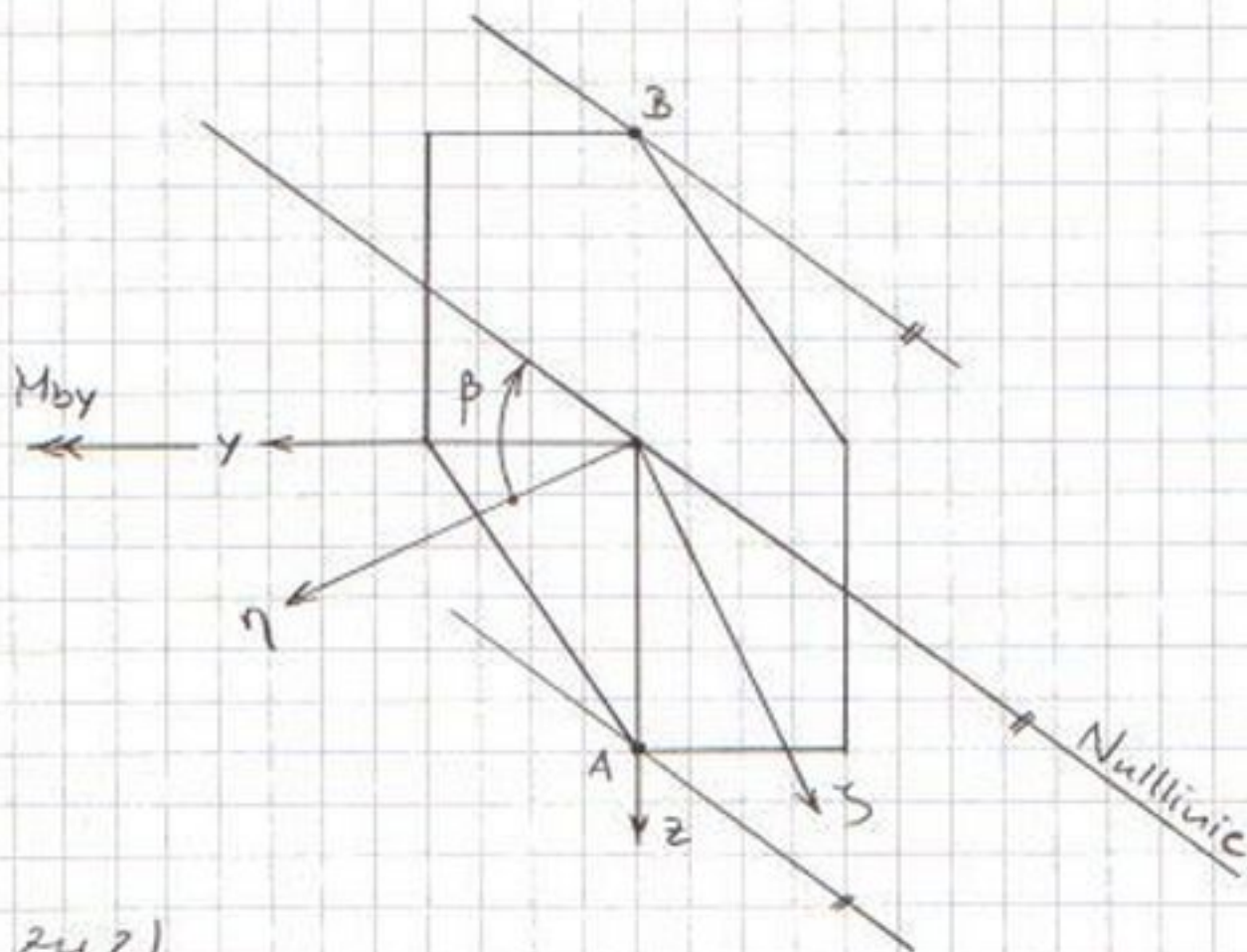


zu 1) $\alpha = -\varphi^* = -25,10^\circ$

$$\tan \beta = \frac{832,41 \text{ cm}^4}{207,59 \text{ cm}^4} \cdot \tan(-25,10^\circ)$$

$$\tan \beta = -1,878$$

$$\beta = -61,97^\circ$$



zu 2)

$$M_{\eta} = M_{by} \cdot \cos \alpha = 5 \text{ kN} \cdot \text{m} \cdot \cos(-25,10^\circ) = 4,53 \text{ kN} \cdot \text{m}$$

$$M_{\xi} = M_{by} \cdot \sin \alpha = 5 \text{ kN} \cdot \text{m} \cdot \sin(-25,10^\circ) = -2,12 \text{ kN} \cdot \text{m}$$

$$z_A = 6 \text{ cm} ; y_A = 0$$

$$z_B = -6 \text{ cm} ; y_B = 0$$

$$\eta_A = z_A \cdot \sin \varphi = 6 \text{ cm} \cdot \sin 25,1^\circ = 2,55 \text{ cm}$$

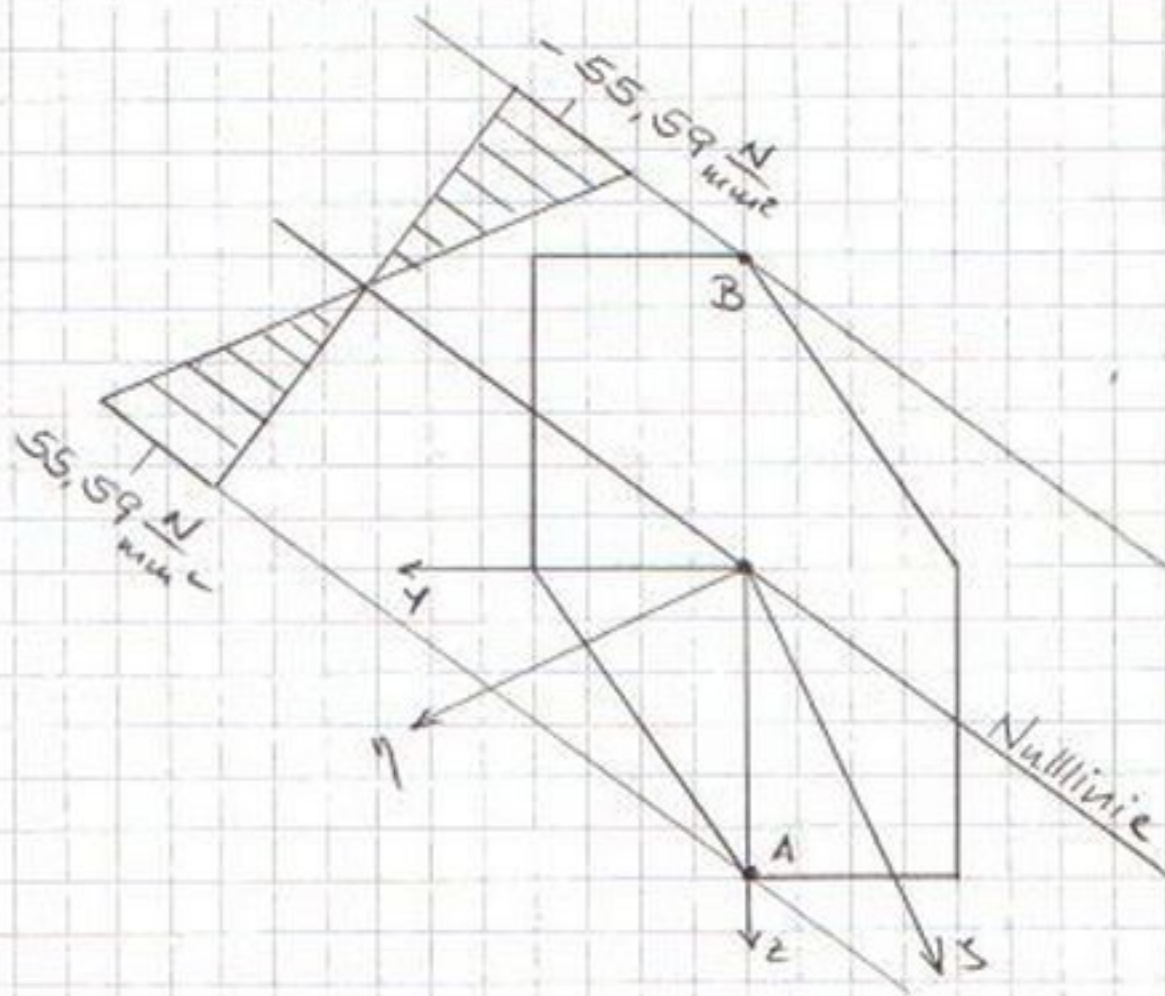
$$\xi_A = z_A \cdot \cos \varphi = 6 \text{ cm} \cdot \cos 25,1^\circ = 5,43 \text{ cm}$$

$$\eta_B = -2,55 \text{ cm} ; \xi_B = -5,43 \text{ cm}$$

$$\sigma_b^A = \frac{4,53 \text{ kN} \cdot \text{cm}}{832,41 \text{ cm}^4} \cdot 5,43 \text{ cm} - \frac{(-2,12 \text{ kN} \cdot \text{cm})}{207,59 \text{ cm}^4} \cdot 2,55 \text{ cm}$$

$$\sigma_b^A = 5,559 \frac{\text{kN}}{\text{cm}^2} = 55,59 \frac{\text{N}}{\text{mm}^2}$$

$$\sigma_b^3 = -55,59 \frac{\text{N}}{\text{mm}^2}$$



$$\text{zu 3) } F_{zul} = \frac{80 \frac{\text{N}}{\text{mm}^2}}{55,59 \frac{\text{N}}{\text{mm}^2}} \cdot 10 \text{ kN} = 14,39 \text{ kN}$$

1) Kriterium: $\tau_{zul} = 60 \frac{N}{mm^2}$

a) Rechteckquerschnitt

$$\frac{h}{b} = \frac{10 \text{ cm}}{8 \text{ cm}} = 1,25$$

$$\alpha = \frac{0,208 + 0,231}{2} = 0,220$$

$$\beta = \frac{0,140 + 0,196}{2} = 0,168$$

$$I_T = 0,168 \cdot 10 \text{ cm} \cdot (8 \text{ cm})^3 = 860,16 \text{ cm}^4 = 860,16 \cdot 10^4 \text{ mm}^4$$

$$W_T = 0,220 \cdot 10 \text{ cm} \cdot (8 \text{ cm})^2 = 140,80 \text{ cm}^3 = 140,80 \cdot 10^3 \text{ mm}^3$$

$$M_{Tzul} = \tau_{zul} \cdot W_T = 60 \frac{N}{mm^2} \cdot 140,80 \cdot 10^3 \text{ mm}^3$$

$$M_{Tzul} = 8448000 \text{ N} \cdot \text{mm} = 8448 \text{ N} \cdot \text{m}$$

b) Hohlprofil

$$\tau = \frac{M_T}{2 \cdot A_{m1} \cdot t_{min}}$$

$$A_{m1} = 75 \text{ mm} \cdot 47 \text{ mm} + \frac{\pi \cdot (37,50 \text{ mm})^2}{2} = 5734 \text{ mm}^2$$

$$M_{Tzul} = 60 \frac{N}{mm^2} \cdot 2 \cdot 5734 \text{ mm}^2 \cdot 5 \text{ mm}$$

$$M_{Tzul} = 3440400 \text{ N} \cdot \text{mm} = 3440 \text{ N} \cdot \text{m}$$

2) Kriterium: $\varphi_{zul} = 3^\circ$

$$\varphi = \varphi_1 + \varphi_2$$

$$\varphi = \frac{M_T}{G \cdot I_{T1}} \cdot l_1 + \frac{M_T}{G \cdot I_{T2}} \cdot l_2$$

$$\varphi = \frac{M_T}{G} \cdot \left(\frac{l_1}{I_{T1}} + \frac{l_2}{I_{T2}} \right)$$

$$I_{T2} = \frac{4 \cdot A_{ui}^2}{\oint \frac{ds}{t}}$$

$$\oint \frac{ds}{t} = \frac{75 \text{ mm}}{6 \text{ mm}} + \frac{2 \cdot 47 \text{ mm}}{5 \text{ mm}} + \frac{7 \cdot 37,5 \text{ mm}}{5 \text{ mm}} = 54,86$$

$$I_{T2} = \frac{4 \cdot (5734 \text{ mm}^2)^2}{54,86} = 2397284 \text{ mm}^4$$

$$M_{Tzul} = \frac{\varphi \cdot G}{\frac{l_1}{I_{T1}} + \frac{l_2}{I_{T2}}}$$

$$M_{Tzul} = \frac{3^\circ \cdot \frac{\pi}{180^\circ} \cdot 8,1 \cdot 10^4 \frac{\text{N}}{\text{mm}^2}}{\frac{2000 \text{ mm}}{860,16 \cdot 10^4 \text{ mm}^4} + \frac{2000 \text{ mm}}{2397284 \text{ mm}^4}} = 3975610 \text{ N} \cdot \text{mm}$$

$$M_{Tzul} = 3975,6 \text{ N} \cdot \text{m}$$

$$\text{Maßgebend: } M_{Tzul} = 3440 \text{ N} \cdot \text{m}$$

A3, 1/2

$$1) I_y = I_z = \frac{\pi \cdot d^4}{64} = \frac{\pi \cdot (75 \text{ mm})^4}{64} = 1553155 \text{ mm}^4$$

$$\delta = \frac{c_w \cdot l^3}{E \cdot I} = \frac{600 \frac{\text{N}}{\text{mm}} \cdot (2000 \text{ mm})^3}{2,1 \cdot 10^5 \frac{\text{N}}{\text{mm}^2} \cdot 1553155 \text{ mm}^4}$$

$$\delta = 14,72 \quad (1)$$

$$F = E \cdot A \cdot \alpha_g \cdot \Delta T$$

$$F = 2,1 \cdot 10^5 \frac{\text{N}}{\text{mm}^2} \cdot \frac{\pi \cdot (75 \text{ mm})^2}{4} \cdot 1,2 \cdot 10^{-5} \text{ K}^{-1} \cdot 20 \text{ K}$$

$$F = 222660 \text{ N} \quad (1)$$

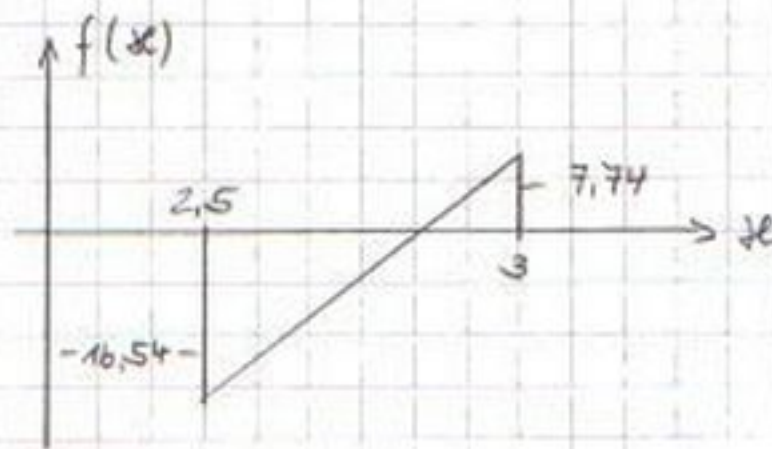
Knickbedingung

$$f(x) = 2 \cdot x^3 + 14,72 \cdot \tan x - 14,72 \cdot x = 0$$

$$f(2,5) = -16,54$$

$$f(3,0) = 7,74$$

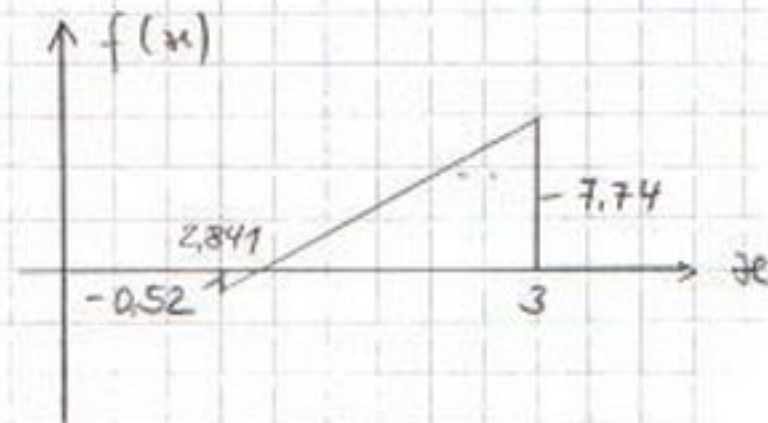
$$\frac{\Delta x}{16,54} = \frac{0,5}{16,54 + 7,74}$$



$$\Delta x = 0,341 \Rightarrow x_{\text{Neu}} = 2,5 + 0,341 = 2,841$$

$$f(x_{\text{Neu}}) = -0,52$$

$$\frac{\Delta x}{0,52} = \frac{3 - 2,841}{0,52 + 7,74}$$



$$\Delta x = 0,010$$

$$x_{\text{Neu}} = 2,851$$

$$f(x_{\text{Neu}}) = -0,02 \approx 0$$

$$\sqrt{\frac{F_k}{E \cdot I}} \cdot l = x$$

$$F_k = \frac{x^2 \cdot E \cdot I}{l^2} = \frac{2.851^2 \cdot 2.1 \cdot 10^5 \frac{\text{N}}{\text{mm}^2} \cdot 1553155 \text{ mm}^4}{(2000 \text{ mm})^2}$$

$$F_k = 662779 \text{ N}$$

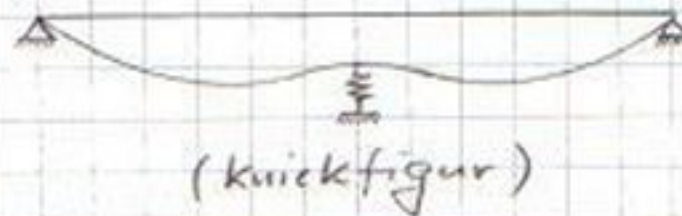
$$\eta_k = \frac{662779 \text{ N}}{222660 \text{ N}} = 2.98$$

$$2) \frac{E \cdot I \cdot \pi^2}{S_k^2} = F_k$$

$$S_k = \sqrt{\frac{E \cdot I \cdot \pi^2}{F_k}}$$

$$S_k = \sqrt{\frac{2.1 \cdot 10^5 \frac{\text{N}}{\text{mm}^2} \cdot 1553155 \text{ mm}^4 \cdot \pi^2}{662779 \text{ N}}}$$

$$S_k = 2204 \text{ mm}$$



$$3) \lambda = \frac{S_k}{i}$$

$$i = \sqrt{\frac{I}{A}} = \sqrt{\frac{\pi \cdot d^4 \cdot 4}{64 \cdot \pi \cdot d^2}} = \sqrt{\frac{d^2}{16}} = \frac{d}{4} = \frac{75 \text{ mm}}{4} = 18.75 \text{ mm}$$

$$\lambda = \frac{2204 \text{ mm}}{18.75 \text{ mm}} = 117.5 > 105 \Rightarrow \text{elastische Knickung} \checkmark$$

o.k.