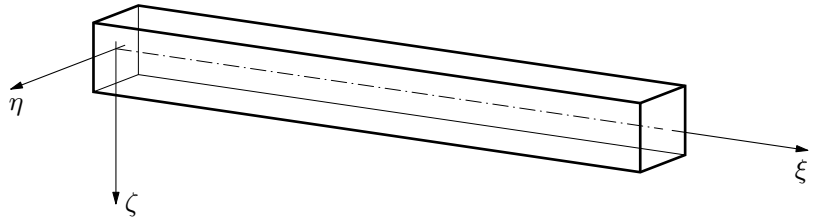
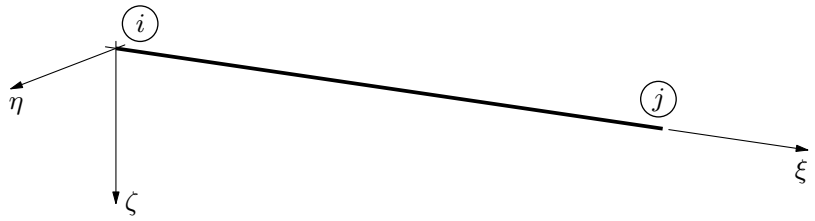
# Metode pomakâ (5)

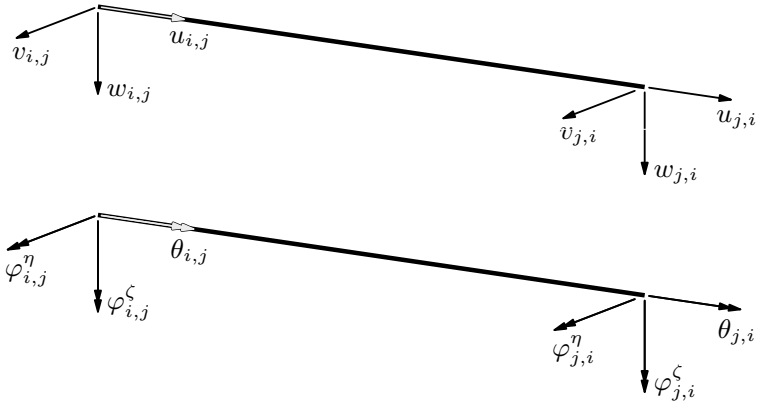
## 7. Prostorne štapne konstrukcije

**prostorni štapni element:**

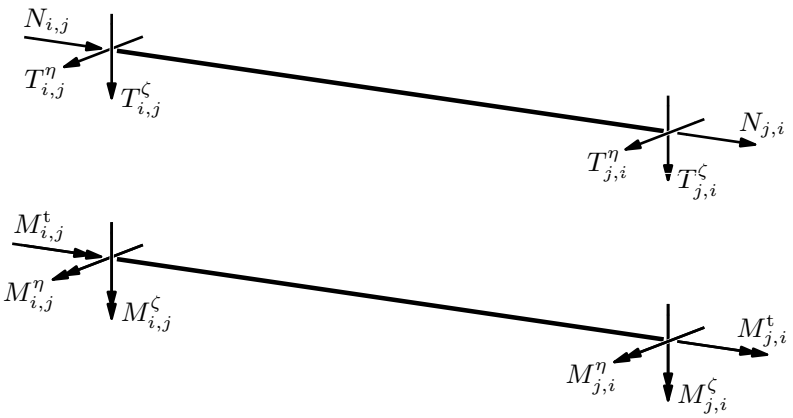



komponente poopćenih pomaka krajeva štapa na pravcima usporednima s osima lokalnoga koordinatnog sustava:



poopćene sile na krajevima štapa:




veza sila i pomakâ:

$$\begin{bmatrix} N_{i,j} \\ T^{\eta}_{i,j} \\ T^{\zeta}_{i,j} \\ M^{\mathrm{t}}_{i,j} \\ M^{\eta}_{i,j} \\ M^{\zeta}_{i,j} \\ N_{j,i} \\ T^{\eta}_{j,i} \\ T^{\zeta}_{i,j} \\ M^{\mathrm{t}}_{j,i} \\ M^{\eta}_{j,i} \\ M^{\zeta}_{j,i} \end{bmatrix} = \mathbf{k}_{(i,j)} \begin{bmatrix} u_{i,j} \\ v_{i,j} \\ w_{i,j} \\ \theta_{i,j} \\ \varphi^{\eta}_{i,j} \\ \varphi^{\zeta}_{i,j} \\ u_{j,i} \\ v_{j,i} \\ w_{i,j} \\ \theta_{j,i} \\ \varphi^{\eta}_{j,i} \\ \varphi^{\zeta}_{j,i} \end{bmatrix} + \begin{bmatrix} \overline{N}_{i,j} \\ \overline{T}^{\eta}_{i,j} \\ \overline{T}^{\zeta}_{i,j} \\ \overline{M}^{\mathrm{t}}_{i,j} \\ \overline{M}^{\eta}_{i,j} \\ \overline{M}^{\zeta}_{i,j} \\ \overline{N}_{j,i} \\ \overline{T}^{\eta}_{j,i} \\ \overline{T}^{\zeta}_{i,j} \\ \overline{M}^{\mathrm{t}}_{j,i} \\ \overline{M}^{\eta}_{j,i} \\ \overline{M}^{\zeta}_{j,i} \end{bmatrix}$$

$$\hat{\mathbf{f}}_{(i,j)} = \mathbf{k}_{(i,j)}\, \mathbf{u}_{(i,j)} + \overline{\mathbf{f}}_{(i,j)}$$

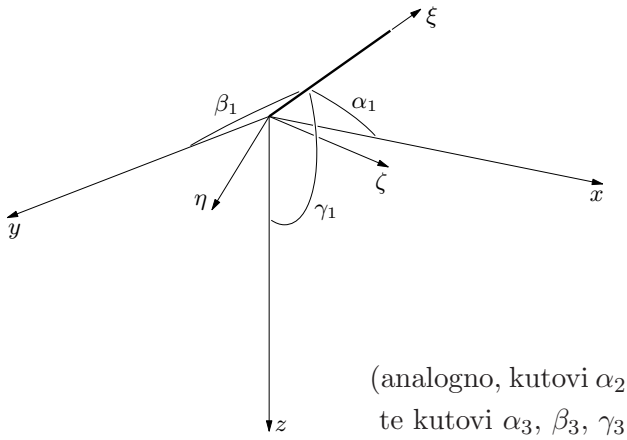
$\mathbf{k}_{(i,j)}$ — matrica krutosti prostornoga štapnog elementa (izražena u lokalnom koordinatnom sustavu)

— matrica $12 \times 12$

struktura lokalne matrice krutosti prostornoga štapnog elementa:

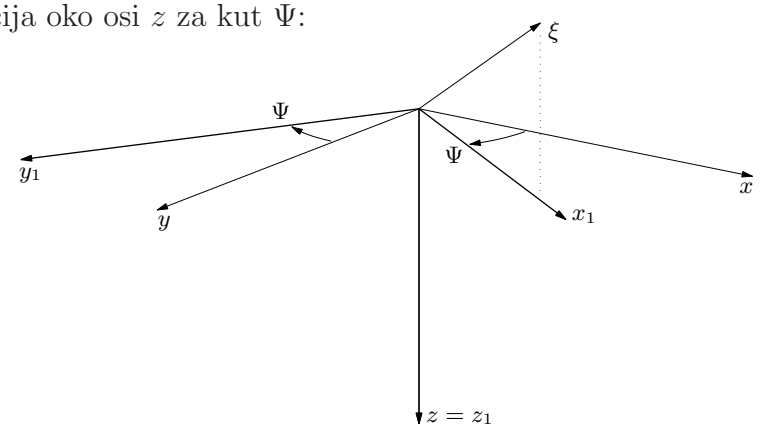
$$\mathbf{k}_{(i,j)} = \begin{bmatrix} \mathsf{X} & 0 & 0 & 0 & 0 & 0 & \mathsf{X} & 0 & 0 & 0 & 0 & 0 \\ 0 & \mathsf{X} & 0 & 0 & 0 & \mathsf{X} & 0 & \mathsf{X} & 0 & 0 & 0 & \mathsf{X} \\ 0 & 0 & \mathsf{X} & 0 & \mathsf{X} & 0 & 0 & 0 & \mathsf{X} & 0 & \mathsf{X} & 0 \\ 0 & 0 & 0 & \mathsf{X} & 0 & 0 & 0 & 0 & 0 & \mathsf{X} & 0 & 0 \\ 0 & 0 & \mathsf{X} & 0 & \mathsf{X} & 0 & 0 & 0 & \mathsf{X} & 0 & \mathsf{X} & 0 \\ 0 & \mathsf{X} & 0 & 0 & 0 & \mathsf{X} & 0 & \mathsf{X} & 0 & 0 & 0 & \mathsf{X} \\ \mathsf{X} & 0 & 0 & 0 & 0 & 0 & \mathsf{X} & 0 & 0 & 0 & 0 & 0 \\ 0 & \mathsf{X} & 0 & 0 & 0 & \mathsf{X} & 0 & \mathsf{X} & 0 & 0 & 0 & \mathsf{X} \\ 0 & 0 & \mathsf{X} & 0 & \mathsf{X} & 0 & 0 & 0 & \mathsf{X} & 0 & \mathsf{X} & 0 \\ 0 & 0 & 0 & \mathsf{X} & 0 & 0 & 0 & 0 & 0 & \mathsf{X} & 0 & 0 \\ 0 & 0 & \mathsf{X} & 0 & \mathsf{X} & 0 & 0 & 0 & \mathsf{X} & 0 & \mathsf{X} & 0 \\ 0 & \mathsf{X} & 0 & 0 & 0 & \mathsf{X} & 0 & \mathsf{X} & 0 & 0 & 0 & \mathsf{X} \end{bmatrix}$$

**prostorni štapni element u prostoru (u globalnom koordinatnom sustavu):**

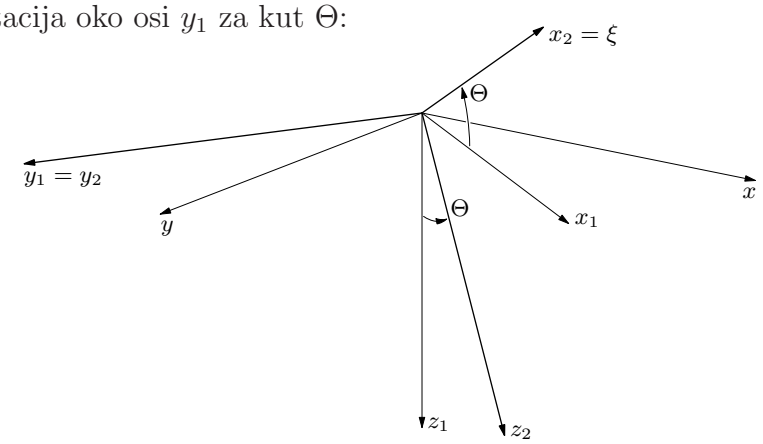



(analogno, kutovi $\alpha_2$, $\beta_2$, $\gamma_2$ između osi $\eta$ i osî $x$, $y$, $z$
te kutovi $\alpha_3$, $\beta_3$, $\gamma_3$ između osi $\eta$ i osî $x$, $y$, $z$)

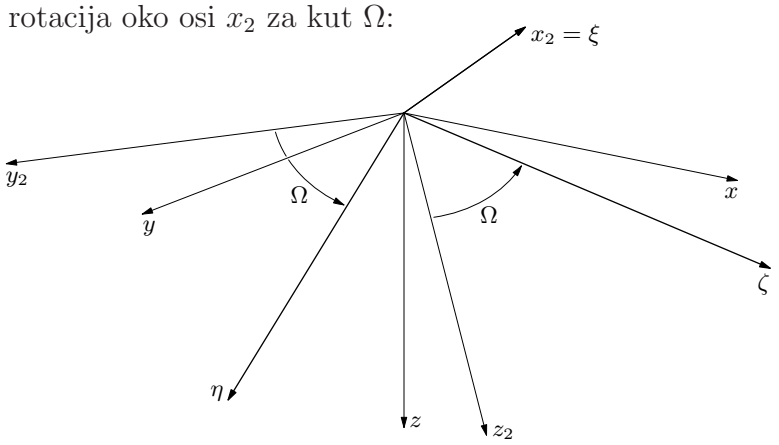
- prvo, rotacija oko osi $z$ za kut $\Psi$:



- potom, rotacija oko osi $y_1$ za kut $\Theta$:

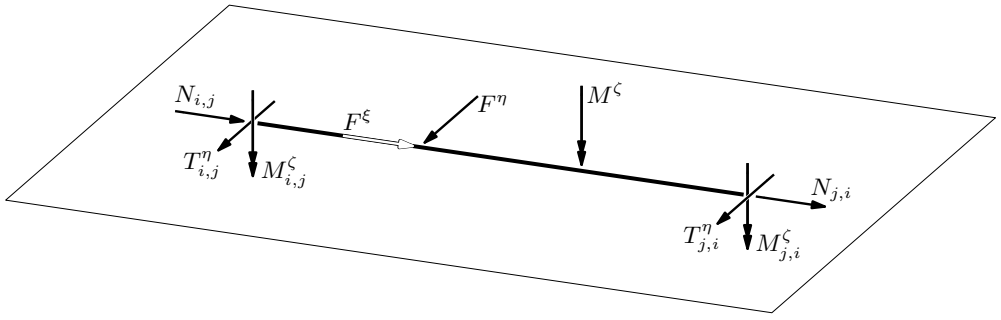



- i na kraju, rotacija oko osi $x_2$ za kut $\Omega$:




**ravninske konstrukcije opterećene prostorno:**

- opterećenje u ravnini konstrukcije — ravninsko djelovanje:



- opterećenje okomito na ravninu konstrukcije — „roštiljno” djelovanje: