standardized IM-joint

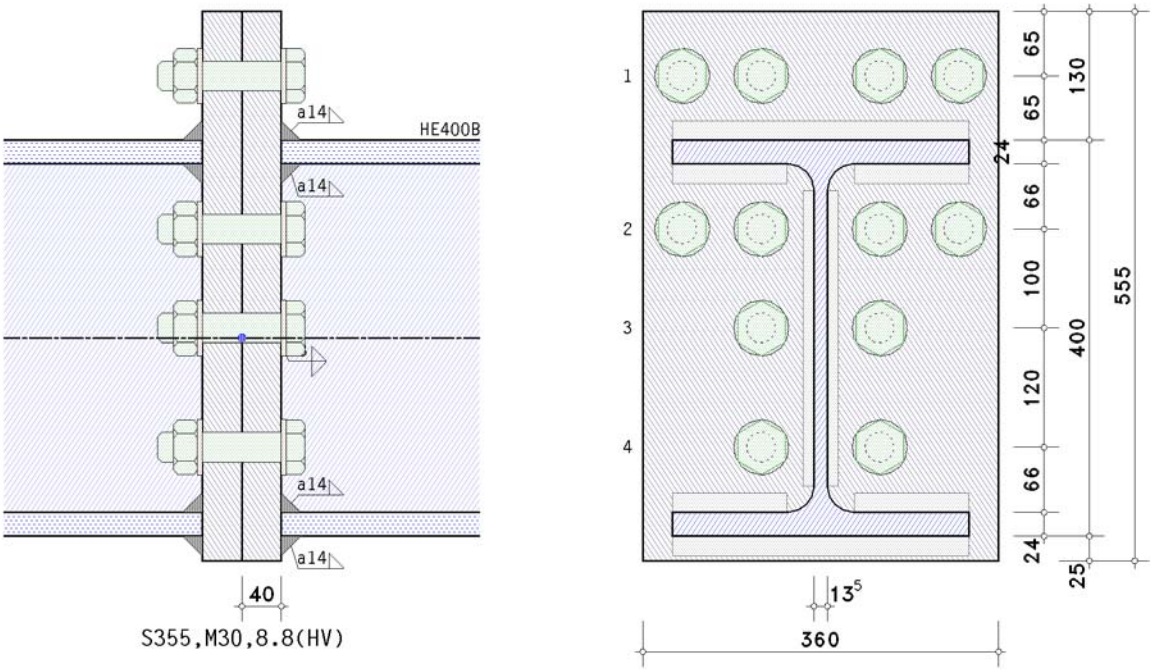
moment resistant joints IM acc. to EC 3-1-8 (12.10), NA: Deutschland

dimensions of beam, bolts, end-plate and welds, material
and arrangement of bolts are taken of the following literature:
'Typisierte Anschlüsse im Stahlhochbau nach DIN EN 1993-1-8, Ergänzungsband 2018,
Stahlbau Verlags- und Service GmbH, Ausgabe 2018'
the current number and associated parameters are recorded.
MN-interaction follows Cerfontaine (in Jaspart/Weynand: Design of Joints in Steel Structures).
connections with 4 bolts per row are verified with AIF-Forschnungsbericht Nr. 15059.
maximum resistance of normal forces are calculated without components of compression/shear and linearization.

beam splice, steel grade S355, bolt class of bolts 8.8

41291: beam section HEB400, bolt size M30, connection with 4 and 2 bolts per row
end-plate: t_p = 40 mm, b_p = 360 mm, h_p = 555 mm, e_1 = 65 mm, $p_{1,1}$ = 155 mm, $p_{1,2}$ = 100 mm
$p_{1,3}$ = 120 mm, u_1 = 130 mm, w = 120 mm, p_2 = 80 mm
fillet welds: a_f = 14 mm, a_w = 8 mm

Rigid beam splice



Lk 1: internal moment (top tension) + shear force

resistance of cross-section

$M_{pl,N,Q}$ = 1130.44 kNm

connection capacity

moment resistance
resistance per bolt-row
row 1 (h_r = 453.0 mm): $F_{tr,Rd}$ = 1180.2 kN
row 2 (h_r = 298.0 mm): $F_{tr,Rd}$ = 1127.0 kN
row 3 (h_r = 198.0 mm): $F_{tr,Rd}$ = 646.3 kN
row 4 (h_r = 78.0 mm): $F_{tr,Rd}$ = 97.9 kN
resistance of flanges
$F_{c,Rd}$ = 3051.5 kN
moment resistance
$M_{j,Rd} = \Sigma(F_{tr,Rd} \cdot h_r)$ = 1006.1 kNm
$N_{j,t,Rd} = \Sigma F_{tr,Rd}^{*}$ = 3599.8 kN
$N_{j,c,Rd} = F_{c,Rd}$ = 3051.5 kN

shear/bearing resistance
resistance per bolt-row

row 1: $F_{vr,Rd}$ = 155.1 kN
row 2: $F_{vr,Rd}$ = 155.1 kN
row 3: $F_{vr,Rd}$ = 155.1 kN
row 4: $F_{vr,Rd}$ = 155.1 kN
shear/bearing resistance
$V_{j,Rd} = \Sigma F_{vr,Rd}$ = 620.4 kN

shear resistance
shear resistance of end plate: $V_{ep,Rd}$ = 1199.00 kN
plastic shear resistance $V_{pl,Rd}$ = 717.1 kN (requirement, s. 'Typisierte Anschlüsse')

total
$M_{j,Rd}$ = 1006.1 kNm $N_{j,t,Rd}$ = 3599.8 kN $N_{j,c,Rd}$ = 3051.5 kN $V_{j,Rd}$ = 620.4 kN $V_{pl,Rd}$ = 717.1 kN $V_{ep,Rd}$ = 1199.0 kN

rotational stiffness

initial rotational stiffness: $S_{j,ini} = (E \cdot z^2) / \Sigma(1/k_i)$ = 841850.5 kNm/rad, $\Sigma(1/k_i)$ = 0.030 mm^{-1}
$|M_{j,Ed}|$ = 1.00 kNm $\leq$ 2/3 $M_{j,Rd}$ = 670.7 kNm $\Rightarrow$ μ = 1
rotational stiffness: $S_{j,Rd} = S_{j,ini} / \mu$ = 841850.5 kNm/rad
rotation: $\varphi_{j,Ed} = M_{j,Ed} / S_{j,Rd}$ = 0.000°

Lk 2: internal moment (bottom tension) + shear force

resistance of cross-section

$M_{pl,N,Q}$ = 1130.44 kNm

connection capacity

moment resistance
resistance per bolt-row
row 1 (h_r = 298.0 mm): $F_{tr,Rd}$ = 646.3 kN
row 2 (h_r = 178.0 mm): $F_{tr,Rd}$ = 386.0 kN
row 3 (h_r = 78.0 mm): $F_{tr,Rd}$ = 169.2 kN
resistance of flanges
$F_{c,Rd}$ = 3051.5 kN
moment resistance
$M_{j,Rd} = \Sigma(F_{tr,Rd} \cdot h_r)$ = 274.5 kNm
$N_{j,t,Rd} = \Sigma F_{tr,Rd}^*$ = 1938.8 kN
$N_{j,c,Rd} = F_{c,Rd}$ = 3051.5 kN

shear/bearing resistance
resistance per bolt-row
row 1: $F_{vr,Rd}$ = 155.1 kN
row 2: $F_{vr,Rd}$ = 155.1 kN
row 3: $F_{vr,Rd}$ = 155.1 kN
row 4: $F_{vr,Rd}$ = 155.1 kN
shear/bearing resistance
$V_{j,Rd} = \Sigma F_{vr,Rd}$ = 620.4 kN

shear resistance
shear resistance of end plate: $V_{ep,Rd}$ = 1199.00 kN
plastic shear resistance $V_{pl,Rd}$ = 717.1 kN (requirement, s. 'Typisierte Anschlüsse')

total
$M_{j,Rd}$ = 274.5 kNm $N_{j,t,Rd}$ = 1938.8 kN $N_{j,c,Rd}$ = 3051.5 kN $V_{j,Rd}$ = 620.4 kN $V_{pl,Rd}$ = 717.1 kN $V_{ep,Rd}$ = 1199.0 kN

rotational stiffness

initial rotational stiffness: $S_{j,ini} = (E \cdot z^2) / \Sigma(1/k_i)$ = 190828.4 kNm/rad, $\Sigma(1/k_i)$ = 0.059 mm^{-1}
$|M_{j,Ed}|$ = 1.00 kNm $\leq$ 2/3 $M_{j,Rd}$ = 183.0 kNm $\Rightarrow$ μ = 1
rotational stiffness: $S_{j,Rd} = S_{j,ini} / \mu$ = 190828.4 kNm/rad
rotation: $\varphi_{j,Ed} = M_{j,Ed} / S_{j,Rd}$ = 0.000°

Lk 3: tension force + internal moment (top tension) + shear force

resistance of cross-section

$M_{pl,N,Q}$ = 1130.44 kNm

connection capacity

bending/tension resistance
resistance per bolt-row
row 1 (h_r = 453.0 mm): $F_{tr,Rd}$ = 0.0 kN
row 2 (h_r = 298.0 mm): $F_{tr,Rd}$ = 646.3 kN
row 3 (h_r = 198.0 mm): $F_{tr,Rd}$ = 429.4 kN
row 4 (h_r = 78.0 mm): $F_{tr,Rd}$ = 169.2 kN
moment resistance
$M_{j,Rd} = \Sigma(F_{tr,Rd} \cdot h_r)$ = 290.8 kNm
$N_{j,t,Rd} = \Sigma F_{tr,Rd}^{*}$ = 1938.8 kN

shear/bearing resistance
resistance per bolt-row
row 1: $F_{vr,Rd}$ = 155.1 kN
row 2: $F_{vr,Rd}$ = 155.1 kN
row 3: $F_{vr,Rd}$ = 155.1 kN
row 4: $F_{vr,Rd}$ = 155.1 kN
shear/bearing resistance
$V_{j,Rd} = \Sigma F_{vr,Rd}$ = 620.4 kN

shear resistance
shear resistance of end plate: $V_{ep,Rd}$ = 1199.00 kN
plastic shear resistance $V_{pl,Rd}$ = 717.1 kN (requirement, s. 'Typisierte Anschlüsse')

total
$M_{j,Rd}$ = 290.8 kNm $N_{j,t,Rd}$ = 1938.8 kN $V_{j,Rd}$ = 620.4 kN $V_{pl,Rd}$ = 717.1 kN $V_{ep,Rd}$ = 1199.0 kN

rotational stiffness

rotational stiffness only für bending connections !!

Lk 4: tension force + internal moment (bottom tension) + shear force

resistance of cross-section

$M_{pl,N,Q}$ = 1130.44 kNm

connection capacity

bending/tension resistance
resistance per bolt-row
row 1 (h_r = 298.0 mm): $F_{tr,Rd}$ = 646.3 kN
row 2 (h_r = 178.0 mm): $F_{tr,Rd}$ = 386.0 kN
row 3 (h_r = 78.0 mm): $F_{tr,Rd}$ = 169.2 kN
row 4 (h_r = -77.0 mm): $F_{tr,Rd}$ = 0.0 kN
moment resistance
$M_{j,Rd} = \Sigma(F_{tr,Rd} \cdot h_r)$ = 274.5 kNm for $h_r \geq 0$
$N_{j,t,Rd} = \Sigma F_{tr,Rd}^{*}$ = 1938.8 kN

shear/bearing resistance
resistance per bolt-row
row 1: $F_{vr,Rd}$ = 155.1 kN
row 2: $F_{vr,Rd}$ = 155.1 kN
row 3: $F_{vr,Rd}$ = 155.1 kN
row 4: $F_{vr,Rd}$ = 155.1 kN
shear/bearing resistance
$V_{j,Rd} = \Sigma F_{vr,Rd}$ = 620.4 kN

shear resistance
shear resistance of end plate: $V_{ep,Rd}$ = 1199.00 kN
plastic shear resistance $V_{pl,Rd}$ = 717.1 kN (requirement, s. 'Typisierte Anschlüsse')

total
$M_{j,Rd}$ = 274.5 kNm $N_{j,t,Rd}$ = 1938.8 kN $V_{j,Rd}$ = 620.4 kN $V_{pl,Rd}$ = 717.1 kN $V_{ep,Rd}$ = 1199.0 kN

rotational stiffness

rotational stiffness only für bending connections !!

Lk 5: compression force + internal moment (top tension)

resistance of cross-section

$M_{pl,N,Q}$ = 1130.44 kNm

connection capacity

bending/comporession resistance
resistance per bolt-row
row 1 (h_r = 453.0 mm): $F_{tr,Rd}$ = 646.3 kN
row 2 (h_r = 298.0 mm): $F_{tr,Rd}$ = 425.1 kN
row 3 (h_r = 198.0 mm): $F_{tr,Rd}$ = 282.5 kN
row 4 (h_r = 78.0 mm): $F_{tr,Rd}$ = 111.3 kN
resistance of flanges
$\Sigma F_{c,Rd}$ = 3051.5+3051.5 = 6103.0 kN
moment resistance
$M_{j,Rd} = \Sigma(F_{tr,Rd} \cdot h_r)$ = 484.1 kNm
$N_{j,c,Rd} = \Sigma F_{c,Rd}$ = 6103.0 kN

shear/bearing resistance
resistance per bolt-row
row 1: $F_{vr,Rd}$ = 155.1 kN
row 2: $F_{vr,Rd}$ = 155.1 kN
row 3: $F_{vr,Rd}$ = 155.1 kN
row 4: $F_{vr,Rd}$ = 155.1 kN
shear/bearing resistance
$V_{j,Rd} = \Sigma F_{vr,Rd}$ = 620.4 kN

shear resistance
shear resistance of end plate: $V_{ep,Rd}$ = 1199.00 kN
plastic shear resistance $V_{pl,Rd}$ = 717.1 kN (requirement, s. 'Typisierte Anschlüsse')

total
$M_{j,Rd}$ = 484.1 kNm $N_{j,c,Rd}$ = 6103.0 kN $V_{j,Rd}$ = 620.4 kN $V_{pl,Rd}$ = 717.1 kN $V_{ep,Rd}$ = 1199.0 kN

rotational stiffness

rotational stiffness only für bending connections !!

Lk 6: compression force + internal moment (bottom tension)

resistance of cross-section

$M_{pl,N,Q}$ = 1130.44 kNm

connection capacity

bending/comporession resistance
resistance per bolt-row
row 1 (h_r = 298.0 mm): $F_{tr,Rd}$ = 646.3 kN
row 2 (h_r = 178.0 mm): $F_{tr,Rd}$ = 386.0 kN
row 3 (h_r = 78.0 mm): $F_{tr,Rd}$ = 169.2 kN
resistance of flanges
$\Sigma F_{c,Rd}$ = 3051.5+3051.5 = 6103.0 kN
moment resistance
$M_{j,Rd} = \Sigma(F_{tr,Rd} \cdot h_r)$ = 274.5 kNm
$N_{j,c,Rd} = \Sigma F_{c,Rd}$ = 6103.0 kN

shear/bearing resistance
resistance per bolt-row
row 1: $F_{vr,Rd}$ = 155.1 kN
row 2: $F_{vr,Rd}$ = 155.1 kN
row 3: $F_{vr,Rd}$ = 155.1 kN
row 4: $F_{vr,Rd}$ = 155.1 kN
shear/bearing resistance
$V_{j,Rd} = \Sigma F_{vr,Rd}$ = 620.4 kN

shear resistance
shear resistance of end plate: $V_{ep,Rd}$ = 1199.00 kN

plastic shear resistance $V_{pl,Rd}$ = 717.1 kN (requirement, s. 'Typisierte Anschlüsse')

total
$M_{j,Rd}$ = 274.5 kNm $N_{j,c,Rd}$ = 6103.0 kN $V_{j,Rd}$ = 620.4 kN $V_{pl,Rd}$ = 717.1 kN $V_{ep,Rd}$ = 1199.0 kN

rotational stiffness

rotational stiffness only für bending connections !!

Final Result

initial stiffness:	$S_{j,ini}$	= 841.9 MNm/rad
moment resistance (M+):	$M_{j1,Rd}$	= 1006.1 kNm
moment resistance (M-):	$M_{j2,Rd}$	= 274.5 kNm
tension resistance:	$N_{jt,Rd}$	= 1938.8 kNm
compression resistance:	$N_{jc,Rd}$	= 6103.0 kNm
shear force resistance:	$V_{j,Rd}$	= 620.4 kNm
moment resistance of beam section:	$M_{c,Rd}$	= 1130.4 kNm