CE 3217
Reinforced Concrete - II
MMI

10/10/2022
Monday

Reinforced Concrete Column

- Two way slab
- columns
- Retaining walls

Books :

Previous sem book (7th ed - WSD , 13th ed - USD)

Introduction

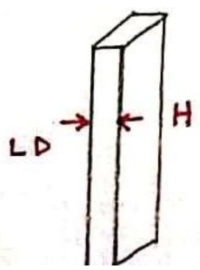
Column :

Column is a $\boxed{\text{axial \& compressive load}}$ carrying member. Column may be $\boxed{\text{inclined or vertical}}$. To carry axial load, its not necessary that the column has to be vertical.

Columns are members, used primarily to support axial compressive load.

Columns have a ratio of height to the least lateral dimension of 3 or greater.

when $\boxed{\text{less than 3}}$, it wont be considered as a column. will be considered as a $\boxed{\text{cylinder}}$. So only crushing failure.



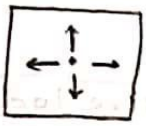
$$\frac{H}{\text{Least Lateral Dimension}} \geq 3$$

Load transformation :

Gravitational force or load → Slab → Beam → Column → Foundation → Soil

Two way slab :

Load transfer to all direction or sides
all sides have supports



concentric load : ~~go~~ Passes or applied through centre of gravity

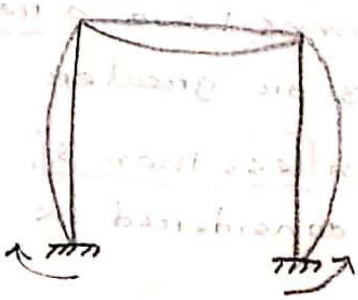
eccentric load : other than concentric load

Kern section

monolithically cast : একই সাথে cast করা হয়।

moment in column :

- due to eccentricity
- due to end restraint / fixed support



It can be assumed that axially loaded columns are those with relatively small ecentricity, e, of about 0.1h or less.

$\leq 0.1h$

h → total depth of column

e → ecentric distance from centre of column

$\boxed{e \leq 0.1h}$

~~Column~~ Concrete → high compressive strength
→ inexpensive material

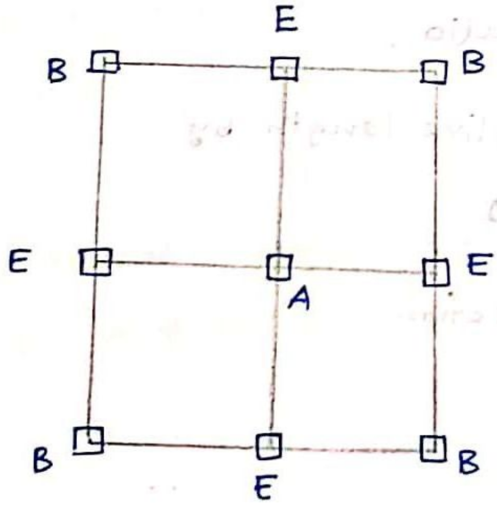
so used in design of compression member economically.

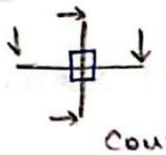
Types of Column :

(a) Based on loading

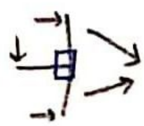
(i) Axially loaded columns

Moment Bearing Column [(ii) Ecentrically loaded columns / Uni axially
(iii) Biaxially loaded columns





Counter balanced axially loaded



Counter Balanced

For this one, one side moment (one axis) so, uni axially or Ecentric

(b) Based on length -

(i) Short Columns

Short → 0 - 32

Intermediate → 32 - 120

Long → >120

- failure by crushing of concrete or
- yielding of steel
- under full load capacity (?)

(ii) Long Columns

- buckling effect and slenderness ratio must be considered in design
- reducing load capacity (?)

$f_y = 60ksi$

↳ yielding point at 60ksi

↳ rupture at more than 60ksi

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To reduce slenderness ratio :

→ reducing effective length by bracing

→ changing section

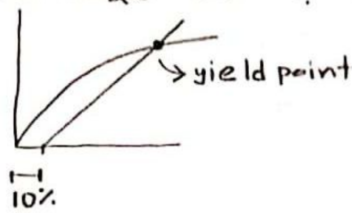
Long Column → Buckling

Short Column → Crushing (when concrete fails, steel must yield too)

materials without yield point is σ vs ε curve, fails without warning

Steel এর Ultimate / yield load ratio → 1.5 (factor of safety).

10% ofset নিয়ে line টেনে যেই বিন্দুতে মিশে তার (concrete, aluminium)



(c) Based on the shape of the cross section

- square
- L shaped
- rectangular
- Octagonal
- round (circular)
- any desired shape with an adequate side width

(d) Based on columnties, columns may be classified as

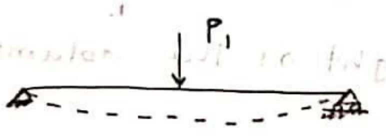
- Tied columns : TC containing steel ties to confine the main longitudinal bars in the columns. Ties are norma[lly] spaced uniformly along the height of the column.

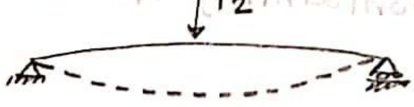
- Spiral columns : SC containing spirals (spring typ[e]) reinforcement and to help

(e) Based on frame bracing (Water Tank)

(f) Based on materials

- Reinforced
- Pre stressed
- Composite (contained rolled steel sections such as I - sections)
- a combination of rolled steel sections & reinforcing bars.





$P_2 > P_1$

এজন্যই curved উপরের দিকে থাকে
and বেশি load carry করতে পারে।
এটাই prestressed

Question: Why should we provide reinforcement ?

when load is increasing, area of concrete will increase too. but section is not unlimited. So, to carry all loads in limited cs Area, reinforcement is provided

- Very few members are truly axially loaded, steel is essential for resisting any bending that may exist.
- If part of the total load is carried by steel with its much greater strength, the cs dimensions of the member can be reduced [to make economical & for practicalability]

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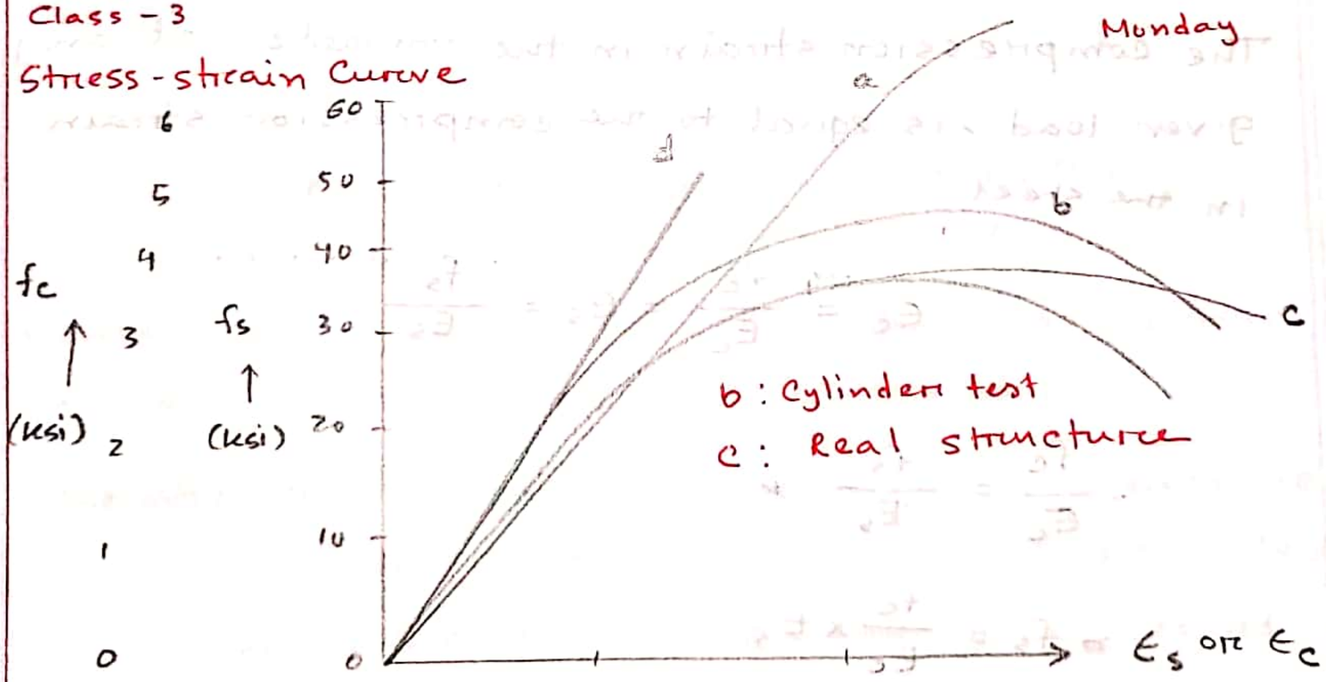
Class - 3

Stress-strain Curve



a steel
b Concrete : fast loading (lab condition)
c Concrete : slow loading (long time)
d Elastic concrete

Max reliable compressive strength of concrete would be $0.85f_c'$ (lab)

At low stress, up to about $f_c'/2$ or $f_c'/3$, the concrete is seen to behave nearly elastically, i.e., stresses and strains are quite closely proportional, the straight line d represents the range of behaviour with little error for both rates of loading.

The compression strain in the concrete, at any given load, is equal to the compression strain in the steel.

- Beam or column যখন as a unit কাজ করে, তখন

$$\epsilon_s = \epsilon_c$$

Elastic Behavior

The compression strain in the concrete, at any given load, is equal to the compression strain in the steel

$$\epsilon_c = \frac{f_c}{E_c} = \epsilon_s = \frac{f_s}{E_s}$$

$$\frac{f_c}{E_c} = \frac{f_s}{E_s}$$

$$\Rightarrow f_s = \frac{f_c}{E_c} \times E_s$$

$$\therefore f_s = n f_c$$

Let,

A_g = Gross Area

A_c = Net area of concrete, i.e. gross area − area occupied by reinforcing bars

A_{st} = total area of reinforcing bars

P = Axial load

$$P = f_c A_c + f_s A_{st} = f_c A_c + n f_c A_{st}$$

$$P = f_c (A_c + n A_{st})$$

$$= f_c [(A_g - A_{st}) + n A_{st}]$$

$$P = f_c [A_g + (n-1) A_{st}]$$

Nominal strength of the axially loaded concrete column can be ~~formed~~ found from

$$P_n = 0.85 f_c' A_c + f_s A_{st}$$

$$P_n = 0.85 f_c' (A_g - A_{st}) + f_y A_{st}$$

Question: Why strength reduction factor of column is smaller?

- Column has a greater importance in structure.
- A beam failure would normally affect only a local region, whereas a column failure could result in the collapse of the entire structure.

Spirally reinforced columns, $\phi = 0.75$

Tied columns, $\phi = 0.65$

Beams, $\phi = 0.9$

K)

A further limitation on column strength is imposed by ACI Code to allow for accidental eccentricities of loading not considered in the analysis.

This is done by imposing an upper limit on the axial load that is less than the calculated

Columns	Strength Reduction factor, ϕ	Upper limit of axial load, k
Spiral columns	0.75	0.85
Tied columns	0.65	0.80

$\therefore$ For spiral column, $\phi = 0.75$
$K = 0.85$

$$\phi P_{n(max)} = P_u$$
$$= K\phi\left[0.85 f_c'(A_g - A_{st}) + f_y A_{st}\right]$$

$\therefore$ for tied column, $\phi = 0.65$, $K = 0.80$

small p

$$\rightarrow \phi P_{n(max)} = K\phi\left[0.85 f_c'(A_g - A_{st}) + f_y A_{st}\right]$$

Problem 1: Determine the allowable design axial load on a 12" square, short tied column reinforced with four #9 bars. Ties are #3 spaced at 12 in. Use $f_c' = 4$ ksi & $f_y = 60$ ksi

Sol^n:

$$P_u = \phi P_n$$

$$= K\phi\left[0.85 f_c'(A_g - A_{st}) + f_y A_{st}\right]$$

$$= 0.80 \times 0.65\left[0.85 \times 4000 \times (144 - 4) + 60000 \times 4\right]$$

$A_g = 12 \times 12$
$= 144 \text{ in}^2$

$$= 373320$$

$A_{st} = 4 \times 1 = 4$

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Class - 4

Problem 02:
Determine the allowable design axial load on a 16" dia, short spiral column, reinforced with 6 #8 bars. spiral are #3 spaced at 12". Use $f_c' = 4$ ksi, $f_y = 60$ ksi

$$P_u = \phi P_n$$

$$= K\phi\left[0.85 f_c'(A_g - A_{st}) + f_y A_{st}\right]$$

$\cancel{A_g = 64\pi}$

$A_{st} = 4.74$

$A_g = 64\pi$

$$= 0.85 \times 0.75\left[0.85 \times 4000 \times (\cancel{64\pi} - 4.74) + 60000 \times 4.74\right]$$

64π

$\cancel{(16 \times 12)}$

$$=$$

Lateral Ties

- Bending moments are large →

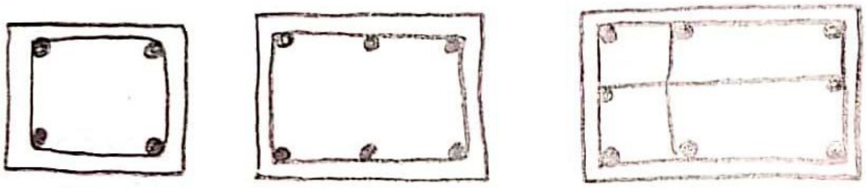
  much of the longitudinal steel at faces of highest compression or tension

- Heavily loaded column ⟶

  large steel percentage → $\frac{A_{st}}{A_g} = \rho_g$ max 8% min 1%

  large no of bars

  each of them positioned & held individually by ties



spacing < 6"   spacing > 6"

A_s : 2-4% generally used
8% max
1% min

Lateral Ties

- Large steel percentages and consequent ties may cause steel congestion which leads to difficulties in placing the concrete.
- In such cases, bundled bars are frequently employed

Function of Lateral Ties & Spirals

- To hold the longitudinal bars in position in the forms while the concrete is being placed.

For this purpose, longitudinal and transverse steel is wired together to form cages, which are then moved into the forms and properly positioned before placing the concrete.

- To prevent the highly stressed, slender longitudinal bars from buckling outward by bursting the thin concrete cover.
- The spacing must be sufficiently small to prevent buckling between ties and that, in any tie plane.
- A sufficient no. of ties must be provided to position & hold all bars

Bar arrangement Rule [ACI Code 7.10.5]

- All bars of tied columns shall be enclosed by lateral ties, least #3 (10 mm) for longitudinal bars upto No. 10 (32mm)
- At least #4 (13 mm) in size for Nos. 11, 14 & 18 (36, 43 and 57 mm) & bundled longitudinal bars.

steel Requirement

- The maximum percentage is 8% of the gross area of the section
- The minimum longitudinal steel percentage is 1%

eg.

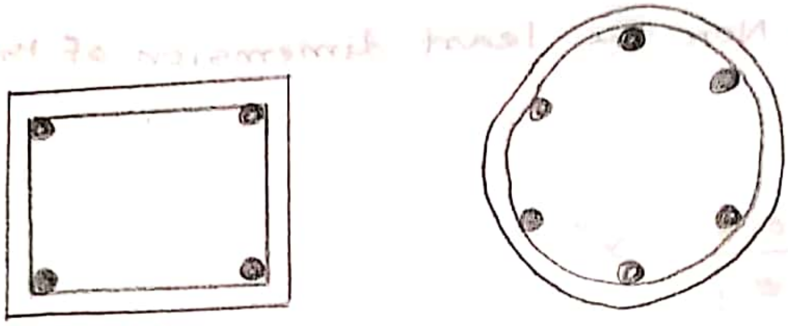
$$1\% \text{ of } A_g < \rho < 8\% \, A_g$$

"more than 8% → section revise"

long time load causing shrinkage

- Minimum reinforcement is necessary to provide resistance to :-
  - → bending, which may exist
  - → to reduce the effects of creep and shrinkage of the concrete under sustained compressive stresses
- practically, it is very difficult to fit more than 8% of steel reinforcement into a column & maintain sufficient space for concrete to flow between bars.

- At least four bars are required for tied circular & rectangular members
- 6 bars are needed for circular members enclosed by spirals



- For other shapes,
    - One bar should be provided at each corner
    - Proper lateral reinforcement must be provided
- For tied triangular columns, at least three bars are required
- Bars shall not be located at a distance greater than 6" clear on either side from a laterally supported bar.
- The minimum concrete ~~ba~~ cover in columns is 1.5"

Bar arrangement Rule :

The spacing of the ties shall not exceed

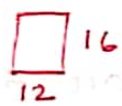
- 16 x diameters of the longitudinal bars
- 48 x diameters of tie bars
- Nor the least dimemsion of the column

eg.

$16 \times \underset{\#4}{\underline{0.5}} = 8''$

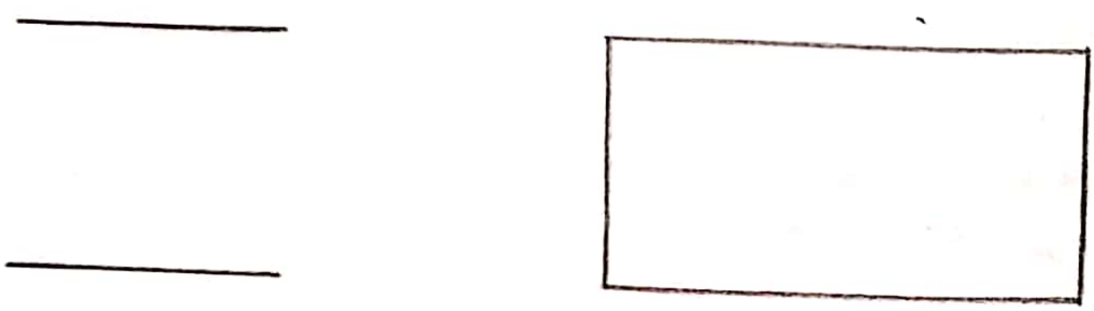
$48 \times \frac{3}{8} = 18''$

12 (least) → use this one

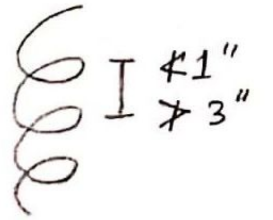


- The ties shall be so arranged that every corner and alternative longitudinal bar shall have lateral support provided by the corner of a tie having an included angle of not more than 135°

- No bar shall be further than 6" in clear on either side from such a laterally supported bar



- Spirals shall consist of a continuous bar or wire not less than 3/8" diameter
- The clear spacing between turns of the spiral must not exceed 3" and not less than 1"



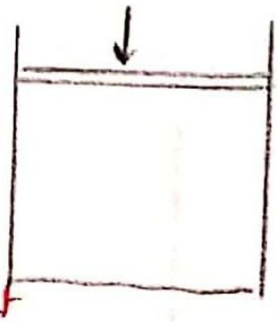
Structural effect of spiral

- Lateral pressure is exerted by the sand causes hoop tension in the wall.
- The load can be increased until the drum burst
- Longitudinal shortening & laterally expansion occures (based on poison ratio)
-

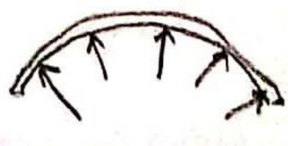
- This causes hoop tension in spiral, while the carrying capacity of the confined concrete in the core is greatly increased

$\frac{pd}{2t}$

- hoop tension create → confinement of the steel drum → takes load until the drum burst



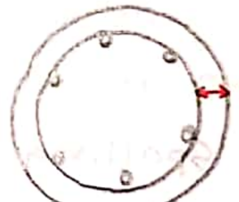
~~be~~ Spiral in column provides confinement and act as a drum → বেশি stress নিতে পারে।



Behavior of Tied Vs spiral column

- At P_n load, the concrete in tied column fails by crushing & shearing outward along inclined planes
- And the longitudinal steel by buckling outward between ties
- In a spirally reinforced column at same load is, the longitudinal

- The concrete in the outer shell, not being so confined does fail i.e. the outer shell spalls off when the load P_n is reached.

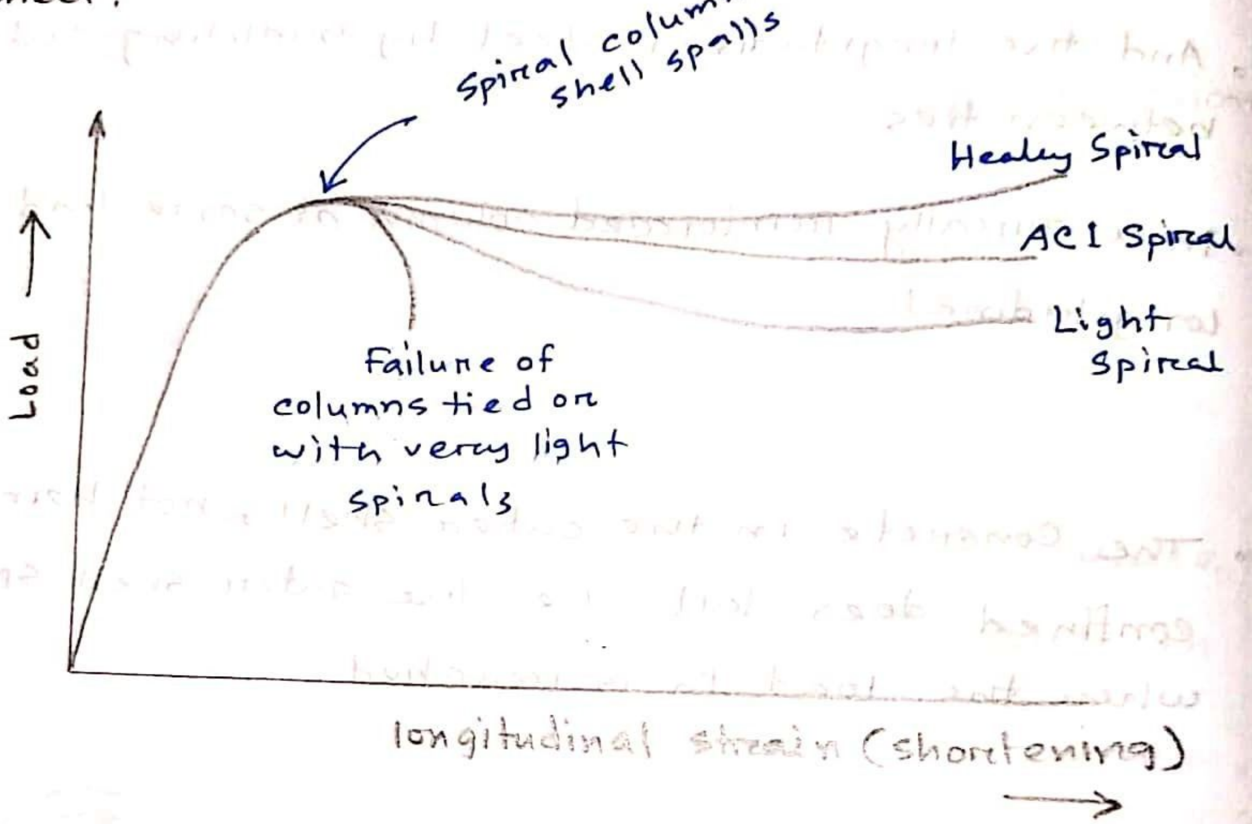


Pn load এ শুধু
concrete cover
fail করবে।
(serviceability
failure)

After crack → weather
exposed → corrosion

- In contrast to the practice, any excess capacity beyond the spalling load of the shell is wasted the member, although not actually failed, would no longer be considered serviceable.

- For this reason, the ACI code provides a minimum spiral reinforcement of such an amount that its contribution to the carrying capacity is just slightly larger than that of the concrete in the sheel.



- Spalling load of a spiral column equal to the ultimate load of the tied column.
- The failure or the tied column is abrupt and complete.
- Light spiral column has strength contribution is considerably less than the strength lost in the spalled shell
- With a heavy spiral the reverse is true

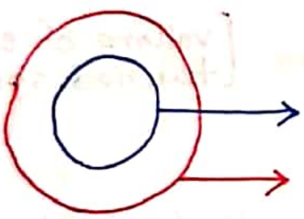
- The "ACI spiral", its strength contribution axial compensating for that lost in the spalled shell, hardly increases the ultimate load.

- However, by preventing instantaneous crushing of concrete and buckling of steel, it produces a more gradual & ductile failure, i.e. a tougher column.

30.10.2022
Sunday

Class - 6

Spiral Reinforcement Ratio :



Concrete এর capability থেকে core এর capability বাদ দিলে spiral এর capability পাওয়া যায়। (capability or capacity)

Spirally reinforced column, spiral steel is at least twice ~~time~~ effective as longitudinal bars.

$$P_n = 0.85 f_c' (A_g - A_{cr})$$

$$P_n = 2 \rho_s f_y A_{cr}$$

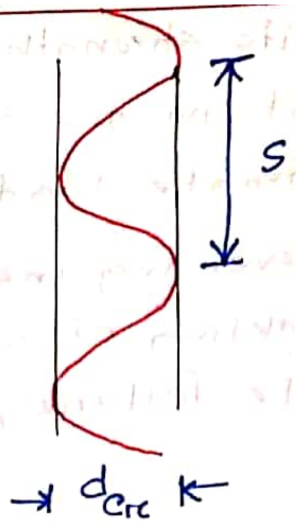
$$0.85 f_c' (A_g - A_{cr}) = 2 \rho_s f_y A_{cr}$$

$$\Rightarrow \rho_s = \frac{0.85 f_c' (A_g - A_{cr})}{2 f_y A_{cr}}$$

$$\Rightarrow \rho_s = 0.425 \left(\frac{A_g}{A_{cr}} - 1\right) \frac{f_c'}{f_y}$$

According to ACI

$$\therefore \boxed{\rho_{s\,min} = 0.45 \left(\frac{A_g}{A_{cr}} - 1\right) \frac{f_c'}{f_y}}$$



Length of a single turn spiral $= \pi D_{cr}$

Area of a single turn spiral $= A_{sp}$ [Bar should be selected according to ACI)]

Volume of spiral, $V_{sp} = \pi D_{cr} A_{sp}$ [Volume of singly turned spiral]

Volume of core, $V_{cr} = \frac{\pi D_{cr}^2}{4} S$

$\therefore \rho_{sp}$

Problem : Design a tied column to support an axial dead load of 400kip and live load of 232 kip. Using $f_c' = 5$ ksi , $f_y = 60$ksi

Assume steel ratio about 5 %. Design necessary ties.

Solution :

1. Factored Load = $1.2DL + 1.6LL$

$$= (1.2 \times 400) + (1.6 \times 232)$$

$$= 851.2 \text{ kips}$$

$$\therefore P_u = 851.2 \text{ kips}$$

We know,

$$P_u = \phi K \left[0.85 f_c' (A_g - A_{st}) + f_y A_{st}\right]$$

$\phi = 0.65$

$K = 0.80$ here, $A_{st} = 5\%$ of A_g

$$= 0.05 A_g$$

$$\therefore P_u = 0.65 \times 0.80 \times \left[0.85 \times 5 \times 0.95 A_g + 60 \times 0.05 \times A_g\right]$$

$$= 0.65 \times 0.80 \times \left[4.0375 A_g + 3 A_g\right]$$

$$\Rightarrow 851.2 = 3.66 A_g$$

$$\therefore A_g = 232.57 \text{ in}^2$$

$$b = \sqrt{232.57} = 15.25'' \approx 15.5''$$

So the dimension for can be taken as

15.5" X 15.5"

2. Steel Calculation

$A_g = 15.5 \times 15.5$

$= 240.25 \ in^2$

$A_{st} = 0.05 \ A_g$

$= 12.0125 \ in^2$

" P_u এর সূত্র দিয়েও A_{st} বের করা যাবে। "

Providing ~~#10~~ 10 #10 bars

3. Tie Design

Let's choose #3 bar as tie

$S_1 = 16 \times 10/8 = 20''$

$S_2 = 48 \times 3/8 = 18''$

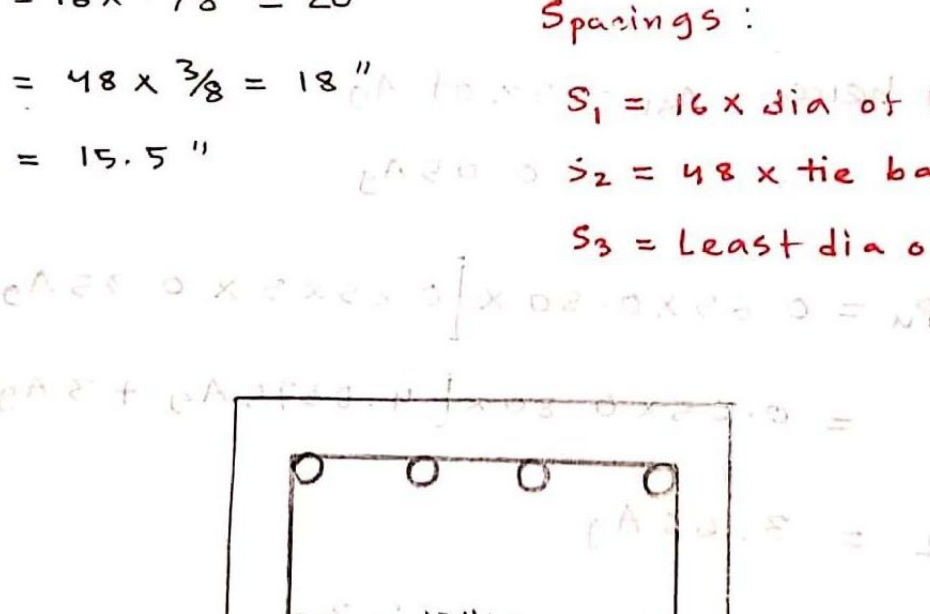
$S_3 = 15.5''$

Spacings :

$S_1 = 16 \times$ dia of longitudinal bars

$S_2 = 48 \times$ tie bar diameter

$S_3 =$ Least dia of column



HW : Rectangular

One side = 14"

31.10.20
Monday

Class - 7

Problem : Design a circular spiral column to support an axial DL of 475 kips and LL of 250 kips. $f_c' = 4$ ksi , $f_y = 60$ ksi ~~Design~~ and steel ratio about 3%. Design necessary spirals

Solution :

1. Factored Load :

$$P_u = 1.2 DL + 1.6 LL$$
$$= (1.2 \times 475) + (1.6 \times 250)$$
$$= 970 \text{ Kips}$$

2. Dimension of columns

$$P_u = K\phi \left[0.85 f_c' (A_g - A_{st}) + f_y A_{st}\right]$$

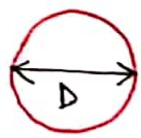
$\rho_s = 0.03$

$A_{st} = 0.03 A_g$

$$\Rightarrow 970 = 0.75 \times 0.85 \times \left[0.85 \times 4000 \times (A_g - 0.03 A_g) + 60000 \times 0.03 A_g\right]$$

~~3. Steel~~ $\Rightarrow A_g = 298.46 \text{ in}^2$

Now, $\frac{\pi}{4} D^2 = A_g$



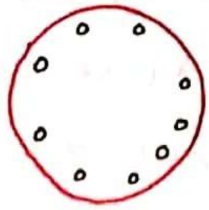
$$\Rightarrow D = 19.5''$$

3. Steel Calculations

$$A_{st} = 0.03 \times 298.46 = 8.954 \text{ in}^2$$

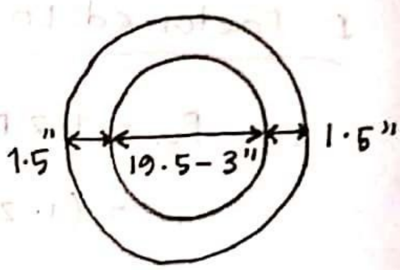
$$\therefore A_{st} = 8.954 \text{ in}^2$$

Providing 9#9 bars



4. Spiral Calculation

$$\rho_{sr(min)} = 0.45 \left(\frac{A_g}{A_{cr}} - 1 \right) \frac{f_c'}{f_y}$$



$$= 0.45 \times \left[\frac{298.46}{213.825} - 1 \right] \frac{4}{60}$$

$$A_{cr} = \pi/4 \times 16.5^2$$

$$= 213.825 \text{ in}^2$$

$$= 0.012$$

Choosing $\boxed{\#3}$ bar as spirals.

$$\rho_s = \frac{4 A_{sp}}{S D_{cr}}$$

A_{sp} → #3 bar area

$$\Rightarrow S = \frac{4 A_{sp}}{D_{cr} \rho_s}$$

$$= \frac{4 \times 0.11}{16.5 \times 0.012}$$

$$= 2.2"$$

Providing #3 bar @ 2" c/c

Problem: Design a rectangular tied column to carry a factored axial load of 1.765 ~~KN~~ $\times 10^3$ KN. Using $f_c' = 30$ MPa, $f_y = 400$ MPa. Column width $b = 300$ mm. Steel ratio = 2%.

Equivalency of Bar