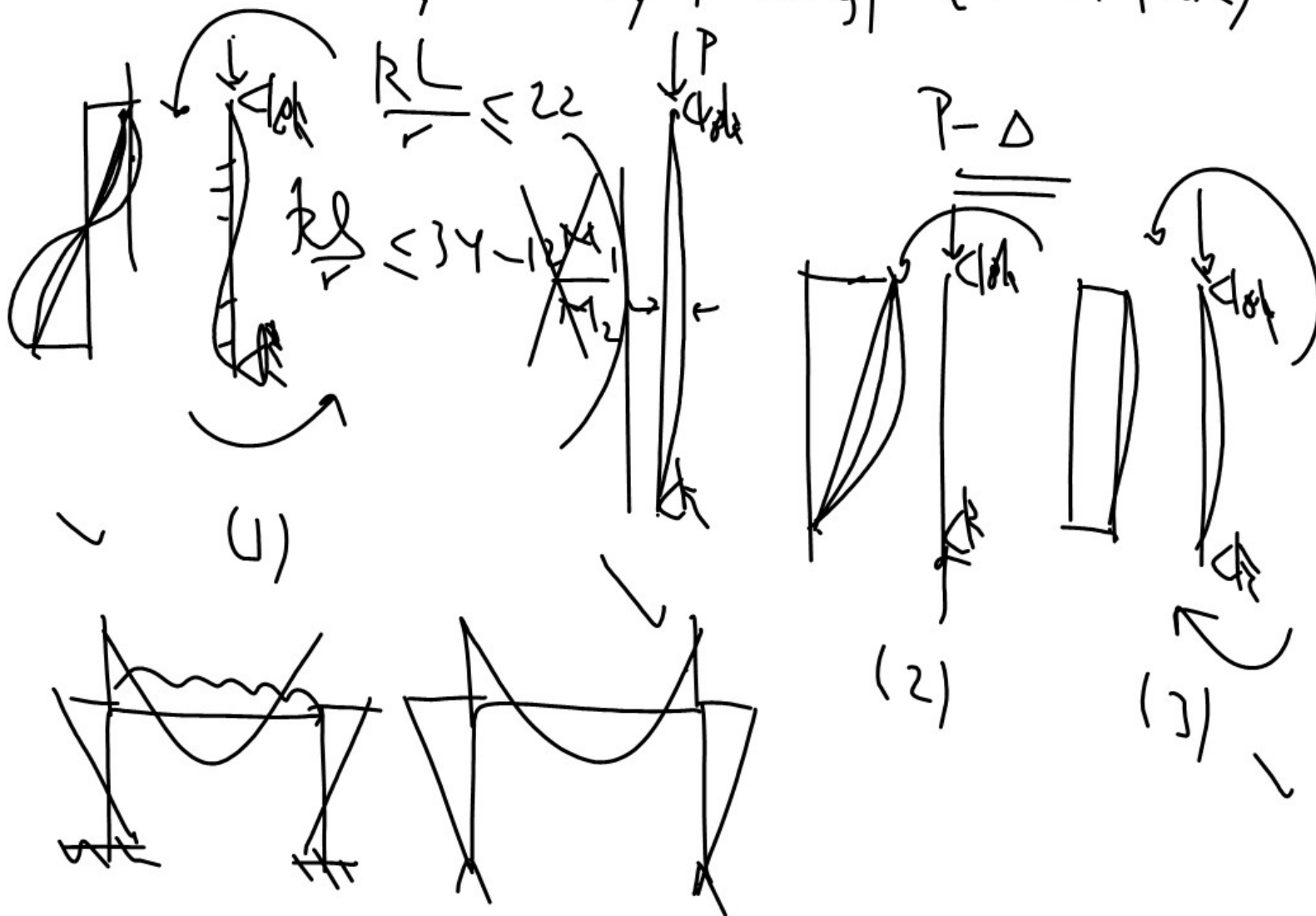


3/4 submission of design of a roof

(slab / beam / column / footing). (First Part)



$$\frac{kL}{r} \leq 34$$

$$\frac{L}{h} \leq \frac{10}{k}$$

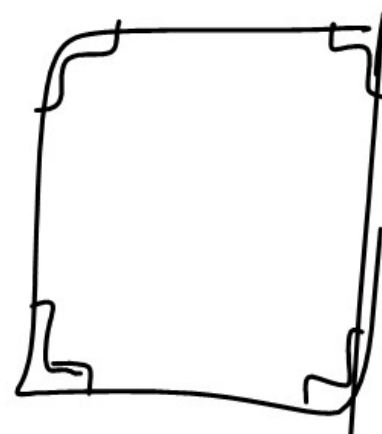
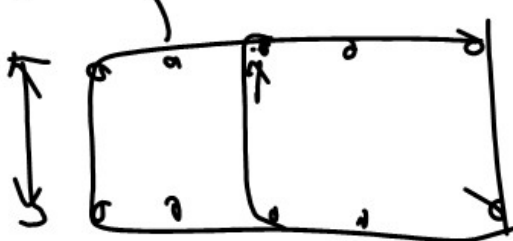
$$r = \sqrt{\frac{I}{A}} = \sqrt{\frac{\frac{bh^3}{12}}{bX}} \approx 0.28h \approx 0.3h$$



$$\frac{kL}{0.3h} \leq 34$$

$$\frac{kL}{h} \leq 10$$

$\phi 10$
 $\phi 8$
 $\phi 6$



4.1 Short Columns

4.2 Beams:

4.2.1 Flexure

4.2.2 Serviceability

4.2.3 Shear

4.2.4 Bar development

4.2.5 Bar splices in tension

4.3 Footings

4.1 Short Columns

General Information

Columns: Vertical Structural members

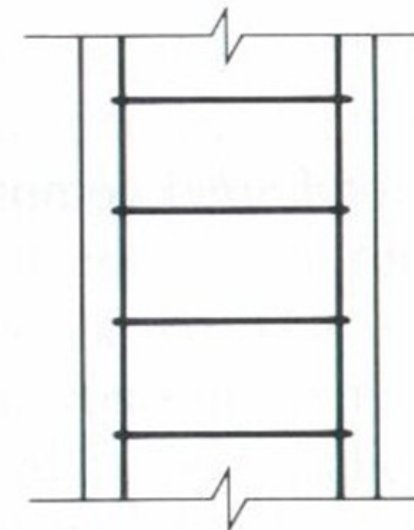
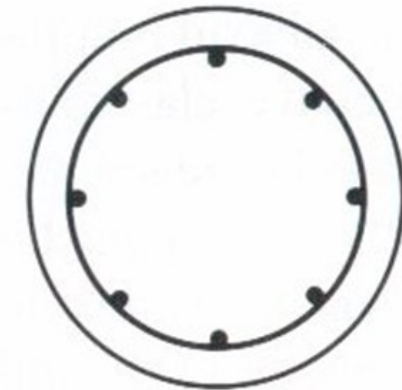
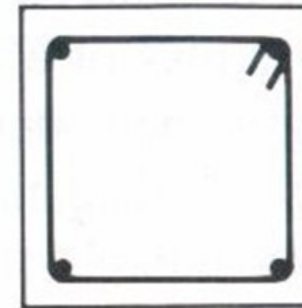
Transmits axial compressive loads with or without moment

transmit loads from the floor & roof to the foundation

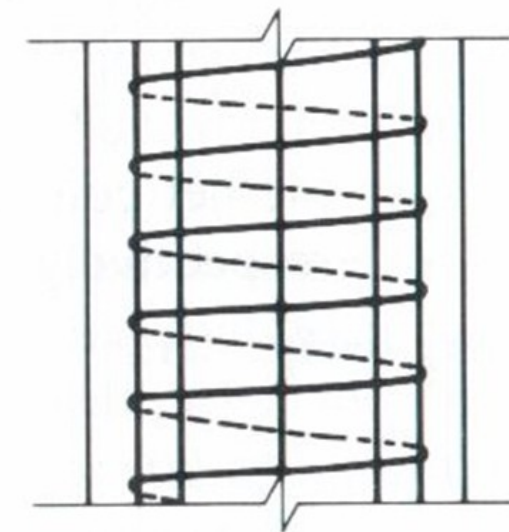
General Information

Column Types:

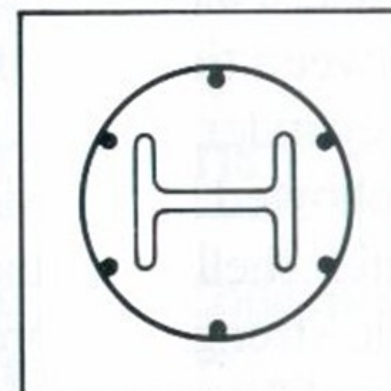
1. Tied
2. Spiral
3. Composite
4. Combination
5. Steel pipe



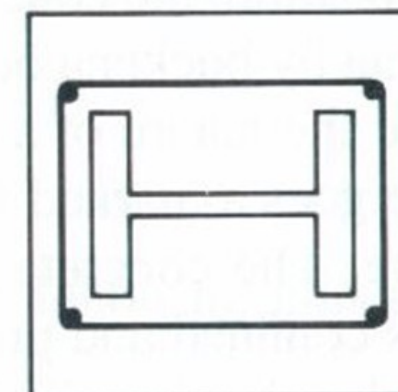
Tied



Spiral



Composite

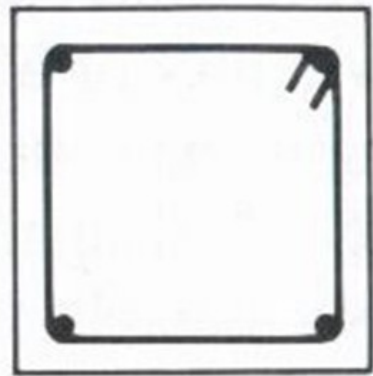


Combination

Steel
pipe

Short Columns: revision

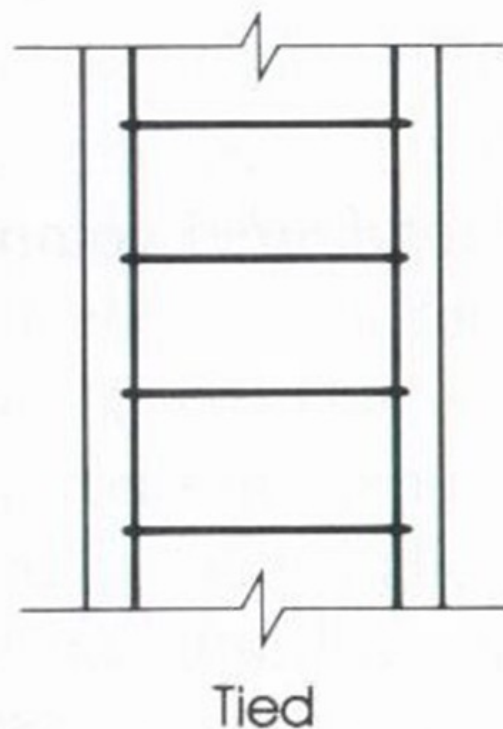
Tied Columns - 95% of all columns in buildings in nonseismic regions are tied



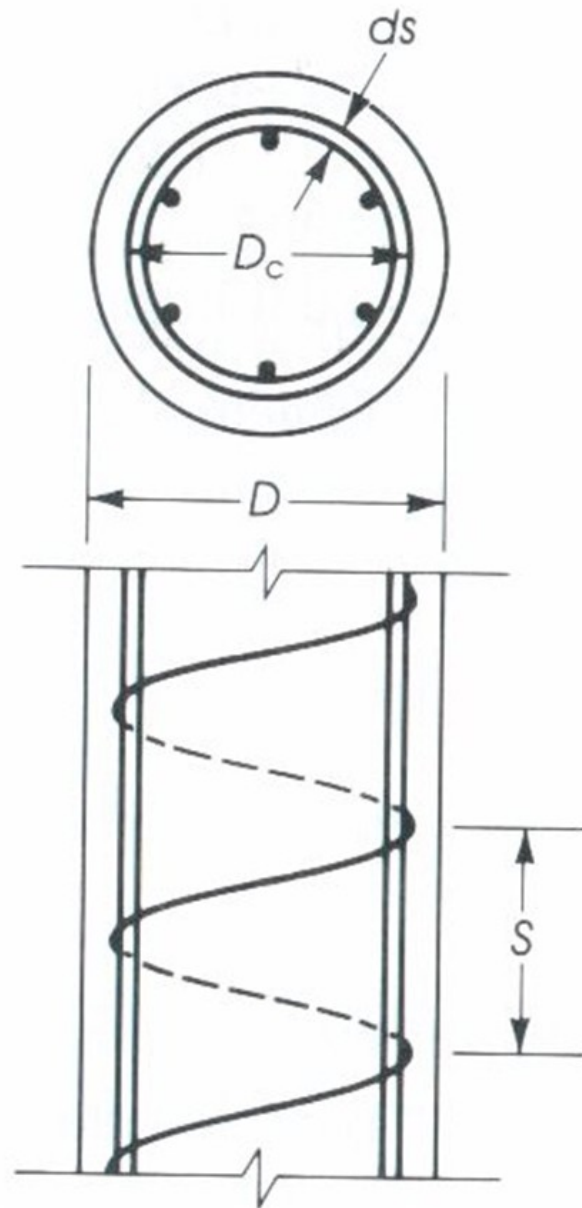
Tie spacing $\approx b$ (except for seismic)

tie supports long bars (reduces buckling)

ties provide negligible restraint to lateral expose of core



Spiral Columns



Pitch = 2.5cm to 7.5cm

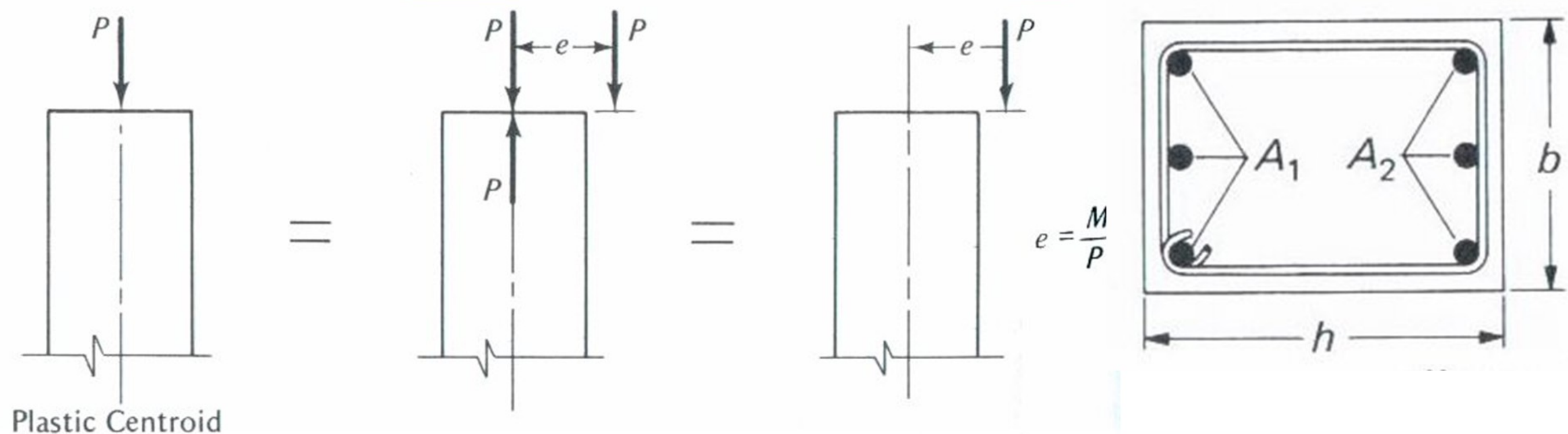
spiral restrains lateral (Poisson's effect)

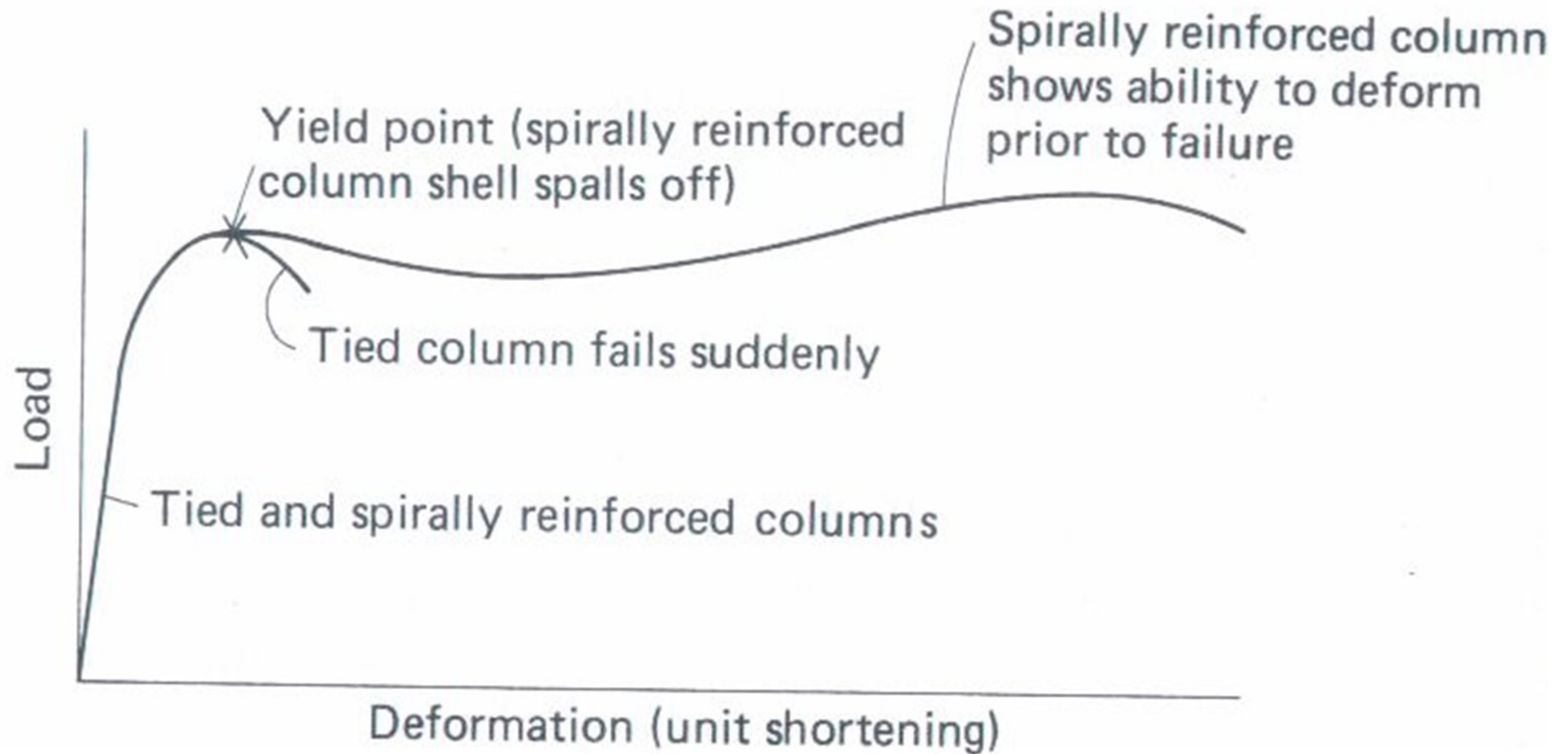
axial load → delays failure (ductile)

Behavior

An “allowable stress” design procedure using an elastic analysis was found to be unacceptable. Reinforced concrete columns have been designed by a “strength” method since the 1940’s.

1. Initial Behavior up to Nominal Load - Tied and spiral columns.





- Use of tributary area: area of floor or roof which supports all of the loads whose load path leads to the column.
- Use load path: slab reactions carried by beams. Beam reactions carried by columns.

$$P_0 = 0.85 f_c * (A_g - A_{st}) + f_y A_{st}$$

Let

A_g = Gross Area = $b * h$ A_{st} = area of long steel

f_c = concrete compressive strength

f_y = steel yield strength

Factor due to less than ideal consolidation and curing conditions for column as compared to a cylinder. It is **not** related to *Whitney's* stress block.

2. Maximum Nominal Capacity for Design $P_{n(max)} \Rightarrow$

$$P_{n(max)} = 0.8P_0 \rightarrow \textit{tied}$$

$$P_{n(max)} = 0.85P_0 \rightarrow \textit{spiral}$$

ACI 10.3.6.1-2

3. Reinforcement Requirements (Longitudinal Steel A_{st})

Let
$$\rho_g = \frac{A_{st}}{A_g}$$

- ACI Code requires $0.01 \leq \rho_g \leq 0.08$
- ACI 10.8.4 use half A_g if column section is much larger than loads.
- Minimum # of Bars (ACI Code 10.9.2): 6 in circular arrangement and 4 in rectangular arrangement

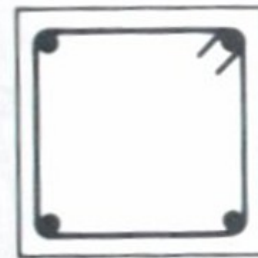
3. Reinforcement Requirements (Lateral Ties)

Vertical spacing: (ACI 7.10.5.1-3)

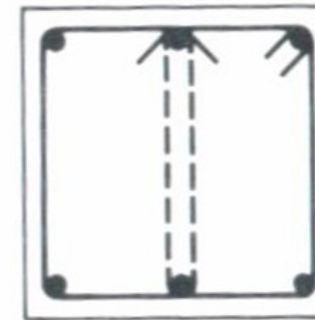
$$\begin{array}{lcl}
 224 & \#10\text{mm bars least dimension of tie} & \\
 16 \times 14 = & s \leq 16 d_b \quad (d_b \text{ for longitudinal bars}) & \\
 480 & s \leq 48 d_b \quad (d_b \text{ for tie bar}) & \\
 200 & s \leq \text{least lateral dimension of column} &
 \end{array}$$

Every corner and alternate longitudinal bar shall have lateral support provided by the corner of a tie with an included angle not more than 135° , and no bar shall be more than 15cm clear on either side from “support” bar.

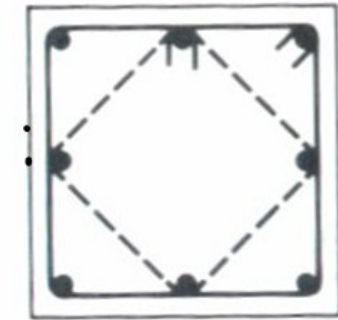
Examples of lateral ties.



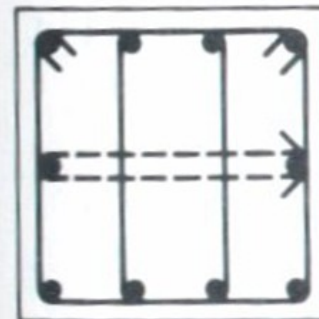
4 bars



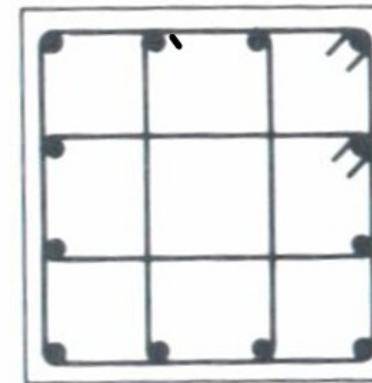
6 bars



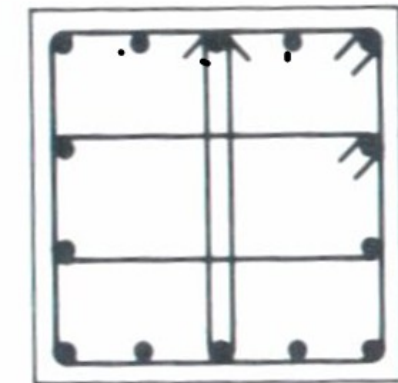
8 bars



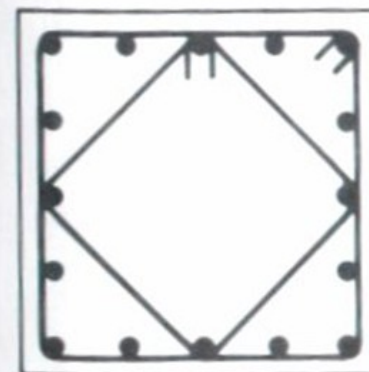
10 bars



12 bars



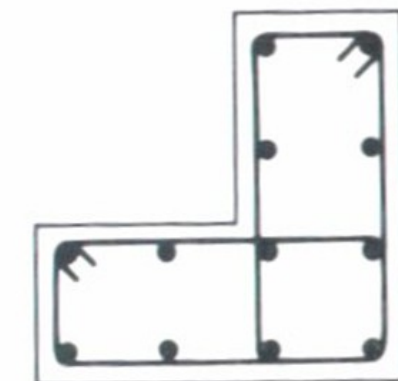
14 bars



16 bars



Wall column



Corner column

3. Reinforcement Requirements (Spirals)

ACI Code 7.10.4

size $\geq$ 10mm “ dia.

2.5cm $\leq$ clear spacing between spirals $\leq$ 7.5cm ACI 7.10.4.3

4. Design for Concentric Axial Loads

(a) General Strength Requirement

$$\phi P_n \geq P_u$$

where, $\phi = 0.65$ for tied columns

$\phi = 0.75$ for spiral columns (ACI 08)

4. Design for Concentric Axial Loads

(b) Expression for Design

defined:

$$\rho_g = \frac{A_{st}}{A_g} \quad \text{ACI Code } (0.01 \leq \rho_g \leq 0.08)$$

Design of Tied Short Columns

$$\phi P_n = \phi 0.8 \left[A_g (0.85 f_c) + A_{st} (f_y - 0.85 f_c) \right] \geq P_u$$

$$\phi P_n = \phi 0.8 A_g \left[0.85 f_c + \rho_g (f_y - 0.85 f_c) \right] \geq P_u$$

- The ultimate load is found using tributary area and number of stories

The design load can be approximated as follows:

Approximate Design of Short Columns

- For a tied column with 1% steel reinforcement

$$\phi P_n = 0.65 * 0.8 A_g \left[0.85 f_c + 0.01 (f_y - 0.85 f_c) \right]$$

$$\phi P_n = A_g \left[0.438 f_c + 0.0052 f_y \right] \geq P_u$$

For 20MPa concrete strength and 420MPa yield strength and representing gross area in cm² and column capacity in kN

$$\phi P_n = 1.1 \times 10^4 (A_g \times 10^{-4}) \approx A_g$$

Thus the area of column in square cm represents approximately its capacity in kN

- Condition for short columns: braced

$$\frac{KL}{r} \leq 34 - 12 \frac{M_1}{M_2} = 34$$

$$0.5 \leq K \leq 1, r \approx 0.3b$$

$$\frac{KL}{0.3b} \leq 34 \rightarrow \frac{L}{b} \leq \frac{34 * 0.3}{K} \rightarrow \frac{L}{b} \leq 10, 20$$

- Thus if the height to width ratio is less than 15 (the mean value) the column is classified as short

- Common practice is to build four stories with 4m span dimensions. What is the size of the column needed to support a common 25cm rib construction (17cm height blocks, 15cm ribs).
- Common practice in the last 50years is to use 6#14mm bars in columns 25cmX50cm, thus a use of 0.72% instead of 1% minimum. Comment!
- In the nineties trying to build columns with 2% reinforcement using common technology at that time yields to honeycombing, comment!
- Is it wise to design columns according to minimum design requirements, comment!

End of 4.1

Let Learning Continue