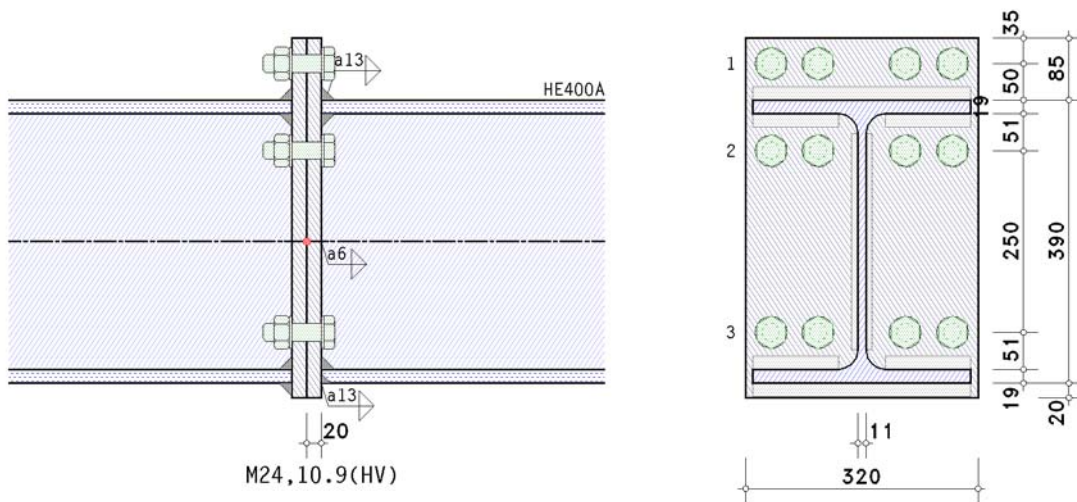
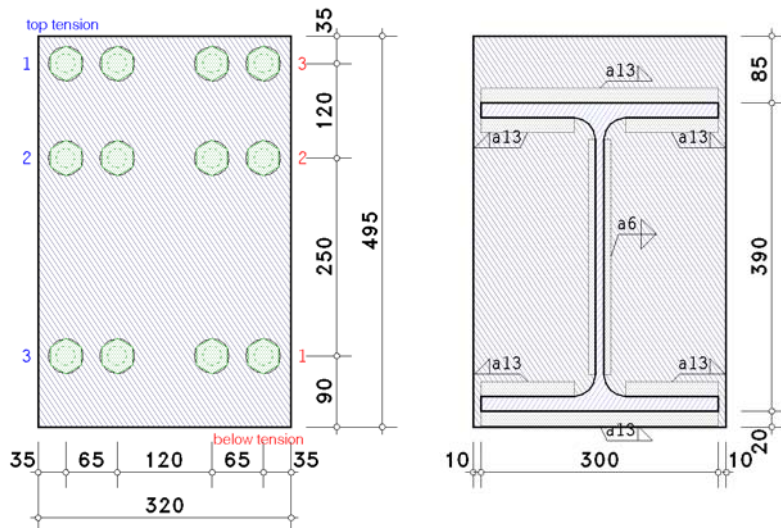


1. input report



details (section A - A)



bolts

bolt class 10.9, bolt size M24

large wrench size (high strength bolt), preloaded (for info: preloading $F_{p,c^*} = 0.7 \cdot f_{yb} \cdot A_s = 222.1$ kN)

shear plane passes through the unthreaded portion of the bolt

beam parameters

section HE400A, steel grade S355

verification parameters

bolted end-plate connection

thickness $t_p = 20.0$ mm, width $b_p = 320.0$ mm, length $l_p = 495.0$ mm, steel grade S235

projections $h_{p,o} = 85.0$ mm, $h_{p,u} = 20.0$ mm

bolts in connection:

3 bolt-rows with 4 bolts

row 1: 4 bolts, row 2: 4 bolts, row 3: 4 bolts
of these 2 bolt-rows top in tension (rows 1-2)

and 1 bolt-row for shear transfer top (row 3)

of these 1 bolt-row below in tension (row 3)

and 2 bolt-rows for shear transfer below (rows 2-3)

calculation method (4 bolts per row) acc. to B. Schmidt, Dissertation, TU Dortmund

centre distance between outer and inner bolt $w_2 = 65.0$ mm

centre distance of the bolts to the lateral edge of the end-plate $e_2 = 35.0$ mm

centre distance of the first bolt-row to the upper edge of the end-plate (end row) $e_o = 35.0$ mm

centre distance of the last bolt-row to the bottom edge of the end-plate (end row) $e_u = 90.0$ mm

centre distance of the bolt-rows from each other $p_{1-2} = 120.0$ mm, $p_{2-3} = 250.0$ mm

welds at the connection point:

beam flange top: fillet weld, weld thickness $a = 13.0$ mm

beam web: fillet weld, weld thickness $a = 6.0$ mm

beam flange below: fillet weld, weld thickness a = 13.0 mm

partial safety factors for material

resistance of cross-sections $\gamma_{M0} = 1.00$

resistance of members in stability failure $\gamma_{M1} = 1.10$

resistance of bolts, welds, plates in bearing $\gamma_{M2} = 1.25$

prestressing of high strength bolts $\gamma_{M7} = 1.10$

notes

connection is verified due to EC 3-1-8 regardless of preloading.

however, connections may be constructed with prestressed high strength bolts.

no verification for cross-sections.

check of data

ok

distances between bolts at end-plate

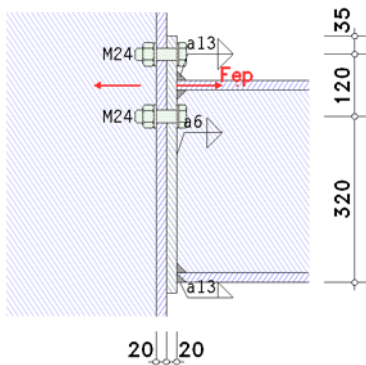
horizontal:	$e_2 = 35.0 \text{ mm} > 1.2 \cdot d_0 = 31.2 \text{ mm}$,	$e_2 = 35.0 \text{ mm} < 4 \cdot t + 40 \text{ mm} = 120.0 \text{ mm}$
horizontal:	$p_2 = 65.0 \text{ mm} > 2.4 \cdot d_0 = 62.4 \text{ mm}$,	$p_2 = 65.0 \text{ mm} < \min(14 \cdot t, 200 \text{ mm}) = 200.0 \text{ mm}$
horizontal:	$p_2 = 120.0 \text{ mm} > 2.4 \cdot d_0 = 62.4 \text{ mm}$,	$p_2 = 120.0 \text{ mm} < \min(14 \cdot t, 200 \text{ mm}) = 200.0 \text{ mm}$
top-below:	$e_1 = 35.0 \text{ mm} > 1.2 \cdot d_0 = 31.2 \text{ mm}$,	$e_1 = 35.0 \text{ mm} < 4 \cdot t + 40 \text{ mm} = 120.0 \text{ mm}$
top-below:	$p_1 = 120.0 \text{ mm} > 2.2 \cdot d_0 = 57.2 \text{ mm}$,	$p_1 = 120.0 \text{ mm} < \min(14 \cdot t, 200 \text{ mm}) = 200.0 \text{ mm}$
top-below:	$p_1 = 250.0 \text{ mm} > 2.2 \cdot d_0 = 57.2 \text{ mm}$,	$p_1 = 250.0 \text{ mm} > \min(14 \cdot t, 200 \text{ mm}) = 200.0 \text{ mm} \quad !!$
top-below:	$e_1 = 90.0 \text{ mm} > 1.2 \cdot d_0 = 31.2 \text{ mm}$,	$e_1 = 90.0 \text{ mm} < 4 \cdot t + 40 \text{ mm} = 120.0 \text{ mm}$

maximum values for spacings and edge distances should be in order to avoid local buckling and to prevent corrosion.

2. Lc 1

2.1. basic components

2.1.1. bc 5: end-plate in bending



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

IH4-connection: connections with 4 bolts per bolt-row are not treated in EC 3-1-8.
verification acc. to B. Schmidt, Dissertation, TU Dortmund.

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: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp}) = 160.0 \text{ mm}$, $l_{eff,cp} = 190.4 \text{ mm}$

in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc} = 160.0 \text{ mm}$

tension resistance of the T-stub flange:

in mode 1+2: $M_{pl,Rd} = (0.25 \cdot \Sigma l_{eff} \cdot t^2 \cdot f_y) / \gamma_{M0} = 3.76 \text{ kNm}$

$F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2} = 253.80 \text{ kN}$, $k_2 = 0.90$

in mode 3: $\Sigma F_{t,Rd} = 4 \cdot n_b \cdot F_{t,Rd} = 1015.20 \text{ kN}$

mode 1: complete yielding of the T-stub flange

$F_{T,1,Rd} = (M_{pl,1,Rd} \cdot (4 - e'/n)) / (m - ((m+n) \cdot e') / (2 \cdot n)) = 734.70 \text{ kN}$

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

$F_{T,2,Rd} = (2 \cdot M_{pl,2,Rd} + n \cdot \Sigma F_{t,Rd}) / (m+n) = 612.47 \text{ kN}$

mode 3: bolt failure

$F_{T,3,Rd} = \Sigma F_{t,Rd} = 1015.20 \text{ kN}$

tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 612.47 \text{ kN}$

tension resistance of beam flange: $\max F_{T,Rd} = (A_f \cdot f_{y,st}) / \gamma_{M0} = 2023.50 \text{ kN} > F_{T,Rd}$ ok

resistance of a fillet weld (req.1): $f_{1w,d} = f_u / (\beta_w \cdot \gamma_{M2}) = 360.0 \text{ N/mm}^2$

tension resistance of welds: $F_{T,w,Rd} = 2^{1/2} \cdot f_{1w,d} \cdot a \cdot l_{eff} = 1058.96 \text{ kN}$ ($\geq 612.47 \text{ kN}$, not decisive)

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

$F_{t,ep,Rd,1} = 612.47 \text{ kN}$, $l_{eff,1} = 160.0 \text{ mm}$

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: $\Sigma l_{eff,1} = l_{eff,1} = \min(l_{eff,nc}, l_{eff,cp}) = 349.9 \text{ mm}$, $l_{eff,cp} = 349.9 \text{ mm}$

in mode 2: $\Sigma l_{eff,2} = l_{eff,2} = l_{eff,nc} = 362.5 \text{ mm}$

tension resistance of the T-stub flange:

in mode 1: $M_{pl,1,Rd} = (0.25 \cdot \Sigma l_{eff,1} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 8.22 \text{ kNm}$

in mode 2: $M_{pl,2,Rd} = (0.25 \cdot \Sigma l_{eff,2} \cdot t_f^2 \cdot f_y) / \gamma_{M0} = 8.52 \text{ kNm}$

$F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2} = 253.80 \text{ kN}$, $k_2 = 0.90$

in mode 3: $\Sigma F_{t,Rd} = 4 \cdot n_b \cdot F_{t,Rd} = 1015.20 \text{ kN}$

mode 1: complete yielding of the T-stub flange

$F_{T,1,F,Rd} = (M_{pl,1,Rd} \cdot \delta F \cdot (4 \cdot e' / n_s)) / (m_s - ((m_s + n_s) \cdot e')) / (2 \cdot n_s) = 1159.91 \text{ kN}$

$F_{T,1,S,Rd} = (M_{pl,1,Rd} \cdot \delta S \cdot (4 \cdot e' / n)) / (m - ((m + n) \cdot e')) / (2 \cdot n) = 181.57 \text{ kN}$

$F_{T,1,Rd} = F_{T,1,F,Rd} + F_{T,1,S,Rd} = 1341.48 \text{ kN}$

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

$F_{T,2,F,Rd} = (2 \cdot M_{pl,2,Rd} \cdot \rho_{Fa} \cdot \delta F + 2 \cdot n_s \cdot F_{t,Rd}) / (m_s + n_s) = 346.67 \text{ kN}$

$F_{T,2,S,Rd} = (2 \cdot M_{pl,2,Rd} \cdot (\rho_{Fi} \cdot \delta F + \delta S) + 2 \cdot n \cdot F_{t,Rd}) / (m + n) = 391.51 \text{ kN}$

$F_{T,2,Rd} = F_{T,2,F,Rd} + F_{T,2,S,Rd} = 738.17 \text{ kN}$

mode 3: bolt failure

$F_{T,3,Rd} = \Sigma F_{t,Rd} = 1015.20 \text{ kN}$

tension resistance of the T-stub flange: $F_{T,Rd} = \min(F_{T,1,Rd}, F_{T,2,Rd}, F_{T,3,Rd}) = 738.17 \text{ kN}$

tension resistance of beam flange: $\max F_{T,Rd} = (A_F + A_s) \cdot f_{y,st} / \gamma_{M0} = 1442.46 \text{ kN} > F_{T,Rd}$ **ok**

resistance of a fillet weld (req.1): $f_{1w,d} = f_u / (\beta_w \cdot \gamma_{M2}) = 360.0 \text{ N/mm}^2$

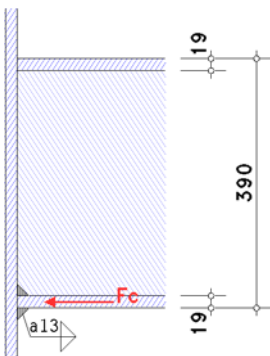
tension resistance of welds: $F_{T,w,Rd} = 2^{1/2} \cdot f_{1w,d} \cdot a \cdot l_{eff} = 1107.25 \text{ kN} (\geq 738.17 \text{ kN}, \text{ not decisive})$

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

$F_{ep,Rd,2} = 738.17 \text{ kN}$, $l_{eff,2} = 362.5 \text{ mm}$

2.1.2. bc 7: beam flange and web in compression

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



resistance $M_{c,Rd} = M_{pl,Rd} = (W_{pl} \cdot f_y) / \gamma_{M0} = 909.36 \text{ kNm}$, $W_{pl} = 2561.57 \text{ cm}^3$

resistance of flange and web in compression

$F_{c,f,Rd} = M_{c,Rd} / (h - t_f) = 2451.09 \text{ kN}$

resistance of welds

compression force $N_{c,Ed} = 2451.1 \text{ kN}$

$\sigma_{1,w,Ed} = 444.4 \text{ N/mm}^2 > f_{1w,d} = 435.6 \text{ N/mm}^2 \Rightarrow U = 1.020 > 1$

$\sigma_{2,w,Ed} = 222.2 \text{ N/mm}^2 < f_{2w,d} = 352.8 \text{ N/mm}^2 \Rightarrow U = 0.630 < 1$

$\Rightarrow F_{c,f,Rd} / \max U = 2402.28 \text{ kN}$

resistance of the upper beam flange:

resistance $M_{c,Rd} = M_{pl,Rd} = (W_{pl} \cdot f_y) / \gamma_{M0} = 909.36 \text{ kNm}$, $W_{pl} = 2561.57 \text{ cm}^3$

resistance of flange and web in compression

$F_{c,f,Rd} = M_{c,Rd} / (h - t_f) = 2451.09 \text{ kN}$

resistance of welds

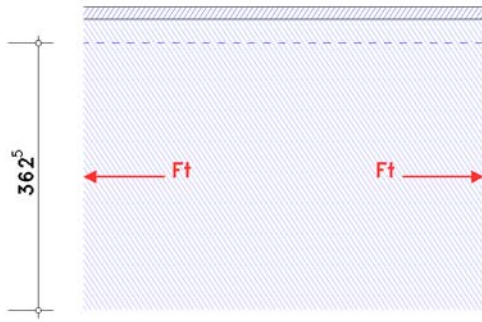
compression force $N_{c,Ed} = 2451.1 \text{ kN}$

$\sigma_{1,w,Ed} = 444.4 \text{ N/mm}^2 > f_{1w,d} = 435.6 \text{ N/mm}^2 \Rightarrow U = 1.020 > 1$

$\sigma_{2,w,Ed} = 222.2 \text{ N/mm}^2 < f_{2w,d} = 352.8 \text{ N/mm}^2 \Rightarrow U = 0.630 < 1$

$\Rightarrow F_{c,f,Rd} / \max U = 2402.28 \text{ kN}$

2.1.3. bc 8: beam web in tension



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

each individual bolt-row:

row 2

effective width $b_{eff,t,wb} = 362.5 \text{ mm}$ (leff from bc 5)

resistance of a beam web in tension

$$F_{t,wb,Rd} = b_{eff,t,wb} \cdot t_{wb} \cdot f_{y,wb} / \gamma_{M0} = 1415.46 \text{ kN}$$

resistance of a fillet weld (req.1): $f_{1w,d} = f_u / (\beta_w \cdot \gamma_{M2}) = 435.6 \text{ N/mm}^2$

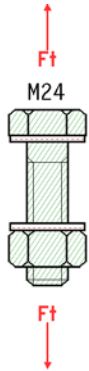
tension resistance of welds: $F_{t,w,Rd} = 2^{1/2} \cdot f_{1w,d} \cdot a \cdot b_{eff,t} = 1339.63 \text{ kN}$

total loading capacity of plate: $F_{t,wb,Rd} = F_{t,w,Rd} = 1339.63 \text{ kN}$

resistance of a beam web in tension (per bolt-row)

$F_{t,wb,Rd,2} = 1339.63 \text{ kN}$, $b_{eff,t,wb} = 362.5 \text{ mm}$ (s. bc 5)

2.1.4. bc 10: bolts in tension



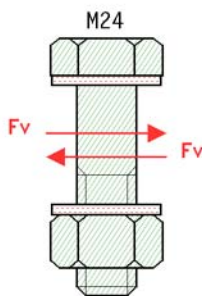
Only the essential sizes are sketched to scale.
The connection geometry is only hinted.

tension resistance of one bolt $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2} = 253.80 \text{ kN}$, $k_2 = 0.90$

punching shear load capacity of a bolt $B_{p,Rd} = (0.6 \cdot \pi \cdot d_m \cdot t_p \cdot f_u) / \gamma_{M2} = 467.95 \text{ kN}$, $t_p = 20.0 \text{ mm}$

tension-/punching shear load capacity for 4 bolts: $\Sigma F_{tp,Rd} = 4 \cdot \min(F_{t,Rd}, B_{p,Rd}) = 1015.20 \text{ kN}$

2.1.5. bc 11: bolts in shear



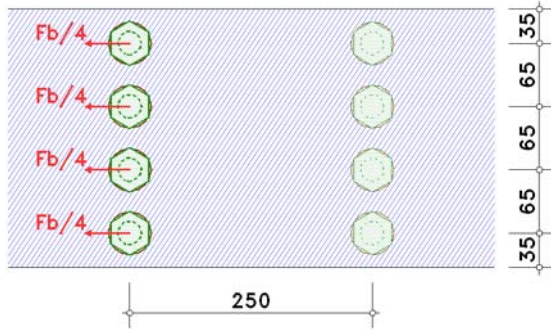
Only the essential sizes are sketched to scale.
The connection geometry is only hinted.

shear resistance $F_{v,Rd} = \alpha_v \cdot f_{ub} \cdot A / \gamma_{M2} = 217.15 \text{ kN}$, $\alpha_v = 0.60$

shear resistance of 4 bolts (1-shear): $\Sigma F_{v,Rd} = 4 \cdot F_{v,Rd} = 868.59 \text{ kN}$

2.1.6. bc 12: plate with bearing resistance

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



row 3

bolt 1: bearing resistance $F_{b,Rd} = (k_m \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 414.72 \text{ kN}$, $k_m = 1.00$, $\alpha_b = 3.00$

bolt 2: bearing resistance $F_{b,Rd} = (k_m \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 414.72 \text{ kN}$, $k_m = 1.00$, $\alpha_b = 3.00$

bolt 3: bearing resistance $F_{b,Rd} = (k_m \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 414.72 \text{ kN}$, $k_m = 1.00$, $\alpha_b = 3.00$

bolt 4: bearing resistance $F_{b,Rd} = (k_m \cdot \alpha_b \cdot f_u \cdot d \cdot t) / \gamma_{M2} = 414.72 \text{ kN}$, $k_m = 1.00$, $\alpha_b = 3.00$

bearing resistance of 1x4 bolts: $\Sigma F_{b,Rd} = 1336.32 \text{ kN}$

2.2. connection capacity

2.2.1. moment resistance

distance of tension-bolt-rows from centre of compression: $h_1 = 430.5 \text{ mm}$, $h_2 = 310.5 \text{ mm}$

resistances acc. to EC 3-1-8, B.3.2.2(6) for bolt-rows considered individually

decisive basic components: 5, 8

row 1: $F_{tr,Rd} = 612.5 \text{ kN}$

row 2: $F_{tr,Rd} = 738.2 \text{ kN}$

resistance per bolt-row (tension)

row 1: $F_{tr,Rd} = 612.5 \text{ kN}$

row 2: $F_{tr,Rd} = 738.2 \text{ kN}$

$\Sigma F_{tr,Rd}^* = 1350.6 \text{ kN}$

deductions acc. to EC 3-1-8, B.3.2.2(7)

decisive basic component: 7

row 1: $F_{tr,Rd} = 612.5 \text{ kN}$

row 2: $F_{tr,Rd} = 738.2 \text{ kN}$

check acc. to EC 3-1-8, B.3.2.2(9)

decisive basic component: 10

row 1: $F_{tr,Rd} = 612.5 \text{ kN}$

resistance per bolt-row (bending)

row 1: $F_{tr,Rd} = 612.5 \text{ kN}$

row 2: $F_{tr,Rd} = 738.2 \text{ kN}$

$\Sigma F_{tr,Rd} = 1350.6 \text{ kN}$

potential failure by basic component 5

resistance of flanges (compression)

$\Sigma F_{c,Rd}^* = 4804.6 \text{ kN}$

moment resistance

$M_{j,Rd} = \Sigma(F_{tr,Rd} \cdot h_r) = 492.9 \text{ kNm}$

tension resistance

$N_{j,t,Rd} = \Sigma F_{tr,Rd}^* = 1350.6 \text{ kN}$

compression resistance

$N_{j,c,Rd} = \Sigma F_{c,Rd}^* = 4804.6 \text{ kN}$

2.2.2. shear/bearing resistance

resistance per bolt-row

decisive basic components: 11, 12

row 3: $F_{vr,Rd} = 868.6 \text{ kN}$

deductions depending on tension force (at full utilization of moment resistance)

decisive basic component: 10

row 3: $F_{vr,Rd} = 868.6 \text{ kN}$

resistance per bolt-row (shear/bearing resistance)

row 3: $F_{vr,Rd} = 868.6 \text{ kN}$

$$\Sigma F_{vr,Rd} = 868.6 \text{ kN}$$

shear/bearing resistance

$$V_{j,Rd} = \Sigma F_{vr,Rd} = 868.6 \text{ kN}$$

2.2.3. total

$$M_{j,Rd} = 492.9 \text{ kNm} \quad N_{j,t,Rd} = 1350.6 \text{ kN} \quad N_{j,c,Rd} = 4804.6 \text{ kN} \quad V_{j,Rd} = 868.6 \text{ kN}$$

2.3. rotational stiffness

stiffness coefficients

equivalent stiffness coefficient for 2 tension-bolt-rows:

$$1: k_5 = 26.21 \text{ mm} \Rightarrow k_{\text{eff},1} = 1 / \Sigma(1/k_{i,1}) = 13.103 \text{ mm}$$

$$2: k_5 = 4.44 \text{ mm} \Rightarrow k_{\text{eff},2} = 1 / \Sigma(1/k_{i,2}) = 23.527 \text{ mm}$$

$$\text{equivalent internal lever arm } z_{\text{eq}} = \Sigma(k_{\text{eff},r} \cdot h_r^2) / \Sigma(k_{\text{eff},r} \cdot h_r) = 362.79 \text{ mm}$$

$$\text{äquivalenter stiffness coefficient } k_{\text{eq}} = \Sigma(k_{\text{eff},r} \cdot h_r) / z_{\text{eq}} = 35.685 \text{ mm}$$

rotational stiffness

$$\text{initial rotational stiffness: } S_{j,\text{ini}} = (E \cdot z^2) / \Sigma(1/k_i) = 986304.5 \text{ kNm/rad}, \quad z = z_{\text{eq}} = 362.8 \text{ mm}, \quad \Sigma(1/k_i) = 0.028 \text{ mm}^{-1}$$

3. Regulations

EN 1990, Eurocode 0: Grundlagen der Tragwerksplanung;

Deutsche Fassung EN 1990:2002 + A1:2005 + A1:2005/AC:2010, Ausgabe Dezember 2010

EN 1990/NA, Nationaler Anhang zur EN 1990, Ausgabe Dezember 2010

EN 1993-1-1, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -

Teil 1-1: Allgemeine Bemessungsregeln und Regeln für den Hochbau;

Deutsche Fassung EN 1993-1-1:2022, Ausgabe April 2025

EN 1993-1-1/NA, Nationaler appendix zur EN 1993-1-1, Ausgabe Oktober 2022

EN 1993-1-8, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -

Teil 1-8: Bemessung von Anschlüssen;

Deutsche Fassung EN 1993-1-8:2024, Ausgabe April 2025

EN 1993-1-8/NA, Nationaler appendix zur EN 1993-1-8, Ausgabe November 2020

Björn Schmidt: Zum Tragverhalten von bolteten momententragfähigen end-platenanschlüssen mit 4 Schrauben in jeder Schraubenreihe, Dissertation, TU Dortmund, 2008