Design and Analysis of Flexural Members and Eccentric Compression Members

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Abstract

Under the action of concentrated load, the beam is easy to be bent and sheared. Under the condition of neglecting the self-weight, the concentrated load of the curved beam member can be solved according to the type of concrete and the reinforcement of the longitudinal reinforcement, and the stirrup arrangement is made to make the member meet the requirements of bending damage.Using ABAQUS to verify the component load, the deflection of the designed flexural member and the crack width are checked.Under the action of eccentric external load, the eccentric leg is eccentrically compressed, and the configuration of the longitudinal column of the ox leg is used to solve the eccentric external load and bending moment. The designed eccentric compression member is checked for deflection and crack width.

Keywords

Bent member, eccentric compression member, deflection, crack width.

1. Introduction

Bending members mainly refer to various types of beams and plates. Commonly used cross-sections are rectangular, T-shaped, I-shaped, trough-shaped, hollow and inverted L-shaped symmetrical and asymmetrical cross-sectional forms. The aspect ratio h/b of a rectangular section beam is generally 2.0-3.5; the commonly used concrete strength grades are C25 and C30, generally not exceeding C40.The strength of the steel bars in the beam should be HRB400 and HRB500. The common diameters are 12mm, 14mm, 16mm, 18mm, 20mm, 22mm and 25mm. When the beam height is greater than or equal to 300mm, the longitudinal reinforcement diameter should not be less than 10mm, when the beam height is less than When 300mm, the longitudinal reinforcement diameter should not be less than 8mm.Beam hoops should be HPB400 grade, HRB335 grade, a small amount of HPB300 grade steel bars, common diameters are 6mm, 8mm and 10mm.The reinforcement ratio of the longitudinally-stretched steel bars on one side of the beam shall not be less than the maximum value of 0.2% and 0.45 ft /fy .

The member mainly subjected to axial pressure is a compression member. The pressure-receiving member can be divided into the axial force receiving member, the unidirectional eccentric compression member and the bidirectional eccentric compression member according to the force receiving condition thereof. A rectangular section axial compression member $l_0/b \le 30$, $l_0/h \le 25$, where l_0 is the calculated length of the column, b is the short side length of the rectangular section, and h is the length of the long side. The cross-sectional dimension of the column should be an integer, 800mm or less, preferably a multiple of 50mm, 800mm or more, and a multiple of 100mm.The longitudinal reinforcement diameter of the column should not be less than 12mm; the reinforcement ratio of all longitudinal reinforcements should not be less than 5%, and the longitudinal reinforcement reinforcement ratio of one side of the section should not be less than 0.2%.

2. Bent member

2.1 Component design

See Figure 1 for the bending of the member, Figure 1 and Figure 2 for the dimensions of the member, 5m for the bent member, b=200mm for the rectangular section, h=500mm, C35 for the concrete, and 3 HRB400 steel bars with a diameter of 22mm for the longitudinal reinforcement.

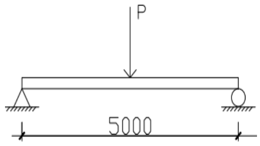

Fig.1 Schematic diagram of member bending

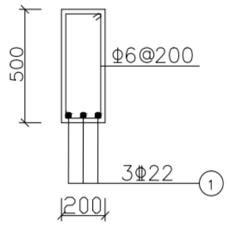

Fig.2 Sectional section

2.2 Component analysis

$$\text{by } \alpha_1 f_c bx = f_y A_s \tag{1}$$

$$x = \frac{f_y A_S}{\alpha_1 f_c b} = \frac{360 \times 1140}{1.0 \times 16.7 \times 200} = 122.87$$

$$x < x_b = 0.518 \times 460 = 238 \tag{2}$$

$$M = f_y A_s \left(h_0 - \frac{x}{2} \right) = 163.57 kN \cdot m \tag{3}$$

$$P = \frac{4M}{l} = \frac{4 \times 163.57}{5} = 130.86 kN \tag{4}$$

$$V = \frac{P}{2} = 65.43 kN$$

$$\text{by } V = \alpha_{cv} f_t bh_0 + f_{yv} \frac{A_{sv}}{s} h_0 \tag{5}$$

$$\frac{A_{sv}}{s} = \frac{V - \alpha_{cv} f_t bh_0}{f_{yv} h_0} = 0.016 \tag{6}$$

using double limbs 6@200

$$\frac{nA_{sv1}}{s} = \frac{2 \times \pi \times 3^2}{200} = 0.28 > 0.016$$

$$\rho_{sv} = \frac{n \cdot A_{sv1}}{bs} = \frac{2 \times \pi \times 3^2}{200 \times 200} = 0.14\% > \rho_{sv,\min} \tag{7}$$

2.3 ABAQUS simulation

The reinforced concrete simply supported beam model is built. The main steps are as follows:

1. Create a concrete simply supported beam with a section of 200 × 500 mm and a net span of 5 m.
2. Establish material properties of concrete and steel, such as density, modulus of elasticity, and plasticity.
3. Assemble the beam into a beam as shown in Figure 3, and divide the feature surface.

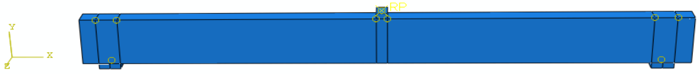

Fig. 3 Beam model after assembly

4. Set the analysis step, create a step-1 after initial, select static, general, incremental type is automatic, maximum incremental step 100, incremental step size, initial incremental step is 0.2, minimum is 1E-06, the largest 1.
5. Coupling the reference point to the surface in the interaction module, binding the spacer and the beam, and embedding the reinforcement mesh into the overall model.

6. The load module is loaded with concentrated force, and the two seats are fixed and hinged respectively.

7. Select the part in the meshing module to draw the mesh. Enter approximately 0.05 for the global size. Divide the components such as: Truss (truss unit), concrete 3D Stress unit, as shown in Figure 4.

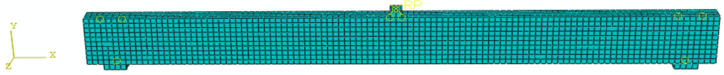

Fig. 4 Simple beam network division

Submit the results. According to the above design, the simply supported beam is simulated in ABAQUS. The added force is 135kN, and the error with the calculated value is within 10%. The design is relatively reasonable.

2.4 Deflection check

$$\rho_{te}=\frac{A_S}{A_{te}}=\frac{1140}{0.5\times 500\times 200}=0.028 \tag{8}$$

$$\sigma_{sq}=\frac{M}{0.87h_0A_s}=\frac{163.57\times 10^6}{0.87\times 460\times 1140}=358.53\,N/mm^2 \tag{9}$$

$$\psi=1.1-0.65\frac{f_{tk}}{\rho_{te}\sigma_{sq}}=1.1-0.65\times\frac{2.2}{0.028\times 358.53}=0.95 \tag{10}$$

$$\alpha_E=\frac{E_s}{E_c}=\frac{2\times 10^5}{3.15\times 10^4}=6.35 \tag{11}$$

$$\rho=\frac{1140}{460\times 200}=0.012$$

$$B_s=\frac{E_sA_sh_0^2}{1.15\psi+0.2+6\alpha_E\rho}=2.76\times 10^{13}\,N/mm^2 \tag{12}$$

$$f=\frac{1}{12}\frac{Ml_0^2}{B}=\frac{1}{12}\times\frac{163.57\times 10^6\times 5000^2}{2.76\times 10^{13}}=12.3mm \tag{13}$$

2.5 Crack width check

$$\begin{aligned}\omega_{\max}&=\alpha_{cr}\psi\frac{\sigma_{sq}}{E_s}\left(1.9c_s+0.08\frac{d_{eq}}{\rho_{te}}\right)\\&=1.9\times 0.95\times\frac{358.53}{2\times 10^5}\times\left(1.9\times 26+0.08\times\frac{22}{0.028}\right)\\&=0.22mm\end{aligned} \tag{14}$$

3. Eccentric compression member

3.1 Component design

The eccentric compression is shown in Figure 5. The component dimensions are shown in Figure 5 and Figure 6. The length of the column is 4 meters, the cross-section is b=300mm, h=400mm, the concrete grade is C35, and the longitudinal reinforcement is symmetrically reinforced. Three HRB400 grade steel bars with a diameter of 22 mm are arranged in the bended area, and HRB335 grade steel bars with a diameter of 8 and 200 are arranged in the stirrups.

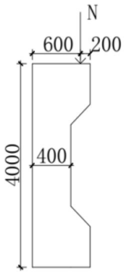

Fig.5 Eccentric pressure diagram

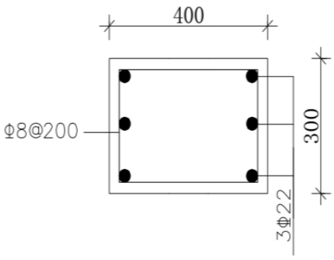

Fig.6 Sectional section

3.2 Component external force solution

assumed $\zeta_c > 1, \zeta_c = 1$

$$\eta_{ns} = 1 + \frac{1}{1300\left(\frac{M_2}{N} + e_a\right)/h_0}\left(\frac{l_c}{h}\right)^2 \zeta_c$$
$$= 1 + \frac{1}{1300 \times 420/360} \times \left(\frac{4000}{400}\right) \times 1$$
$$= 1.07 \quad (15)$$

$$e = \eta_{ns} e_0 + e_a + \frac{h}{2} - a_s = 1.07 \times 400 + 20 + \frac{400}{2} - 40 = 608 \quad (16)$$

$$N = \alpha_1 f_c bx \quad (17)$$

$$Ne = \alpha_1 f_c bx\left(h_0 - \frac{x}{2}\right) + f_y' A_S'\left(h_0 - a_s'\right) \quad (18)$$

from the above two formulas

$$\alpha_1 f_c bxe = \alpha_1 f_c bx\left(h_0 - \frac{x}{2}\right) + f_y' A_S'\left(h_0 - a_s'\right) \quad (19)$$

solutions have to $x = 89.5$ $2a_s' < x < x_b$

$$N = \alpha_1 f_c bx = 16.7 \times 300 \times 89.5 = 448kN \quad (20)$$

$$\zeta_c' = \frac{0.5 f_c A}{N} = \frac{0.5 \times 16.7 \times 400 \times 300}{448000} = 2.2 > 1 \text{ ,take } \zeta_c = 1 \quad (21)$$

axial compression bearing capacity perpendicular to the plane of action of the bending moment

$$N_u = 0.9\varphi\left(f_c A + f_y' A_s'\right) = 2364.36kN > N \quad (22)$$

$$M = \eta_{ns} e_0 N = 191.7kN \cdot m \quad (23)$$

3.3 ABAQUS simulation

The design of the bovine leg design with reference to the above model found that the error was within 10%, and the design was relatively reasonable.

3.4 Check mid-span deflection

$$\rho_{te} = \frac{A_s}{A_{te}} = \frac{1140}{0.5 \times 400 \times 300} = 0.019 \quad (24)$$

$$\sigma_{sq} = \frac{N(e-z)}{A_s z} = \frac{448\times10^3\times(608-360)}{1140\times360} = 271\,N/mm^2 \tag{25}$$

$$\psi = 1.1 - 0.65\frac{f_{tk}}{\rho_{te}\sigma_{sq}} = 1.1 - 0.65\times\frac{2.2}{0.019\times271} = 0.82 \tag{26}$$

$$\alpha_E = \frac{E_s}{E_c} = \frac{2\times10^5}{3.15\times10^4} = 6.35 \tag{27}$$

$$\rho = \frac{A_s}{bh_0} = \frac{1140}{300\times360} = 0.01 \tag{28}$$

$$B_s = \frac{E_s A_s h_0^2}{1.15\psi + 0.2 + \frac{6\alpha_E\rho}{1+3.5\gamma_f'}} = 1.94\times10^{13} \tag{29}$$

$$f = \frac{1}{16}\frac{Ml_0^2}{B_s} = \frac{1}{16}\times\frac{191.7\times10^6\times4000^2}{1.94\times10^{13}} = 9.88mm \tag{30}$$

3.5 Check crack width

$$\omega_{max} = \alpha_{cr}\psi\frac{\sigma_{sq}}{E_s}\left(1.9c_s + 0.08\frac{d_{eq}}{\rho_{te}}\right)$$
$$= 1.9\times0.82\times\frac{271}{2\times10^5}\left(1.9\times28 + 0.08\times\frac{22}{0.019}\right)$$
$$= 0.3mm \tag{31}$$

4. Conclusion

The ABAQUS is used to verify the component load, and the error is controlled within 10%. For the designed flexural members and eccentric compression members, check the deflection and crack width to ensure that the components can be used normally. By observing the deflection of the flexural member, the deflection is 12.3 mm and the crack width is 0.22 mm, which is within the normal range. The deflection of the eccentric compression column is 9.88 mm, and the width of the crack is 0.3 mm, which is verified to meet normal requirements.

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