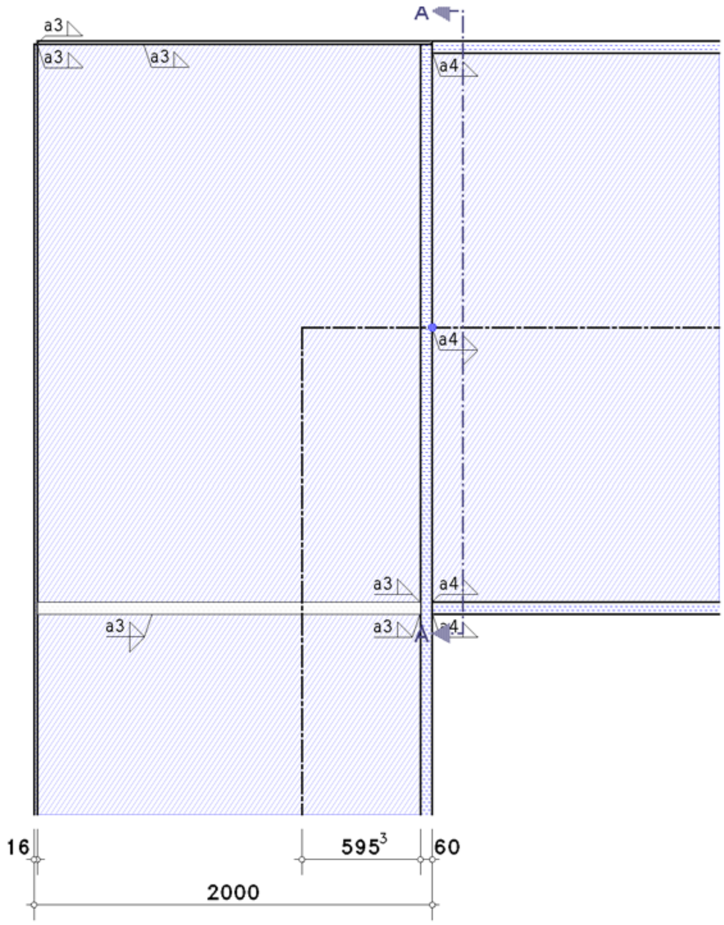
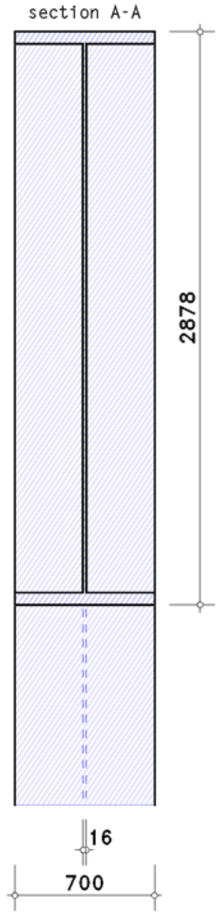
POS. 7: BSP. BUCKLING

4H-EC3RE version: 5/2014-1x

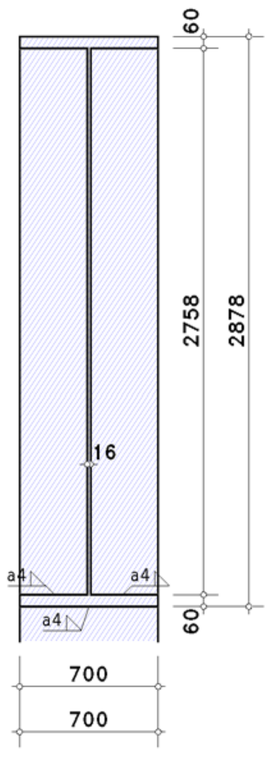
frame corner

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





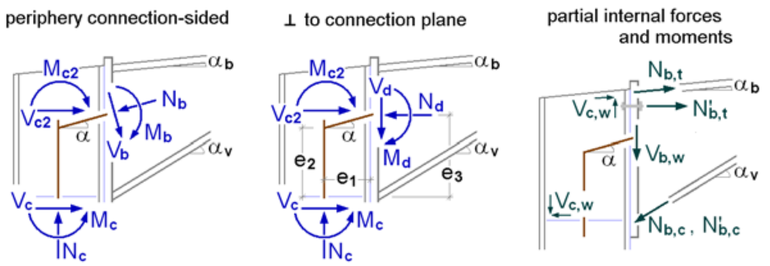
details



steel grade
steel grade S 355
column parameters
parameter (I-section):
overall depth $h = 2000.0$ mm, web thickness $t_w = 16.0$ mm
flange width top $b_{fo} = 700.0$ mm, flange thickness top $t_{fo} = 16.0$ mm
flange width bottom $b_{fu} = 700.0$ mm, flange thickness bottom $t_{fu} = 60.0$ mm
reinforcement of the section with transverse stiffeners (web stiffeners, $d_{st} = 2818.0$ mm):
thickness $t_{st} = 60.0$ mm
welds $a_{st,f} = 3.0$ mm, $a_{st,w} = 3.0$ mm
beam parameters
section parameters (H-section):
overall depth $h = 2878.0$ mm, web thickness $t_w = 16.0$ mm
flange width $b_f = 700.0$ mm, flange thickness $t_f = 60.0$ mm
verification parameters
welded connection:
tension plate: thickness $t_z = 16.0$ mm, width $b_z = 700.0$ mm
welds $a_{z,f} = 3.0$ mm, $a_{z,w} = 3.0$ mm
welds at the connection point:
beam flange top: fillet weld, weld thickness $a = 4.0$ mm
beam web: fillet weld, weld thickness $a = 4.0$ mm
beam flange bottom: fillet weld, weld thickness $a = 4.0$ mm
internal forces and moments in the periphery of the connection refering to the system axes
Lk 1: $N_{b1,Ed} = 2323.00$ kN $M_{b1,Ed} = 8650.00$ kNm $V_{b1,Ed} = 6000.00$ kN
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 $\gamma_{M2} = 1.25$

Lk 1:

design values



sign definition of EC3: a positive axial force means <u>compression</u>, a positive bending moment produces tension at the <u>top</u>

angle of inclination: $\alpha_b = \alpha_v = \alpha = 0°$
distance: $e_1 = z_{cu} = 655.3$ mm, $e_3 = z_{bu}\text{-}t_{bfu}/2 = 1409.0$ mm

periphery column (bottom)
$N_{c,Ed} = N_{b,Ed}\cdot\sin(\alpha) + V_{b,Ed}\cdot\cos(\alpha) = 6000.00$ kN
$M_{c,Ed} = M_{b,Ed} - V_{c,Ed}\cdot e_3 + N_{c,Ed}\cdot e_1 = 9308.47$ kNm
$V_{c,Ed} = N_{b,Ed}\cdot\cos(\alpha) - V_{b,Ed}\cdot\sin(\alpha) = 2323.00$ kN
internal forces and moments perpendicular to the connection plane
$N_d = N_{b,Ed} = 2323.00$ kN
$M_d = M_{b,Ed} = 8650.00$ kNm
$V_d = V_{b,Ed} = 6000.00$ kN
partial internal forces and moments
$N_{b,t} = -N_d\cdot z_{bu}/z_b + M'_d/z_b = 1908.05$ kN, $z_b = 2818.0$ mm, $z_{bu} = 1409.0$ mm
$N_{b,c} = N_d\cdot z_{bo}/z_b + M'_d/z_b = 4231.05$ kN, $z_b = 2818.0$ mm, $z_{bo} = 1409.0$ mm

verifications

<u>verification of buckling resistance</u>

column web
requirements concerning stiffeners: verification of web stiffeners required !!
verification method 'elastic-plastic' ⇒ valid section class 2
plate buckling: section class of the web plate 4 > 2 ⇒ particular verification is required !!
shear buckling: $h_p/t_p = 120.25 > 72/(\eta\cdot\varepsilon) = 48.82$, $h_p = 1924.0$ mm, $t_p = 16.0$ mm ⇒ particular verification is required !!
method of reduced stresses

assumption: shear distortions will be ignored.
buckling area: $a = 2780.0$ mm, $b = 1923.8$ mm, $t = 16.0$ mm, $\sigma_1 = -175.5$ N/mm², $\sigma_2 = 182.06$ N/mm², $\tau = 74.0$ N/mm²
buckling stresses: $\sigma_{Ed} = 182.06$ N/mm², $\tau_{Ed} = 74.0$ N/mm²

plate buckling

two-side supported plated panel: stress ratio $\Psi = \sigma_2/\sigma_1 = -0.964 \Rightarrow$ buckling factor $k_\sigma = 22.96$
critical buckling stress $\sigma_{cr,p} = k_\sigma \cdot \sigma_E = 301.5$ N/mm² with $\sigma_E = (\pi^2 \cdot E \cdot t^2)/(12 \cdot (1-\mu) \cdot b^2) = 13.1$ N/mm²
buckling slenderness ratio $\lambda_p = (f_y/\sigma_{cr,p})^{1/2} = 1.085$
reduction factor for $\lambda_p > 0.5 + (0.085-0.055 \cdot \Psi)^{1/2} = 0.872$: $\rho = (\lambda_p - 0.055 \cdot (3+\Psi))/\lambda_p^2 = 0.826 \leq 1$
ultimate buckling stress $\sigma_{Rd} = \rho \cdot f_y/\gamma_{M1} = 266.7$ N/mm²
verification: $\sigma_{Ed}/\sigma_{Rd} = 0.683 < 1$ ok.

shear buckling

buckling factor of shear für $a/h_w > 1$: $k_\tau = 5.34 + 4/(a/h_w)^2 = 7.26$, $a = 2780.0$ mm, $h_w = 1924.0$ mm
critical buckling stress of shear $\tau_{cr,p} = k_\tau \cdot \sigma_E = 95.2$ N/mm² with $\sigma_E = (\pi^2 \cdot E \cdot t^2)/(12 \cdot (1-\mu) \cdot b^2) = 13.1$ N/mm²
modified slenderness $\lambda_w = 0.76 \cdot (f_{yw}/\tau_{cr,p}) = 1.467$
reduction factor for $\lambda_w \geq 1.08$: $\chi_w = 1.37/(0.7+\lambda_w) = 0.632$
ultimate buckling stress $\tau_{Rd} = \chi_w \cdot f_y/(3^{1/2} \cdot \gamma_{M1}) = 117.8$ N/mm²
verification: $\tau_{Ed}/\tau_{Rd} = 0.628 < 1$ ok.

interaction

load increase factor for stresses $\alpha_{ult} = 1 / ((\sigma_{Ed}/f_y)^2 + 3 \cdot (\tau_{Ed}/f_y)^2)^{1/2} = 1.595$
load increase factor for stability $\alpha_{cr} = 1 / ((1+\Psi)/(4 \cdot \alpha_{cr,x}) + (((1+\Psi)/(4 \cdot \alpha_{cr,x}))^2 + (1-\Psi)/(2 \cdot \alpha_{cr,x}^2) + 1/\alpha_{cr,\tau}^2)^{1/2}) = 1.014$
with $\alpha_{cr,x} = \sigma_{cr,p}/\sigma_{Ed} = 1.656$, $\alpha_{cr,\tau} = \tau_{cr,p}/\tau_{Ed} = 1.287$
non-dimensional slenderness ratio $\lambda_p = \lambda_w = (\alpha_{ult}/\alpha_{cr})^{1/2} = 1.254$
reduction factor for $\lambda_p > 0.5 + (0.085-0.055 \cdot \Psi)^{1/2} = 0.872$: $\rho = (\lambda_p - 0.055 \cdot (3+\Psi))/\lambda_p^2 = 0.726 \leq 1$
reduction factor for $\lambda_w \geq 1.08$: $\chi_w = 1.37/(0.7+\lambda_w) = 0.701$
ultimate buckling stressen $\sigma_{Rd} = \rho \cdot f_y/\gamma_{M1} = 234.4$ N/mm², $\tau_{Rd} = \chi_w \cdot f_y/\gamma_{M1} = 226.3$ N/mm²
verification: $(\sigma_{Ed}/\sigma_{Rd})^2 + 3 \cdot (\tau_{Ed}/\tau_{Rd})^2 = 0.924 < 1$ ok.

verification result

maximum utilization: max $U = 0.924 < 1$ ok.

Final result

maximum utilization: max $U = 0.924 < 1$ ok.

verification succeeded

Regulations

DIN EN 1990, Eurocode 0: Grundlagen der Tragwerksplanung;
Deutsche Fassung EN 1990:2002 + A1:2005 + A1:2005/AC:2010, Ausgabe Dezember 2010
DIN EN 1990/NA, Nationaler Anhang zur DIN EN 1990, Ausgabe Dezember 2010

DIN EN 1993-1-1, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -
Teil 1-1: Allgemeine Bemessungsregeln und Regeln für den Hochbau;
Deutsche Fassung EN 1993-1-1:2005 + AC:2009, Ausgabe Dezember 2010
DIN EN 1993-1-1/NA, Nationaler Anhang zur DIN EN 1993-1-1, Ausgabe Dezember 2010

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

DIN EN 1993-1-5, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -
Teil 1-5: Plattenförmige Bauteile;
Deutsche Fassung EN 1993-1-5:2006 + AC:2009, Ausgabe Dezember 2010
DIN EN 1993-1-5/NA, Nationaler Anhang zur DIN EN 1993-1-5, Ausgabe Dezember 2010