CALCULATION OF STATIC UNCERTAIN CONTINUOUS BEAMS

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Abstract. *In practice, the most common method of calculating static uncertain systems is the force method. However, at present, in the technical universities of our republic, the force method is used only for the calculation of static uncertain constructions, and the calculation of continuous beams is carried out using three moment equations.*

Keywords: *continuous beams, external force, three moment equation, balance equation, base reaction, static indeterminacy.*

Continuous beams are an important class of static indeterminate beam systems and are often used in construction and other branches of modern technology.

In practice, the most common method of calculating static uncertain systems is the force method [1-4]. However, at present, in the technical universities of our republic, the force method is used only for the calculation of static uncertain constructions, and the calculation of continuous beams is carried out using three moment equations. Using the method of calculating continuous beams using three moment equations also has a number of important disadvantages [5]. It is appropriate to use the force method to calculate any static uncertain systems (stem, frame, hammer, spatial systems).

We propose to calculate the continuous beam under the influence of external force using two methods - force method and three moment equations.

Example. We choose a continuous beam under the influence of an external force (Fig. 1). 1. We determine the degree of static uncertainty of the beam (Fig. 1a). We use the following formula to determine redundant connections in statically uncertain steerable systems: $L = C_T + 2Sh - 3D$. Here C_T – number of base reaction forces; Sh - the number of intermediate hinges; D –number of disks. For continuous beams (Sh = 0 and D = 1) the above equation looks like this.

$$L=C_T-3. \qquad (1)$$

In our example, $C_T = 6$. is L = 6 - 3 = 3. So, the beam is three times statically indeterminate hammer.

2. We select the main system. (Figure 1). Unknown unit as reaction force X_1, X_2, X_3 we get base reaction forces and bending moments.

3. We construct the canonical equations of the force method. For three times statically uncertain hammer $\delta_{13} = \delta_{31} = 0$ taking into account that, we have a system of canonical equations:

Such a structure of equations is appropriate for any system.

4. We are the only bending moments (Fig. 1, v) and loading (Fig. 1, g) diagrams, we consider each span of the beam as a separate simple two-support beam, the last span is considered together with the cantilever

$$\begin{aligned} &\delta_{11}X_1+\delta_{12}X_2+0+\Delta_{1F}=0;\\ &\delta_{21}X_1+\delta_{22}X_2+\delta_{23}X_3+\Delta_{2F}=0;\\ &0+\delta_{32}X_2+\delta_{33}X_3+\Delta_{3F}=0. \end{aligned} \qquad (2)$$

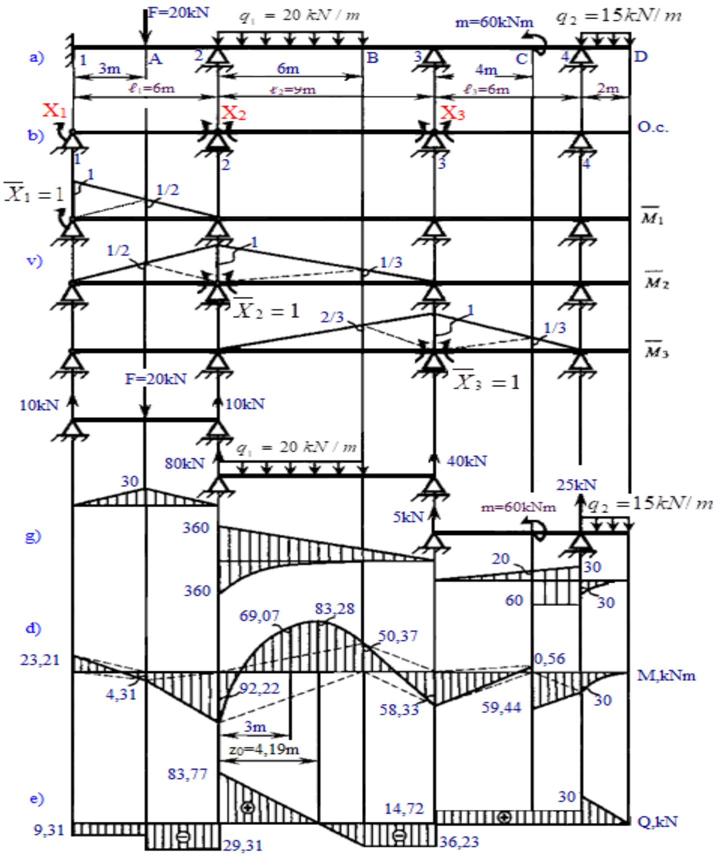

Fig.1

5. Using the Maxwell-Mohr integral, we find the coefficients and free terms of the canonical equations (2), we use the method of "multiplying" the curves according to the rule of A. N.Vereshchagin:

$$\delta_{11}=\sum\int\frac{\overline{M}_1\overline{M}_1}{EJ}dz=\frac{1}{EJ}(\overline{M}_1\overline{M}_1)=\frac{1}{EJ}\left(\frac{1}{2}\cdot 6\cdot 1\frac{3}{2}\cdot 1\right)=\frac{2}{EJ};$$

$$\delta_{12}=\delta_{21}=\frac{1}{EJ};\qquad \delta_{22}=\frac{5}{EJ};\qquad \delta_{23}=\delta_{32}=\frac{1{,}5}{EJ};\quad \delta_{33}=\frac{5}{EJ};$$

$$\Delta_{1F}=\sum\int\frac{M_F\overline{M}_1}{EJ}dz=\frac{45}{EJ};\quad \Delta_{2F}=\frac{525}{EJ};\quad \Delta_{3F}=\frac{430}{EJ}.$$

6. Substituting the found values into the system of equations (2), we find by solving it:

$$X_1=23{,}61kN\cdot m;\quad X_2=-92{,}22kN\cdot m;\quad X_3=-58{,}33kN\cdot m.$$

7. We construct a curve of bending moments for the entire beam. We use the following formula to calculate the bending moments in the characteristic sections of the beam

$$M = \overline{M}_1 X_1 + \overline{M}_2 X_2 + \overline{M}_3 X_3 + M_F . \qquad (3)$$

Accounted:

$$M_1 = 1 \cdot 23{,}61 = 23{,}61 kN \cdot m; \qquad M_A = \frac{1}{2} \cdot 23{,}61 + \frac{1}{2}(-92{,}22) + 30 = -4{,}31 kN \cdot m;$$

$$M_2 = 1(-92{,}22) = -92{,}22 kN \cdot m; \quad M_B = \frac{1}{3} \cdot (-92{,}22) + \frac{2}{3}(-58{,}33) + 120 = 50{,}37 kN \cdot m;$$

$$M_3 = 1(-58{,}33) = -58{,}33 kN \cdot m; \; M_4 = -30 kN \cdot m; \quad M_D = 0;$$

$$M_C^{chap} = \frac{1}{3}(-58{,}33) + 20 = 0{,}56 kN \cdot m; \qquad M_C^{chap} = 0{,}56 - 60 = -59{,}44 kN \cdot m.$$

The value of the bending moment in the middle of the section with a uniformly distributed load q- is as follows

$$M_{l_2 = 3m} = \frac{1 + \frac{1}{3}}{2}(-92{,}22) + \frac{\frac{2}{3}}{2} = (-58{,}33) + \left(\frac{360 + 120}{2} - 20 \cdot 3 \cdot 1{,}5 \right) = 69{,}07 kN \cdot m.$$

Based on the calculations, we construct the map M (Fig. 1d).

8. Let's build a diagram of transverse forces. To do this, we use Juravsky's formula for the differential connection between a uniformly distributed load and a transverse force in bending:

$$Q = \frac{dM}{dz}; \qquad Q = Q_0 + \frac{M_{o'ng} - M_{chap}}{l} \qquad (4)$$

Here Q_0- transverse force generated in the section of the beam under the influence of a uniformly distributed load. When looking at the beam from left to right, the direction of the transverse force is determined according to the following rule: in sections with an increasing bending moment, the transverse force is positive, and vice versa, negative [6].

We calculate:

$$Q_{1A} = -\frac{23{,}61 + 4{,}31}{3} = -9{,}31 kN; \quad Q_{A2} = -\frac{92{,}22 - 4{,}31}{3} = -29{,}3 kN;$$

$$Q_2 = \frac{q_1 (l_2 - 3)}{2} + \frac{M_B - M_2}{l_2 - 3} = \frac{20 \cdot 6}{2} + \frac{50{,}37 - (-92{,}22)}{6} - 36{,}23 kN;$$

$$Q_{A2} = -\frac{92{,}22 - 4{,}31}{3} = -29{,}3 kN; \qquad Q_{3C} = \frac{58{,}33 + 0{,}56}{4} = 14{,}72 kN;$$

$$Q_{C4} = \frac{59{,}44 - 30}{2} = 14{,}72 kN; \quad Q_4 = q_2 a = 15 \cdot 2 = 30 kN; \quad Q_D = 0.$$

Based on the calculations, we construct the graph Q (Fig. 1,e).

We calculate the maximum bending moment in the section where the flat load q_1 is applied. From plot Q we find the following:

$$z_0 = \frac{Q_{\max}}{q_1} = \frac{83{,}77}{20} = 4{,}19;$$

$$M_{\max} = \frac{Q_{\max} z_0}{2} + M_2 = \frac{83{,}77 \cdot 4{,}19}{2} - 92{,}22 = 83{,}28 kN \cdot m.$$

9. We check the correctness of the calculated values.

Static check. We find the support reactions of the continuous beam from the equation Q using the following formula

$$R_n = Q^n_{o'ng} - Q^n_{chap}, \qquad (5)$$

here $Q^n_{o'ng}, Q^n_{chap}$ - transverse forces acting on the right and left sides.

We calculate: $R_1 = -9{,}31 kN;$ $R_2 = 83{,}77 - (-29{,}31) = 113{,}08 kN;$ $R_3 = 14{,}72 - (-36{,}23) = 50{,}95 kN;$ $R_4 = 30 - 14{,}72 = 15{,}28 kN.$

Checking the balance of the whole bean:

$$\sum y = 0; \quad \sum R_n + \sum F = 0;$$

$$R_1 + R_2 + R_3 + R_4 - F - q_1(l_2 - 3) - q_2 a = 0;$$

$$-9{,}31 + 113{,}08 + 50{,}95 + 15{,}28 - 20 - 20 \cdot 6 - 15 \cdot 2 = 0;$$

$$-179{,}31 + 179{,}31 = 0.$$

Kinematic (deformation) check $\theta_1 = 0$, consists of checking whether the angle of rotation of the section on the clamped support is equal to zero, as well as the mutual angle of rotation of the sections on the intermediate supports (for example, $\theta_2 = 0$).). Let's check the last condition.

$$\theta_2 = \sum \int \frac{M \overline{M}_2}{EJ} dz = \frac{1}{EJ}\left[\frac{3 \cdot 23{,}61}{2} \cdot \frac{1}{3} \cdot \frac{1}{2} - \frac{3 \cdot 4{,}31}{2} \cdot \frac{2}{3} \cdot \frac{1}{2} - \frac{3 \cdot 4{,}31}{2} \cdot \left(\frac{2}{3} \cdot \frac{1}{2} + \frac{1}{3} \cdot 1 \right) - \frac{3 \cdot 92{,}22}{2} \cdot \right]$$

$$\cdot \left(\frac{1}{3} \cdot \frac{1}{2} + \frac{2}{3} \cdot 1 \right) + \frac{2}{3} \cdot 6 \cdot \frac{20 \cdot 6^2}{8} \cdot \frac{1 + \frac{1}{3}}{2} + \frac{6 \cdot 50{,}37}{2} \cdot \left(\frac{2}{3} \cdot \frac{1}{3} + \frac{1}{3} \cdot 1 \right) - \frac{6 \cdot 92{,}22}{2} \cdot \left(\frac{2}{3} \cdot 1 + \frac{1}{3} \cdot \frac{1}{3} \right) +$$

$$+ \frac{3 \cdot 50{,}37}{2} \cdot \frac{2}{3} \cdot \frac{1}{3} - \frac{3 \cdot 58{,}33}{2} \cdot \frac{1}{3} \cdot \frac{1}{3} = \frac{1}{EJ}(346{,}64 - 346{,}64) = 0$$

10. We select the cross-section of the double-barreled hammer. Allowable bending stress for this $[\sigma] = 160 MPa$ we find the required moment of resistance of the section [7].

$$W_x \geq \frac{|M_{\max}|}{[\sigma]} = \frac{92{,}22 \cdot 10^6}{160} = 576{,}35 \cdot 10^3 mm^3 = 576{,}35^3 sm^3.$$

According to the assortment table, the moment of resistance $W_x = 597 sm^3$ because it is, we will choose the double beam number 33.

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