detailed problems acc. to Eurocode 3

EC 3-1-9 (12.10), NA: Deutschland

steel grade

steel grade S 235

cross-section

beam: section HE300B

longitudinal stiffeners (right): number $n_{st} = 2$

section parameters (flat steel):

height h = 100.0 mm, thickness t = 20.0 mm

distance of the first stiffener to the top edge of beam $d_{st,0}$ = 100.0 mm

constant distance of stiffeners d_{st} = 100.0 mm

parameters

damage equivalent stress factors λ_σ = 0.315, λ_τ = 0.500

notch class / valid notch stresses:

Pt.	y_f mm	z_f mm	$\Delta\sigma_{x,Rd}$ N/mm²	$\Delta\tau_{Rd}$ N/mm²	$\Delta\sigma_{z,Rd}$ N/mm²	notch point	EC 3-1-9, tab.
17	-5.5	90.0	56.0	100.0	0.0	due to longit.stiff.	8.4(1) 8.1(6)
18	-5.5	110.0	56.0	100.0	0.0	due to longit.stiff.	8.4(1) 8.1(6)
19	-5.5	190.0	56.0	100.0	0.0	due to longit.stiff.	8.4(1) 8.1(6)
20	-5.5	210.0	56.0	100.0	0.0	due to longit.stiff.	8.4(1) 8.1(6)

loading

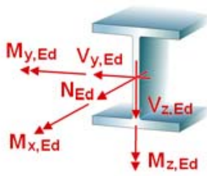
internal forces and moments refering to the unstiffened cross-secion:

Lk 1: $M_{y,Ed}$ = 100.3 kNm

Lk 2: $M_{y,Ed}$ = -20.1 kNm

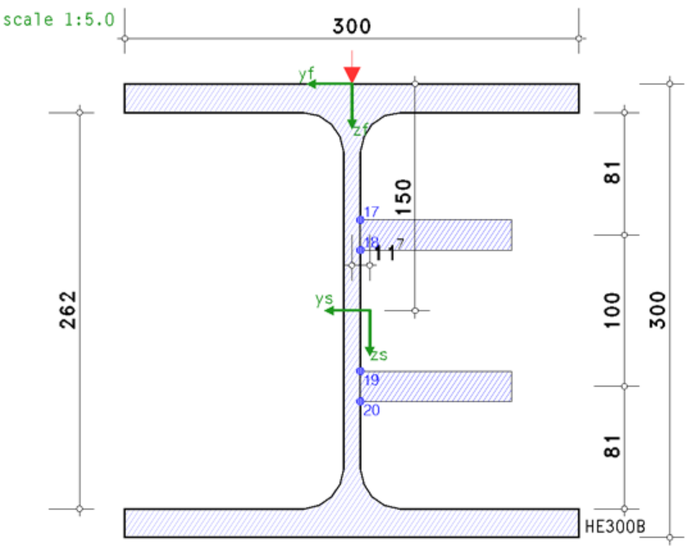
transverse loading on top flange:

design value of the vertical single load $F_{z,Ed}$ = 79.60 kN, loading length s_s = 69.1 mm



material safety factor

design concept: damage tolerance, damage consequence: high ⇒ fatigue strength γ_{Mf} = 1.15



Fatigue Design

cross-sectional properties

A = 189.08 cm², z_s = 150.0 mm, I_y = 26179.23 cm⁴, y_s = 11.7 mm, I_z = 9867.62 cm⁴

internal moments refering to the stiffened cross-section

$M_{y,Ed}' = M_{y,Ed} - N_{Ed} \cdot \Delta z_s$ (Δz_s = -0.0 mm), $M_{z,Ed}' = M_{z,Ed} + N_{Ed} \cdot \Delta y_s$ (Δy_s = -11.7 mm)

Lk 1: $M_{y,Ed}'$ = 100.3 kNm $M_{z,Ed}'$ = 0.0 kNm

Lk 2: $M_{y,Ed}'$ = -20.1 kNm $M_{z,Ed}'$ = 0.0 kNm

elastic stresses / stress ranges

$\Delta\sigma_{x,Ed} = \sigma_{x,max} - \sigma_{x,min}$, $\tau_{Ed} = \tau_{xz,max} - \tau_{xz,min} + 2 \cdot \tau_o$, $\Delta\sigma_{z,Ed} = -\sigma_{oz}$

pt. 17:	y_f = -5.5 mm, z_f = 90.0 mm	Lk 1:	σ_x = -23.0 N/mm²	τ_{xz} = 0.0 N/mm²
		2:	σ_x = 4.6 N/mm²	τ_{xz} = 0.0 N/mm²
			$\Delta\sigma_{x,Ed}$ = 27.6 N/mm²	
18:	y_f = -5.5 mm, z_f = 110.0 mm	Lk 1:	σ_x = -15.3 N/mm²	τ_{xz} = 0.0 N/mm²
		2:	σ_x = 3.1 N/mm²	τ_{xz} = 0.0 N/mm²
			$\Delta\sigma_{x,Ed}$ = 18.4 N/mm²	
19:	y_f = -5.5 mm, z_f = 190.0 mm	Lk 1:	σ_x = 15.3 N/mm²	τ_{xz} = 0.0 N/mm²
		2:	σ_x = -3.1 N/mm²	τ_{xz} = 0.0 N/mm²
			$\Delta\sigma_{x,Ed}$ = 18.4 N/mm²	
20:	y_f = -5.5 mm, z_f = 210.0 mm	Lk 1:	σ_x = 23.0 N/mm²	τ_{xz} = 0.0 N/mm²
		2:	σ_x = -4.6 N/mm²	τ_{xz} = 0.0 N/mm²
			$\Delta\sigma_{x,Ed}$ = 27.6 N/mm²	

equivalent constand amplitude stress range

$\Delta\sigma_{x,f} = \Delta\sigma_{x,Ed} \cdot \lambda_\sigma$, $\Delta\tau_f = \Delta\tau_{Ed} \cdot \lambda_\tau$, $\Delta\sigma_{z,f} = \Delta\sigma_{z,Ed} \cdot \lambda_\sigma$

pt. 17:	y_f = -5.5 mm, z_f = 90.0 mm	$\Delta\sigma_{x,f}$ = 8.7 N/mm²
18:	y_f = -5.5 mm, z_f = 110.0 mm	$\Delta\sigma_{x,f}$ = 5.8 N/mm²
19:	y_f = -5.5 mm, z_f = 190.0 mm	$\Delta\sigma_{x,f}$ = 5.8 N/mm²
20:	y_f = -5.5 mm, z_f = 210.0 mm	$\Delta\sigma_{x,f}$ = 8.7 N/mm²

valid notch stresses

$\Delta\sigma_{x,Rd,f} = \Delta\sigma_{x,Rd}/\gamma_{Mf}$, $\Delta\tau_{Rd,f} = \Delta\tau_{Rd}/\gamma_{Mf}$, $\Delta\sigma_{z,Rd,f} = \Delta\sigma_{z,Rd}/\gamma_{Mf}$

pt. 17:	y_f = -5.5 mm, z_f = 90.0 mm	$\Delta\sigma_{x,Rd,f}$ = 48.7 N/mm²	$\Delta\tau_{Rd,f}$ = 87.0 N/mm²
18:	y_f = -5.5 mm, z_f = 110.0 mm	$\Delta\sigma_{x,Rd,f}$ = 48.7 N/mm²	$\Delta\tau_{Rd,f}$ = 87.0 N/mm²
19:	y_f = -5.5 mm, z_f = 190.0 mm	$\Delta\sigma_{x,Rd,f}$ = 48.7 N/mm²	$\Delta\tau_{Rd,f}$ = 87.0 N/mm²
20:	y_f = -5.5 mm, z_f = 210.0 mm	$\Delta\sigma_{x,Rd,f}$ = 48.7 N/mm²	$\Delta\tau_{Rd,f}$ = 87.0 N/mm²

verification of notch stresses

pt. 17:	y = -5.5 mm, z = 90.0 mm	$\Delta\sigma_{x,f}$ = 8.7 N/mm² < $\Delta\sigma_{x,Rd,f}$ = 48.7 N/mm²	⇒ $U_{\Delta\sigma x}$ = 0.179	ok.
18:	y = -5.5 mm, z = 110.0 mm	$\Delta\sigma_{x,f}$ = 5.8 N/mm² < $\Delta\sigma_{x,Rd,f}$ = 48.7 N/mm²	⇒ $U_{\Delta\sigma x}$ = 0.119	ok.
19:	y = -5.5 mm, z = 190.0 mm	$\Delta\sigma_{x,f}$ = 5.8 N/mm² < $\Delta\sigma_{x,Rd,f}$ = 48.7 N/mm²	⇒ $U_{\Delta\sigma x}$ = 0.119	ok.
20:	y = -5.5 mm, z = 210.0 mm	$\Delta\sigma_{x,f}$ = 8.7 N/mm² < $\Delta\sigma_{x,Rd,f}$ = 48.7 N/mm²	⇒ $U_{\Delta\sigma x}$ = 0.179	ok.

Final Result

fatigue design [pt. 20]: max U = 0.179 < 1 ok.

verification succeeded