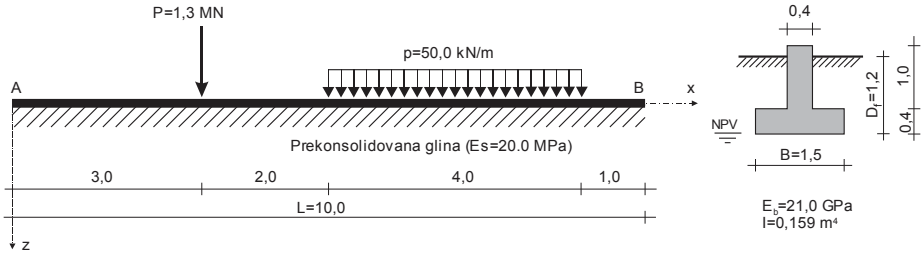
BROJNI PRIMER – 5

Armirano betonski temeljni nosač (slika 6.6), fundiran je na dubini od D_f =1.5m, u sloju prekonsolidovane gline sa modulom elastičnosti *Es*=20.0 MN/m^2 i Poisson-ovim koeficijentom ν_s=0.30. Odrediti pomeranja i presečne sile nosača u $^1/_{10}$ raspona. Odrediti ekvivalentni modul reakcije po Vesiću i uporediti rezultate sa rešenjem za nosač na Vinklerovoj i elastičnoj podlozi. Proračun izvršiti numerički, koristeći MKR.



Slika 6.6 Temeljni nosač na sloju prekonsolidovane gline

Rešenje:

Elementi matrice uticajnih funkcija [*f*] za podelu temeljnog nosača na *n*=10 jednakih delova, (koristeći program napisan u *EXCEL*-u) glase:

$$E_b I = 21.0 \cdot 10^6 \cdot 0.159 = 3.339 \cdot 10^6 \ \ MNm^2, \quad c = \frac{L}{n} = \frac{10.0}{10} = 1.0\,m, \quad \frac{c}{B} = \frac{1.0}{1.5} = 0.667$$

$$[f] = \begin{vmatrix} 0.45253 & 0.31335 & 0.15865 & 0.10597 & 0.07952 & 0.06363 & 0.05304 & 0.04546 & 0.03978 & 0.03536 & 0.01631 \\ 0.19135 & 0.90505 & 0.31335 & 0.15865 & 0.10597 & 0.07952 & 0.06363 & 0.05304 & 0.04546 & 0.03978 & 0.01817 \\ 0.08890 & 0.31335 & 0.90505 & 0.31335 & 0.15865 & 0.10597 & 0.07952 & 0.06363 & 0.05304 & 0.04546 & 0.02051 \\ 0.05733 & 0.15865 & 0.31335 & 0.90505 & 0.31335 & 0.15865 & 0.10597 & 0.07952 & 0.06363 & 0.05304 & 0.02354 \\ 0.04222 & 0.10597 & 0.15865 & 0.31335 & 0.90505 & 0.31335 & 0.15865 & 0.10597 & 0.07952 & 0.06363 & 0.02762 \\ 0.03340 & 0.07952 & 0.10597 & 0.15865 & 0.31335 & 0.90505 & 0.31335 & 0.15865 & 0.10597 & 0.07952 & 0.03340 \\ 0.02762 & 0.06363 & 0.07952 & 0.10597 & 0.15865 & 0.31335 & 0.90505 & 0.31335 & 0.15865 & 0.10597 & 0.04222 \\ 0.02354 & 0.05304 & 0.06363 & 0.07952 & 0.10597 & 0.15865 & 0.31335 & 0.90505 & 0.31335 & 0.15865 & 0.05733 \\ 0.02051 & 0.04546 & 0.05304 & 0.06363 & 0.07952 & 0.10597 & 0.15865 & 0.31335 & 0.90505 & 0.31335 & 0.08890 \\ 0.01817 & 0.03978 & 0.04546 & 0.05304 & 0.06363 & 0.07952 & 0.10597 & 0.15865 & 0.31335 & 0.90505 & 0.19135 \\ 0.01631 & 0.03536 & 0.03978 & 0.04546 & 0.05304 & 0.06363 & 0.07952 & 0.10597 & 0.15865 & 0.31335 & 0.45253 \end{vmatrix}$$

Matrica krutosti je:

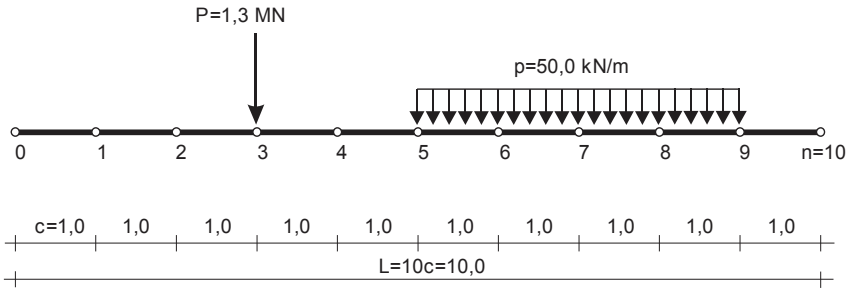
$$[K_t] = \frac{E_b I}{c^3}\left([D] + \frac{c^4}{E_b I}\frac{E_s}{1-\nu_s^2}[f]^{-1}\right) = \frac{3.339 \cdot 10^6}{1.0^3}\left([D] + \frac{1.0^4}{3.339 \cdot 10^6}\frac{20.0 \cdot 10^3}{1-0.3^2}[f]^{-1}\right)$$

$$[K_t] = 3.339 \cdot 10^6\left([D] + 6.583 \cdot 10^{-3}[f]^{-1}\right) \qquad kN/m$$

Elementi matrice krutosti (koristeći program napisan u *EXCEL*-u) iznose:

$$[K_t] = \begin{vmatrix}
6.735E+3 & -1.337E+4 & 6.675E+3 & -1.811E+0 & -1.201E+0 & -8.969E-1 & -7.135E-1 & -5.959E-1 & -5.201E-1 & -4.854E-1 & -5.324E-1 \\
-6.689E+3 & 1.673E+4 & -1.336E+4 & 3.338E+3 & -6.428E-1 & -4.078E-1 & -2.978E-1 & -2.339E-1 & -1.950E-1 & -1.754E-1 & -1.874E-1 \\
3.338E+3 & -1.336E+4 & 2.006E+4 & -1.336E+4 & 3.338E+3 & -6.808E-1 & -4.368E-1 & -3.224E-1 & -2.573E-1 & -2.240E-1 & -2.340E-1 \\
-8.652E-1 & 3.338E+3 & -1.336E+4 & 2.006E+4 & -1.336E+4 & 3.338E+3 & -6.725E-1 & -4.320E-1 & -3.218E-1 & -2.661E-1 & -2.688E-1 \\
-5.573E-1 & -7.040E-1 & 3.338E+3 & -1.336E+4 & 2.006E+4 & -1.336E+4 & 3.338E+3 & -6.728E-1 & -4.363E-1 & -3.362E-1 & -3.243E-1 \\
-4.114E-1 & -4.550E-1 & -6.802E-1 & 3.338E+3 & -1.336E+4 & 2.006E+4 & -1.336E+4 & 3.338E+3 & -6.802E-1 & -4.550E-1 & -4.114E-1 \\
-3.243E-1 & -3.362E-1 & -4.363E-1 & -6.728E-1 & 3.338E+3 & -1.336E+4 & 2.006E+4 & -1.336E+4 & 3.338E+3 & -7.040E-1 & -5.573E-1 \\
-2.688E-1 & -2.661E-1 & -3.218E-1 & -4.320E-1 & -6.725E-1 & 3.338E+3 & -1.336E+4 & 2.006E+4 & -1.336E+4 & 3.338E+3 & -8.652E-1 \\
-2.340E-1 & -2.240E-1 & -2.573E-1 & -3.224E-1 & -4.368E-1 & -6.808E-1 & 3.338E+3 & -1.336E+4 & 2.006E+4 & -1.336E+4 & 3.338E+3 \\
-1.874E-1 & -1.754E-1 & -1.950E-1 & -2.339E-1 & -2.978E-1 & -4.078E-1 & -6.428E-1 & 3.338E+3 & -1.336E+4 & 1.673E+4 & -6.689E+3 \\
-5.324E-1 & -4.854E-1 & -5.201E-1 & -5.959E-1 & -7.135E-1 & -8.969E-1 & -1.201E+0 & -1.811E+0 & 6.675E+3 & -1.337E+4 & 6.735E+3
\end{vmatrix}$$

Elementi vektora P_i i čvornog opterećenja p_i određeni su na osnovu donje slike :



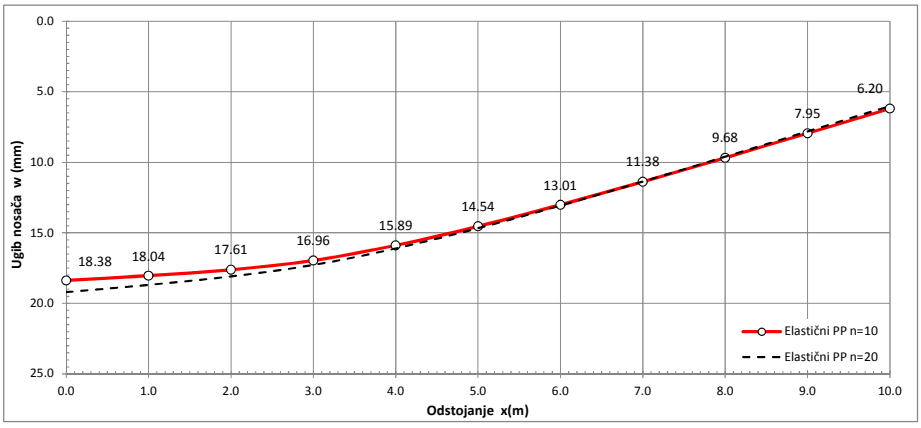
$$P_0 = cp_0 = P_1 = cp_1 = 0$$
$$P_2 = cp_2 = 1.0 \cdot 1300.0\left(1.0 - 1.0\right)/1.0^2 = 0$$
$$P_3 = cp_3 = 1.0 \cdot 1300.0 \cdot 1.0/1.0^2 = 1300.0\ kN$$
$$P_4 = cp_4 = 0$$
$$P_5 = cp_5 = 1.0 \cdot 50.0 \cdot 1.0\left[1.0 - \left(0 + 1.0/2\right)\right]/1.0^2 = 25.0\ kN$$
$$P_6 = cp_6 = 1.0 \cdot 50.0 \cdot 1.0\left(0 + 1.0/2\right)/1.0^2 + 1.0 \cdot 50.0 \cdot 1.0\left[1.0 - \left(0 + 1.0/2\right)\right]/1.0^2 = 50.0\ \ kN$$
$$P_7 = cp_7 = 1.0 \cdot 50.0 \cdot 1.0\left(0 + 1.0/2\right)/1.0^2 + 1.0 \cdot 50.0 \cdot 1.0\left[1.0 - \left(0 + 1.0/2\right)\right]/1.0^2 = 50.0\ \ kN$$
$$P_8 = cp_8 = 1.0 \cdot 50.0 \cdot 1.0\left(0 + 1.0/2\right)/1.0^2 + 1.0 \cdot 50.0 \cdot 1.0\left[1.0 - \left(0 + 1.0/2\right)\right]/1.0^2 = 50.0\ \ kN$$
$$P_9 = cp_9 = 1.0 \cdot 50.0 \cdot 1.0\left[1.0 - \left(0 + 1.0/2\right)\right]/1.0^2 = 25.0\ kN$$
$$P_{10} = cp_{10} = 0$$

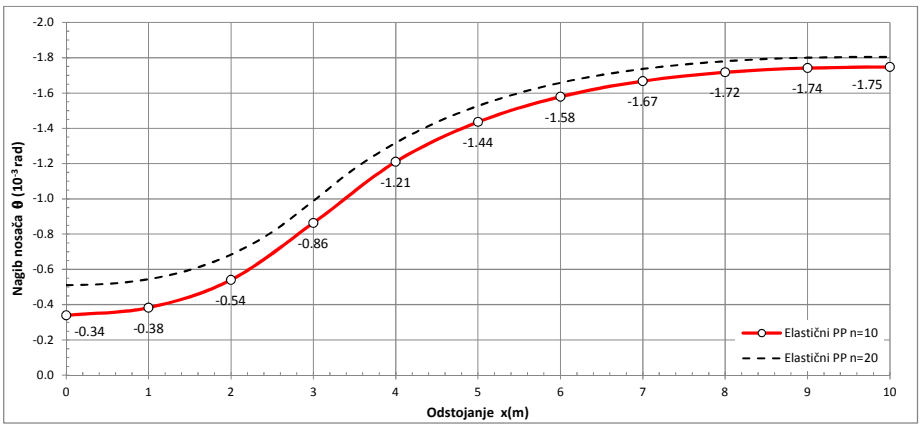
Sleganje i kontaktni napon se mogu odrediti na osnovu jednačine (6.13 i 6.12):

$$\{w\} = \left[K_t\right]^{-1}\{P\} \quad , \qquad \{q\} = \frac{E_s}{1-\nu_s^2}\frac{1}{B}\left[f\right]^{-1}\{w\}$$

Rezultati proračuna nosača na elastičnoj sredini, prikazani su tabelarno i grafički:

$$\{w\}=\begin{Bmatrix}18.38\\18.04\\17.61\\16.96\\15.89\\14.54\\13.01\\11.38\\9.68\\7.95\\6.20\end{Bmatrix}mm,\qquad \{q\}=\begin{Bmatrix}391.71\\112.23\\121.91\\113.95\\103.08\\91.00\\78.36\\65.47\\52.55\\36.73\\57.78\end{Bmatrix}\frac{kN}{m^2},\qquad \{\theta\}=\begin{Bmatrix}-0.34\\-0.38\\-0.54\\-0.86\\-1.21\\-1.44\\-1.58\\-1.67\\-1.72\\-1.74\\-1.75\end{Bmatrix}10^{-3}\ rad$$

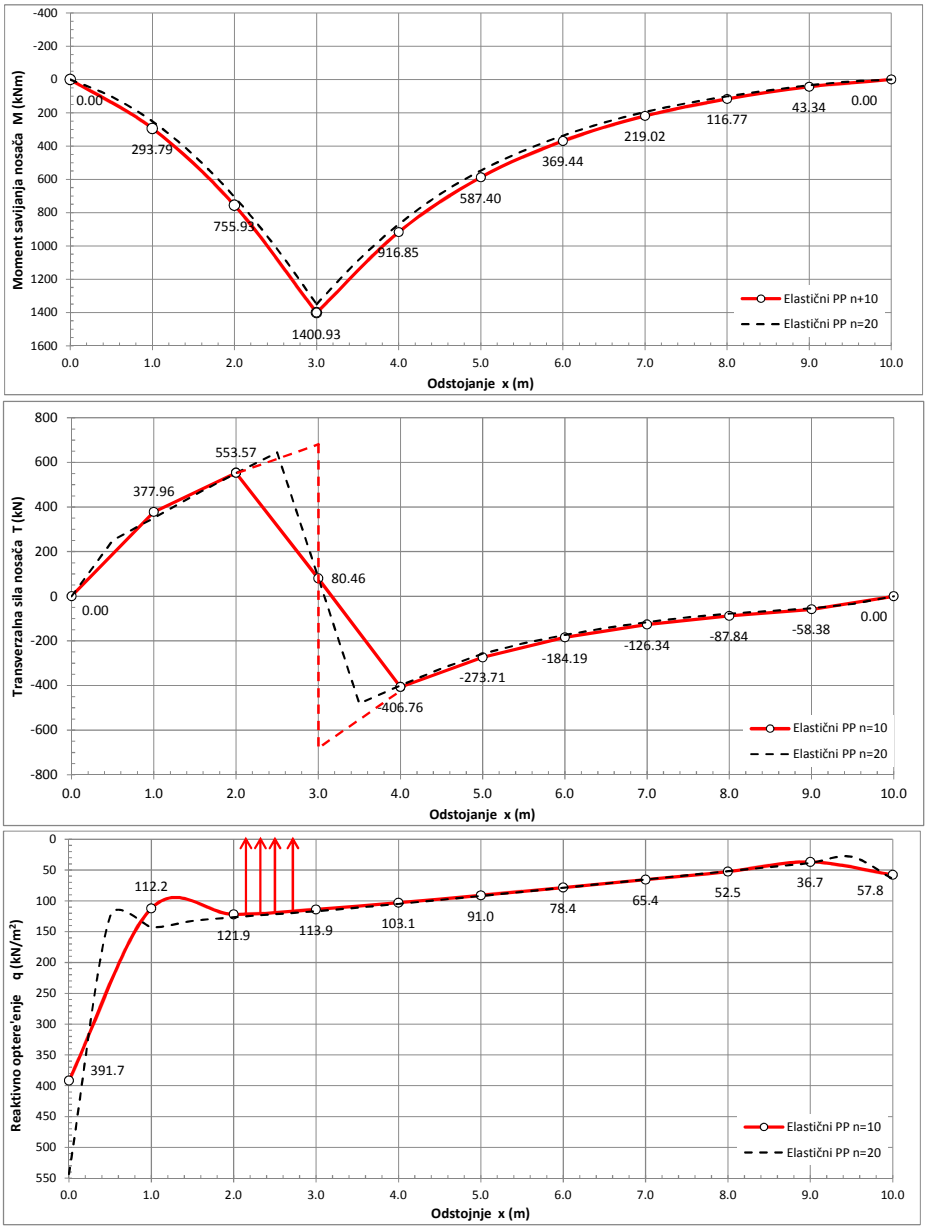




Slika 6.7a Rezultati proračuna ugiba i nagiba nosača prema MKR

Presečne sile su određene preko ugiba nosača. Rezultati su prikazani grafički. Tačnije vrednosti transverzalne sile oko koncentrisane sile, mogu se dobiti usvajanjem finije podele (vidi sliku, n=20) ili proračunom na osnovu zadatog i reaktivnog opterećenja.

$$T_{3l} + T_{3d} = T_3 = 80.46,\ \ T_{3l} - T_{3d} = P = 1300.0 \Rightarrow T_{3l} = 690.23\ kN, T_{3d} = -609.77\ kN$$



Slika 6.7b Rezultati proračuna presečnih sila i kontaktnog napona prema MKR