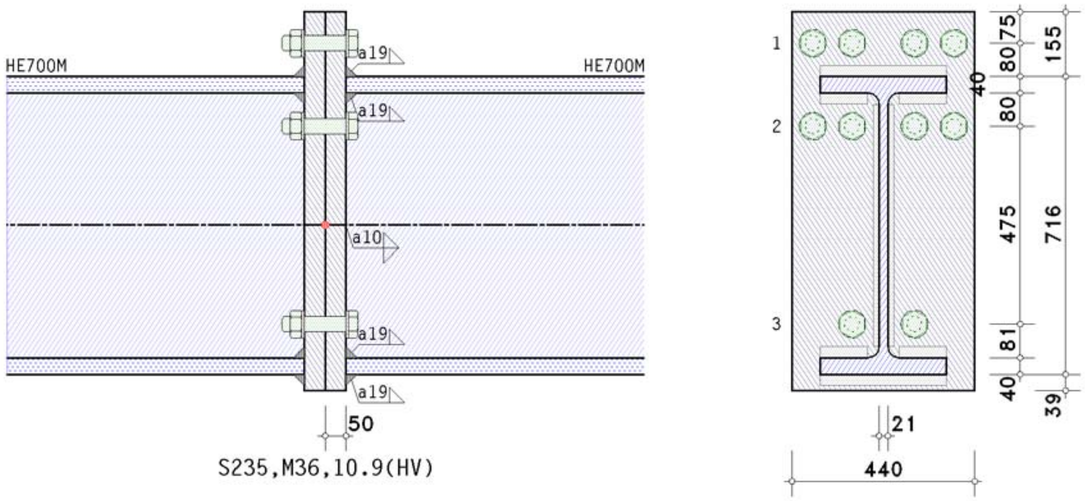
POS. 79: DAST IM 11748

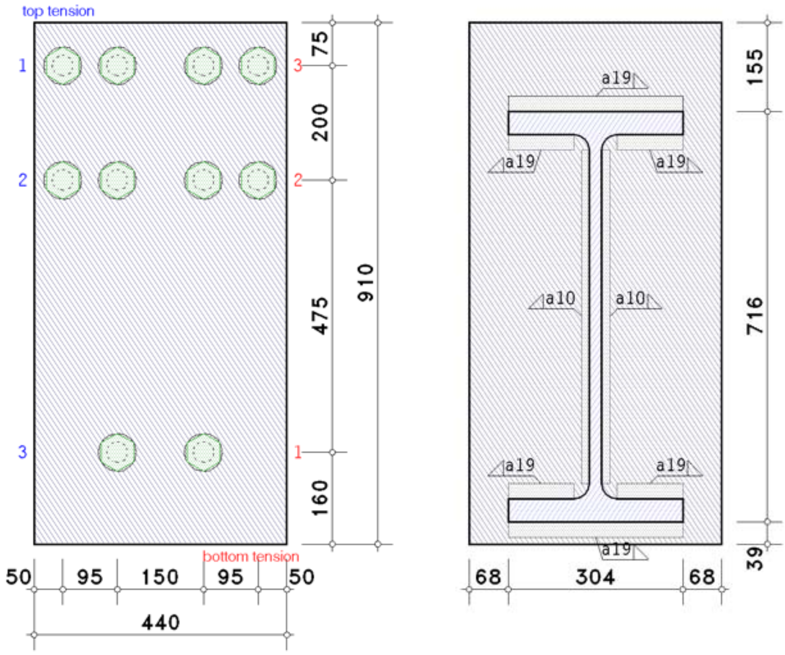
4H-ec3BT version: 4/2013-5l

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 M36

large wrench size (high strength bolt), preloaded (for info: preloading $F_{p,C}^* = 0.7 \cdot f_{yb} \cdot A_s = 514.7$ kN)

shear plane passes through the unthreaded portion of the bolt

beam parameters

section HE700M

verification parameters

bolted end-plate connection:

thickness $t_p = 50.0$ mm, width $b_p = 440.0$ mm, length $l_p = 910.0$ mm

projections $h_{p,o} = 155.0$ mm, $h_{p,u} = 39.0$ mm

bolts in connection:

3 bolt-rows with 4 bolts (maximum):

row 1: 4 bolts, row 2: 4 bolts, row 3: 2 inner bolts

all bolt-rows considered individually

all bolt-rows for shear transfer (rows 1-3)

verification with der Component method: MNV-interaction acc. to Cerfontaine (in Jaspart/Weynand)

calculation method (4 bolts per row) acc. to the final report of AIF-project 15059

centre distance between outer and inner bolt w_2 = 95.0 mm
centre distance of the bolts to the lateral edge of the end-plate e_2 = 50.0 mm
centre distance of the first bolt-row to the upper edge of the end-plate (end row) e_o = 75.0 mm
centre distance of the last bolt-row to the bottom edge of the end-plate (end row) e_u = 160.0 mm
centre distance of the bolt-rows from each other p_{1-2} = 200.0 mm, p_{2-3} = 475.0 mm

welds at the connection point:
beam flange top: fillet weld, weld thickness a = 19.0 mm
beam web: fillet weld, weld thickness a = 10.0 mm
beam flange bottom: fillet weld, weld thickness a = 19.0 mm

internal forces and moments in the intersection point of system axes

Lk 1: $M_{j,b,Ed}$ = -2200.00 kNm $V_{j,b,Ed}$ = 800.00 kN
Lk 2: $M_{j,b,Ed}$ = 650.00 kNm $V_{j,b,Ed}$ = 800.00 kN
Lk 3: $N_{j,b,Ed}$ = 2100.00 kN
Lk 4: $N_{j,b,Ed}$ = -7300.00 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
--	---	---	---	---
1	0.892	0.968	0.331	0.968
2	0.416	0.933	0.331	0.933
3	0.232	0.858	---	0.858
4	0.807	0.996	---	0.996*

$U_{\sigma,b}$: stress utilization at the beam; U_{MNV}: utilization due to MNV-interaction; U_{pl}: utilization due to shear in end-plate
U: 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	3033.8	3033.8	0.042	0.968	0.00	800.00	2200.00	!!
2	647.9	647.9	0.057	0.933	0.00	800.00	650.00	!!
3	0.0	0.0	0	0.858	2100.00	0.00	0.00	!!
4	0.0	0.0	0	0.996*	7300.00	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 4]: max U = 0.996 < 1 ok

verification succeeded

3. Detailed edition of Lk 1

notes
no verfication for welds within the connection.
notes
connection is verified due to EC 3-1-8 regardless of preloading.
however, connections may be constructed with prestressed high strength bolts.
simplified calculation of shear force resistance takes all bolt-rows into account.
no consideration of bolt groups in joints with 4 bolts per row.

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 = 2200.00 kNm, V_d = 800.00 kN

partial internal forces and moments

internal forces and moments in the periphery end-plate-beam: $M'_d = M_d - V_d \cdot t_{ep}$ = 2160.00 kNm
$N_{b,t} = -N_d \cdot z_{bu}/z_b + M'_d/z_b$ = 3195.27 kN, z_b = 676.0 mm, z_{bu} = 338.0 mm
$N_{b,c} = N_d \cdot z_{bo}/z_b + M'_d/z_b$ = 3195.27 kN, z_b = 676.0 mm, z_{bo} = 338.0 mm

3.2. resistance of cross-section

plastic cross-sectional check for M_y = -2160.00 kNm, V_z = 800.00 kN
valid normal/shear stress: zul σ_{Rd} = 23.50 kN/cm², zul τ_{Rd} = 13.57 kN/cm²
top flange: resistance forces $N_{max,O}$ = 2857.60 kN, $N_{min,O}$ = -2857.60 kN
bottom flange: resistance forces $N_{max,U}$ = 2857.60 kN, $N_{min,U}$ = -2857.60 kN
web: shear force V_S = 800.00 kN, shear stress τ_S = 5.64 kN/cm² ⇒ $U_{\tau,S}$ = 0.415
resistance forces $N_{max,S}$ = 3034.68 kN, $N_{min,S}$ = -3034.68 kN
main bending: moment M_y = -2160.00 kNm, resistance moments $M_{y,max}$ = 2444.60 kNm, $M_{y,min}$ = -2444.60 kNm ⇒ U_{My} = 0.884
total (possibly due to load increase): max U = 0.892 < 1 ok
utilizations: resistance U_σ = 0.892 < 1 ok, c/t-ratio $U_{c/t}$ = 0.334 < 1 ok

3.3. basic components

3.3.1. Gk 5: end-plate in bending

connections with 4 bolts per bolt-row are not treated in EC 3-1-8.
verification follows the final report of AIF-project 15059.

extended part of end-plate
in projecting part of end plate only one bolt-row (n_b = 1) is considered (4 bolts per row).
effective length of the T-stub flange (end-plate):
in mode 1: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp})$ = 220.0 mm, $l_{eff,cp}$ = 473.8 mm
in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc}$ = 220.0 mm
tension resistance of the T-stub flange:
in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma_{M0}$ = 29.56 kNm
in mode 3: $\Sigma F_{t,Rd} = 4 \cdot n_b \cdot F_{t,Rd}$ = 2352.96 kN
mode 1: complete yielding of the T-stub flange
$F_{T,1,Rd} = ((8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}) / (2 \cdot m \cdot n - e_w \cdot (m+n))$ = 2560.80 kN
mode 2: bolt failure simultaneously with yielding of the T-stub flange
$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n)$ = 1756.36 kN
mode 3: bolt failure
$F_{T,3,Rd} = \Sigma F_{t,Rd}$ = 2352.96 kN
tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd})$ = 1756.36 kN
resistance of a weld (req.1): $f_{1w,d} = f_u / (\beta_w \cdot \gamma_{M2})$ = 360.0 N/mm²
tension resistance of welds: $F_{T,w,Rd} = 2^{1/2} \cdot f_{1w,d} \cdot a \cdot l_{eff}$ = 2128.11 kN (≥ 1756.36 kN, not decisive)
resistance and effective length of end-plate in bending (projection)
$F_{t,ep,Rd,1}$ = 1756.36 kN, $l_{eff,1}$ = 220.0 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 (4 bolts per row)
effective length of the T-stub flange (end-plate):
in mode 1: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp})$ = 416.8 mm, $l_{eff,cp}$ = 668.4 mm
in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc}$ = 416.8 mm
tension resistance of the T-stub flange:
in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t_f^2 \cdot f_y) / \gamma_{M0}$ = 56.01 kNm
in mode 3: $\Sigma F_{t,Rd} = 4 \cdot n_b \cdot F_{t,Rd}$ = 2352.96 kN
mode 1: complete yielding of the T-stub flange
$F_{T,1,Rd} = ((8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}) / (2 \cdot m \cdot n - e_w \cdot (m+n))$ = 5493.02 kN
mode 2: bolt failure simultaneously with yielding of the T-stub flange
$F_{T,2,p,Rd} = (2 \cdot M_{pl,2,Rd} + 0.5 \cdot \Sigma F_{t,Rd} \cdot (n_1^2 + 2 \cdot n_2^2 + 2 \cdot n_1 \cdot n_2)/(n_1+n_2)) / (m+n_1+n_2)$ = 1528.31 kN
$F_{T,2,np,Rd} = (2 \cdot M_{pl,1,Rd} + 0.5 \cdot \Sigma F_{t,Rd} \cdot n_1) / (m+n_1)$ = 1510.13 kN
$F_{T,2,Rd} = \min(F_{T,2,p,Rd}, F_{T,2,np,Rd})$ = 1510.13 kN
mode 3: bolt failure
$F_{T,3,Rd} = 0.9 \cdot \Sigma F_{t,Rd}$ = 2117.66 kN
tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd})$ = 1510.13 kN
resistance of a weld (req.1): $f_{1w,d} = f_u / (\beta_w \cdot \gamma_{M2})$ = 360.0 N/mm²
tension resistance of welds: $F_{T,w,Rd} = 2^{1/2} \cdot f_{1w,d} \cdot a \cdot l_{eff}$ = 2122.01 kN (≥ 1510.13 kN, not decisive)
row 3 (2 bolts per row)
effective length of the T-stub flange (end-plate):
in mode 1: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp})$ = 334.2 mm, $l_{eff,cp}$ = 334.2 mm
in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc}$ = 418.4 mm
tension resistance of the T-stub flange:
in mode 1: $M_{pl,1,Rd} = (0.25 \cdot \Sigma l_{eff,1} \cdot t_f^2 \cdot f_y) / \gamma_{M0}$ = 44.91 kNm
in mode 2: $M_{pl,2,Rd} = (0.25 \cdot \Sigma l_{eff,2} \cdot t_f^2 \cdot f_y) / \gamma_{M0}$ = 56.22 kNm
in mode 3: $\Sigma F_{t,Rd} = 2 \cdot n_b \cdot F_{t,Rd}$ = 1176.48 kN
mode 1: complete yielding of the T-stub flange
$F_{T,1,Rd} = ((8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}) / (2 \cdot m \cdot n - e_w \cdot (m+n))$ = 4394.70 kN
mode 2: bolt failure simultaneously with yielding of the T-stub flange
$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n)$ = 1593.16 kN
mode 3: bolt failure
$F_{T,3,Rd} = \Sigma F_{t,Rd}$ = 1176.48 kN

tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 1176.48$ kN
resistance of a weld (req.1): $f_{1w,d} = f_u / (\beta_w \cdot \gamma_{M2}) = 360.0$ N/mm^2
tension resistance of welds: $F_{T,w,Rd} = 2^{1/2} \cdot f_{1w,d} \cdot a \cdot l_{eff} = 1701.36$ kN ($\geq$ 1176.48 kN, not decisive)

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

$F_{ep,Rd,2} = 1510.13$ kN, $l_{eff,2} = 416.8$ mm
$F_{ep,Rd,3} = 1176.48$ kN, $l_{eff,3} = 334.2$ mm

3.3.2. Gk 7: beam flange and web in compression

flange bottom: section class for $c/(\varepsilon \cdot t) = 2.86$: 1
web: section class for $\alpha = 0.50$ and $c/(\varepsilon \cdot t) = 27.71$: 1
section class of beam: 1
taking into account the moment-shear force-interaction $V_{Ed} = 800.0$ kN
stress due to bending with shear force: $V_{Ed} = 800.0$ kN $\leq$ 1152.0 kN = $V_{pl,Rd}/2$ $\Rightarrow$ no effect
resistance $M_{c,Rd} = M_{pl,Rd} = (W_{pl} \cdot f_y) / \gamma_{M0} = 2476.67$ kNm, $W_{pl} = 10539.00$ cm^3
resistance of a flange (and web) with compression
$F_{c,f,Rd} = M_{c,Rd} / (h - t_f) = 3663.71$ kN

resistance of upper beam flange:

stress due to bending with shear force: $V_{Ed} = 800.0$ kN $\leq$ 1152.0 kN = $V_{pl,Rd}/2$ $\Rightarrow$ no effect
resistance $M_{c,Rd} = M_{pl,Rd} = (W_{pl} \cdot f_y) / \gamma_{M0} = 2476.67$ kNm, $W_{pl} = 10539.00$ cm^3
resistance of a flange (and web) with compression
$F_{c,f,Rd} = M_{c,Rd} / (h - t_f) = 3663.71$ kN

3.3.3. Gk 8: beam web in tension

each individual bolt-row:

row 2
effective width $b_{eff,t,wb} = 416.8$ mm (l_{eff} from bc 5)
resistance of a beam web in tension
$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_{y,wb} / \gamma_{M0} = 2056.9$ kN
row 3
effective width $b_{eff,t,wb} = 334.2$ mm (l_{eff} from bc 5)
resistance of a beam web in tension
$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_{y,wb} / \gamma_{M0} = 1649.2$ kN

3.3.4. Gk 10: bolts in tension

tension resistance of one bolt $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2} = 588.24$ kN, $k_2 = 0.90$
punching shear load capicity $B_{p,Rd} = (0.6 \cdot \pi \cdot d_m \cdot t_p \cdot f_u)) / \gamma_{M2} = 1716.00$ kN, $t_p = 50.0$ mm
tension-/punching shear load capicity for 4 bolts: $\Sigma F_{tp,Rd} = 4 \cdot \min(F_{t,Rd}, B_{p,Rd}) = 2352.96$ kN
row (shear): $\Sigma F_{tp,Rd,1} = 1176.5$ kN, $\Sigma F_{tp,Rd,2} = 1176.5$ kN, $\Sigma F_{tp,Rd,3} = 1176.5$ kN
row (bending): $\Sigma F_{tp,Rd,1} = 2353.0$ kN, $\Sigma F_{tp,Rd,2} = 2353.0$ kN, $\Sigma F_{tp,Rd,3} = 1176.5$ kN

3.3.5. Gk 11: bolts in shear

shear resistance per shear plane $F_{v,Rd} = \alpha_v \cdot f_{ub} \cdot A / \gamma_{M2} = 488.58$ kN, $\alpha_v = 0.60$
shear resistance of 4 bolts (1-shear): $\Sigma F_{v,Rd} = 4 \cdot F_{v,Rd} = 1954.32$ kN
row: $\Sigma F_{v,Rd,1} = 977.2$ kN, $\Sigma F_{v,Rd,2} = 977.2$ kN, $\Sigma F_{v,Rd,3} = 977.2$ kN

3.3.6. Gk 12: plate with bearing resistance

row 1
bolt 1: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 568.33$ kN, $k_1 = 1.71$, $\alpha_b = 0.64$
bolt 2: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 568.33$ kN, $k_1 = 1.71$, $\alpha_b = 0.64$
bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd} = 1136.66$ kN
row 2
bolt 1: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 886.60$ kN, $k_1 = 1.71$, $\alpha_b = 1.00$
bolt 2: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 886.60$ kN, $k_1 = 1.71$, $\alpha_b = 1.00$
bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd} = 1773.19$ kN
row 3
bolt 1: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 886.60$ kN, $k_1 = 1.71$, $\alpha_b = 1.00$
bolt 2: bearing resistance $F_{b,Rd} = (k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 886.60$ kN, $k_1 = 1.71$, $\alpha_b = 1.00$
bearing resistance of 1x2 bolts: $\Sigma F_{b,Rd} = 1773.19$ kN

bearing resistance (3 rows)

$\Sigma F_{b,Rd,1} = 1136.66$ kN
$\Sigma F_{b,Rd,2} = 1773.19$ kN
$\Sigma F_{b,Rd,3} = 1773.19$ kN

3.4. connection capacity

3.4.1. moment resistance

distance of tension-bolt-rows from centre of compression: h_1 = 776.0 mm, h_2 = 576.0 mm, h_3 = 101.0 mm

resistance per bolt-row (MNV-interaction)
row 1: $F_{tr,Rd}$ = 1756.4 kN
row 2: $F_{tr,Rd}$ = 1510.1 kN
row 3: $F_{tr,Rd}$ = 397.2 kN

resistance of flanges (MNV-interaction)
bottom: $F_{c,Rd}$ = 3663.7 kN

moment resistance (MNV-interaction)
$M_{j,Rd} = \Sigma(F_{tr,Rd} \cdot h_r)$ = 2272.9 kNm

shear force resistance (MNV-interaction)
$V_{j,Rd}$ = 826.5 kN

3.4.2. shear resistance

shear resistance of end plate
end-plate: $V_{ep,Rd}$ = 3612.19 kN
welds: $F_{w,Rd}$ = 2419.33 kN
shear resistance of end plate: $V_{ep,Rd} = F_{w,Rd}$ = 2419.33 kN

3.5. verifications

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

U_{MNV} = 0.968 < 1 ok
$V_{Ed}/V_{ep,Rd}$ = 0.331 < 1 ok

3.5.2. verification result

maximum utilization: max U = 0.968 < 1 ok

3.6. rotational stiffness

stiffness coefficients
equivalent stiffness coefficient for 3 tension-bolt-rows:
1: k_5 = 123.60 mm, k_{10} = 9.49 mm ⇒ $k_{eff,1} = 1 / \Sigma(1/k_{i,1})$ = 14.520 mm
2: k_5 = 311.66 mm, k_{10} = 9.49 mm ⇒ $k_{eff,2} = 1 / \Sigma(1/k_{i,2})$ = 16.919 mm
3: k_5 = 249.88 mm, k_{10} = 9.49 mm ⇒ $k_{eff,3} = 1 / \Sigma(1/k_{i,3})$ = 8.820 mm
$k_{eq} = \Sigma(k_{eff,r} \cdot h_r) / z_{eq}$ = 33.209 mm, $z_{eq} = \Sigma(k_{eff,r} \cdot h_r^2) / \Sigma(k_{eff,r} \cdot h_r)$ = 659.6 mm
rotational stiffness
initial rotational stiffness: $S_{j,ini} = (E \cdot z^2) / \Sigma(1/k_i)$ = 3033835.4 kNm/rad, $z = z_{eq}$ = 659.6 mm, $\Sigma(1/k_i)$ = 0.030 mm^{-1}
rotational stiffness: $S_{j,Rd} = S_{j,ini} / \mu$ = 3033835.4 kNm/rad, μ = 1
rotation: $\varphi_{j,Ed} = M_{j,Ed} / S_{j,Rd}$ = 0.042°