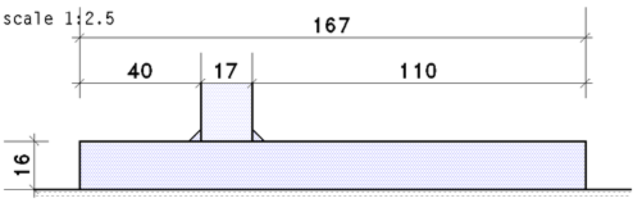
verification

$F_{T,Ed} = 2 \cdot \Sigma F_{t,Ed}$ = 188.0 kN $<$ $F_{T,Rd}$ = 405.11 kN $\Rightarrow$ utilization U = 0.464 $<$ 1 **ok.**

maximum utilization: U_{max} = 0.464

T-stub in compression

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



T-stub flange with thickness t = 16.0 mm, width b = 250.0 mm

steel grade S 275

loading

design value of compression force $F_{C,Ed}$ = 254.0 kN

verification parameters

joint coefficient β_j = 0.6667

load expansion coefficient A_{c1}/A_{c0} = 2.80

concrete/mortar compressive strength f_{ck} = 20.0 N/mm²

expansion width c_{left} = 40.0 mm, c_{right} = 110.0 mm, web thickness t_s = 17.0 mm

partial safety factors

resistance of cross-sections γ_{M0} = 1.00

design resistance

design compression resistance of the T-sub flange

maximum partial distributed load $F_{Rd,u} = A_{c0} \cdot f_{cd} \cdot (A_{c1}/A_{c0})^{1/2}$ = 791.76 kN

design value of concrete compression $f_{jd} = \beta_j \cdot F_{Rd,u} / (b_{eff} \cdot l_{eff})$ = 1.26 kN/cm²

allowable bearing width $c_{max} = t \cdot (f_y / (3 \cdot f_{jd} \cdot \gamma_{M0}))^{1/2}$ = 43.1 mm

c_{left} = 40.0 mm < c_{max} = 43.08 mm **ok.**
compression capacity of the T-sub flange $F_{C,Rd} = f_{jd} \cdot b_{eff} \cdot l_{eff}$ = 527.84 kN

verifications
$F_{C,Ed}$ = 254.0 kN < $F_{C,Rd}$ = 527.84 kN ⇒ utilization U = 0.481 < 1 **ok.**

maximum utilization: U_{max} = 0.481

result

maximum utilization: U_{max} = 3.340
fault - design resistance of welded connection not ensured !!

selected design parameters of National Annex
Germany

DIN EN 1993-1-1 (EC 3)

chapter	value	definition
6.1(1)		partial factors for structural steel
	γ_{M0} = 1.00	collapse of cross-sections
	γ_{M1} = 1.10	instability
	γ_{M2} = 1.25	fracture cross-sections in tension

DIN EN 1993-1-8 (EC 3, connections)

chapter	value	definition
2.2(2)		partial safety factors for connections
	γ_{M3} = 1.25	slip resistance (cat.C, ULS)
	$\gamma_{M3,ser}$ = 1.10	slip resistance (cat.B, SLS)
	γ_{M4} = 1.00	injection bolts
	$\gamma_{M6,ser}$ = 1.00	pins (SLS)

DIN EN 1992-1-1 (EC 2)

chapter	value	definition
2.4.2.4(1)		Partial safety factor for concrete and reinforcement
	γ_c = 1.50 γ_s = 1.15	permanent and transient design situation
3.1.6(1)P	α_{cc} = 0.85	Coeff. to consider the long-term influence of compression strength of concrete and the unfavourable effect due to the kind of action effect

regulations

DIN EN 1990, Eurocode 0: Basis of structural design;
German version EN 1990:2002 + A1:2005 + A1:2005/AC:2010, edition December 2010
DIN EN 1990/NA, National Annex DIN EN 1990, edition December 2010

DIN EN 1992-1-1, Eurocode 2: Design of concrete structures -
part 1-1: General rules and rules for buildings;
German version EN 1992-1-1:2004 + AC:2010, edition January 2011
DIN EN 1992-1-1/NA, National Annex DIN EN 1992-1-1, edition January 2011

DIN EN 1993-1-1, Eurocode 3: Design of steel structures - part 1-1:
General rules and rules for buildings;
German version EN 1993-1-1:2005 + AC:2009, edition December 2010
DIN EN 1993-1-1/NA, National Annex DIN EN 1993-1-1, edition December 2010

DIN EN 1993-1-8, Eurocode 3: Design of steel structures - part 1-8:
Design of joints; German version EN 1993-1-8:2005 + AC:2009, edition December 2010
DIN EN 1993-1-8/NA, National Annex DIN EN 1993-1-8, edition December 2010