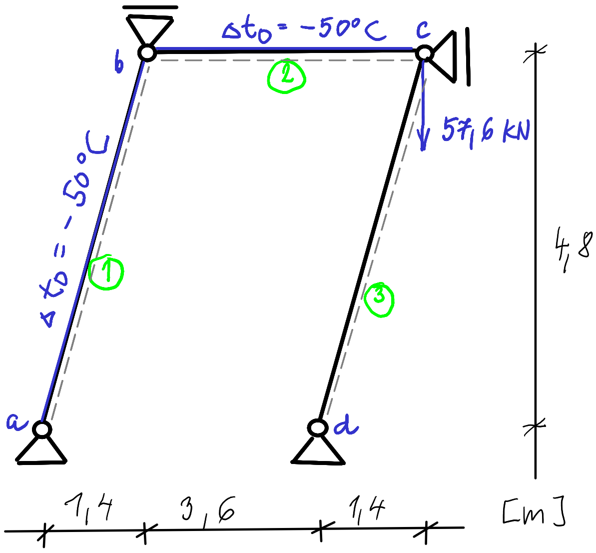
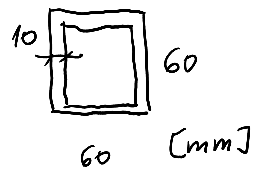
ŘEŠTE OBECNOU DEFORMAČNÍ METODOU (V MATICOVÉ NEBO SKALÁRNÍ FORMĚ):



$\alpha_t = 1{,}2 \cdot 10^{-5}\ K^{-1}$

$E = 50\ GPa = 50 \cdot 10^{6}\ kPa$



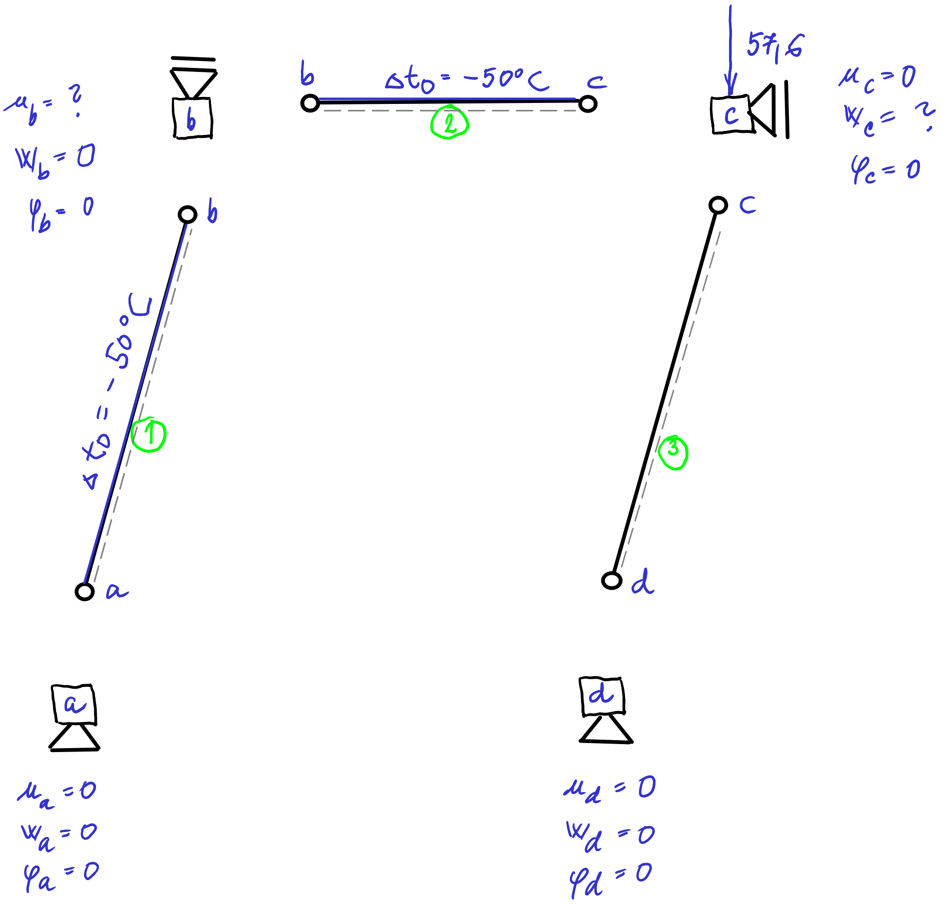
$A = 60^2 - 40^2 = 2000\ mm^2$

$A = 2 \cdot 10^{-3}\ m^2$

(BUDEME DODRŽOVAT JEDNOTKY [m, kN, kPa])

→ MATICOVÁ FORMA (KOMPLETNÍ ŘEŠENÍ)

- výpočtový model (rozdělení na styčníky a pruty):

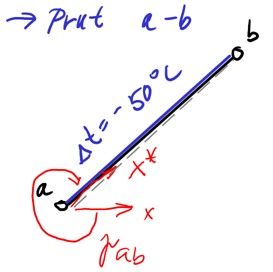


1) vektor neznámých parametrů deformace; vektor styčníkového zatížení

$$\{r\} = \begin{Bmatrix} u_b \\ w_c \end{Bmatrix} \qquad \{S\} = \begin{Bmatrix} 0 \\ 57{,}6 \end{Bmatrix} \begin{matrix} x_b \\ z_c \end{matrix}$$

2) analýza prutů – matice tuhosti, vektory primárních koncových sil

→ Prut a-b

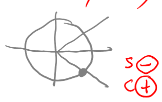


$l_{ab} = \sqrt{1,4^2 + 4,8^2} = 5\,m$

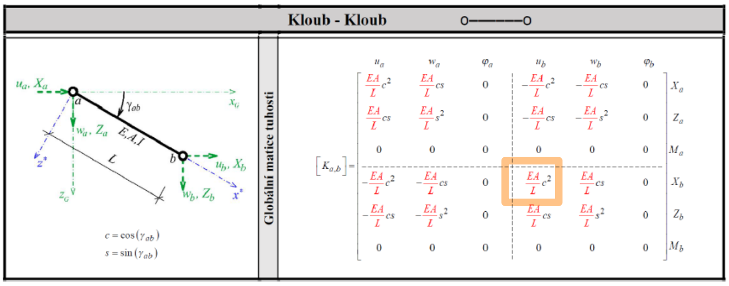
$EA = 50\cdot 10^6 \cdot 2\cdot 10^{-3} = 100\cdot 10^3\ kPa\cdot m^2$

$(\gamma_{ab} = 286,26°) \longrightarrow s_{ab} = \sin\gamma_{ab} = -0,96$

$c_{ab} = \cos\gamma_{ab} = 0,28$



$$[T_{ab}] = \begin{bmatrix} 0,28 & -0,96 & 0 & & \emptyset & \\ 0,96 & 0,28 & 0 & & & \\ 0 & 0 & 1 & & & \\ & \emptyset & & 0,28 & -0,96 & 0 \\ & & & 0,96 & 0,28 & 0 \\ & & & 0 & 0 & 1 \end{bmatrix}$$



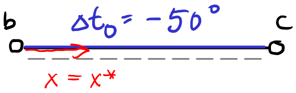
$$\begin{array}{c} \\ \end{array}[k_{ab}] = \begin{array}{cccccc|c} u_a & w_a & \varphi_a & u_b & w_b & \varphi_b & \\ & & & -1568 & & & \hat{X}_a \\ & & & 5376 & & & \hat{Z}_a \\ & & & 0 & & & \hat{M}_a \\ & & & \boxed{1568} & & & \hat{X}_b \\ & & & -5376 & & & \hat{Z}_b \\ & & & 0 & & & \hat{M}_b \end{array}$$

(8.14/10)
$EA\alpha_T\Delta T_0$
0
0
$-EA\alpha_T\Delta T_0$
0
0

$$\{\bar{R}^*_{ab}\} = \begin{pmatrix} -60 \\ 0 \\ 0 \\ 60 \\ 0 \\ 0 \end{pmatrix} \begin{matrix} \bar{X}^*_a \\ \bar{Z}^*_a \\ \bar{M}^*_a \\ \bar{X}^*_b \\ \bar{Z}^*_b \\ \bar{M}^*_b \end{matrix}$$

⟶ z LSS do GSS $\{\bar{R}_{ab}\} = [T_{ab}]^T \cdot \{\bar{R}^*_{ab}\} = \begin{pmatrix} -16,8 \\ 57,6 \\ 0 \\ \boxed{16,8} \\ -57,6 \\ 0 \end{pmatrix} \begin{matrix} \bar{X}_a \\ \bar{Z}_a \\ \bar{M}_a \\ \bar{X}_b \\ \bar{Z}_b \\ \bar{M}_b \end{matrix}$

→ Prut b-c

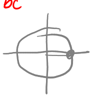


$l_{bc} = 5\,m$

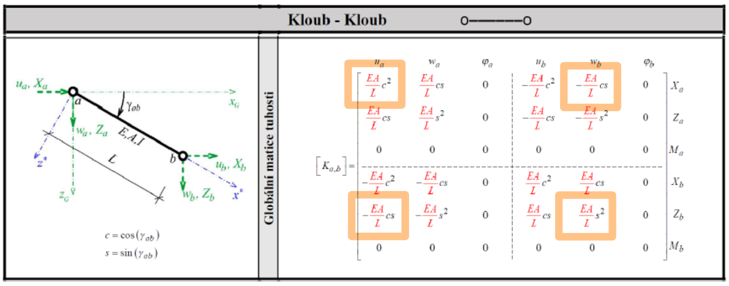
$EA = 50\cdot 10^6 \cdot 2\cdot 10^{-3} = 100\cdot 10^3\ kPa\cdot m^2$

$\gamma_{bc} = 0 \longrightarrow s_{bc} = \sin\gamma_{bc} = 0$

$c_{bc} = \cos\gamma_{bc} = 1$



$$[T_{bc}] = \begin{bmatrix} 1 & 0 & 0 & & \emptyset & \\ 0 & 1 & 0 & & & \\ 0 & 0 & 1 & & & \\ & \emptyset & & 1 & 0 & 0 \\ & & & 0 & 1 & 0 \\ & & & 0 & 0 & 1 \end{bmatrix}$$



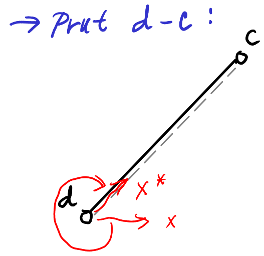
$$[k_{bc}] = \begin{array}{cccccc|c} u_b & w_b & \varphi_b & u_c & w_c & \varphi_c & \\ \boxed{20000} & & & & \boxed{0} & & \hat{X}_b \\ 0 & & & & 0 & & \hat{Z}_b \\ 0 & & & & 0 & & \hat{M}_b \\ -20000 & & & & 0 & & \hat{X}_c \\ \boxed{0} & & & & \boxed{0} & & \hat{Z}_c \\ 0 & & & & 0 & & \hat{M}_c \end{array}$$

(8.14/10)
$EA\alpha_T\Delta T_0$
0
0
$-EA\alpha_T\Delta T_0$
0
0

$$\{\bar{R}^*_{bc}\} = \begin{pmatrix} -60 \\ 0 \\ 0 \\ 60 \\ 0 \\ 0 \end{pmatrix} \begin{matrix} \bar{X}^*_b \\ \bar{Z}^*_b \\ \bar{M}^*_b \\ \bar{X}^*_c \\ \bar{Z}^*_c \\ \bar{M}^*_c \end{matrix}$$

⟶ z LSS do GSS $\{\bar{R}_{bc}\} = [T_{bc}]^T \cdot \{\bar{R}^*_{bc}\} = \begin{pmatrix} \boxed{-60} \\ 0 \\ 0 \\ 60 \\ \boxed{0} \\ 0 \end{pmatrix} \begin{matrix} \bar{X}_b \\ \bar{Z}_b \\ \bar{M}_b \\ \bar{X}_c \\ \bar{Z}_c \\ \bar{M}_c \end{matrix}$

→ Prut d-c :

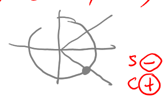


$$\ell_{dc} = \sqrt{1{,}4^2 + 4{,}8^2} = 5\,m$$

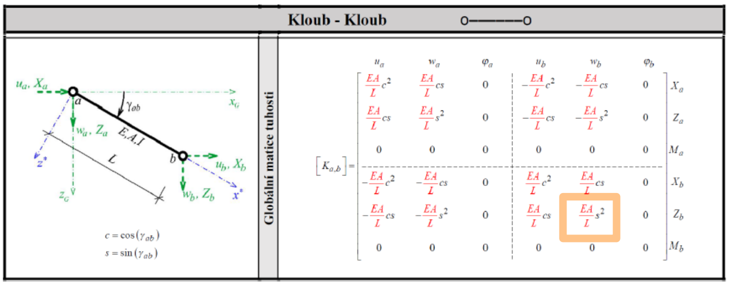
$$EA = 50 \cdot 10^6 \cdot 2 \cdot 10^{-3} = 100 \cdot 10^3 \ kPa \cdot m^2$$

$$(\gamma_{dc} = 286{,}26^\circ) \rightarrow s_{dc} = \sin \gamma_{dc} = -0{,}96$$

$$c_{ds} = \cos \gamma_{dc} = 0{,}28$$



$$[T_{dc}] = \begin{bmatrix} 0{,}28 & -0{,}96 & 0 & & & \\ 0{,}96 & 0{,}28 & 0 & & \emptyset & \\ 0 & 0 & 1 & & & \\ & & & 0{,}28 & -0{,}96 & 0 \\ & \emptyset & & 0{,}96 & 0{,}28 & 0 \\ & & & 0 & 0 & 1 \end{bmatrix}$$



$$[K_{a,b}] = \begin{array}{c} \begin{array}{cccccc} u_a & w_a & \varphi_a & u_b & w_b & \varphi_b \end{array} \\ \begin{bmatrix} \frac{EA}{L}c^2 & \frac{EA}{L}cs & 0 & -\frac{EA}{L}c^2 & -\frac{EA}{L}cs & 0 \\ \frac{EA}{L}cs & \frac{EA}{L}s^2 & 0 & -\frac{EA}{L}cs & -\frac{EA}{L}s^2 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ -\frac{EA}{L}c^2 & -\frac{EA}{L}cs & 0 & \frac{EA}{L}c^2 & \frac{EA}{L}cs & 0 \\ -\frac{EA}{L}cs & -\frac{EA}{L}s^2 & 0 & \frac{EA}{L}cs & \boxed{\frac{EA}{L}s^2} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \end{array} \begin{array}{c} X_a \\ Z_a \\ M_a \\ X_b \\ Z_b \\ M_b \end{array}$$

$$[k_{dc}] = [k_{ab}] = \begin{array}{c} \begin{array}{cccccc} u_d & w_d & \varphi_d & u_c & w_c & \varphi_c \end{array} \\ \begin{bmatrix} & & & & 5376 & \\ & & & & -18432 & \\ & & & & 0 & \\ & & & & -5376 & \\ & & & & \boxed{18432} & \\ & & & & 0 & \end{bmatrix} \end{array} \begin{array}{c} \bar{X}_d \\ \bar{Z}_d \\ \bar{M}_d \\ \bar{X}_c \\ \bar{Z}_c \\ \bar{M}_c \end{array}$$

$$\{\bar{R}^*_{dc}\} = \begin{Bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{Bmatrix} \begin{array}{c} \bar{X}^*_d \\ \bar{Z}^*_d \\ \bar{M}^*_d \\ \bar{X}^*_c \\ \bar{Z}^*_c \\ \bar{M}^*_c \end{array} \longrightarrow \text{z LSS do GSS} \quad \{\bar{R}_{dc}\} = [T_{dc}]^T \cdot \{\bar{R}^*_{dc}\} = \begin{Bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ \boxed{0} \\ 0 \end{Bmatrix} \begin{array}{c} \bar{X}_d \\ \bar{Z}_d \\ \bar{M}_d \\ \bar{X}_c \\ \bar{Z}_c \\ \bar{M}_c \end{array}$$

3) Matice modelu, vektor pravé strany {F}

$$[K] = \begin{array}{c} \begin{array}{cc} u_b & w_c \end{array} \\ \begin{bmatrix} 21568 & 0 \\ 0 & 18432 \end{bmatrix} \end{array} \begin{array}{c} X_b \\ Z_c \end{array}$$

! MATICE MUSÍ BÝT SYMETRICKÁ PODLE HLAVNÍ DIAGONÁLY (zde 0 = 0)

$$\{F\} = \{S\} - \{\bar{R}\} = \begin{Bmatrix} 0 \\ 57{,}6 \end{Bmatrix} - \begin{Bmatrix} 16{,}8 - 60 \\ 0 + 0 \end{Bmatrix} = \begin{Bmatrix} 43{,}2 \\ 57{,}6 \end{Bmatrix} \begin{array}{c} X_b \\ Z_c \end{array}$$

4) Řešení rovnice $[K] \cdot \{r\} = \{F\}$ → $\{r\} = [K]^{-1} \cdot \{F\}$

nebo rozepsat soustavu rovnic

$$21\,568 \ u_b + 0 \ w_c = 43{,}2$$

$$0 \ u_b + 18432 \ w_c = 57{,}6$$

$$\{r\} = \begin{Bmatrix} u_b \\ w_c \end{Bmatrix} = \begin{Bmatrix} 2{,}003 \cdot 10^{-3}\,m \\ 3{,}125 \cdot 10^{-3}\,m \end{Bmatrix}$$

5) Dopočet koncových sil $\{R\} = \{\bar{R}\} + [k]\cdot\{r\}$

$$\{R_{ab}\} = \begin{array}{c} \\ \left\{\begin{array}{c} -16{,}8 \\ 57{,}6 \\ 0 \\ \boxed{16{,}8} \\ -57{,}6 \\ 0 \end{array}\right\} \end{array} \begin{array}{c} \\ \bar{X}_a \\ \bar{Z}_a \\ \bar{M}_a \\ \bar{X}_b \\ \bar{Z}_b \\ \bar{M}_b \end{array} + \begin{array}{cccccc} u_a & w_a & \varphi_a & u_b & w_b & \varphi_b \\ \hline & & & -1568 & & \\ & & & 5376 & & \\ & & & 0 & & \\ & & & \boxed{1568} & & \\ & & & -5376 & & \\ & & & 0 & & \end{array} \begin{array}{c} \\ \hat{X}_a \\ \hat{Z}_a \\ \hat{M}_a \\ \hat{X}_b \\ \hat{Z}_b \\ \hat{M}_b \end{array} \cdot \left\{\begin{array}{c} 0 \\ 0 \\ 0 \\ 2{,}003\cdot 10^{-3} \\ 0 \\ 0 \end{array}\right\} \begin{array}{c} u_a \\ w_a \\ \varphi_a \\ u_b \\ w_b \\ \varphi_b \end{array} = \left\{\begin{array}{c} -19{,}94 \\ 68{,}37 \\ 0 \\ 19{,}94 \\ -68{,}37 \\ 0 \end{array}\right\} \begin{array}{c} X_a \\ Z_a \\ M_a \\ X_b \\ Z_b \\ M_b \end{array}$$

$\rightarrow$ z GSS do LSS: $\{R^*_{ab}\} = [T_{ab}]\cdot\{R_{ab}\} =$

$$\left[\begin{array}{cccccc} 0{,}28 & -0{,}96 & 0 & & & \\ 0{,}96 & 0{,}28 & 0 & & \emptyset & \\ 0 & 0 & 1 & & & \\ & & & 0{,}28 & -0{,}96 & 0 \\ & \emptyset & & 0{,}96 & 0{,}28 & 0 \\ & & & 0 & 0 & 1 \end{array}\right] \left\{\begin{array}{c} -19{,}94 \\ 68{,}37 \\ 0 \\ 19{,}94 \\ -68{,}37 \\ 0 \end{array}\right\} \begin{array}{c} X_a \\ Z_a \\ M_a \\ X_b \\ Z_b \\ M_b \end{array} = \left\{\begin{array}{c} -71{,}22 \\ 0 \\ 0 \\ 71{,}22 \\ 0 \\ 0 \end{array}\right\} \begin{array}{c} X^*_a \\ Z^*_a \\ M^*_a \\ X^*_b \\ Z^*_b \\ M^*_b \end{array}$$

$$\{R_{bc}\} = \begin{array}{c} \\ \left\{\begin{array}{c} \boxed{-60} \\ 0 \\ 0 \\ 60 \\ \boxed{0} \\ 0 \end{array}\right\} \end{array} \begin{array}{c} \\ \bar{X}_b \\ \bar{Z}_b \\ \bar{M}_b \\ \bar{X}_c \\ \bar{Z}_c \\ \bar{M}_c \end{array} + \begin{array}{cccccc} u_b & w_b & \varphi_b & u_c & w_c & \varphi_c \\ \hline \boxed{20000} & & & & \boxed{0} & \\ 0 & & & & 0 & \\ 0 & & & & 0 & \\ -20000 & & & & 0 & \\ \boxed{0} & & & & \boxed{0} & \\ 0 & & & & 0 & \end{array} \begin{array}{c} \\ \hat{X}_b \\ \hat{Z}_b \\ \hat{M}_b \\ \hat{X}_c \\ \hat{Z}_c \\ \hat{M}_c \end{array} \cdot \left\{\begin{array}{c} 2{,}003\cdot 10^{-3} \\ 0 \\ 0 \\ 0 \\ 3{,}125\cdot 10^{-3} \\ 0 \end{array}\right\} \begin{array}{c} u_b \\ w_b \\ \varphi_b \\ u_c \\ w_c \\ \varphi_c \end{array} = \left\{\begin{array}{c} -19{,}94 \\ 0 \\ 0 \\ 19{,}94 \\ 0 \\ 0 \end{array}\right\} \begin{array}{c} X_b \\ Z_b \\ M_b \\ X_c \\ Z_c \\ M_c \end{array}$$

$\rightarrow$ z GSS do LSS : $\{R^*_{bc}\} = [T_{bc}]\cdot\{R_{bc}\} =$

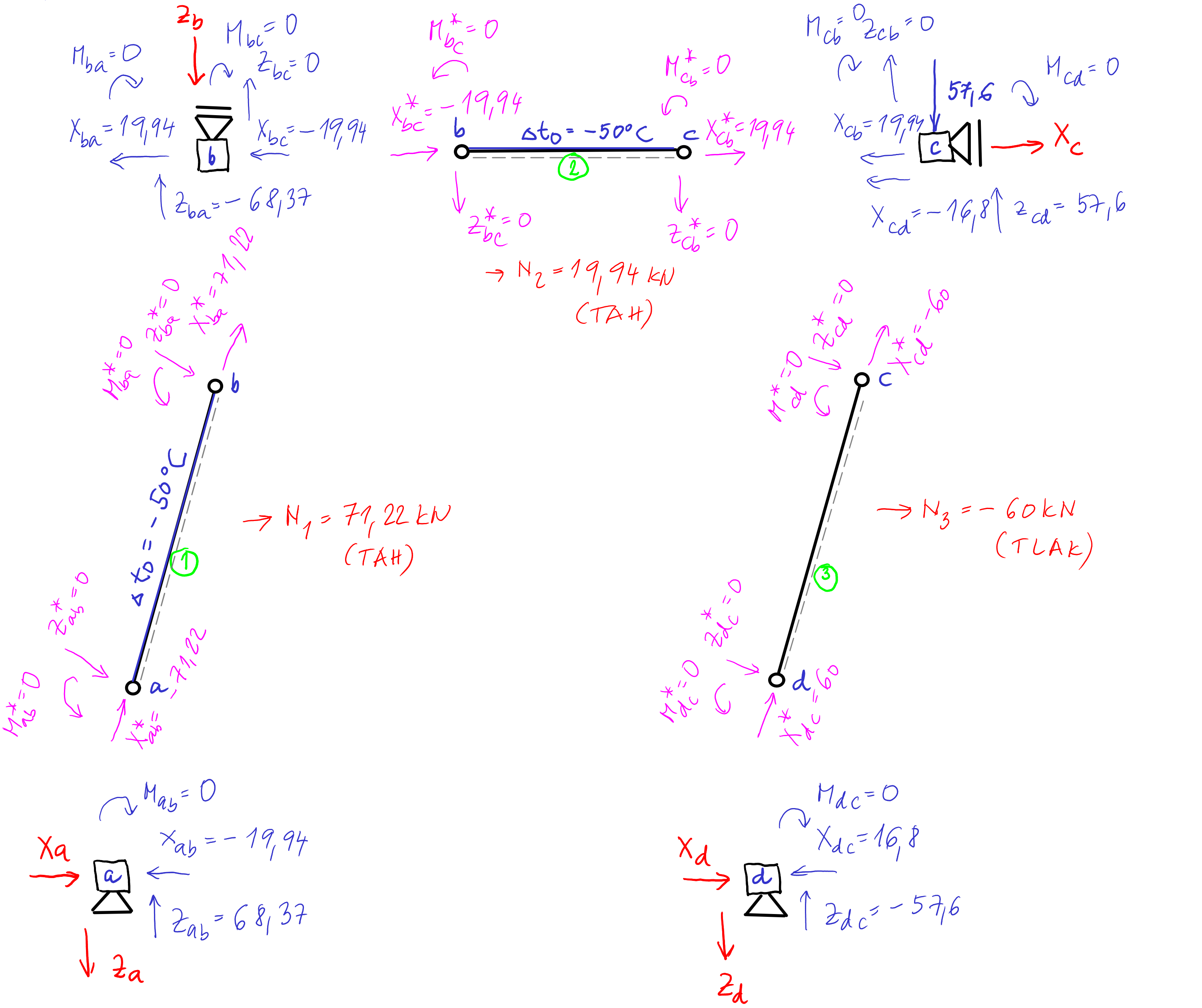
$$\left[\begin{array}{cccccc} 1 & 0 & 0 & & & \\ 0 & 1 & 0 & & \emptyset & \\ 0 & 0 & 1 & & & \\ & & & 1 & 0 & 0 \\ & \emptyset & & 0 & 1 & 0 \\ & & & 0 & 0 & 1 \end{array}\right] \left\{\begin{array}{c} -19{,}94 \\ 0 \\ 0 \\ 19{,}94 \\ 0 \\ 0 \end{array}\right\} \begin{array}{c} X_b \\ Z_b \\ M_b \\ X_c \\ Z_c \\ M_c \end{array} = \left\{\begin{array}{c} -19{,}94 \\ 0 \\ 0 \\ 19{,}94 \\ 0 \\ 0 \end{array}\right\} \begin{array}{c} X^*_b \\ Z^*_b \\ M^*_b \\ X^*_c \\ Z^*_c \\ M^*_c \end{array}$$

$$\{R_{dc}\} = \begin{array}{c} \\ \left\{\begin{array}{c} 0 \\ 0 \\ 0 \\ 0 \\ \boxed{0} \\ 0 \end{array}\right\} \end{array} \begin{array}{c} \\ \bar{X}_d \\ \bar{Z}_d \\ \bar{M}_d \\ \bar{X}_c \\ \bar{Z}_c \\ \bar{M}_c \end{array} + \begin{array}{cccccc} u_d & w_d & \varphi_d & u_c & w_c & \varphi_c \\ \hline & & & & 5376 & \\ & & & & -18432 & \\ & & & & 0 & \\ & & & & -5376 & \\ & & & & \boxed{18432} & \\ & & & & 0 & \end{array} \begin{array}{c} \\ \hat{X}_d \\ \hat{Z}_d \\ \hat{M}_d \\ \hat{X}_c \\ \hat{Z}_c \\ \hat{M}_c \end{array} \cdot \left\{\begin{array}{c} 0 \\ 0 \\ 0 \\ 0 \\ 3{,}125\cdot 10^{-3} \\ 0 \end{array}\right\} \begin{array}{c} u_d \\ w_d \\ \varphi_d \\ u_c \\ w_c \\ \varphi_c \end{array} = \left\{\begin{array}{c} 16{,}8 \\ -57{,}6 \\ 0 \\ -16{,}8 \\ 57{,}6 \\ 0 \end{array}\right\} \begin{array}{c} X_d \\ Z_d \\ M_d \\ X_c \\ Z_c \\ M_c \end{array}$$

$\rightarrow$ z GSS do LSS: $\{R^*_{dc}\} = [T_{dc}]\cdot\{R_{dc}\} =$

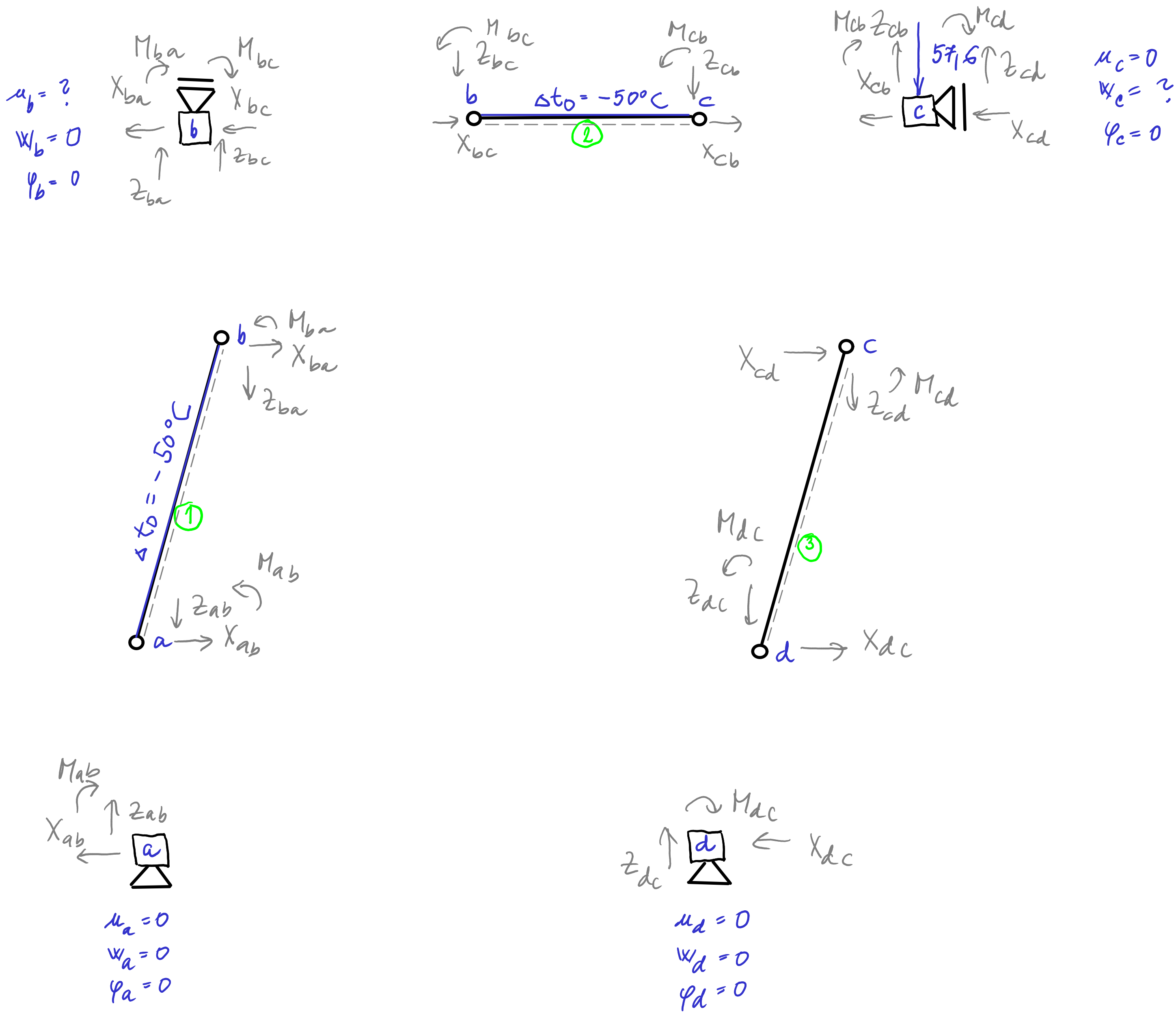
$$\left[\begin{array}{cccccc} 0{,}28 & -0{,}96 & 0 & & & \\ 0{,}96 & 0{,}28 & 0 & & \emptyset & \\ 0 & 0 & 1 & & & \\ & & & 0{,}28 & -0{,}96 & 0 \\ & \emptyset & & 0{,}96 & 0{,}28 & 0 \\ & & & 0 & 0 & 1 \end{array}\right] \left\{\begin{array}{c} 16{,}8 \\ -57{,}6 \\ 0 \\ -16{,}8 \\ 57{,}6 \\ 0 \end{array}\right\} \begin{array}{c} X_d \\ Z_d \\ M_d \\ X_c \\ Z_c \\ M_c \end{array} = \left\{\begin{array}{c} 60 \\ 0 \\ 0 \\ -60 \\ 0 \\ 0 \end{array}\right\} \begin{array}{c} X^*_d \\ Z^*_d \\ M^*_d \\ X^*_c \\ Z^*_c \\ M^*_c \end{array}$$

5) Kontrola rovnováhy → dopočet reakcí, vykreslení vnitřních sil



styčník	a	b	c	d
$\Sigma F_{ix}=0$:	$X_a - X_{ab}=0$ $X_a=-19{,}94$ kN	$-X_{ba}-X_{bc}=0$ ✓	$X_c - X_{cb} - X_{cd}=0$ $X_c=3{,}14$ kN	$X_d - X_{dc}=0$ $X_d=16{,}8$ kN
$\Sigma F_{iz}=0$:	$Z_a - Z_{ab}=0$ $Z_a=68{,}37$ kN	$Z_b - Z_{ba} - Z_{bc}=0$ $Z_b=-68{,}37$ kN	$-Z_{cb}-Z_{cd}+F=0$ ✓	$Z_d - Z_{dc}=0$ $Z_d=-57{,}6$ kN
$\Sigma M_i=0$	$0=0$ ✓	$0+0=0$ ✓	$0+0=0$ ✓	$0=0$ ✓

→ SKALÁRNÍ FORMA (VÝPOČET NORMÁLOVÝCH SIL)
(siny a cosiny viz maticová forma)



1) neznámé deformace + odpovídající rovnice rovnováhy ve styčnících:

$u_b : \sum F_{ix,b} = 0 \qquad X_{ba} + X_{bc} = 0$

$w_c : \sum F_{iz,c} = 0 \qquad Z_{cb} + Z_{cd} - 57{,}6 = 0$

2) vyjádření koncových sil pomocí tuhosti a deformací:

$$X_{ba} = N_1 \cdot c_{ab} = \frac{EA}{\ell_{ab}} \left[(u_b - 0) \cdot c_{ab} + (0-0) \cdot s_{ab} \right] \cdot c_{ab} - EA \alpha_T \Delta t_0 \, c_{ab}$$

$$X_{ba} = \frac{100 \cdot 10^3}{5} \left[0{,}28 \, u_b \right] \cdot 0{,}28 - 100 \cdot 10^3 \cdot 1{,}2 \cdot 10^{-5} \cdot (-50) \cdot 0{,}28$$

$$X_{bc} = -N_2 \cdot c_{bc} = -\frac{EA}{\ell_{bc}} \left[(0 - u_b) \cdot c_{bc} + (w_c - 0) \, s_{bc} \right] \cdot c_{bc} + EA \alpha_T \Delta t_0 \, c_{bc}$$

$$X_{bc} = -\frac{100 \cdot 10^3}{5} \left[-1 u_b \right] \cdot 1 + 100 \cdot 10^3 \cdot 1{,}2 \cdot 10^{-5} \cdot (-50) \cdot 1$$

$$Z_{cb} = N_2 \cdot s_{bc} = \frac{EA}{\ell_{bc}} \left[(0 - u_b) \cdot c_{bc} + (w_c - 0) \cdot s_{bc} \right] \cdot s_{bc} - EA \alpha_T \Delta t_0 \cdot s_{bc}$$

$$Z_{cb} = \emptyset$$

$$Z_{cd} = N_3 \cdot s_{dc} = \frac{EA}{\ell_{dc}} \left[(0-0) \cdot c_{dc} + (w_c - 0) \cdot s_{dc} \right] \cdot s_{dc}$$

$$Z_{cd} = \frac{100 \cdot 10^3}{5} \left[-0{,}96 \cdot w_c \right] \cdot (-0{,}96)$$

3) Dosazení, úprava a řešení soustavy rovnic:

$$u_b: \quad 1568 \, u_b + 16{,}8 + 20\,000 \, u_b - 60 = 0$$

$$w_c: \quad 18\,432 \, w_c - 57{,}6 = 0$$

$$21\,568 \, u_b = 43{,}2 \quad \longrightarrow \quad u_b = 2{,}003 \cdot 10^{-3} \, m$$

$$18\,432 \, w_c = 57{,}6 \quad \longrightarrow \quad w_c = 3{,}125 \cdot 10^{-3} \, m$$

4) Dopočet normálových sil:

$$X_{ba} = N_1 \cdot c_{ab} = \frac{EA}{\ell_{ab}} \left[(u_b - 0) \cdot c_{ab} + (0-0) \cdot s_{ab} \right] \cdot c_{ab} - EA \alpha_T \Delta t_0 \, c_{ab}$$

$$N_1 = \frac{100 \cdot 10^3}{5} \left[2{,}003 \cdot 10^{-3} \cdot 0{,}28 \right] - 100 \cdot 10^3 \cdot 1{,}2 \cdot 10^{-5} \cdot (-50) \doteq 71{,}22 \text{ kN}$$

$$\underline{\underline{N_1 = 71{,}22 \text{ kN} \quad (\text{TAH})}}$$

$$X_{bc} = -N_2 \cdot c_{bc} = -\frac{EA}{\ell_{bc}} \left[(0 - u_b) \cdot c_{bc} + (w_c - 0) \, s_{bc} \right] \cdot c_{bc} + EA \alpha_T \Delta t_0 \, c_{bc}$$

nebo

$$Z_{cb} = N_2 \cdot s_{bc} = \frac{EA}{\ell_{bc}} \left[(0 - u_b) \cdot c_{bc} + (w_c - 0) \cdot s_{bc} \right] \cdot s_{bc} - EA \alpha_T \Delta t_0 \cdot s_{bc}$$

$$N_2 = \frac{100 \cdot 10^3}{5} \left(-2{,}003 \cdot 10^{-3} \cdot 1 \right) - 100 \cdot 10^3 \cdot 1{,}2 \cdot 10^{-5} \cdot (-50) = 19{,}94 \text{ kN}$$

$$\underline{\underline{N_2 = 19{,}94 \text{ kN} \quad (\text{TAH})}}$$

$$X_{dc} = -N_3 \cdot c_{dc} = -\frac{EA}{\ell_{dc}} \left[(u_c - u_d) \, c_{dc} + (w_c - w_d) \, s_{dc} \right] \cdot c_{dc}$$

$$-N_3 = -\frac{100 \cdot 10^3}{5} \left[3{,}125 \cdot 10^{-3} \cdot (-0{,}96) \right] = 60 \text{kN}$$

$$\underline{\underline{N_3 = -60 \text{ kN} \quad (\text{TLAK})}}$$