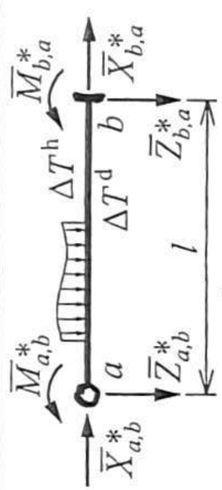
Tabulka 8.1 Primární lokální vektory koncových sil prutu $\{R_{a,b}^*\}$ (pokračování) – úprava VLK 2018

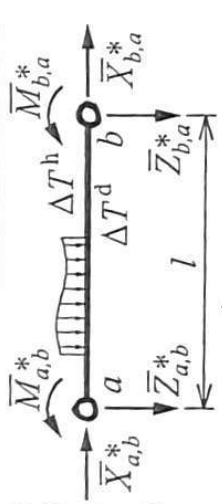
(c)



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

(d)



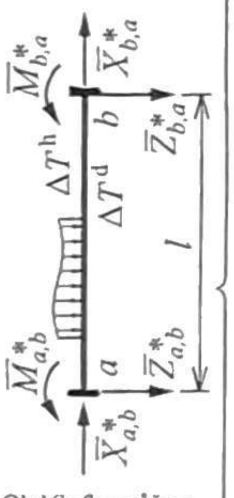
Obdélník. průřez: $\Delta T_0=(\Delta T^d+\Delta T^h)/2$; $\Delta T_1=\Delta T^d-\Delta T^h$

	(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)
$X_{a,b}^*$	$-\frac{b}{l}F_x$	$-\frac{1}{2}F_x$	0	0	0	$-\frac{1}{2}nl$	$-\frac{2al-a^2}{2l}n$	$-\frac{1}{8}nl$	$-\frac{2n_a+n_b}{6}l$	$EA\alpha_T\Delta T_0$
$Z_{a,b}^*$	$-\frac{b}{l}F_z$	$-\frac{1}{2}F_z$	$-\frac{M}{l}$	$-\frac{M}{l}$	$-\frac{M_1+M_2}{l}$	$-\frac{1}{2}ql$	$-\frac{2al-a^2}{2l}q$	$-\frac{1}{8}ql$	$-\frac{2q_a+q_b}{6}l$	0
$\overline{M}_{a,b}^*$	0	0	0	0	0	0	0	0	0	0
$X_{b,a}^*$	$-\frac{a}{l}F_x$	$-\frac{1}{2}F_x$	0	0	0	$-\frac{1}{2}nl$	$-\frac{a^2}{2l}n$	$-\frac{3}{8}nl$	$-\frac{n_a+2n_b}{6}l$	$-EA\alpha_T\Delta T_0$
$Z_{b,a}^*$	$-\frac{a}{l}F_z$	$-\frac{1}{2}F_z$	$\frac{M}{l}$	$\frac{M}{l}$	$\frac{M_1+M_2}{l}$	$-\frac{1}{2}ql$	$-\frac{a^2}{2l}q$	$-\frac{3}{8}ql$	$-\frac{q_a+2q_b}{6}l$	0
$\overline{M}_{b,a}^*$	0	0	0	0	0	0	0	0	0	0

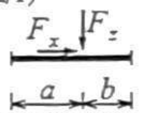
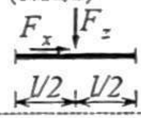
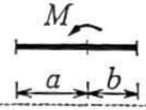
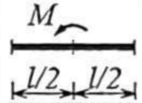
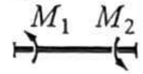
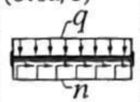
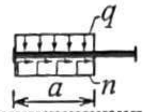
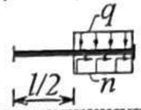
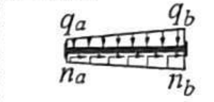
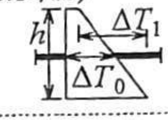
Tabulka 8.1 Primární lokální vektory koncových sil prutu $\{R_{a,b}^*\}$

úprava VIII 2018

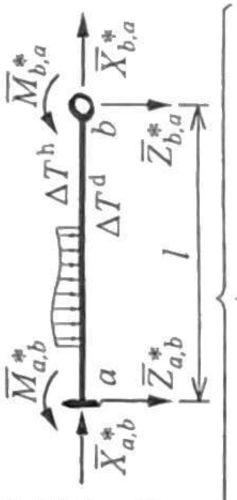
(a)



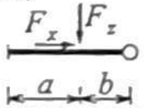
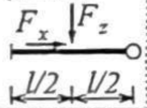
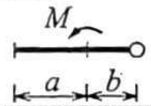
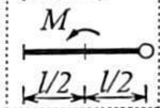
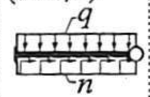
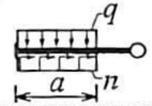
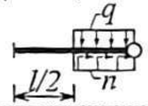
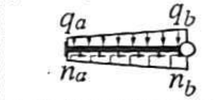
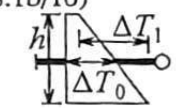
Obdélník. průřez: $\Delta T_0=(\Delta T^d+\Delta T^h)/2$; $\Delta T_1=\Delta T^d-\Delta T^h$

	(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) 
$X_{a,b}^*$	$-\frac{b}{l}F_x$	$-\frac{1}{2}F_x$	0	0	Zatěžovací momenty tuze připojených konců se uplatní jako uzlové zatížení	$-\frac{1}{2}nl$	$-\frac{2al-a^2}{2l}n$	$-\frac{1}{8}nl$	$-\frac{2n_a+n_b}{6}l$	$EA\alpha_T\Delta T_0$
$Z_{a,b}^*$	$-b^2\frac{3l-2b}{l^3}F_z$	$-\frac{1}{2}F_z$	$-6\frac{ab}{l^3}M$	$-\frac{3}{2}\frac{M}{l}$		$-\frac{1}{2}ql$	$-\frac{2al^3-2a^3l+a^4}{2l^3}q$	$-\frac{3}{32}ql$	$-\frac{7q_a+3q_b}{20}l$	0
$M_{a,b}^*$	$\frac{ab^2}{l^2}F_z$	$\frac{1}{8}F_zl$	$b\frac{2l-3b}{l^2}M$	$\frac{1}{4}M$		$\frac{1}{12}ql^2$	$\frac{6a^2l^2-8a^3l+3a^4}{12l^2}q$	$\frac{5}{192}ql^2$	$\frac{3q_a+2q_b}{60}l^2$	$\frac{EI}{h}\alpha_T\Delta T_1$
$X_{b,a}^*$	$-\frac{a}{l}F_x$	$-\frac{1}{2}F_x$	0	0		$-\frac{1}{2}nl$	$-\frac{a^2}{2l}n$	$-\frac{3}{8}nl$	$-\frac{n_a+2n_b}{6}l$	$-EA\alpha_T\Delta T_0$
$Z_{b,a}^*$	$-a^2\frac{3l-2a}{l^3}F_z$	$-\frac{1}{2}F_z$	$6\frac{ab}{l^3}M$	$\frac{3}{2}\frac{M}{l}$		$-\frac{1}{2}ql$	$-\frac{2a^3l-a^4}{2l^3}q$	$-\frac{13}{32}ql$	$-\frac{3q_a+7q_b}{20}l$	0
$M_{b,a}^*$	$-\frac{a^2b}{l^2}F_z$	$-\frac{1}{8}F_zl$	$a\frac{2l-3a}{l^2}M$	$\frac{1}{4}M$		$-\frac{1}{12}ql^2$	$-\frac{4a^3l-3a^4}{12l^2}q$	$-\frac{11}{192}ql^2$	$-\frac{2q_a+3q_b}{60}l^2$	$-\frac{EI}{h}\alpha_T\Delta T_1$

(b)

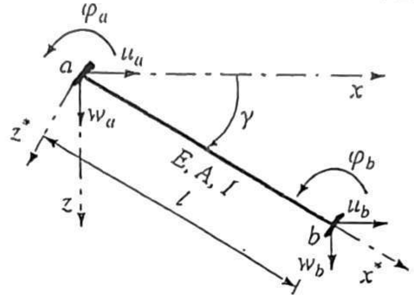


Obdélník. průřez: $\Delta T_0=(\Delta T^d+\Delta T^h)/2$; $\Delta T_1=\Delta T^d-\Delta T^h$

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

(a) Prut oboustranně monoliticky připojený

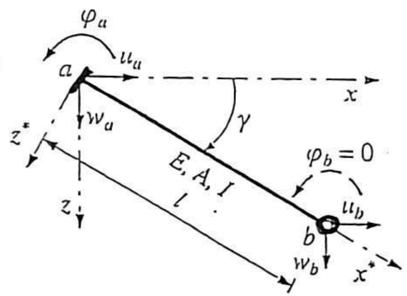
$c = \cos\gamma$
$s = \sin\gamma$



$$
\mathrm{k}_{ab} = \left[\begin{array}{ccc|ccc}
\frac{EA}{l}c^2 + \frac{12EI}{l^3}s^2 & \left(\frac{EA}{l} - \frac{12EI}{l^3}\right)cs & \frac{6EI}{l^2}s & -\left(\frac{EA}{l}c^2 + \frac{12EI}{l^3}s^2\right) & -\left(\frac{EA}{l} - \frac{12EI}{l^3}\right)cs & \frac{6EI}{l^2}s \\
\left(\frac{EA}{l} - \frac{12EI}{l^3}\right)cs & \frac{EA}{l}s^2 + \frac{12EI}{l^3}c^2 & -\frac{6EI}{l^2}c & -\left(\frac{EA}{l} - \frac{12EI}{l^3}\right)cs & -\left(\frac{EA}{l}s^2 + \frac{12EI}{l^3}c^2\right) & -\frac{6EI}{l^2}c \\
\frac{6EI}{l^2}s & -\frac{6EI}{l^2}c & \frac{4EI}{l} & -\frac{6EI}{l^2}s & \frac{6EI}{l^2}c & \frac{2EI}{l} \\
\hline
-\left(\frac{EA}{l}c^2 + \frac{12EI}{l^3}s^2\right) & -\left(\frac{EA}{l} - \frac{12EI}{l^3}\right)cs & -\frac{6EI}{l^2}s & \frac{EA}{l}c^2 + \frac{12EI}{l^3}s^2 & \left(\frac{EA}{l} - \frac{12EI}{l^3}\right)cs & -\frac{6EI}{l^2}s \\
-\left(\frac{EA}{l} - \frac{12EI}{l^3}\right)cs & -\left(\frac{EA}{l}s^2 + \frac{12EI}{l^3}c^2\right) & \frac{6EI}{l^2}c & \left(\frac{EA}{l} - \frac{12EI}{l^3}\right)cs & \frac{EA}{l}s^2 + \frac{12EI}{l^3}c^2 & \frac{6EI}{l^2}c \\
\frac{6EI}{l^2}s & -\frac{6EI}{l^2}c & \frac{2EI}{l} & -\frac{6EI}{l^2}s & \frac{6EI}{l^2}c & \frac{4EI}{l}
\end{array}\right]
$$

(b) Prut pravostranně kloubově připojený

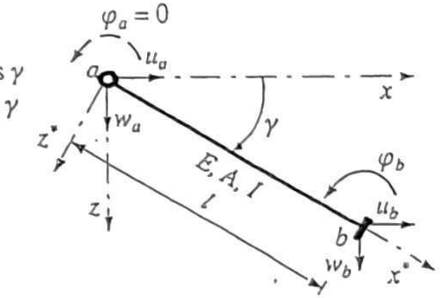
$c = \cos\gamma$
$s = \sin\gamma$



$$
\mathrm{k}_{ab} = \left[\begin{array}{ccc|ccc}
\frac{EA}{l}c^2 + \frac{3EI}{l^3}s^2 & \left(\frac{EA}{l} - \frac{3EI}{l^3}\right)cs & \frac{3EI}{l^2}s & -\left(\frac{EA}{l}c^2 + \frac{3EI}{l^3}s^2\right) & -\left(\frac{EA}{l} - \frac{3EI}{l^3}\right)cs & 0 \\
\left(\frac{EA}{l} - \frac{3EI}{l^3}\right)cs & \frac{EA}{l}s^2 + \frac{3EI}{l^3}c^2 & -\frac{3EI}{l^2}c & -\left(\frac{EA}{l} - \frac{3EI}{l^3}\right)cs & -\left(\frac{EA}{l}s^2 + \frac{3EI}{l^3}c^2\right) & 0 \\
\frac{3EI}{l^2}s & -\frac{3EI}{l^2}c & \frac{3EI}{l} & -\frac{3EI}{l^2}s & \frac{3EI}{l^2}c & 0 \\
\hline
-\left(\frac{EA}{l}c^2 + \frac{3EI}{l^3}s^2\right) & -\left(\frac{EA}{l} - \frac{3EI}{l^3}\right)cs & -\frac{3EI}{l^2}s & \frac{EA}{l}c^2 + \frac{3EI}{l^3}s^2 & \left(\frac{EA}{l} - \frac{3EI}{l^3}\right)cs & 0 \\
-\left(\frac{EA}{l} - \frac{3EI}{l^3}\right)cs & -\left(\frac{EA}{l}s^2 + \frac{3EI}{l^3}c^2\right) & \frac{3EI}{l^2}c & \left(\frac{EA}{l} - \frac{3EI}{l^3}\right)cs & \frac{EA}{l}s^2 + \frac{3EI}{l^3}c^2 & 0 \\
0 & 0 & 0 & 0 & 0 & 0
\end{array}\right]
$$

(c) Prut levostranně kloubově připojený

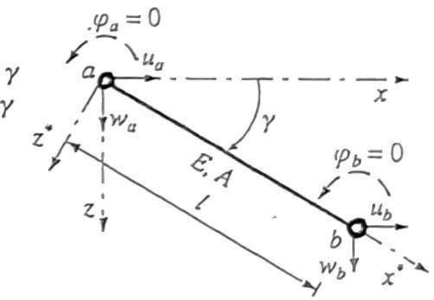
$c = \cos\gamma$
$s = \sin\gamma$



$$
\mathrm{k}_{ab} = \left[\begin{array}{ccc|ccc}
\frac{EA}{l}c^2 + \frac{3EI}{l^3}s^2 & \left(\frac{EA}{l} - \frac{3EI}{l^3}\right)cs & 0 & -\left(\frac{EA}{l}c^2 + \frac{3EI}{l^3}s^2\right) & -\left(\frac{EA}{l} - \frac{3EI}{l^3}\right)cs & \frac{3EI}{l^2}s \\
\left(\frac{EA}{l} - \frac{3EI}{l^3}\right)cs & \frac{EA}{l}s^2 + \frac{3EI}{l^3}c^2 & 0 & -\left(\frac{EA}{l} - \frac{3EI}{l^3}\right)cs & -\left(\frac{EA}{l}s^2 + \frac{3EI}{l^3}c^2\right) & -\frac{3EI}{l^2}c \\
0 & 0 & 0 & 0 & 0 & 0 \\
\hline
-\left(\frac{EA}{l}c^2 + \frac{3EI}{l^3}s^2\right) & -\left(\frac{EA}{l} - \frac{3EI}{l^3}\right)cs & 0 & \frac{EA}{l}c^2 + \frac{3EI}{l^3}s^2 & \left(\frac{EA}{l} - \frac{3EI}{l^3}\right)cs & -\frac{3EI}{l^2}s \\
-\left(\frac{EA}{l} - \frac{3EI}{l^3}\right)cs & -\left(\frac{EA}{l}s^2 + \frac{3EI}{l^3}c^2\right) & 0 & \left(\frac{EA}{l} - \frac{3EI}{l^3}\right)cs & \frac{EA}{l}s^2 + \frac{3EI}{l^3}c^2 & \frac{3EI}{l^2}c \\
\frac{3EI}{l^2}s & -\frac{3EI}{l^2}c & 0 & -\frac{3EI}{l^2}s & \frac{3EI}{l^2}c & \frac{3EI}{l}
\end{array}\right]
$$

(d) Prut oboustranně kloubově připojený

$c = \cos\gamma$
$s = \sin\gamma$



$$
\mathrm{k}_{ab} = \frac{EA}{l}\left[\begin{array}{ccc|ccc}
c^2 & cs & 0 & -c^2 & -cs & 0 \\
cs & s^2 & 0 & -cs & -s^2 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 \\
\hline
-c^2 & -cs & 0 & c^2 & cs & 0 \\
-cs & -s^2 & 0 & cs & s^2 & 0 \\
0 & 0 & 0 & 0 & 0 & 0
\end{array}\right]
$$

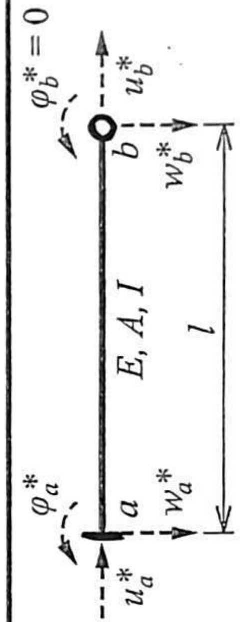
K výpočtu lokálních koncových sil z globálních parametrů deformace:

$$
\hat{\mathrm{R}}^*_{ab} = \mathrm{k}^*_{ab}\mathrm{r}^*_{ab} = \mathrm{k}^*_{ab}\mathrm{T}_{ab}\mathrm{r}_{ab} = \frac{EA}{l}\left[\begin{array}{ccc|ccc}
c & s & 0 & -c & -s & 0 \\
0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 \\
\hline
-c & -s & 0 & c & s & 0 \\
0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0
\end{array}\right]\mathrm{r}_{ab}
$$

Tabulka 8.3 Lokální matice tuhosti prutu $[k_{a,b}^*]$

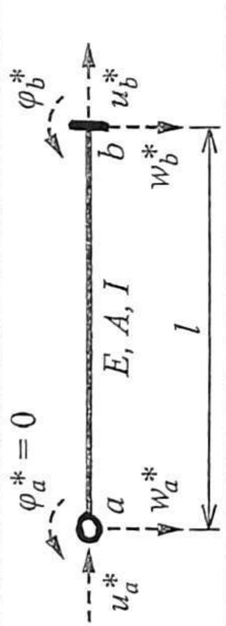
(8.3a)

$$[k_{a,b}^*]= \begin{array}{c} \\ u_a \\ w_a \\ \varphi_a \\ u_b \\ w_b \\ \varphi_b \end{array} \begin{array}{cccccc} u_a & w_a & \varphi_a & u_b & w_b & \varphi_b \\ \frac{EA}{l} & 0 & 0 & -\frac{EA}{l} & 0 & 0 \\ 0 & \frac{12EI}{l^3} & -\frac{6EI}{l^2} & 0 & -\frac{12EI}{l^3} & -\frac{6EI}{l^2} \\ 0 & -\frac{6EI}{l^2} & \frac{4EI}{l} & 0 & \frac{6EI}{l^2} & \frac{2EI}{l} \\ -\frac{EA}{l} & 0 & 0 & \frac{EA}{l} & 0 & 0 \\ 0 & -\frac{12EI}{l^3} & \frac{6EI}{l^2} & 0 & \frac{12EI}{l^3} & \frac{6EI}{l^2} \\ 0 & -\frac{6EI}{l^2} & \frac{2EI}{l} & 0 & \frac{6EI}{l^2} & \frac{4EI}{l} \end{array}$$



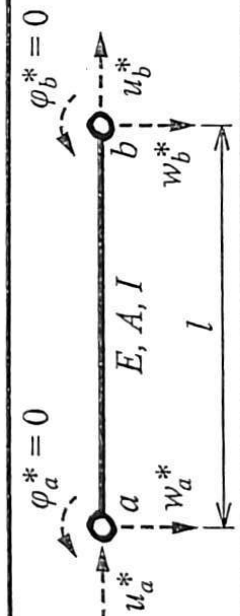
(8.3b)

$$[k_{a,b}^*]= \begin{array}{c} \\ u_a \\ w_a \\ \varphi_a \\ u_b \\ w_b \\ \varphi_b \end{array} \begin{array}{cccccc} u_a & w_a & \varphi_a & u_b & w_b & \varphi_b \\ \frac{EA}{l} & 0 & 0 & -\frac{EA}{l} & 0 & 0 \\ 0 & \frac{3EI}{l^3} & -\frac{3EI}{l^2} & 0 & -\frac{3EI}{l^3} & 0 \\ 0 & -\frac{3EI}{l^2} & \frac{3EI}{l} & 0 & \frac{3EI}{l^2} & 0 \\ -\frac{EA}{l} & 0 & 0 & \frac{EA}{l} & 0 & 0 \\ 0 & -\frac{3EI}{l^3} & \frac{3EI}{l^2} & 0 & \frac{3EI}{l^3} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{array}$$



(8.3c)

$$[k_{a,b}^*]= \begin{array}{c} \\ u_a \\ w_a \\ \varphi_a \\ u_b \\ w_b \\ \varphi_b \end{array} \begin{array}{cccccc} u_a & w_a & \varphi_a & u_b & w_b & \varphi_b \\ \frac{EA}{l} & 0 & 0 & -\frac{EA}{l} & 0 & 0 \\ 0 & \frac{3EI}{l^3} & 0 & 0 & -\frac{3EI}{l^3} & -\frac{3EI}{l^2} \\ 0 & 0 & 0 & 0 & 0 & 0 \\ -\frac{EA}{l} & 0 & 0 & \frac{EA}{l} & 0 & 0 \\ 0 & -\frac{3EI}{l^3} & 0 & 0 & \frac{3EI}{l^3} & \frac{3EI}{l^2} \\ 0 & -\frac{3EI}{l^2} & 0 & 0 & \frac{3EI}{l^2} & \frac{3EI}{l} \end{array}$$



(8.3d)

$$[k_{a,b}^*]= \begin{array}{c} \\ u_a \\ w_a \\ \varphi_a \\ u_b \\ w_b \\ \varphi_b \end{array} \begin{array}{cccccc} u_a & w_a & \varphi_a & u_b & w_b & \varphi_b \\ \frac{EA}{l} & 0 & 0 & -\frac{EA}{l} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ -\frac{EA}{l} & 0 & 0 & \frac{EA}{l} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{array}$$

Transformace vektorů

z lokálních do globálních souřadnic

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

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

z globálních do lokálních souřadnic

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

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