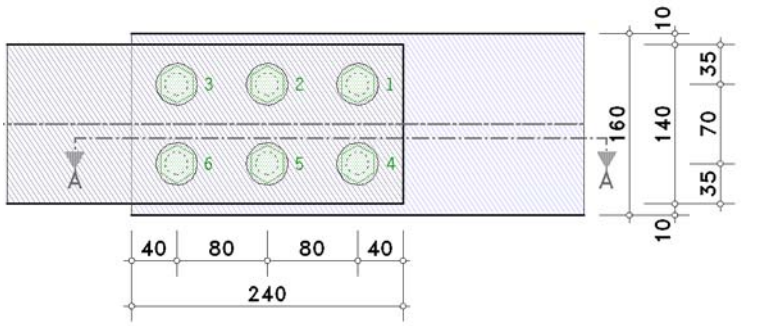
POS. 170: BOLTED SPLICE (DIRECT, SINGLE-SIDED)

axial force connection 4H-EC3NV version: 6/2018-1n

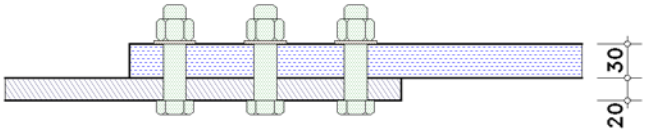
bolted splice (direct, single-sided) EC 3-1-8 (12.10), NA: Deutschland

1. input report (4H-EC3GT)



steel grade S235
bolts M20-10.9

section A-A:



steel grade
steel grade S235
bolts
bolt class 10.9, bolt size M20, normal wrench size
shear plane passes through the unthreaded portion of the bolt
geometry
supported beam
section parameters (flat steel):
height h = 160.0 mm, thickness t = 30.0 mm
joint configuration
connection plate: thickness t_p = 20.0 mm, width b_p = 140.0 mm, length l_p = 240.0 mm
plate lengths: h_o = 0.0 mm, $ü_o$ = 10.0 mm (h_u = 0.0 mm, $ü_u$ = 10.0 mm), s = 0.0 mm
bolts: n_z = 2, $e_{z,0}$ = 35.0 mm, $p_{z,1-2}$ = 70.0 mm, n_x = 3, $e_{x,0}$ = 40.0 mm, $p_{x,1-2}$ = 80.0 mm
$p_{x,2-3}$ = 80.0 mm
partial safety factors for material
resistance of cross-sections γ_{M0} = 1.00
resistance of bolts, welds, plates in bearing γ_{M2} = 1.25
internal forces and moments
Lk 1: N_{Ed} = 70.00 kN

check of data
ok
distances between bolts

horizontal:	e_1 = 40.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 40.0 mm < 4·t + 40 mm = 120.0 mm
horizontal:	p_1 = 80.0 mm > 2.2·d_0 = 48.4 mm,	p_1 = 80.0 mm < min(14·t, 200 mm) = 200.0 mm
horizontal:	p_1 = 80.0 mm > 2.2·d_0 = 48.4 mm,	p_1 = 80.0 mm < min(14·t, 200 mm) = 200.0 mm
horizontal:	e_1 = 40.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 40.0 mm < 4·t + 40 mm = 120.0 mm
vertical:	e_2 = 35.0 mm > 1.2·d_0 = 26.4 mm,	e_2 = 35.0 mm < 4·t + 40 mm = 120.0 mm
vertical:	p_2 = 70.0 mm > 2.4·d_0 = 52.8 mm,	p_2 = 70.0 mm < min(14·t, 200 mm) = 200.0 mm
vertical:	e_2 = 35.0 mm > 1.2·d_0 = 26.4 mm,	e_2 = 35.0 mm < 4·t + 40 mm = 120.0 mm

2. Lk 1

2.1. resistance of the connection

cross-section of points:
coordinates of centroid y_s' = 120.0 mm, z_s' = 70.0 mm
cross-sectional area A' = $n_x \cdot n_z$ = 6, polar moment of inertia $I_p' = \Sigma y_i'^2 + \Sigma z_i'^2$ = 329.50 cm²
member forces in centroid V_y' = -70.0 kN, V_z' = 0.0 kN, M_x' = 0.00 kNm
stress $T_{y,i} = V_y'/A' - M_x'/I_p' \cdot z_i'$, $T_{z,i} = V_z'/A' + M_x'/I_p' \cdot y_i'$, $T_i = (T_{y,i}^2 + T_{z,i}^2)^{1/2}$
point 1: y_1' = -80.0 mm z_1' = -35.0 mm $T_1 = T_{y,1}$ = 11.67 kN

point 2: $y_2' = 0.0$ mm $z_2' = -35.0$ mm $T_2 = T_{y,2} = 11.67$ kN
point 3: $y_3' = 80.0$ mm $z_3' = -35.0$ mm $T_3 = T_{y,3} = 11.67$ kN
point 4: $y_4' = -80.0$ mm $z_4' = 35.0$ mm $T_4 = T_{y,4} = 11.67$ kN
point 5: $y_5' = 0.0$ mm $z_5' = 35.0$ mm $T_5 = T_{y,5} = 11.67$ kN
point 6: $y_6' = 80.0$ mm $z_6' = 35.0$ mm $T_6 = T_{y,6} = 11.67$ kN

bolts in shear
bolt category A:
shear plane passes through the unthreaded portion of the bolt: $\alpha_v = 0.6$, $A = 3.14$ cm²
shear resistance per shear plane: $F_{v,Rd} = \alpha_v \cdot f_{ub} \cdot A / \gamma_{M2} = 150.80$ kN, $f_{ub} = 1000.0$ N/mm²
bolt 1: $U_1 = T_1 / (1 \cdot F_{v,Rd}) = 0.077$, $T_1 = 11.67$ kN
bolt 2: $U_2 = T_2 / (1 \cdot F_{v,Rd}) = 0.077$, $T_2 = 11.67$ kN
bolt 3: $U_3 = T_3 / (1 \cdot F_{v,Rd}) = 0.077$, $T_3 = 11.67$ kN
bolt 4: $U_4 = T_4 / (1 \cdot F_{v,Rd}) = 0.077$, $T_4 = 11.67$ kN
bolt 5: $U_5 = T_5 / (1 \cdot F_{v,Rd}) = 0.077$, $T_5 = 11.67$ kN
bolt 6: $U_6 = T_6 / (1 \cdot F_{v,Rd}) = 0.077$, $T_6 = 11.67$ kN
total: max $U_i = 0.077$
total resistance of axial force: $N_{Rd,1} = N_{1,Ed} / \max U_i = 904.8$ kN

connection plate with bearing resistance
bolt 1: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 174.55$ kN, $k_1 = 2.50$, α_b
horizontal: $U_{y,1} = T_{y,1} / (1 \cdot F_{b,Rd}) = 0.067$, $T_{y,1} = 11.67$ kN
bolt 2: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 174.55$ kN, $k_1 = 2.50$, α_b
horizontal: $U_{y,2} = T_{y,2} / (1 \cdot F_{b,Rd}) = 0.067$, $T_{y,2} = 11.67$ kN
bolt 3: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 174.55$ kN, $k_1 = 2.50$, α_b
horizontal: $U_{y,3} = T_{y,3} / (1 \cdot F_{b,Rd}) = 0.067$, $T_{y,3} = 11.67$ kN
bolt 4: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 174.55$ kN, $k_1 = 2.50$, α_b
horizontal: $U_{y,4} = T_{y,4} / (1 \cdot F_{b,Rd}) = 0.067$, $T_{y,4} = 11.67$ kN
bolt 5: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 174.55$ kN, $k_1 = 2.50$, α_b
horizontal: $U_{y,5} = T_{y,5} / (1 \cdot F_{b,Rd}) = 0.067$, $T_{y,5} = 11.67$ kN
bolt 6: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 174.55$ kN, $k_1 = 2.50$, α_b
horizontal: $U_{y,6} = T_{y,6} / (1 \cdot F_{b,Rd}) = 0.067$, $T_{y,6} = 11.67$ kN
total: max $U_i = 0.067$
total resistance of axial force: $N_{Rd,2} = N_{1,Ed} / \max U_i = 1047.3$ kN

connection plate in tension (net section)
tension resistance $N_{t,Rd} = N_{u,Rd} = (0.9 \cdot A_{net} \cdot f_u) / \gamma_{Mu} = 497.66$ kN, $A_{net} = b_{net} \cdot t = 19.20$ cm², $b_{net} = 96.0$ mm, $\gamma_{Mu} = 1.25$
total resistance of axial force: $N_{Rd,3} = 497.7$ kN

connection plate in tension and shear (shear block)
tension: $A_{nt} = t_p \cdot h_{net} = 9.60$ cm², $h_{net} = 48.0$ mm
shear: $A_{nv} = t_p \cdot b_{net} = 29.00$ cm², $b_{net} = 145.0$ mm
symmetrical group of bolts with centric load:
shear resistance $V_{eff,Rd} = (A_{nt} \cdot f_u) / \gamma_{M2} + (A_{nv} \cdot f_y / 3^{1/2}) / \gamma_{M0} = 965.45$ kN, $f_u = 360.0$ N/mm², $f_y = 235.0$ N/mm²
total resistance of axial force: $N_{Rd,4} = 965.5$ kN

connection plate in bending
verification incl. moment of eccentricity due to $e_y = 25.0$ mm
resistance of axial force $N_{Rd} = f_y / \gamma_{M0} / (1/A + e_y / W_z) = 77.41$ kN
with $A = 28.00$ cm², $W_z = 9.33$ cm³, $e_y = 25.0$ mm
total resistance of axial force: $N_{Rd,5} = 77.4$ kN

supported beam with bearing resistance
bolt 1: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 261.82$ kN, $k_1 = 2.50$, α_b
horizontal: $U_{y,1} = T_{y,1} / F_{b,Rd} = 0.045$, $T_{y,1} = 11.67$ kN
bolt 2: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 261.82$ kN, $k_1 = 2.50$, α_b
horizontal: $U_{y,2} = T_{y,2} / F_{b,Rd} = 0.045$, $T_{y,2} = 11.67$ kN
bolt 3: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 261.82$ kN, $k_1 = 2.50$, α_b
horizontal: $U_{y,3} = T_{y,3} / F_{b,Rd} = 0.045$, $T_{y,3} = 11.67$ kN
bolt 4: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 261.82$ kN, $k_1 = 2.50$, α_b
horizontal: $U_{y,4} = T_{y,4} / F_{b,Rd} = 0.045$, $T_{y,4} = 11.67$ kN
bolt 5: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 261.82$ kN, $k_1 = 2.50$, α_b
horizontal: $U_{y,5} = T_{y,5} / F_{b,Rd} = 0.045$, $T_{y,5} = 11.67$ kN
bolt 6: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 261.82$ kN, $k_1 = 2.50$, α_b
horizontal: $U_{y,6} = T_{y,6} / F_{b,Rd} = 0.045$, $T_{y,6} = 11.67$ kN
total: max $U_i = 0.045$
total resistance of axial force: $N_{Rd,6} = N_{1,Ed} / \max U_i = 1570.9$ kN

supported beam in tension (net section)
tension resistance $N_{t,Rd} = N_{u,Rd} = (0.9 \cdot A_{net} \cdot f_u) / \gamma_{Mu} = 902.02$ kN, $A_{net} = b_{net} \cdot t = 34.80$ cm², $b_{net} = 116.0$ mm, $\gamma_{Mu} = 1.25$
total resistance of axial force: $N_{Rd,7} = 902.0$ kN

supported beam in tension and shear (shear block)
tension: $A_{nt} = t_w \cdot h_{net} = 14.40$ cm², $h_{net} = 48.0$ mm
shear: $A_{nv} = t_w \cdot b_{net} = 43.50$ cm², $b_{net} = 145.0$ mm
symmetrical group of bolts with centric load:
shear resistance $V_{eff,Rd} = (A_{nt} \cdot f_u) / \gamma_{M2} + (A_{nv} \cdot f_y / 3^{1/2}) / \gamma_{M0} = 1448.18$ kN, $f_u = 360.0$ N/mm², $f_y = 235.0$ N/mm²

total resistance of axial force: $N_{Rd,8}$ = 1448.2 kN

supported beam in bending
verification incl. moment of eccentricity due to e_y = 25.0 mm
resistance of axial force $N_{Rd} = f_y/\gamma_{M0} / (1/A+e_y/W_z)$ = 188.00 kN
with A = 48.00 cm², W_z = 24.00 cm³, e_y = 25.0 mm
total resistance of axial force: $N_{Rd,9}$ = 188.0 kN

resistance of axial force: min $N_{Rd,p}$ = $N_{Rd,5}$ = 77.4 kN

2.2. verification of the connection

N_{Ed} = 70.0 kN: N_{Ed} / min N_{Rd} = 0.904 < 1 ok

3. final result

maximum utilisation: resistance max U = 0.904 < 1 ok

verification succeeded

4. Regulations

EN 1990, Eurocode 0: Basis of structural design;
Deutsche Fassung EN 1990:2002 + A1:2005 + A1:2005/AC:2010, Ausgabe Dezember 2010
EN 1990/NA, Nationaler appendix zur EN 1990, Ausgabe Dezember 2010

EN 1993-1-1, Eurocode 3: Bemessung and Konstruktion von steelbauten -
Teil 1-1: Allgemeine Bemessungsregeln und Regeln für den Hochbau;
Deutsche Fassung EN 1993-1-1:2005 + AC:2009, Ausgabe Dezember 2010
EN 1993-1-1/A1, Ergänzungen zur EN 1993-1-1, Ausgabe Juli 2014
EN 1993-1-1/NA, Nationaler appendix zur EN 1993-1-1, Ausgabe Dezember 2018

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

ECCS Document No. 126: European Recommendations for the Design of Simple Joints in Steel Structures.
ECCS TC10 - Structural Connections, 2009. J.P. Jaspart, J.F. Demonceau, S. Renkin, M.L. Guillaume