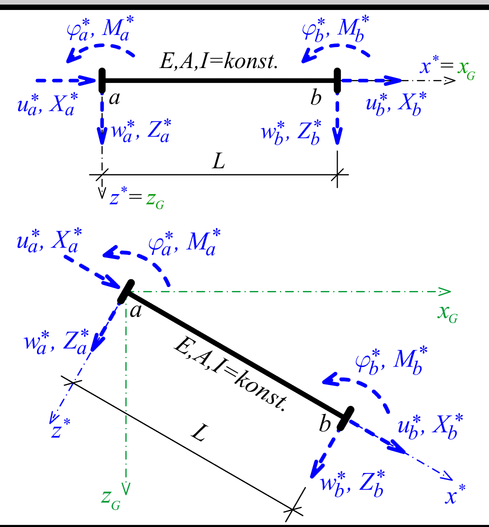
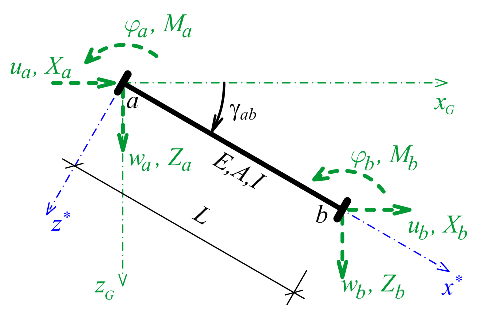
Vetknutí - Vetknutí |———|

Lokální matice tuhosti



$$\left[K^*_{a,b}\right]=\begin{array}{c}\begin{matrix} u_a^* & w_a^* & \varphi_a^* & u_b^* & w_b^* & \varphi_b^* \end{matrix}\\ \left[\begin{array}{ccc|ccc} \frac{EA}{L} & 0 & 0 & -\frac{EA}{L} & 0 & 0 \\ 0 & \frac{12EI}{L^3} & -\frac{6EI}{L^2} & 0 & -\frac{12EI}{L^3} & -\frac{6EI}{L^2} \\ 0 & -\frac{6EI}{L^2} & \frac{4EI}{L} & 0 & \frac{6EI}{L^2} & \frac{2EI}{L} \\ \hline -\frac{EA}{L} & 0 & 0 & \frac{EA}{L} & 0 & 0 \\ 0 & -\frac{12EI}{L^3} & \frac{6EI}{L^2} & 0 & \frac{12EI}{L^3} & \frac{6EI}{L^2} \\ 0 & -\frac{6EI}{L^2} & \frac{2EI}{L} & 0 & \frac{6EI}{L^2} & \frac{4EI}{L} \end{array}\right]\end{array}\begin{matrix} X_a^* \\ Z_a^* \\ M_a^* \\ X_b^* \\ Z_b^* \\ M_b^* \end{matrix}$$

Globální matice tuhosti



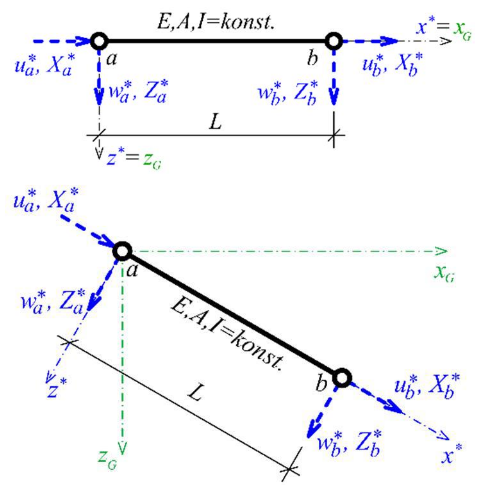
$$D=\frac{EA}{L}-\frac{12EI}{L^3}$$

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

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

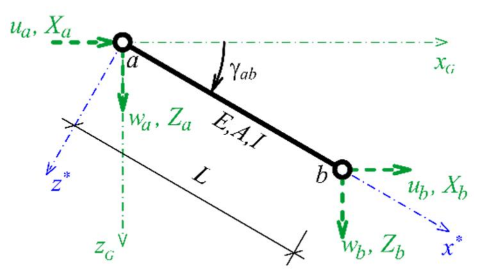
Kloub - Kloub o———o

Lokální matice tuhosti



$$\left[K^*_{a,b}\right]=\begin{array}{c}\begin{matrix} u_a^* & w_a^* & \varphi_a^* & u_b^* & w_b^* & \varphi_b^* \end{matrix}\\ \left[\begin{array}{ccc|ccc} \frac{EA}{L} & 0 & 0 & -\frac{EA}{L} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ \hline -\frac{EA}{L} & 0 & 0 & \frac{EA}{L} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{array}\right]\end{array}\begin{matrix} X_a^* \\ Z_a^* \\ M_a^* \\ X_b^* \\ Z_b^* \\ M_b^* \end{matrix}$$

Globální matice tuhosti

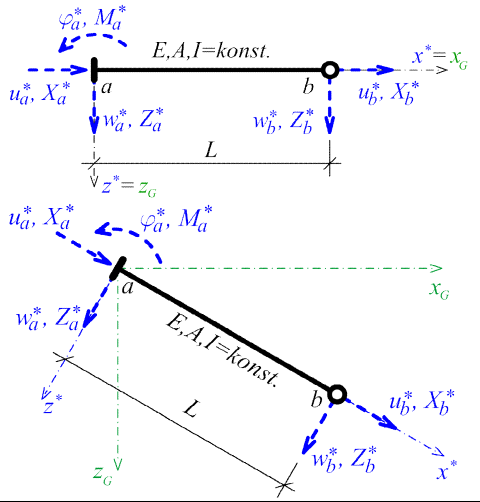


$$c=\cos(\gamma_{ab})$$
$$s=\sin(\gamma_{ab})$$

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

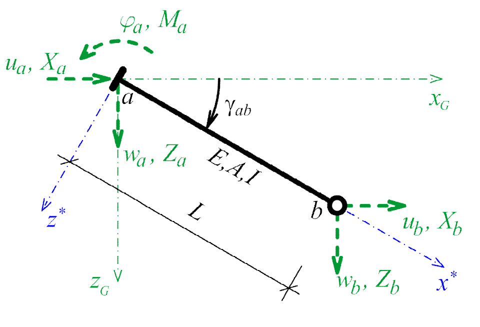
Vetknutí - Kloub

Lokální matice tuhosti



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

Globální matice tuhosti

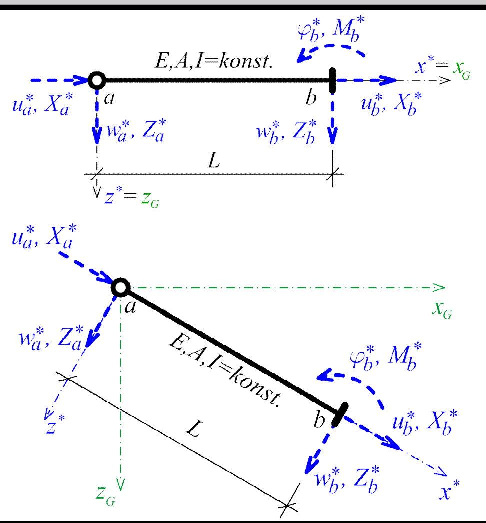


$$D=\frac{EA}{L}-\frac{3EI}{L^3} \qquad c=\cos\left(\gamma_{ab}\right) \qquad s=\sin\left(\gamma_{ab}\right)$$

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

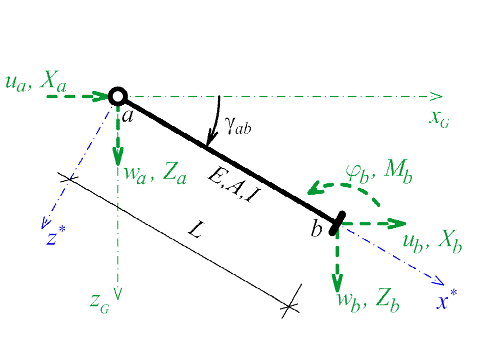
Kloub - Vetknutí

Lokální matice tuhosti



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

Globální matice tuhosti



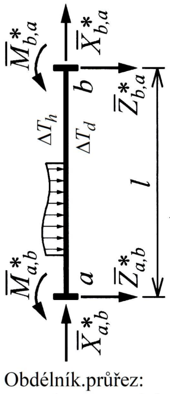
$$D=\frac{EA}{L}-\frac{3EI}{L^3} \qquad c=\cos\left(\gamma_{ab}\right) \qquad s=\sin\left(\gamma_{ab}\right)$$

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

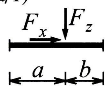
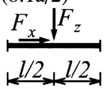
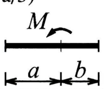
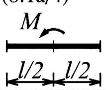
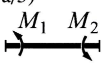
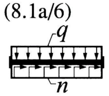
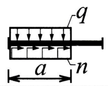
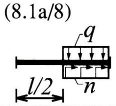
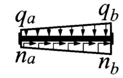
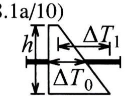
Tabulka 8.1 Primární lokální vektory koncových sil prutu $\{\boldsymbol{R}^*_{a,b}\}$

Oprava: Ing. Zbyněk Vlk, Ph.D. - 2025

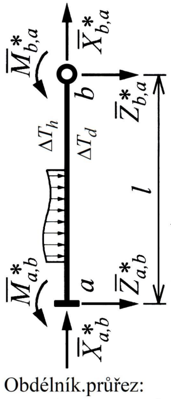
(a)



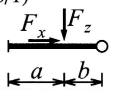
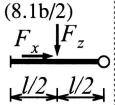
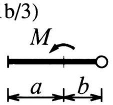
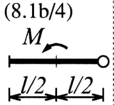
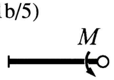
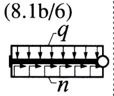
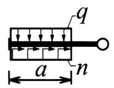
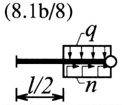
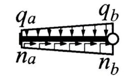
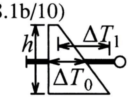
Obdélník.průřez:
$\Delta T_0 = (\Delta T_d + \Delta T_h)/2$
$\Delta T_1 = \Delta T_d - \Delta T_h$

	(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)



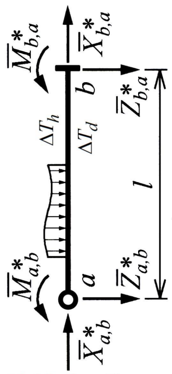
Obdélník.průřez:
$\Delta T_0 = (\Delta T_d + \Delta T_h)/2$
$\Delta T_1 = \Delta T_d - \Delta T_h$

	(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

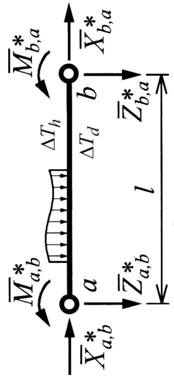
(c)



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

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

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

z globálních do lokálních souřadnic

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

$$\left\{\mathbf{r}^*_{a,b}\right\} = \left\{\begin{array}{c} u_a \cos\gamma_{ab} + w_a \sin\gamma_{ab} \\ -u_a \sin\gamma_{ab} + w_a \cos\gamma_{ab} \\ \varphi_a \\ \hdashline u_b \cos\gamma_{ab} + w_b \sin\gamma_{ab} \\ -u_b \sin\gamma_{ab} + w_b \cos\gamma_{ab} \\ \varphi_b \end{array}\right\}$$