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STATIK NOANIQ RAMALARNI HISOBLASH

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Annotatsiya. *Maqolada statik noaniq ramalar hisobi kuchlar usulining analitik va matritsa usullarida bajarilgan. Statik noaniq ramalar hisobini zamonaviy komp'yuter texnologiyalaridan foydalanib bajarish matritsalar usulida qulay ekanligi ko'rsatilgan.*

Kalit so'zlar: *statik noaniq ramalar, kuchlar usuli, kanonik tenglamalar sistemasi, matritsalar usuli.*

РАСЧЕТ СТАТИЧЕСКИ НЕОПРЕДЕЛЕННЫХ РАМ

Аннотация. *В статье выполнен расчет статических неопределенных рам с использованием аналитического и матричного методов метода сил. Показано, что расчет статических неопределенных кадров удобно выполнять с использованием современных компьютерных технологий матричным методом.*

Ключевые слова: *статические неопределенные системы отсчета, метод сил, система канонических уравнений, метод матриц.*

CALCULATION OF STATICALLY UNCERTAIN FRAMES

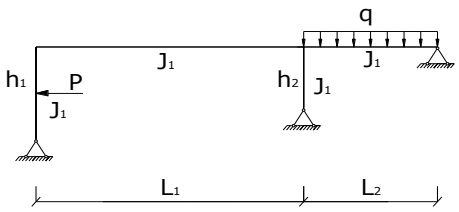
Abstract. *In the article, the calculation of static indeterminate frames is performed using the analytical and matrix methods of force method. It is shown that it is convenient to perform the calculation of static uncertain frames using modern computer technologies using the matrix method.*

Key words: *static uncertain frames, method of forces, system of canonical equations, method of matrices.*

KIRISH

Qurilishda asosan statik aniqmas ramalar qo'llaniladi, chunki statik aniqmas sistemalar statik aniq sistemalarga qaraganda bir qator afzalliklarga ega, jumladan bu sistemalar tejamli va mustahkam bo'ladi [1-3].

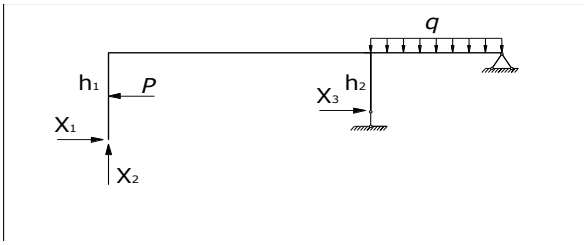
Maqolada statik noaniq ramalar hisobini kuchlar usulining analitik va matritsa usullarida bajaramiz. Statik noaniq ramalar hisobini quyidagi misolda ko'ramiz.



Bu chizmadagi parametrlar uchun quyidagi son qiymatlar olingan: L_1 =8 m, L_2 =4 m, h_1 =3 m, h_2 =2 m, P =10 kN, q =8 kN/m, J_1/J_2=2;

1-shakl

Berilgan ramaning statik aniqmaslik darajasini aniqlash uchun quyidagi ifodadan foydalanamiz: $n = 3 \cdot k - C_T = 3 \cdot 2 - 3 = 3$. Ma'lumki, kuchlar usulida asosiy tizimlar variantlari cheksiz ko'p, biz quyidagi asosiy tizimlar variantini tanlaymiz:



Tanlangan asosiy tizimda berilgan statik aniqmas tizimda olib tashlangan bog'lanishlar yo'nalishi bo'yicha X_1, X_2, X_3 noma'lum kuchlar qo'yilgan.

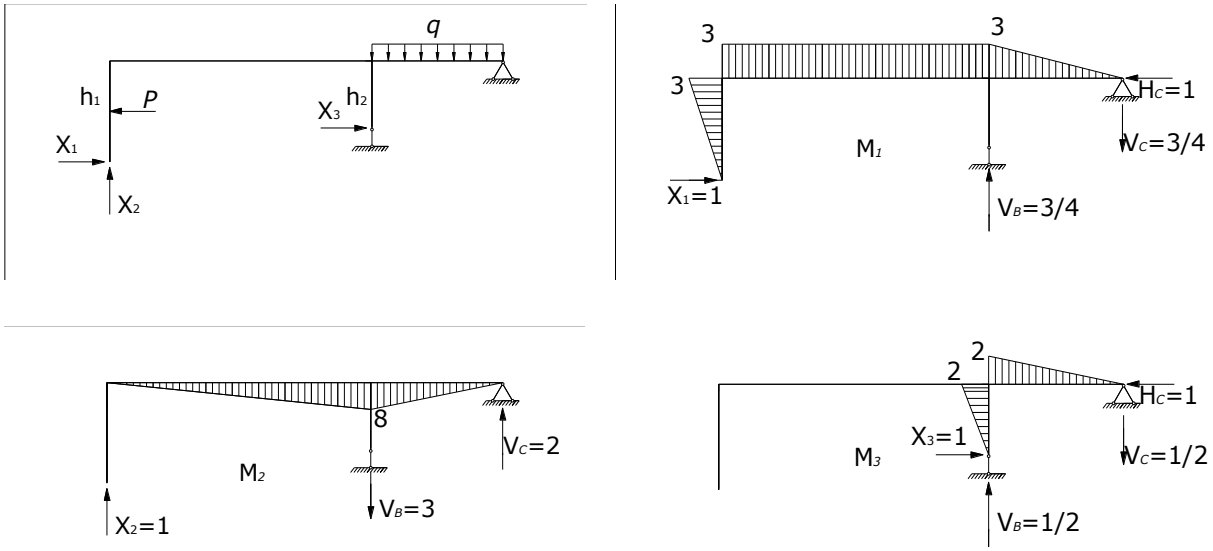
2-shakl

TADQIQOT METODI VA METODOLOGIYASI

Berilgan rama uchun kuchlar usulining kanonik tenglamalar sistemasi quyidagicha bo'ladi:

$$\begin{aligned}\delta_{11}x_1+\delta_{12}x_2+\delta_{13}x_3+\Delta_{1P}=0,\\ \delta_{21}x_1+\delta_{22}x_2+\delta_{23}x_3+\Delta_{2P}=0,\\ \delta_{31}x_1+\delta_{32}x_2+\delta_{33}x_3+\Delta_{3P}=0;\end{aligned} \qquad (1)$$

Kanonik tenglamalardagi (δ_{ik}) koeffitsiyentlarni aniqlash uchun tanlab olingan asosiy tizimda noma'lum kuchlar yo'nalishlariga mos birlik kuchlar ta'siridan birlik eguvchi moment epyuralari quriladi (3-shakl).



3-shakl

Kanonik tenglamadagi (Δ_{iP}) ozod hadlarni aniqlash uchun yuk epyurasi quriladi, buning uchun asosiy tizimga mos ramada tayanch reaksiyalari aniqlanadi va rama uchastkalarga ajratilib ichki kuchlar hisoblanadi:

Tayanch reaksiyalarni aniqlash:

$$\sum X = 0; \quad -P + H_C = 0; \quad H_C = P = 10kN;$$
$$\sum M_B = 0; \quad -P \cdot 0.5 + q \cdot 4 \cdot 2 + H_C \cdot 2 - V_C \cdot 4 = 0;$$
$$V_C = \frac{-10 \cdot 0.5 + 8 \cdot 4 \cdot 2 + 10 \cdot 2}{4} = \frac{79}{4} = 19.75kN;$$
$$\sum M_C = 0; \quad P \cdot 1.5 + V_B \cdot 4 - q \cdot 4 \cdot 2 = 0;$$
$$V_B = \frac{-10 \cdot 1.5 + 8 \cdot 4 \cdot 2}{4} = \frac{49}{4} = 12.25kN;$$

Tayanch reaksiyalarni tekshirish:

$$\sum Y = 0; \quad -q \cdot 4 + V_B + V_C = 0; \quad -8 \cdot 4 + 12.25 + 19.75 = 0; \quad 0 = 0;$$

Rama uchastkalari bo'yicha moment tenglamalari quyidagicha:

$M_I(z_1) = 0;$ $0 \le z_1 \le 1.5m;$

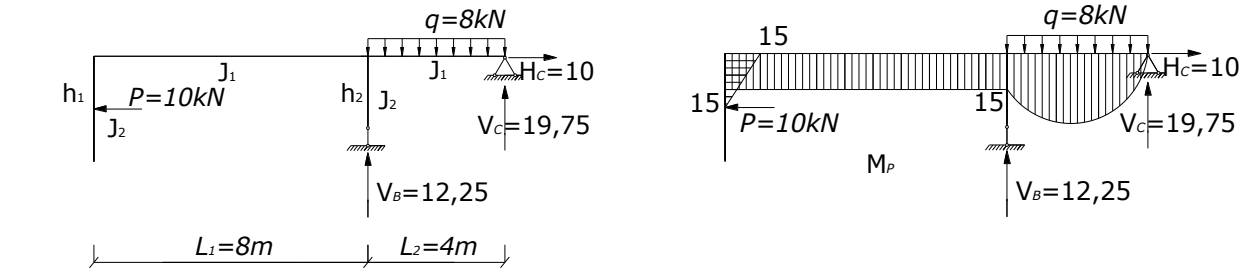
$M_{II}(z_2) = P \cdot (z_2 - 1.5);$ $1.5m \le z_2 \le 3m;$

$M_{III}(z_3) = 0;$ $0 \le z_3 \le 2m;$

$M_{IV}(z_4) = P \cdot 1.5;$ $0 \le z_4 \le 8m;$

$M_V(z_5) = V_C \cdot z_5 - q \cdot z_5 \cdot \frac{z_4}{2};$ $0 \le z_5 \le 4m;$

Yuqoridagi tenglamalarga ko'ra M_P epyurasi quriladi (4-shakl).



4-shakl

Kanonik tenglamalardagi noma'lum koeffitsiyentlar (δ_{ik}) va ozod hadlari (Δ_{iP}) *3*- va 4-shakllardan foydalaib Vereshagin usulida aniqlanadi, bunda $J_1 = 2J_2 : \; J_2 = J_x;$

$$\delta_{11} = (\overline{M}_1 \cdot \overline{M}_1) / EJ_x = 3 \cdot 8 \cdot 3 + \frac{3 \cdot 4}{2} \cdot \frac{2}{3} \cdot 3) / EJ_1 + (\frac{3 \cdot 3}{2} \cdot \frac{2}{3} \cdot 3) / EJ_2 = \frac{51}{EJ_x};$$

$$\delta_{22} = (\overline{M}_2 \cdot \overline{M}_2) / EJ_x = (\frac{8 \cdot 8}{2} \cdot \frac{2}{3} \cdot 8 + \frac{8 \cdot 4}{2} \cdot \frac{2}{3} \cdot 8) / EJ_1 = \frac{128}{EJ_x};$$

$$\delta_{33} = (\overline{M}_3 \cdot \overline{M}_3) / EJ_x = (\frac{2 \cdot 4}{2} \cdot \frac{2}{3} \cdot 4) / EJ_1 + (\frac{2 \cdot 2}{2} \cdot \frac{2}{3} \cdot 2) / EJ_2 = \frac{16}{3EJ_x};$$

$$\delta_{12} = \delta_{21} = (\overline{M}_1 \cdot \overline{M}_2) / EJ_x = -(\frac{8 \cdot 8}{2} \cdot 3 + \frac{8 \cdot 4}{2} \cdot \frac{2}{3} \cdot 3) / EJ_1 = -\frac{64}{EJ_x};$$

$$\delta_{13} = \delta_{31} (\overline{M}_1 \cdot \overline{M}_3) / EJ_x = (\frac{2 \cdot 4}{2} \cdot \frac{2}{3} \cdot 3) / EJ_1 = \frac{4}{EJ_x};$$

$$\delta_{23} = \delta_{32} = (\overline{M}_2 \cdot \overline{M}_3) / EJ_x = -(\frac{2 \cdot 4}{2} \cdot \frac{2}{3} \cdot 8) / EJ_1 = -\frac{32}{EJ_x};$$

$$\Delta_{1P} = (\overline{M}_1 \cdot \overline{M}_P) / EJ_x = -(15 \cdot 8 \cdot 3 + \cdot 8 \cdot \frac{4^3}{12} \cdot 1.5 + \frac{15 \cdot 4}{2} \cdot \frac{2}{3} \cdot 3) / EJ_1 -$$

$$-(\frac{15 \cdot 1.5}{2} \cdot 2.5) EJ_2 = -\frac{270.125}{EJ_x};$$

$$\Delta_{2P} = (\overline{M}_2 \cdot \overline{M}_P) / EJ_x = (15 \cdot 8 \cdot \frac{2}{3} \cdot 8 + \cdot 8 \cdot \frac{4^3}{12} \cdot 4 + \frac{15 \cdot 4}{2} \cdot \frac{2}{3} \cdot 8) / EJ_1 = \frac{405.3333}{EJ_x};$$

$$\Delta_{3P} = (\overline{M}_3 \cdot \overline{M}_P) / EJ_x = -(8 \cdot \frac{4^3}{12} \cdot 1 + \frac{15 \cdot 4}{2} \cdot \frac{2}{3} \cdot 2) / EJ_1 = -\frac{41.3333}{EJ_x};$$

Aniqlangan koeffitsiyentlar va ozod hadlarning qiymatlarini tekshirish uchun qo'shimcha $\overline{M}_S$ epyurasi hosil qilinadi. Bu epyuraning ordinatalari barcha birlik epyuralarning ordinatalarini algebraik yig'indisiga tengdir (epyuralarni qo'shish usuli). So'ngra satr tekshiruvi va universal tekshiruv o'tkaziladi.

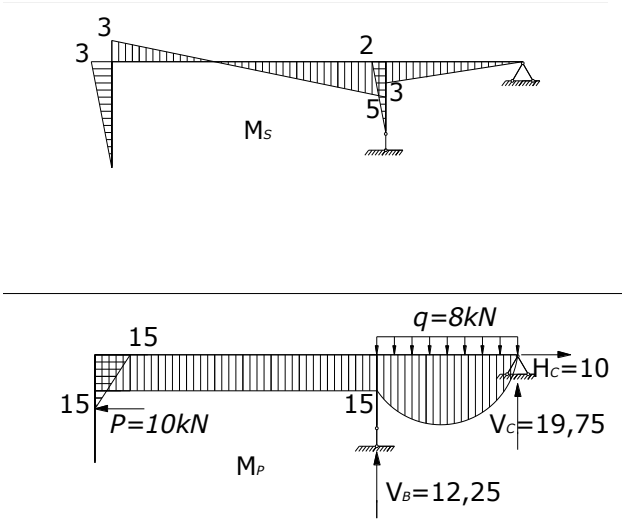
Satr tekshiruvi:

$$\delta_{11} + \delta_{12} + \delta_{13} = (\overline{M}_1 \cdot \overline{M}_S); \qquad \delta_{21} + \delta_{22} + \delta_{23} = (\overline{M}_2 \cdot \overline{M}_S); \qquad \delta_{31} + \delta_{32} + \delta_{33} = (\overline{M}_3 \cdot \overline{M}_S);$$

Universal tekshiruv:

$$\delta_{11} + \delta_{22} + \delta_{33} + 2(\delta_{12} + \delta_{13} + \delta_{23}) = (\overline{M}_S \cdot \overline{M}_S); \qquad \Delta_{1P} + \Delta_{2P} + \Delta_{3P} = (\overline{M}_P \cdot \overline{M}_S).$$

Odatda, universal tekshiruvni bajarish bilan ham cheklanish mumkin.



5-shakl

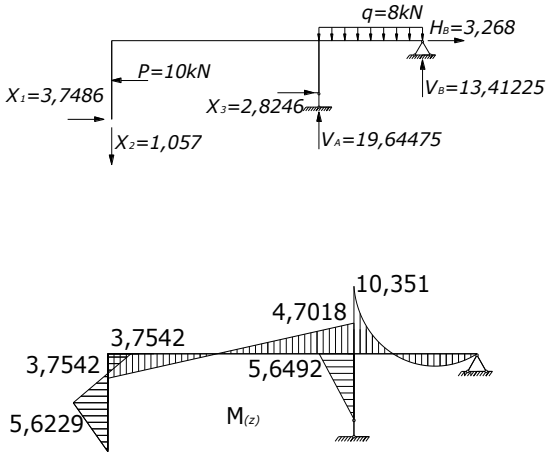
$$\frac{\overline{M}_S \cdot \overline{M}_S}{EJ_x} = (\frac{3\cdot 3}{3}\cdot\frac{2}{3}\cdot 3 + \frac{5\cdot 5}{2}\cdot\frac{2}{3}\cdot 5 + \frac{3\cdot 4}{2}\cdot\frac{2}{3}\cdot 3) / EJ_1 + (\frac{2\cdot 2}{2}\cdot\frac{2}{3}\cdot 2 + \frac{3\cdot 3}{2}\cdot\frac{2}{3}\cdot 3) / EJ_2 = \frac{43}{EJ_2};$$

Kanonik tenglamalar sistemasini yechib natijalar tekshirib ko'riladi:

$$51x_1 - 64x_2 + 4x_3 - 270.125 = 0, \qquad x_1 \approx 3.7486,$$
$$-64x_1 + 128x_2 - 32/3x_3 + 405.3333 = 0, \qquad x_2 \approx -1.057,$$
$$4x_1 - 32x_2/3 + 16x_3/3 - 41.3333 = 0; \qquad x_3 \approx 2.8246;$$

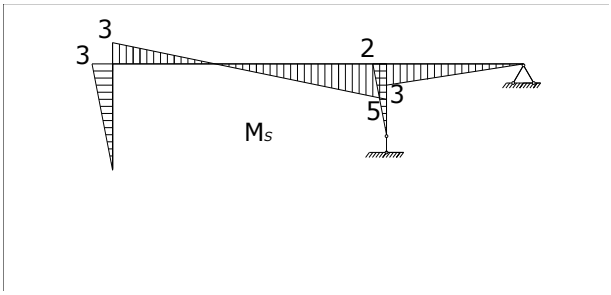
$$51\cdot 3.7486 + 64\cdot 1.057 + 4\cdot 2.8246 - 270.125 = 0, \qquad 0 = 0,$$
$$-64\cdot 3.7487 - 128\cdot 1.057 - 32\cdot 2.8246/3 + 405.3333 = 0, \qquad 0.002 \approx 0,$$
$$4\cdot 3.7487 - 32\cdot 1.057/3 + 16\cdot 2.8246/3 - 41.3333 = 0; \qquad 0.0001 \approx 0;$$

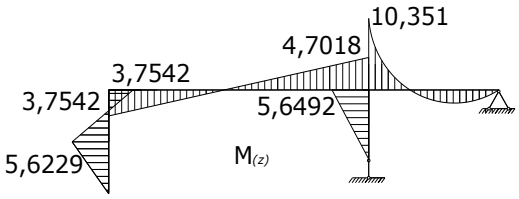
Aniqlangan X_1, X_2, X_3 lardan foydalanib natijaviy eguvchi moment epyurasi quriladi:



6-shakl

Deformatsion tekshiruv o'tkaziladi:





7-shakl

$$\Delta = (\overline{M}_S \cdot \overline{M}_Z) / EJ_X = 0.$$

$$\Delta = (\overline{M}_S \cdot \overline{M}_Z) / EJ_X = \left[-\frac{10.351 \cdot 0.652}{2} \cdot 3.255 + \frac{8 \cdot 0.2772}{12} \cdot \frac{1}{2} \cdot 5.51 \frac{8 \cdot 37.5281}{12} \cdot \frac{1}{2} \cdot 2.51 + \right.$$

$$\left. + \frac{3.7542 \cdot 8}{2} (5 \cdot \frac{1}{3} - 3 \cdot \frac{2}{3}) + \frac{4.7018 \cdot 8}{2} (3 \cdot \frac{1}{3} - 5 \cdot \frac{2}{3}) \right] \cdot \frac{1}{EJ_1} +$$

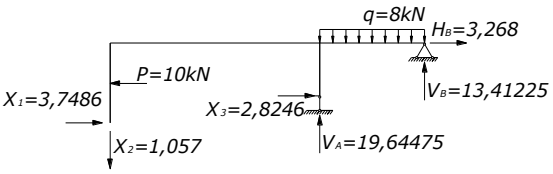
$$+ \left[\frac{5.6492 \cdot 2}{2} \cdot \frac{2}{3} \cdot 2 + \frac{5.6229 \cdot 1.5}{2} \cdot \frac{2}{3} \cdot 1.5 + \frac{5.6229 \cdot 0.9}{2} \cdot 2.1 - \frac{3.7542 \cdot 0.6}{2} \cdot 2.8 \right] \cdot \frac{1}{EJ_2} =$$

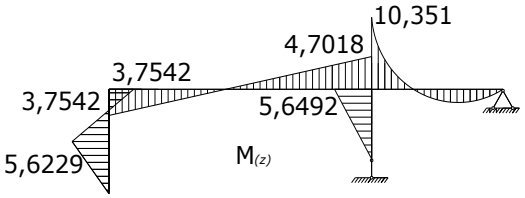
$$= \frac{1}{EJ_X} [-5.4919 + 0.2545 + 15.6992 - 2.5028 - 21.9417 + 7.5323 + 4.2172 + 5.3136 - 3.1535$$

$$= \frac{1}{EJ_X} (-33.0899 + 33.0168) = -\frac{0.0731}{EJ_X};$$

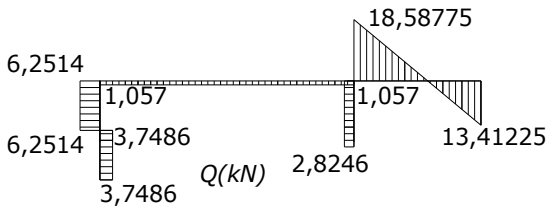
$$Xatolik = \frac{0.0731}{33.0899} \cdot 100\% = 0.22\%.$$

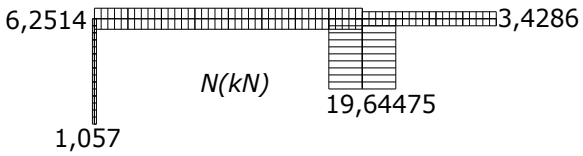
Ichki kuchlar M, Q va N epyuralari quriladi:



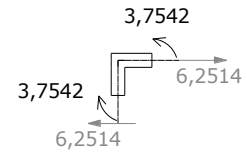


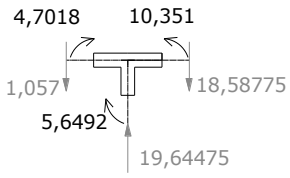
8-shakl





9-shakl

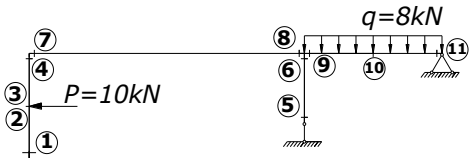


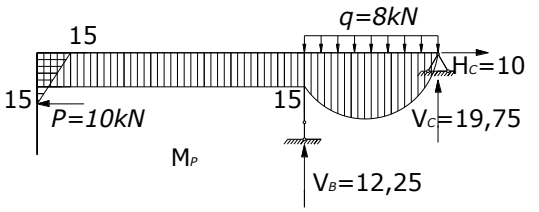


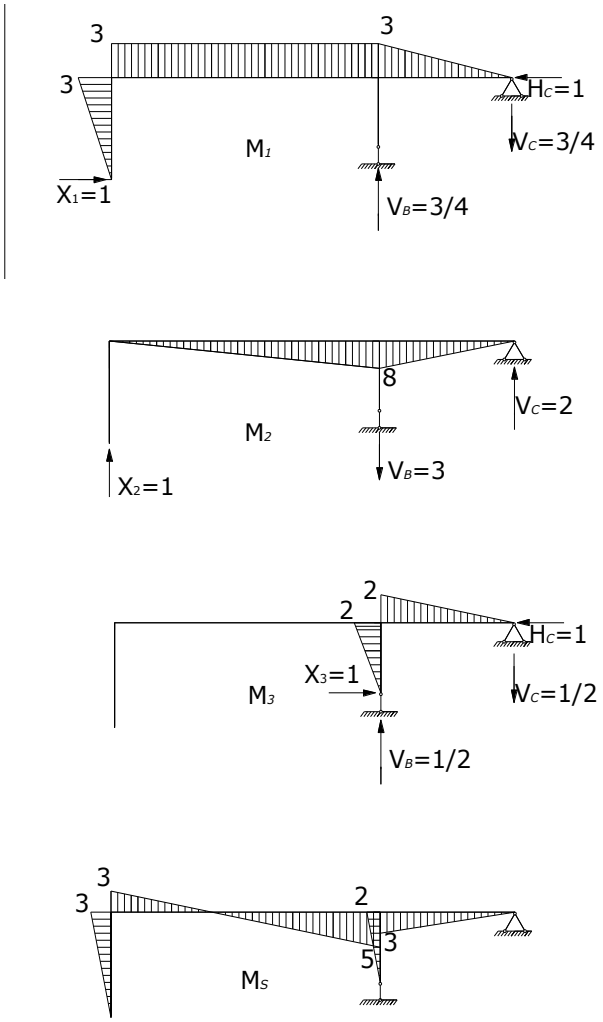
10-shakl

TADQIQOT NATIJASI

Statik aniqmas ramalarni kuchlar usulida matritsalar yordamida hisoblaymiz. Buning uchun yuqorida tanlangan asosiy tizimda rama oraliqlarga ajratilib, xarakterli kesimlar belgilanadi.







11-shakl

Birlik eguvchi moment epyuralaridan $\boldsymbol{L_M}$ ta'sir matritsasi va tashqi yuk eguvchi moment epyurasidan $\boldsymbol{M_P}$ matritsa tuziladi. Ramaning moyillik matritsasi $\boldsymbol{B}$ ramaning yuqorida ajratilgan oraliqlar uchun yozilgan $\boldsymbol{b_i}$ moyillik matritsalaridan tuziladi. Bu yerda L_M^T matritsa $\boldsymbol{L_M}$ matritsaning transponirlangan matritsasi.

$$b_1 = \frac{1.5}{6EJ_X}\begin{Vmatrix} 2 & 1 \\ 1 & 2 \end{Vmatrix} = \frac{1}{6EJ_X}\begin{Vmatrix} 3 & 1.5 \\ 1.5 & 3 \end{Vmatrix};$$

$$b_2 = \frac{1.5}{6EJ_X}\begin{Vmatrix} 2 & 1 \\ 1 & 2 \end{Vmatrix} = \frac{1}{6EJ_X}\begin{Vmatrix} 3 & 1.5 \\ 1.5 & 3 \end{Vmatrix};$$

$$b_3 = \frac{2}{6EJ_X}\begin{Vmatrix} 2 & 1 \\ 1 & 2 \end{Vmatrix} = \frac{1}{6EJ_X}\begin{Vmatrix} 4 & 2 \\ 2 & 4 \end{Vmatrix};$$

$$L_M = \begin{Vmatrix} 0 & 0 & 0 \\ -1.5 & 0 & 0 \\ -1.5 & 0 & 0 \\ -3 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ -3 & 0 & 0 \\ -3 & 8 & 0 \\ -3 & 8 & -2 \\ -1.5 & 4 & -1 \\ 0 & 0 & 0 \end{Vmatrix}; \qquad M_P = \begin{Vmatrix} 0 \\ 0 \\ 0 \\ 15 \\ 0 \\ 0 \\ 15 \\ 15 \\ 15 \\ 23.5 \\ 0 \end{Vmatrix};$$

$$b_5 = \frac{1.5}{6EJ_X}\begin{Vmatrix} 1 & 0 & 0 \\ 0 & 4 & 0 \\ 0 & 0 & 1 \end{Vmatrix} = \frac{1}{6EJ_X}\begin{Vmatrix} 2 & 0 & 0 \\ 0 & 8 & 0 \\ 0 & 0 & 2 \end{Vmatrix};$$

$$L_M^T = \begin{Vmatrix} 0 & -1.5 & -1.5 & -3 & 0 & 0 & -3 & -3 & -3 & -1.5 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 8 & 8 & 4 & 0 \\ 0 & 0 & 0 & 0 & 0 & 2 & 0 & 0 & -2 & -1 & 0 \end{Vmatrix};$$

$$b_4 = \frac{4}{6EJ_X}\begin{Vmatrix} 2 & 1 \\ 1 & 2 \end{Vmatrix} = \frac{1}{6EJ_X}\begin{Vmatrix} 8 & 4 \\ 4 & 8 \end{Vmatrix};$$

$$B = \frac{1}{6EJ_X}\begin{Vmatrix} 3 & 1.5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1.5 & 3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 3 & 1.5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1.5 & 3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 4 & 2 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 2 & 4 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 8 & 4 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 4 & 8 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 2 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 8 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 2 \end{Vmatrix};$$

$$L_M^T \times B = \begin{Vmatrix} 0 & -1.5 & -1.5 & -3 & 0 & 0 & -3 & -3 & -3 & -1.5 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 8 & 8 & 4 & 0 \\ 0 & 0 & 0 & 0 & 0 & 2 & 0 & 0 & -2 & -1 & 0 \end{Vmatrix} \cdot \begin{Vmatrix} 3 & 1.5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1.5 & 3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 3 & 1.5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1.5 & 3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 4 & 2 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 2 & 4 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 8 & 4 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 4 & 8 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 2 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 8 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 2 \end{Vmatrix} =$$

$$= \begin{Vmatrix} -2.25 & -4.5 & -9 & -11.25 & 0 & 0 & -36 & -36 & -6 & -12 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 32 & 64 & 16 & 32 & 0 \\ 0 & 0 & 0 & 0 & 4 & 8 & 0 & 0 & - & -8 & 0 \end{Vmatrix};$$

MUHOKAMA

Yuqorida aniqlangan matritsalar yordamida A_δ birlik ko'chishlar matritsasini hisoblaymiz:

$$A_\delta = L_M^T \cdot B \cdot L_M = \frac{1}{6EJ_X} \begin{Vmatrix} -2.25 & -4.5 & -9 & -11.25 & 0 & 0 & -36 & -36 & -6 & -12 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 32 & 64 & 16 & 32 & 0 \\ 0 & 0 & 0 & 0 & 4 & 8 & 0 & 0 & - & -8 & 0 \end{Vmatrix} \cdot$$

$$\cdot \begin{Vmatrix} 0 & 0 & 0 \\ -1.5 & 0 & 0 \\ -1.5 & 0 & 0 \\ -3 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ -3 & 0 & 0 \\ -3 & 8 & 0 \\ -3 & 8 & -2 \\ -1.5 & 4 & -1 \\ 0 & 0 & 0 \end{Vmatrix} = \frac{1}{6EJ_X} \begin{Vmatrix} 306 & -384 & 24 \\ -384 & 768 & -64 \\ 24 & -64 & 32 \end{Vmatrix} = \frac{1}{EJ_X} \begin{Vmatrix} 51 & -64 & 4 \\ -64 & 128 & -\frac{32}{3} \\ 4 & -\frac{32}{3} & \frac{16}{3} \end{Vmatrix};$$

Tashqi yuklardan hosil bo'lgan Δ_P ko'chishlar matritsasini hisoblaymiz:

$$\Delta_P = L_M^T \cdot B \cdot M_P = \frac{1}{6EJ_X}\begin{Vmatrix} -2.25 & -4.5 & -9 & -11.25 & 0 & 0 & -36 & -36 & -6 & -12 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 32 & 64 & 16 & 32 & 0 \\ 0 & 0 & 0 & 0 & 4 & 8 & 0 & 0 & - & -8 & 0 \end{Vmatrix} \cdot \begin{Vmatrix} 0 \\ 0 \\ 0 \\ 15 \\ 0 \\ 0 \\ 15 \\ 15 \\ 15 \\ 23.5 \\ 0 \end{Vmatrix} =$$

$$= \frac{1}{6EJ_X}\begin{Vmatrix} -1620.75 \\ 2432 \\ 248 \end{Vmatrix} = \frac{1}{EJ_X}\begin{Vmatrix} -270.125 \\ 405.3333 \\ -41.3333 \end{Vmatrix};$$

Noma'lum X_1, X_2, X_3 larni aniqlash uchun A_δ matritsani teskari matritsasi $A_\delta^{-1} = \bar{A}_\delta / Det\, A_\delta$ ni aniqlanadi, bu yerda $D_0 = Det\, A_\delta$, $\bar{A}_\delta = (-1)^{i+j} M_{ij}$ bo'lib, quyidagicha aniqlanadi:

$$D_0 = \begin{vmatrix} \delta_{11} & \delta_{12} & \delta_{13} \\ \delta_{21} & \delta_{22} & \delta_{23} \\ \delta_{31} & \delta_{32} & \delta_{33} \end{vmatrix} = \delta_{11}\delta_{22}\delta_{33} + \delta_{12}\delta_{23}\delta_{31} + \delta_{13}\delta_{21}\delta_{32} - \delta_{22}\delta^2{}_{13} - \delta_{11}\delta^2{}_{23} - \delta_{33}\delta^2{}_{12} = 10581.33333/(EJ_x)^3;$$

$$M_{11} = \frac{(-1)^{1+1}}{(EJ_x)^2}\begin{vmatrix} 128 & -\frac{32}{3} \\ -\frac{32}{3} & \frac{16}{3} \end{vmatrix} = \frac{568.89}{(EJ_x)^2}; \quad M_{12} = \frac{(-1)^{1+2}}{(EJ_x)^2}\begin{vmatrix} -64 & -\frac{32}{3} \\ 4 & \frac{16}{3} \end{vmatrix} = \frac{298.67}{(EJ_x)^2};$$

$$M_{13} = \frac{(-1)^{1+3}}{(EJ_x)^2}\begin{vmatrix} -64 & 128 \\ 4 & -\frac{32}{3} \end{vmatrix} = \frac{170.67}{(EJ_x)^2}; \quad M_{21} = \frac{(-1)^{2+1}}{(EJ_x)^2}\begin{vmatrix} -64 & 4 \\ -\frac{32}{3} & \frac{16}{3} \end{vmatrix} = \frac{298.67}{(EJ_x)^2};$$

$$M_{22} = \frac{(-1)^{2+2}}{(EJ_x)^2}\begin{vmatrix} 51 & 4 \\ 4 & \frac{16}{3} \end{vmatrix} = \frac{256}{(EJ_x)^2}; \quad M_{23} = \frac{(-1)^{2+3}}{(EJ_x)^2}\begin{vmatrix} 51 & -64 \\ 4 & -\frac{32}{3} \end{vmatrix} = \frac{288}{(EJ_x)^2};$$

$$M_{31}=\frac{(-1)^{3+1}}{(EJ_x)^2}\begin{vmatrix}-64 & 4\\ 128 & -\frac{32}{3}\end{vmatrix}=\frac{170.67}{(EJ_x)^2};\quad M_{32}=\frac{(-1)^{3+2}}{(EJ_x)^2}\begin{vmatrix}51 & 4\\ -64 & -\frac{32}{3}\end{vmatrix}=\frac{288}{(EJ_x)^2};$$

$$M_{33}=\frac{(-1)^{3+3}}{(EJ_x)^2}\begin{vmatrix}51 & -64\\ -64 & 128\end{vmatrix}=\frac{5492}{(EJ_x)^2};\quad A_{\delta}^{-1}=\frac{1}{D_0}\begin{vmatrix}568.89 & 298.67 & 170.67\\ 298.67 & 256 & 288\\ 170.67 & 288 & 5492\end{vmatrix};$$

$$X=-A_{\delta}^{-1}\cdot\Delta_P=\frac{1}{10581.33333}\begin{vmatrix}568.89 & 298.67 & 170.67\\ 298.67 & 256 & 288\\ 170.67 & 288 & 5492\end{vmatrix}\cdot\begin{vmatrix}-270.125\\ 405.3333\\ -4.3333\end{vmatrix}=\begin{vmatrix}3.7486\\ -1.057\\ 2.8246\end{vmatrix};$$

XULOSA

Noma'lumlarning qiymatlarini asosiy tizimga qo'yib, hosil bo'lgan statik aniq rama hisobini bajarishga o'tish mumkin.

Adabiyotlar:

1.Odilho'jayev E.A., G'ulomov T.G'., Abdukomilov T .K. Qurilish mexanikasi. T.: O'qituvchi.-1985.-272 b.

2.Abdusattorov A., Xaydarov A.X., Matkarimov A.X. Qurilish mexanikasi. T.: O'qituvchi.-2017.-164 b.

3.Matkarimov A.X., Mengliev I. Statik noaniq tutash balkalarni turli usullarda-hisoblash // Talqin va tadqiqotlar respublika ilmiy-uslubiy jurnali №5 June 30, 2022, 30-33 бетлар.