Analysis and Design of Slabs

TYPES OF SLABS

DESIGN OF ONE-WAY SLABS

TEMPERATURE & SHRINKAGE REINFORCEMENT

TWO-WAY EDGE-SUPPORTED SLABS

TWO-WAY COLUMN-SUPPORTED SLABS

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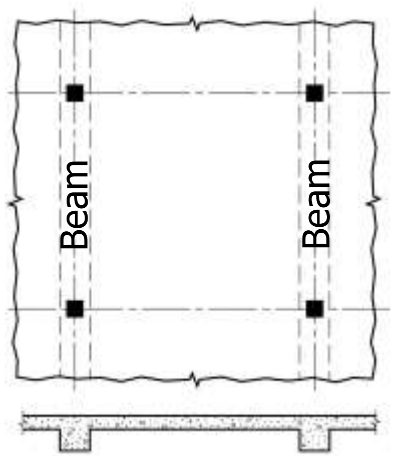
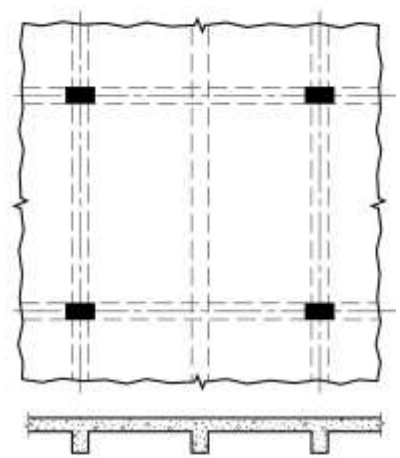
10. Analysis and Design of Slabs

TYPES OF SLABS

One-way Slabs

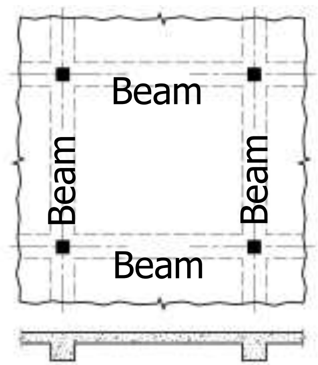
- Slabs which are supported on two opposite side only
- Slabs of which the ratio of length to width is larger than about 2





TYPES OF SLABS

Two-way Slabs



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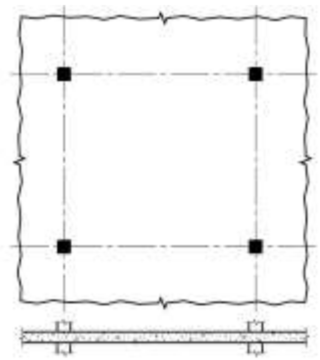

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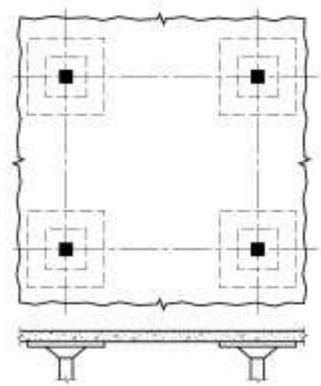

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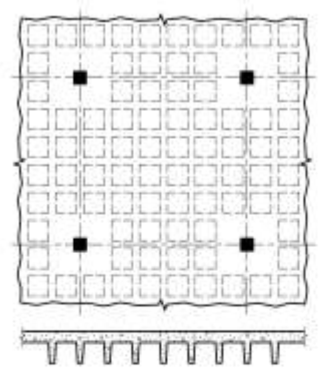
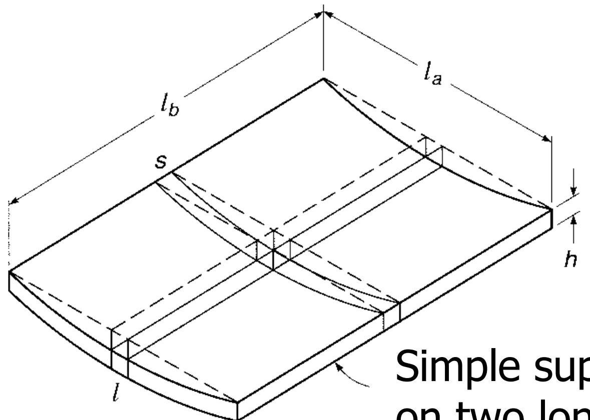
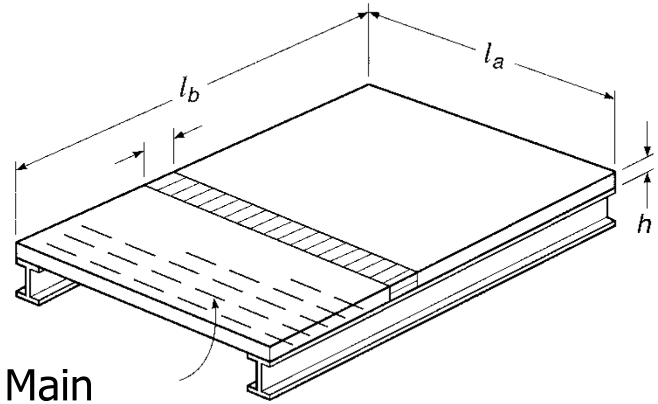


<Grid or waffle slab>

10. Analysis and Design of Slabs

DESIGN OF ONE-WAY SLABS





Cylindrical bending : A one-way slab consists of a set of parallel rectangular beams(strips).

⇨ Design and Analysis of a one-way slab is almost the same as those of a rectangular beam.

DESIGN OF ONE-WAY SLABS

Minimum Thickness *h*

KCI Code 4.3.1 specifies the minimum thickness for non-prestressed slab of normal-weight concrete (w_c=2,300kg/m^3) using 400MPa reinforcement.

Simply supported	$l/20$
One end continuous	$l/24$
Both end continuous	$l/28$
Cantilever	$l/10$

DESIGN OF ONE-WAY SLABS

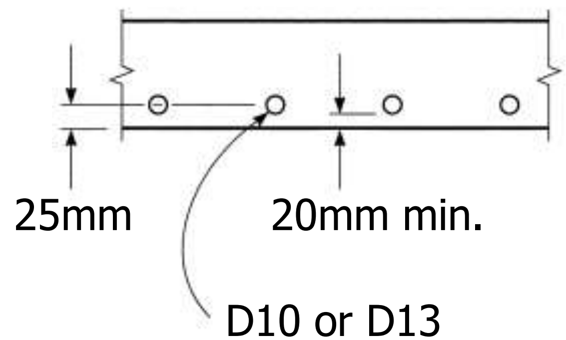
Minimum Thickness *h*

Note

1) Span length *l* is in mm.
2) For light-weight concrete 1,500~2,000kg/m^3, the values shall be multiplied by (1.65-0.00031w_c) but not less than 1.09, where w_c is in kg/m^3.
3) For f_y other than 400MPa, the values shall be multiplied by (0.43+f_y/700).

Other Details

- The concrete protection below the reinforcement should follow the requirements of KCI Code 5.4, calling for 20mm. (25mm below the center of steel)



- The lateral spacing of the bars should not exceed 3 times the thickness *h* or 400mm, whichever is less.
- Actual spacing is not less than about 1.5 times the slab thickness to avoid excessive cost.

TEMPERATURE & SHRINKAGE REINFORCEMENT

- In one way slabs, it is necessary to provide special reinforcement for shrinkage and temperature in the direction perpendicular to the main reinforcement.

  ; know as temperature or shrinkage reinforcement distribution steel.

10. Analysis and Design of Slabs

TEMPERATURE & SHRINKAGE REINFORCEMENT

KCI Code provisions (5.7.2)

Specifies the minimum ratios of steel area to gross concrete area.

Slabs where $f_y \leq 400$MPa deformed bars are used	0.002
Slabs where $f_y \geq 400$MPa at yield strain of 0.0035 is used	$0.002 \times 400 / f_y$

But in no cases may them be placed farther apart than 5 times the slab thickness or more than 400mm.

In no case is the reinforcement ratio to be less than 0.0014.

10. Analysis and Design of slab

Example 13.1 One –way Slab Design

A reinforced concrete slab is built integrally with its supports and consists of two equal spans, each with a clear span of 4.5m.

The service live load is 5kN/m^2 and 27MPa concrete is specified for use with a yield stress equal to 400MPa.

Design the slab

10. Analysis and Design of slab

Solution>

- Determination of slab thickness

  This structural system corresponds to the case of both ends being continuous

$$\frac{l}{28} = 160mm$$

The trial thickness of 180mm will be need, for which the weight is

$$\left(180 \times 10^{-3}\right) \times \underbrace{\left(24 \, {}^{kN}\!/_{m^2}\right)}_{unit\ weight\ conc.} = 4.32 \, {}^{kN}\!/_{m^2}$$

10. Analysis and Design of slab

- Factored load

$$DL : 1.2 \times 4.32 = 5.184$$

$$LL : 1.6 \times 5.00 = 8.0$$

$$Total = 13.184 \ kN/m^2$$

- Factored moment at critical sections (Handout 13-1)

At interior support $-M = \frac{1}{9} \times 13.184 \times 4.5^2 = 29.7 \ kN \cdot m$

At midspan $+M = \frac{1}{14} \times 13.184 \times 4.5^2 = 19.1 \ kN \cdot m$

At exterior support $-M = \frac{1}{24} \times 13.184 \times 4.5^2 = 11.1 \ kN \cdot m$

10. Analysis and Design of slab

- The maximum reinforcement ratio (Handout #3-2)

$$\rho_{\max} = (0.85)^2 \frac{27}{400} \frac{0.003}{0.003 + 0.004} = 0.021$$

- If the maximum ρ were actually used, the minimum required effective depth, controlled by negative moment at the interior support would be obtained

$$d^2 = \frac{M_u}{\phi \rho f_y b \left(1 - 0.59 \rho \frac{f_y}{f_{ck}}\right)}$$

10. Analysis and Design of slab

Recall

$$\phi M_n = \phi A_s f_y \left(d - \frac{a}{2} \right)$$

$$= \phi \rho f_y b d^2 \left(1 - 0.59 \frac{\rho f_y}{f_{ck}} \right)$$

$$= \phi R b d^2$$

$$= \frac{(29.7)(10^3)(10^3)}{(0.85)(0.021)(400)(1000)\left(1 - 0.59 \times 0.021 \times \frac{400}{27}\right)}$$

$$= 5095 mm^2$$

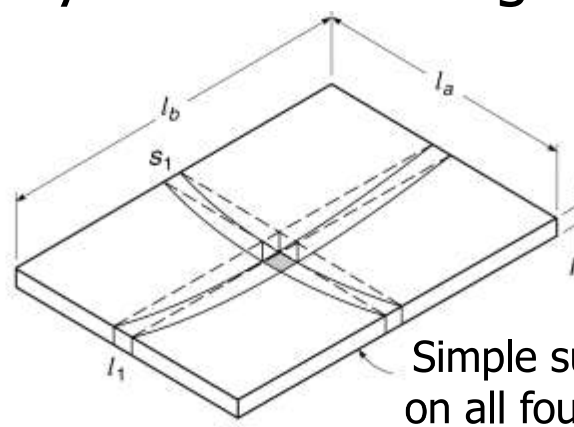
Homework #4 Complete the design

TWO-WAY EDGE-SUPPORTED SLABS

- Consider a simplest type of TWO-WAY slab which is supported along its four edges by relatively DEEP, STIFF, MONOLITHIC concrete beams or by walls or steel griders.

The deflections at the intersection point must be the same.

$$\frac{5w_a l_a^4}{384EI} = \frac{5w_b l_b^4}{384EI}$$



where w_a is the share of the distributed load w carried in the short direction and w_b is the share in the long direction.

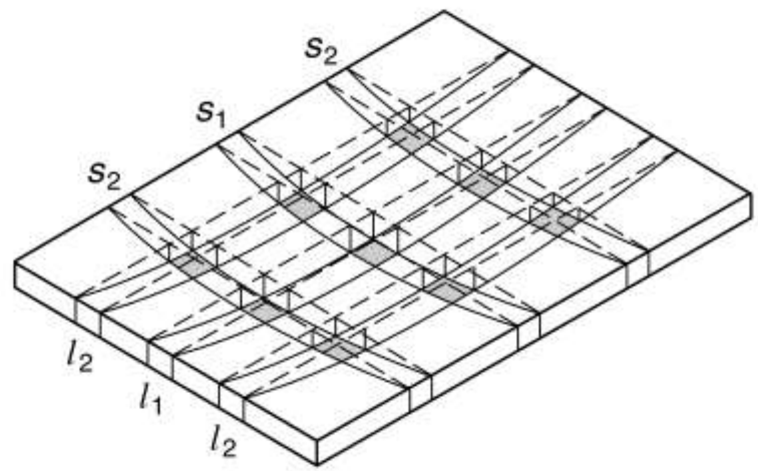
$$\frac{w_a}{w_b} = \frac{l_b^4}{l_a^4} \quad \Rightarrow \quad w_a > w_b$$

TWO-WAY EDGE-SUPPORTED SLABS

- The outer strips s_2 and l_2 are not only bent but also TWISTED.

  ⇨ This twisting results in torsional stresses and moments.

  ⇨ Total loads on the slab is carried by two-way bending moment plus twisting moments.



TWO-WAY EDGE-SUPPORTED SLABS

Proof

Consider a simply supported square slab.

i) assuming that only bending is present, the maximum moment

$$\frac{(w/2)l^2}{8} = 0.0625wl^2$$

ii) The exact theory of elastic plates gives $0.048\,wl^2$

⇦ Twisting moments relieve the bending moment by about 25%

10. Analysis and Design of Slabs

TWO-WAY EDGE-SUPPORTED SLABS

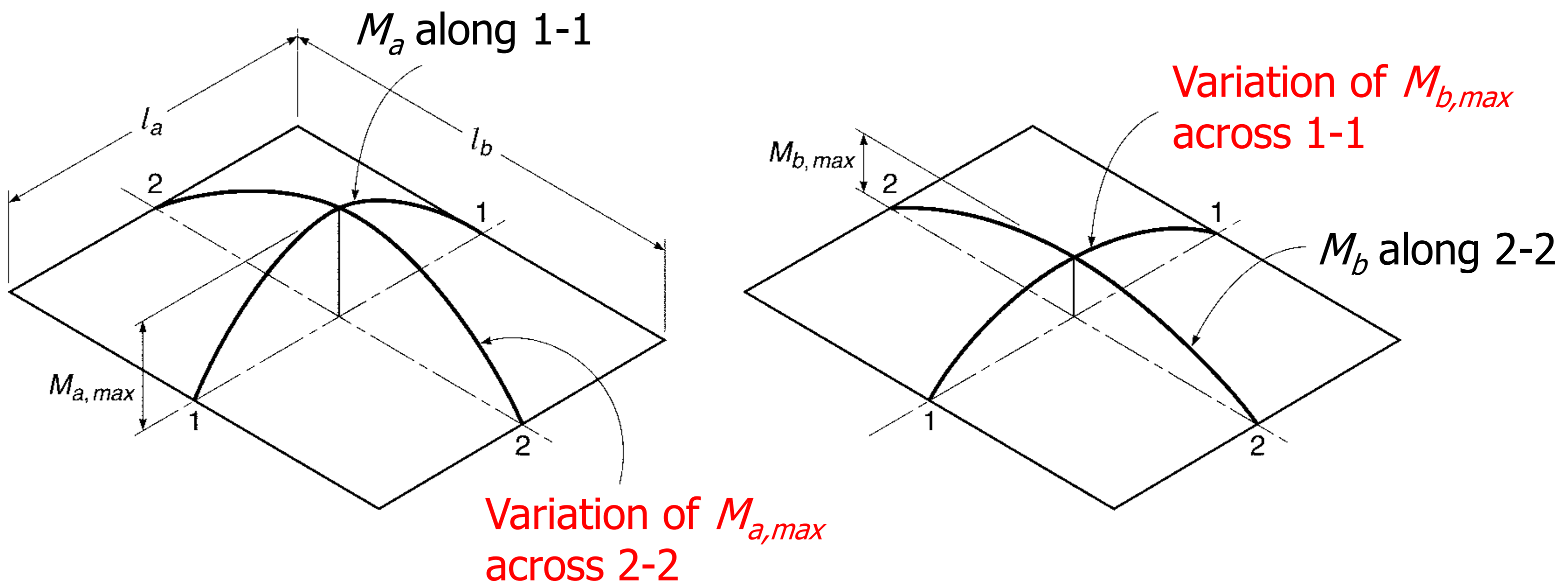
- If the load is increased, so that the steel at the middle of strip s_1 is yielding, the slab will not show immediate failure due to inelastic redistribution.
  Center -> in the both direction

  ⇨ slabs need not be designed for the absolute maximum moment in each of the two directions, but only for a SMALLER AVERAGE moment in each of the two directions in the central portion of the slab.

Note

For example, one of the several analytical methods in general use permits a square slab to be designed for a moment of $0.036wl^2$.

TWO-WAY EDGE-SUPPORTED SLABS



- Most practical approximated design method considering the variation in maximum moment is designing for a reduced (averaged) moment in the outer quarters of the slab span in each direction.

TWO-WAY EDGE-SUPPORTED SLABS

Note

1) Two layers positive bars are placed in two-way slab.
   ⇨ Short / Long direction bars are placed on the top of bars.

2) According to KCI Code 10.6.1, the minimum reinforcement in each direction for two-way slabs is the same required for shrinkage and temperature crack control as for one-way slab.

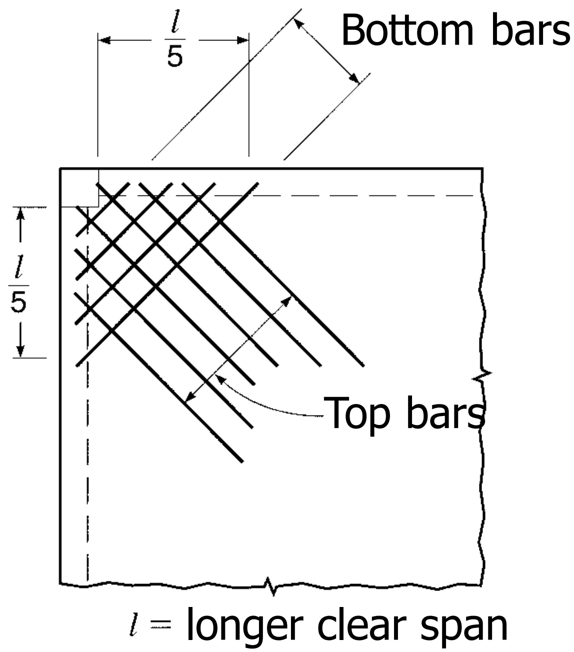
3) The spacing of flexural reinforcement at critical section must not exceed 2 times the slab thickness *h*.

10. Analysis and Design of Slabs

- The twisting moments are usually of importance only at EXTERIOR corners, where they tend to crack the slab

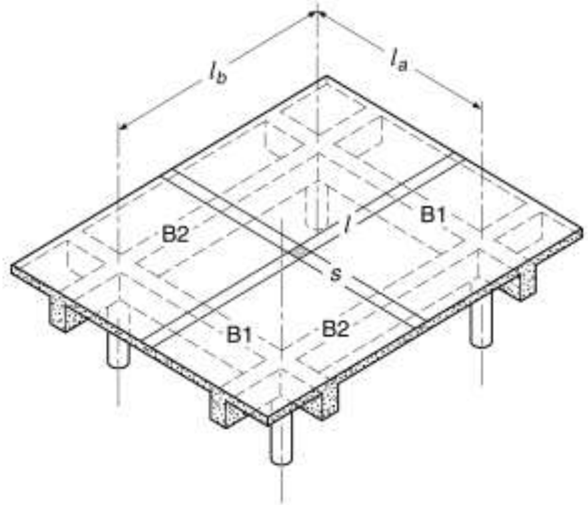
  - at the bottom along the panel diagonal

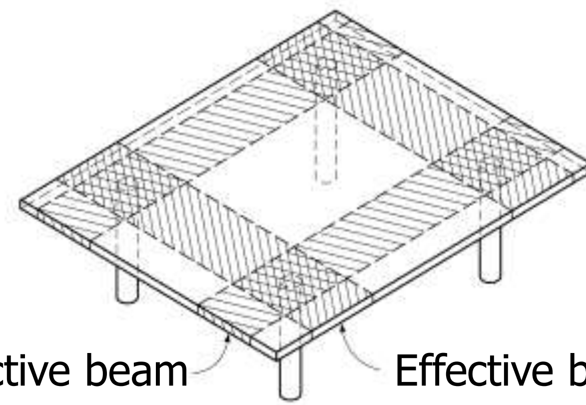
  - at the top perpendicular to the panel diagonal



TWO-WAY COLUMN-SUPPORTED SLABS

- Consider a two-way slab which are supported by relatively SHALLOW, FLEXIBLE beams, or flat plates, flat slabs, or two-way joist system.

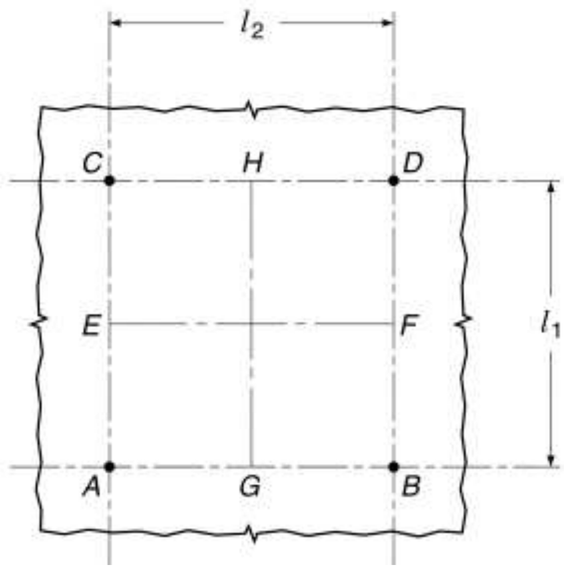




For column supported construction, 100% of the applied load must be carried in each direction, jointly by the slab and its supporting beams.

TWO-WAY COLUMN-SUPPORTED SLABS

- Consider a flat floor supported by 4 columns, assuming that $l_2 > l_1$



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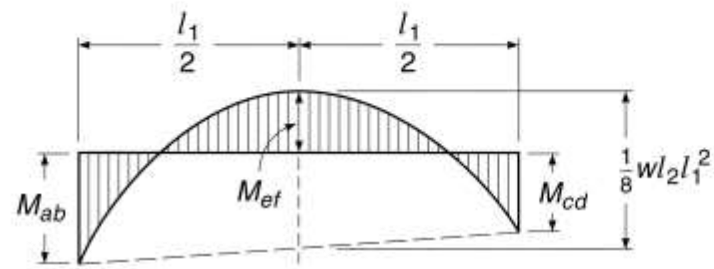


<moment variation along a span>

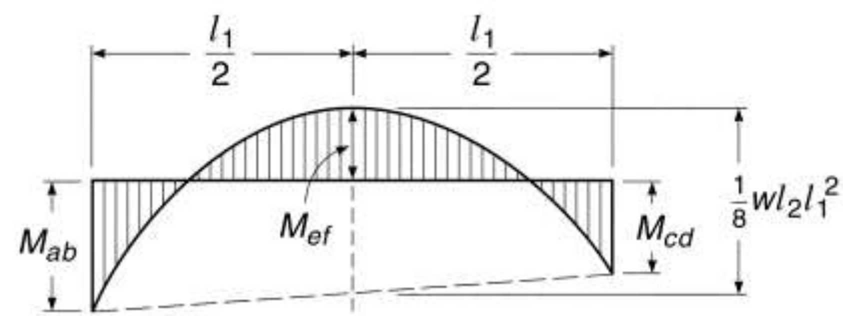
TWO-WAY COLUMN-SUPPORTED SLABS

In any span of a continuous beam, the sum of the midspan positive moment and negative moments at adjacent supports is equal to the midspan positive moment of a corresponding simply supported beam.

$$\frac{1}{2}(M_{ab}+M_{cd})+M_{ef}=\frac{1}{8}(wl_2)l_1^2$$

Similarly,

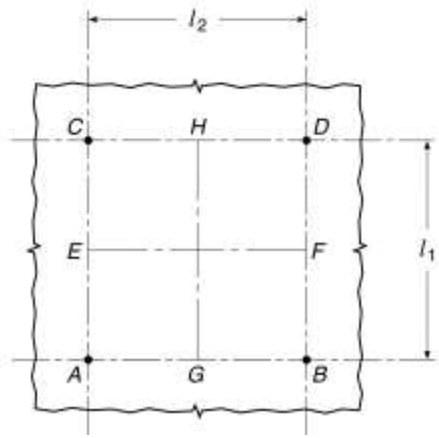
$$\frac{1}{2}(M_{ac}+M_{bd})+M_{gh}=\frac{1}{8}(wl_1)l_2^2$$



<moment variation along a span>

⇨ BUT, these results disclose NOTHING about the support moments and midspan moments.

TWO-WAY COLUMN-SUPPORTED SLABS



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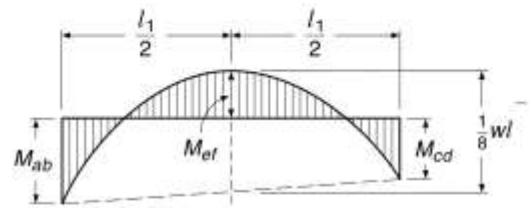

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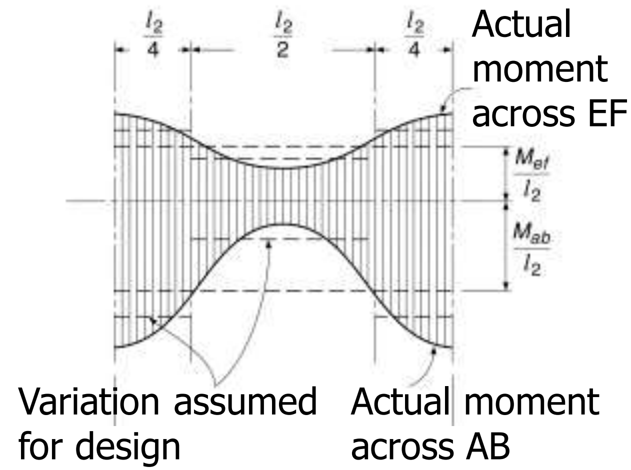


<moment variation across the width of critical sections>

The moments across the width of critical sections, such as AB or EF are NOT constant but vary as above.

⇨ For design purpose, it is convenient to divide each panel into column strips and middle strip between column strips.

TWO-WAY COLUMN-SUPPORTED SLABS

- KCI Code 10.3.2 permits design "by any procedure satisfying conditions of equilibrium and geometrical compatibility".

  In addition, specific reference is made to two alternative approaches :

  - a semi-empirical "direct design method (DDM)"

  - an approximate elastic analysis known as the equivalent frame method (EFM).

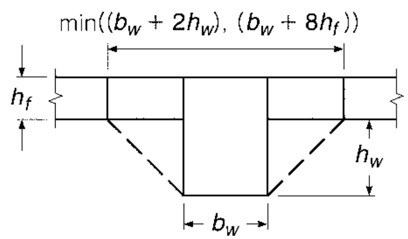
TWO-WAY COLUMN-SUPPORTED SLABS

Note

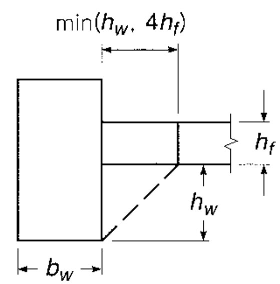
1. Both DDM and EFM employ the concepts of column/middle strip.

   - A column strip has a width on each side of the column centerline equal to one-fourth the smaller of the panel dimensions.

2. Portions of slab to be included with beam.



<symmetric slab>



<single side slab>