

Přihradový kosmík - silová metoda

Tr 100x10

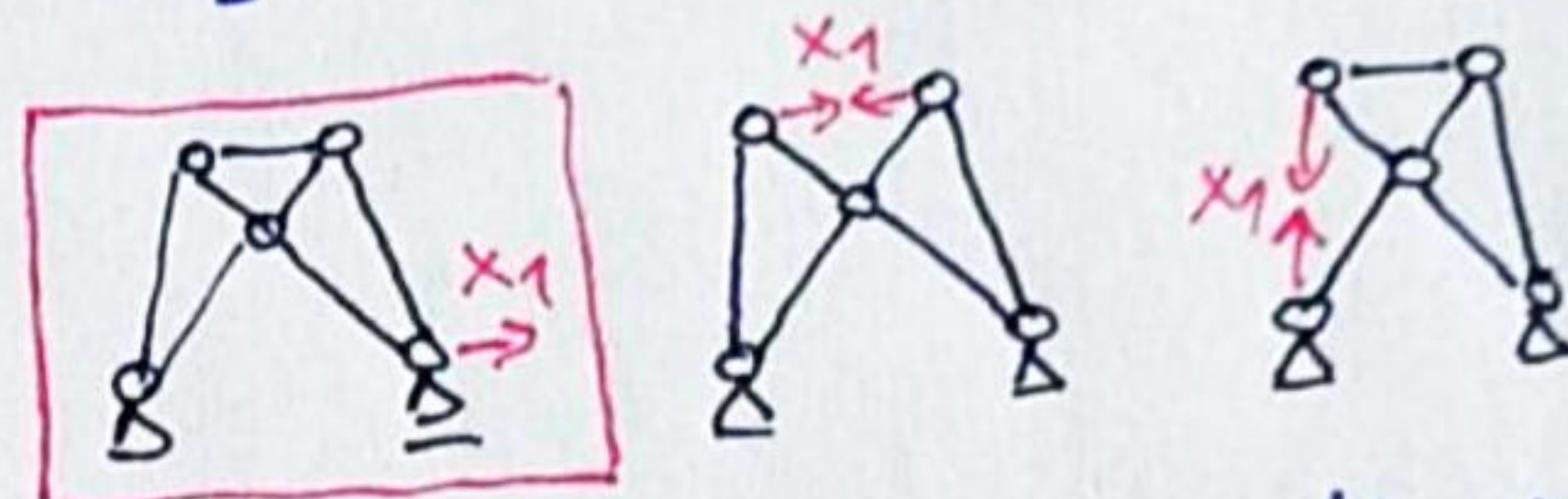
$$E = 210 \text{ GPa}$$

$$A = \pi \frac{(d^2 - d_0^2)}{4} = 1,49225651 \cdot 10^{-3} \text{ m}^2$$

$$EA = 313343,8671 \text{ kPa m}^2$$

1) stupeň statické neurčitosti:
a základní SV soustava

$$m_s = 1x$$



2) (vykreslení) výpočet normálových sil v jednotlivých prutech pro jednotlivé zatěžovací stavy

0) Reakce:

$$\sum F_{ix} = 0 \oplus \rightarrow$$

$$R_{ax} + F_x = 0 \Rightarrow R_{ax} = -F_x = -10 \text{ kN}$$

$$\sum M_{ia} = 0 \oplus \downarrow$$

$$F_x \cdot 4 + F_z \cdot 3 - R_{bz} \cdot 8 = 0$$

$$R_{bz} = 10,625 \text{ kN}$$

$$\sum M_{ib} = 0 \oplus \downarrow$$

$$R_{az} \cdot 8 + F_x \cdot 4 - F_z \cdot 5 = 0$$

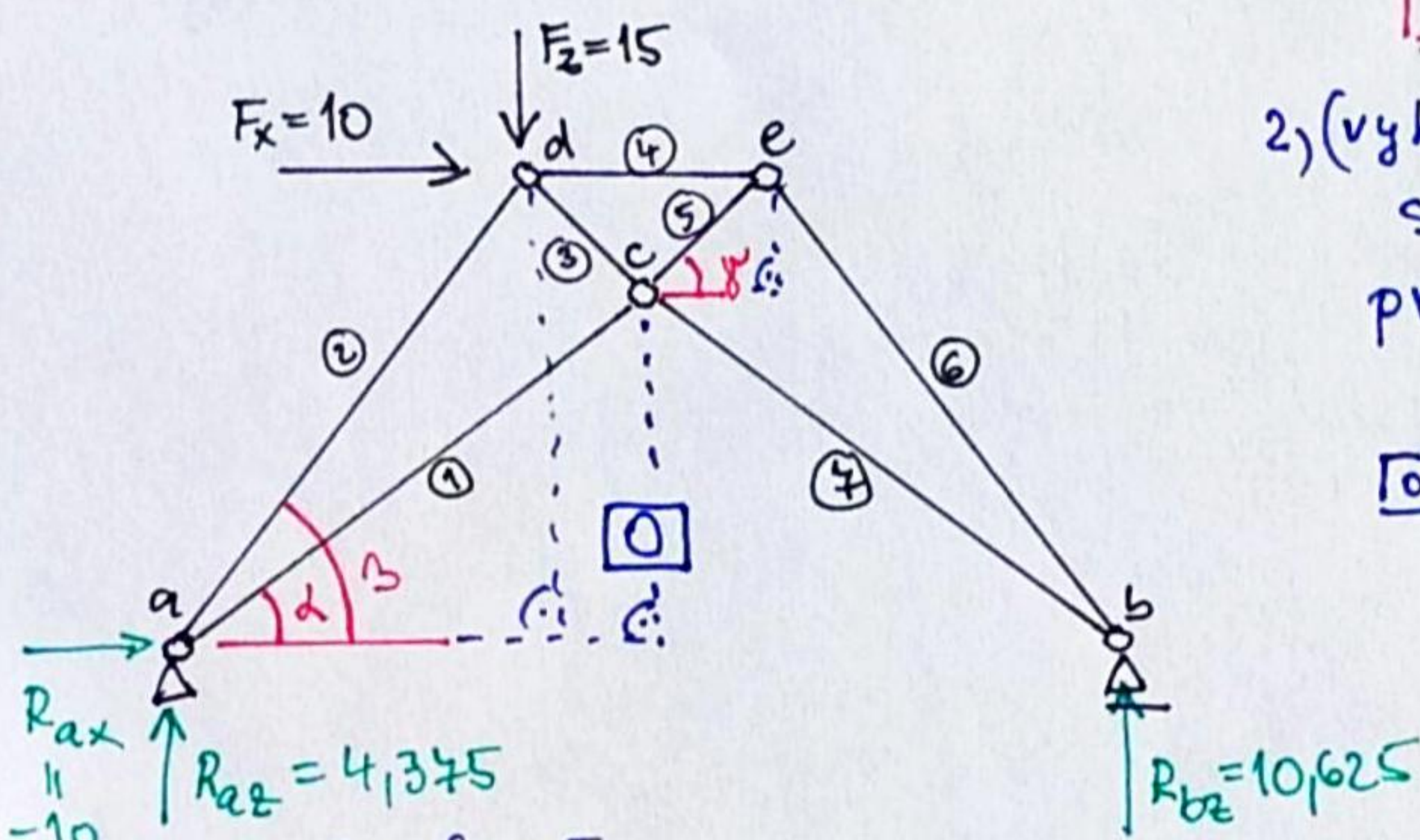
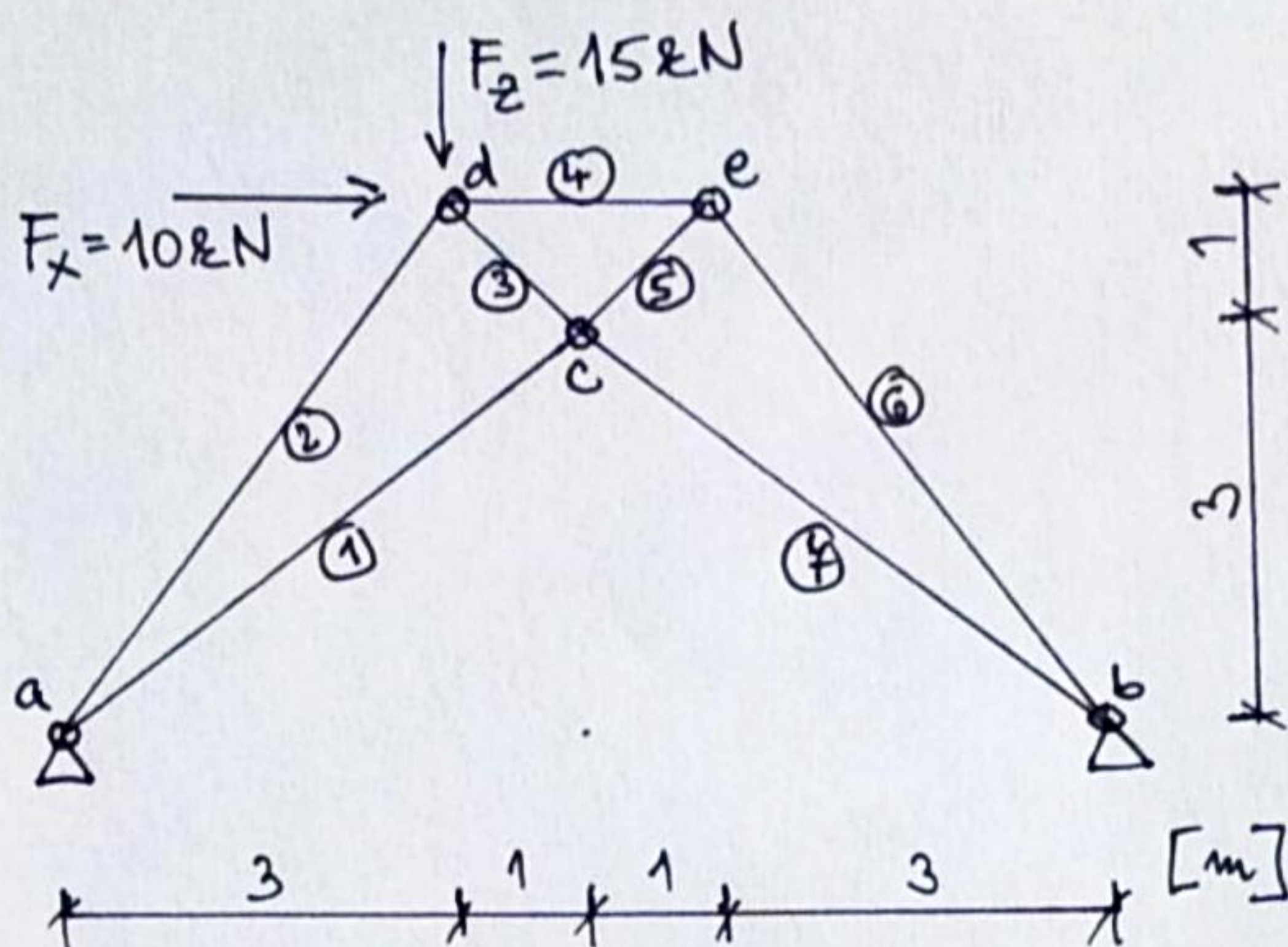
$$R_{az} = 4,375 \text{ kN}$$

kontrola:

$$\sum F_{iz} = 0 \oplus \uparrow$$

$$R_{az} + R_{bz} - F_z = 0$$

$$0 = 0 \checkmark$$



$$l_1 = l_2 = l_6 = l_7 = 5 \text{ m}$$

$$l_3 = l_5 = \sqrt{2} \text{ m}$$

$$l_4 = 2 \text{ m}$$

$$\sin \alpha = \frac{3}{5}$$

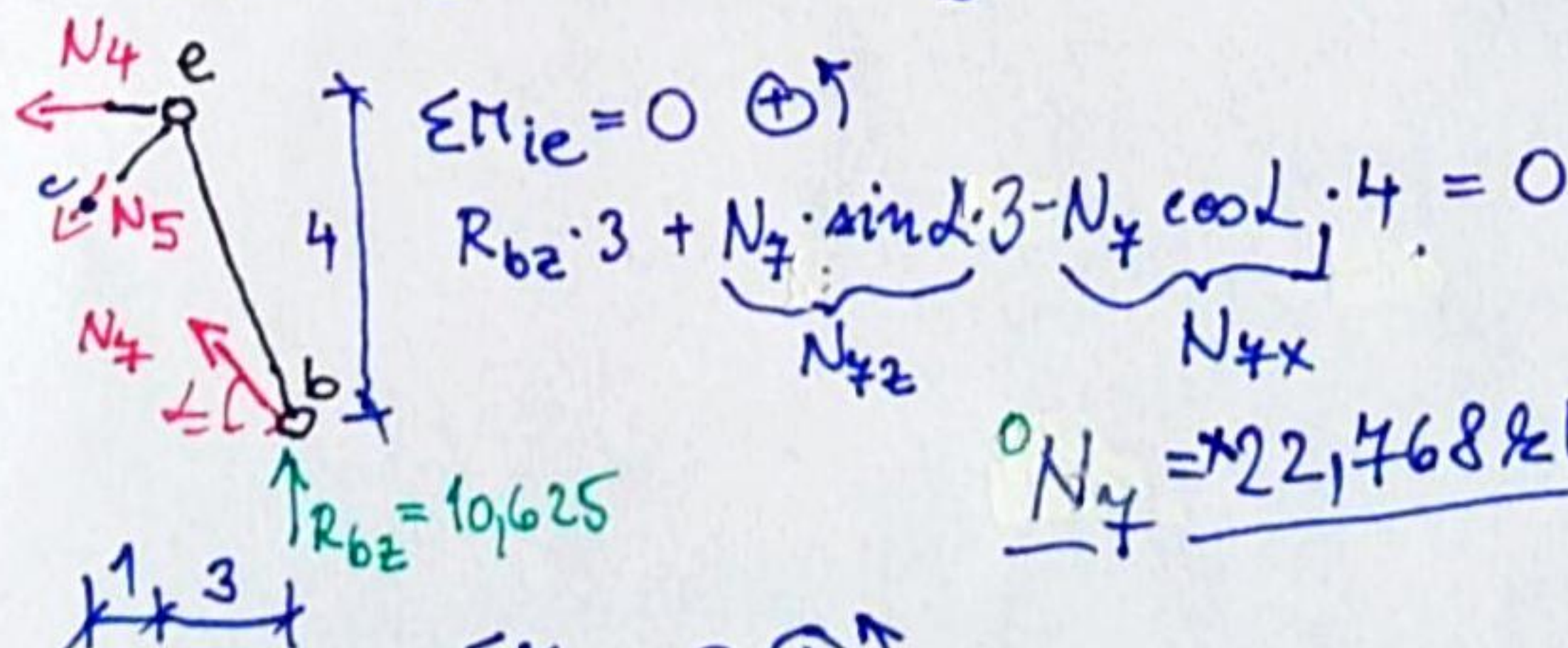
$$\sin \beta = \frac{4}{5}$$

$$\sin \gamma = \frac{1}{\sqrt{2}}$$

$$\cos \alpha = \frac{4}{5}$$

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

$$\cos \gamma = \frac{1}{\sqrt{2}}$$



$$\sum M_{ie} = 0 \oplus \uparrow$$

$$R_{bz} \cdot 3 + N_7 \cdot \sin \alpha \cdot 3 - N_7 \cdot \cos \alpha \cdot 4 = 0$$

$$N_7 = 22,468 \text{ kN}$$

$$\sum M_{ic} = 0 \oplus \uparrow$$

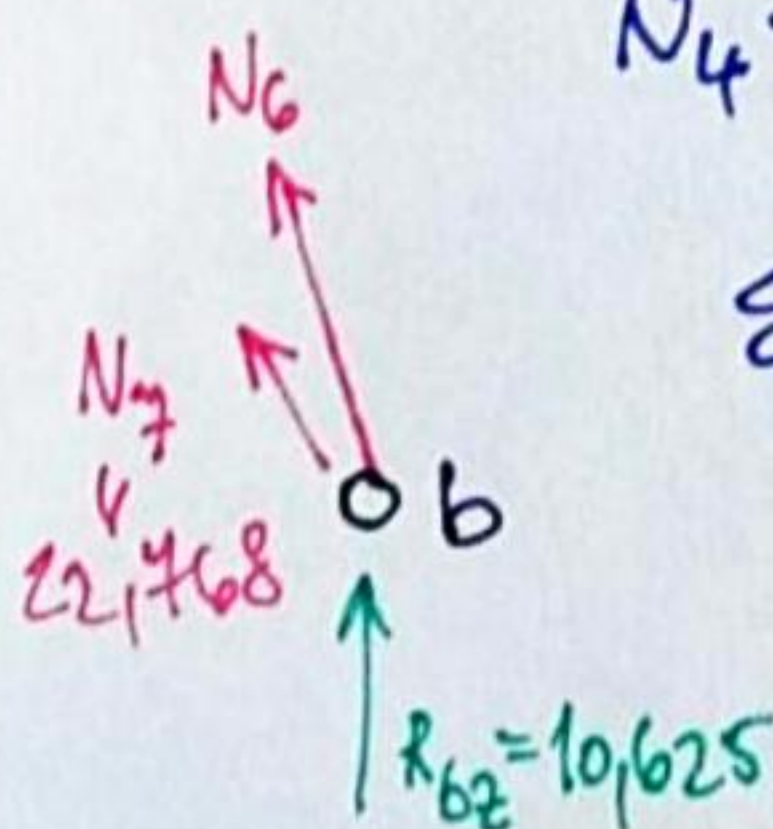
$$N_4 \cdot 1 + R_{bz} \cdot 4 = 0 \Rightarrow N_4 = -42,5 \text{ kN}$$

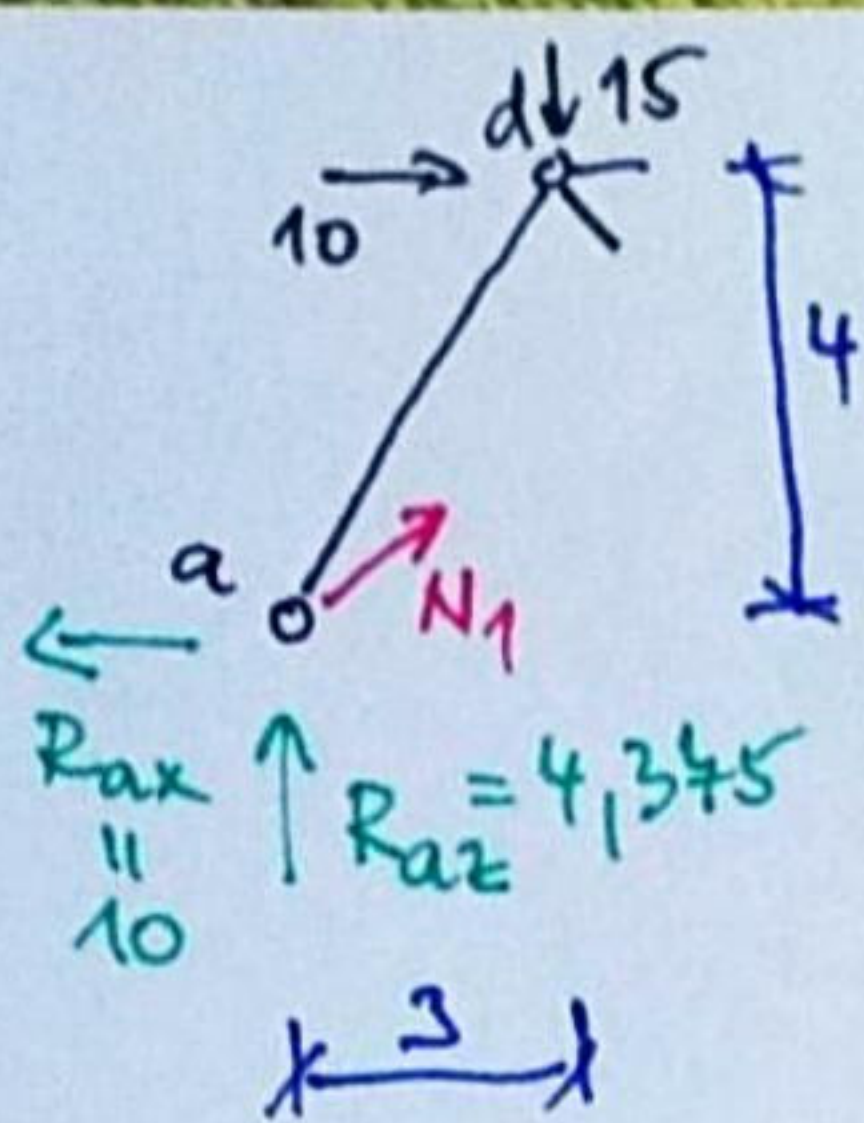
$$\sum F_{ix} = 0 \oplus \leftarrow$$

$$N_{4x} + N_{6x} = 0$$

$$N_4 \cdot \cos \alpha + N_6 \cdot \cos \beta = 0$$

$$N_6 = -30,357 \text{ kN}$$





$$\sum M_{id} = 0 \quad \oplus \curvearrowright$$

$$R_{ax} \cdot 4 + R_{az} \cdot 3 - \overbrace{N_1 \cos \alpha}^{N_{1x}} \cdot 4 + \overbrace{N_1 \sin \alpha}^{N_{1z}} \cdot 3 = 0$$

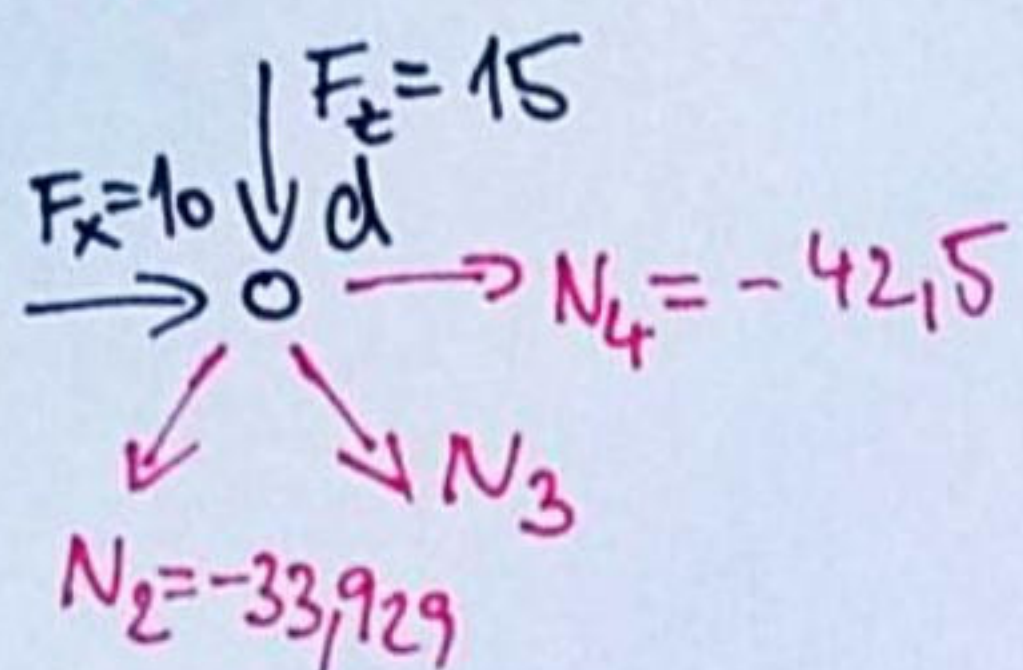
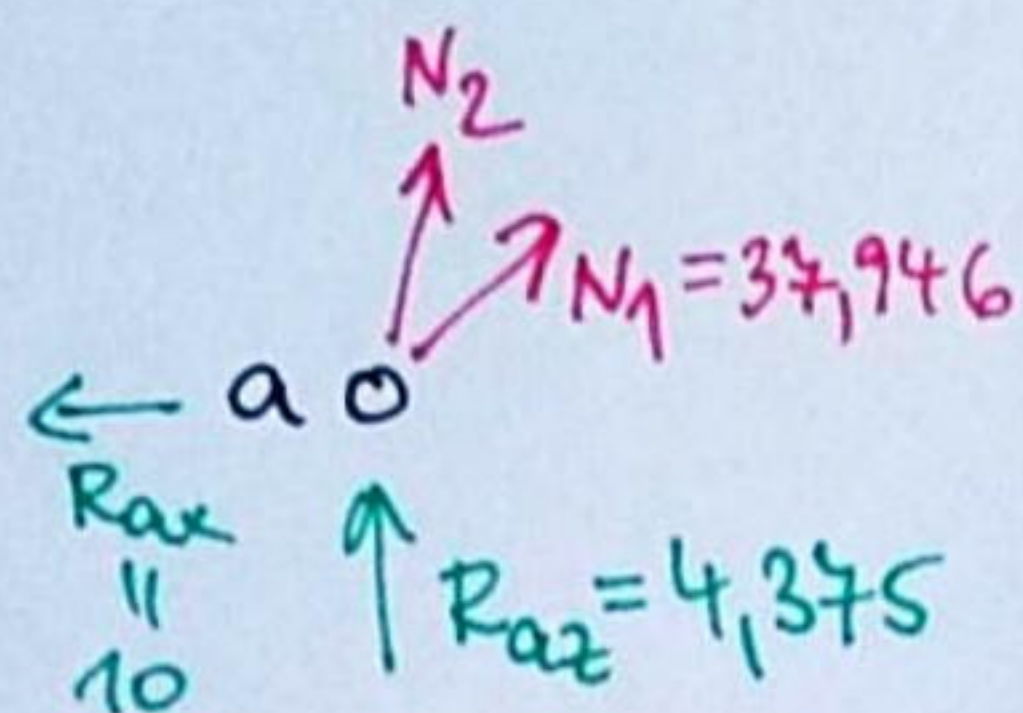
$$\circ N_1 = 34,946 \text{ kN}$$

$$\sum F_{ix} = 0 \quad \oplus \leftarrow$$

$$R_{ax} - N_{2x} - N_{1x} = 0$$

$$R_{ax} - N_2 \cdot \cos \beta - N_1 \cos \alpha = 0$$

$$\circ N_2 = -33,929 \text{ kN}$$

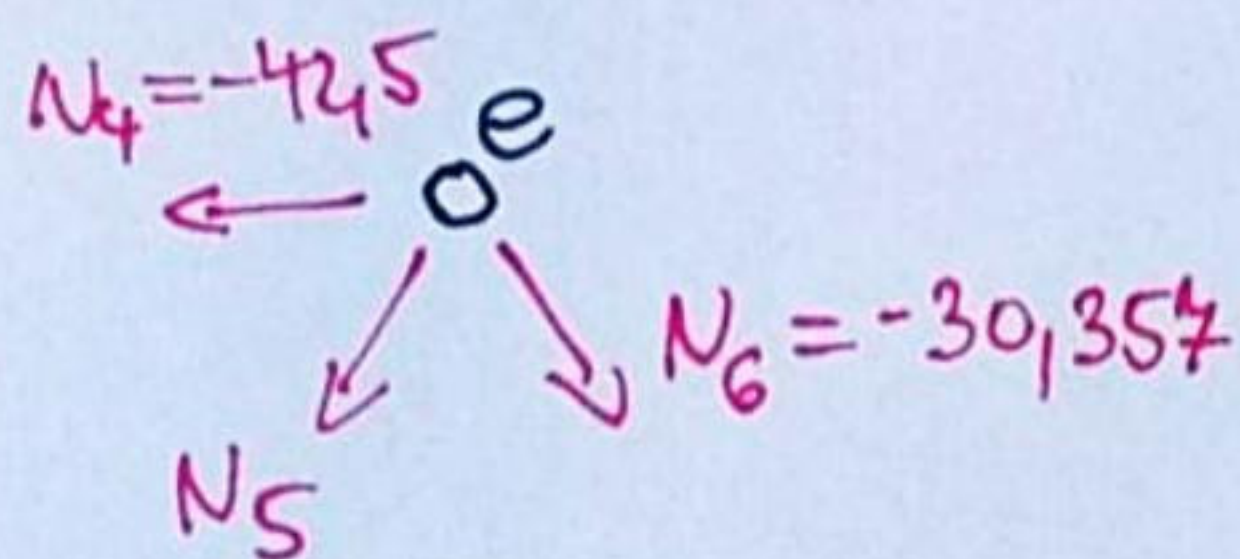


$$\sum F_{iz} = 0 \quad \oplus \downarrow$$

$$F_z + N_{2z} + N_{3z} = 0$$

$$F_z + N_2 \sin \beta + N_3 \sin \gamma = 0$$

$$\circ N_3 = 17,143 \text{ kN}$$



$$\sum F_{iz} = 0 \quad \oplus \downarrow$$

$$N_{5z} + N_{6z} = 0$$

$$N_5 \cdot \sin \gamma + N_6 \cdot \sin \beta = 0$$

$$\circ N_5 = 34,345 \text{ kN}$$

kontrola: (c) $\sum F_{ix} = 0$ (d) $\sum F_{ix} = 0$ (a) $\sum F_{iz} = 0$ (b) $\sum F_{iz} = 0$
u výpočtu N_1 $\sum M_{ic} = 0 \Rightarrow N_4$ atd.

1 reakce:

$$\sum F_{ix} = 0$$

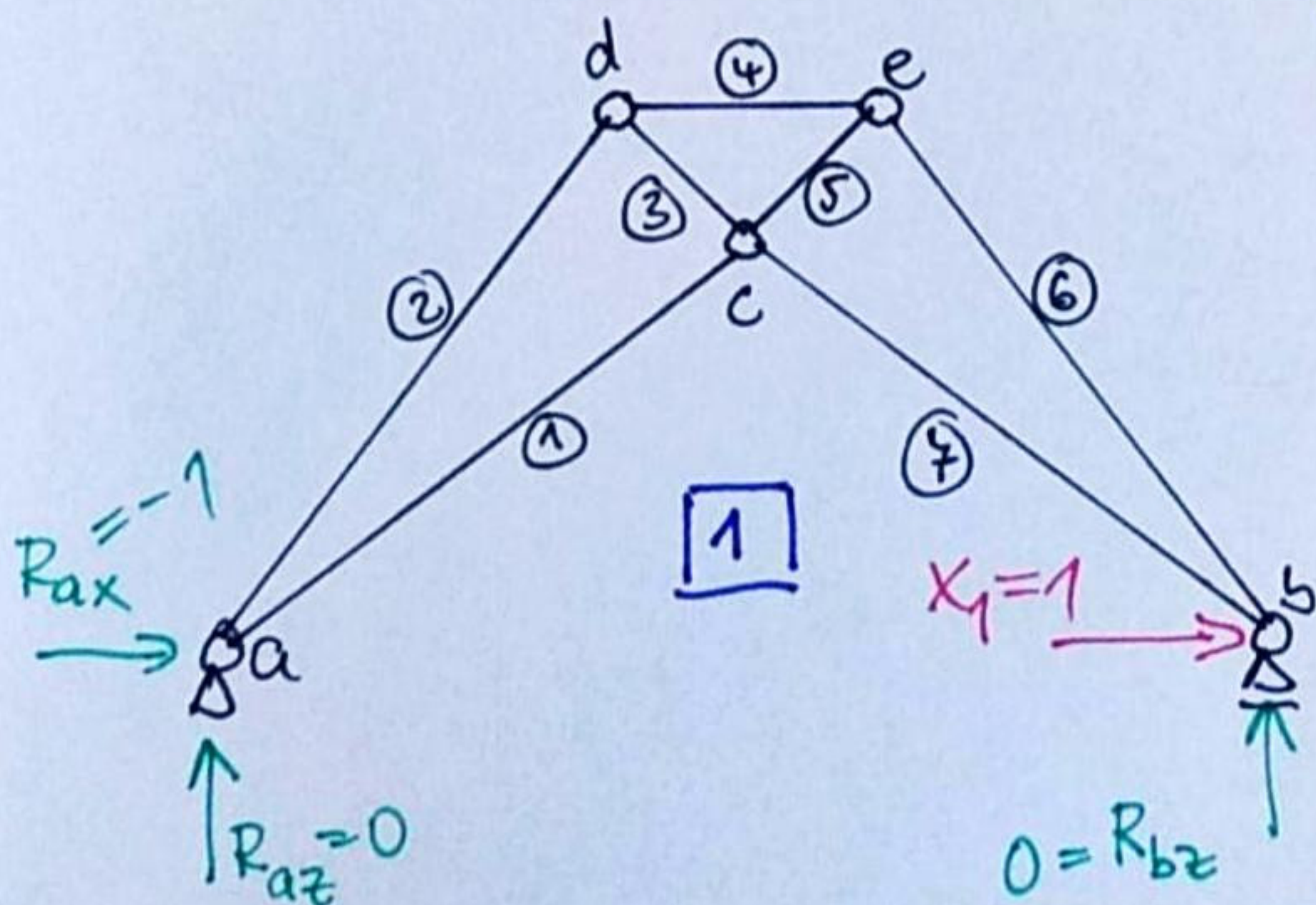
$$R_{ax} + X_1 = 0$$

$$\circ R_{ax} = -1 \text{ kN}$$

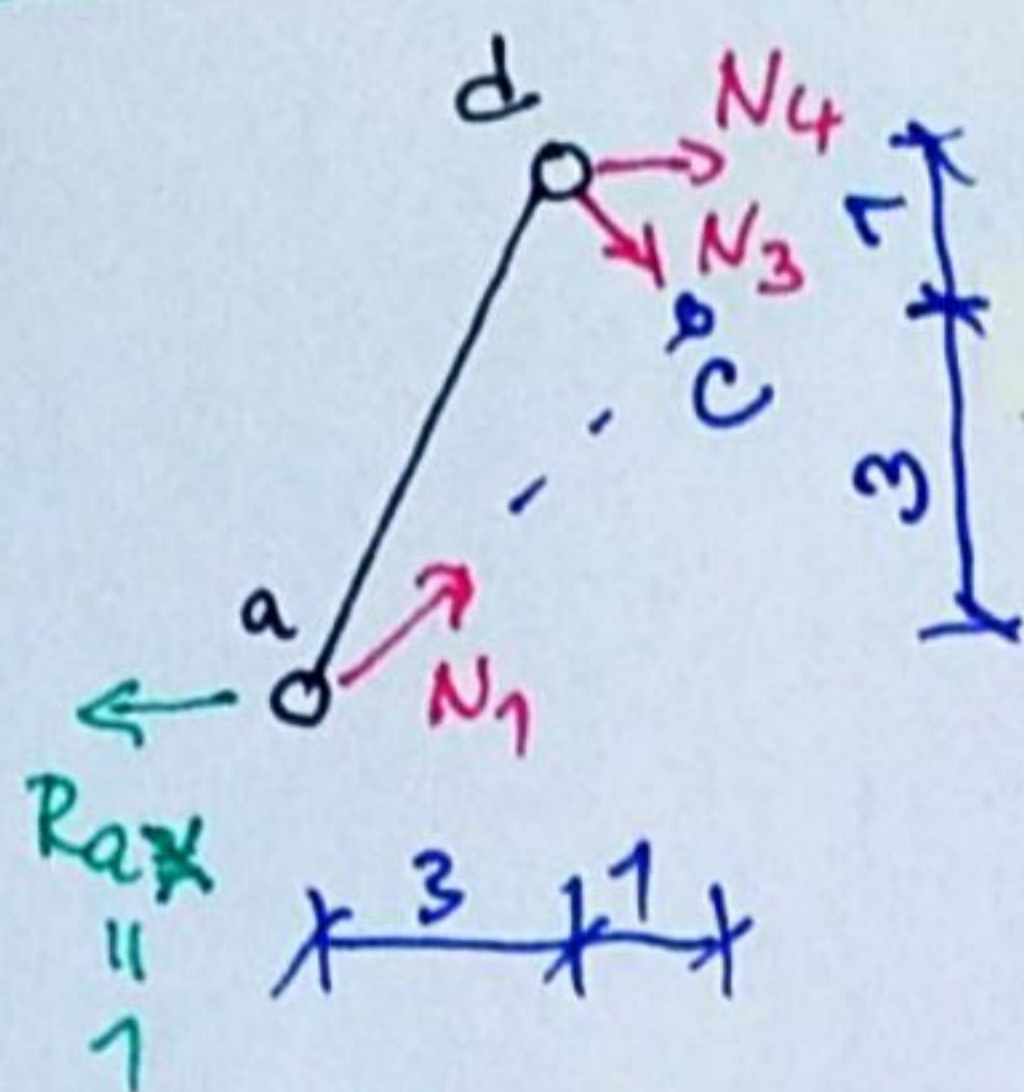
$$\sum M_{ai} = 0 \Rightarrow R_{bz} = 0$$

$$\sum M_{bi} = 0 \Rightarrow R_{az} = 0$$

$$\sum F_{zi} = 0 \Rightarrow 0 = 0 \checkmark$$



-symetrické zatížení



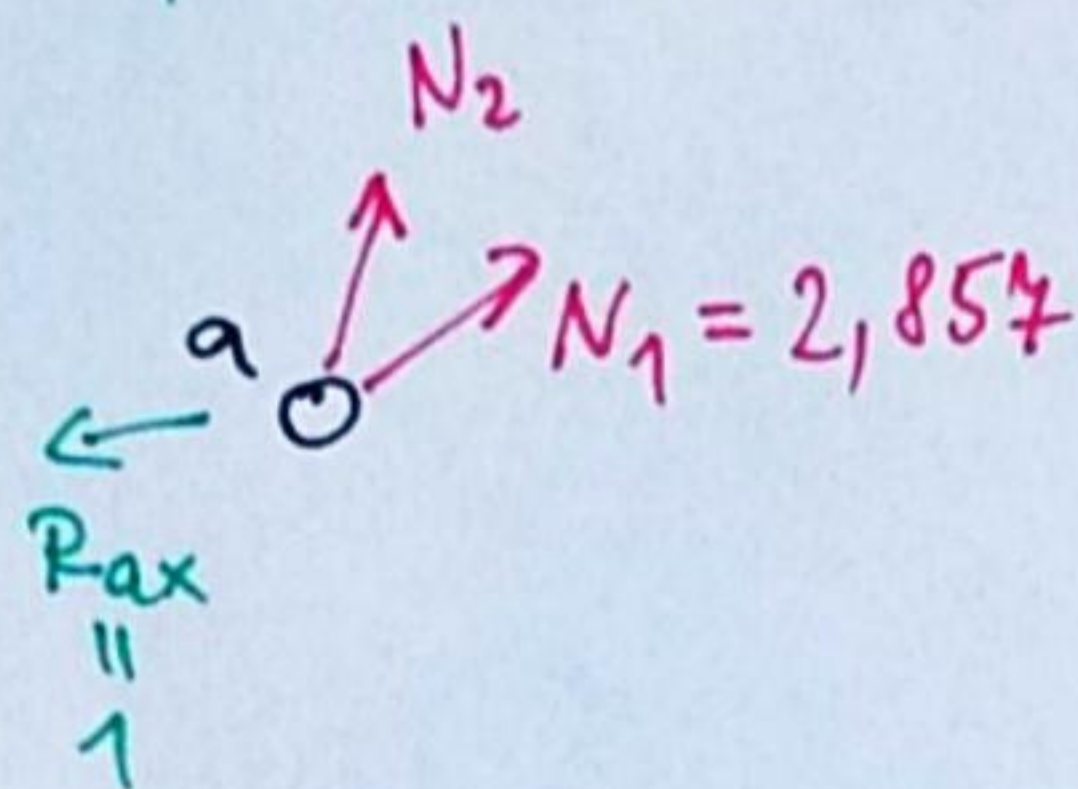
$$\sum M_{id} = 0 \quad (+\curvearrowright)$$

$$R_{ax} \cdot 4 + N_1 \cdot \sin 45^\circ \cdot 3 - N_1 \cdot \cos 45^\circ \cdot 4 = 0$$

$$N_1 = 2,857 \text{ kN} = N_4$$

$$\sum M_{ic} = 0 \quad (+\curvearrowright)$$

$$N_4 \cdot 1 + R_{ax} \cdot 3 = 0 \Rightarrow N_4 = -3 \text{ kN}$$

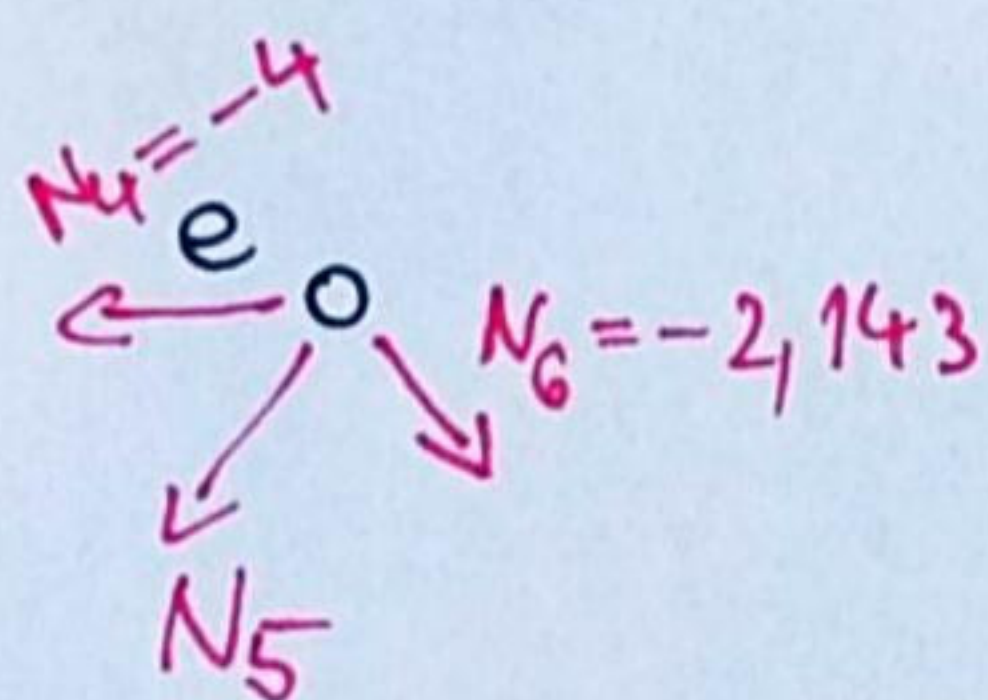


$$\sum F_{iz} = 0 \quad (+\uparrow)$$

$$N_{1z} + N_{2z} = 0$$

$$N_1 \sin 45^\circ + N_2 \sin 45^\circ = 0$$

$$N_2 = -2,143 \text{ kN} = N_6$$



$$\sum F_{iz} = 0 \quad (+\downarrow)$$

$$N_{5z} + N_{6z} = 0$$

$$N_5 \sin 45^\circ + N_6 \sin 45^\circ = 0$$

$$N_5 = 2,143 \text{ kN} = N_3$$

3) rovnice (přetvárná)

$$\delta_{11} X_1 + \delta_{10} = 0 \Rightarrow X_1 = -\frac{\delta_{10}}{\delta_{11}}$$

4) vyčíslení členů $\delta = \int \frac{1}{EA} N \bar{N} ds$ - kombinuji pouze obdélníky

$$\delta_{11} = \frac{1}{EA} \left[\int N_1^1 N_1^1 ds + \int N_2^1 N_2^1 ds + \dots + \int N_4^1 N_4^1 ds \right] =$$

$$= \frac{1}{EA} \left[(2,857 \cdot l_1 \cdot 2,857 + l_2 \cdot 2,143^2 + l_3 \cdot 2,143^2) \cdot 2 + l_4 \cdot 3^2 \right] = \frac{162,1819}{EA}$$

$$\delta_{10} = \frac{1}{EA} \left[\int N_1^0 N_1^1 ds + \int N_2^0 N_2^1 ds + \dots + \int N_4^0 N_4^1 ds \right] =$$

$$\frac{1}{EA} \left[37,946 \cdot l_1 \cdot 2,857 + (-33,929) \cdot l_2 \cdot (-2,143) + 17,143 \cdot l_3 \cdot 2,143 + \right. \\ \left. + (-42,5) \cdot l_4 \cdot (-3) + 34,345 \cdot l_5 \cdot 2,143 + (-30,357) \cdot l_6 \cdot (-2,143) + \right. \\ \left. + 22,468 \cdot l_4 \cdot 2,857 \right] = \frac{1987,8033}{EA}$$

5) výpočet X_1

$$\underline{\underline{X_1}} = -\frac{F_{10}}{F_{11}} = -\frac{\frac{19878033}{EA}}{\frac{1621819}{EA}} = -\underline{\underline{12,257 \text{ kN}}}$$

6) vnitřní síly na zadané staticky neurčité konstrukci $\Rightarrow$

	$\boxed{0}$	$\boxed{1}$	$\boxed{0} + \boxed{1} \cdot X_1$
N_1	34,946	2,857	2,929
N_2	-33,929	-2,143	-4,663
N_3	14,143	2,425	-12,549
N_4	-42,5	-3	-5,730
N_5	34,345	2,425	4,623
N_6	-30,357	-2,143	-4,091
N_7	22,768	2,857	-12,249

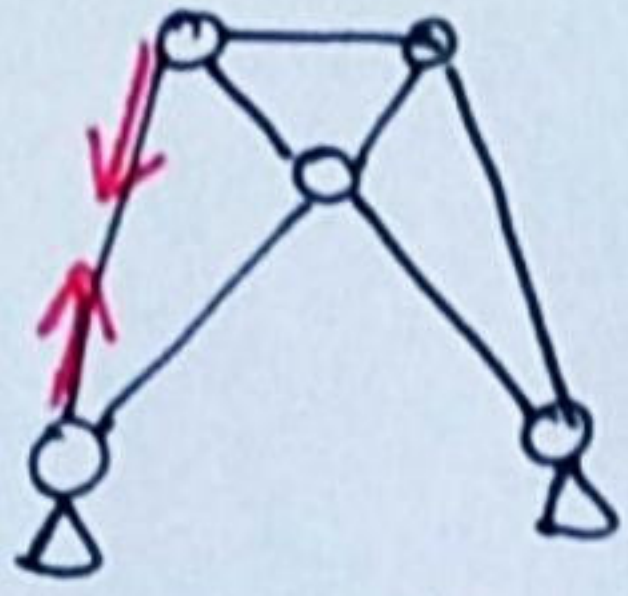
$$R_{ax} = {}^0R_{ax} + {}^1R_{ax} \cdot X_1 = 2,257 \text{ kN}$$

$$R_{az} = {}^0R_{az} + {}^1R_{az} \cdot X_1 = 4,357 \text{ kN}$$

$$R_{bz} = {}^0R_{bz} + {}^1R_{bz} \cdot X_1 = 10,625 \text{ kN}$$

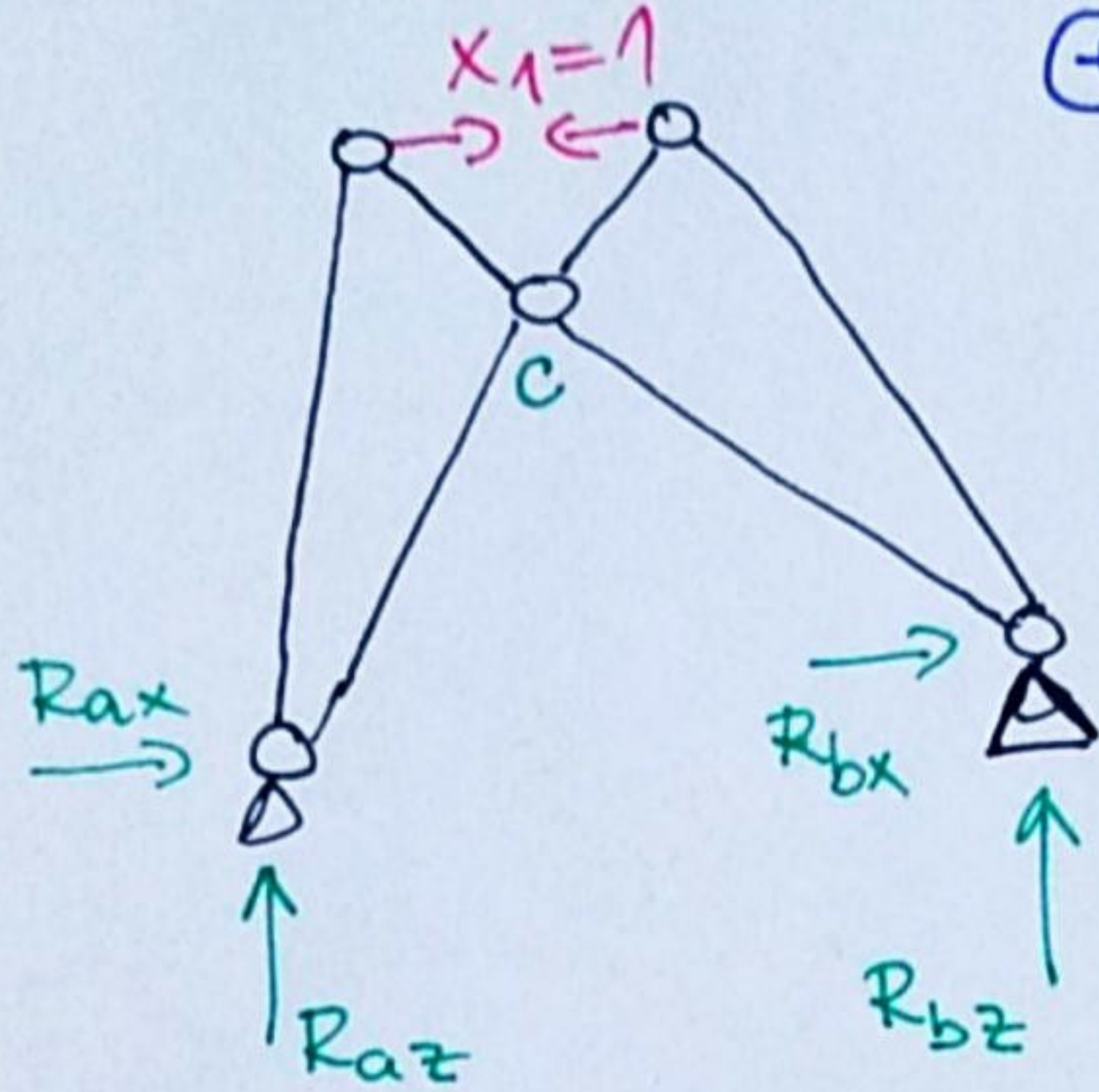
$$R_{bx} = X_1 = -12,257 \text{ kN}$$

7 základní soustava s odebraným vnitřním prutem



⊖ nevýhoda nesymetrické

⊕ symetrické



$$\begin{aligned} N_1 &= -0,952 \\ N_2 &= 0,414 \\ N_3 &= -0,808 \\ N_5 &= -0,808 \\ N_6 &= 0,414 \\ N_4 &= -0,952 \end{aligned}$$

$$\sum M_{ia} = 0 \quad \oplus \uparrow \Rightarrow R_{bz} = 0$$

$$\sum M_{bi} = 0 \quad \oplus \downarrow \Rightarrow R_{az} = 0$$

$$\sum M_{ci}^P = 0 \quad \oplus \uparrow \quad R_{bx} \cdot 3 + X_1 \cdot 1 = 0$$

$$R_{bx} = -\frac{1}{3} \text{ kN}$$

$$\sum M_{ci}^L = 0 \quad \oplus \downarrow \quad R_{ax} \cdot 3 + X_1 \cdot 1 = 0$$

$$R_{ax} = -\frac{1}{3} \text{ kN} \quad \checkmark$$