CIVL471 DESIGN OF RC STRUCTURES

LECTURE NOTE #1

CHAPTER III

SHORT COLUMNS-REVIEW

Introduction

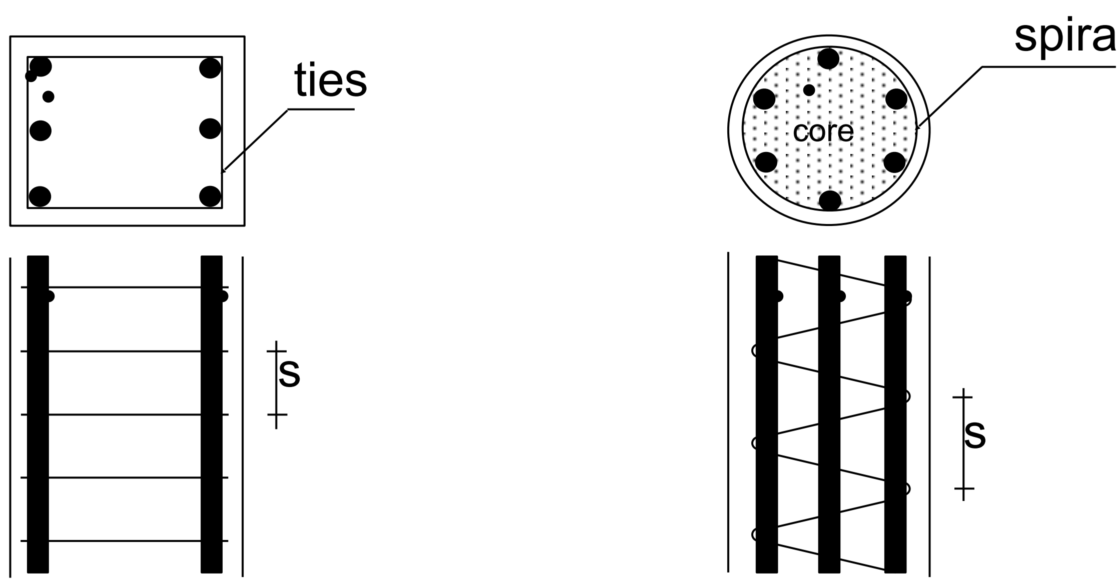
- In conventional buildings all loads are transmitted to the ground by means of stone or brick load bearing walls ending with footings.
- In skeletal structures slab loads are first transmitted to the beams and these loads in addition to the beam own weight and wall weight transmitted to the columns.
- Each column transmit this load and its own weight to the column below and the columns at the bottom of the building transmit these cumulated loads to the ground.
- Positions of the columns in a structure are important and columns should be well arranged.
- It is better to locate the columns at the intersection points of a grid system of the axes.
- Span lengths should not differ to much.
- Vertical axes of the columns in the same vertical line should be as close as possible.
- Regular and simple structural system will be easier to analyze and more reliable.

- Columns are essentially vertical prismatic structural members and they are primarily subjected to compression.

- Compressive force may be concentric or eccentric. Eccentric force means axial force plus bending.

- Therefore, columns can not be made of concrete alone. Reinforcements should be provided under all conditions. Reinforcement will also take compressive stresses as well as tensile stresses.

- Two basic shapes of reinforced concrete columns are shown in Fig. 3.1. Rectangular shape shown in Fig.3.1a is the widely used shape for “tied columns”. They have at least four vertical bars placed at the corners. This main reinforcement is tied by a number of closed hoops or ties. These ties keep the vertical bars in position and prevent their buckling. They also contribute to the shear strength of the column. Columns shown in Fig.3.1b are called “spirally reinforced” or briefly “spiral columns”. They are usually circular. Main steel is surrounded by a continuous and closely spaced spiral bar. This bar confines the core concrete.



a) Tied column

b) Spiral column

Figure 3.1

- In Fig.3.2 various shapes of tied column cross-sections are shown. When axial load is large and moment is small longitudinal bars may be distributed around the perimeter. If bending moment is large most of the steel should be placed at the sides parallel to the axis of bending.

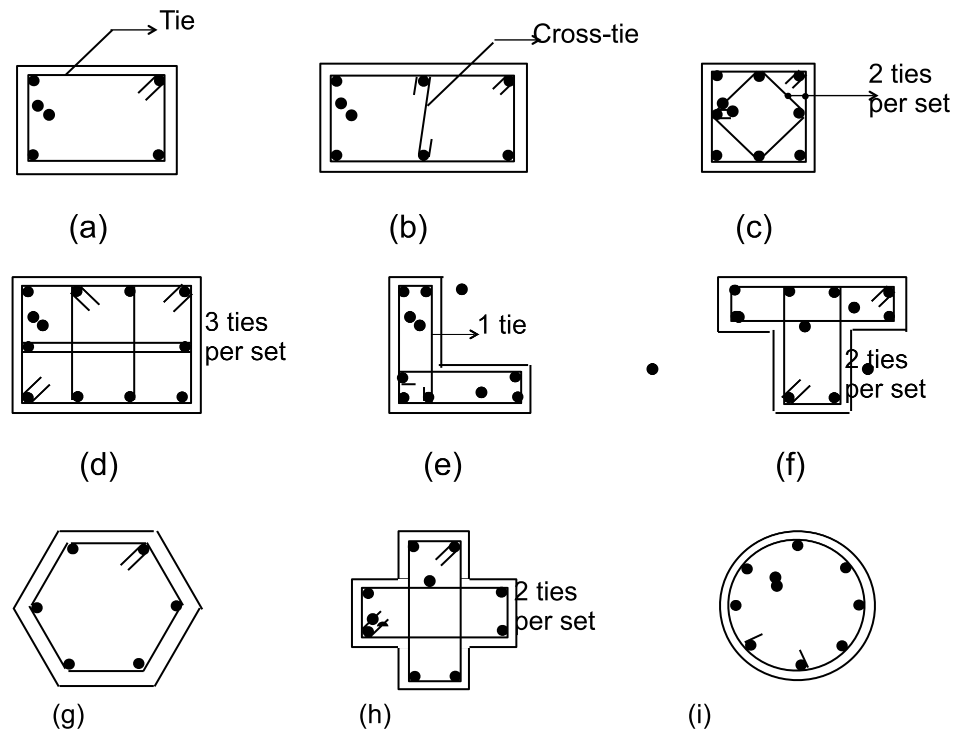


Figure 3.2

Columns may be studied in two groups as short columns and slender columns regardless of the material. Short columns fail when the ultimate strengths of the materials are reached. On the other hand slender columns fail by buckling of the column. In this chapter only short columns will be studied. The influence of the slenderness will be introduced in the next chapter.

BEHAVIOR OF CONCENTRICALLY LOADED SHORT COLUMNS

- Concentric loading of columns is a very rare case (almost impossible). Therefore, TS 500 does not allow design of concentrically loaded columns. However, this will be reviewed here to understand general behavior of columns.

- A column behaves linearly and elastically if subjected to relatively small loads. The equilibrium equation between the external load (***N***) and internal load (stresses) can be written as follows:

$$N = (A_c - A_{st})\, f_c + A_{st} n f_c$$

or $$N = f_c\, [\, A_c + (\, n - 1\,) A_{st}\,] \qquad (3.1)$$

in which $\boldsymbol{A_c}$ is the gross area of the column cross-section, $\boldsymbol{A_{st}}$ is the total area of main reinforcing bars, f_c is the concrete stress and $\boldsymbol{n}$ is the ratio of the elasticity modulus values of steel to concrete ($\boldsymbol{n = E_s / E_c}$). The term in brackets is known as transformed section.

- Concrete and steel stresses can be calculated from Eq. (3.1) as long as concrete and steel remain elastic linear.

$$f_c = \frac{N}{A_c + (n-1)A_{st}} \qquad (3.2)$$

$$f_s = n\, f_c \qquad (3.3)$$

Let $\rho_t = \frac{A_{st}}{A_c}$ (percentage of reinforcement in the column section) , Eq.(3.1) can be rewritten as:

$$N = f_c A_c \,[\, 1 + (n-1)\rho_t \,] \qquad (3.4)$$

In allowable stress design method this equation can be used for review or design problems.

- If the strains in a column reach to inelastic regions equations given above can not be used anymore since “n” is not constant in the inelastic zones. But most important fact is the change of the elasticity modulus of concrete and stresses due to time dependent deformations of concrete. Thus even if a column is initially subjected to elastic stresses there will be significant changes in stresses such that results of Eqs.(3.1 to 3.4) will become meaningless. Therefore, columns should be designed by ultimate strength method.

- Tests on columns showed that steel yields and concrete reach the crushing strength at the moment of failure. Whichever is reached first does not change the result. As a result determination of failure load becomes very easy. Total load causing failure can be calculated by summing the strength of the concrete part and the load carried by yielding steel.

- However test results showed that the strength of concrete in the columns is approximately equal to 85% of the strength of the standard test cylinders if column is slowly loaded or is under sustained loads. Therefore the ultimate concentric load that can be resisted by a tied short column can be written as,

$$N_u = 0.85 f_{ck} A_c + A_{st} f_{yk} \qquad (3.5)$$

Note that in this equation difference between the net concrete area and gross area of column cross-section is ignored.
Design Strength of the column can be determined by replacing characteristic strength values by design strength values:

$$N_o = 0.85 f_{cd} A_c + A_{st} f_{yd} \qquad (3.6)$$

- In spiral columns spiral bar confines the core concrete very effectively and thus increases the ductility of the member. As a result energy absorption capacity is increased. This property makes them desirable for the structures subject to dynamic loads. In spiral columns a volumetric ratio for the spiral bar is defined as the ratio of the volume of one turn of the spiral bar to the volume of the concrete for one turn:

$$\rho_s = \frac{\pi D A_o}{A_{ck} s} \qquad (3.7)$$

in which D is the core diameter, A_{ck} is the area of core and A_o is the area of spiral bar. In 1985 version of TS500 a minimum value was defined for ρ_s as,

$$\overline{\rho}_s = 0.45 \frac{f_{ck}}{f_{ywk}} \left(\frac{A_c}{A_{ck}} - 1\right) \qquad (3.8)$$

Note that 10% of increase in the load carrying capacity of the spiral column is allowed if

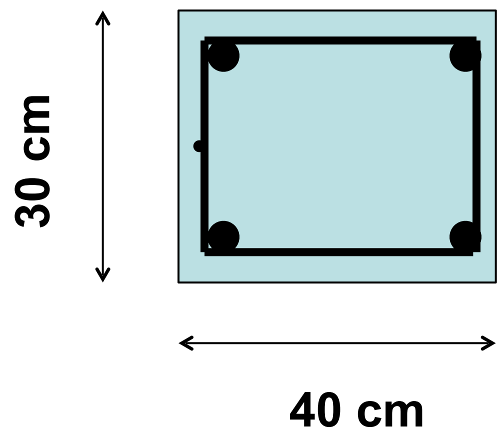
$$\rho_s > \overline{\rho}_s$$

and N_o becomes;

$$N_o = 1.1(0.85 f_{cd} A_c + A_{st} f_{yd}) \qquad (3.9)$$

Example:

Determine the concentric axial compressive force carrying capacity of the column shown below.



4Φ18

Materials C20 and S220

See class notes

TS 500 SPECIFICATIONS FOR COLUMNS

- Minimum dimension of a column is 25 cm. (In earthquake regions it should be 25X30)
- In I, T or L shaped columns minimum dimension can be 20 cm.
- Thickness of the side walls in hallow sections should not be less than 12 cm
- Clear concrete cover should be minimum 2 cm (for indoor condition) and 2.5 cm (for out door condition).
- $\boldsymbol{A_c > N_d / (0.6 f_{ck})}$
- Minimum steel ratio (min ρ_t) should be 0.01 and at least 4Φ14 for tied columns and 6Φ14 for spiral columns should be used.
- Steel ratio can be dropped to 0.005 if provided steel ratio is 1.3 times the required ratio.
- In lap splicing region max ρ_t =0.06 but between the lap splicing regions max ρ_t =0.04.
- Distance between the vertical bars should not be more than 30cm.
- Diameter of the tie bar should not be less than 1/3 of the main steel diameter.
- Spacing of ties should not be more than 12 times the main steel diameter and 20 cm.
- In spiral columns ρ_s should not be less than (min ρ_s) and more than 0.02. Maximum spacing between the turns of the spiral bar is D/5 and 8 cm.