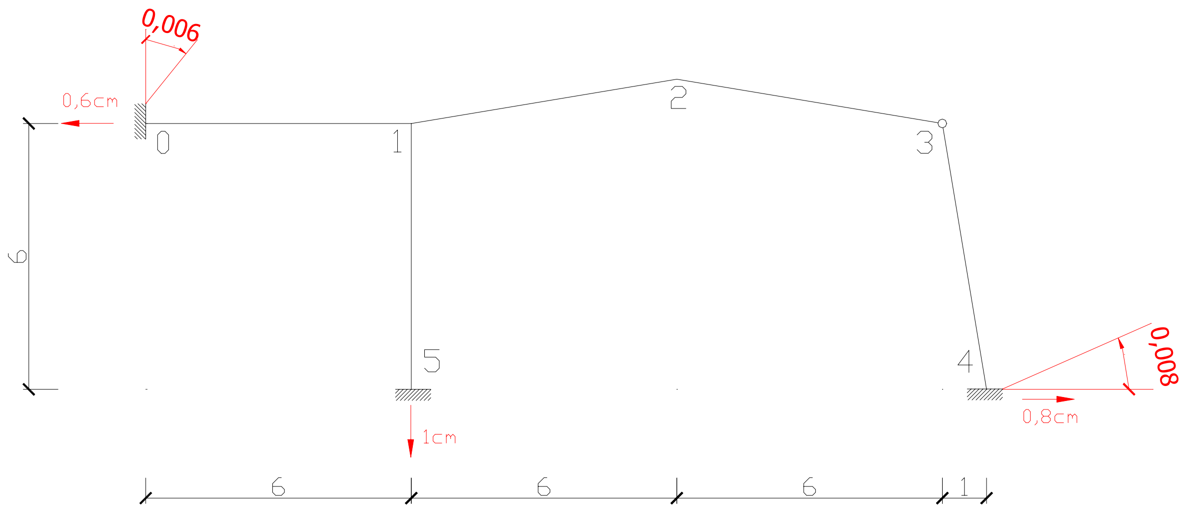
Osiadanie podpór



$\varphi_0 = 0{,}006$

$\varphi_4 = -0{,}008$

Równanie łańcucha kinematycznego:

34 $\longrightarrow$

$-\psi_{43} \cdot 6 = 0{,}008 \qquad \psi_{43} = -\dfrac{0{,}008}{6}$

015 $\downarrow$

$\psi_{01} \cdot 6 = 0{,}01 \qquad \psi_{10} = \dfrac{0{,}01}{6}$

510 $\leftarrow$

$-\psi_{51} \cdot 6 = 0{,}006 \qquad \psi_{51} = -\dfrac{0{,}006}{6}$

3210 $\leftarrow$

$-\psi_{23} \cdot 1 + \psi_{12} \cdot 1 = 0{,}006 \qquad \psi_{12} = \psi_{23} + 0{,}006$

43215 $\downarrow$

$-\psi_{43} \cdot 1 - \psi_{23} \cdot 6 - \psi_{12} \cdot 6 = 0{,}01 \qquad \psi_{23} = -0{,}00372(2)$

$\psi_{12} = 0{,}00227(7)$

Momenty od osiadań z policzonymi obrotami i zadanymi osiadaniami:

$$\varphi_0 = 0{,}006 \qquad \varphi_1 = 0 \qquad \psi_{01} = \frac{0{,}01}{6} \qquad EI_0 = 8712{,}5\ \left[kNm^2\right]$$

$$M_{01} = \frac{2EI_2}{l}\cdot\left(2\cdot\varphi_0 + \varphi_1 - 3\cdot\psi_{01}\right) = \frac{2EI_0}{6}\cdot\left(2\cdot 0{,}006 + 0 - 3\cdot\frac{0{,}01}{6}\right) = 20{,}3291\left[kNm\right]$$

$$M_{10} = \frac{2EI_2}{l}\cdot\left(2\cdot\varphi_1 + \varphi_0 - 3\cdot\psi_{01}\right) = \frac{2EI_0}{6}\cdot\left(2\cdot 0 + 0{,}006 - 3\cdot\frac{0{,}01}{6}\right) = 2{,}9041\left[kNm\right]$$

$$\varphi_1 = 0 \qquad \varphi_5 = 0 \qquad \psi_{15} = -\frac{0{,}006}{6} \qquad EI_0 = 8712{,}5\ \left[kNm^2\right]$$

$$M_{15} = \frac{2EI_1}{l}\cdot\left(2\cdot\varphi_1 + \varphi_5 - 3\cdot\psi_{15}\right) = \frac{2EI_0\cdot 0{,}487}{6}\cdot\left(2\cdot 0 + 0 - 3\cdot\left(-\frac{0{,}006}{6}\right)\right) = 4{,}2429\ [\mathrm{kNm}]$$

$$M_{51} = \frac{2EI_1}{l}\cdot\left(2\cdot\varphi_5 + \varphi_1 - 3\cdot\psi_{15}\right) = \frac{2EI_0\cdot 0{,}487}{6}\cdot\left(2\cdot 0 + 1 - 3\cdot\left(-\frac{0{,}006}{6}\right)\right) = 4{,}2429\left[kNm\right]$$

$$\varphi_1 = 0 \qquad \varphi_2 = 0 \qquad \psi_{12} = 0{,}00227(7) \qquad EI_0 = 8712{,}5\ \left[kNm^2\right]$$

$$M_{12} = \frac{2EI_2}{l}\cdot\left(2\cdot\varphi_1 + \varphi_2 - 3\cdot\psi_{12}\right) = \frac{2EI_0}{\sqrt{37}}\cdot\left(2\cdot 0 + 0 - 3\cdot 0{,}002277\right) = -19{,}5751\left[kNm\right]$$

$$M_{21} = \frac{2EI_2}{l}\cdot\left(2\cdot\varphi_2 + \varphi_1 - 3\cdot\psi_{12}\right) = \frac{2EI_0}{\sqrt{37}}\cdot\left(2\cdot 0 + 0 - 3\cdot 0{,}002277\right) = -19{,}5751\left[kNm\right]$$

$$\varphi_2 = 0 \qquad \varphi_3 = 0 \qquad \psi_{23} = -0{,}0037(2) \qquad EI_0 = 8712{,}5\ \left[kNm^2\right]$$

$$M_{23} = \frac{3EI_2}{l}\cdot\left(\varphi_2 - \psi_{23}\right) = \frac{3EI_0}{\sqrt{37}}\cdot\left(0 + 0{,}003722\right) = 15{,}9943\left[kNm\right]$$

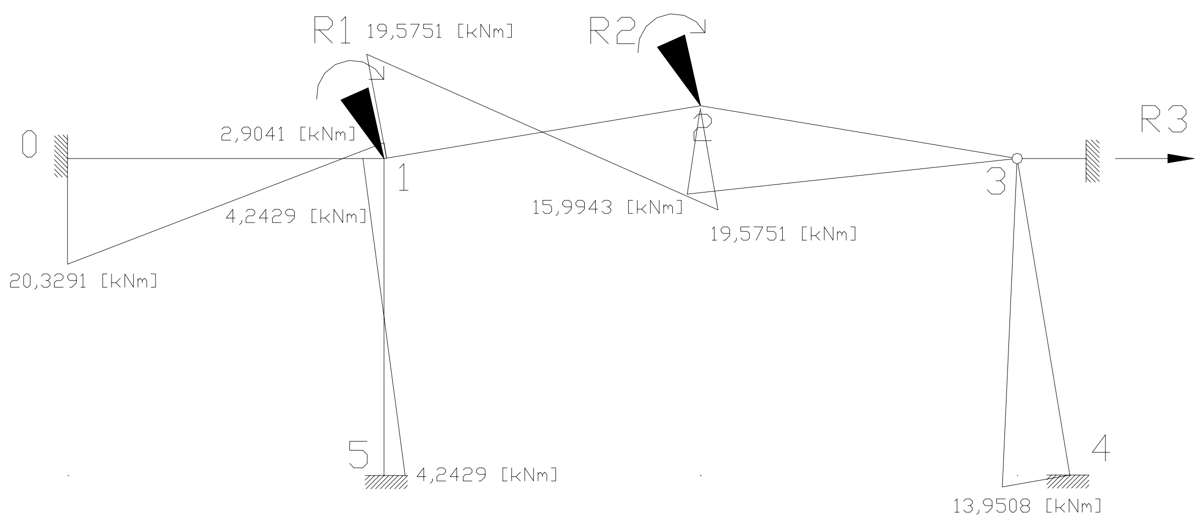
$$M_{32} = 0$$

$$\varphi_3 = 0 \qquad \varphi_4 = -0{,}008 \qquad \psi_{34} = -\frac{0{,}008}{6} \qquad EI_0 = 8712{,}5\ \left[kNm^2\right]$$

$$M_{34} = 0$$

$$M_{43} = \frac{3EI_2}{l}\cdot\left(\varphi_4 - \psi_{43}\right) = \frac{3EI_0\cdot 0{,}487}{\sqrt{37}}\cdot\left(-0{,}008 - \left(-\frac{0{,}008}{6}\right)\right) = -13{,}9508\left[kNm\right]$$

M^{Δ} [kNm]



Wyznaczenie reakcji $R_{1\Delta}$ i $R_{2\Delta}$ z równowagi węzłów:

$R_{1\Delta}$ = -12,4281 [kNm]

$R_{2\Delta}$ = -3,5808 [kNm]

Reakcje $R_{3\Delta}$ obliczę korzystając z równania pracy wirtualnej (obroty ψ ze strony 2):

$$\psi_{10}=0 \qquad \psi_{15}=0 \qquad \psi_{12}=\frac{35}{72}\Delta \qquad \psi_{23}=-\frac{37}{72}\Delta \qquad \psi_{34}=\frac{\Delta}{6}$$

$$R_{33}\cdot\bar{1}-(19{,}5751\cdot 2)\cdot\overline{\psi_{12}}+15{,}9943\cdot\overline{\psi_{23}}-13{,}9508\cdot\overline{\psi_{34}}=0$$

$R_{3\Delta}$ = 29,5757 [kNm]

Obliczone wartości podstawiam do układu równań, podstawiając współczynniki r_{ik} z części pierwszej (str.8):

$$\begin{bmatrix} 1{,}64896\cdot EI_0 & 0{,}32879\cdot EI_0 & -0{,}47949\cdot EI_0 \\ 0{,}32879\cdot EI_0 & 1{,}15078\cdot EI_0 & -0{,}22604\cdot EI_0 \\ -0{,}47949\cdot EI_0 & -0{,}22604\cdot EI_0 & 0{,}60308\cdot EI_0 \end{bmatrix}$$

$$\begin{cases} r_{11}\cdot\varphi_1+r_{12}\cdot\varphi_2+r_{13}\cdot\Delta_3+R_{1\Delta}=0 \\ r_{21}\cdot\varphi_1+r_{22}\cdot\varphi_2+r_{23}\cdot\Delta_3+R_{2\Delta}=0 \\ r_{31}\cdot\varphi_1+r_{32}\cdot\varphi_2+r_{33}\cdot\Delta_3+R_{3\Delta}=0 \end{cases}$$

$$\begin{cases} 1{,}64896\cdot EI_0\cdot\varphi_1+0{,}32879\cdot EI_0\cdot\varphi_2-0{,}47949\cdot EI_0\cdot\Delta_3-12{,}4281=0 \\ 0{,}32879\cdot EI_0\cdot\varphi_1+1{,}15078\cdot EI_0\cdot\varphi_2-0{,}22604\cdot EI_0\cdot\Delta_3-3{,}5808=0 \\ -0{,}47949\cdot EI_0\cdot\varphi_1-0{,}22604\cdot EI_0\cdot\varphi_2+0{,}60308\cdot EI_0\cdot\Delta_3+29{,}5757=0 \end{cases}$$

Po wyliczeniu układu równań (MathCad) otrzymujemy:

$$\varphi_1=-8.04981\cdot\frac{1}{EI_0}$$

$$\varphi_2=-5.91403\cdot\frac{1}{EI_0}$$

$$\Delta_3=-57.65792\cdot\frac{1}{EI_0}$$

Wyliczone przemieszczenia podstawiamy do wzorów transformacyjnych na momenty (obroty ψ ze strony 2) i dodajemy do nich momenty od stanu M^{Δ}:

$$\varphi_0=0 \qquad \varphi_1=-8.04981\cdot\frac{1}{EI_0} \qquad \psi_{01}=0 \qquad M_{01}^{\Delta}=20{,}3291[kNm]$$

$$M_{01}=M_{01}^{\Delta}+\frac{2EI_2}{l}\cdot(2\cdot\varphi_0+\varphi_1-3\cdot\psi_{01})=17.64582\ [\text{kNm}]$$

$$\varphi_0=0 \qquad \varphi_1=-8.04981\cdot\frac{1}{EI_0} \qquad \psi_{01}=0 \qquad M_{10}^{\Delta}=2{,}9041[kNm]$$

$$M_{10}=M_{10}^{\Delta}+\frac{2EI_2}{l}\cdot(2\cdot\varphi_1+\varphi_0-3\cdot\psi_{01})=-2{,}46244[kNm]$$

$\varphi_1 = -8.04981 \cdot \frac{1}{EI_0} \qquad \varphi_5 = 0 \qquad \psi_{15} = 0 \qquad M_{15} = 4{,}2429\ [kNm]$

$M_{15} = M_{15}^{\Delta} + \frac{2EI_1}{l} \cdot (2 \cdot \varphi_1 + \varphi_5 - 3 \cdot \psi_{15}) = 1{,}62939\ [\mathrm{kNm}]$

$\varphi_1 = -8.04981 \cdot \frac{1}{EI_0} \qquad \varphi_5 = 0 \qquad \psi_{15} = 0 \qquad M_{51} = 4{,}2429\ [kNm]$

$M_{51} = M_{51}^{\Delta} + \frac{2EI_1}{l} \cdot (2 \cdot \varphi_5 + \varphi_1 - 3 \cdot \psi_{15}) = 2{,}936\ [kNm]$

$\varphi_1 = -8.04981 \cdot \frac{1}{EI_0} \qquad \varphi_2 = -5.91403 \cdot \frac{1}{EI_0} \qquad \psi_{12} = \frac{35}{72} \cdot \Delta \qquad M_{12} = -19{,}5751\ [kNm]$

$M_{12} = M_{12}^{\Delta} + \frac{2EI_2}{l} \cdot (2 \cdot \varphi_1 + \varphi_2 - 3 \cdot \psi_{12}) = 0{,}834\ [kNm]$

$\varphi_1 = -8.04981 \cdot \frac{1}{EI_0} \qquad \varphi_2 = -5.91403 \cdot \frac{1}{EI_0} \qquad \psi_{12} = \frac{35}{72} \cdot \Delta \qquad M_{21} = -19{,}5751\ [kNm]$

$M_{21} = M_{21}^{\Delta} + \frac{2EI_2}{l} \cdot (2 \cdot \varphi_2 + \varphi_1 - 3 \cdot \psi_{12}) = 1{,}536\ [kNm]$

$\varphi_2 = -5.91403 \cdot \frac{1}{EI_0} \qquad \varphi_3 = 0 \qquad \psi_{23} = -\frac{37}{72} \cdot \Delta \qquad M_{23} = 15{,}9943\ [kNm]$

$M_{23} = M_{23}^{\Delta} + \frac{3EI_2}{l} \cdot (\varphi_2 - \psi_{23}) = -1{,}536\ [kNm]$

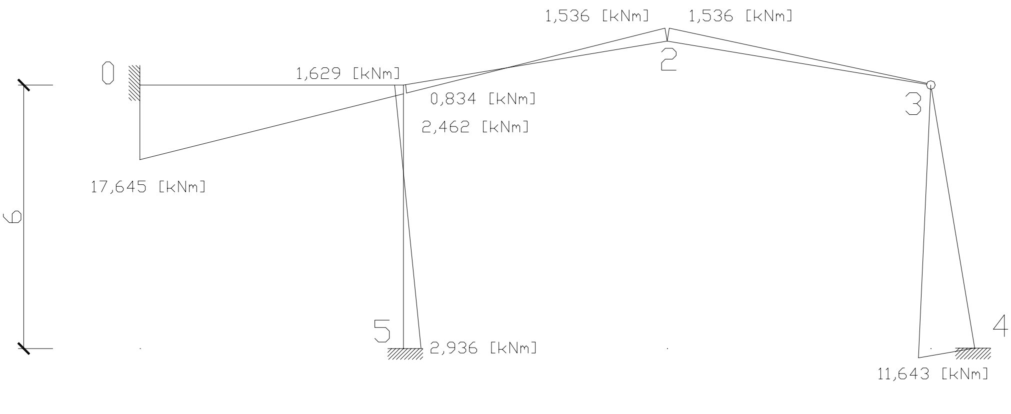
$M_{32} = 0$

$\varphi_3 = 0 \qquad \varphi_4 = 0 \qquad \psi_{34} = \frac{1}{6} \cdot \Delta \qquad M_{43} = -13{,}9508\ [kNm^2]$

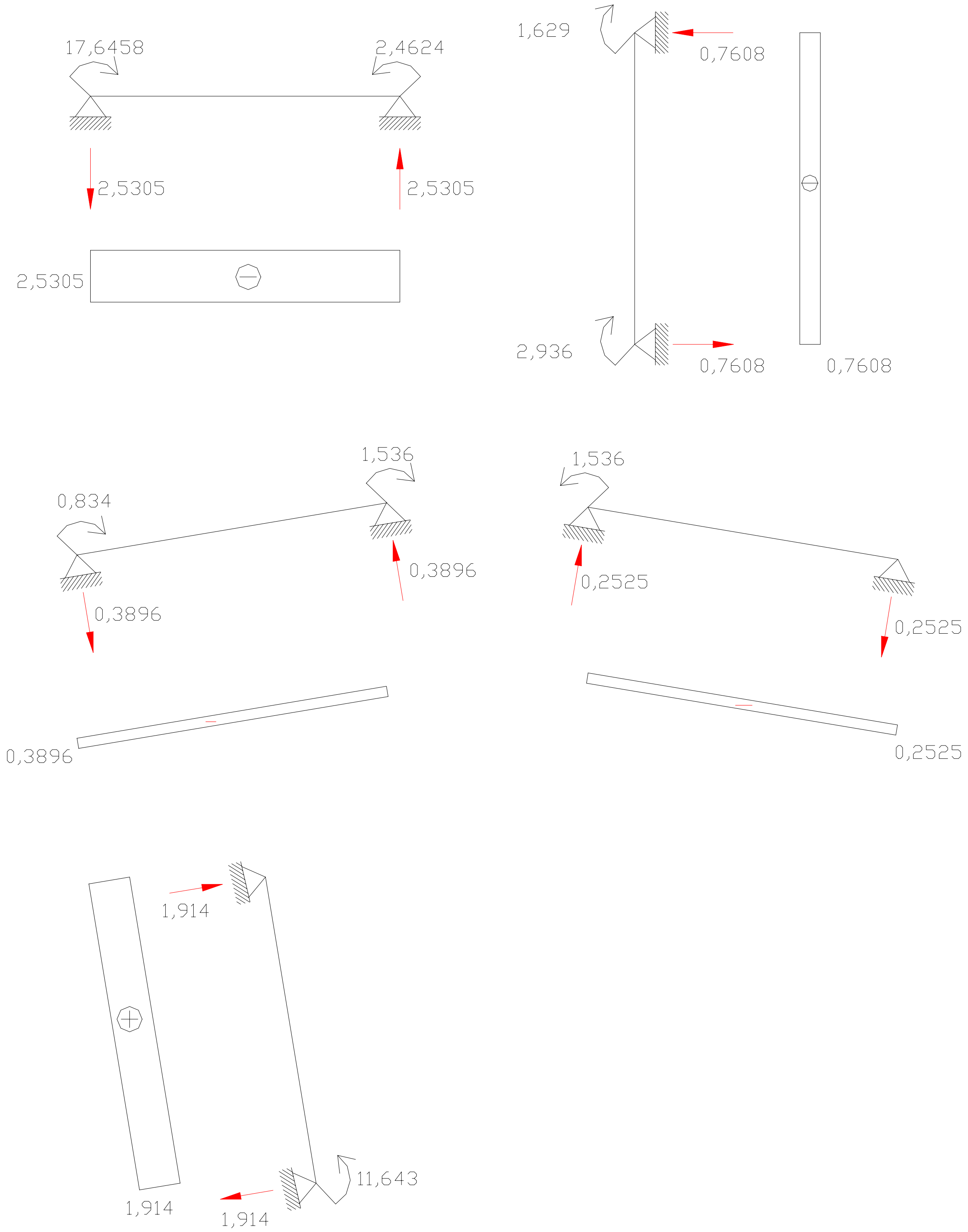
$M_{34} = 0$

$M_{43} = M_{43}^{\Delta} + \frac{3EI_1}{l} \cdot (\varphi_4 - \psi_{43}) = -16{,}259\ [kNm]$

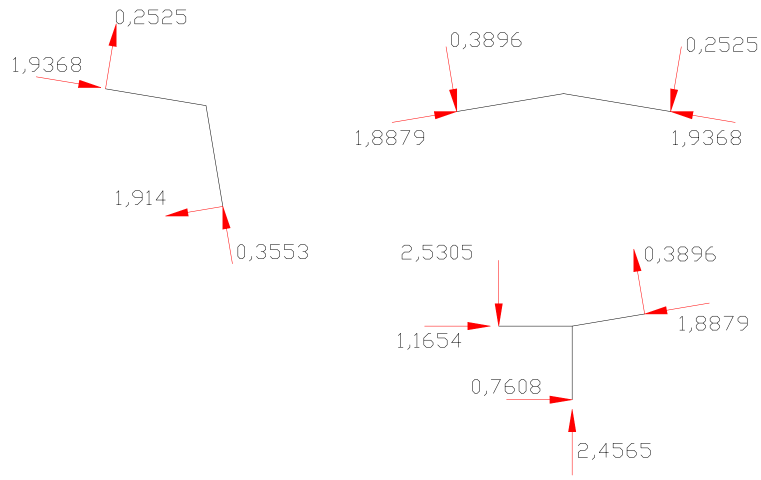
M^n [kNm]



Obliczenie wartości sił tnących:

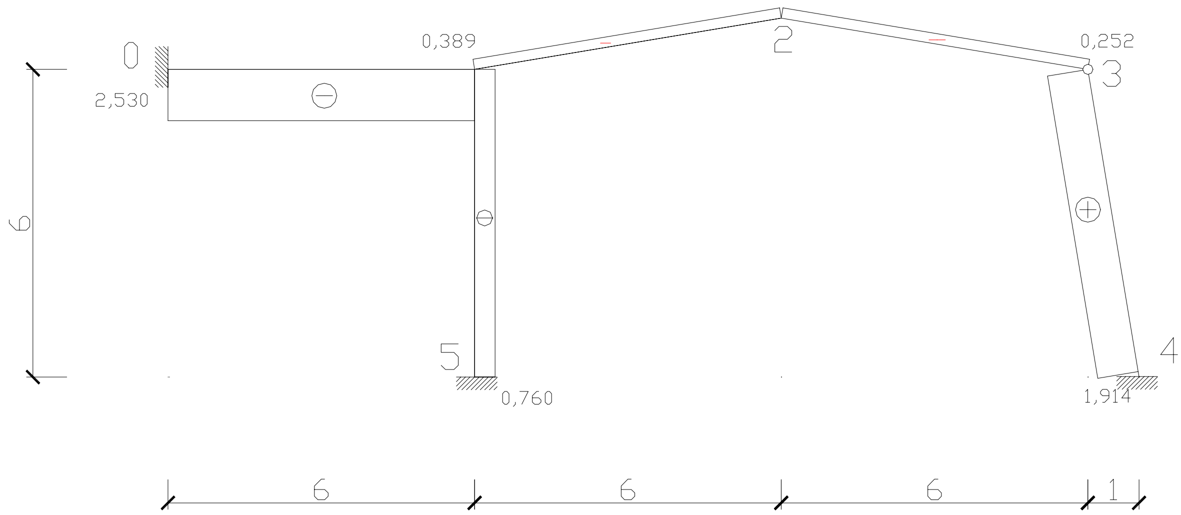


Obliczenie siły normalnej z równowagi węzłów:



Sprawdzenie węzła 2 po osi $\sum y = -0{,}0045$

T^n [kN]



N^n [kN]