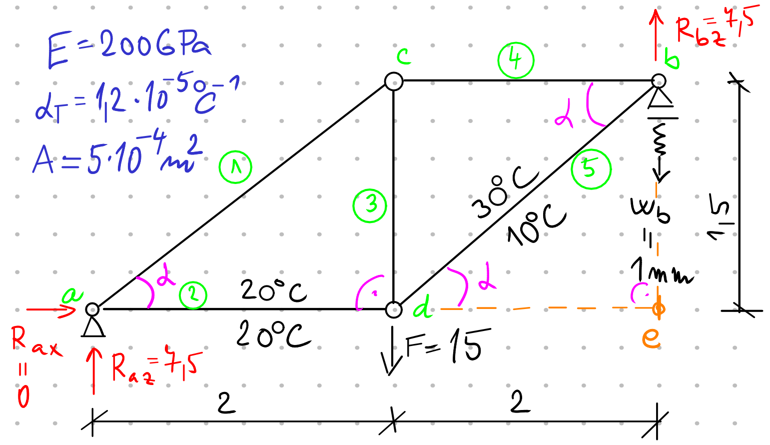
$E = 200\,GPa$

$\alpha_T = 1{,}2 \cdot 10^{-5}\,°C^{-1}$

$A = 5 \cdot 10^{-4}\,m^2$



$[m, kN]$ $\quad w_d \,|\, u_d = ?$

Reakce:

$\Sigma F_{xi} = 0: \quad R_{ax} = \underline{0}$

$\Sigma M_{ai} = 0: \oplus$

$R_{bz} \cdot 4 - F \cdot 2 = 0 \Rightarrow R_{bz} = \frac{F \cdot 2}{4} = \underline{7{,}5\,kN}$

$\Sigma M_{ei} = 0: \oplus$

$R_{az} \cdot 4 - F \cdot 2 = 0 \Rightarrow R_{az} = \frac{F \cdot 2}{4} = \underline{7{,}5\,kN}$

kontrola: $\Sigma F_{zi} = 0: \oplus \uparrow$

$R_{az} + R_{bz} - F = 0$ ✓

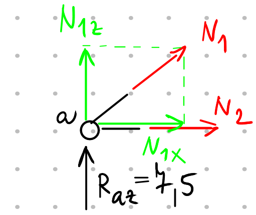
$\ell_1 = \sqrt{2^2 + 1{,}5^2} = 2{,}5\,m$

$\sin\alpha = \frac{1{,}5}{2{,}5} = \frac{3}{5} = 0{,}6$

$\cos\alpha = \frac{2}{2{,}5} = \frac{4}{5} = 0{,}8$

$$\delta = \int \frac{N\bar{N}}{EA}\,dx + \int \bar{N} \alpha_T \Delta T_0\,dx - \sum_r \left(R_{rx} \cdot u_r + R_{rz} \cdot w_r + M_r \varphi_r\right)$$

Styčníková metoda



$\Sigma F_{zi} = 0: \oplus \uparrow$

$N_{1z} + R_{az} = 0$

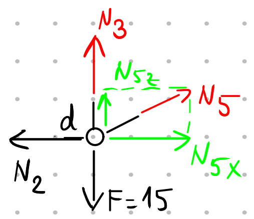
$N_1 \cdot \sin\alpha = -R_{az}$

$N_1 = -\frac{7{,}5 \cdot 5}{3} = \underline{\underline{-12{,}5\,kN}}$

$\Sigma F_{xi} = 0 \oplus \rightarrow$

$N_{1x} + N_2 = 0 \Rightarrow N_2 = -N_{1x}$

$N_2 = -N_1 \cos\alpha = +12{,}5 \cdot \frac{4}{5} = \underline{\underline{10\,kN}}$



$\Sigma F_{xi} = 0: \oplus \rightarrow$

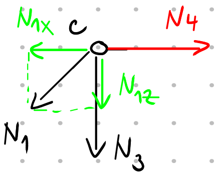
$\underbrace{N_{5x}}_{N_5 \cos\alpha} - N_2 = 0$

$N_5 = \frac{N_2}{\cos\alpha} = \frac{10 \cdot 5}{4} = \underline{12{,}5\,kN}$

$\Sigma F_{zi} = 0 \oplus \uparrow$

$N_3 + \underbrace{N_{5z}}_{N_5 \sin\alpha} - F = 0$

$N_3 = -N_5 \cdot \sin\alpha + F = -12{,}5 \cdot \frac{3}{5} + 15 = \underline{\underline{7{,}5\,kN}}$



$\Sigma F_{xi} = 0: \oplus \rightarrow$

$N_4 - N_{1x} = 0$

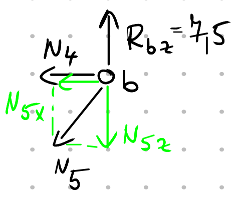
$N_4 = N_1 \cos\alpha = -12{,}5 \cdot \frac{4}{5} = \underline{-10\,kN}$

kontrola:

$\Sigma F_{zi} = 0 \oplus \downarrow$

$N_{1z} + N_3 = 0 \Rightarrow N_1 \sin\alpha + N_3 = 0$

$-12{,}5 \cdot \frac{3}{5} + 7{,}5 = 0$ ✓



kontrola:

$\Sigma F_{zi} = 0: \oplus \uparrow$

$R_{bz} - \underbrace{N_{5z}}_{N_5 \sin\alpha} = 0$

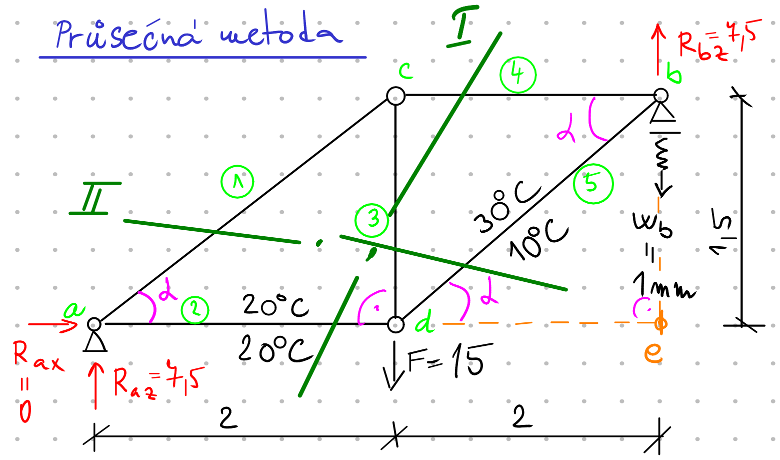
$7{,}5 - 12{,}5 \cdot \frac{3}{5} = 0$ ✓

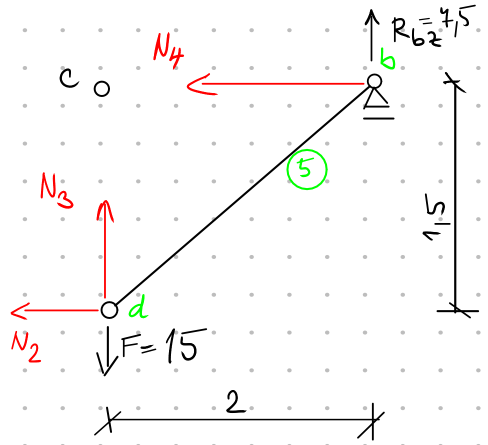
$\Sigma F_{xi} = 0: \oplus \leftarrow$

$N_4 + \underbrace{N_{5x}}_{N_5 \cos\alpha} = 0$

$-10 + 12{,}5 \cdot \frac{4}{5} = 0$ ✓

Průsečná metoda





$$\Sigma M_{di} = 0 \ \oplus \circlearrowleft$$

$$N_4 \cdot 1,5 + R_{bz} \cdot 2 = 0$$

$$N_4 = \frac{-R_{bz} \cdot 2}{1,5} = \frac{-7,5 \cdot 2}{1,5} = \underline{-10 \text{ kN}}$$

$$\Sigma M_{ci} = 0 : \oplus \circlearrowleft$$

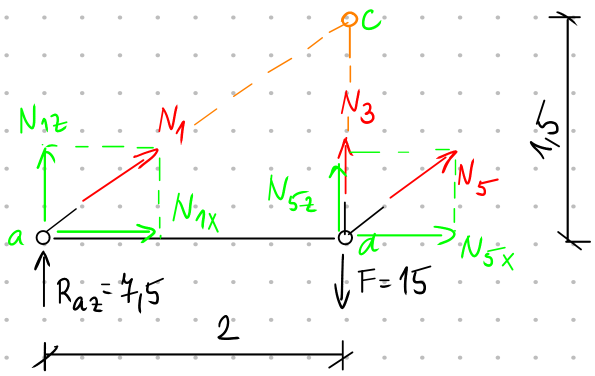
$$R_{bz} \cdot 2 - N_2 \cdot 1,5 = 0$$

$$N_2 = \frac{R_{bz} \cdot 2}{1,5} = \underline{10 \text{ kN}}$$

$N_2 \cap N_4$ v ∞ ΣM přechází na $\Sigma F \perp$ na N_2 a N_4

$$\Sigma F_{zi} = 0 : \oplus \uparrow$$

$$N_3 - F + R_{bz} = 0 \Rightarrow N_3 = F - R_{bz} = 15 - 7,5 = \underline{7,5 \text{ kN}}$$



$$\Sigma M_{di} = 0 : \oplus \circlearrowright$$

$$R_{az} \cdot 2 + N_{1z} \cdot 2 = 0$$

$$N_1 = -\frac{R_{az}}{\sin\alpha} = -\frac{7,5 \cdot 5}{3} = \underline{-12,5 \text{ kN}}$$

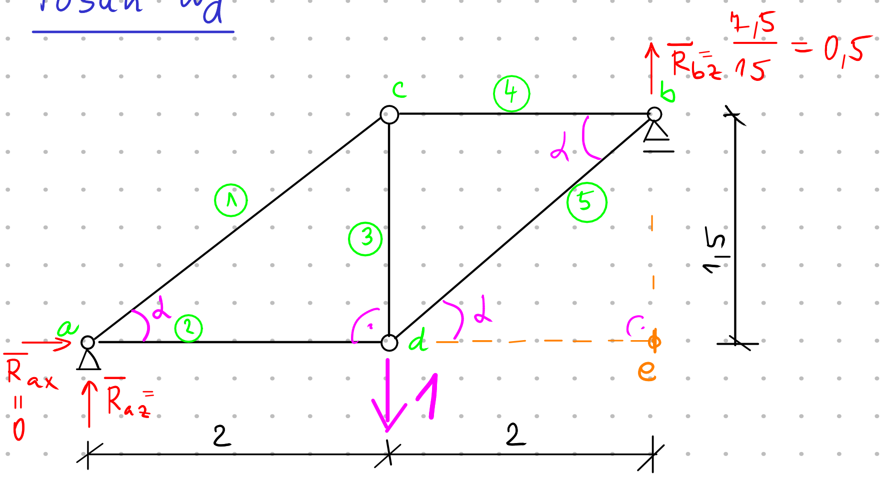
$$\Sigma M_{ci} = 0 : \oplus \circlearrowright$$

$$R_{az} \cdot 2 - N_{5x} \cdot 1,5 = 0$$

$$N_5 = \frac{R_{az} \cdot 2}{1,5 \cos\alpha} = \frac{7,5 \cdot 2 \cdot 5}{1,5 \cdot 4} = \underline{12,5 \text{ kN}}$$

$$\boxed{\begin{aligned} N_1 &= -12,5 \text{ kN} \\ N_2 &= 10 \text{ kN} \\ N_3 &= 7,5 \text{ kN} \\ N_4 &= -10 \text{ kN} \\ N_5 &= 12,5 \text{ kN} \end{aligned}}$$

Posun w_d



$$N_1 = -12,5\,kN \Rightarrow \bar{N}_1 = \frac{-12,5}{15} = -0,8\bar{3} \qquad l_1 = 2,5\,m$$

$$N_2 = 10\,kN \Rightarrow \bar{N}_2 = \frac{10}{15} = 0,\bar{6} \qquad l_2 = 2\,m$$

$$N_3 = 7,5\,kN \Rightarrow \bar{N}_3 = \frac{7,5}{15} = 0,5 \qquad l_3 = 1,5\,m$$

$$N_4 = -10\,kN \Rightarrow \bar{N}_4 = -\frac{10}{15} = -0,\bar{6} \qquad l_4 = 2\,m$$

$$N_5 = 12,5\,kN \Rightarrow \bar{N}_5 = \frac{12,5}{15} = 0,8\bar{3} \qquad l_5 = 2,5\,m$$

$$w_d = \frac{1}{E_1A_1}\int N_1\bar{N}_1\,dx + \frac{1}{E_2A_2}\int N_2\bar{N}_2\,dx + \dots + \alpha_{T_2}\Delta T_{02}\int \bar{N}_2\,dx + \alpha_{T_5}\Delta T_{05}\int \bar{N}_5\,dx - \bar{R}_{bz}\cdot w_b$$

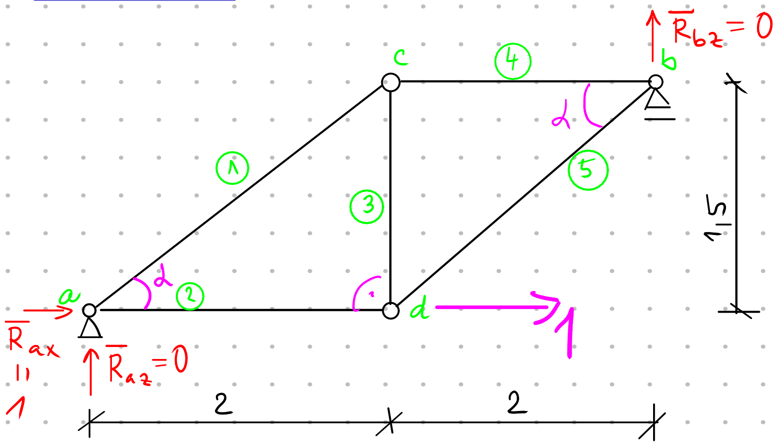
$$w_d = \frac{1}{EA}\left[+(12,5\cdot 2,5)\cdot 0,8\bar{3} + 10\cdot 2\cdot 0,\bar{6} + 7,5\cdot 1,5\cdot 0,5 + 10\cdot 2\cdot 0,\bar{6} + 12,5\cdot 2,5\cdot 0,8\bar{3}\right]$$

$$+1,2\cdot 10^{-5}\cdot 20\cdot\left[+0,\bar{6}\cdot 2\right] + 1,2\cdot 10^{-5}\cdot 20\cdot\left[+0,8\bar{3}\cdot 2,5\right] - \left[-0,5\cdot 10^{-3}\right] =$$

$$= \frac{84,375}{EA} + \qquad EA = 200\cdot 10^{6}\cdot 5\cdot 10^{-4}$$

$$= 0,84375\cdot 10^{-3} + 0,82\cdot 10^{-3} + 0,5\cdot 10^{-3} = \underline{\underline{2,16375\cdot 10^{-3}\,m}}$$

Posun u_d



$\overline{N}_2 = 1\,kN \qquad l_2 = 2\,m \qquad N_2 = 10\,kN$

$$u_d = \frac{1}{EA}\int N_2 \overline{N}_2\,dx + \alpha_{T2}\,\Delta T_{02}\int \overline{N}_2\,dx =$$

$$= \frac{1}{EA}\left[+ 10 \cdot 2 \cdot 1 \right] + 1{,}2\cdot 10^{-5} \cdot 20 \cdot \left[+ 1 \cdot 2 \right] =$$

$$= \frac{20}{EA} + 0{,}48 \cdot 10^{-3} = 0{,}2 \cdot 10^{-3} + 0{,}48 \cdot 10^{-3} = \underline{0{,}68 \cdot 10^{-3}\,m}$$

$$\boxed{\begin{aligned} u_b &= 9{,}4781 \cdot 10^{-4}\,m \\ u_c &= 1{,}1478 \cdot 10^{-3}\,m \\ w_c &= 2{,}0512 \cdot 10^{-3}\,m \end{aligned}}$$