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College of Engineering
Civil Engineering Department
4th Class

Reinforced Concrete Designs II
According to ACI 318

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Syllabus:

50601403 Reinforced Concrete Structures I

Direct Design Method: (Type of slab systems, Limitation of D.D.M., Minimum slab thickness for deflection control, total factored static moment, Longitudinal distribution of moments, Transverse distribution of longitudinal moments, Shear in two way slab systems, one-way shear (beam action), two-way shear (punching Shear), punching shear without moment transfer, punching shear with moment transfer, Effect of openings on shear strength.

Yield line theory of slabs: Basic concepts, work done, mechanism, guide line to draw axis of rotation, notation, Yield line by virtual work method, Yield line analysis of one way slab, Yield line analysis of two way slab.

References:-

1- Design of Concrete Structures, 16th Ed., 2021, by By David Darwin, Charles Dolan and Arthur Nilson, McGraw Hill.

2- Reinforced Concrete : A Fundamental Approach, 6th Ed., 2009, by Edward G. Nawy, Prentice- Hall. Inc., USA.

3- ACI Committee 318, Building Code Requirements for Structural Concrete Institute, USA.

Introduction

The slabs are presented in two groups:
One-Way Slabs and Two-Way Slabs

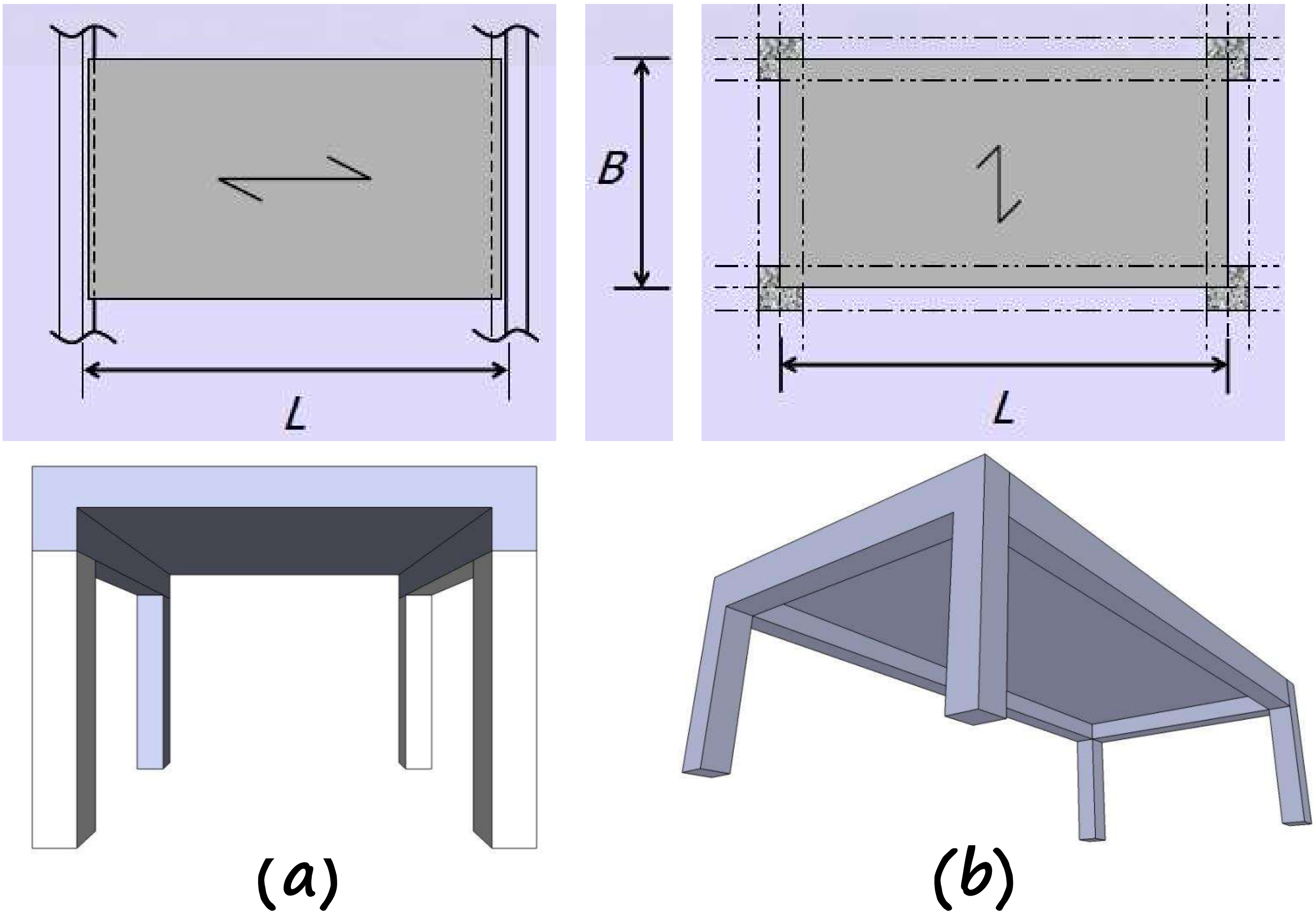
One-Way Slabs:

Rectangular slabs can be divided into the two groups based on the support conditions and length-to-width ratios. The one-way slabs are identified as follows:

1) When a rectangular slab is supported only on two opposite edges, it is a one-way slab spanning in the direction perpendicular to the edges.

2) When a rectangular slab is supported on all the four edges and the length-to-width (L/B) ratio is equal or greater than 2, the slab is considered to be a one-way slab. The slab spans predominantly in the direction parallel to the shorter edge. the loads being carried by the slab in the direction perpendicular to the supporting beams.

The following figure shows the two cases of one-way slabs.



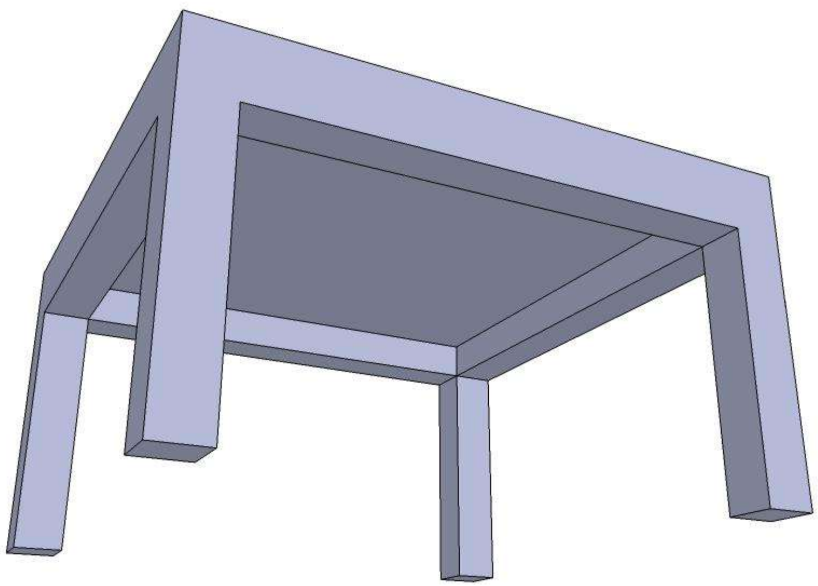
(a) Supported on two opposite edges (b) Supported on all edges ($L/B \geq 2$)

Figure(1)

Plans of one-way slabs

Two-Way Slabs:

When a rectangular slab is supported on all the sides and the length-to-width ratio is less than 2, it is considered to be a two-way slab. The slab spans in both the orthogonal directions and carries the load in the two directions. Figure (2) shows the two way system.



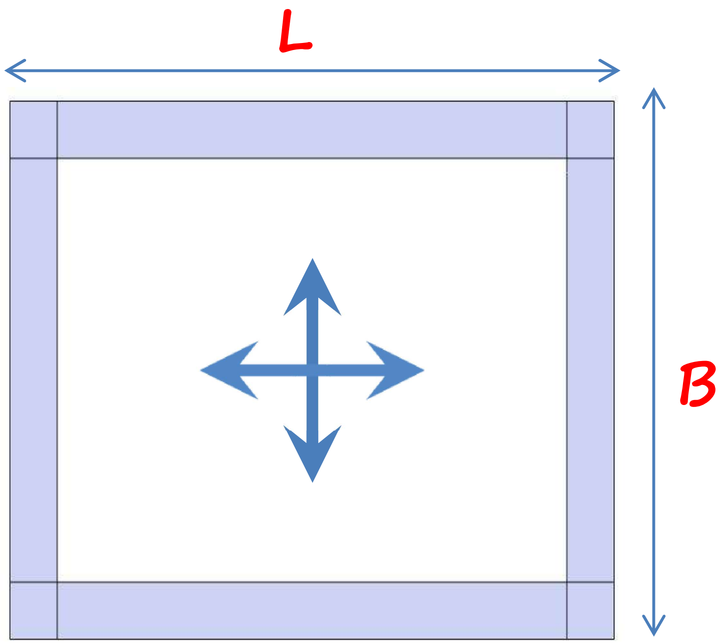


Figure (2)

(a) two way slab ($L/B < 2$)

(b) Loading transmission ($L/B < 2$)

Approximate Analysis Methods of ACI

A-Two-Way Slab on Stiff Supports: Stiff support (brick walls, reinforced concrete walls or stiff beams with $h_{beam} > 3h_{slab}$) on all four sides may be used for slab supports, so that Two-Way Slab action is obtained. Method 3 has been proposed for analysis and design of Two-Way Slab that supported on stiff supports. Direct design method and equivalent frame method can provide alternative approaches for analysis and design of Two-Way Slab system on stiff supports.

B-Two-Way Slabs on Flexible Supports: Two-Way Slab may be supported on flexible beams ($h_{beam} < 3h_{slab}$) on four sides. Method 3 cannot be used for analysis or design of these slab systems. Then the direct design method or equivalent frame method can be considered as the main design approaches for these systems.

Types of RC Two Way Slabs

1-Flat Plate:

Slab carried directly by columns without the use of beams or girders and is commonly used where spans are not large and load not heavy, (for relatively light loads as in apartments or offices) suitable span 4.5m to 6.0m with LL= 3-5kN/m^2, Figure (3)

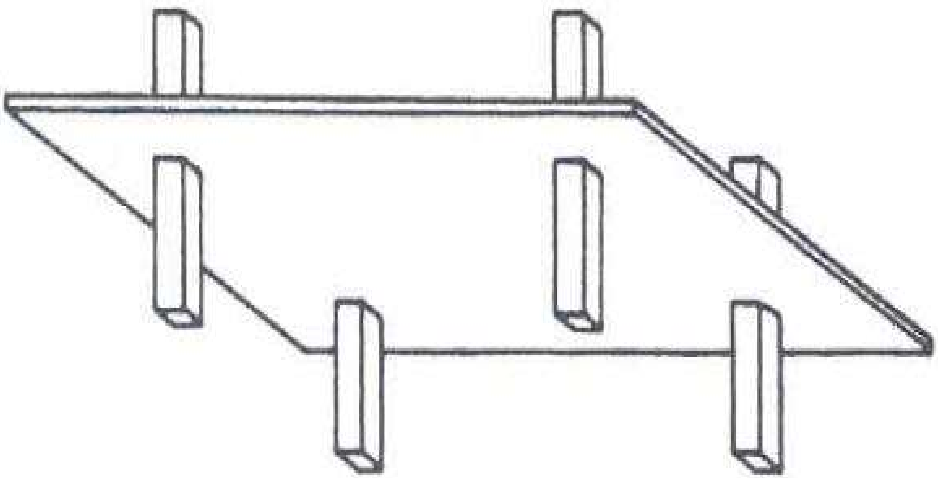


Figure (3)

Flat Plate

2-Flat slab:

The slab may be strengthened by increase the thickness around the columns with drop panel with or without expanding the columns with column capital. Drop panel and column capital are devices to reduce stresses due to shear and negative bending moments around the columns, (for heavy industrial loads) suitable span 6 to 9m with LL= 5-7.5kN/m². figure (4)

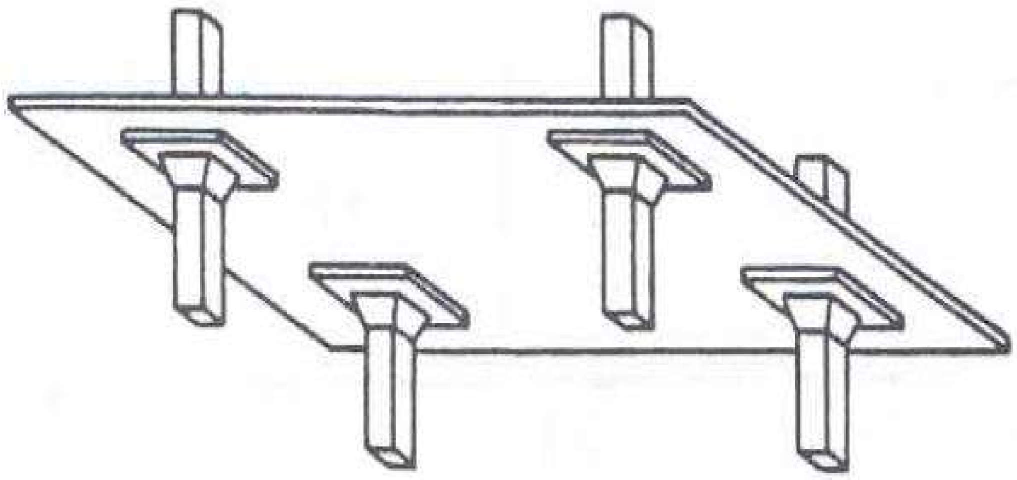


Figure (4)

Flat Slab

3-Slab with Beams:

slab is supported from four sides by beams

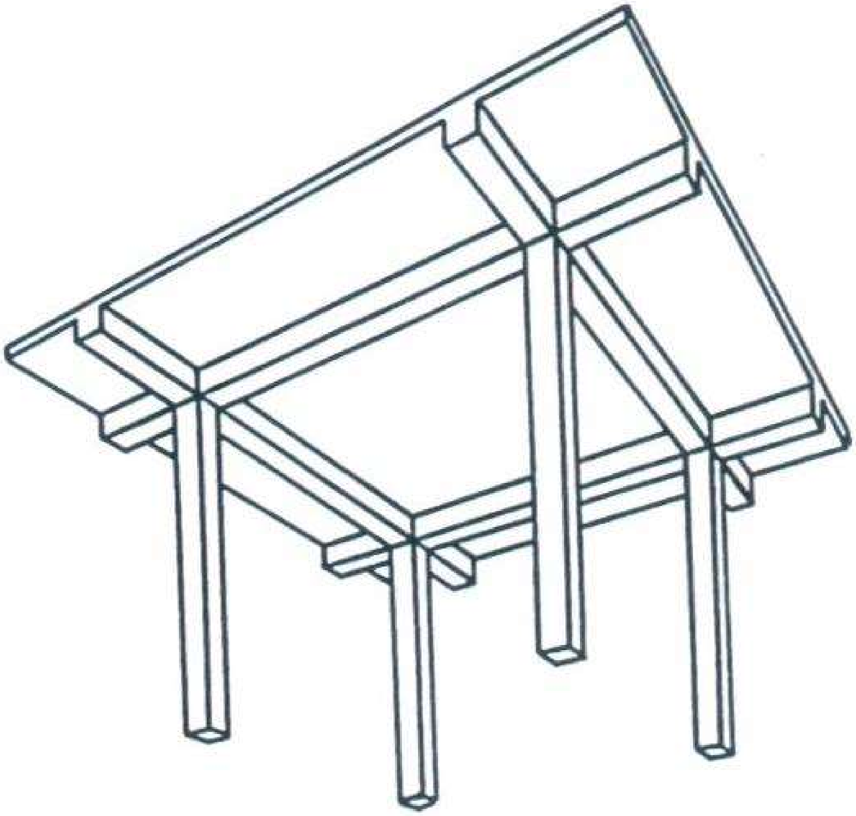


Figure (5)

Slab with beams

4- waffle Slab (Two Way Ribbed Slab)

To reduce the dead load of the solid slab, voids are formed rectilinear pattern through use of metal or fiber glass form inserts to result a two way ribbed construction. The thickness of waffle slab system is usually 50mm to 100mm and is supported by ribs in two directions. The ribs are arranged in each direction at spacing of about 500mm to 750mm. suitable span 7.5m to 12m with LL= 4-7.5kN/m^2.

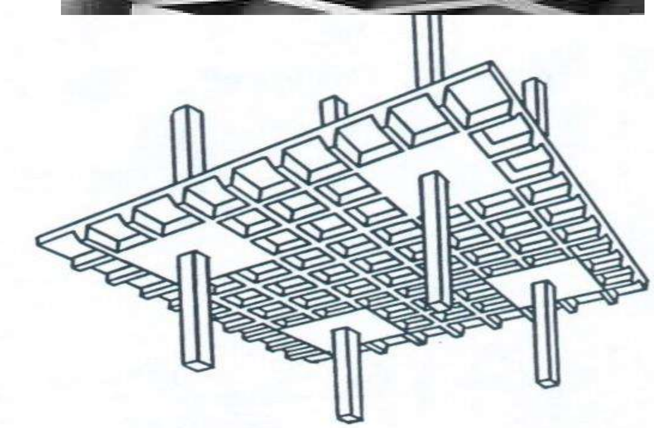


Figure (6)
Waffle Slab

Drop Panel Dimensions : ACI (8.2.4)

When used to reduce the amount of negative reinforcement over a column or minimum required slab thickness, a drop panel shall project below the slab at least (1/4) of the slab thickness (h) beyond the drop and extend in each direction from the centerline of support at distance not less than (1/6) the span length measured from center to center of supports.

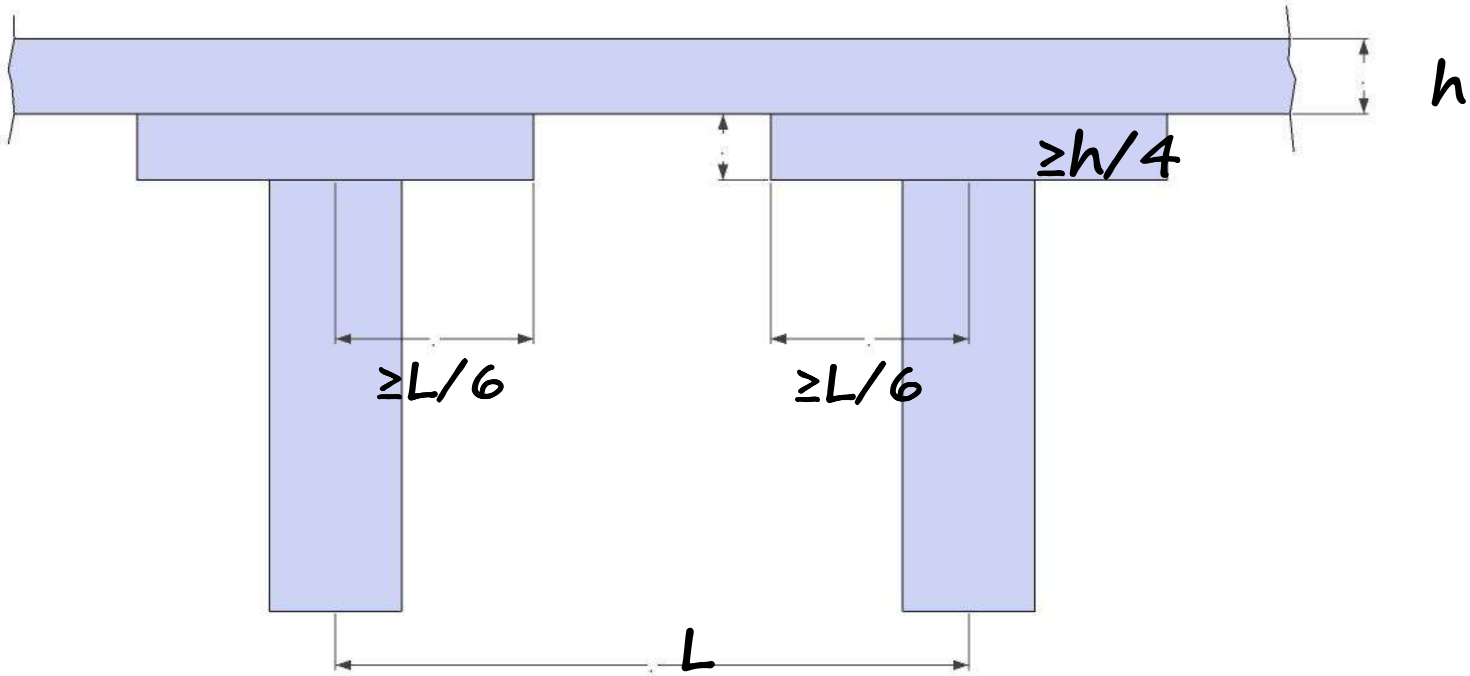


Figure (7)
Drop Panel Dimensions

Drop panel with dimensions less than those specified in ACI (8.2.4) may be used to increase shear strength. In computing required slab reinforcement, the thickness of drop panel below the slab shall not assumed greater than (1/4) the distance from edge of column or column capital.

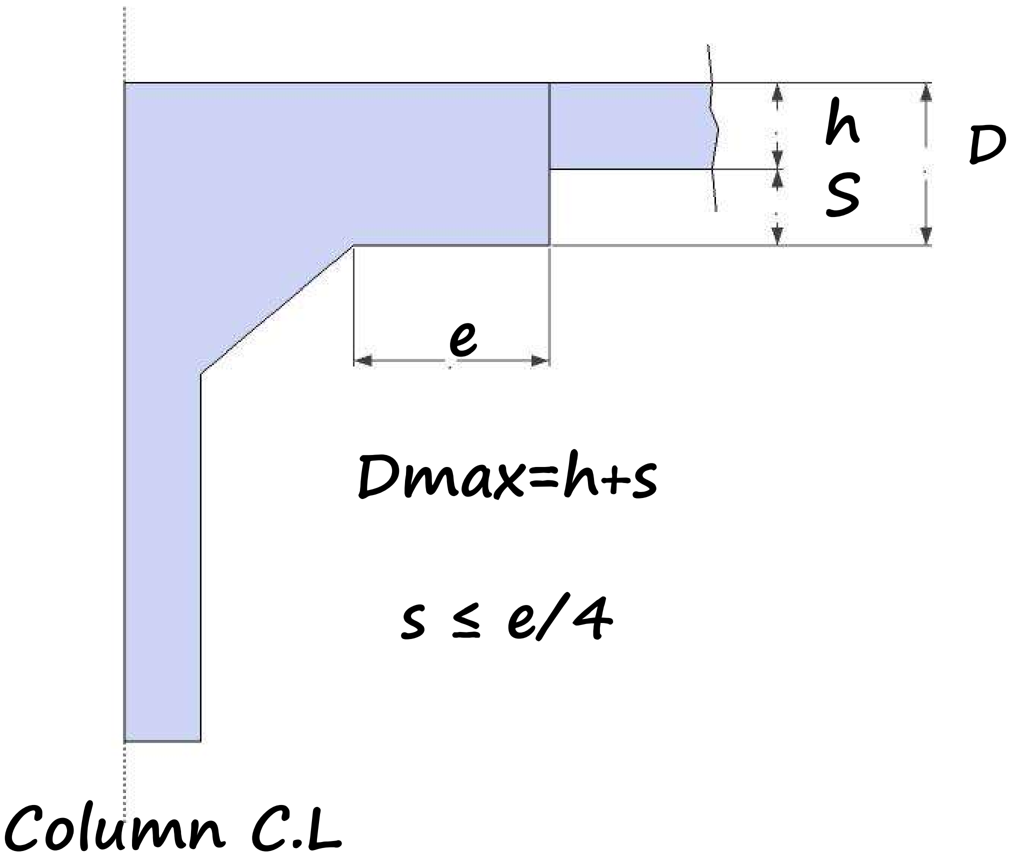


Figure (8)

Beam Section According to ACI (8.4.1.8)

Beams are defined to include that portion of slab on each side of the beam extending a distance equal to the projection of the beam above or below the slab, whichever is greater, but not greater than four times the slab thickness (≤ 4hf).

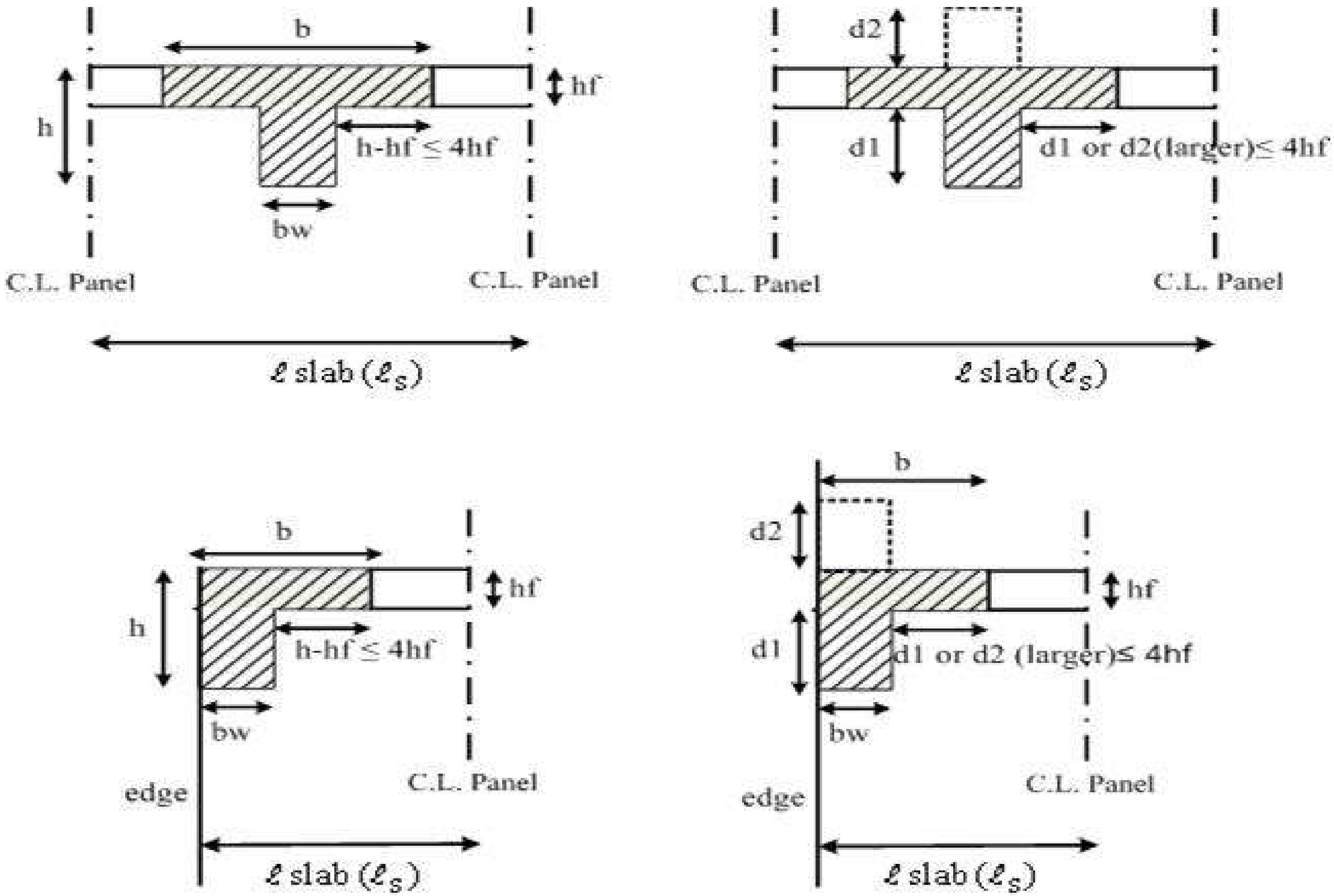
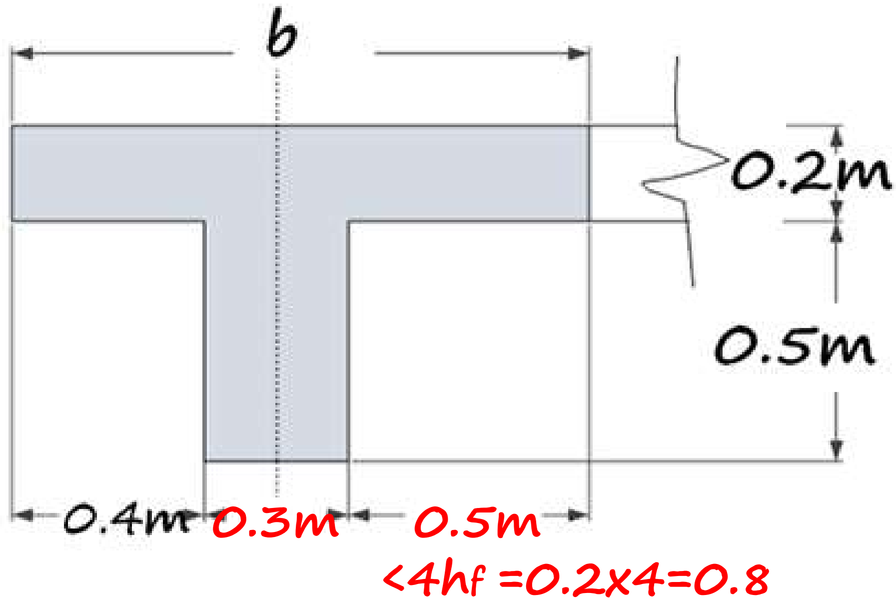
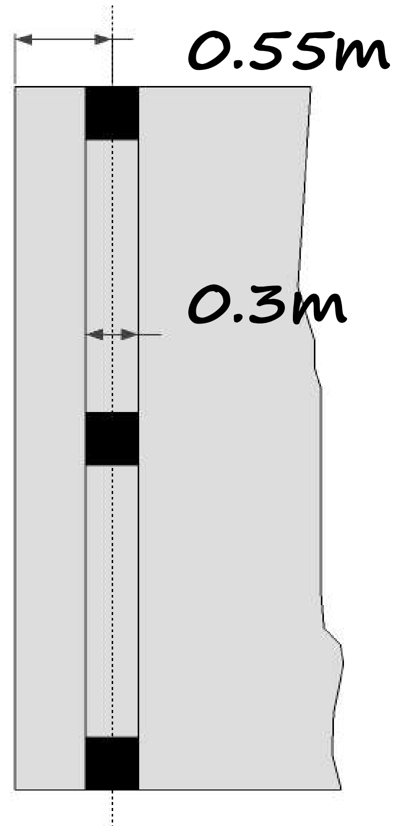


Figure (9)

Exercise:

Find effective b





<u>Sol:</u>

b= 0.5+0.3+0.4=1.2m

Ratio of Flexure Stiffness of Longitudinal Beams and Slabs (α_f) :

When beams are used along the column lines in a two way floor system then the relative size of the beam to the thickness of slab can be considered as an important parameter that affecting the behavior and design of the floor system. This parameter (α_f) can be best measured by the ratio of the flexural stiffness of the beam to the flexural stiffness of the slab whose width equals the distance between the centerline of panels on each side of the beam.

$$\alpha_f = \frac{4E_{cb}I_b/l}{4E_{cs}I_s/l} \quad , \qquad E_c = 4700\sqrt{f'_c}$$

When $f'_{c\,beam} = f'_{c\,slab}$ then $\alpha_f = \dfrac{I_b}{I_s}$, where I_b

And I_s are the moments of inertia of the effective beam and slab

Approximation Method for finding (I):

The moment of inertia of the beam about its own centroidal axis can be computed as follows:

$$I_b \cong (b_w h^3 / 12) \times 2$$ for interior beam

$$I_b \cong (b_w h^3 / 12) \times 1.5$$ for edge beam

The effective length of the slab used in computing the moment of inertia is the distance between the centerlines of the adjacent panels for the slab above the interior beams, while the length of slab above the edge beam is the distance from the centerline of the panel to the end edge.

Exercise: find l_s for the figure shown

For B1 (edge beam):

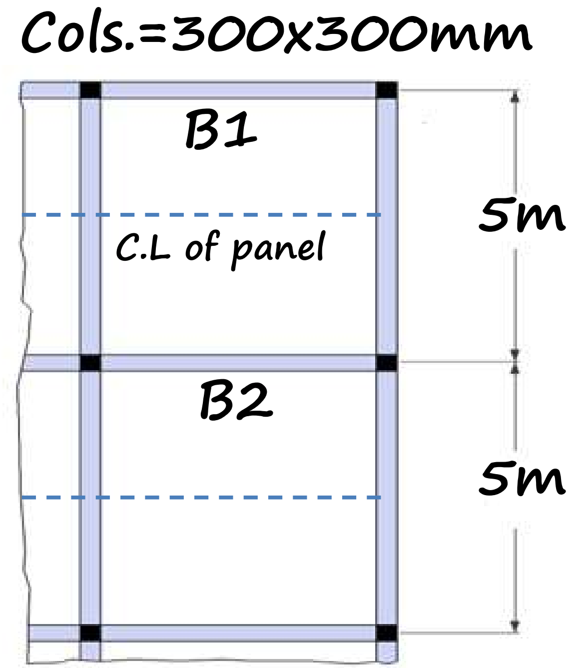
Sol.

$$l_s = 2.5 + 0.15 = 2.65m$$

For B2 (interior beam):

Sol.

$$l_s = 2.5 + 2.5 = 5m$$



Exercise: find l_s for the figure shown

Sol.

$$l_s = 2.5 + 1.15 = 3.65m$$