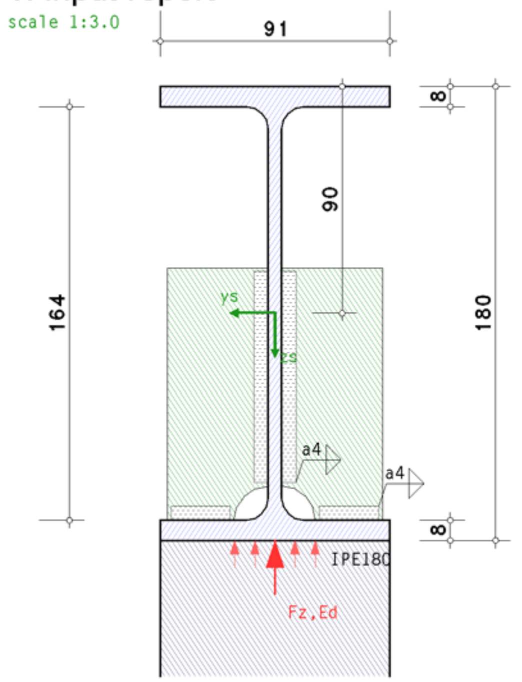
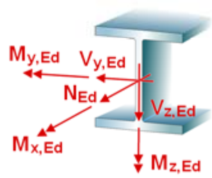
POS. 10: BSP. 8 BIEGETRÄGER

detailed problems acc. to Eurocode 3, EC 3-6 (12.10), NA: Deutschland 4H-EC3LK version: 11/2016-1f

1. input report



steel grade
steel grade S235
cross-section
beam: section IPE180
transverse stiffeners zur Aussteifung der local loading: thickness $t_{st,q}$ = 20.0 mm, width $b_{st,q}$ = 40.0 mm, length $l_{st,q}$ = 100.0 mm
recess at transverse stiffener $c_{st,q}$ = 13.5 mm
weld thickness $a_{st,q}$ = 4.0 mm
distance of transverse stiffeners a = 400.0 cm
loading



internal forces and moments at limit state of resistance (ULS):
Lk 1: $M_{y,Ed}$ = -28.4 kNm, $V_{z,Ed}$ = 29.0 kN
Lk 2: $M_{y,Ed}$ = 33.1 kNm, $V_{z,Ed}$ = -54.0 kN
internal forces and moments at limit state of serviceability (SLS):
Lk 1: $M_{y,Ed}$ = -28.4 kNm, $V_{z,Ed}$ = 29.0 kN
transverse loading on bottom flange:
vertical single load $F_{z,Ed,ULS}$ = 52.30 kN, $F_{z,Ed,SLS}$ = 52.30 kN an einem Auflager, effective Lagerlänge b_{eff} = 200.0 mm
verification at intermediate support
partial safety factors for material
resistance of cross-sections γ_{M0} = 1.00

2. verification der local loading

assumption: flange induced web buckling is excluded.
assumption: plated structures-/shear buckling is excluded.
assumption: transverse stiffeners serve as rigid support of the plated panel.
assumption: local buckling of stiffeners is excluded.

<u>cross-sectional properties</u>
A = 23.95 cm², z_s = 90.0 mm, I_y = 1316.97 cm⁴, y_s = 0.0 mm, I_z = 100.85 cm⁴

Lasteinzugsbreite by den beam $s_s' = 2 \cdot t_f + t_w + 1.172 \cdot r$ = 31.8 mm, t_f = 8.0 mm
feed length of load by das Auflager $s_s = b_{eff}$ = 200.0 mm
For info: Lagerpressung $F_{z,Ed,ULS}/(s_s \cdot s_s')$ = 8.21 N/mm², $F_{z,Ed,SLS}/(s_s \cdot s_s')$ = 8.21 N/mm²
effective loading length $l_{eff} = s_s + 2 \cdot t_f$ = 216.0 mm, t_f = 8.0 mm

<u>length of local loading</u>
refering to outer edge of flange $s_s = l_{eff} - 2 \cdot t_f$ = 200.0 mm / auf den webanschnitt $s_w = l_{eff} + 2 \cdot r$ = 234.0 mm

2.1. compression of web (ULS)

permissible stresses

$\sigma_{Rd} = f_y/\gamma_{M0} = 235.0$ N/mm², $\tau_{Rd} = f_y/(3^{1/2}\cdot\gamma_{M0}) = 135.7$ N/mm²

Lastübertragung with transverse stiffeners (ribs)
verification of the welds with the directional method.
dimensions, lever arms, forces per rib

$b_R = b_{st} = 40.0$ mm, $b_1 = b_R - r_R = 26.5$ mm, $e_F = b_R - 0.5\cdot b_1 = 26.7$ mm with $r_R = 13.5$ mm
zweiseitiger ribsanschluss:
$l_R = l_{st} = 100.0$ mm, $l_1 = l_R - r_R = 86.5$ mm, $e_H = l_R - l_1/3 = 71.2$ mm, $t_R = 20.0$ mm
$F = 0.5\cdot F_{c,Ed}\cdot(b_f - 2\cdot r - t_w)/b_f = 19.5$ kN, $H = F\cdot e_F/e_H = 7.3$ kN
assumption: stiffeners do not buckle (verification method 'elastic-elastic' ⇒ max. section class 3)
c/t-ratio $c/t = 2.00 \leq 9.00 = 9\cdot\varepsilon$, $\varepsilon = (235/f_y)^{1/2} = 1.00$ ⇒ section class 1 ≤ 3 ⇒ assumption succeeded !!

cross-section at flange

compression resistance $N_{c,Rd} = (A\cdot f_y)/\gamma_{M0} = 124.55$ kN
design value: $F_{Ed} = (F^2 + 3\cdot H^2)^{1/2} = 23.2$ kN
$F_{Ed} = 23.2$ kN < $F_{Rd} = 124.6$ kN ⇒ U = 0.186 < 1 ok

cross-section at web

compression resistance $N_{c,Rd} = (A\cdot f_y)/\gamma_{M0} = 470.00$ kN
design value: $F_{Ed} = (H^2 + 3\cdot F^2)^{1/2} = 34.5$ kN
$F_{Ed} = 34.5$ kN < $F_{Rd} = 470.0$ kN ⇒ U = 0.073 < 1 ok

flange welds

fillet weld with a = 4.0 mm
design values: $F_{Ed}(\sigma_s) = F/(2\cdot b_1) = 3.67$ kN/cm, $F_{Ed}(\tau_p) = H/(2\cdot b_1) = 1.38$ kN/cm
stresses on the design area of the weld: $\sigma_s = 9.18$ kN/cm² $\tau_p = 3.45$ kN/cm²
$\sigma_{1,w,Ed} = (\sigma_s^2 + 3\cdot(\tau_s^2 + \tau_p^2))^{1/2} = 10.95$ kN/cm²
resistance of a weld (req.1): $f_{1w,d} = f_u/(\beta_w\cdot\gamma_{M2}) = 36.00$ kN/cm²
$\sigma_{1,w,Ed} = 10.95$ kN/cm² < $f_{1w,d} = 36.00$ kN/cm² ⇒ U = 0.304 < 1 ok
$\sigma_{2,w,Ed} = |\sigma_s| = 9.18$ kN/cm²
resistance of a weld (req.2): $f_{2w,d} = 0.9\cdot f_u/\gamma_{M2} = 25.92$ kN/cm²
$\sigma_{2,w,Ed} = 9.18$ kN/cm² < $f_{2w,d} = 25.92$ kN/cm² ⇒ U = 0.354 < 1 ok

web welds

fillet weld with a = 4.0 mm
design values: $F_{Ed}(\sigma_s) = H/(2\cdot l_1) = 0.42$ kN/cm, $F_{Ed}(\tau_p) = F/(2\cdot l_1) = 1.12$ kN/cm
weld thickness a = 4.0 mm > $a_{max} = 0.7\cdot t_{min} = 3.7$ mm !!
stresses on the design area of the weld: $\sigma_s = 1.06$ kN/cm² $\tau_p = 2.81$ kN/cm²
$\sigma_{1,w,Ed} = (\sigma_s^2 + 3\cdot(\tau_s^2 + \tau_p^2))^{1/2} = 4.98$ kN/cm²
resistance of a weld (req.1): $f_{1w,d} = f_u/(\beta_w\cdot\gamma_{M2}) = 36.00$ kN/cm²
$\sigma_{1,w,Ed} = 4.98$ kN/cm² < $f_{1w,d} = 36.00$ kN/cm² ⇒ U = 0.138 < 1 ok
$\sigma_{2,w,Ed} = |\sigma_s| = 1.06$ kN/cm²
resistance of a weld (req.2): $f_{2w,d} = 0.9\cdot f_u/\gamma_{M2} = 25.92$ kN/cm²
$\sigma_{2,w,Ed} = 1.06$ kN/cm² < $f_{2w,d} = 25.92$ kN/cm² ⇒ U = 0.041 < 1 ok

total: utilization der ribs $U_R = 0.354$ < 1 ok

stresses at first cut of web

local Querspannungen $\sigma_{oz,Ed} = 0$ N/mm²
Lk 1: $M_{y,Ed} = 28.4$ kNm, $V_{z,Ed} = -29.0$ kN
normal stress $\sigma_{x,Ed} = -157.4$ N/mm²
$|\sigma_{x,Ed}| = 157.4$ N/mm² < $\sigma_{Rd} = 235.0$ N/mm² ⇒ U = 0.670 < 1 ok
shear stress $\tau_{xz,Ed} = 25.8$ N/mm²
$|\tau_{xz,Ed}| = 25.8$ N/mm² < $\tau_{Rd} = 135.7$ N/mm² ⇒ U = 0.190 < 1 ok
equivalent stress $\sigma_v = (\sigma_{x,Ed}^2 + \sigma_{oz,Ed}^2 - \sigma_{x,Ed}\cdot\sigma_{oz,Ed} + 3\cdot\tau_{xz,Ed}^2)^{1/2} = 163.6$ N/mm²
$\sigma_v = 163.6$ N/mm² < $\sigma_{Rd} = 235.0$ N/mm² ⇒ U = 0.696 < 1 ok
Lk 2: $M_{y,Ed} = -33.1$ kNm, $V_{z,Ed} = 54.0$ kN
normal stress $\sigma_{x,Ed} = 183.5$ N/mm²
$|\sigma_{x,Ed}| = 183.5$ N/mm² < $\sigma_{Rd} = 235.0$ N/mm² ⇒ U = 0.781 < 1 ok
shear stress $\tau_{xz,Ed} = 48.0$ N/mm²
$|\tau_{xz,Ed}| = 48.0$ N/mm² < $\tau_{Rd} = 135.7$ N/mm² ⇒ U = 0.354 < 1 ok
equivalent stress $\sigma_v = (\sigma_{x,Ed}^2 + \sigma_{oz,Ed}^2 - \sigma_{x,Ed}\cdot\sigma_{oz,Ed} + 3\cdot\tau_{xz,Ed}^2)^{1/2} = 201.4$ N/mm²
$\sigma_v = 201.4$ N/mm² < $\sigma_{Rd} = 235.0$ N/mm² ⇒ U = 0.857 < 1 ok
utilization at first cut of web max $U_\sigma = 0.857$ < 1 ok

maximum utilization: max $U_{ULS} = 0.857$ < 1 ok

2.2. buckling of transverse loading (ULS)

transverse stiffeners zum load out-transfer no effect (nicht betweenhorizontal)
buckling field a = 4000.0 mm, $h_w = 164.0$ mm, $t_w = 5.3$ mm
buckling factor $k_F = 3.5 + 2\cdot(h_w/a)^2 = 3.50$ (type (b))
critical buckling load $F_{cr} = k_F\cdot\sigma_E\cdot t_w\cdot h_w = 603.6$ kN, $\sigma_E = \pi^2\cdot E/(12\cdot(1-\mu^2))\cdot(t/b')^2 = 198.2$ N/mm², b' = 164.0 mm
effective load expansion length $l_y = s_s + 2\cdot t_f\cdot(1+m_1^{1/2}) = 282.3$ mm, $m_1 = b_f/t_w = 17.17$
yield load $F_y = f_y\cdot t_w\cdot l_y = 351.6$ kN

slenderness $\lambda_F = (F_y/F_{cr})^{1/2} = 0.763$
reduction factor $\chi_F = 0.5/\lambda_F = 0.655$
effective buckling length $L_{eff} = \chi_F \cdot l_y = 184.9$ mm
resistance of buckling $F_{z,Rd} = f_y \cdot L_{eff} \cdot t_w / \gamma_{M1} = 209.40$ kN
verification
$F_{z,Ed}/F_{z,Rd} = 0.250 < 1$ ok

interaction (without plated structures-/shear buckling)
transverse loading and equivalent stress $(\eta_2 + 0.8 \cdot \eta_1) / 1.4 = 0.668 < 1$ ok
with $\eta_2 = F_{z,Ed}/F_{z,Rd} = 0.250$, $\eta_1 = \max U_\sigma = 0.857$

3. final result

maximum utilization: max U = 0.857 < 1 ok

verification succeeded