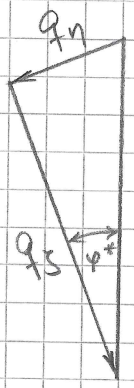
zu 1)



$$q_\eta = q \cdot \sin 21{,}35^\circ = 0{,}3641 \cdot q$$

$$q_\zeta = q \cdot \cos 21{,}35^\circ = 0{,}9314 \cdot q$$

$$f_\eta = \frac{5}{384} \cdot \frac{0{,}3641 \cdot q \cdot (4000\,mm)^4}{2{,}1 \cdot 10^5 \frac{N}{mm^2} \cdot 252 \cdot 10^4\,mm^4} = 2{,}2934\ \frac{mm^2}{N} \cdot q$$

$$f_\zeta = \frac{5}{384} \cdot \frac{0{,}9314 \cdot q \cdot (4000\,mm)^4}{2{,}1 \cdot 10^5 \frac{N}{mm^2} \cdot 1543 \cdot 10^4\,mm^4} = 0{,}9581\ \frac{mm^2}{N} \cdot q$$

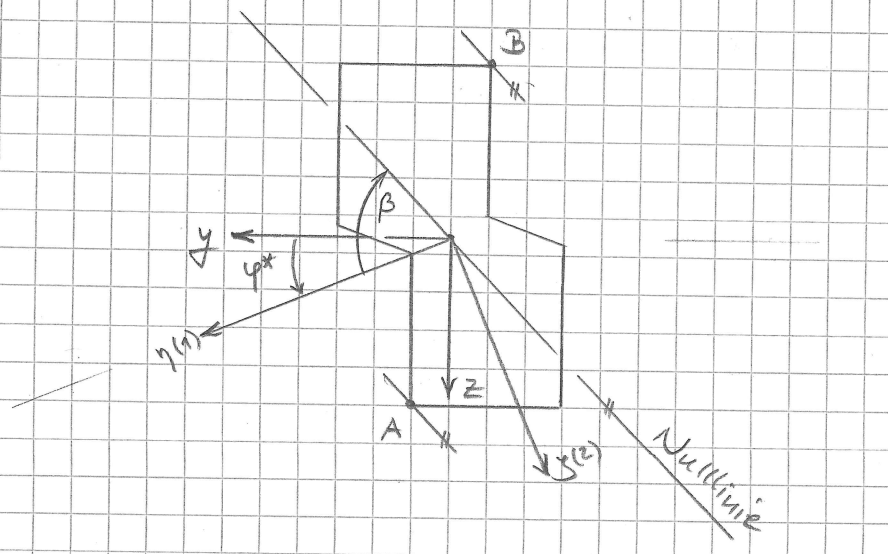
$$f = q \cdot \sqrt{\left(2{,}2934\ \frac{mm^2}{N}\right)^2 + \left(0{,}9581\ \frac{mm^2}{N}\right)^2} = 10\,mm$$

$$q = \frac{10\,mm}{2{,}4855\ \frac{mm^2}{N}} = 4{,}023\ \frac{N}{mm} = 4{,}023\ \frac{kN}{m}$$

zu 2) $\alpha = -\varphi^* = -21{,}35^\circ$

$$\tan\beta = \frac{1543\,cm^4}{252\,cm^4} \cdot \tan(-21{,}35^\circ) = -2{,}3934$$

$$\beta = -67{,}32^\circ$$



zu 3) $M_{by\,max} = \frac{1}{8} \cdot 3\,\frac{kN}{m} \cdot (4m)^2 = 6\,kN \cdot m$

$M_{by} = 6\,kN \cdot m \cdot \cos(-21{,}35°) = 5{,}588\,kN \cdot m$

$M_{bz} = 6\,kN \cdot m \cdot \sin(-21{,}35°) = -2{,}184\,kN \cdot m$

Punkt A: $y_A = 1{,}5\,cm$; $z_A = 7\,cm$

$y_A = 7\,cm \cdot \sin 21{,}35° + 1{,}5\,cm \cdot \cos 21{,}35° = 3{,}95\,cm$

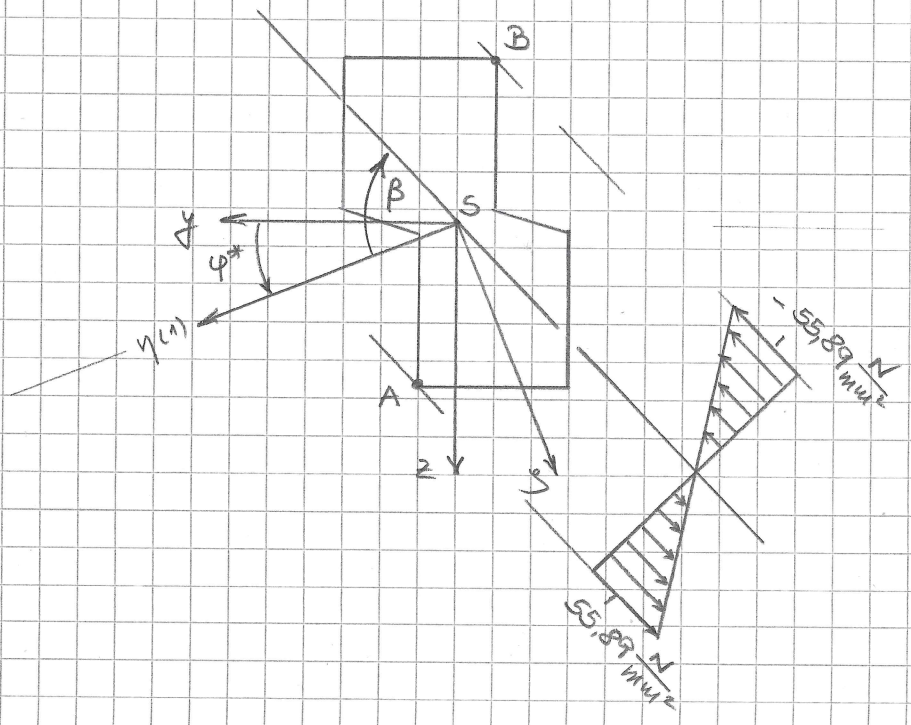
$z_A = 7\,cm \cdot \cos 21{,}35° - 1{,}5\,cm \cdot \sin 21{,}35° = 5{,}97\,cm$

Punkt B: $y_B = -3{,}95\,cm$; $z_B = -5{,}97\,cm$

$$\sigma_b^A = \frac{5{,}598 \cdot 100\,kN \cdot cm}{1543\,cm^4} \cdot 5{,}97\,cm - \frac{(-2{,}184) \cdot 100\,kN \cdot cm}{252\,cm^4} \cdot 3{,}95\,cm$$

$$\sigma_b^A = 5{,}589\,\frac{kN}{cm^2} = 55{,}89\,\frac{N}{mm^2}$$

$$\sigma_b^B = -55{,}89\,\frac{N}{mm^2}$$



1/ $S_{y1} = 0$

$S_{y2} = 4 \cdot 2 \cdot 5{,}52 + 2 \cdot \frac{1 \cdot 2}{2} \cdot (6{,}52 - 1{,}33) = 54{,}33\,cm^3$

$S_{y3} = 54{,}33 + 6 \cdot 2 \cdot 3{,}52 + 2 \cdot \frac{1 \cdot 2}{2} \cdot (6{,}52 + 3{,}33) = 102{,}95\,cm^3$

$S_{y4} = 102{,}95 + 8 \cdot 2 \cdot 1{,}52 + 2 \cdot \frac{1 \cdot 2}{2} \cdot (6{,}52 - 5{,}33) = 129{,}64\,cm^3$

$S_{y5} = 129{,}64 + 10 \cdot 2 \cdot (-0{,}48) = 120{,}04\,cm^3$

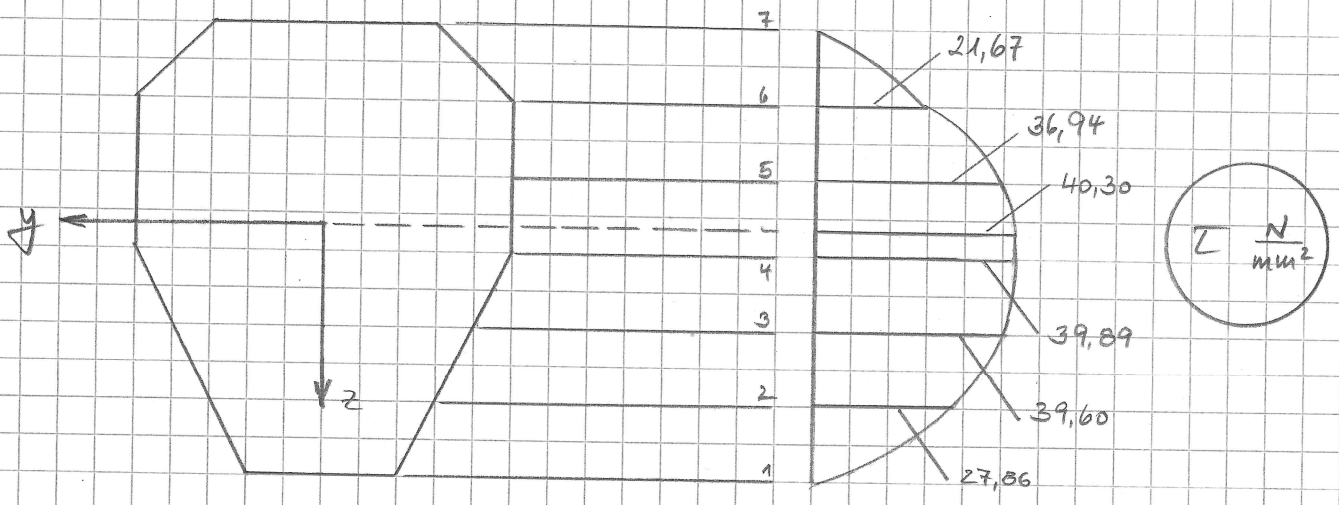
$S_{y6} = 120{,}04\,cm^3 + 10 \cdot 2 \cdot (-2{,}48) = 70{,}44\,cm^3$

$S_{y7} = 70{,}44 + 6cm \cdot 2cm \cdot (-4{,}48) + 2 \cdot \frac{2 \cdot 2}{2} \cdot (-4{,}15) = 0{,}08\,cm^3 \approx 0$

schnitt	S_y cm^3	b cm	τ kN/cm^2	τ N/mm^2
1	0	4	0	0
2	54,33	6	2,786	27,86
3	102,95	8	3,960	39,60
4	129,64	10	3,989	39,89
5	120,04	10	3,694	36,94
6	70,44	10	2,167	21,67
7	0	6	0	0

2/ $S_{ymax} = 129{,}64\,cm^3 + 10cm \cdot \frac{(0{,}52cm)^2}{2} = 130{,}99\,cm^3$

$\tau_{max} = \frac{300\,kN \cdot 130{,}99\,cm^3}{975\,cm^4 \cdot 10cm} = 4{,}030\,\frac{kN}{cm^2} = 40{,}30\,\frac{N}{mm^2}$



zu 1)

$$\frac{k_1}{k_2} = \frac{\sqrt{\frac{F}{E \cdot I_1}}}{\sqrt{\frac{F}{E \cdot I_2}}} = \sqrt{\frac{I_2}{I_1}} = \sqrt{\frac{\pi \cdot a^4}{4} \cdot \frac{12}{a^4}} = \sqrt{3 \cdot \pi}$$

$$\frac{k_1}{k_2} = 3{,}07$$

$$k_2 = \frac{1}{3{,}07} \cdot k_1 = 0{,}3257 \cdot k_1$$

$$\varkappa_2 = k_2 \cdot l_2 = k_2 \cdot l_1 = 0{,}3257 \cdot k_1 \cdot l_1 = 0{,}3257 \cdot \varkappa_1$$

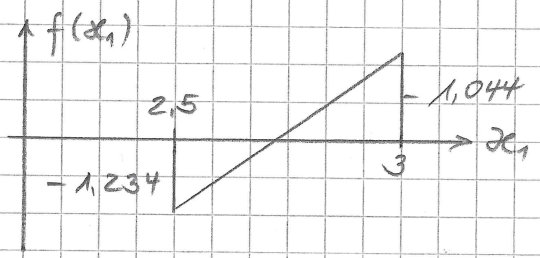
Knickbedingung

$$f(\varkappa_1) = 3{,}07 \cdot \tan \varkappa_1 + \tan(0{,}3257 \cdot \varkappa_1) = 0$$

$$f(2{,}5) = -1{,}234$$

$$f(3{,}0) = 1{,}044$$

1. Iteration



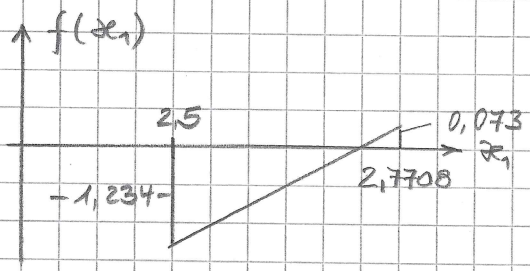
$$\frac{\Delta \varkappa_1}{1{,}234} = \frac{0{,}5}{1{,}234 + 1{,}044}$$

$$\Delta \varkappa_1 = 0{,}2708$$

$$\varkappa_{1\,Neu} = 2{,}5 + 0{,}2708 = 2{,}7708$$

$$f(\varkappa_{1\,Neu}) = 0{,}073$$

2. Iteration



$$\frac{\Delta x_1}{1,234} = \frac{0,2708}{1,234 + 0,073}$$

$$\Delta x_1 = 0,2556$$

$$x_{1Neu} = 2,5 + 0,2556 = 2,7556$$

$$f(x_{1Neu}) = 0,0061$$

$$x_1 = k_1 \cdot l = \sqrt{\frac{F_K}{E \cdot I_1}} \cdot l_1$$

$$F_K = \frac{x_1^2 \cdot E \cdot I_1}{l_1^2} = \frac{x_1^2 \cdot E \cdot a^4}{12 \cdot l_1^2} = 4 \cdot F$$

$$a^4 = \frac{48 \cdot F \cdot l_1^2}{x_1^2 \cdot E}$$

$$a = \sqrt[4]{\frac{48 \cdot F \cdot l_1^2}{x_1^2 \cdot E}} = \sqrt[4]{\frac{48 \cdot 100000\,N \cdot (1000\,mm)^2}{2,7556^2 \cdot 2,1 \cdot 10^5 \frac{N}{mm^2}}}$$

$$a = 41,65\,mm$$

gewählt: $a = 42\,mm$

zu 2)

$$A_{min} = A_1 = (42\,mm)^2 = 1764\,mm^2$$

$$\sigma_K = \frac{4 \cdot 100000\,N}{1764\,mm^2} = 226,76 \frac{N}{mm^2} < 285 \frac{N}{mm^2} = \sigma_{dP}$$