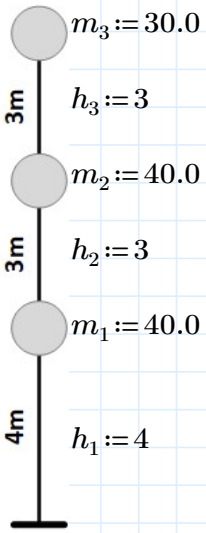
Primer-MDOF-Spektralna-analiza-odgovora

Podaci: E = 33 GPa, b/d = 30/100 cm, m_1 = 40 t, m_2 = 40 t, m_3 = 30 t, referentno maksimalno ubrzanje tla u horizontalnom pravcu a_{gR} = 0,1g, faktor ponašanja q = 1.5, tip tla C, tip elastičnog odgovora 1, faktor značaja γ_I=1.0, relativno prigušenje 5%.



$E := 33 \cdot 10^6$ $b := 0.3$ $d := 1.0$

Napomena: pri analizi će se koristiti homogene karakteristike poprečnih preseka

$A := b \cdot d = 0.30$ $I := \frac{b \cdot d^3}{12} = 0.0250$

Projektno maksimalno ubrzanje tla u horizontalnom pravcu a_g

$\gamma_I := 1.0$ $a_{gR} := 0.1 \cdot 9.81 = 0.981$ $a_g := \gamma_I \cdot a_{gR} = 0.981$

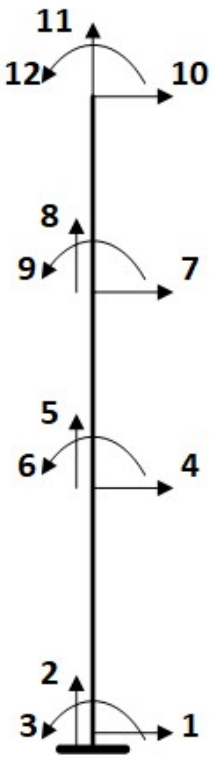
$q := 1.5$ $tipTla := \text{“C”}$ $\eta := 1$

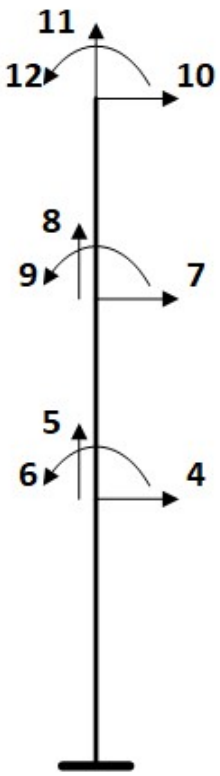
Statički i dinamički model

Napomena: analiza obuhvata samo vibracije u horizontalnom pravcu

Statički model

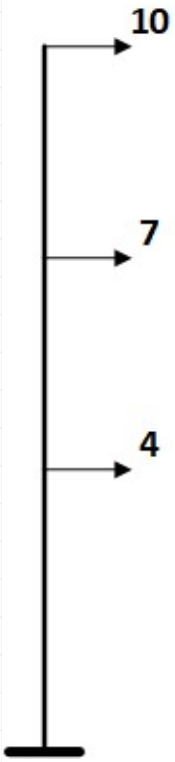
Stepeni slobode (pasivni): 1, 2, 3
Stepeni slobode (aktivni): 4, 5, 6, 7, 8, 9, 10, 11 i 12





Dinamički model

Stepeni slobode (bitni):
4, 7 i 10



Matrica krutosti i matrica transformacije

Štap tipa *k* (funkcija za matricu krutosti i matricu transformacije)

$$k_k(E,L,A,I) := \frac{E\cdot I}{L^3}\cdot\begin{bmatrix} \frac{A\cdot L^2}{I} & 0 & 0 & -\frac{A\cdot L^2}{I} & 0 & 0 \\ 0 & 12 & 6\cdot L & 0 & -12 & 6\cdot L \\ 0 & 6\cdot L & 4\cdot L^2 & 0 & -6\cdot L & 2\cdot L^2 \\ -\frac{A\cdot L^2}{I} & 0 & 0 & \frac{A\cdot L^2}{I} & 0 & 0 \\ 0 & -12 & -6\cdot L & 0 & 12 & -6\cdot L \\ 0 & 6\cdot L & 2\cdot L^2 & 0 & -6\cdot L & 4\cdot L^2 \end{bmatrix}$$

$$T_k(\alpha) := \begin{bmatrix} \cos(\alpha) & \sin(\alpha) & 0 & 0 & 0 & 0 \\ -\sin(\alpha) & \cos(\alpha) & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & \cos(\alpha) & \sin(\alpha) & 0 \\ 0 & 0 & 0 & -\sin(\alpha) & \cos(\alpha) & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

Štap 1

$L_1 := h_1 \qquad T_1 := T_k(90\ \mathit{deg}) \qquad k_{1_LKS} := k_k(E, L_1, A, I) \qquad k_{1_GKS} := T_1^{\mathrm{T}} \cdot k_{1_LKS} \cdot T_1$

$$k_{1_GKS} = \begin{array}{c} \begin{matrix} 1 & 2 & 3 & 4 & 5 & 6 \end{matrix} \\ \begin{bmatrix} 154687.5 & 0.0 & -309375.0 & -154687.5 & 0.0 & -309375.0 \\ 0.0 & 2475000.0 & 0.0 & 0.0 & -2475000.0 & 0.0 \\ -309375.0 & 0.0 & 825000.0 & 309375.0 & 0.0 & 412500.0 \\ -154687.5 & 0.0 & 309375.0 & 154687.5 & 0.0 & 309375.0 \\ 0.0 & -2475000.0 & 0.0 & 0.0 & 2475000.0 & 0.0 \\ -309375.0 & 0.0 & 412500.0 & 309375.0 & 0.0 & 825000.0 \end{bmatrix} \end{array} \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{bmatrix}$$

Vektor stepeni slobode štapa: $ss_1 := [1\ 2\ 3\ 4\ 5\ 6]^{\mathrm{T}}$

Štap 2

$L_2 := h_2 \qquad T_2 := T_k(90\ \mathit{deg}) \qquad k_{2_LKS} := k_k(E, L_2, A, I) \qquad k_{2_GKS} := T_2^{\mathrm{T}} \cdot k_{2_LKS} \cdot T_2$

$$k_{2_GKS} = \begin{array}{c} \begin{matrix} 4 & 5 & 6 & 7 & 8 & 9 \end{matrix} \\ \begin{bmatrix} 366666.7 & 0.0 & -550000.0 & -366666.7 & 0.0 & -550000.0 \\ 0.0 & 3300000.0 & 0.0 & 0.0 & -3300000.0 & 0.0 \\ -550000.0 & 0.0 & 1100000.0 & 550000.0 & 0.0 & 550000.0 \\ -366666.7 & 0.0 & 550000.0 & 366666.7 & 0.0 & 550000.0 \\ 0.0 & -3300000.0 & 0.0 & 0.0 & 3300000.0 & 0.0 \\ -550000.0 & 0.0 & 550000.0 & 550000.0 & 0.0 & 1100000.0 \end{bmatrix} \end{array} \begin{bmatrix} 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \end{bmatrix}$$

Vektor stepeni slobode štapa: $ss_2 := [4\ 5\ 6\ 7\ 8\ 9]^{\mathrm{T}}$

Štap 3

$L_3 := h_3$ $\quad T_3 := T_k(90\ deg)$ $\quad k_{3_LKS} := k_k(E, L_3, A, I)$ $\quad k_{3_GKS} := T_3^{\mathrm{T}} \cdot k_{3_LKS} \cdot T_3$

$$k_{3_LKS} = \begin{array}{c} \begin{matrix} 7 & 8 & 9 & 10 & 11 & 12 \end{matrix} \\ \begin{bmatrix} 3300000.0 & 0.0 & 0.0 & -3300000.0 & 0.0 & 0.0 \\ 0.0 & 366666.7 & 550000.0 & 0.0 & -366666.7 & 550000.0 \\ 0.0 & 550000.0 & 1100000.0 & 0.0 & -550000.0 & 550000.0 \\ -3300000.0 & 0.0 & 0.0 & 3300000.0 & 0.0 & 0.0 \\ 0.0 & -366666.7 & -550000.0 & 0.0 & 366666.7 & -550000.0 \\ 0.0 & 550000.0 & 550000.0 & 0.0 & -550000.0 & 1100000.0 \end{bmatrix} \end{array} \begin{bmatrix} 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \end{bmatrix}$$

Vektor stepeni slobode štapa: $ss_3 := [7\ \ 8\ \ 9\ \ 10\ \ 11\ \ 12]^{\mathrm{T}}$

Kondenzovana matrica krutosti

Pasivni stepeni slobode: 1, 2 i 3 Aktivni stepeni slobode: 4, 5, 6, 7, 8, 9, 10, 11 i 12

Bitni stepeni slobode: 4, 7 i 10 $b_s := [4\ \ 7\ \ 10]^{\mathrm{T}}$

Nebitni stepeni slobode: 5, 6, 8, 9, 11 i 12 $n_s := [5\ \ 6\ \ 8\ \ 9\ \ 11\ \ 12]^{\mathrm{T}}$

$$niz_{ss} := \begin{bmatrix} ss_1 \\ ss_2 \\ ss_3 \end{bmatrix} \qquad niz_{mk} := \begin{bmatrix} k_{1_GKS} \\ k_{2_GKS} \\ k_{3_GKS} \end{bmatrix}$$

Funkcija za formiranje matrice sistema povezanih štapova (koristi brojeve stepeni slobode štapova i matrice krutosti štapova)

$K(niz_{ss}, niz_{mk}, ssv, ssk) :=$

$K_{last(ssv), last(ssk)} \leftarrow 0$

for $m \in 0..last(niz_{ss})$

$SSstap \leftarrow niz_{ss_m}$

for $i \in 0..last(SSstap)$

for $j \in 0..last(ssv)$

if $SSstap_i = ssv_j$

for $k \in 0..last(SSstap)$

for $l \in 0..last(ssk)$

if $SSstap_k = ssk_l$

$MK \leftarrow niz_{mk_m}$

$K_{j,l} \leftarrow K_{j,l} + MK_{i,k}$

return K

$Kbb := K(niz_{ss}, niz_{mk}, b_s, b_s)$ $Kbn := K(niz_{ss}, niz_{mk}, b_s, n_s)$

$Knb := K(niz_{ss}, niz_{mk}, n_s, b_s)$ $Knn := K(niz_{ss}, niz_{mk}, n_s, n_s)$

$$Kbb = \begin{matrix} \\ 4 \\ 7 \\ 10 \end{matrix} \begin{matrix} \begin{matrix} 4 & 7 & 10 \end{matrix} \\ \begin{bmatrix} 521354.2 & -366666.7 & 0.0 \\ -366666.7 & 733333.3 & -366666.7 \\ 0.0 & -366666.7 & 366666.7 \end{bmatrix} \end{matrix} \begin{bmatrix} 4 \\ 7 \\ 10 \end{bmatrix}$$

$$Kbn = \begin{bmatrix} 5 & 6 & 8 & 9 & 11 & 12 \\ 0.0 & -240625.0 & 0.0 & -550000.0 & 0.0 & 0.0 \\ 0.0 & 550000.0 & 0.0 & 0.0 & 0.0 & -550000.0 \\ 0.0 & 0.0 & 0.0 & 550000.0 & 0.0 & 550000.0 \end{bmatrix} \begin{bmatrix} 4 \\ 7 \\ 10 \end{bmatrix}$$

$$Knb = \begin{matrix} \\ 5 \\ 6 \\ 8 \\ 9 \\ 11 \\ 12 \end{matrix} \begin{matrix} \begin{matrix} 4 & 7 & 10 \end{matrix} \\ \begin{bmatrix} 0.0 & 0.0 & 0.0 \\ -240625.0 & 550000.0 & 0.0 \\ 0.0 & 0.0 & 0.0 \\ -550000.0 & 0.0 & 550000.0 \\ 0.0 & 0.0 & 0.0 \\ 0.0 & -550000.0 & 550000.0 \end{bmatrix} \end{matrix} \begin{bmatrix} 5 \\ 6 \\ 8 \\ 9 \\ 11 \\ 12 \end{bmatrix}$$

$\text{if}\left(Knb = Kbn^{\mathrm{T}}, \text{“OK”}, \text{“NO OK”}\right) = \text{“OK”}$

$$Knn = \begin{matrix} \\ 5 \\ 6 \\ 8 \\ 9 \\ 11 \\ 12 \end{matrix} \begin{matrix} \begin{matrix} 5 & 6 & 8 & 9 & 11 & 12 \end{matrix} \\ \begin{bmatrix} 5775000.0 & 0.0 & -3300000.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 1925000.0 & 0.0 & 550000.0 & 0.0 & 0.0 \\ -3300000.0 & 0.0 & 6600000.0 & 0.0 & -3300000.0 & 0.0 \\ 0.0 & 550000.0 & 0.0 & 2200000.0 & 0.0 & 550000.0 \\ 0.0 & 0.0 & -3300000.0 & 0.0 & 3300000.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 550000.0 & 0.0 & 1100000.0 \end{bmatrix} \end{matrix} \begin{bmatrix} 5 \\ 6 \\ 8 \\ 9 \\ 11 \\ 12 \end{bmatrix}$$

$Kc := Kbb - Kbn \cdot Knn^{-1} \cdot Knb$

$$Kc = \begin{matrix} \\ 4 \\ 7 \\ 10 \end{matrix} \begin{matrix} \begin{matrix} 4 & 7 & 10 \end{matrix} \\ \begin{bmatrix} 360269.1 & -265833.3 & 74861.1 \\ -265833.3 & 293333.3 & -110000.0 \\ 74861.1 & -110000.0 & 48888.9 \end{bmatrix} \end{matrix} \begin{bmatrix} 4 \\ 7 \\ 10 \end{bmatrix}$$

Matrica mase

$$Mc := \begin{bmatrix} m_1 & 0 & 0 \\ 0 & m_2 & 0 \\ 0 & 0 & m_3 \end{bmatrix} = \begin{matrix} \\ 4 \\ 7 \\ 10 \end{matrix} \begin{matrix} \begin{matrix} 4 & 7 & 10 \end{matrix} \\ \begin{bmatrix} 40.0 & 0.0 & 0.0 \\ 0.0 & 40.0 & 0.0 \\ 0.0 & 0.0 & 30.0 \end{bmatrix} \end{matrix} \begin{bmatrix} 4 \\ 7 \\ 10 \end{bmatrix}$$

Kružne frekvencije i periodi svojstvenih vibracija

$$\omega_{rac} := \sqrt{\text{eigenvals}\left(Mc^{-1} \cdot Kc\right)} = \begin{bmatrix} 125.883 \\ 45.475 \\ 7.422 \end{bmatrix} \qquad T_{rac} := \frac{2 \cdot \pi}{\omega_{rac}} = \begin{bmatrix} 0.04991 \\ 0.13817 \\ 0.84654 \end{bmatrix}$$

$T_{ton_1} := T_{rac_2} = 0.84654$ $T_{ton_2} := T_{rac_1} = 0.13817$ $T_{ton_3} := T_{rac_0} = 0.04991$

Oblici svojstvenih vibracija

$$A_{rac} := \text{eigenvecs}\left(Mc^{-1} \cdot Kc\right) = \begin{bmatrix} -0.70651 & 0.63972 & 0.1884 \\ 0.64535 & 0.50467 & 0.49297 \\ -0.29045 & -0.57972 & 0.8494 \end{bmatrix}$$

Ton 1: $A_{rac_1} := A_{rac}^{\langle 2 \rangle} = \begin{bmatrix} 0.1884 \\ 0.49297 \\ 0.8494 \end{bmatrix}$ Ton 2: $A_{rac_2} := A_{rac}^{\langle 1 \rangle} = \begin{bmatrix} 0.63972 \\ 0.50467 \\ -0.57972 \end{bmatrix}$

Ton 3: $A_{rac_3} := -A_{rac}^{\langle 0 \rangle} = \begin{bmatrix} 0.70651 \\ -0.64535 \\ 0.29045 \end{bmatrix}$

Ortonormiranje svojstvenih oblika

Ton 1

$M_{gen_1} := A_{rac_1}{}^{\mathrm{T}} \cdot Mc \cdot A_{rac_1} = 32.78514$

$$\phi_1 := \frac{1}{\sqrt{M_{gen_1}}} \cdot A_{rac_1} = \begin{bmatrix} 0.03290 \\ 0.08610 \\ 0.14835 \end{bmatrix}$$

$M_1 := \phi_1{}^{\mathrm{T}} \cdot Mc \cdot \phi_1 = 1.00000$

Ton 2

$M_{gen_2} := A_{rac_2}{}^{\mathrm{T}} \cdot Mc \cdot A_{rac_2} = 36.63930$

$$\phi_2 := \frac{1}{\sqrt{M_{gen_2}}} \cdot A_{rac_2} = \begin{bmatrix} 0.10569 \\ 0.08337 \\ -0.09577 \end{bmatrix}$$

$M_2 := \phi_2{}^{\mathrm{T}} \cdot Mc \cdot \phi_2 = 1.00000$

Ton 3

$M_{gen_3} := A_{rac_3}{}^{\mathrm{T}} \cdot Mc \cdot A_{rac_3} = 39.15640$

$$\phi_3 := \frac{1}{\sqrt{M_{gen_3}}} \cdot A_{rac_3} = \begin{bmatrix} 0.11291 \\ -0.10313 \\ 0.04642 \end{bmatrix}$$

$M_3 := \phi_3{}^{\mathrm{T}} \cdot Mc \cdot \phi_3 = 1.00000$

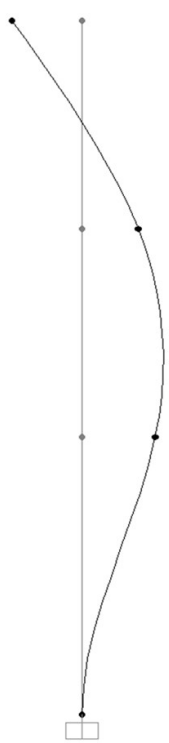
$T_{ton_1} = 0.847$ $T_{ton_2} = 0.138$ $T_{ton_3} = 0.050$



$\phi_{1_2} = 0.1483$

$\phi_{1_1} = 0.0861$

$\phi_{1_0} = 0.0329$



$\phi_{2_2} = -0.0958$

$\phi_{2_1} = 0.0834$

$\phi_{2_0} = 0.1057$



$\phi_{3_2} = 0.0464$

$\phi_{3_1} = -0.1031$

$\phi_{3_0} = 0.1129$

Elastični i projektni spektar odgovora za horizontalan pravac

Tip 1 elastičnog odgovora

$$parametri_tip_1(tipTla) := \begin{cases} \text{if } tipTla = \text{“A”} \\ \quad [1.00 \;\; 0.15 \;\; 0.4 \;\; 2.0] \\ \text{if } tipTla = \text{“B”} \\ \quad [1.20 \;\; 0.15 \;\; 0.5 \;\; 2.0] \\ \text{if } tipTla = \text{“C”} \\ \quad [1.15 \;\; 0.20 \;\; 0.6 \;\; 2.0] \\ \text{if } tipTla = \text{“D”} \\ \quad [1.35 \;\; 0.20 \;\; 0.8 \;\; 2.0] \\ \text{if } tipTla = \text{“E”} \\ \quad [1.40 \;\; 0.15 \;\; 0.5 \;\; 2.0] \end{cases}$$

$niz := parametri_tip_1(tipTla) = [1.15 \;\; 0.2 \;\; 0.6 \;\; 2]$

$Ss := niz_{0,0} = 1.15$ $Tb := niz_{0,1} = 0.2$ $Tc := niz_{0,2} = 0.6$ $Td := niz_{0,3} = 2$

$$Se(T_{ton}) := \begin{array}{l} \text{if } 0 \le T_{ton} \le Tb \\ \quad a_g \cdot Ss \cdot \left(1 + \frac{T_{ton}}{Tb} \cdot (\eta \cdot 2.5 - 1)\right) \\ \text{if } Tb < T_{ton} \le Tc \\ \quad a_g \cdot Ss \cdot \eta \cdot 2.5 \\ \text{if } Tc < T_{ton} \le Td \\ \quad a_g \cdot Ss \cdot \eta \cdot 2.5 \cdot \frac{Tc}{T_{ton}} \\ \text{if } Td < T_{ton} \le 4 \\ \quad a_g \cdot Ss \cdot \eta \cdot 2.5 \cdot \frac{Tc \cdot Td}{T_{ton}^{\,2}} \end{array}$$

$$Sd(T_{ton}, q) := \begin{array}{l} \text{if } 0 \le T_{ton} \le Tb \\ \quad a_g \cdot Ss \cdot \left(\frac{2}{3} + \frac{T_{ton}}{Tb} \cdot \left(\frac{2.5}{q} - \frac{2}{3}\right)\right) \\ \text{if } Tb < T_{ton} \le Tc \\ \quad a_g \cdot Ss \cdot \frac{2.5}{q} \\ \text{if } Tc < T_{ton} \le Td \\ \quad a_g \cdot Ss \cdot \frac{2.5}{q} \cdot \frac{Tc}{T_{ton}} \\ \text{if } Td < T_{ton} \\ \quad a_g \cdot Ss \cdot \frac{2.5}{q} \cdot \frac{Tc \cdot Td}{T_{ton}^{\,2}} \end{array}$$

Projektno spektralno ubrzanje

$Sa1 := Sd(T_{ton_1}, q) = 1.333$ $\quad Sa2 := Sd(T_{ton_2}, q) = 1.531$

$Sa3 := Sd(T_{ton_3}, q) = 1.034$ $\quad \beta := 0.2$ $\quad \beta \cdot a_g = 0.196$

Ograničenje projektnog spektralnog ubrzanja:

$$Sa(Spa) := \begin{array}{l} \text{if } Spa < \beta \cdot a_g \\ \quad \text{return } \beta \cdot a_g \\ \text{else} \\ \quad \text{return } Spa \end{array}$$

$Sd1 := Sa(Sa1) = 1.333$

$Sd2 := Sa(Sa2) = 1.531$

$Sd3 := Sa(Sa3) = 1.034$

Faktor "participacije"

Vektor uticajnih koeficijenata: $s := \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$

$\Gamma_1 := \frac{\phi_1^{\,T} \cdot Mc \cdot s}{M_1} = 9.210$ $\quad \Gamma_2 := \frac{\phi_2^{\,T} \cdot Mc \cdot s}{M_2} = 4.689$ $\quad \Gamma_3 := \frac{\phi_3^{\,T} \cdot Mc \cdot s}{M_3} = 1.783$

Efektivna masa

Ukupna masa dinamičkog modela:

$$Mukupno := \begin{array}{l} suma \leftarrow 0 \\ \text{for } i \in 0 .. \text{last}(Mc^{\langle 0 \rangle}) \\ \quad suma \leftarrow suma + Mc_{i,i} \\ \text{return } suma \end{array} = 110.0$$

Efektivna masa za T1:

$L1 := \phi_1^{\,T} \cdot Mc \cdot s = 9.210$ $\quad Mef_1 := \frac{L1^2}{M_1} = 84.83$ $\quad \frac{Mef_1}{Mukupno} = 0.771$

Efektivna masa za T2:

$L2 := \phi_2{}^{T} \cdot Mc \cdot s = 4.689$ $\quad Mef_2 := \frac{L2^2}{M_2} = 21.99$ $\quad \frac{Mef_2}{Mukupno} = 0.200$

Efektivna masa za T3:

$L3 := \phi_3{}^{T} \cdot Mc \cdot s = 1.783$ $\quad Mef_3 := \frac{L3^2}{M_3} = 3.18$ $\quad \frac{Mef_3}{Mukupno} = 0.029$

$Mef_1 + Mef_2 + Mef_3 = 110.0$

$\frac{Mef_1 + Mef_2 + Mef_3}{Mukupno} = 1$

Projektne seizmičke sile

Ton 1: $S1 := \Gamma_1 \cdot Mc \cdot \phi_1 \cdot Sd1 = \begin{bmatrix} 16.15492 \\ 42.27061 \\ 54.62535 \end{bmatrix}$

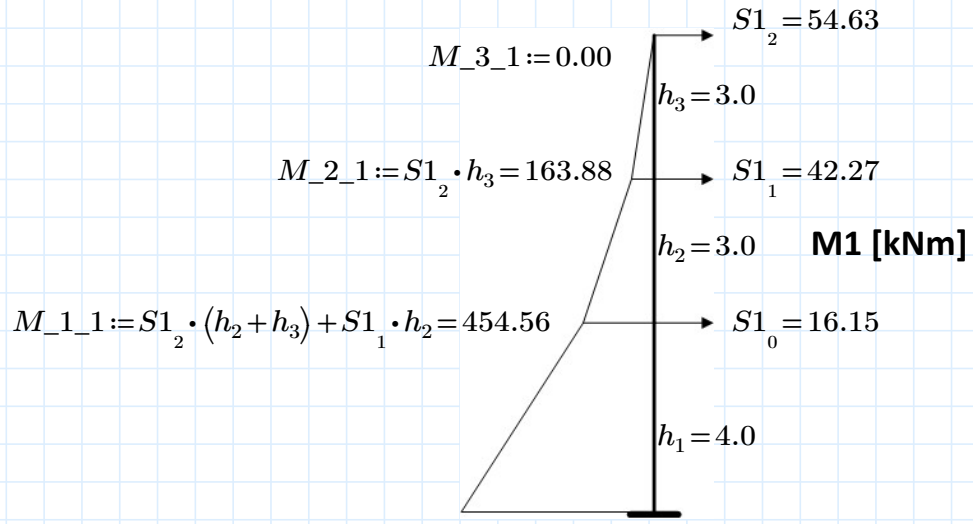
Ton 2: $S2 := \Gamma_2 \cdot Mc \cdot \phi_2 \cdot Sd2 = \begin{bmatrix} 30.35893 \\ 23.94970 \\ -20.63348 \end{bmatrix}$

Ton 3: $S3 := \Gamma_3 \cdot Mc \cdot \phi_3 \cdot Sd3 = \begin{bmatrix} 8.32540 \\ -7.60471 \\ 2.56694 \end{bmatrix}$

Dijagram momenata savijanja (SRSS pravilo)

Ton 1

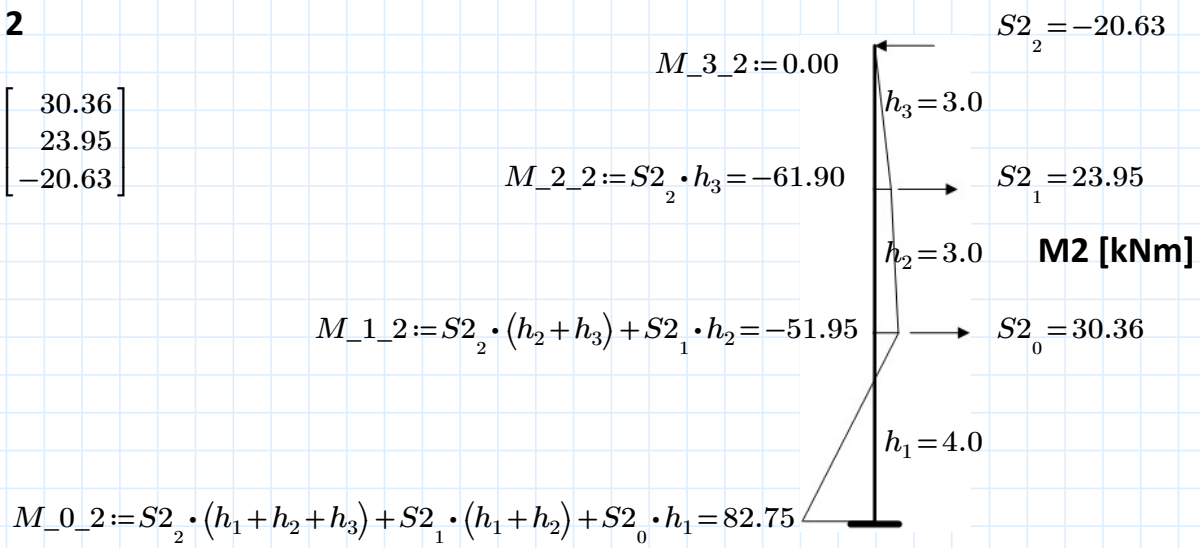
$S1 = \begin{bmatrix} 16.15 \\ 42.27 \\ 54.63 \end{bmatrix}$



$M_0_1 := S1_2 \cdot (h_1 + h_2 + h_3) + S1_1 \cdot (h_1 + h_2) + S1_0 \cdot h_1 = 906.77$

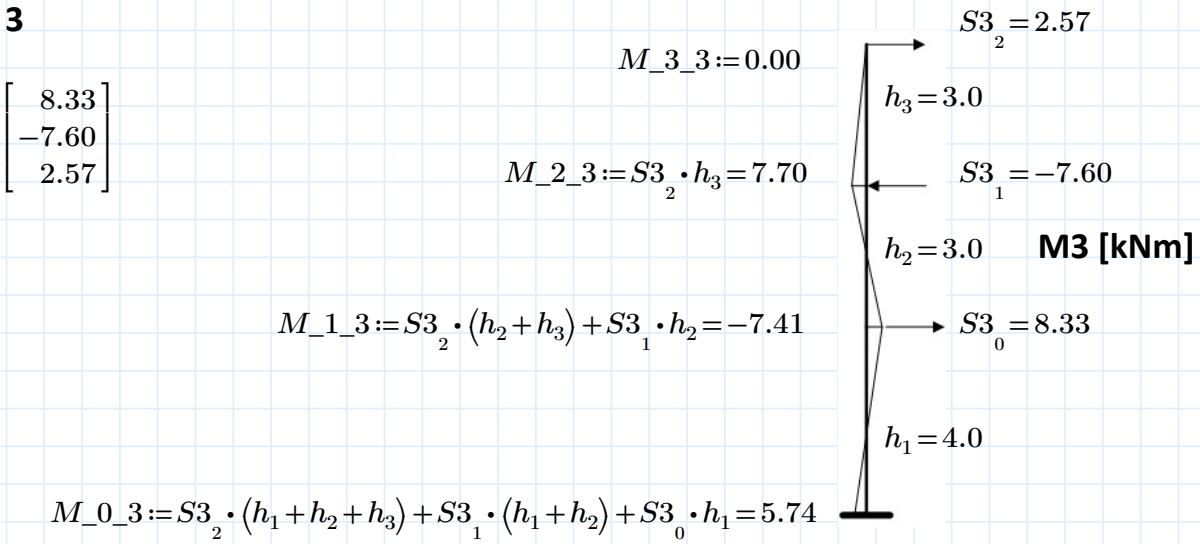
Ton 2

$$S2 = \begin{bmatrix} 30.36 \\ 23.95 \\ -20.63 \end{bmatrix}$$

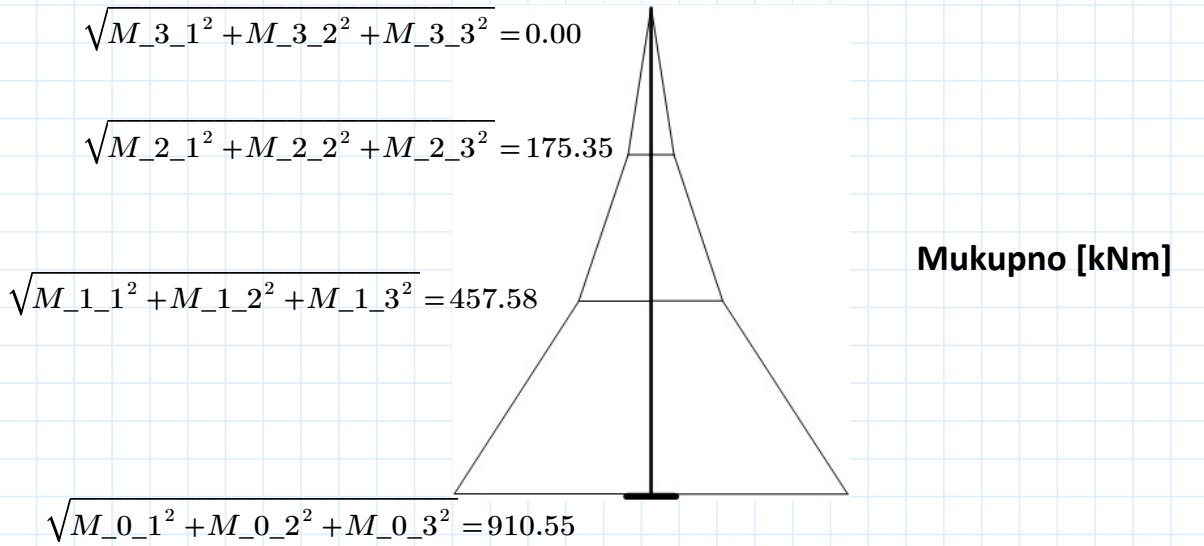


Ton 3

$$S3 = \begin{bmatrix} 8.33 \\ -7.60 \\ 2.57 \end{bmatrix}$$



Ukupni dijagram M (SRSS pravilo)



Relativno horizontalno pomeranje u nivou masa (SRSS pravilo)

Napomena: $T_{ton_1} = 0.847 \quad > \quad Tc = 0.600$

$$u1 := \Gamma_1 \cdot \phi_1 \cdot \frac{Sd1}{\omega_{rac_2}^{\,2}} \cdot q = \begin{bmatrix} 0.01100 \\ 0.02877 \\ 0.04958 \end{bmatrix} \qquad u2 := \Gamma_2 \cdot \phi_2 \cdot \frac{Sd2}{\omega_{rac_1}^{\,2}} \cdot q = \begin{bmatrix} 0.00055 \\ 0.00043 \\ -0.00050 \end{bmatrix}$$

$$u3 := \Gamma_3 \cdot \phi_3 \cdot \frac{Sd3}{\omega_{rac_0}^{\,2}} \cdot q = \begin{bmatrix} 0.00002 \\ -0.00002 \\ 0.00001 \end{bmatrix}$$

$$u := \begin{bmatrix} \sqrt{(u1_0)^2 + (u2_0)^2 + (u3_0)^2} \\ \sqrt{(u1_1)^2 + (u2_1)^2 + (u3_1)^2} \\ \sqrt{(u1_2)^2 + (u2_2)^2 + (u3_2)^2} \end{bmatrix} = \begin{bmatrix} 0.01101 \\ 0.02878 \\ 0.04958 \end{bmatrix}$$

