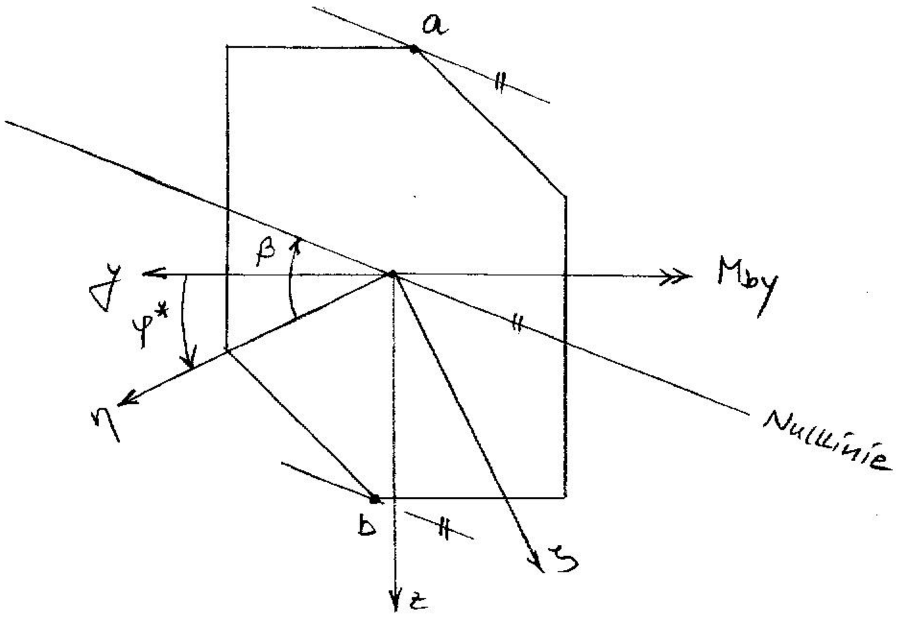
zu 1) $\alpha = 180° - \varphi^* = 180° - 25{,}2° = 154{,}8°$ 1

$$\tan\beta = \frac{1041\,\text{cm}^4}{446\,\text{cm}^4} \cdot \tan 154{,}8° = -1{,}0983$$

$\beta = -47{,}68°$ 1



1

zu 2) $y_a = -0{,}5\,\text{cm}$; $z_a = -6\,\text{cm}$

$\eta_a = -6\,\text{cm} \cdot \sin 25{,}2° - 0{,}5\,\text{cm} \cdot \cos 25{,}2° = -3{,}01\,\text{cm}$

1

$\zeta_a = -6\,\text{cm} \cdot \cos 25{,}2° + 0{,}5\,\text{cm} \cdot \sin 25{,}2° = -5{,}22\,\text{cm}$

$$\sigma_b^a = M_{by} \cdot \left(\frac{\cos\alpha}{I_\eta} \cdot \zeta_a - \frac{\sin\alpha}{I_\zeta} \cdot \eta_A \right)$$

$$\text{zul } M_{by} = \frac{6\,\frac{\text{kN}}{\text{cm}^2}}{\frac{\cos 154{,}8°}{1041\,\text{cm}^4} \cdot (-5{,}22\,\text{cm}) - \frac{\sin 154{,}8°}{446\,\text{cm}^4} \cdot (-3{,}01\,\text{cm})}$$

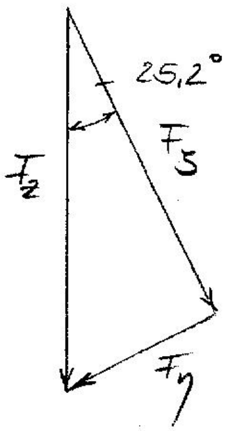
1

$\text{zul } M_{by} = 810\,\text{kN} \cdot \text{cm} = 8{,}10\,\text{kN} \cdot \text{m}$

$$\text{zul } M_{by} = F_{z\,zul} \cdot 1\,m = 8{,}10\,kN \cdot m$$ 1/2

$$F_{zul} = 8{,}10\,kN$$ 1

zu 3)



$$F_\eta = 7\,kN \cdot \sin 25{,}2° = 2{,}98\,kN$$

$$F_\zeta = 7\,kN \cdot \cos 25{,}2° = 6{,}33\,kN$$

1

$$f_\eta = \frac{2{,}98 \cdot 10^3\,N \cdot (2000\,mm)^3}{8 \cdot 0{,}7 \cdot 10^5 \frac{N}{mm^2} \cdot 446 \cdot 10^4\,mm^4} = 9{,}55\,mm$$

1

$$f_\zeta = \frac{6{,}33 \cdot 10^3\,N \cdot (2000\,mm)^3}{8 \cdot 0{,}7 \cdot 10^5 \frac{N}{mm^2} \cdot 1041 \cdot 10^4\,mm^4} = 8{,}69\,mm$$

1

$$f = \sqrt{(9{,}55\,mm)^2 + (8{,}69\,mm)^2} = 12{,}91\,mm$$

1

zu 1)

$$S_{y1} = 0$$

$$S_{y2} = 2cm \cdot 9cm \cdot 5{,}91cm - \frac{\pi \cdot (2cm)^2}{2} \cdot \left(6{,}91cm - \frac{4 \cdot 2cm}{3 \cdot \pi}\right)$$

$$S_{y2} = 68{,}30\ cm^3$$

$$S_{y3} = 68{,}30\ cm^3 + 2cm \cdot 9cm \cdot 3{,}91cm = 138{,}68\ cm^3$$

$$S_{y4} = 138{,}68\ cm^3 + 3cm \cdot 2cm \cdot 1{,}91cm + 2 \cdot \left(\frac{3cm \cdot 2cm}{2} \cdot 2{,}24\bar{3}\right) = 163{,}60\ cm^3$$

$$S_{y5} = 163{,}60\ cm^3 + 5cm \cdot 3cm \cdot (-1{,}59cm) = 139{,}75\ cm^3$$

$$S_{y6} = 139{,}75\ cm^3 + 3cm \cdot 1cm \cdot (-4{,}59cm) + 2 \cdot \left(\frac{1cm \cdot 1{,}5cm}{2} \cdot (-4{,}75\bar{6})\right) = 118{,}85\ cm^3$$

4

$$S_{y7} = 118{,}85\ cm^3 + 6cm \cdot 3cm \cdot (-6{,}59cm) = 0{,}23 \approx 0$$

Schnitt	S_y cm^3	b cm	τ kN/cm^2	τ N/mm^2
1	0	5	0	0
2	68,30	9	0,892	8,92
3	138,68	9	1,812	18,12
4	163,60	3	6,412	64,12
5	139,75	3	5,477	54,77
6	118,85	6	2,329	23,29
7	0	6	0	0

3

zu 2)

$$S_{ymax} = 163{,}6\ cm^3 + 3cm \cdot 0{,}91cm \cdot \frac{0{,}91cm}{2}$$

$$S_{ymax} = 164{,}84\ cm^3$$

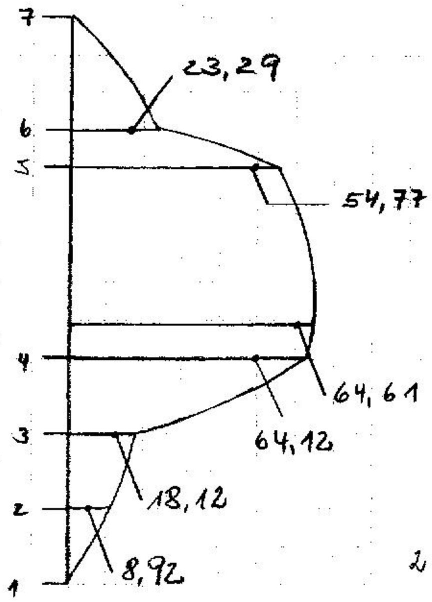
1

$$\tau_{max} = \frac{200\ kN \cdot 164{,}84\ cm^3}{1701\ cm^4 \cdot 3cm} = 6{,}461 \frac{kN}{cm^2} = 64{,}61 \frac{N}{mm^2}$$

1

τ_{max} tritt in der Faser $z = 0$ auf.

zu 3)



τ
N/mm²

1) 3|1

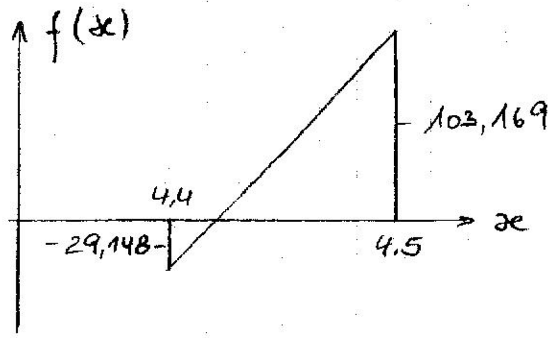
$$\delta = \frac{500 \frac{N}{mm} \cdot (3000\,mm)^3}{2{,}1 \cdot 10^5 \frac{N}{mm^2} \cdot 73{,}3 \cdot 10^4\,mm^4} = 87{,}70$$ 1

Knickbedingung: $f(x) = x^3 + 87{,}70 \cdot \tan x - 87{,}70 \cdot x = 0$

$f(4{,}4) = -29{,}148$

$f(4{,}5) = 103{,}169$ 1

1. Iteration



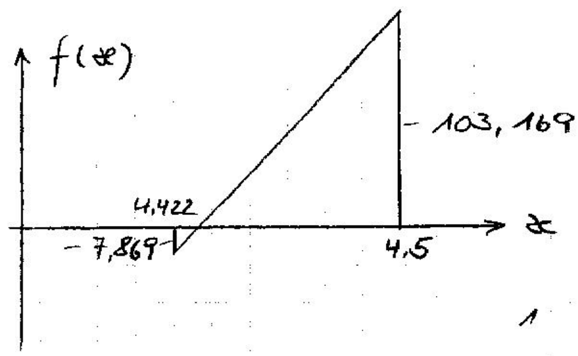
$$\frac{\Delta x}{29{,}148} = \frac{0{,}1}{29{,}148 + 103{,}169}$$

$\Delta x = 0{,}022$

$x_{Neu} = 4{,}422$ 1

$f(x_{Neu}) = -7{,}869$

2. Iteration



$$\frac{\Delta x}{7{,}869} = \frac{0{,}078}{7{,}869 + 103{,}169}$$

$\Delta x = 0{,}006$ 1

$x_{Neu} = 4{,}428$

$$F_K = \frac{x^2 \cdot E \cdot I}{l^2} = \frac{4{,}428^2 \cdot 2{,}1 \cdot 10^5 \frac{N}{mm^2} \cdot 73{,}3 \cdot 10^4\,mm^4}{(3000\,mm)^2}$$ 1

$F_K = 335348\,N$

2) Knicksicherheit

$$\nu_K = \frac{F_K}{F} = \frac{335348\,N}{80000\,N} = 4{,}19 \qquad 1$$

3) Knicklänge

$$F_K = \frac{E \cdot I \cdot \pi^2}{s_K^2}$$

$$s_K = \sqrt{\frac{E \cdot I \cdot \pi^2}{F_K}} = \sqrt{\frac{2{,}1 \cdot 10^5 \frac{N}{mm^2} \cdot 73{,}3 \cdot 10^4\,mm^4 \cdot \pi^2}{335348\,N}}$$

$$s_K = 2128\,mm \qquad 1$$

4) $$i_{min} = \sqrt{\frac{I_y}{A}} = \sqrt{\frac{73{,}3 \cdot 10^4\,mm^4}{19{,}2 \cdot 10^2\,mm^2}} = 19{,}54\,mm$$

$$\lambda = \frac{s_K}{i_{min}} = \frac{2128\,mm}{19{,}54\,mm} = 109 > 105 = \lambda_{grenz}$$

Elastische Knickung o.K. 2