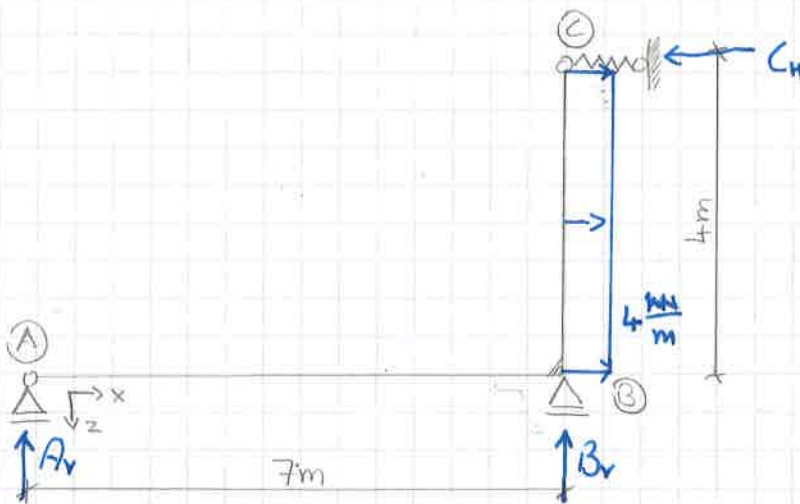


Aufgabe 1

a)



$$A_v = \frac{1}{7} (4 \cdot 4 \cdot 2) = \frac{32}{7} \text{ kN}$$

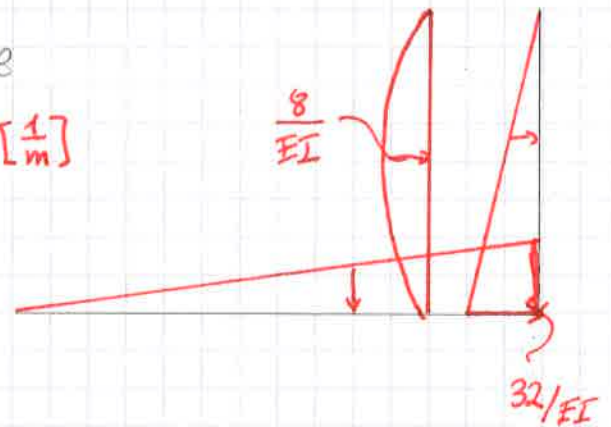
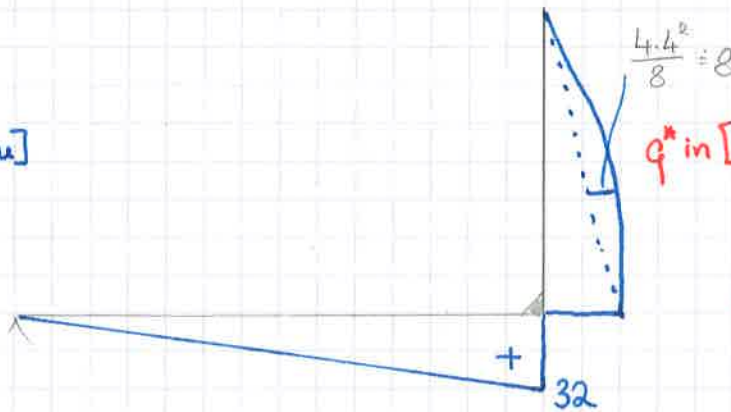
$$B_v = -A_v = -\frac{32}{7} \text{ kN}$$

$$C_H = 4 \cdot 4 = 16 \text{ kN}$$

Momentenverlauf

Erdbelast q^*

Min [kNm]



Stab 1-2

$$w_{1-2}(x) = \frac{32}{EI} \cdot \frac{7^2}{6} \left(\frac{x}{7} - \left(\frac{x}{7} \right)^3 \right); \quad w_{\max} = \frac{32}{EI} \cdot \frac{49}{9\sqrt{3}} = 0.010 \text{ m}; \quad \text{Stelle } x: \frac{1}{\sqrt{3}} \cdot 7 = 4.04 \text{ m}$$

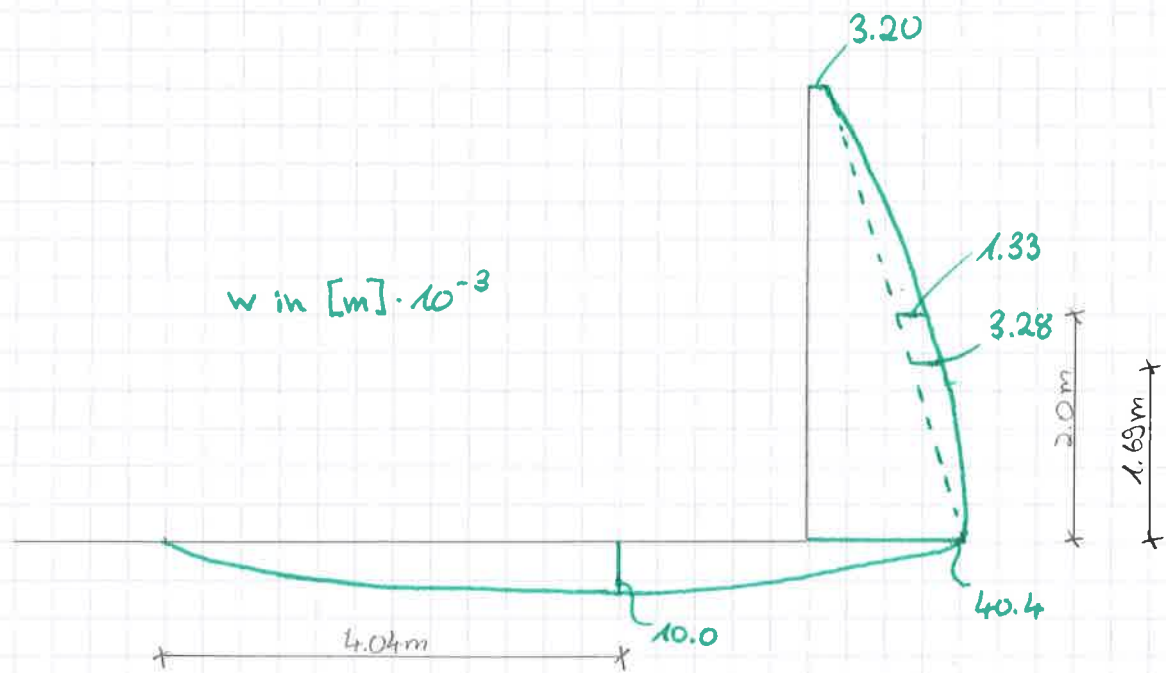
Stab 2-3

$$w_2 = u_2 = 40.4 \text{ mm} = 40.4 \cdot 10^{-3} \text{ m}; \quad w_3 = \frac{C_H}{K_F} = \frac{16}{5000} = 3.20 \cdot 10^{-3} \text{ m}$$

$$w_{2-3}(x) = \frac{32}{EI} \frac{16}{6} \left(\frac{(4-x)}{4} - \left(\frac{(4-x)}{4} \right)^3 \right) + \frac{8}{EI} \frac{16}{3} \left(\frac{x}{4} - 2 \left(\frac{x}{4} \right)^3 + \left(\frac{x}{4} \right)^4 \right) + w_2 \frac{(4-x)}{4} + w_3 \frac{x}{4}$$

$$w_{\max}^{\text{Dreieck}} = \frac{32}{EI} \frac{16}{9\sqrt{3}} = 3.28 \cdot 10^{-3}; \quad \text{Stelle } x: 0.4226 \cdot 4 = 1.69 \text{ m}$$

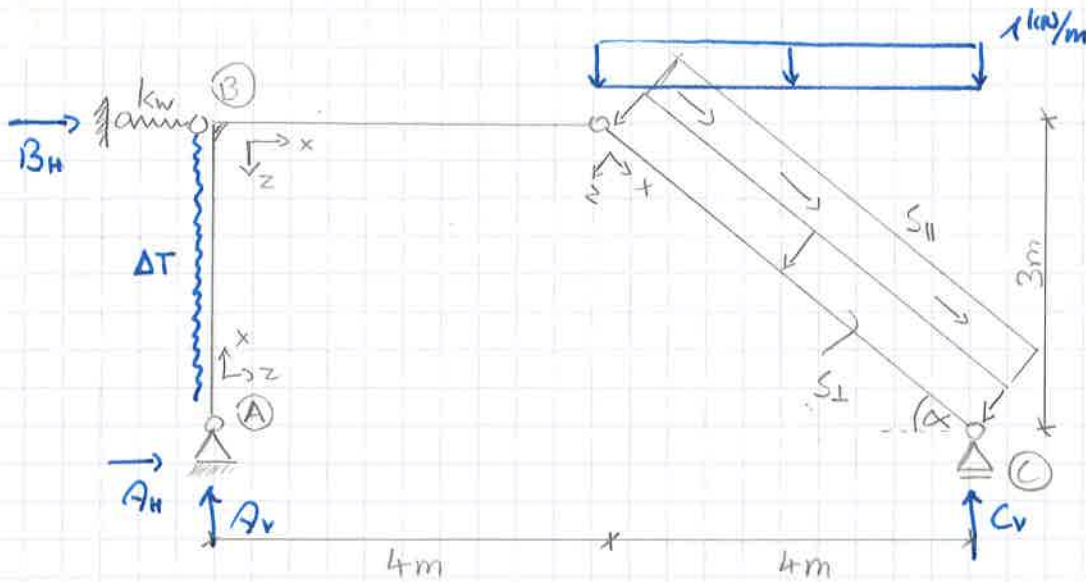
$$w_{\max}^{\text{Parabel}} = \frac{8}{EI} \frac{5 \cdot 16}{48} = 1.33 \cdot 10^{-3}; \quad \text{Stelle } x: 0.5 \cdot 4 = 2 \text{ m}$$

Biegelinie

- b) Die Krümmungsanteile der Biegelinie würden sich nicht ändern. Es würde zu einer gleichmäßigen Ausdehnung in beide Richtungen kommen, was die Knotenverformungen von ① und ② betreffen würde.

Aufgabe 2

③



$$C_V = \frac{1}{4} (1 \cdot 4 \cdot 2) = 2 \text{ kN}$$

$$A_V = -C_V + 1 \cdot 4 = 2 \text{ kN}$$

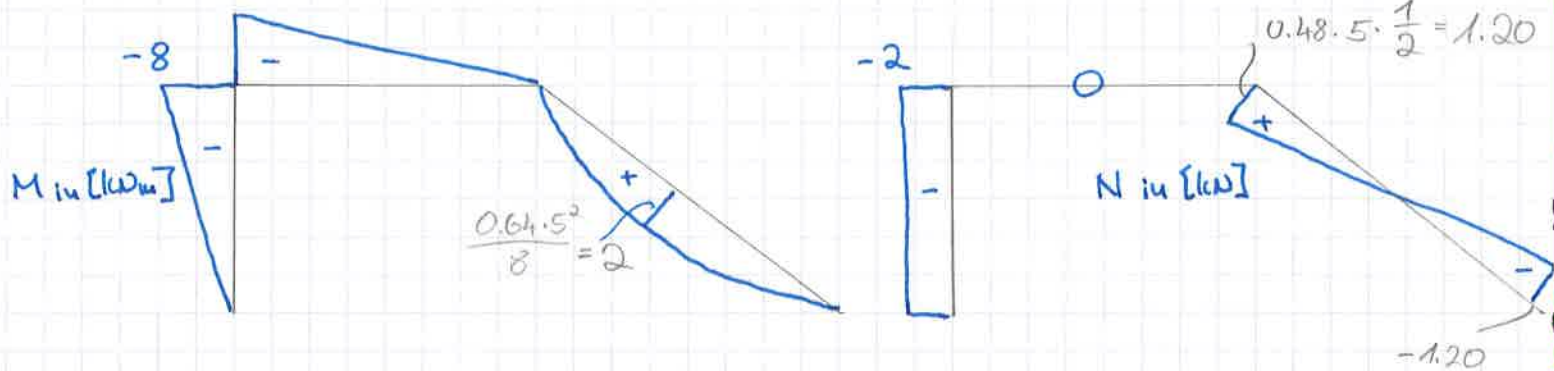
$$A_H = \frac{1}{3} (2 \cdot 4) = \frac{8}{3} \text{ kN}$$

$$B_H = -A_H = -\frac{8}{3} \text{ kN}$$

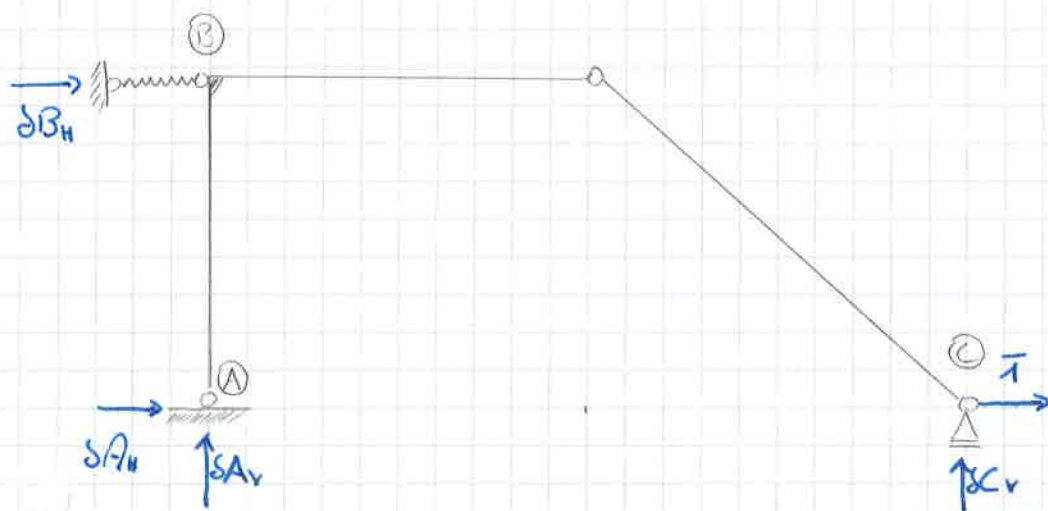
$$S_{\perp} = \cos^2 \alpha \cdot 1 = 0.64 \text{ kN/m}$$

$$S_{\parallel} = \sin \alpha \cos \alpha \cdot 1 = 0.48 \text{ kN/m}$$

Schnittgrößenverläufe



Virtueller Schnittgrößenverlauf



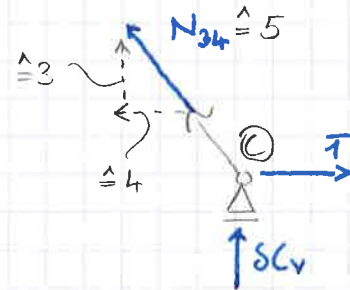
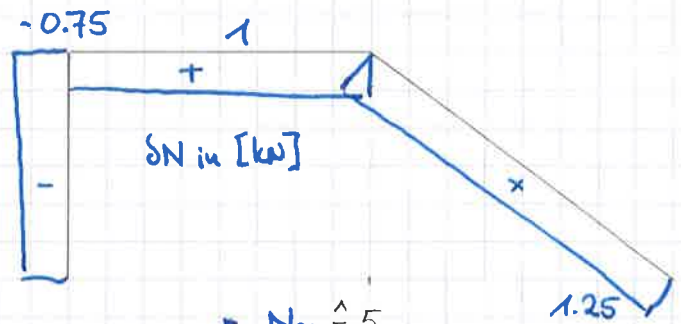
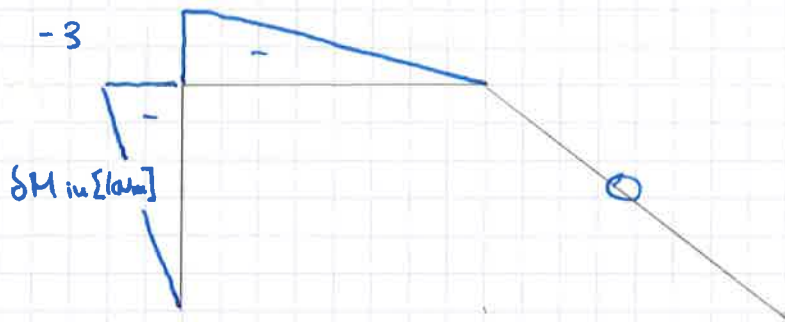
$$\delta C_V = \frac{1}{4} (-1 \cdot 3) = -0.75 \text{ kN}$$

$$\delta A_V = -\delta C_V = 0.75 \text{ kN}$$

$$\delta A_H = \frac{1}{3} \left(+\frac{3}{4} \cdot 4 \right) = 1 \text{ kN}$$

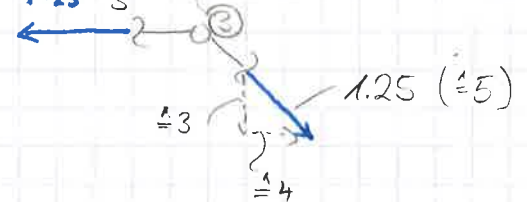
$$\delta B_H = -\delta A_H - 1 = -2 \text{ kN}$$

④



$$N_{34} = \sqrt{1^2 + 0.75^2} = 1.25 \text{ kN}$$

$$N_{23} = \frac{4}{5} \cdot 1.25 = 1.0 \text{ kN}$$



Verschiebung am Knoten ④:

$$u_4 = \frac{1}{3} \cdot 3 \cdot (-3) \cdot (-8) \cdot \frac{1}{EI} + \frac{1}{3} \cdot 4 \cdot (-3) \cdot (-8) \cdot \frac{1}{EI}$$

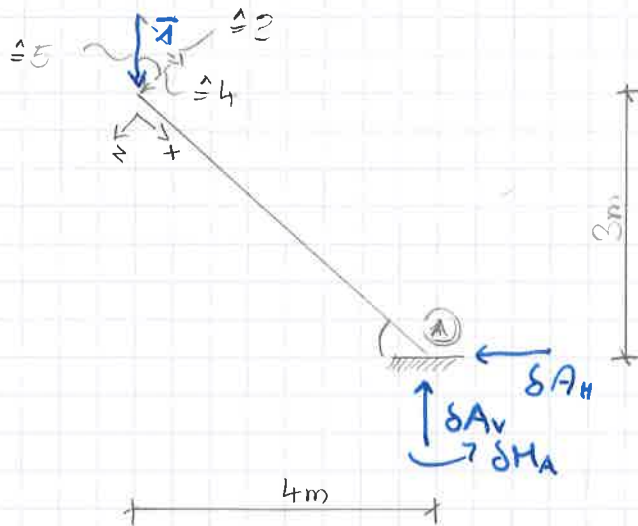
$$+ 3 \cdot (-2) \cdot (-0.75) \cdot \frac{1}{EA} + 0 + \frac{8}{3} \cdot 2 \cdot \frac{1}{k_w}$$

$$+ \frac{1}{2} \cdot 3 \cdot \frac{10^{-5} \cdot (-20)}{0.15} \cdot (-3)$$

$$= 0.065 \text{ m}$$

b) Virtueller Schnittgrößenverlauf

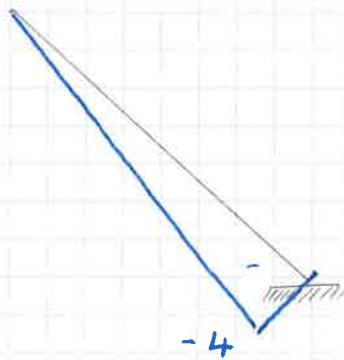
⑤



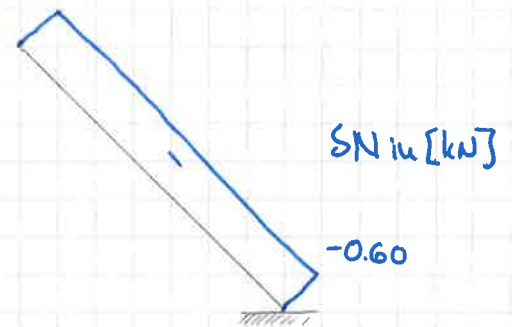
$$\delta A_v = 1 \text{ kN}$$

$$\delta A_H = 0$$

$$\delta M_A = +4 \text{ kNm}$$



δM in [kNm]



δN in [kN]

$$w_2 = \left(\frac{1}{3} \cdot 5 \cdot 4 \cdot (-8.655) + \frac{1}{3} \cdot 5 \cdot 4 \cdot 2 \right) \frac{1}{EI} + \left(5 \cdot (-0.60) \cdot (-0.088) + \frac{1}{2} \cdot 5 \cdot (-0.60) \cdot (-2.33) \right) \frac{1}{EA}$$

$$= 4.33 \cdot 10^{-3} \text{ m}$$

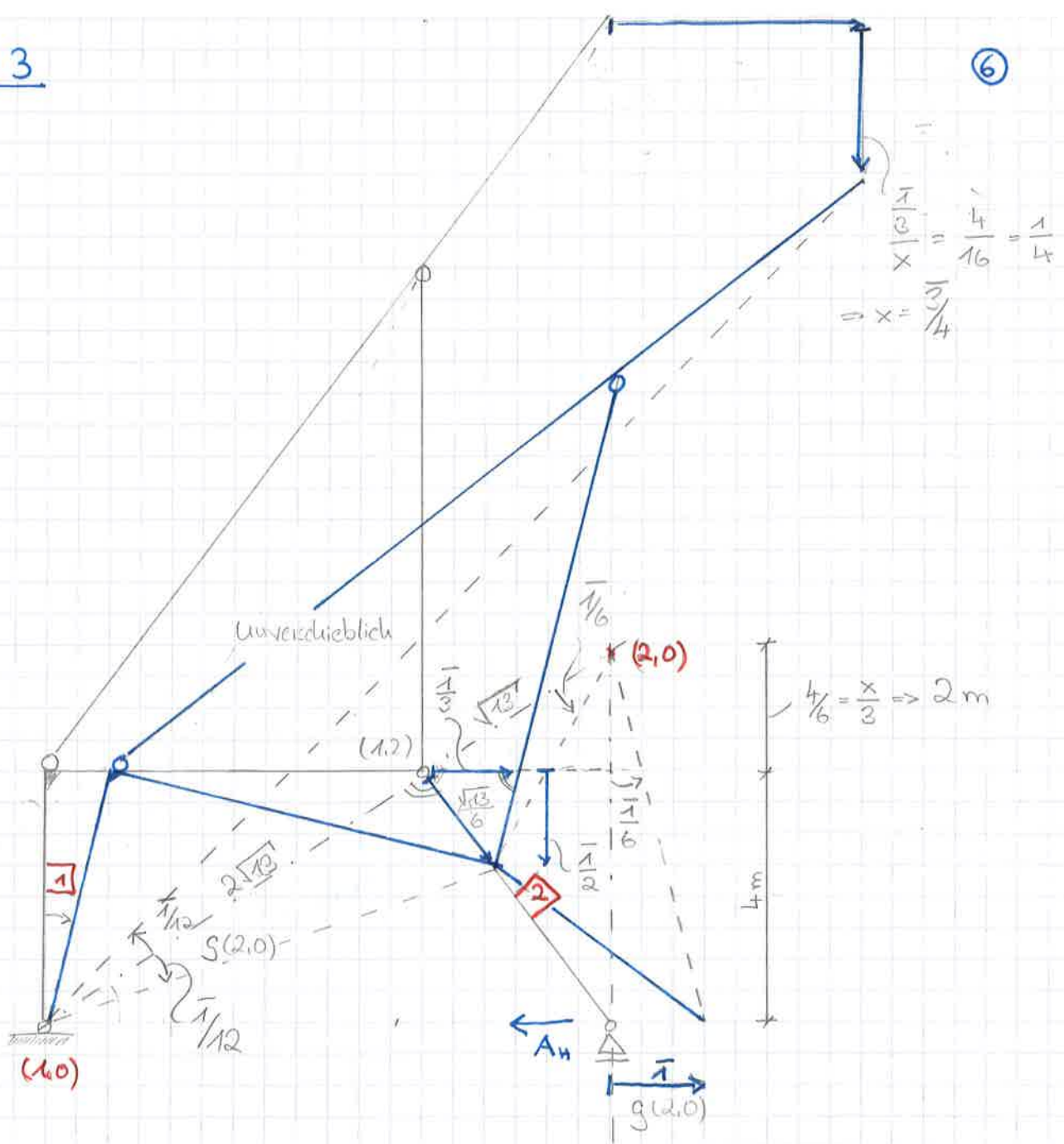
→ Verschiebung senkrecht zum Stab 3-4:

$$w_{3\perp} = \frac{4}{5} \cdot 4.33 \cdot 10^{-3} = 3.51 \cdot 10^{-3} \text{ m}$$

Aufgabe 3

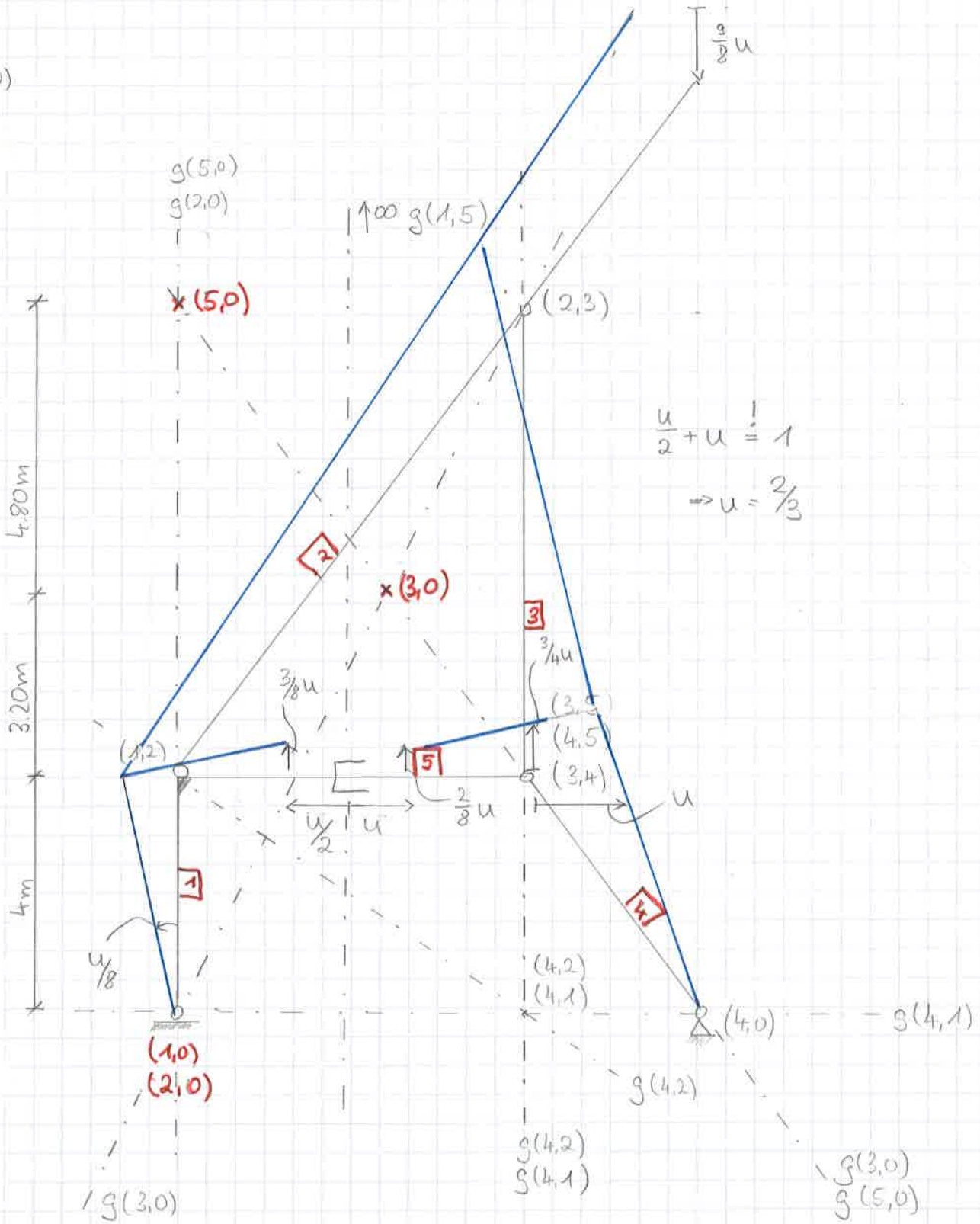
6

a)



$$-A_H = 200 \cdot \frac{3}{4} + 150 \cdot \frac{1}{12} = 162.5$$

b)



$$\frac{u}{2} + u = 1$$

$$\Rightarrow u = \frac{2}{3}$$

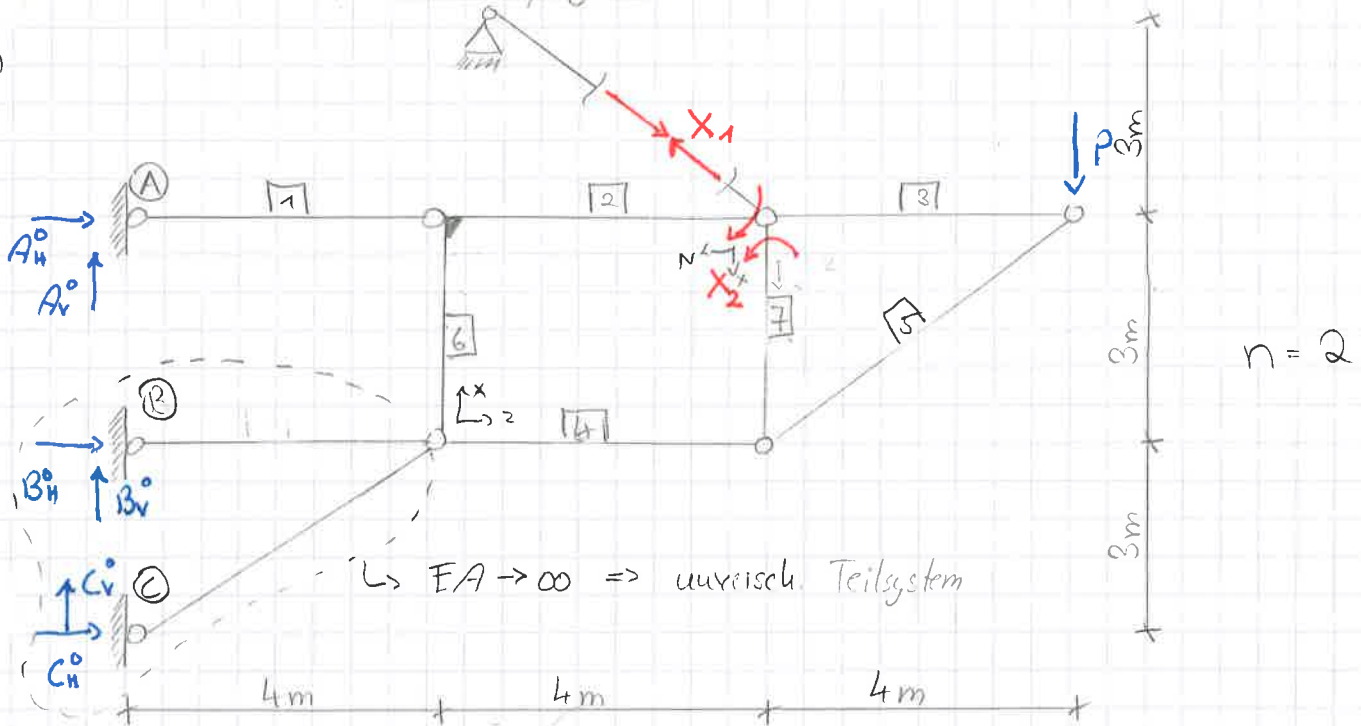
$$N = -\frac{9}{8}u \cdot 200 - \frac{u}{8} \cdot 150 = -162.50 \text{ kN}$$

Aufgabe 4

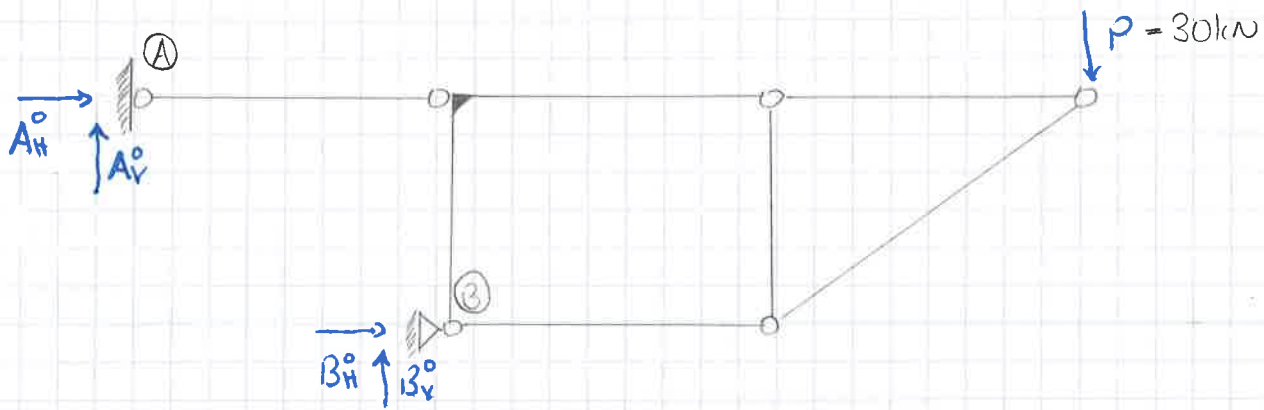
8

Statisch bestimmtes Hauptsystem

a)



b) LSZ



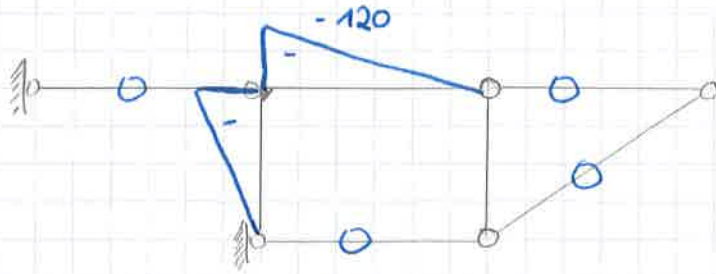
$$A_V^0 = 0$$

$$A_H^0 = \frac{1}{3}(-30 \cdot 8) = -80 \text{ kN}$$

$$B_H^0 = -A_H^0 = 80 \text{ kN}$$

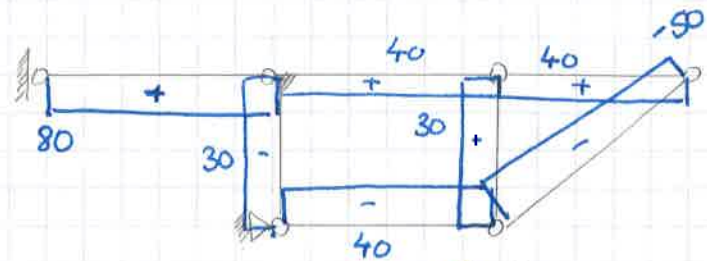
$$B_V^0 = P = 30 \text{ kN}$$

M in [kNm]



N in [kN]

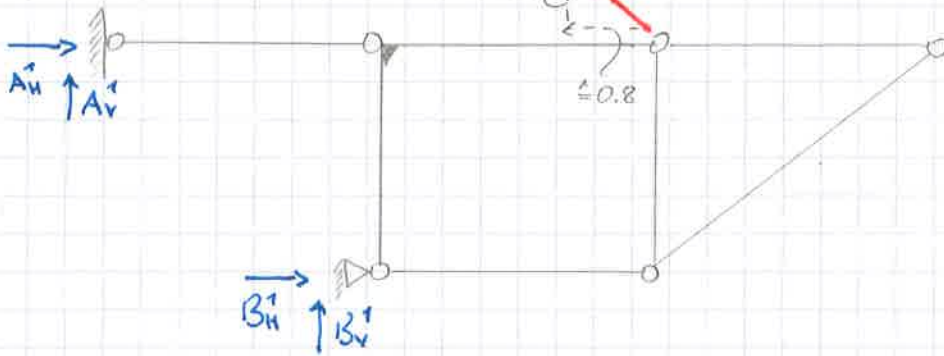
⑨



$$\begin{aligned} M_7^o &= 0 \\ N_7^o &= 0 \\ V_7^o &= 0 \end{aligned}$$

$$\begin{aligned} B_H^o &= 0 \\ B_V^o &= 0 \\ N_4^o &= 0 \\ N_7^o - B_V^o &= -30 \text{ kN} \end{aligned}$$

Est 1



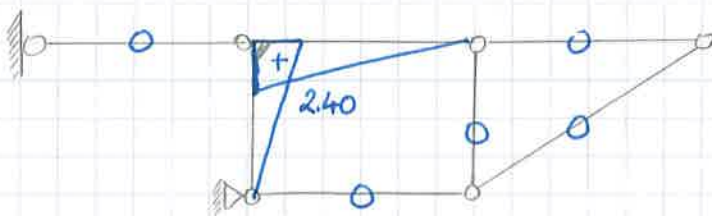
$$A_V = 0$$

$$B_V = -0.60 \text{ kN}$$

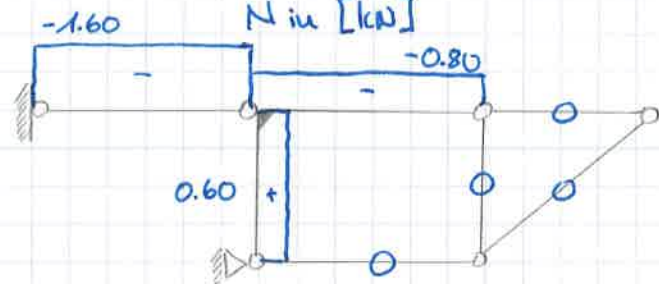
$$B_H = \frac{1}{5} (0.6 \cdot 4 - 0.6 \cdot 8) = -0.80 \text{ kN}$$

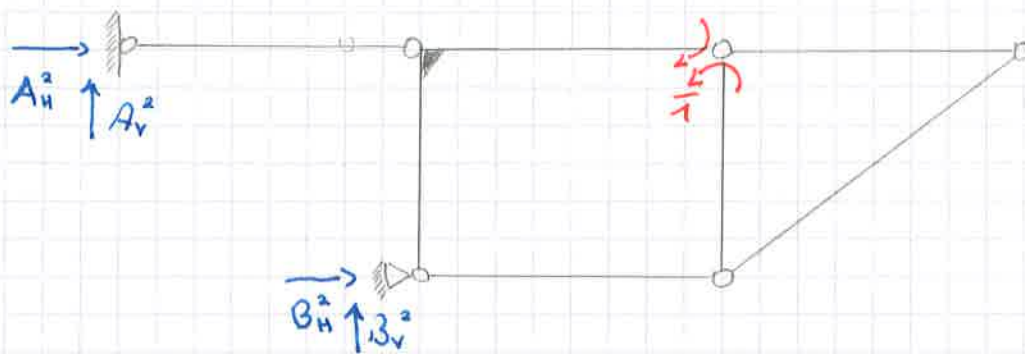
$$A_H = 0.80 + 0.80 = 1.60 \text{ kN}$$

M in [kNm]



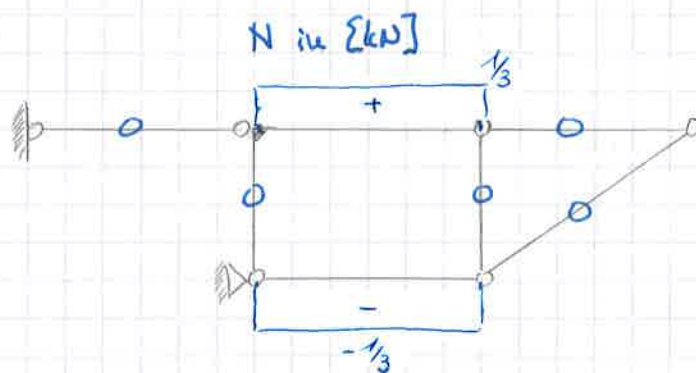
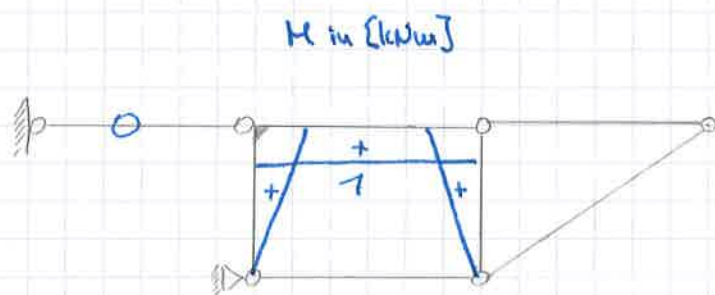
N in [kN]





$$A_V^2 = 0 ; B_H^2 = 0$$

$$B_V^2 = 0 ; A_H^2 = 0$$



Flexibilitäten

$$d_{10} = \frac{1}{EI} \left(\frac{1}{3} \cdot 3 \cdot (-120) \cdot 240 + \frac{1}{3} \cdot 4 \cdot (-120) \cdot 240 \right) + \frac{1}{EA} \left(4 \cdot 80 \cdot (-160) + 4 \cdot 40 \cdot (-0.80) \right)$$

$$= -0.45 \cdot 1$$

$$d_{20} = \frac{1}{EI} \left(\frac{1}{3} \cdot 3 \cdot (-120) \cdot 1 + \frac{1}{3} \cdot 4 \cdot (-120) \cdot 1 \right) + \frac{1}{EA} \left(4 \cdot \frac{1}{3} \cdot 40 \right)$$

$$= -0.045$$

$$d_{11} = \frac{1}{EI} \left(\frac{1}{3} \cdot 3 \cdot 240^2 + \frac{1}{3} \cdot 4 \cdot 240^2 \right) + \frac{1}{EA} \left(4 \cdot (-160)^2 + 4 \cdot (-0.80)^2 \right) + \left(\frac{EA_{skel}}{5} \right)^{-1}$$

$$= 9.55 \cdot 10^{-2}$$

$$d_{22} = \frac{1}{EI} \left(\frac{1}{3} \cdot 3 \cdot 1^2 \cdot 2 + 4 \cdot 1^2 \right) + \frac{1}{EA} \left(4 \cdot \left(\frac{1}{3} \right)^2 \right)$$

$$= 1.42 \cdot 10^{-3}$$

$$d_{12} = \frac{1}{EI} \left(\frac{1}{3} \cdot 3 \cdot 240 \cdot 1 + \frac{1}{3} \cdot 4 \cdot 240 \cdot 1 \right) + \frac{1}{EA} \left(4 \cdot \left(\frac{1}{3} \right) \cdot (-0.80) \right)$$

$$= 9.06 \cdot 10^{-4}$$

Gleichungssystem

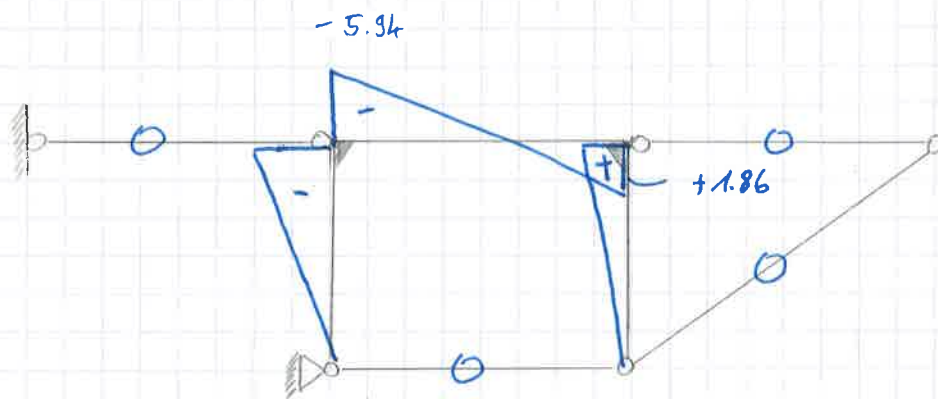
11

$$\begin{bmatrix} 3.55 \cdot 10^{-3} & 3.06 \cdot 10^{-4} \\ \text{sym.} & 1.42 \cdot 10^{-3} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = - \begin{bmatrix} -0.45 \\ -0.045 \end{bmatrix}$$

$$X_1 = 46.75$$

$$X_2 = 1.86$$

Momentenverlauf



M in [kNm]

$$N_{\text{seil}} = X_1 = 46.75 \text{ kN}$$