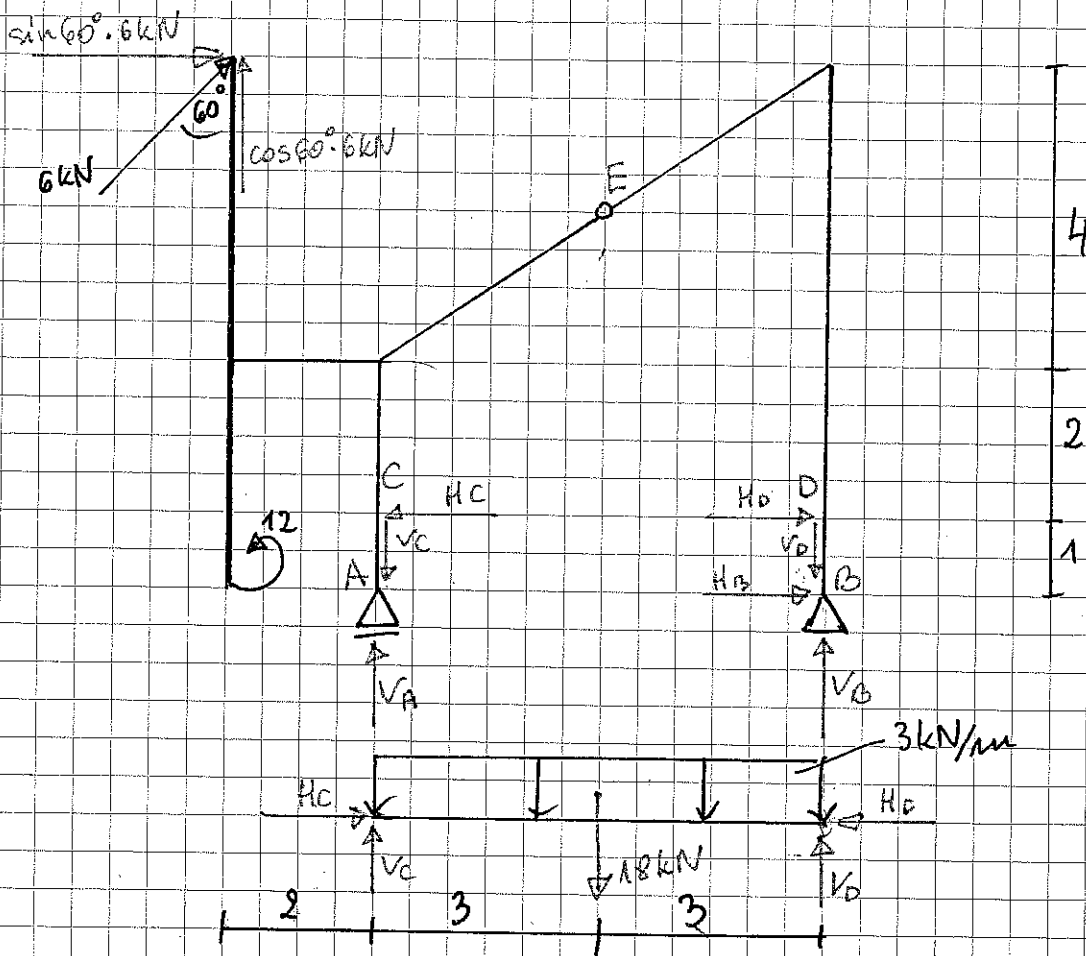


### III WYZNACZANIE REAKCJI PODPOROWYCH W RAMIE



$$\textcircled{1} \sum X = 6\text{kN} \cdot \sin 60^\circ + H_B = 0 \Rightarrow H_B = -3\sqrt{3}\text{kN} \approx -5,196\text{kN}$$

$$\textcircled{2} \sum Y = V_A + V_B + 6\text{kN} \cdot \cos 60^\circ - 18\text{kN} = 0 \Rightarrow V_A + V_B = 15\text{kN}$$

$$\textcircled{3} \sum M_A = -12\text{kNm} + 6\text{kN} \cdot \sin 60^\circ \cdot 7\text{m} + 6\text{kN} \cdot \cos 60^\circ \cdot 2\text{m} + 18\text{kN} \cdot 3\text{m} - V_B \cdot 6\text{m} = 0$$

$$V_B = 14,062\text{kN}$$

$$\Rightarrow V_A = 0,938\text{kN}$$

$$\textcircled{4} \sum X = H_C - H_D = 0 \Rightarrow H_C = H_D$$

$$\textcircled{5} \sum Y = V_C + V_D - 18\text{kN} = 0 \Rightarrow V_C + V_D = 18\text{kN}$$

$$\textcircled{6} \sum M_C = 18\text{kN} \cdot 3\text{m} - V_D \cdot 6\text{m} = 0 \Rightarrow V_D = 9\text{kN} \quad V_C = 9\text{kN}$$

$$\textcircled{7} \sum M_E = -14,062\text{kN} \cdot 3\text{m} + 9\text{kN} \cdot 3\text{m} + 5,196\text{kN} \cdot 5\text{m} - H_D \cdot 4\text{m} = 0$$

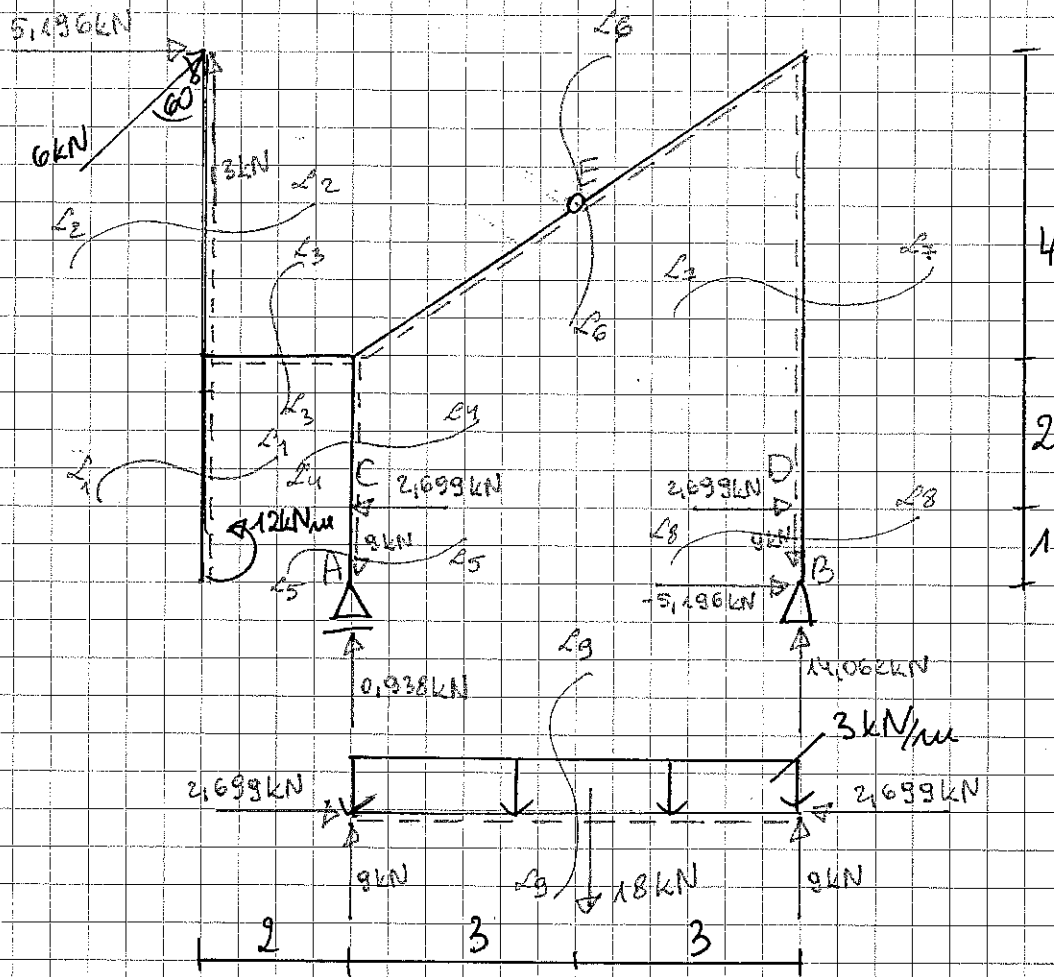
$$H_D = 2,699\text{kN}$$

$$H_C = 2,699\text{kN}$$

Spr:

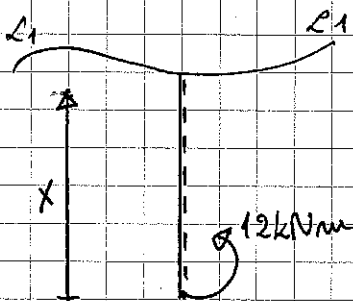
$$\sum M_B = 0,938\text{kN} \cdot 6\text{m} + 5,196\text{kN} \cdot 7\text{m} - 12\text{kNm} + 3\text{kN} \cdot 8\text{m} - 18\text{kN} \cdot 3\text{m} = 0$$

# IV WYZNACZENIE I WYKRESY REAKCJI SIŁ WEWNĘTRZNYCH. N, T, M.



## PRZEKROJE - OBLICZENIA

$$L_1 - L_1 \quad x \in \langle 0, 3 \rangle \text{ m}$$

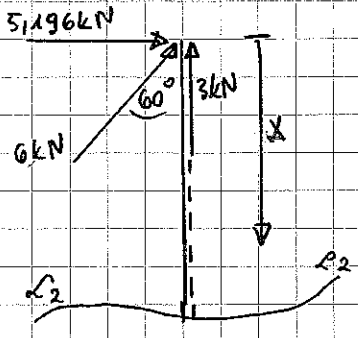


$$N_{L_1} = 0$$

$$T_{L_1} = 0$$

$$M_{L_1} = -12 \text{ kNm}$$

$\mathcal{L}_2 - \mathcal{L}_2 \quad x \in \langle 0, 4 \rangle \text{ m}$



$$N_{\mathcal{L}_2} = 3 \text{ kN}$$

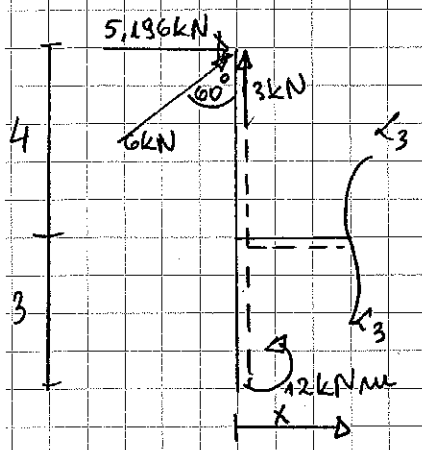
$$T_{\mathcal{L}_2} = 5,196 \text{ kN}$$

$$M_{\mathcal{L}_2} = -5,196 \text{ kN} \cdot x$$

$$x = 0 \quad M_{\mathcal{L}_2} = 0$$

$$x = 4 \text{ m} \quad M_{\mathcal{L}_2} = -20,784 \text{ kNm}$$

$\mathcal{L}_3 - \mathcal{L}_3 \quad x \in \langle 0, 2 \rangle \text{ m}$



$$N_{\mathcal{L}_3} = -5,196 \text{ kN}$$

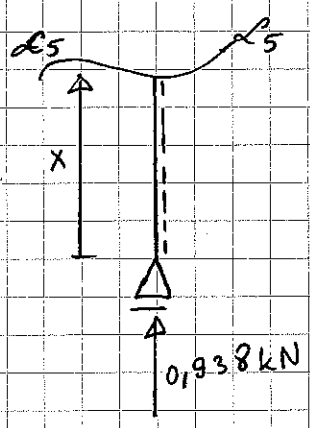
$$T_{\mathcal{L}_3} = 3 \text{ kN}$$

$$M_{\mathcal{L}_3} = 3 \text{ kN} \cdot x - 12 \text{ kNm} + 5,196 \text{ kN} \cdot 4 = 3 \text{ kN} \cdot x + 8,784$$

$$x = 0 \quad M_{\mathcal{L}_3} = 8,784 \text{ kNm}$$

$$x = 2 \text{ m} \quad M_{\mathcal{L}_3} = 14,784 \text{ kNm}$$

$\mathcal{L}_5 - \mathcal{L}_5 \quad x \in \langle 0, 1 \rangle \text{ m}$

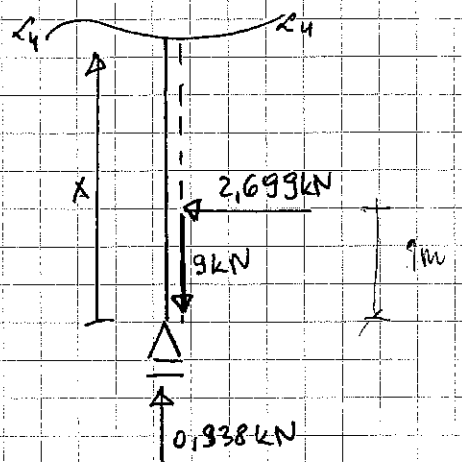


$$N_{\mathcal{L}_5} = -0,938 \text{ kN}$$

$$T_{\mathcal{L}_5} = 0$$

$$M_{\mathcal{L}_5} = 0$$

$\mathcal{L}_4 - \mathcal{L}_4 \quad x \in \langle 1, 3 \rangle \text{ m}$



$$N_{\mathcal{L}_4} = -0,938 \text{ kN} + 9 \text{ kN} = 8,062 \text{ kN}$$

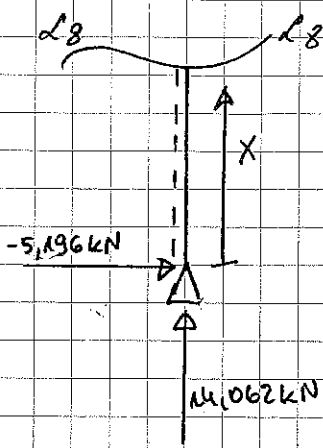
$$T_{\mathcal{L}_4} = 2,699 \text{ kN}$$

$$M_{\mathcal{L}_4} = 2,699 \text{ kN} \cdot (x - 1 \text{ m}) = 2,699 \text{ kN} \cdot x - 2,699 \text{ kNm}$$

$$x = 1 \text{ m} \quad M_{\mathcal{L}_4} = 0$$

$$x = 3 \text{ m} \quad M_{\mathcal{L}_4} = 5,398 \text{ kNm}$$

$L_8 - R_8 \quad x \in \langle 0, 1 \rangle \text{ m}$



$$N_{L_8} = -14,062 \text{ kN}$$

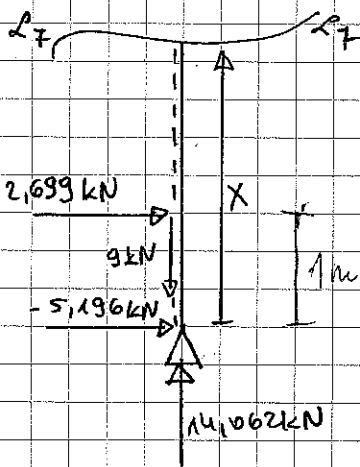
$$T_{L_8} = 5,196 \text{ kN}$$

$$M_{L_8} = -5,196 \text{ kN} \cdot \text{m}$$

$$x=0 \quad M_{L_8} = 0$$

$$x=1 \text{ m} \quad M_{L_8} = -5,196 \text{ kN} \cdot \text{m}$$

$L_7 - R_7 \quad x \in \langle 1, 7 \rangle \text{ m}$



$$N_{L_7} = -14,062 \text{ kN} + 9 \text{ kN} = -5,062 \text{ kN}$$

$$T_{L_7} = 5,196 \text{ kN} - 2,699 \text{ kN} = 2,497 \text{ kN}$$

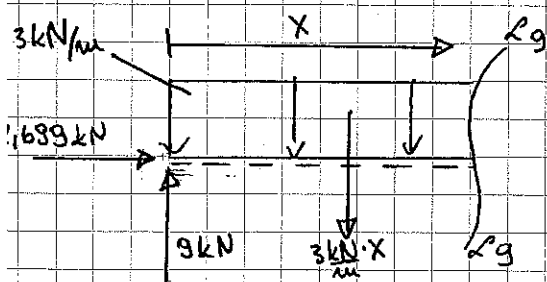
$$M_{L_7} = -5,196 \text{ kN} \cdot x + 2,699 \text{ kN} \cdot (x-1 \text{ m})$$

$$= -2,497 \text{ kN} \cdot x - 2,699 \text{ kN} \cdot \text{m}$$

$$x=1 \text{ m} \quad M_{L_7} = -5,196 \text{ kN} \cdot \text{m}$$

$$x=7 \text{ m} \quad M_{L_7} = -20,198 \text{ kN} \cdot \text{m}$$

$L_9 - R_9 \quad x \in \langle 0, 6 \rangle \text{ m}$



$$N_{L_9} = -2,699 \text{ kN}$$

$$T_{L_9} = 9 \text{ kN} - 3 \text{ kN/m} \cdot x$$

$$x=0 \quad T_{L_9} = 9 \text{ kN}$$

$$x=6 \text{ m} \quad T_{L_9} = -2,699 \text{ kN}$$

$$T_{L_9} = 0 \quad x=3 \text{ m}$$

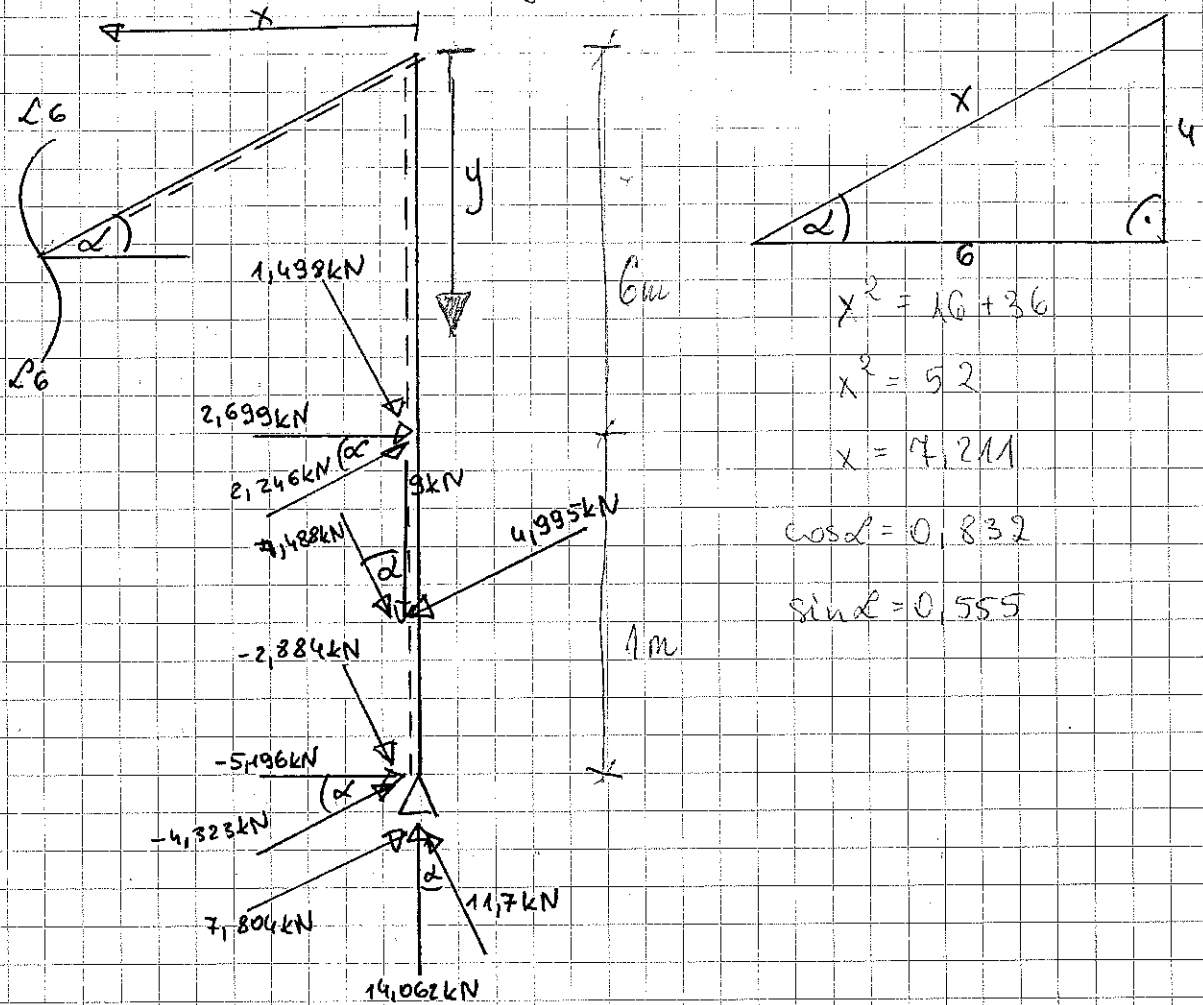
$$M_{L_9} = 9 \text{ kN} \cdot x - 3 \text{ kN/m} \cdot x \cdot \frac{x}{2} = 9 \text{ kN} \cdot x - \frac{3}{2} x^2$$

$$x=0 \quad M_{L_9} = 0$$

$$x=3 \text{ m} \quad M_{L_9} = 13,5 \text{ kN} \cdot \text{m}$$

$$x=6 \text{ m} \quad M_{L_9} = 0$$

$$L_6 \quad L_6 \quad x \in \langle 0, 6 \rangle \text{ m} \quad y \in \langle 0, 4 \rangle \text{ m}$$



$$x^2 = 16 + 36$$

$$x^2 = 52$$

$$x = 7.211$$

$$\cos \alpha = 0.832$$

$$\sin \alpha = 0.555$$

$$N_{L_6} = 2.246 \text{ kN} - 4.995 \text{ kN} - 4.323 \text{ kN} + 7.804 \text{ kN} = 0.732 \text{ kN}$$

$$T_{L_6} = 1.499 \text{ kN} + 7.148 \text{ kN} - 2.884 \text{ kN} - 11.9 \text{ kN} = -5.598 \text{ kN}$$

$$M_{L_6} = 2.699 \text{ kN}(6 \text{ m} - y) - 9 \text{ kN} \cdot x - 5.196 \text{ kN} \cdot (7.211 \text{ m} - y) + 14.062 \text{ kN} \cdot x$$

$$x = 0$$

$$M_{L_6} = -20.178 \text{ kNm}$$

$$y = 4 \text{ m}$$

$$x = 6 \text{ m}$$

$$M_{L_6} = 20.182 \text{ kNm}$$

$$y = 0$$

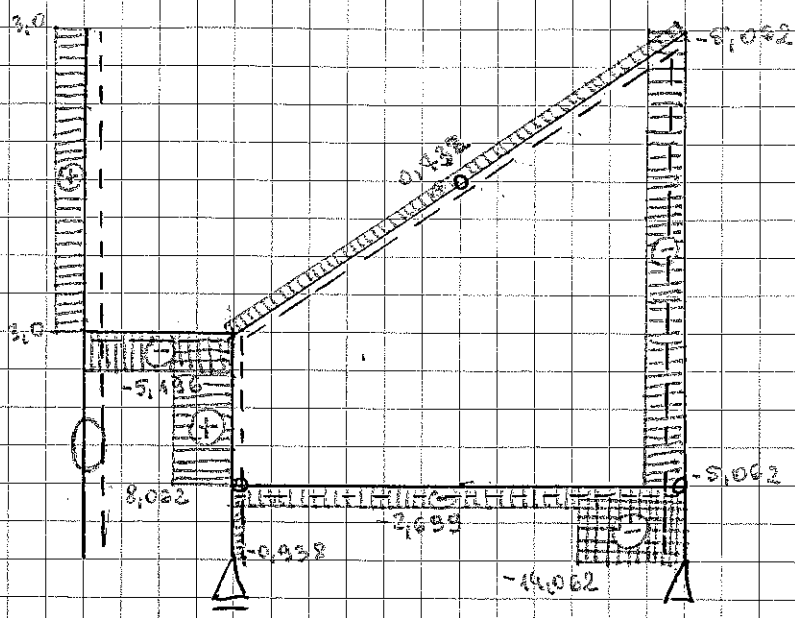
$$x = 3 \text{ m}$$

$$M_{L_6} = 0 \text{ kNm}$$

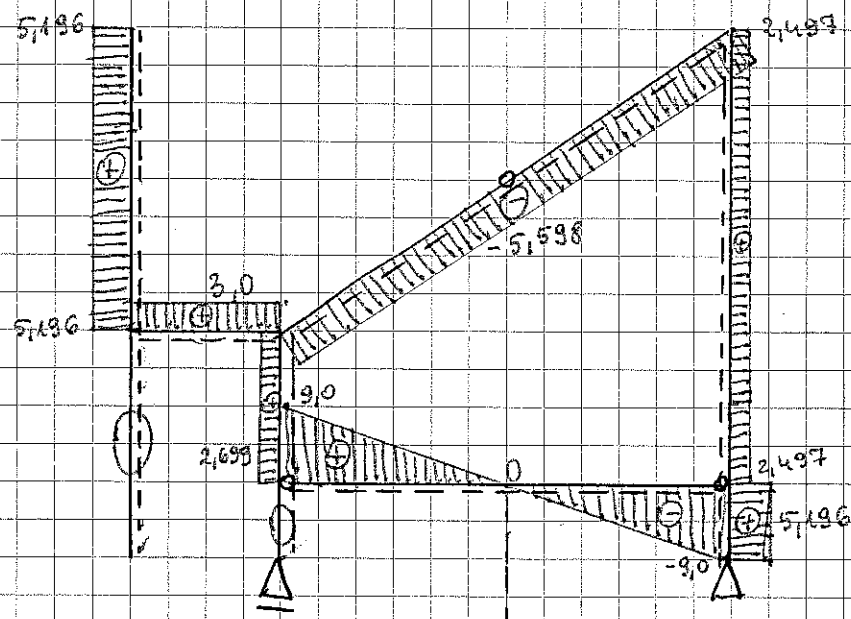
$$y = 2 \text{ m}$$

WYKRESY

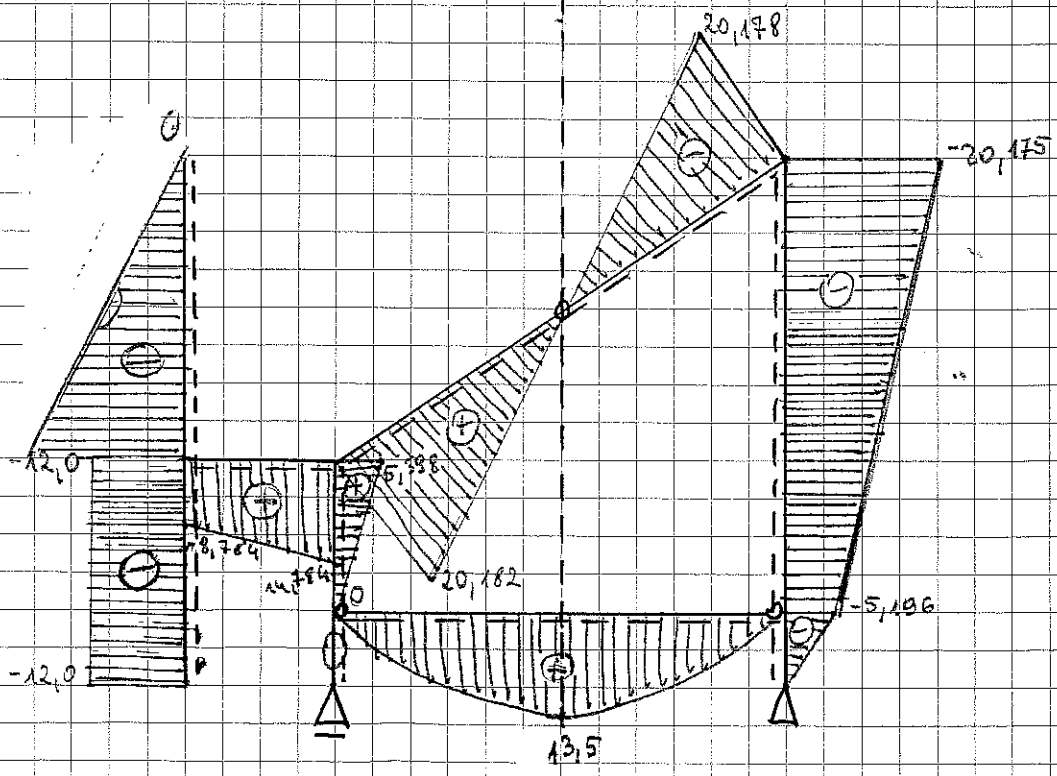
N [kN]



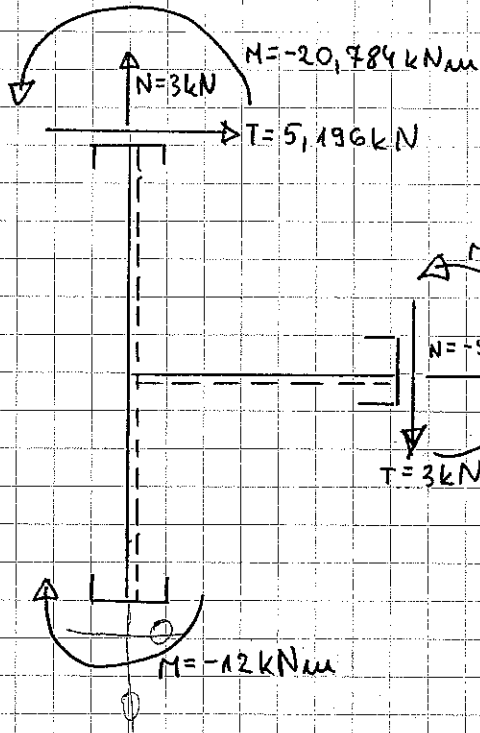
T [kN]



M [kNm]



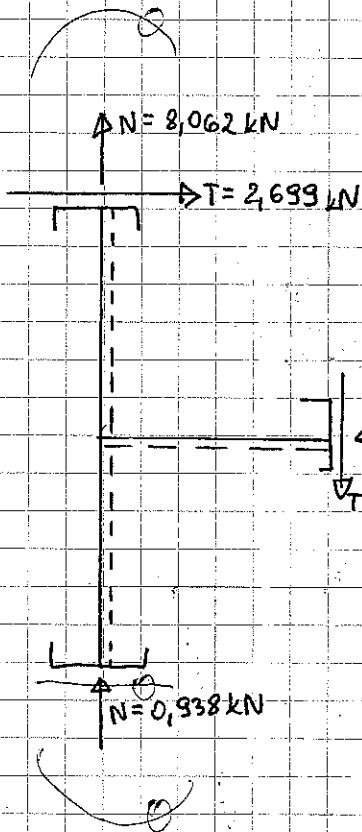
# SPRAWDZENIE W WĘZŁACH



$$\sum X = 5,196 \text{ kN} - 5,196 \text{ kN} = 0$$

$$\sum Y = 3 \text{ kN} - 3 \text{ kN} = 0$$

$$\sum M = -12 \text{ kNm} - (-20,784) \text{ kNm} - 8,784 \text{ kNm} = 0$$



$$\sum X = 2,699 \text{ kN} - 2,699 \text{ kN} = 0$$

$$\sum Y = 8,062 \text{ kN} + 0,938 \text{ kN} - 9 \text{ kN} = 0$$