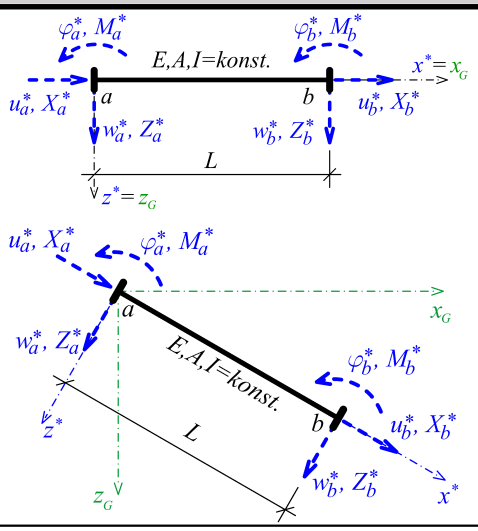
## Vetknutí - Vetknutí |————|

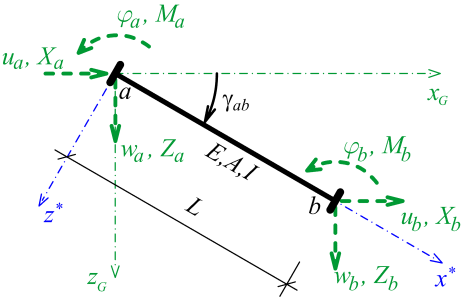






Lokální matice tuhosti

$$\left[K^*_{a,b}\right]=\begin{array}{c|cccccc} & u^*_a & w^*_a & \varphi^*_a & u^*_b & w^*_b & \varphi^*_b \\ \hline X^*_a & \frac{EA}{L} & 0 & 0 & -\frac{EA}{L} & 0 & 0 \\ Z^*_a & 0 & \frac{12EI}{L^3} & -\frac{6EI}{L^2} & 0 & -\frac{12EI}{L^3} & -\frac{6EI}{L^2} \\ M^*_a & 0 & -\frac{6EI}{L^2} & \frac{4EI}{L} & 0 & \frac{6EI}{L^2} & \frac{2EI}{L} \\ \hline X^*_b & -\frac{EA}{L} & 0 & 0 & \frac{EA}{L} & 0 & 0 \\ Z^*_b & 0 & -\frac{12EI}{L^3} & \frac{6EI}{L^2} & 0 & \frac{12EI}{L^3} & \frac{6EI}{L^2} \\ M^*_b & 0 & -\frac{6EI}{L^2} & \frac{2EI}{L} & 0 & \frac{6EI}{L^2} & \frac{4EI}{L} \end{array}$$



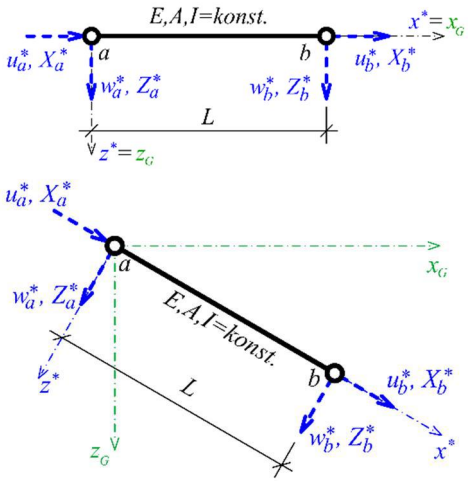

$$D=\frac{EA}{L}-\frac{12EI}{L^3}$$

$$c=\cos(\gamma_{ab})$$
$$s=\sin(\gamma_{ab})$$

Globální matice tuhosti

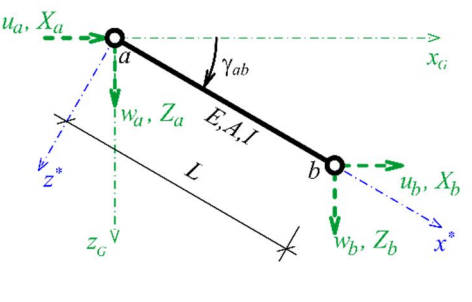
$$\left[K_{a,b}\right]=\begin{array}{c|cccccc} & u_a & w_a & \varphi_a & u_b & w_b & \varphi_b \\ \hline X_a & \left(\frac{12EI}{L^3}+Dc^2\right) & Dcs & \frac{6EI}{L^2}s & -\left(\frac{12EI}{L^3}+Dc^2\right) & -Dcs & \frac{6EI}{L^2}s \\ Z_a & Dcs & \left(\frac{EA}{L}-Dc^2\right) & -\frac{6EI}{L^2}c & -Dcs & -\left(\frac{EA}{L}-Dc^2\right) & -\frac{6EI}{L^2}c \\ M_a & \frac{6EI}{L^2}s & -\frac{6EI}{L^2}c & \frac{4EI}{L} & -\frac{6EI}{L^2}s & \frac{6EI}{L^2}c & \frac{2EI}{L} \\ \hline X_b & -\left(\frac{12EI}{L^3}+Dc^2\right) & -Dcs & -\frac{6EI}{L^2}s & \left(\frac{12EI}{L^3}+Dc^2\right) & Dcs & -\frac{6EI}{L^2}s \\ Z_b & -Dcs & -\left(\frac{EA}{L}-Dc^2\right) & \frac{6EI}{L^2}c & Dcs & \left(\frac{EA}{L}-Dc^2\right) & \frac{6EI}{L^2}c \\ M_b & \frac{6EI}{L^2}s & -\frac{6EI}{L^2}c & \frac{2EI}{L} & -\frac{6EI}{L^2}s & \frac{6EI}{L^2}c & \frac{4EI}{L} \end{array}$$

## Kloub - Kloub o————o




Lokální matice tuhosti

$$\left[K^*_{a,b}\right]=\begin{array}{c|cccccc} & u^*_a & w^*_a & \varphi^*_a & u^*_b & w^*_b & \varphi^*_b \\ \hline X^*_a & \frac{EA}{L} & 0 & 0 & -\frac{EA}{L} & 0 & 0 \\ Z^*_a & 0 & 0 & 0 & 0 & 0 & 0 \\ M^*_a & 0 & 0 & 0 & 0 & 0 & 0 \\ \hline X^*_b & -\frac{EA}{L} & 0 & 0 & \frac{EA}{L} & 0 & 0 \\ Z^*_b & 0 & 0 & 0 & 0 & 0 & 0 \\ M^*_b & 0 & 0 & 0 & 0 & 0 & 0 \end{array}$$



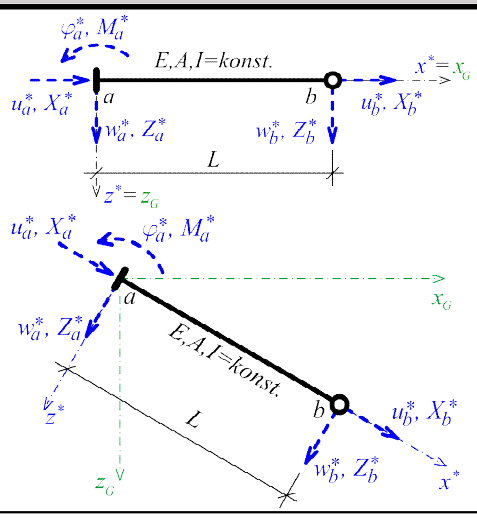

$$c=\cos(\gamma_{ab})$$
$$s=\sin(\gamma_{ab})$$

Globální matice tuhosti

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

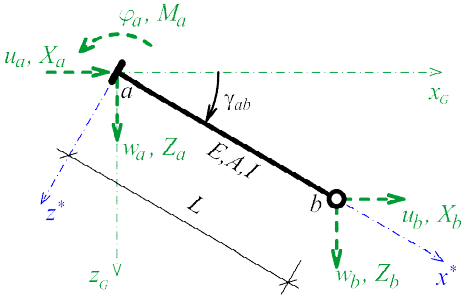
Ing. Zbyněk Vlk, Ph.D. - 2024

## Vetknutí - Kloub




**Lokální matice tuhosti**

$$\left[K^*_{a,b}\right]=\begin{array}{c}\begin{matrix}u_a^* & w_a^* & \varphi_a^* & u_b^* & w_b^* & \varphi_b^*\end{matrix}\\ \left[\begin{array}{cccc:cc} \frac{EA}{L} & 0 & 0 & -\frac{EA}{L} & 0 & 0 \\ 0 & \frac{3EI}{L^3} & -\frac{3EI}{L^2} & 0 & -\frac{3EI}{L^3} & 0 \\ 0 & -\frac{3EI}{L^2} & \frac{3EI}{L} & 0 & \frac{3EI}{L^2} & 0 \\ \hdashline -\frac{EA}{L} & 0 & 0 & \frac{EA}{L} & 0 & 0 \\ 0 & -\frac{3EI}{L^3} & \frac{3EI}{L^2} & 0 & \frac{3EI}{L^3} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{array}\right]\end{array}\begin{matrix}X_a^*\\ Z_a^*\\ M_a^*\\ X_b^*\\ Z_b^*\\ M_b^*\end{matrix}$$

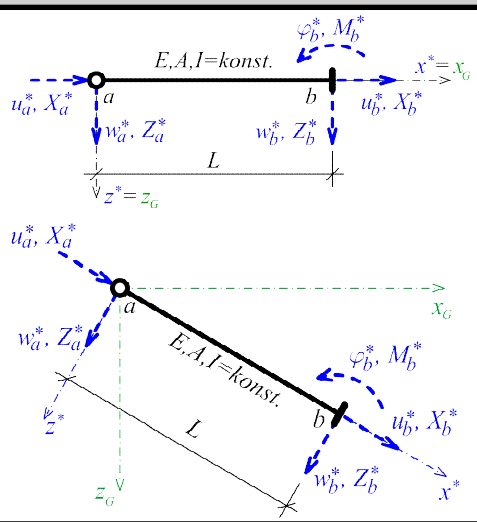



$$D=\frac{EA}{L}-\frac{3EI}{L^3}\qquad c=\cos(\gamma_{ab})\qquad s=\sin(\gamma_{ab})$$

**Globální matice tuhosti**

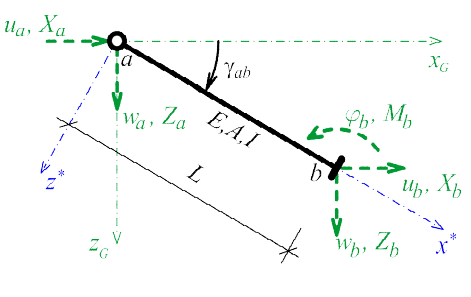
$$\left[K_{a,b}\right]=\begin{array}{c}\begin{matrix}u_a & w_a & \varphi_a & u_b & w_b & \varphi_b\end{matrix}\\ \left[\begin{array}{cccc:cc} \left(\frac{3EI}{L^3}+Dc^2\right) & Dcs & \frac{3EI}{L^2}s & -\left(\frac{3EI}{L^3}+Dc^2\right) & -Dcs & 0 \\ Dcs & \left(\frac{EA}{L}-Dc^2\right) & -\frac{3EI}{L^2}c & -Dcs & -\left(\frac{EA}{L}-Dc^2\right) & 0 \\ \frac{3EI}{L^2}s & -\frac{3EI}{L^2}c & \frac{3EI}{L} & -\frac{3EI}{L^2}s & \frac{3EI}{L^2}c & 0 \\ \hdashline -\left(\frac{3EI}{L^3}+Dc^2\right) & -Dcs & -\frac{3EI}{L^2}s & \left(\frac{3EI}{L^3}+Dc^2\right) & Dcs & 0 \\ -Dcs & -\left(\frac{EA}{L}-Dc^2\right) & \frac{3EI}{L^2}c & Dcs & \left(\frac{EA}{L}-Dc^2\right) & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{array}\right]\end{array}\begin{matrix}X_a\\ Z_a\\ M_a\\ X_b\\ Z_b\\ M_b\end{matrix}$$

## Kloub - Vetknutí




**Lokální matice tuhosti**

$$\left[K^*_{a,b}\right]=\begin{array}{c}\begin{matrix}u_a^* & w_a^* & \varphi_a^* & u_b^* & w_b^* & \varphi_b^*\end{matrix}\\ \left[\begin{array}{cccc:cc} \frac{EA}{L} & 0 & 0 & -\frac{EA}{L} & 0 & 0 \\ 0 & \frac{3EI}{L^3} & 0 & 0 & -\frac{3EI}{L^3} & -\frac{3EI}{L^2} \\ 0 & 0 & 0 & 0 & 0 & 0 \\ \hdashline -\frac{EA}{L} & 0 & 0 & \frac{EA}{L} & 0 & 0 \\ 0 & -\frac{3EI}{L^3} & 0 & 0 & \frac{3EI}{L^3} & \frac{3EI}{L^2} \\ 0 & -\frac{3EI}{L^2} & 0 & 0 & \frac{3EI}{L^2} & \frac{3EI}{L} \end{array}\right]\end{array}\begin{matrix}X_a^*\\ Z_a^*\\ M_a^*\\ X_b^*\\ Z_b^*\\ M_b^*\end{matrix}$$




$$D=\frac{EA}{L}-\frac{3EI}{L^3}\qquad c=\cos(\gamma_{ab})\qquad s=\sin(\gamma_{ab})$$

**Globální matice tuhosti**

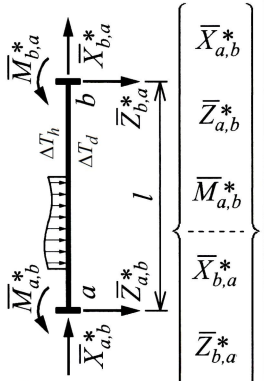
$$\left[K_{a,b}\right]=\begin{array}{c}\begin{matrix}u_a & w_a & \varphi_a & u_b & w_b & \varphi_b\end{matrix}\\ \left[\begin{array}{cccc:cc} \left(\frac{3EI}{L^3}+Dc^2\right) & Dcs & 0 & -\left(\frac{3EI}{L^3}+Dc^2\right) & -Dcs & \frac{3EI}{L^2}s \\ Dcs & \left(\frac{EA}{L}-Dc^2\right) & 0 & -Dcs & -\left(\frac{EA}{L}-Dc^2\right) & -\frac{3EI}{L^2}c \\ 0 & 0 & 0 & 0 & 0 & 0 \\ \hdashline -\left(\frac{3EI}{L^3}+Dc^2\right) & -Dcs & 0 & \left(\frac{3EI}{L^3}+Dc^2\right) & Dcs & -\frac{3EI}{L^2}s \\ -Dcs & -\left(\frac{EA}{L}-Dc^2\right) & 0 & Dcs & \left(\frac{EA}{L}-Dc^2\right) & \frac{3EI}{L^2}c \\ \frac{3EI}{L^2}s & -\frac{3EI}{L^2}c & 0 & -\frac{3EI}{L^2}s & \frac{3EI}{L^2}c & \frac{3EI}{L} \end{array}\right]\end{array}\begin{matrix}X_a\\ Z_a\\ M_a\\ X_b\\ Z_b\\ M_b\end{matrix}$$

Ing. Zbyněk Vlk, Ph.D. - 2024

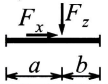
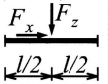
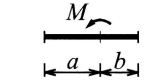
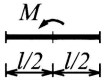
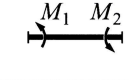
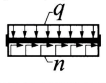
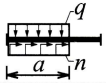
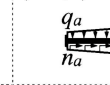
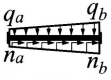
# Tabulka 8.1 Primární lokální vektory koncových sil prutu $\{R^*_{a,b}\}$

Oprava: Ing. Zbyněk Vlk, Ph.D. - 2025

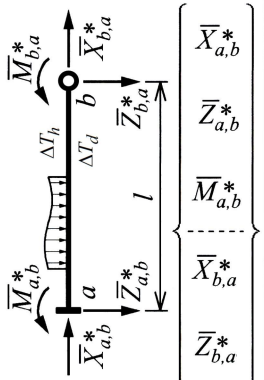
## (a)



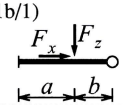
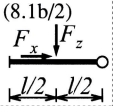
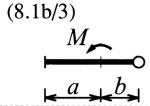
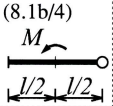
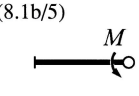
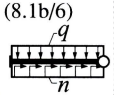
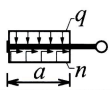
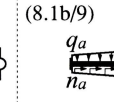
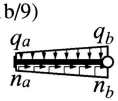
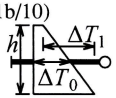

Obdélník.průřez:
$\Delta T_0=(\Delta T_d+\Delta T_h)/2$
$\Delta T_1=\Delta T_d-\Delta T_h$

| | (8.1a/1) | (8.1a/2) | (8.1a/3) | (8.1a/4) | (8.1a/5) | (8.1a/6) | (8.1a/7) | (8.1a/8) | (8.1a/9) | (8.1a/10) |
|---|---|---|---|---|---|---|---|---|---|---|
| |  |  |  |  |  |  |  |  |  |  |
| $\overline{X}^*_{a,b}$ | $-\frac{b}{l}F_x$ | $-\frac{1}{2}F_x$ | $0$ | $0$ | $0$ | $-\frac{1}{2}nl$ | $-\frac{2al-a^2}{2l}n$ | $-\frac{1}{8}nl$ | $-\frac{2n_a+n_b}{6}l$ | $EA\alpha_T\Delta T_0$ |
| $\overline{Z}^*_{a,b}$ | $-b^2\frac{3l-2b}{l^3}F_z$ | $-\frac{1}{2}F_z$ | $-6\frac{ab}{l^3}M$ | $-\frac{3}{2}\frac{M}{l}$ | $0$ | $-\frac{1}{2}ql$ | $-\frac{2al^3-2a^3l+a^4}{2l^3}q$ | $-\frac{3}{32}ql$ | $-\frac{7q_a+3q_b}{20}l$ | $0$ |
| $\overline{M}^*_{a,b}$ | $\frac{ab^2}{l^2}F_z$ | $\frac{1}{8}F_zl$ | $b\frac{2l-3b}{l^2}M$ | $\frac{1}{4}M$ | $-M_1$ | $\frac{1}{12}ql^2$ | $\frac{6a^2l^2-8a^3l+3a^4}{12l^2}q$ | $\frac{5}{192}ql^2$ | $\frac{3q_a+2q_b}{60}l^2$ | $\frac{EI}{h}\alpha_T\Delta T_1$ |
| $\overline{X}^*_{b,a}$ | $-\frac{a}{l}F_x$ | $-\frac{1}{2}F_x$ | $0$ | $0$ | $0$ | $-\frac{1}{2}nl$ | $-\frac{a^2}{2l}n$ | $-\frac{3}{8}nl$ | $-\frac{n_a+2n_b}{6}l$ | $-EA\alpha_T\Delta T_0$ |
| $\overline{Z}^*_{b,a}$ | $-a^2\frac{3l-2a}{l^3}F_z$ | $-\frac{1}{2}F_z$ | $6\frac{ab}{l^3}M$ | $\frac{3}{2}\frac{M}{l}$ | $0$ | $-\frac{1}{2}ql$ | $-\frac{2a^3l-a^4}{2l^3}q$ | $-\frac{13}{32}ql$ | $-\frac{3q_a+7q_b}{20}l$ | $0$ |
| $\overline{M}^*_{b,a}$ | $-\frac{a^2b}{l^2}F_z$ | $-\frac{1}{8}F_zl$ | $a\frac{2l-3a}{l^2}M$ | $\frac{1}{4}M$ | $-M_2$ | $-\frac{1}{12}ql^2$ | $-\frac{4a^3l-3a^4}{12l^2}q$ | $-\frac{11}{192}ql^2$ | $-\frac{2q_a+3q_b}{60}l^2$ | $-\frac{EI}{h}\alpha_T\Delta T_1$ |

## (b)



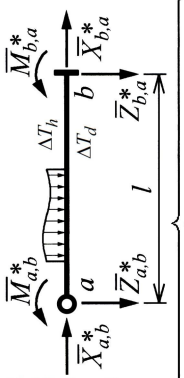

Obdélník.průřez:
$\Delta T_0=(\Delta T_d+\Delta T_h)/2$
$\Delta T_1=\Delta T_d-\Delta T_h$

| | (8.1b/1) | (8.1b/2) | (8.1b/3) | (8.1b/4) | (8.1b/5) | (8.1b/6) | (8.1b/7) | (8.1b/8) | (8.1b/9) | (8.1b/10) |
|---|---|---|---|---|---|---|---|---|---|---|
| |  |  |  |  |  |  |  |  |  |  |
| $\overline{X}^*_{a,b}$ | $-\frac{b}{l}F_x$ | $-\frac{1}{2}F_x$ | $0$ | $0$ | $0$ | $-\frac{1}{2}nl$ | $-\frac{2al-a^2}{2l}n$ | $-\frac{1}{8}nl$ | $-\frac{2n_a+n_b}{6}l$ | $EA\alpha_T\Delta T_0$ |
| $\overline{Z}^*_{a,b}$ | $-b\frac{3l^2-b^2}{2l^3}F_z$ | $-\frac{11}{16}F_z$ | $-3\frac{l^2-b^2}{2l^3}M$ | $-\frac{9}{8}\frac{M}{l}$ | $-\frac{3}{2}\frac{M}{l}$ | $-\frac{5}{8}ql$ | $-\frac{8al^3-4a^3l+a^4}{8l^3}q$ | $-\frac{23}{128}ql$ | $-\frac{16q_a+9q_b}{40}l$ | $-\frac{3}{2}\frac{EI}{hl}\alpha_T\Delta T_1$ |
| $\overline{M}^*_{a,b}$ | $ab\frac{l+b}{2l^2}F_z$ | $\frac{3}{16}F_zl$ | $\frac{l^2-3b^2}{2l^2}M$ | $\frac{1}{8}M$ | $\frac{1}{2}M$ | $\frac{1}{8}ql^2$ | $\frac{(2al-a^2)^2}{8l^2}q$ | $\frac{7}{128}ql^2$ | $\frac{8q_a+7q_b}{120}l^2$ | $\frac{3}{2}\frac{EI}{h}\alpha_T\Delta T_1$ |
| $\overline{X}^*_{b,a}$ | $-\frac{a}{l}F_x$ | $-\frac{1}{2}F_x$ | $0$ | $0$ | $0$ | $-\frac{1}{2}nl$ | $-\frac{a^2}{2l}n$ | $-\frac{3}{8}nl$ | $-\frac{n_a+2n_b}{6}l$ | $-EA\alpha_T\Delta T_0$ |
| $\overline{Z}^*_{b,a}$ | $-a^2\frac{3l-a}{2l^3}F_z$ | $-\frac{5}{16}F_z$ | $3\frac{l^2-b^2}{2l^3}M$ | $\frac{9}{8}\frac{M}{l}$ | $\frac{3}{2}\frac{M}{l}$ | $-\frac{3}{8}ql$ | $-\frac{4a^3l-a^4}{8l^3}q$ | $-\frac{41}{128}ql$ | $-\frac{4q_a+11q_b}{40}l$ | $\frac{3}{2}\frac{EI}{hl}\alpha_T\Delta T_1$ |
| $\overline{M}^*_{b,a}$ | $0$ | $0$ | $0$ | $0$ | $0$ | $0$ | $0$ | $0$ | $0$ | $0$ |

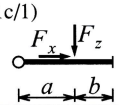
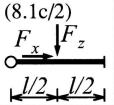
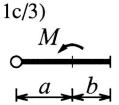
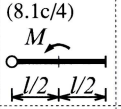
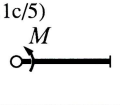
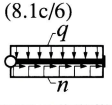
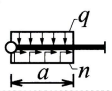
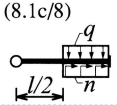
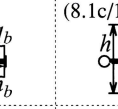
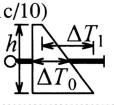
# Tabulka 8.1 Primární lokální vektory koncových sil prutu $\{R^*_{a,b}\}$ (pokračování)

Oprava: Ing. Zbyněk Vlk, Ph.D. - 2025

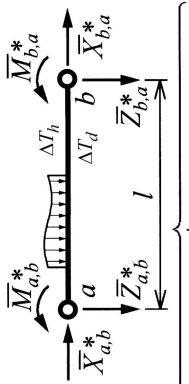
## (c)



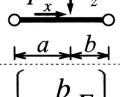
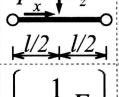
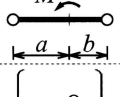
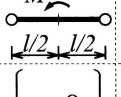
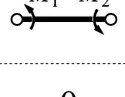
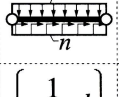
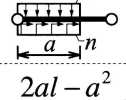
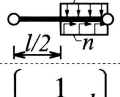
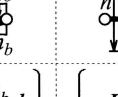
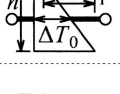

Obdélník.průřez:
$\Delta T_0=(\Delta T_d+\Delta T_h)/2$
$\Delta T_1=\Delta T_d-\Delta T_h$

| | (8.1c/1) | (8.1c/2) | (8.1c/3) | (8.1c/4) | (8.1c/5) | (8.1c/6) | (8.1c/7) | (8.1c/8) | (8.1c/9) | (8.1c/10) |
|---|---|---|---|---|---|---|---|---|---|---|
| |  |  |  |  |  |  |  |  |  |  |
| $\overline{X}^*_{a,b}$ | $-\frac{b}{l}F_x$ | $-\frac{1}{2}F_x$ | $0$ | $0$ | $0$ | $-\frac{1}{2}nl$ | $-\frac{2al-a^2}{2l}n$ | $-\frac{1}{8}nl$ | $-\frac{2n_a+n_b}{6}l$ | $EA\alpha_T\Delta T_0$ |
| $\overline{Z}^*_{a,b}$ | $-b^2\frac{3l-b}{2l^3}F_z$ | $-\frac{5}{16}F_z$ | $-3\frac{l^2-a^2}{2l^3}M$ | $-\frac{9}{8}\frac{M}{l}$ | $-\frac{3}{2}\frac{M}{l}$ | $-\frac{3}{8}ql$ | $-\frac{8al^3-6a^2l^2+a^4}{8l^3}q$ | $-\frac{7}{128}ql$ | $-\frac{11q_a+4q_b}{40}l$ | $\frac{3}{2}\frac{EI}{hl}\alpha_T\Delta T_1$ |
| $\overline{M}^*_{a,b}$ | $0$ | $0$ | $0$ | $0$ | $0$ | $0$ | $0$ | $0$ | $0$ | $0$ |
| $\overline{X}^*_{b,a}$ | $-\frac{a}{l}F_x$ | $-\frac{1}{2}F_x$ | $0$ | $0$ | $0$ | $-\frac{1}{2}nl$ | $-\frac{a^2}{2l}n$ | $-\frac{3}{8}nl$ | $-\frac{n_a+2n_b}{6}l$ | $-EA\alpha_T\Delta T_0$ |
| $\overline{Z}^*_{b,a}$ | $-a\frac{3l^2-a^2}{2l^3}F_z$ | $-\frac{11}{16}F_z$ | $3\frac{l^2-a^2}{2l^3}M$ | $\frac{9}{8}\frac{M}{l}$ | $\frac{3}{2}\frac{M}{l}$ | $-\frac{5}{8}ql$ | $-\frac{6a^2l^2-a^4}{8l^3}q$ | $-\frac{57}{128}ql$ | $-\frac{9q_a+16q_b}{40}l$ | $-\frac{3}{2}\frac{EI}{hl}\alpha_T\Delta T_1$ |
| $\overline{M}^*_{b,a}$ | $-ab\frac{l+a}{2l^2}F_z$ | $-\frac{3}{16}F_zl$ | $\frac{l^2-3a^2}{2l^2}M$ | $\frac{1}{8}M$ | $\frac{1}{2}M$ | $-\frac{1}{8}ql^2$ | $-\frac{2a^2l^2-a^4}{8l^2}q$ | $-\frac{9}{128}ql^2$ | $-\frac{7q_a+8q_b}{120}l^2$ | $-\frac{3}{2}\frac{EI}{h}\alpha_T\Delta T_1$ |

## (d)




Obdélník.průřez:
$\Delta T_0=(\Delta T_d+\Delta T_h)/2$
$\Delta T_1=\Delta T_d-\Delta T_h$

| | (8.1d/1) | (8.1d/2) | (8.1d/3) | (8.1d/4) | (8.1d/5) | (8.1d/6) | (8.1d/7) | (8.1d/8) | (8.1d/9) | (8.1d/10) |
|---|---|---|---|---|---|---|---|---|---|---|
| |  |  |  |  |  |  |  |  |  |  |
| $\overline{X}^*_{a,b}$ | $-\frac{b}{l}F_x$ | $-\frac{1}{2}F_x$ | $0$ | $0$ | $0$ | $-\frac{1}{2}nl$ | $-\frac{2al-a^2}{2l}n$ | $-\frac{1}{8}nl$ | $-\frac{2n_a+n_b}{6}l$ | $EA\alpha_T\Delta T_0$ |
| $\overline{Z}^*_{a,b}$ | $-\frac{b}{l}F_z$ | $-\frac{1}{2}F_z$ | $-\frac{M}{l}$ | $-\frac{M}{l}$ | $-\frac{M_1+M_2}{l}$ | $-\frac{1}{2}ql$ | $-\frac{2al-a^2}{2l}q$ | $-\frac{1}{8}ql$ | $-\frac{2q_a+q_b}{6}l$ | $0$ |
| $\overline{M}^*_{a,b}$ | $0$ | $0$ | $0$ | $0$ | $0$ | $0$ | $0$ | $0$ | $0$ | $0$ |
| $\overline{X}^*_{b,a}$ | $-\frac{a}{l}F_x$ | $-\frac{1}{2}F_x$ | $0$ | $0$ | $0$ | $-\frac{1}{2}nl$ | $-\frac{a^2}{2l}n$ | $-\frac{3}{8}nl$ | $-\frac{n_a+2n_b}{6}l$ | $-EA\alpha_T\Delta T_0$ |
| $\overline{Z}^*_{b,a}$ | $-\frac{a}{l}F_z$ | $-\frac{1}{2}F_z$ | $\frac{M}{l}$ | $\frac{M}{l}$ | $\frac{M_1+M_2}{l}$ | $-\frac{1}{2}ql$ | $-\frac{a^2}{2l}q$ | $-\frac{3}{8}ql$ | $-\frac{q_a+2q_b}{6}l$ | $0$ |
| $\overline{M}^*_{b,a}$ | $0$ | $0$ | $0$ | $0$ | $0$ | $0$ | $0$ | $0$ | $0$ | $0$ |

# Transformace vektorů

z lokálních do globálních souřadnic

$$\left\{\bar{\mathbf{R}}^{*}_{a,b}\right\} \;\rightarrow\; \left\{\bar{\mathbf{R}}_{a,b}\right\}$$

$$\left\{\bar{\mathbf{R}}_{a,b}\right\} = \left\{\begin{array}{c} \bar{X}^{*}_{a}\cos\gamma_{ab} - \bar{Z}^{*}_{a}\sin\gamma_{ab} \\ \bar{X}^{*}_{a}\sin\gamma_{ab} + \bar{Z}^{*}_{a}\cos\gamma_{ab} \\ \bar{M}^{*}_{a} \\ \hline \bar{X}^{*}_{b}\cos\gamma_{ab} - \bar{Z}^{*}_{b}\sin\gamma_{ab} \\ \bar{X}^{*}_{b}\sin\gamma_{ab} + \bar{Z}^{*}_{b}\cos\gamma_{ab} \\ \bar{M}^{*}_{b} \end{array}\right\}$$

z globálních do lokálních souřadnic

$$\left\{\mathbf{r}_{a,b}\right\} \;\rightarrow\; \left\{\mathbf{r}^{*}_{a,b}\right\}$$

$$\left\{\mathbf{r}^{*}_{a,b}\right\} = \left\{\begin{array}{c} u_{a}\cos\gamma_{ab} + w_{a}\sin\gamma_{ab} \\ -u_{a}\sin\gamma_{ab} + w_{a}\cos\gamma_{ab} \\ \varphi_{a} \\ \hline u_{b}\cos\gamma_{ab} + w_{b}\sin\gamma_{ab} \\ -u_{b}\sin\gamma_{ab} + w_{b}\cos\gamma_{ab} \\ \varphi_{b} \end{array}\right\}$$