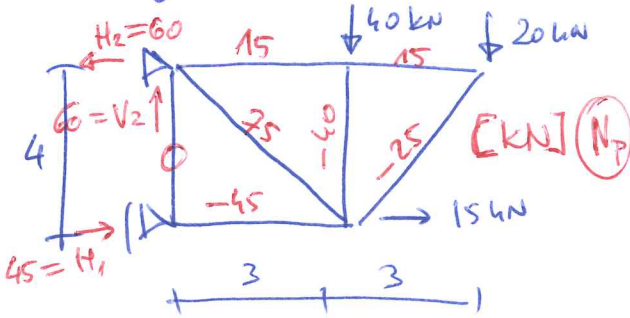


$$\cos d = \frac{3}{5}$$

$$\sin d = \frac{4}{5}$$

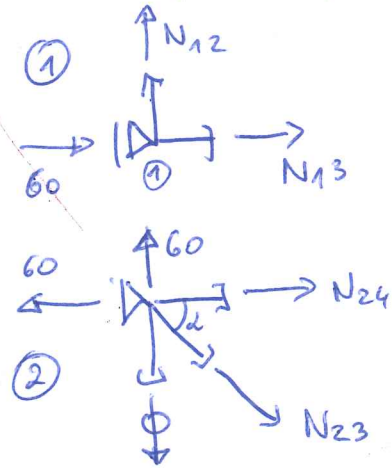
$V_5 = ?$   
 $H_5 = ?$  (kat obrotu pręta)  
 pręty - rurę prostokątne  
 $\Phi 60 \times 5 \text{ mm}$   $A = 1100 \text{ mm}^2$   
 metal - stal  
 $E = 210 \text{ GPa}$   
 $\alpha_t = 1,2 \cdot 10^{-5} \frac{1}{^\circ\text{C}}$

① Siły normalne dla obciążenia temperaturą.



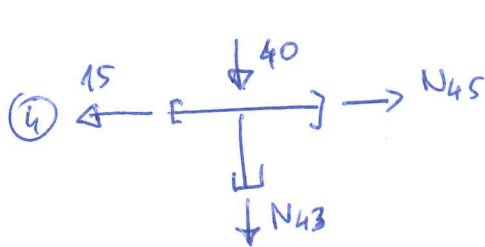
$$\left\{ \begin{aligned} \sum M_2 &= -4H_1 + 40 \cdot 3 + 20 \cdot 6 - 15 \cdot 4 = 0 \Rightarrow H_1 = 45 \text{ kN} \\ \sum X &= H_1 - H_2 + 15 = 0 \Rightarrow H_2 = 60 \text{ kN} \\ \sum Y &= V_2 - 40 - 20 = 0 \Rightarrow V_2 = 60 \text{ kN} \end{aligned} \right.$$

Sp. mp:  $\sum M_5 = 0$

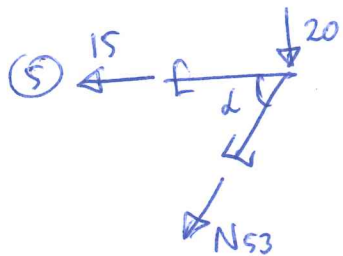


$$\left\{ \begin{aligned} \sum X &= N_{13} + 45 = 0 \Rightarrow N_{13} = -45 \text{ kN} \\ \sum Y &= N_{12} = 0 \end{aligned} \right.$$

$$\left\{ \begin{aligned} \sum Y &= 60 - N_{23} \cdot \sin d = 0 \Rightarrow N_{23} = 75 \text{ kN} \\ \sum X &= N_{24} + N_{23} \cdot \cos d - 60 = 0 \Rightarrow N_{24} = 15 \text{ kN} \end{aligned} \right.$$

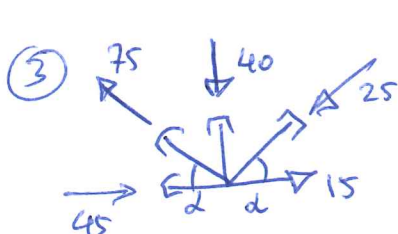


$$\left\{ \begin{aligned} \sum X &= N_{45} - 15 = 0 \Rightarrow N_{45} = 15 \text{ kN} \\ \sum Y &= -40 - N_{43} = 0 \Rightarrow N_{43} = -40 \text{ kN} \end{aligned} \right.$$



$$\sum Y = -20 - N_{53} \cdot \sin d = 0 \Rightarrow N_{53} = -25 \text{ kN}$$

Sp. mp:  $\sum X = -15 + 25 \cdot \cos d = 0$



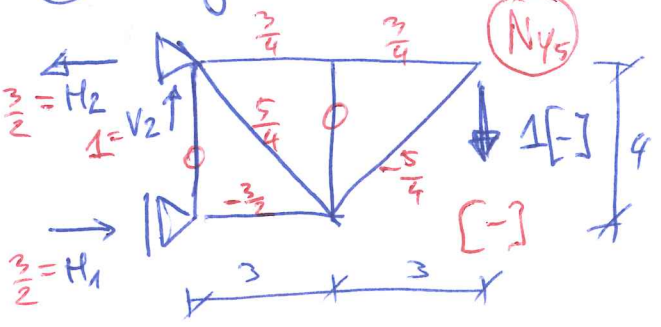
Sp. mp

$$\left\{ \begin{aligned} \sum X &= 15 + 45 - 25 \cos d - 75 \cos d = 0 \\ \sum Y &= -40 - 25 \sin d + 75 \sin d = 0 \end{aligned} \right.$$

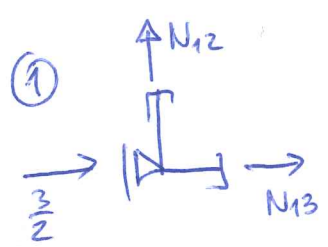
0.k

Rozwiązanie można również przeprowadzić metodą RITTERA, albo z wykorzystaniem obu metod: równoważenie węzłów i Rittera.

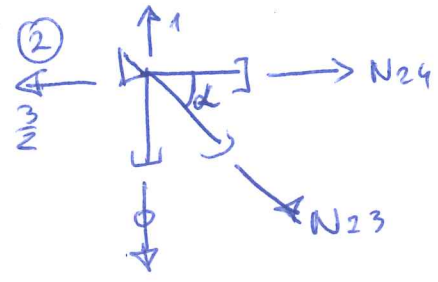
2) Sily normale dla obciężenia jednostkowego na kierunku y5



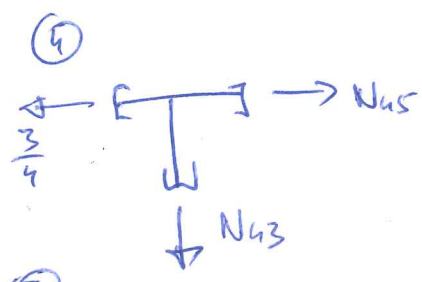
$$\begin{cases} \sum M_2 = -4H_1 + 1 \cdot 6 = 0 \Rightarrow H_1 = \frac{3}{2} [-] \\ \sum X = -H_2 + H_1 = 0 \Rightarrow H_2 = \frac{3}{2} [-] \\ \sum Y = V_2 - 1 = 0 \Rightarrow V_2 = 1 [-] \end{cases}$$



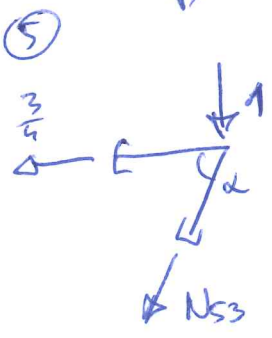
$$\begin{aligned} \sum X = N_{13} + \frac{3}{2} = 0 &\Rightarrow N_{13} = -\frac{3}{2} [-] \\ \sum Y = N_{12} = 0 & \end{aligned}$$



$$\begin{aligned} \sum Y = -N_{23} \cdot \sin \alpha + 1 = 0 &\Rightarrow N_{23} = \frac{5}{4} [-] \\ \sum X = N_{24} + N_{23} \cdot \cos \alpha - \frac{3}{2} = 0 &\Rightarrow N_{24} = \frac{3}{4} [-] \end{aligned}$$



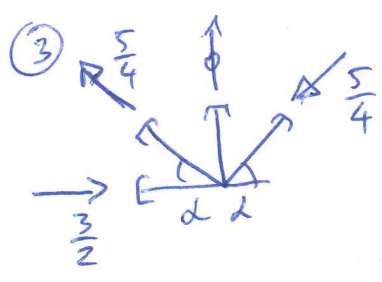
$$\begin{aligned} \sum Y = N_{43} = 0 \\ \sum X = N_{45} - \frac{3}{4} = 0 &\Rightarrow N_{45} = \frac{3}{4} [-] \end{aligned}$$



$$\sum Y = -1 - N_{53} \sin \alpha = 0 \Rightarrow N_{53} = -\frac{5}{4} [-]$$

Spw

$$\sum X = -\frac{3}{4} + \frac{5}{4} \cdot \cos \alpha = 0$$



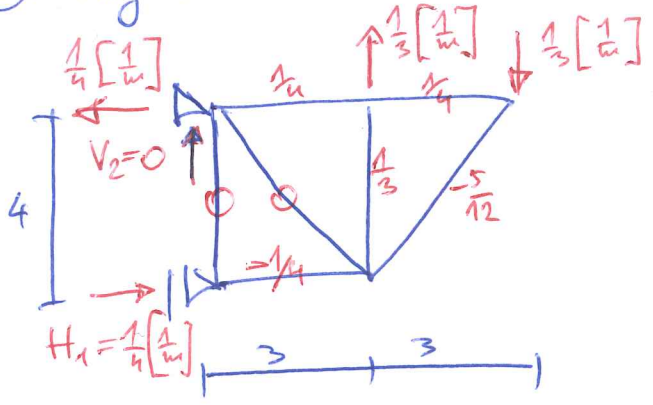
Spw

$$\sum Y = \frac{5}{4} \sin \alpha - \frac{5}{4} \sin \alpha = 0$$

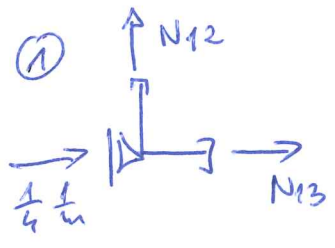
$$\sum X = \frac{3}{2} - \frac{5}{4} \cdot \cos \alpha - \frac{5}{4} \cdot \cos \alpha = 0$$

} o.k

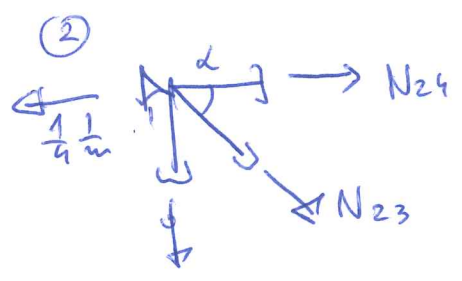
③ Siy normale de obuciere ne kromulu q45



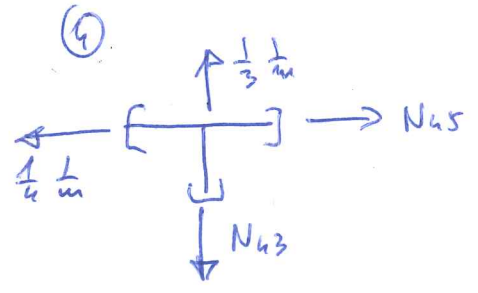
$$\begin{cases} \sum M_2 = \frac{1}{3} \cdot 6 - \frac{1}{3} \cdot 3 - H_1 \cdot 4 = 0 \Rightarrow H_1 = \frac{1}{4} \left[ \frac{1}{m} \right] \\ \sum X = H_1 - H_2 = 0 \Rightarrow H_2 = \frac{1}{4} \left[ \frac{1}{m} \right] \\ \sum Y = V_2 = 0 \end{cases}$$



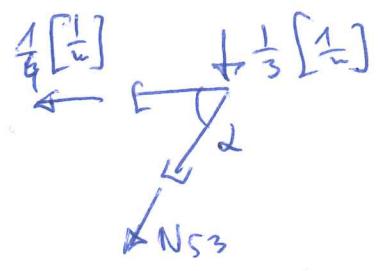
$$\begin{aligned} \sum X &\rightarrow N_{12} = 0 \\ \sum X &\rightarrow N_{13} = -\frac{1}{4} \left[ \frac{1}{m} \right] \end{aligned}$$



$$\begin{aligned} \sum Y &\rightarrow N_{23} = 0 \\ \sum X &\rightarrow N_{24} = \frac{1}{4} \left[ \frac{1}{m} \right] \end{aligned}$$



$$\begin{aligned} \sum Y &\rightarrow N_{43} = \frac{1}{3} \left[ \frac{1}{m} \right] \\ \sum X &\rightarrow N_{45} = \frac{1}{4} \left[ \frac{1}{m} \right] \end{aligned}$$



$$\sum Y = -\frac{1}{3} - N_{53} \cdot \sin \alpha = 0 \Rightarrow N_{53} = -\frac{5}{12} \left[ \frac{1}{m} \right]$$

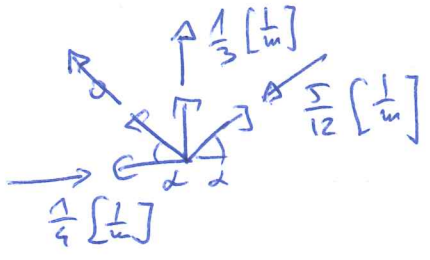
Sm

$$\sum X = -\frac{1}{4} + \frac{5}{12} \cdot \cos \alpha = 0$$

$$\sum X = \frac{1}{4} - \frac{5}{12} \cdot \cos \alpha = 0$$

$$\sum Y = \frac{1}{3} - \frac{5}{12} \cdot \sin \alpha = 0$$

O.K.



h) Wyznaczenie  $X_5$  oraz  $\varphi_{45}$

pret	$d \text{ (upsc)}$ [m]	$N_p$ [kN]	$N_{y5}$ [-]	$N_{\varphi_{45}}$ [1/m]	$N_p \cdot N_{y5} \cdot L$ [kNm]	$N_p \cdot N_{\varphi_{45}} \cdot L$ [kN]	$t_0$ [°C]	$N_{y5} t_0 L$ [°Cm]	$N_{\varphi_{45}} t_0 L$ [°C]
1-2	4	0	0	0	0	0			
3-4	4	-40	0	0,333	0	-93,33			
1-3	3	-45	-1,5	-0,25	202,5	33,75	20	45	15
2-4	3	15	0,75	0,25	33,75	11,25			
4-5	3	15	0,75	0,25	33,75	11,25			
2-3	5	75	1,25	0	468,75	0			
3-5	5	-25	-1,25	-0,4167	156,25	52,0833	-15	93,75	31,2525
$\Sigma$					895	55,0042		138,75	46,2525

$$\begin{aligned} y_5 &= \frac{895 \text{ kNm}}{EA} + \alpha t \cdot 138,75 \text{ °Cm} = \frac{895 \text{ kNm}}{210 \cdot 10^6 \frac{\text{kN}}{\text{m}^2} \cdot 1100 \cdot 10^{-6} \text{ m}^2} + 1,2 \cdot 10^{-5} \frac{1}{\text{°C}} \cdot 138,75 \text{ °Cm} \\ &= 0,00387 \text{ m} + 0,001665 \text{ m} = 0,005535 \text{ m} = \boxed{5,535 \text{ mm}} \end{aligned}$$

$$\begin{aligned} \varphi_{45} &= \frac{55,0042 \text{ kN}}{210 \cdot 10^6 \frac{\text{kN}}{\text{m}^2} \cdot 1100 \cdot 10^{-6} \text{ m}^2} + 1,2 \cdot 10^{-5} \frac{1}{\text{°C}} \cdot 46,2525 \text{ °C} = 0,0002383 + 0,000555 \\ &= 0,000793 \text{ rad} \approx 0,045^\circ \end{aligned}$$

Wzrost Maxwella - Mohra

$$1 \cdot \delta = \sum_{i=1}^n \frac{N_p \cdot N_i \cdot L}{EA} + \sum_{i=1}^m N_i \alpha t_0 L - \sum_{i=1}^k R_i \cdot \Delta p$$

czyli sumujemy wzdłuż kolumny

n - liczba pretów

m - liczba pretów z temperaturą

k - liczba obszarów generowanych.