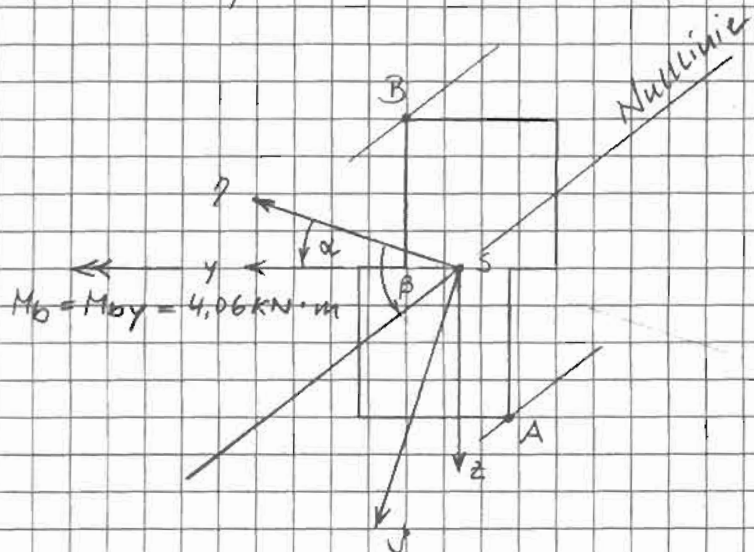
A1, 1/2

zu 1) $\alpha = -\varphi^* = 18{,}44°$

$$\tan\beta = \frac{936\,cm^4}{216\,cm^4} \cdot \tan 18{,}44° = 1{,}4449$$

$$\beta = 55{,}31°$$



zu 2)

$$M_{b\eta} = M_b \cdot \cos\alpha = 4{,}06\,kN\cdot m \cdot \cos(18{,}44°) = 3{,}852\,kN\cdot m$$

$$M_{b\zeta} = M_b \cdot \sin\alpha = 4{,}06\,kN\cdot m \cdot \sin(18{,}44°) = 1{,}284\,kN\cdot m$$

Punkt A: $y_A = -2\,cm$; $z_A = 6\,cm$

$$\eta_A = 6\,cm \cdot \sin(-18{,}44°) - 2\,cm \cdot \cos(-18{,}44°) = -3{,}80\,cm$$

$$\zeta_A = 6\,cm \cdot \cos(-18{,}44°) + 2\,cm \cdot \sin(-18{,}44°) = 5{,}06\,cm$$

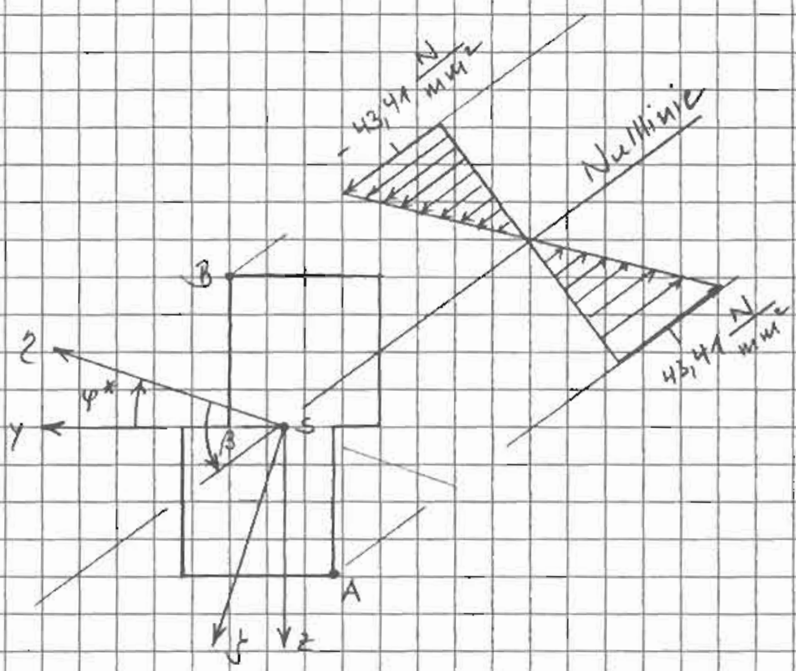
Punkt B: $y_B = 2\,cm$; $z_B = -6\,cm$

$\eta_B = 3{,}80\,cm$; $\zeta_B = -5{,}06\,cm$

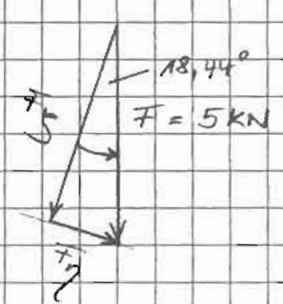
$$\sigma_b^A = \frac{3{,}852\,kN\cdot m \cdot 100\,\frac{cm}{m}}{936\,cm^4} \cdot 5{,}06\,cm - \frac{1{,}284\,kN\cdot m \cdot 100\,\frac{cm}{m}}{216\,cm^4} \cdot (-3{,}80\,cm) = 4{,}341\,\frac{kN}{cm^2} = 43{,}41\,\frac{N}{mm^2}$$

$$\sigma_b^B = -43{,}41\,\frac{N}{mm^2}$$

zu 3)



zu 4)



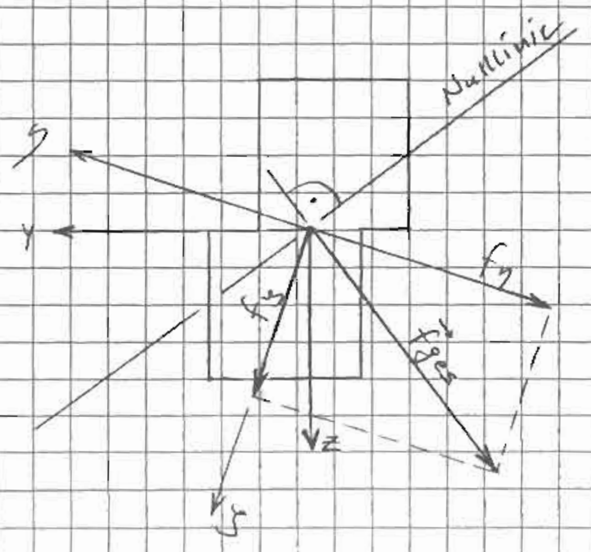
$F_\eta = -5\,kN \cdot \sin 18{,}44° = -1{,}582\ kN$

$F_\zeta = 5\,kN \cdot \cos 18{,}44° = 4{,}743\ kN$

$$f_\eta = -\frac{3 \cdot 1582\,N \cdot (4000\,mm)^3}{200 \cdot 2{,}1 \cdot 10^5 \frac{N}{mm^2} \cdot 216 \cdot 10^4\,mm^4} = -3{,}348\,mm$$

$$f_\zeta = \frac{3 \cdot 4743\,N \cdot (4000\,mm)^3}{200 \cdot 2{,}1 \cdot 10^5 \frac{N}{mm^2} \cdot 936 \cdot 10^4\,mm^4} = 2{,}316\,mm$$

$$|\vec{f}_{ges}| = \sqrt{(-3{,}348\,mm)^2 + (2{,}316\,mm)^2} = 4{,}071\,mm$$



A2, 1/2

zu 1)

Schnitt 1: $S_y = 0$

Schnitt 2: $S_y = 6\,cm \cdot 4\,cm \cdot 7{,}9\,cm = 189{,}6\,cm^3$

Schnitt 3: $S_y = 6\,cm \cdot 6\,cm \cdot 6{,}9\,cm - \frac{\pi \cdot (4\,cm)^2}{8} \cdot \left(3{,}9\,cm + \frac{4 \cdot 2\,cm}{3 \cdot \pi}\right)$

$S_y = 218{,}56\,cm^3$

Schnitt 4: $S_y = 6\,cm \cdot 8\,cm \cdot 5{,}9\,cm - \frac{\pi \cdot (4\,cm)^2}{4} \cdot 3{,}9\,cm$

$S_y = 234{,}19\,cm^3$

Schnitt 5: $S_y = 234{,}19\,cm^3 + 6\,cm \cdot 2\,cm \cdot 0{,}9\,cm$

$S_y = 244{,}99\,cm^3$

Schnitt 6: $S_y = 244{,}99\,cm^3 + 6\,cm \cdot 3\,cm \cdot (-1{,}6\,cm) + 2 \cdot \frac{3\,cm \cdot 2\,cm}{2} \cdot (-2{,}1\,cm)$

$S_y = 203{,}59\,cm^3$

Schnitt 7: $S_y = 203{,}59\,cm^3 + 10\,cm \cdot 4\,cm \cdot (-5{,}1\,cm)$

$S_y = -0{,}41\,cm^3 \sim 0$

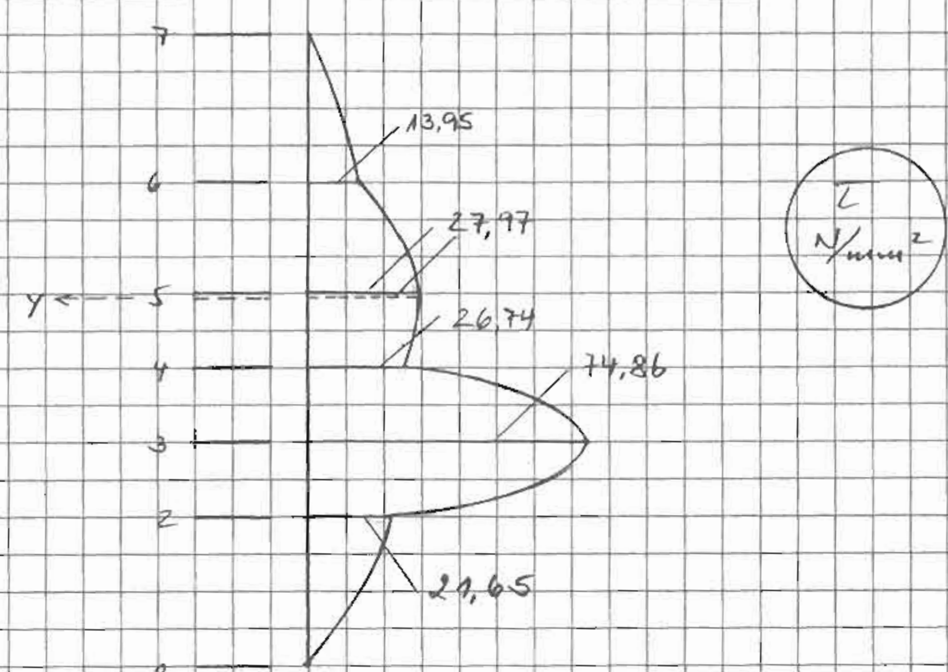
$$\tau = \frac{F_{qz}}{I_y} \cdot \frac{S_y}{b} = \frac{200\,kN}{2920\,cm^4} \cdot \frac{S_y}{b} = 0{,}0685\,\frac{kN}{cm^4} \cdot \frac{S_y}{b}$$

Schnitt	S_y cm^3	b cm	τ kN/cm^2	τ N/mm^2
1	0	6	0	0
2	189,6	6	2,165	21,65
3	218,56	2	7,486	74,86
4	234,19	6	2,674	26,74
5	244,99	6	2,797	27,97
6	203,59	10	1,395	13,95
7	0	10	0	0

zu 2) $S_{y\,max} = 234{,}19\ cm^3 + 6\,cm \cdot 1{,}9\,cm \cdot \frac{1{,}9\,cm}{2} = 245{,}02\,cm^3$

$\tau_S = 2{,}797\ \frac{kN}{cm^2} = 27{,}97\ \frac{N}{mm^2}$

zu 3)



zu 1) $s_K = 0{,}7 \cdot l = 0{,}7 \cdot 4000\,mm = 2800\,mm$

$F = E \cdot A \cdot \alpha_\vartheta \cdot \Delta\vartheta$

$$\nu \cdot \cancel{E} \cdot A \cdot \alpha_\vartheta \cdot \Delta\vartheta = \frac{\cancel{E} \cdot I_z \cdot \pi^2}{s_K^2}$$

$$\nu \cdot 8 \cdot \cancel{a^2} \cdot \alpha_\vartheta \cdot \Delta\vartheta = \frac{\frac{10}{3} \cdot a^{\cancel{4}\,2} \cdot \pi^2}{s_K^2}$$

$$a = \sqrt{\frac{3 \cdot \nu \cdot 8 \cdot \alpha_\vartheta \cdot \Delta\vartheta \cdot s_K^2}{10 \cdot \pi^2}}$$

$$a = \sqrt{\frac{3 \cdot 4 \cdot 8 \cdot 1{,}2 \cdot 10^{-5}\,K \cdot 30\,K \cdot (2800\,mm)^2}{10 \cdot \pi^2}}$$

$$a = 52{,}40\,mm$$

Überprüfen der Schlankheit:

$$i = \sqrt{\frac{10 \cdot a^4}{3 \cdot 8 \cdot a^2}} = 0{,}6455 \cdot a = 33{,}82\,mm$$

$$\lambda = \frac{s_K}{i} = \frac{2800\,mm}{33{,}82\,mm} = 82{,}79 < \lambda_{grenz} = 85$$

Berechnung nach Tetmajer

$$\sigma_K = 470 - 2{,}3 \cdot \lambda$$

$$\nu \cdot E \cdot \alpha_\vartheta \cdot \Delta\vartheta = 470 - 2{,}30 \cdot \frac{s_K}{i} = 470 - 2{,}3 \cdot \frac{s_K}{0{,}6455 \cdot a}$$

$$\frac{2{,}3 \cdot s_K}{0{,}6455 \cdot a} = 470 - \nu \cdot E \cdot \alpha_\vartheta \cdot \Delta\vartheta$$

$$a = \frac{2{,}3 \cdot s_K}{0{,}6455 \cdot (470 - \nu \cdot E \cdot \alpha_\vartheta \cdot \Delta\vartheta)}$$

$$a = \frac{2,3 \cdot 2800\,mm}{0,6455 \cdot (470 - 4 \cdot 2,1 \cdot 10^5 \cdot 1,2 \cdot 10^{-5} \cdot 30)}$$

$$a = 59,5\,mm$$

zu 2) $a = 60\,mm$

$$\sigma = E \cdot \left(\frac{\Delta l}{l_0} - \alpha_\vartheta \cdot \Delta\vartheta\right)$$

$$\sigma = 2,1 \cdot 10^5 \frac{N}{mm^2} \cdot \left(\frac{0,4\,mm}{4000\,mm} - 1,2 \cdot 10^{-5} K^{-1} \cdot 30 K\right)$$

$$\sigma = -54,6 \frac{N}{mm^2}$$

$$\sigma_K = 470 \frac{N}{mm^2} - 2,3 \frac{N}{mm^2} \cdot \frac{2800\,mm}{0,6455 \cdot 60\,mm}$$

$$\sigma_K = 303,72 \frac{N}{mm^2}$$

$$\nu = \frac{\sigma_K}{\sigma} = \frac{303,72 \frac{N}{mm^2}}{54,6 \frac{N}{mm^2}}$$

$$\nu = 5,56$$