POS. 173: KUHLMANN, SK'03, S.484

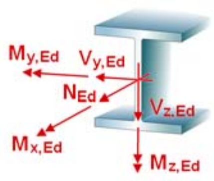
detailed problems acc. to Eurocode 3

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

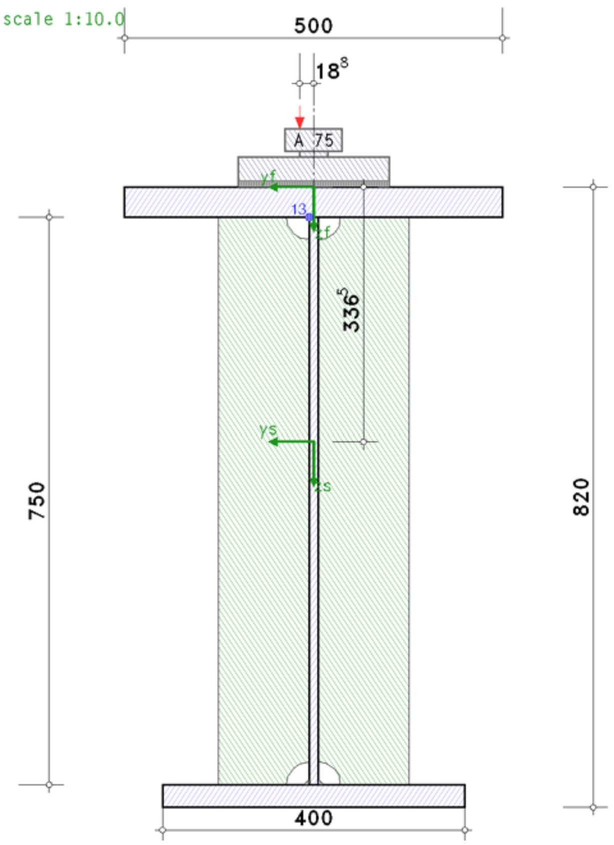
steel grade
steel grade S 235
cross-section
beam: parameter (I-section):
overall depth h = 820.0 mm, web thickness t_w = 12.0 mm
flange width top b_{fo} = 500.0 mm, flange thickness top t_{fo} = 40.0 mm
flange width bottom b_{fu} = 400.0 mm, flange thickness bottom t_{fu} = 30.0 mm
welded section, weld thickness a_o = 0.0 mm, a_u = 5.0 mm
transverse stiffeners: section parameters (flat steel):
height h = 120.0 mm, thickness t = 20.0 mm
recess at transverse stiffener $c_{st,q}$ = 30.0 mm
distance of transverse stiffeners a = 200.0 cm
crane gantry
A-crane rail 75, floating with clamps joined with the girder, crane rail underlay
crane rail: head width b_k = 75.0 mm, bottom width b_r = 200.0 mm, height of fretted rail h_r = 77.0 mm
moment of inertia, cross-sectional area of fretted rail I_{yr} = 401.00 cm^4, A_r = 65.80 cm^2
parameters
damage equivalent stress factors for crane class S4: λ_σ = 0.500, λ_τ = 0.660, crane class S5: $\lambda_{\sigma+}$ = 0.630, $\lambda_{\tau+}$ = 0.758
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
13	6.0	40.0	100.0	80.0	71.0	at beam web

loading
Lk 1: $M_{y,Ed}$ = 0.0 kNm, $V_{z,Ed}$ = 113.5 kN
Lk 2: $M_{y,Ed}$ = 0.0 kNm, $V_{z,Ed}$ = -213.5 kN
Lk 3: $M_{y,Ed}$ = 864.7 kNm, $V_{z,Ed}$ = 0.0 kN
transverse loading on top flange:
design value of vertical wheel load $F_{z,Ed}$ = 263.60 kN (eccentricity e_y = 18.75 mm)



material safety factor
design concept: damage tolerance, damage consequence: high $\Rightarrow$ fatigue strength γ_{Mf} = 1.15



Fatigue Design

cross-sectional properties

$A = 410.00\ cm^2$, $z_s = 336.5\ mm$, $I_y = 511825.39\ cm^4$, $y_s = 0.0\ mm$, $I_z = 57677.47\ cm^4$

effective loading length from crane gantry

effective width $b_{eff} = b_r+h_r+t_{fo} = 317.0\ mm \le b_{fo}$

effective moment of inertia of beam flange $I_{f,eff} = b_{eff} \cdot t_{fo}^3/12 = 169.07\ cm^4$

moment of inertia of crane rail $I_r = 401.00\ cm^4$

effective length $l_{eff} = 4.25 \cdot ((I_r+I_{f,eff})/t_w)^{1/3} = 331.6\ mm$

local stresses from crane gantry

effective loading length refered ...

... to outer edge of flange $s_s = l_{eff} - 2 \cdot t_f = 251.6\ mm$ / ... to web $s_w = l_{eff} = 331.6\ mm$

local stresses ...

... at crane rail $\sigma_{oz} = -87.3\ N/mm^2$, $\tau_o = 17.5\ N/mm^2$

... at beam web $\sigma_{oz} = -66.2\ N/mm^2$, $\tau_o = 13.2\ N/mm^2$

bending stress of web

$M_{T,Ed} = F_{z,Ed} \cdot e_y = 4.94\ kNm \Rightarrow \sigma_T = (6 \cdot M_{T,Ed})/(a \cdot t_w^2) \cdot \eta \cdot \tanh(\eta) = 17.8\ N/mm^2$

with $\eta = ((0.75 \cdot a \cdot t_w^3)/I_t \cdot \sinh^2(\pi \cdot h_w/a)/(\sinh^2(2 \cdot \pi \cdot h_w/a)-2 \cdot \pi \cdot h_w/a))^{0.5} = 0.428$, $I_t = 1066.67\ cm^4$

elastic stresses / stress ranges

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

pt. 13: $y_f = 6.0\ mm$, $z_f = 40.0\ mm$	Lk 1:	$\sigma_x = 0.0\ N/mm^2$	$\tau_{xz} = 11.7\ N/mm^2$	
	2:	$\sigma_x = 0.0\ N/mm^2$	$\tau_{xz} = -22.0\ N/mm^2$	
	3:	$\sigma_x = -50.1\ N/mm^2$	$\tau_{xz} = 0.0\ N/mm^2$	
		$\Delta\sigma_{x,Ed} = 50.1\ N/mm^2$	$\Delta\tau_{Ed} = 60.2\ N/mm^2$	$\Delta\sigma_{z,Ed} = 84.0\ N/mm^2$

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. 13: $y_f = 6.0\ mm$, $z_f = 40.0\ mm$ ($\lambda_{\tau\sigma z+}$) $\Delta\sigma_{x,f} = 25.0\ N/mm^2$ $\Delta\tau_f = 45.7\ N/mm^2$ $\Delta\sigma_{z,f} = 52.9\ N/mm^2$

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. 13: $y_f = 6.0\ mm$, $z_f = 40.0\ mm$ $\Delta\sigma_{x,Rd,f} = 87.0\ N/mm^2$ $\Delta\tau_{Rd,f} = 69.6\ N/mm^2$ $\Delta\sigma_{z,Rd,f} = 61.7\ N/mm^2$

verification of notch stresses

pt. 13: $y = 6.0\ mm$, $z = 40.0\ mm$

$\Delta\sigma_{x,f} = 25.0\ N/mm^2 < \Delta\sigma_{x,Rd,f} = 87.0\ N/mm^2 \Rightarrow U_{\Delta\sigma x} = 0.288$ ok.

$\Delta\tau_f = 45.7\ N/mm^2 < \Delta\tau_{Rd,f} = 69.6\ N/mm^2 \Rightarrow U_{\Delta\tau} = 0.656$ ok.

$\Delta\sigma_{z,f} = 52.9\ N/mm^2 < \Delta\sigma_{z,Rd,f} = 61.7\ N/mm^2 \Rightarrow U_{\Delta\sigma z} = 0.857$ ok.

interaction $U_i = U_{\Delta\sigma x}^3+U_{\Delta\sigma z}^3+U_{\Delta\tau}^5 = 0.775 < 1$ ok.

Final Result

fatigue design [pt. 13]: max $U = 0.857 < 1$ ok.

verification succeeded