CIVL471 DESIGN OF RC STRUCTURES

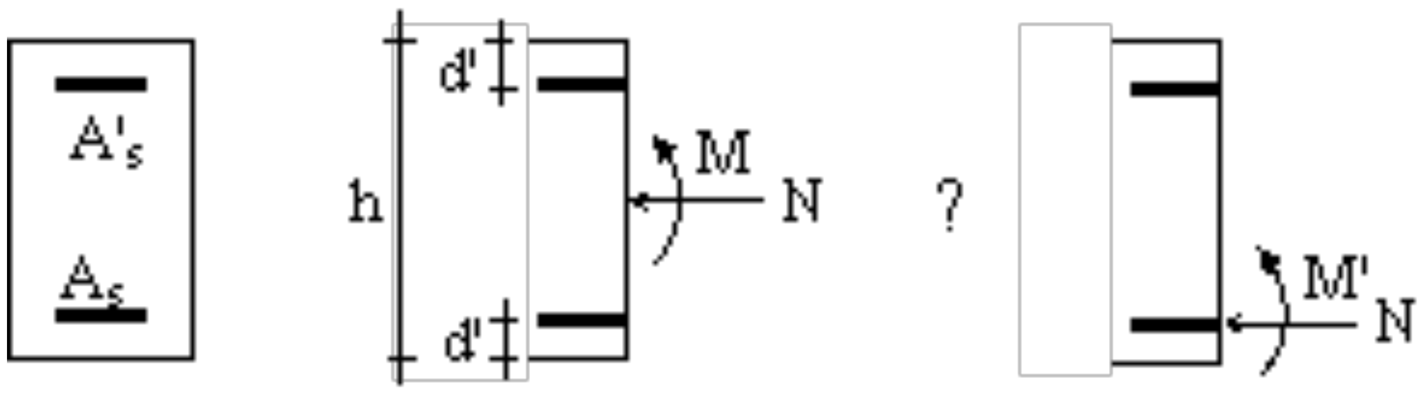
LECTURE NOTE #3

CHAPTER III

SHORT COLUMNS- REVIEW- Continued

Other Design Methods

- Eccentrically loaded columns can be designed by other methods especially when asymmetrical placement of the reinforcement is desired. One of the widely used method is Mörsch method. In this method columns can be designed symmetrically or asymmetrically by using Mörsch diagrams. Another wellknown method is designing the columns like members subjected to pure bending. If eccentricity of the load is very high and at the same direction in all load combinations, behaviour of the column will be similar to a member subjected to pure bending. In that case column may be reinforced asymmetrically. Calculations can be done as follows (See Fig.3.13):



Internal forces calculated at the centroid of the cross-section are carried to the point where the tension reinforcement is. Thus,

$$M' = M + N\,(h/2 - d') \qquad (3.23)$$

First reinforcement is calculated by using pure bending equations then tension steel corresponding to N is substracted from that.

BIAXIAL BENDING OF COLUMNS

- So far it is assumed that bending is uniaxial, that is, about one of the principle axis of the column cross-section. But columns are generally subjected to biaxial bending since the beams are framed into the columns in two directions. Even if bending is uniaxial due to vertical loads, horizontal loads such as earthquake or wind loads acting in the other direction cause biaxial bending. In Fig.3.14 compression plus biaxial bending is shown.

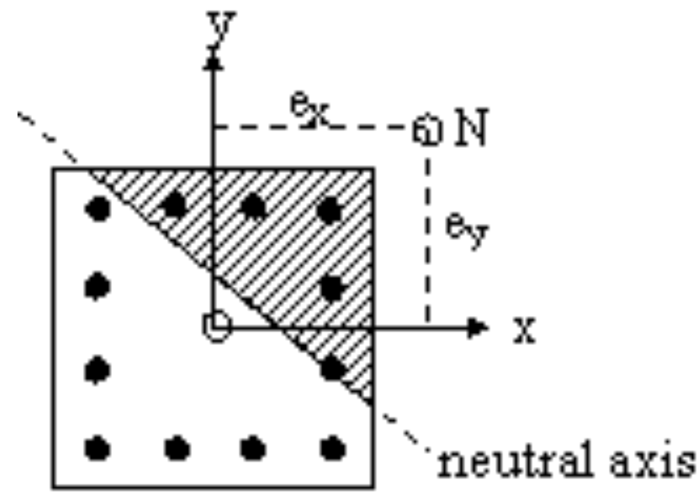


Figure 3.14

- In the biaxial bending case neutral axis is an inclined line. It is rather difficult to establish the position of the neutral axis. For the design an approach similar to interaction diagram method may be used. But in such a method three dimensional charts, that is, interaction surfaces should be produced. In Fig.3.15 such a surface is shown.

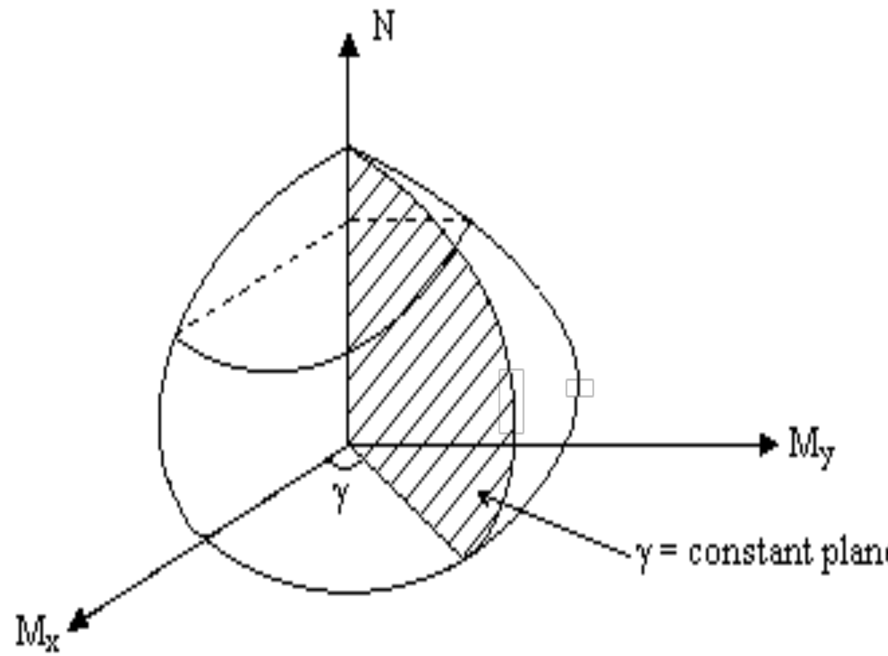


Figure 3.15

Any point on such a surface corresponds to a set of load values N, $M_x = Ne_y$ and $M_y = Ne_x$ resisted by the column. Obviously to produce a three dimensional chart is not easy and convinient for practical purposes. Therefore curves corresponding to a number of γ values may be plotted or programmed for computer. Since

$$tg\gamma = \frac{M_y}{M_x} = \frac{e_x}{e_y} \tag{3.24}$$

column can be designed by using appropriate curve.

There are some other methods developed for the design of biaxially bent columns. One of them is called reciprocal load method. This approximate method developed by B. Bresler proposes the use of the reciprocal load equation:

$$\frac{1}{N_{xy}} = \frac{1}{N_x} + \frac{1}{N_y} - \frac{1}{N_0} \tag{3.25}$$

where N_{xy} = Ultimate load resisted in biaxial bending with the eccentricities e_x and e_y.

N_x = Ultimate load resisted when only e_y is present ($e_x = 0$).

N_y = Ultimate load resisted when only e_x is present ($e_y = 0$).

N_0 = Ultimate load resisted by concentrically loaded column ($e_x = e_y = 0$).

Eq. (3.25) is applicable if $N \geq 0.1N_0$. Otherwise column may be designed by neglecting the axial load. In practice the column is designed for uniaxial bending frequently by neglecting the smallest of the eccentricities. But if the ratio of the eccentricities exceeds 0.2 it is not advisable since it may lead to significant errors.

It is clear that Eq.(3.25) can only be used for rewiev problems. That is, dimensions and the reinforcement of the column should be known and then N_{xy} is calculated. If $N_{xy} < N$ dimensions or reinforcement or both of them shoul be increased and calculations should be repeated.

Example 3.2

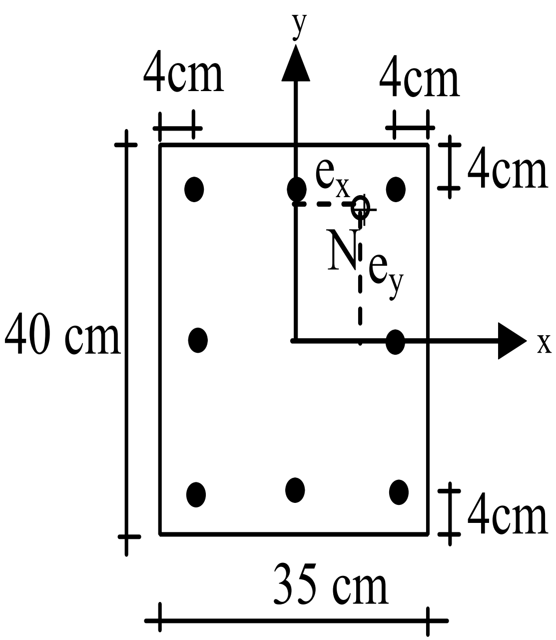


Figure 3.16

Design loads:

$N = 1200$ kN

$M_x = 100$ kN-m

$M_y = 42$ kN-m

Materials: C20 S420

Check adequacy of this column by using Bresler's equation if 8Ø16 bars are placed as shown in Fig.3.16 .

Solution:

a) Calculation of N_x:

$$e_y = \frac{M_x}{N} = \frac{100}{1200} = 0.0833\,\text{m} \qquad \frac{e_y}{h} = \frac{0.0833}{0.40} \approx 0.2$$

$$d'' = 40 - 8 = 32\text{ cm} \qquad d''/h = 32/40 = 0.80 \qquad \lambda = 2/8 = 1/4$$

Chart A-7 will be used. $A_{st} = 16.08\text{ cm}^2$ (8Ø16)

$$\rho_t = \frac{16.08}{35*40} = 0.011 \qquad m = \frac{365}{13} = 28.1 \qquad \rho_t m = 0.011*28.1 = 0.31$$

$$\frac{N}{bhf_{cd}} = 0.72 \text{ can be read on the chart.}$$

$$N_x = 0.72*350*400*13 = 13104010\text{ N} = 1310.4\text{ kN}$$

b) Calculation of N_y:

$$e_x = \frac{M_y}{N} = \frac{42}{1200} = 0.035\,\text{m} \qquad \frac{e_x}{h} = \frac{0.035}{0.35} = 0.10$$

$$d'' = 35 - 8 = 27\ \text{cm} \qquad d''/h = 27/35 \approx 0.8 \qquad \lambda = 2/8 = 1/4$$

In this direction Chart A-7 will also be used.

$$\frac{N}{bhf_{cd}} = 0.94 \quad \text{is read on the graph.}$$

$$N_y = 0.94*400*350*13 = 1710800\ \text{N} = 1710.8\ \text{kN}$$

c) Calculation of N_0:

N_0 can be calculated by Eq. (3.6) or any chart can be used with $\rho_t m = 0.31$.

$$\frac{N}{bhf_{cd}} = 1.17$$ is read on any chart. $N_0 = 1.17*350*400*13 = 2129400$

N = 2129 kN

$N_0 = 0.85*13*350*400 + 1608*365 = 2133920$ N = 2134 kN (Eq. (3.6))

$$\frac{1}{N_{xy}} = \frac{1}{1310} + \frac{1}{1711} - \frac{1}{2134} = (0.763 + 0.584 - 0.469)*10^{-3} = 0.878*10^{-3}$$

$$N_{xy} = \frac{10^3}{0.878} = 1139 \text{ kN} < N = 1200 \text{ kN}$$ Not adequate!

BAR SPLICING IN COLUMNS

- It is common practice to splice the column bars just above the each floor. One reason for that is the dificulty of erecting two or more storey high bars in vertical position. If the bar sizes are to be changed it is another reason to splice the bars. In Fig. 3.17 lap splicing of column bars is shown. If the difference between the dimensions of two columns are not too great bottom column bars are inclined with a maximum slope 1 to 6. This permits proper positioning of the bars above. Below the bending level of lower column bars special ties should be placed to resist the outward thrust which developes there.
- If upper column is too small such that bottom bars can not be inclined with a slope less than 1 to 6, lower column bars are terminated by bending them into the floor as shown in Fig. 3.18. In that case special dowel bars are provided for splicing.

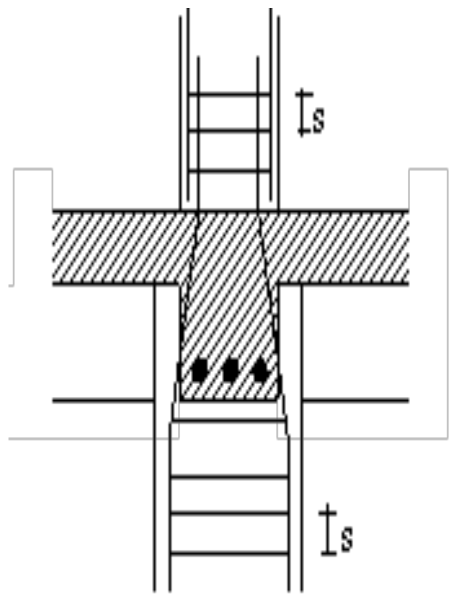


Figure 3.17

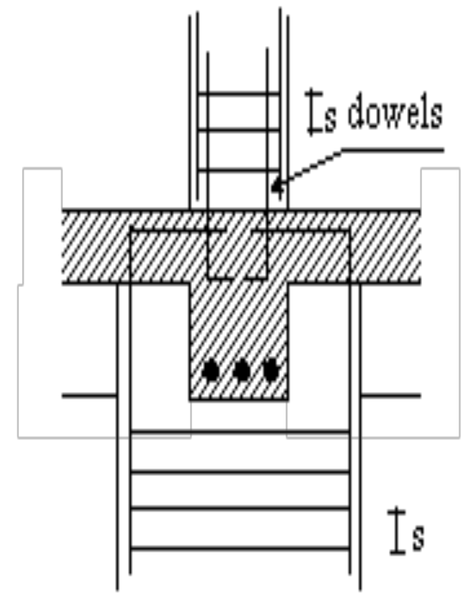


Figure 3.18

Splicing lengths are related to the developement lengths. Developement lengths given by TS500 are as follows:

$$l_b = (0.24 \frac{f_{yd}}{f_{ctd}} Ø) \geq 40Ø \quad \text{(for plain bars)} \qquad (3.26)$$

$$l_b = (0.12 \frac{f_{yd}}{f_{ctd}} Ø) \geq 30Ø \quad \text{(for deformed bars)} \qquad (3.27)$$

where Ø is the diameter of the bar. If the bars in the column are in compression in all loading cases splicing lengths should be equal at least to the development lengths but not less than 30 cm. There should be hoops along the splicing length with the spacing not less than d/4. There should not be hooks at the ends of the bars. Lap splicing should not be used for the compression bars if diameter is greater than 30 mm. They should be spliced with special sleeves which are proved to be safe by laboratory tests. Mechanical and welded connections may also be used for splicing.

If the bars of the column will be subjected to tension in some loading cases, lap splicing length should be selected as follows:

a) If the number of spliced bars is less than half of the total bars: $1.25l_b$

b) Otherwise: $1.5l_b$

If these tension bars are plain bars end hooks should be provided.