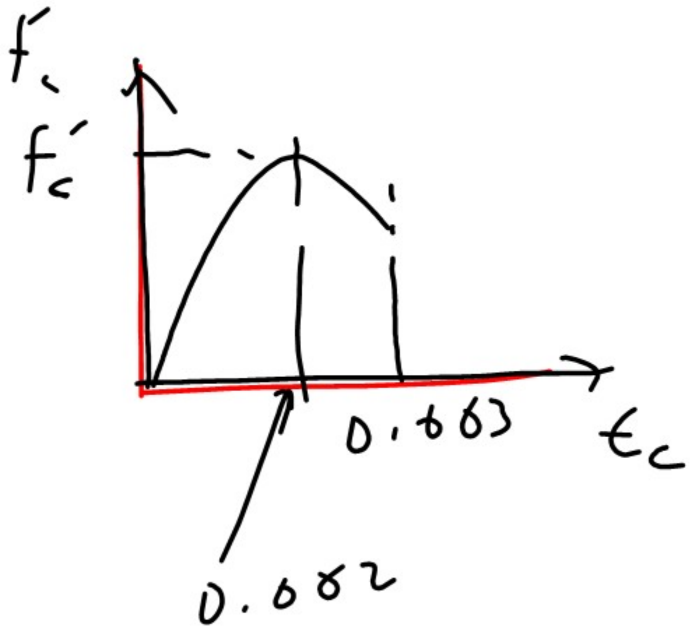
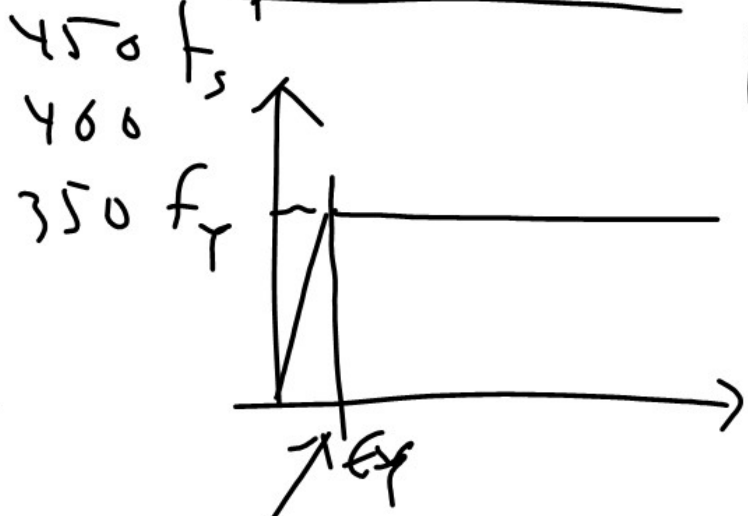




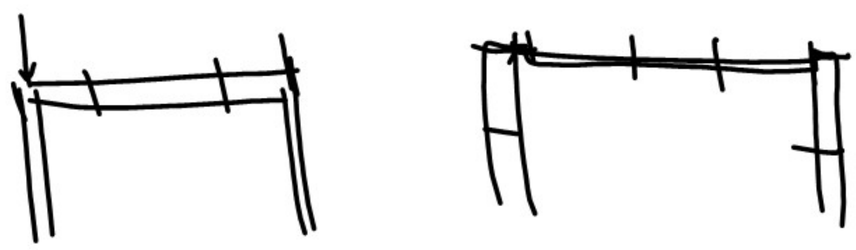
$E = 200 \times 10^3$

0.00175	350
0.002	400
0.0025	450

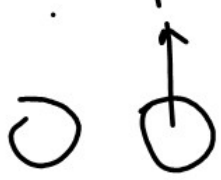
$P_n = A_c f_c' + A_s f_y$

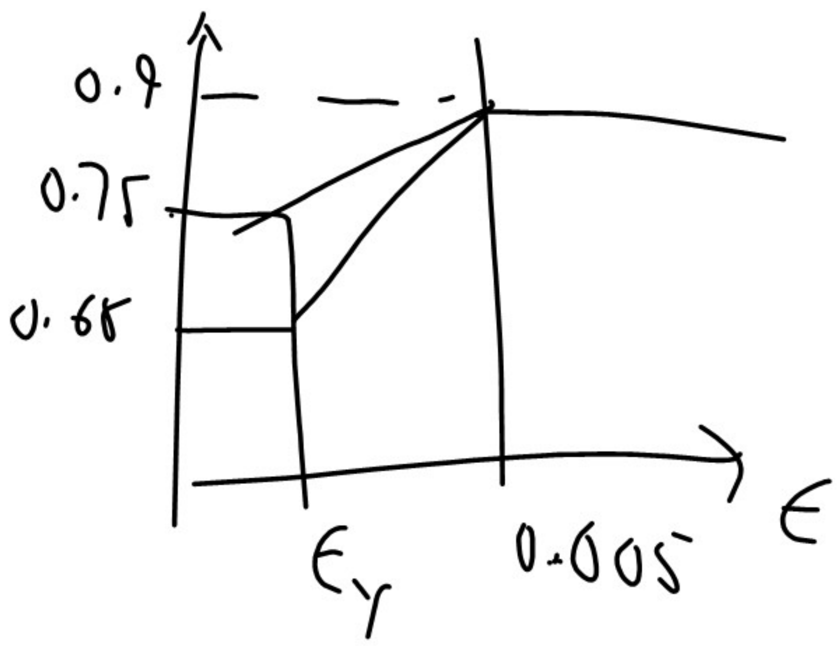
(↓ 0.85)

30 X 60



$P_u = \lambda \phi P_n$





Element design

- 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

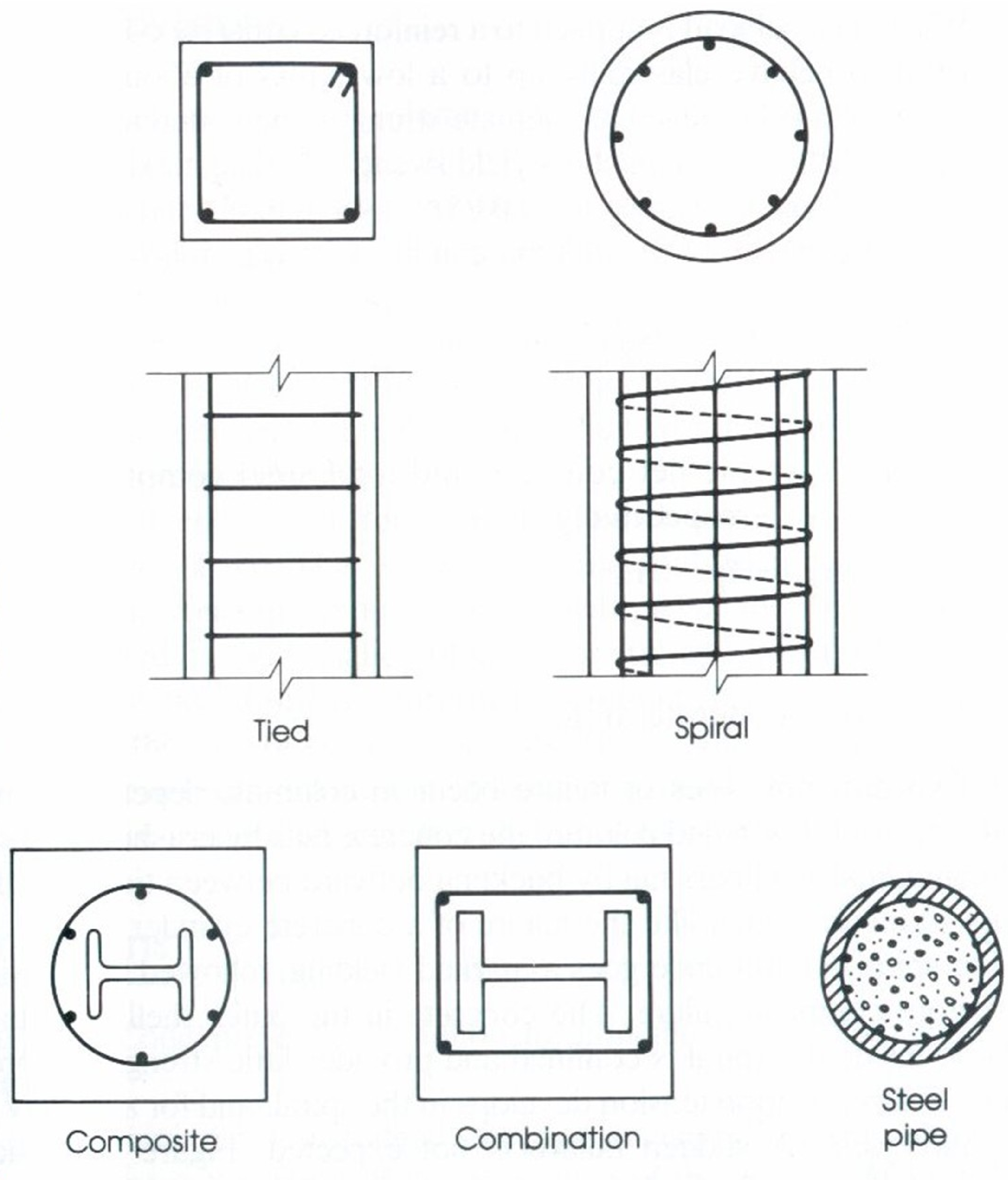
Transmits axial compressive loads with or without moment

transmit loads from the floor & roof to the foundation

General Information

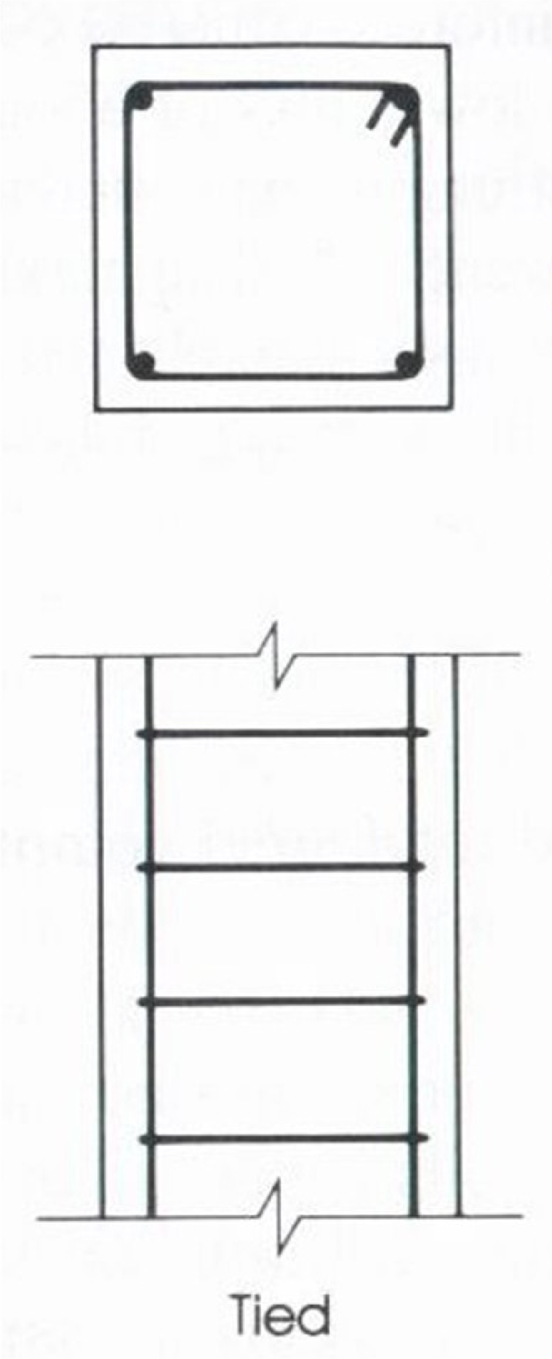
Column Types:

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



Short Columns: revision

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



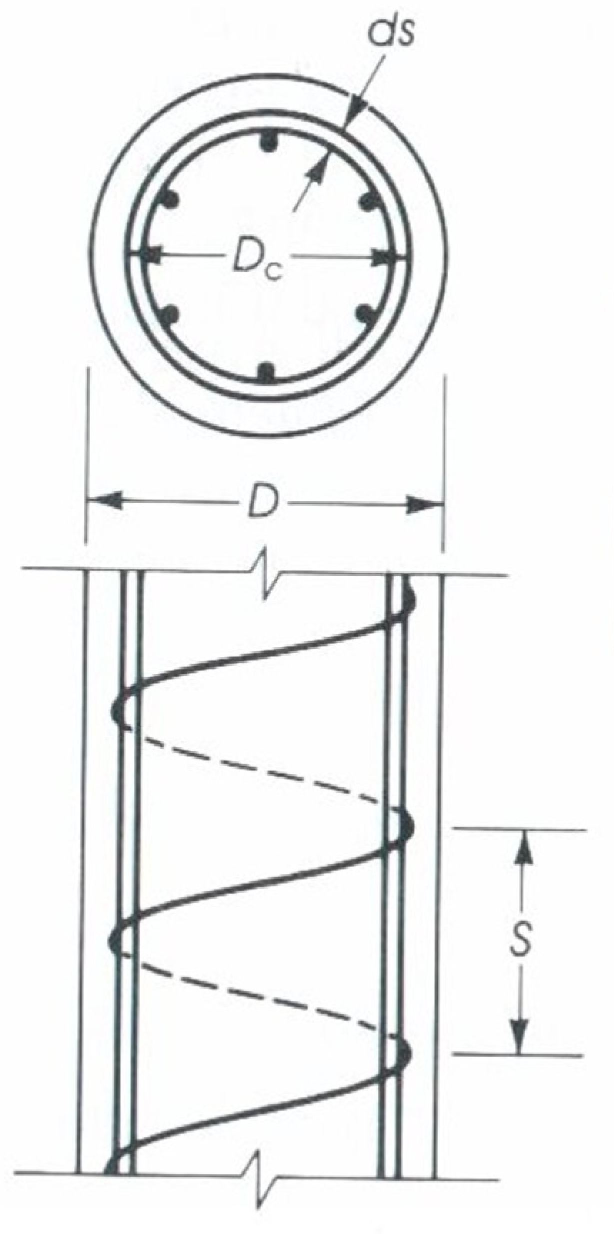
Tie spacing ≈ b (except for seismic)

tie supports long bars (reduces buckling)

ties provide negligible restraint to lateral expose of core

Short Columns: revision

Spiral Columns



Pitch =2.5cm to 7.5cm

spiral restrains lateral (Poisson's effect)

axial load ⟶ delays failure (ductile)

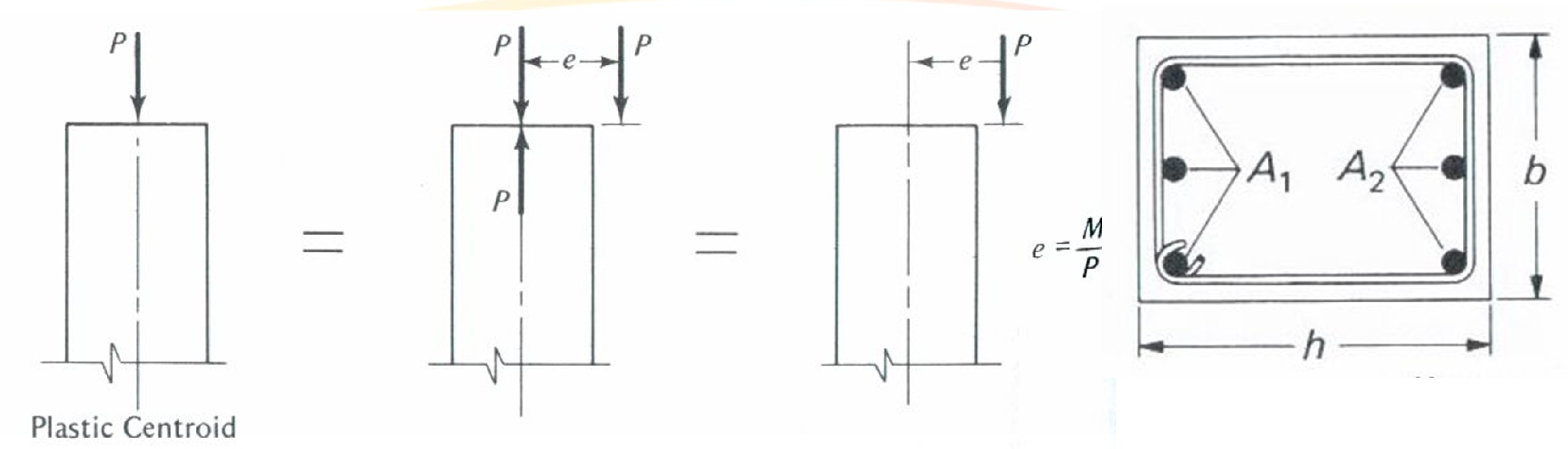
Short Columns: revision

Behavior

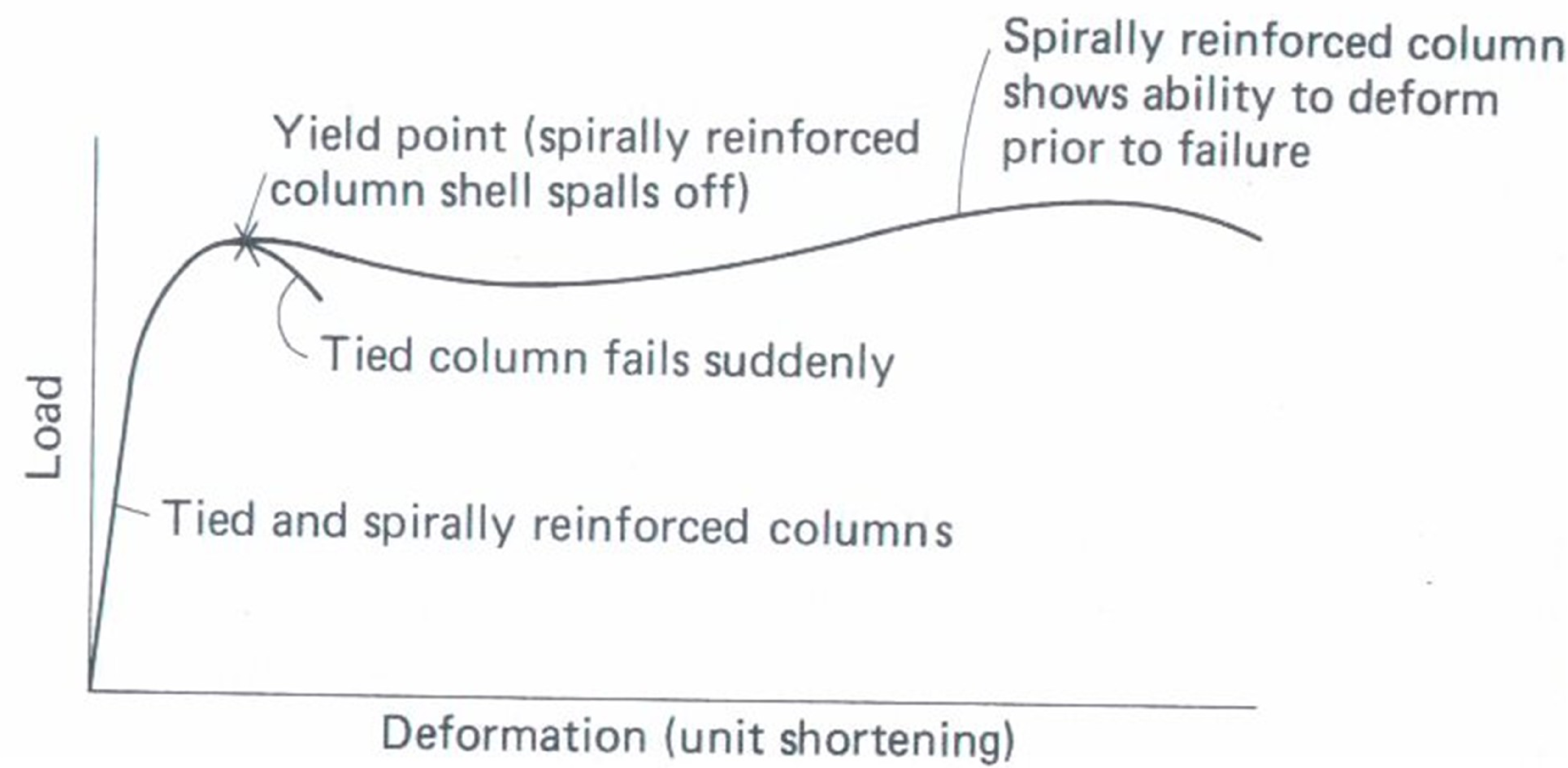
An "allowable stress" design procedure using an elastic analysis was found to be unacceptable. Reinforced concrete columns have been designed by a "strength" method since the 1940's.

Short Columns: revision

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



Short Columns: revision



Approximate Analysis

- 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.

Design of Short Columns

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

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.

Design of Short Columns

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

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

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

ACI 10.3.6.1-2

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

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

- ACI Code requires $0.01 \le \rho_g \le 0.08$

-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)

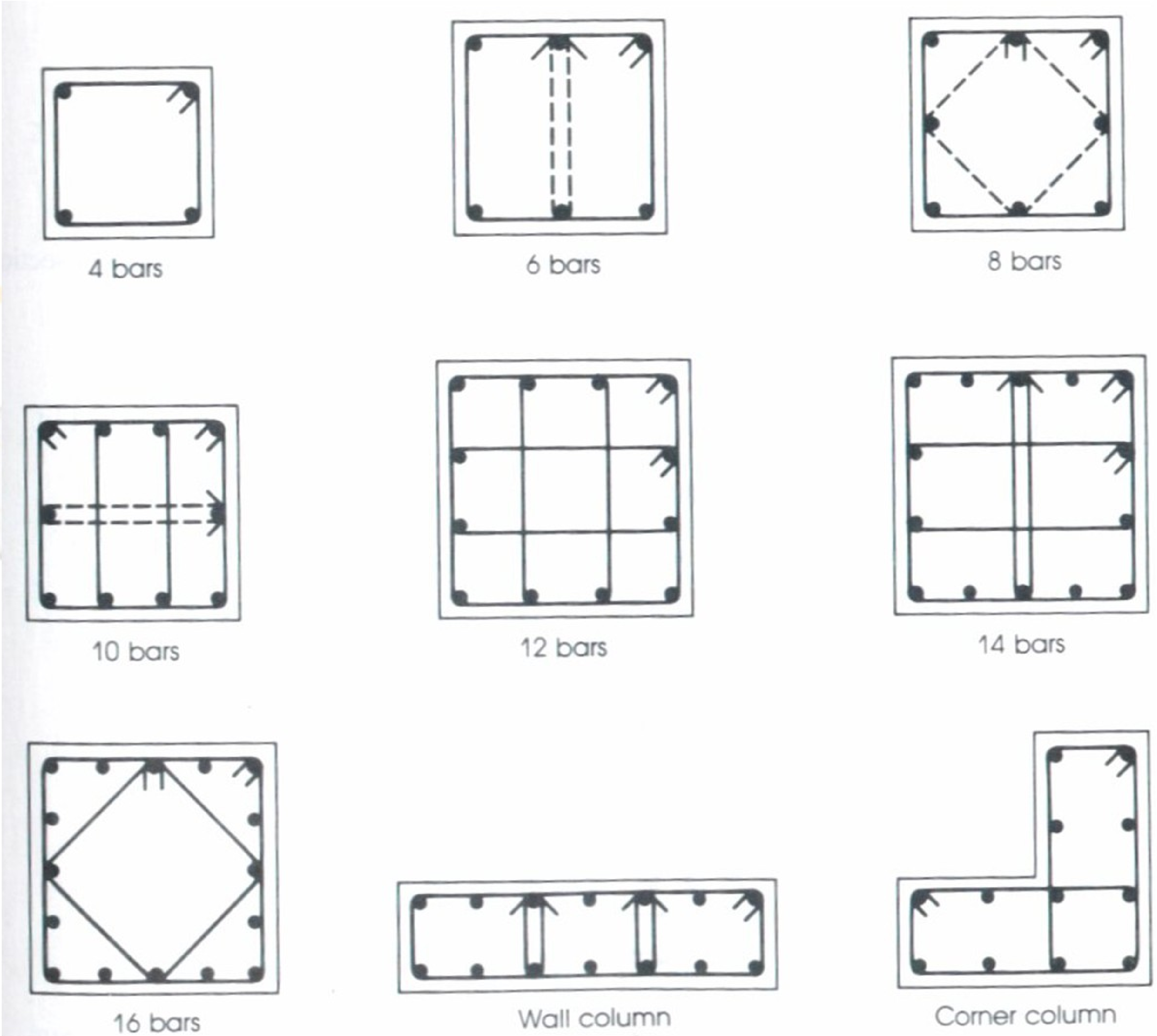
#10mm bars least dimension of tie

$s \leq 16\ d_b$ (d_b for longitudinal bars)
$s \leq 48\ d_b$ (d_b for tie bar)
$s \leq$ least lateral dimension of column

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.

Design of Short Columns

Examples of lateral ties.



Design of Short Columns

3. Reinforcement Requirements (Spirals)

ACI Code 7.10.4

size $\geq$ 10mm " dia.

$$2.5\text{cm} \leq \begin{matrix}\text{clear spacing} \\ \text{between spirals}\end{matrix} \leq 7.5\text{cm}$$ ACI 7.10.4.3

Design of Short Columns

4. Design for Concentric Axial Loads

(a) General Strength Requirement

$$\phi P_n \geq P_u$$

where, ϕ= 0.65 for tied columns

ϕ= 0.75 for spiral columns (ACI 08)

Design of Short Columns

4. Design for Concentric Axial Loads

(b) Expression for Design

defined:

$$\rho_g = \frac{A_{st}}{A_g} \qquad \text{ACI Code} \left(0.01 \le \rho_g \le 0.08\right)$$

Design of Tied Short Columns

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

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

- 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

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

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

For 20MPa concrete strength and 420MPa yield strength and representing gross area in cm^2 and column capacity in kN

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

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

Length to width ratio

- 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

Problem set # 4

- 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