

# *ARCHITECTURAL STRUCTURES: FORM, BEHAVIOR, AND DESIGN*

*ARCH 331*

*HÜDAVERDİ TOZAN*

*SPRING 2013*

## *lecture twenty five*

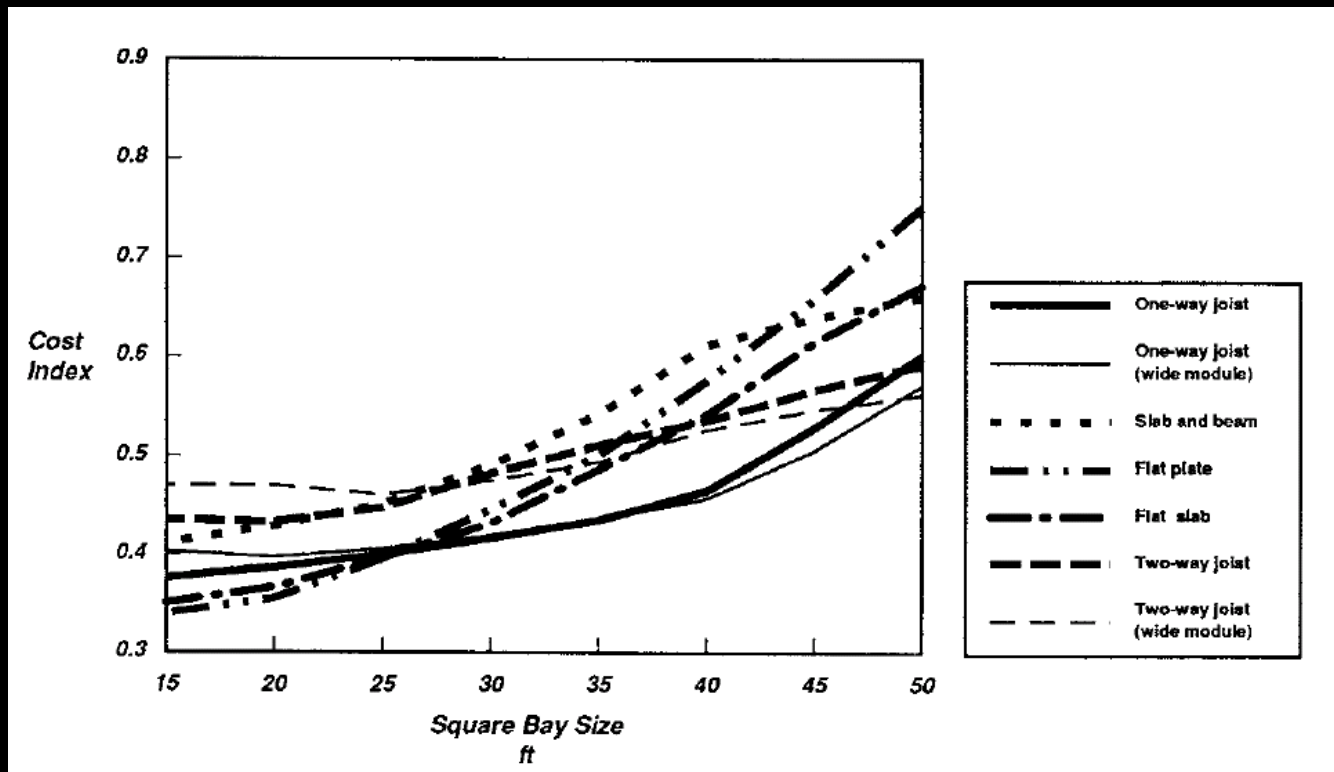


<http://nisee.berkeley.edu/godden>

# ***concrete construction: flat spanning systems***

# Reinforced Concrete Design

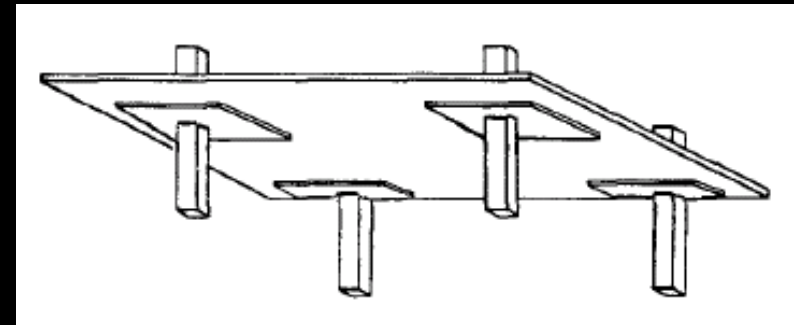
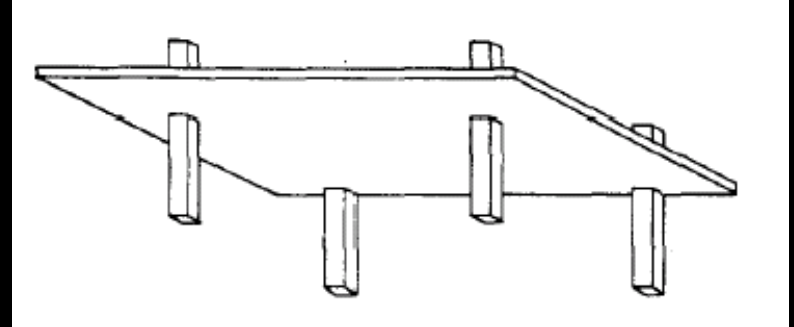
- economical & common
- resist lateral loads



# Reinforced Concrete Design

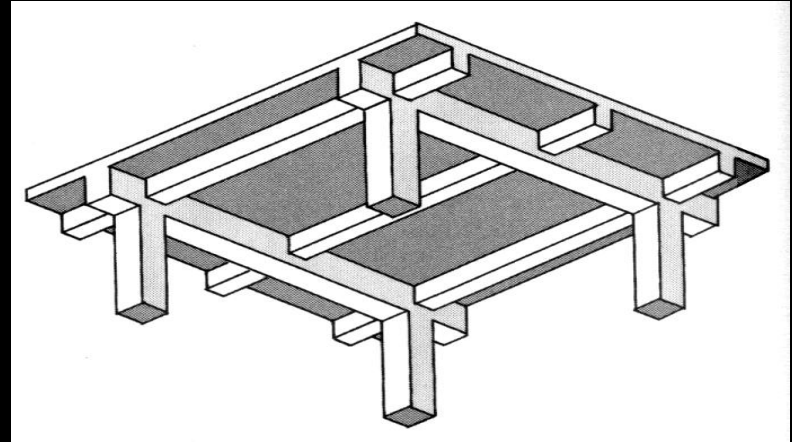
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- *flat plate*
  - 5"-10" thick
  - simple formwork
  - lower story heights
- *flat slab*
  - same as plate
  - 2 1/4"–8" drop panels

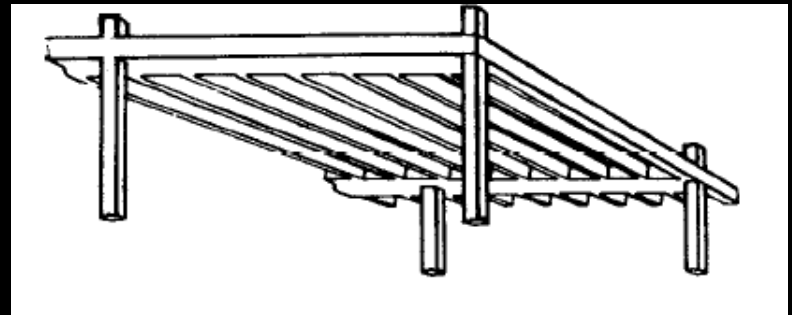


# Reinforced Concrete Design

- *beam supported*
  - slab depth  $\sim L/20$
  - 8"–60" deep
- *one-way joists*
  - 3"–5" slab
  - 8"–20" stems
  - 5"-7" webs



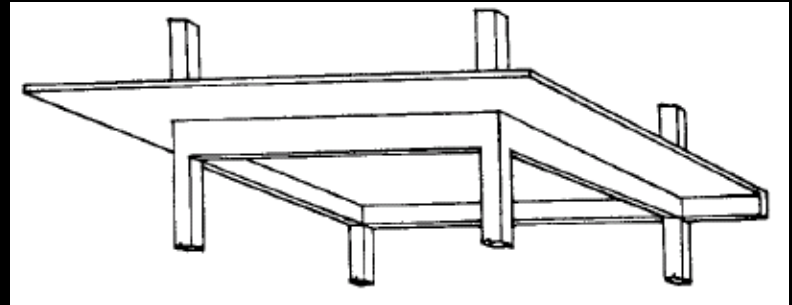
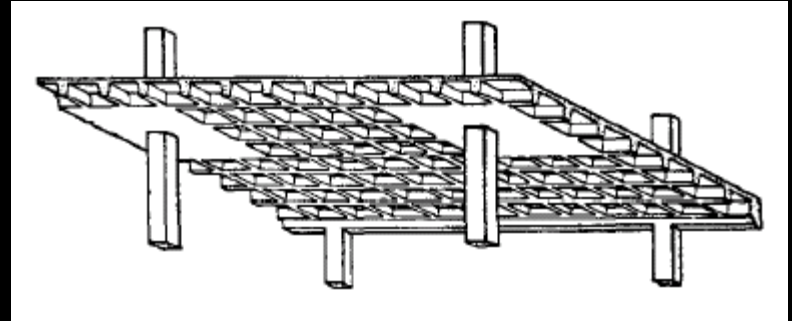
*The Architect's Studio Companion*



# Reinforced Concrete Design

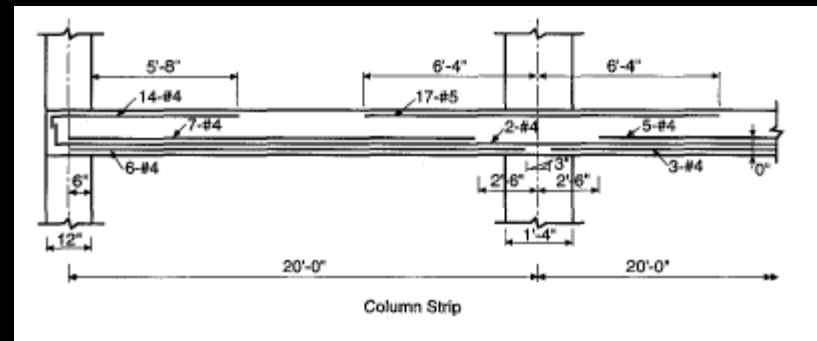
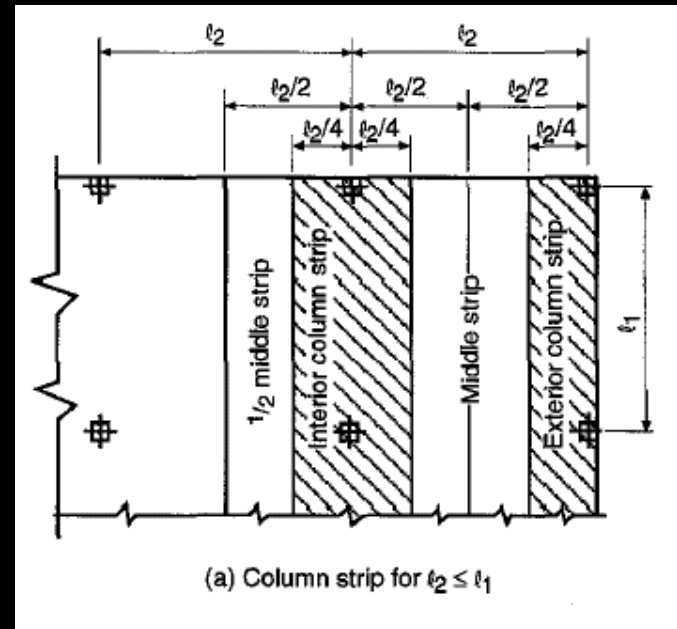
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- *two-way joist*
  - “waffle slab”
  - 3”-5” slab
  - 8”-24” stems
  - 6”-8” webs
- *beam supported slab*
  - 5”-10” slabs
  - taller story heights



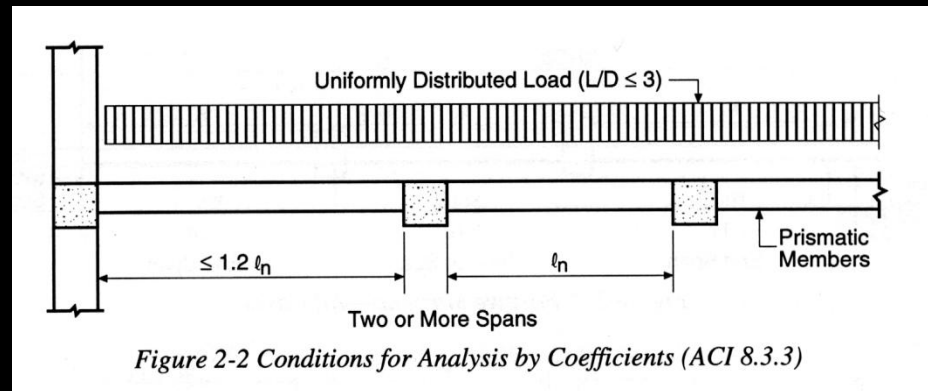
# Reinforced Concrete Design

- *simplified frame analysis*
  - strips, like continuous beams
- *moments require flexural reinforcement*
  - top & bottom
  - both directions of slab
  - continuous, bent or discontinuous



# Reinforced Concrete Design

- *one-way slabs (wide beam design)*
  - *approximate analysis for moment & shear coefficients*
  - *two or more spans*
  - *~ same lengths*
  - *$w_u$  from combos*
  - *uniform loads with  $L/D \leq 3$*
  - *$\ell_n$  is clear span (+M) or average of adjacent clear spans (-M)*



# Reinforced Concrete Design

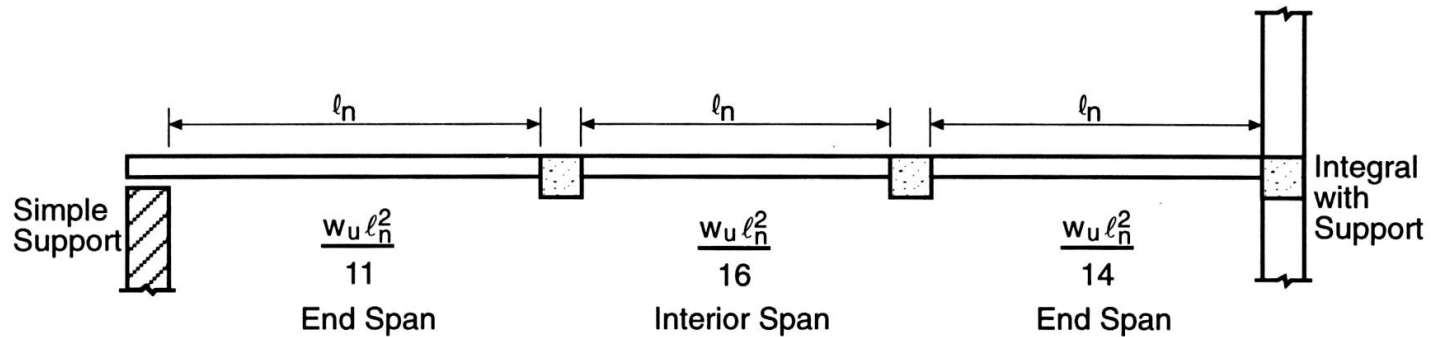


Figure 2-3 Positive Moments—All Cases

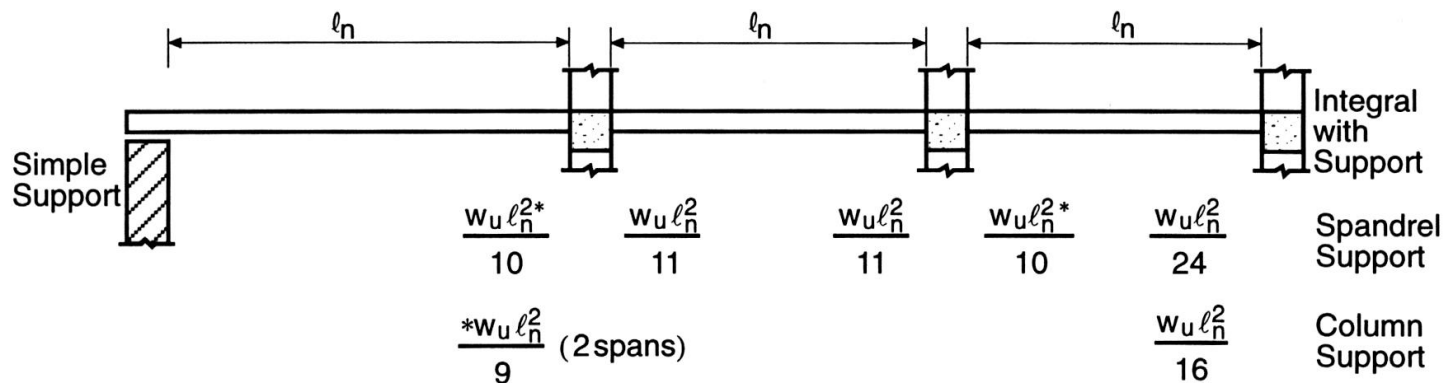
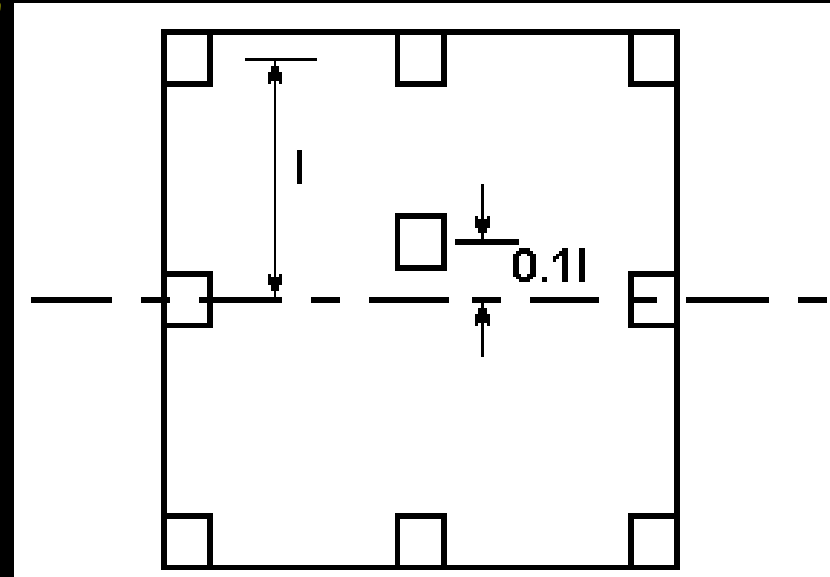


Figure 2-4 Negative Moments—Beams and Slabs

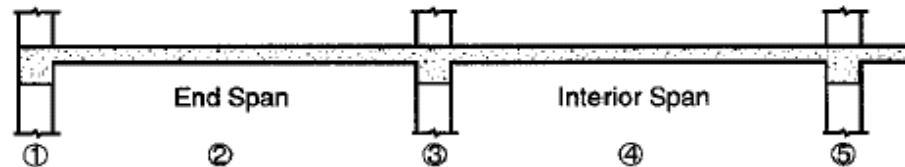
# Reinforced Concrete Design

- *two-way slabs - Direct Design Method*
  - 3 or more spans each way
  - uniform loads with  $L/D \leq 2$
  - rectangular panels with long/short span  $\leq 2$
  - successive spans can't differ  $> \text{longer}/3$
  - column offset no more than 10% span



# Reinforced Concrete Design

Table 4-6 Two-Way Beam-Supported Slab

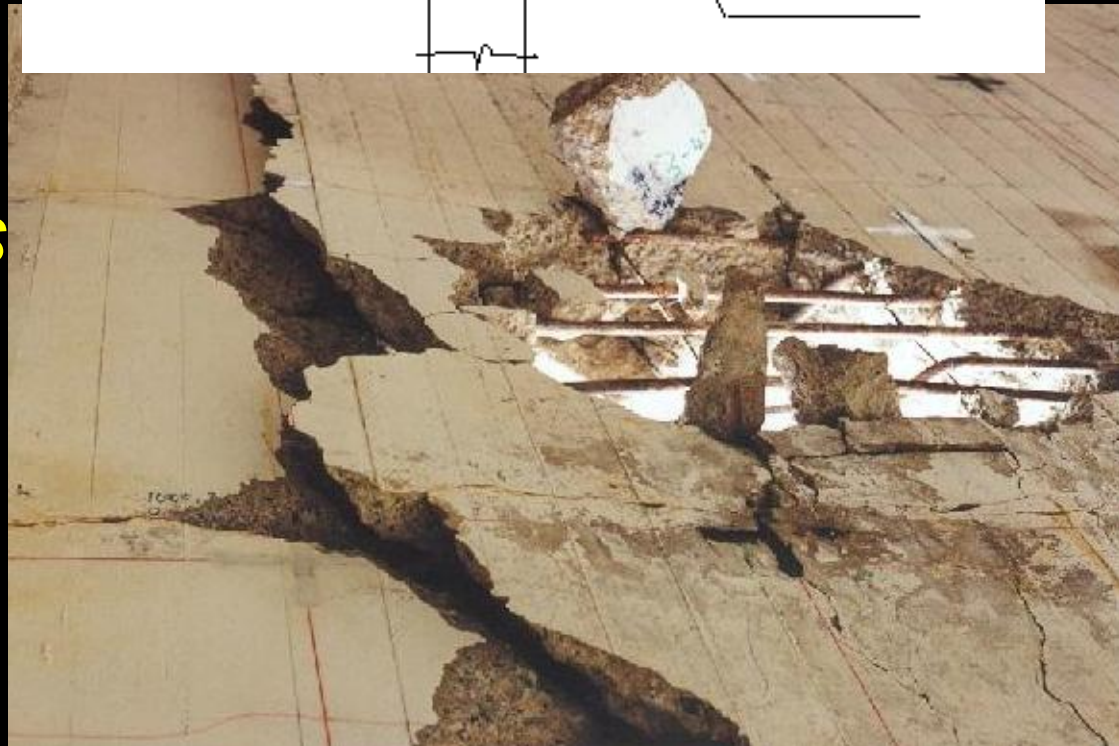
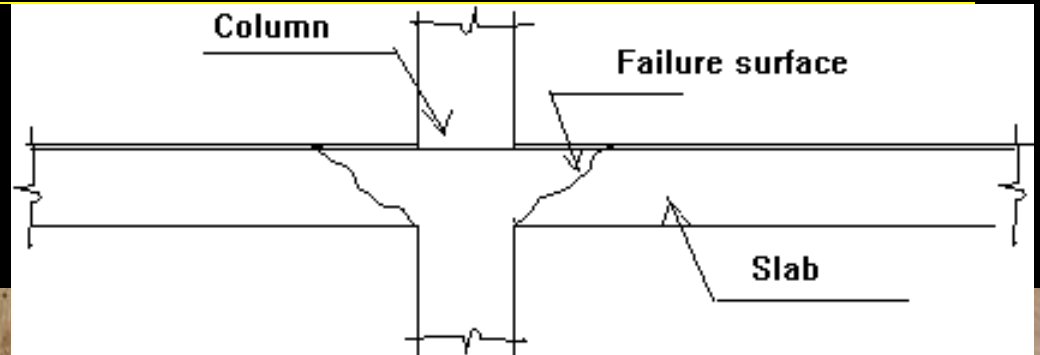


Span ratio	Slab Moments	End Span			Interior Span	
		1 Exterior Negative	2 Positive	3 First Interior Negative	4 Positive	5 Interior Negative
$l_2/l_1$	Total Moment	$0.16 M_o$	$0.57 M_o$	$0.70 M_o$	$0.35 M_o$	$0.65 M_o$
0.5	Column Strip	$0.12 M_o$	$0.43 M_o$	$0.54 M_o$	$0.27 M_o$	$0.50 M_o$
	Beam	$0.02 M_o$	$0.08 M_o$	$0.09 M_o$	$0.05 M_o$	$0.09 M_o$
	Slab					
1.0	Middle Strip	$0.02 M_o$	$0.06 M_o$	$0.07 M_o$	$0.03 M_o$	$0.06 M_o$
	Column Strip	$0.10 M_o$	$0.37 M_o$	$0.45 M_o$	$0.22 M_o$	$0.42 M_o$
	Beam	$0.02 M_o$	$0.06 M_o$	$0.08 M_o$	$0.04 M_o$	$0.07 M_o$
2.0	Slab					
	Middle Strip	$0.04 M_o$	$0.14 M_o$	$0.17 M_o$	$0.09 M_o$	$0.16 M_o$
	Column Strip	$0.06 M_o$	$0.22 M_o$	$0.27 M_o$	$0.14 M_o$	$0.25 M_o$
	Beam	$0.01 M_o$	$0.04 M_o$	$0.05 M_o$	$0.02 M_o$	$0.04 M_o$
	Slab					
	Middle Strip	$0.09 M_o$	$0.31 M_o$	$0.38 M_o$	$0.19 M_o$	$0.36 M_o$

- Notes:
- (1) Beams and slab satisfy stiffness criteria:  $\alpha_1 l_2/l_1 \geq 1.0$  and  $\beta_t \geq 2.5$ .
  - (2) Interpolate between values shown for different  $l_2/l_1$  ratios.
  - (3) All negative moments are at face of support.
  - (4) Concentrated loads applied directly to beams must be accounted for separately.

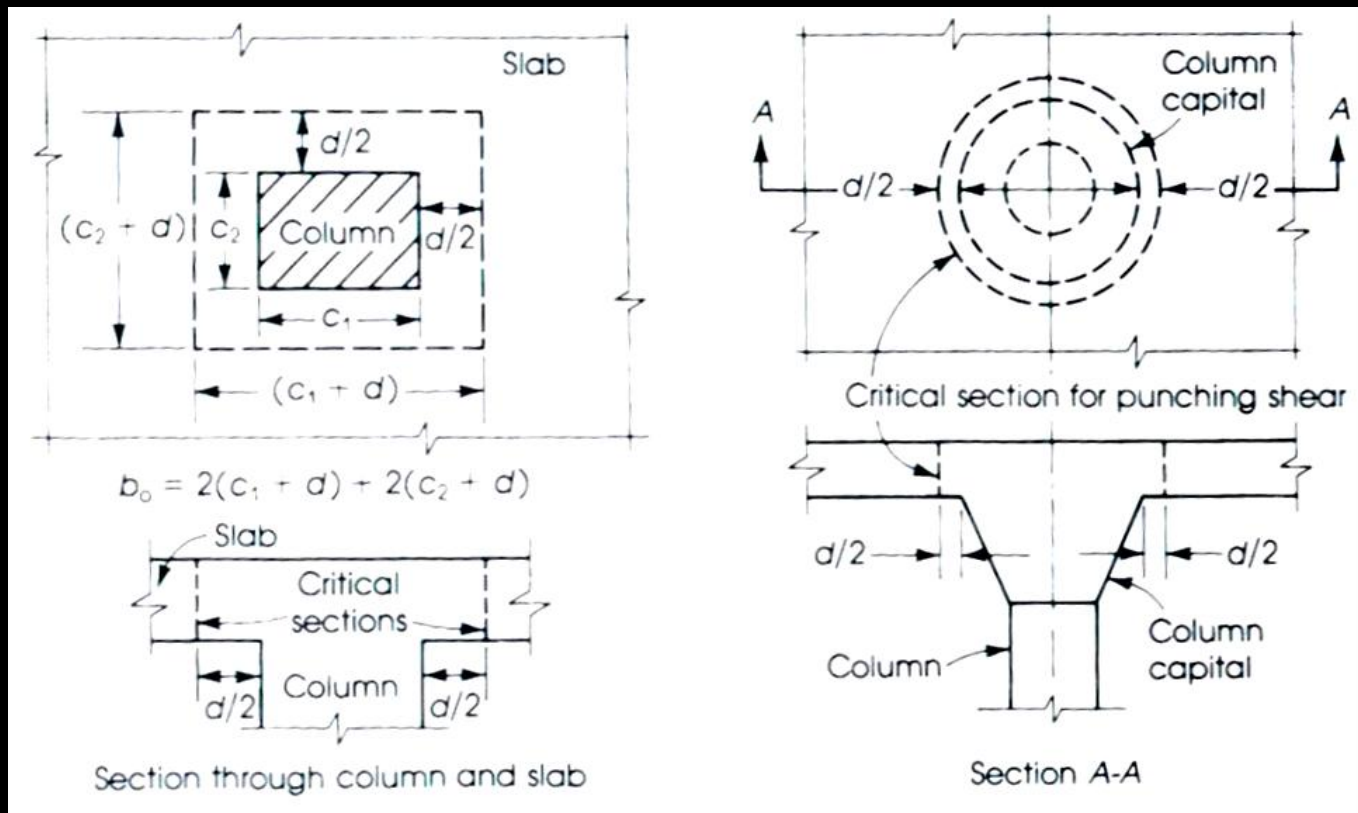
# Shear in Concrete

- *at columns*
- *want to avoid stirrups*
- *can use shear studs or heads*



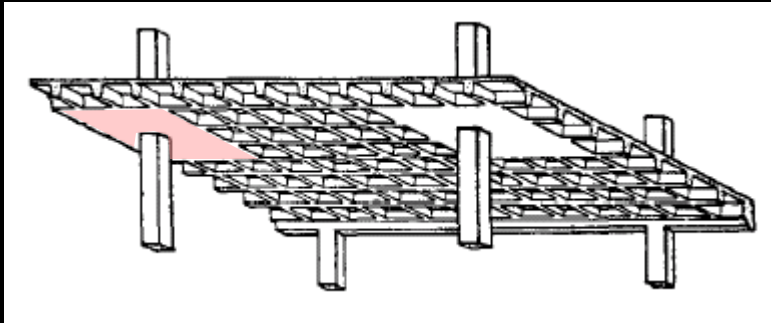
# Shear in Concrete

- critical section at  $d/2$  from
  - column face, column capital or drop panel



# Shear in Concrete

- *at columns with waffle slabs*



# Openings in Slabs

- careful placement of holes
- shear strength reduced
- bending & deflection can increase

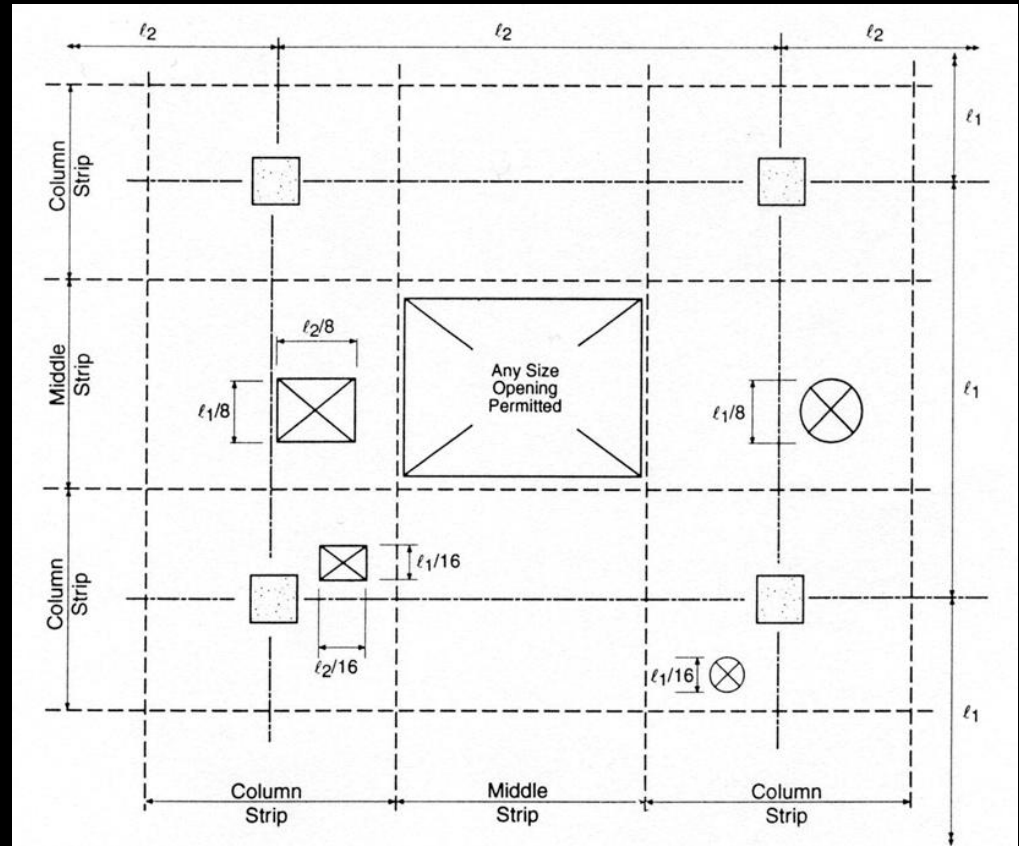
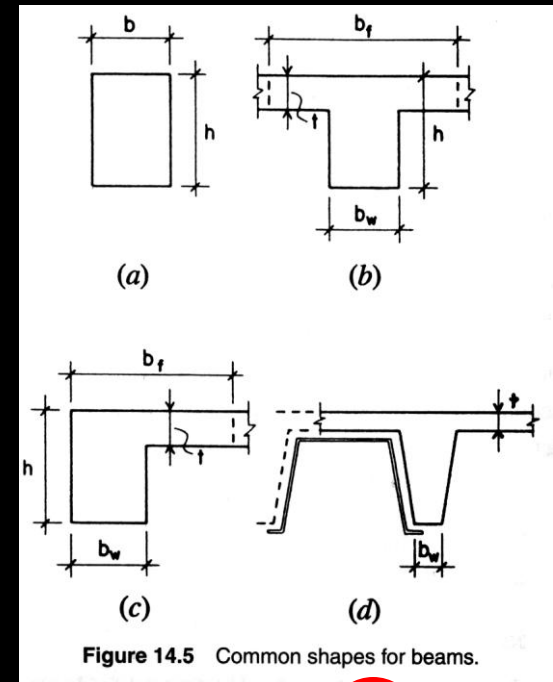


Figure 18-11 Openings in Slab Systems without Beams

# General Beam Design

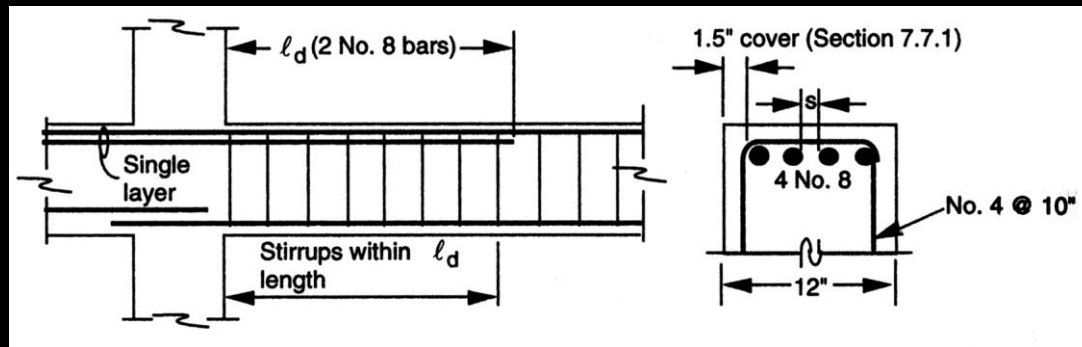
- $f'_c$  &  $f_y$  needed
- usually size just  $b$  &  $h$ 
  - even inches typical (forms)
  - similar joist to beam depth
  - $b:h$  of 1:1.5-1:2.5
  - $b_w$  &  $b_f$  for T
  - to fit reinforcement + stirrups
- slab design,  $t$ 
  - deflection control & shear



$$S = \frac{bh^2}{6}$$

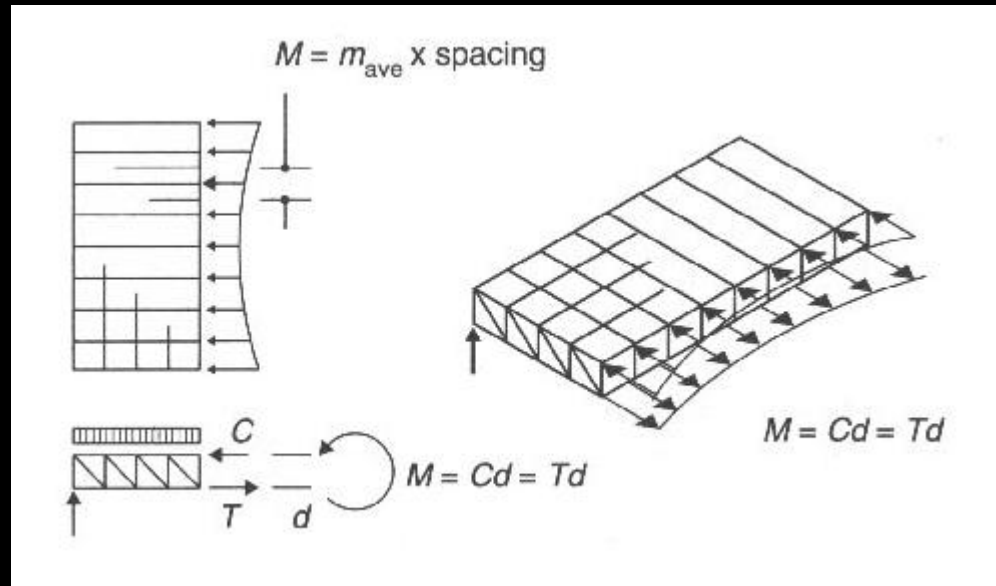
# General Beam Design (cont'd)

- *custom design:*
  - *longitudinal steel*
  - *shear reinforcement*
  - *detailing*



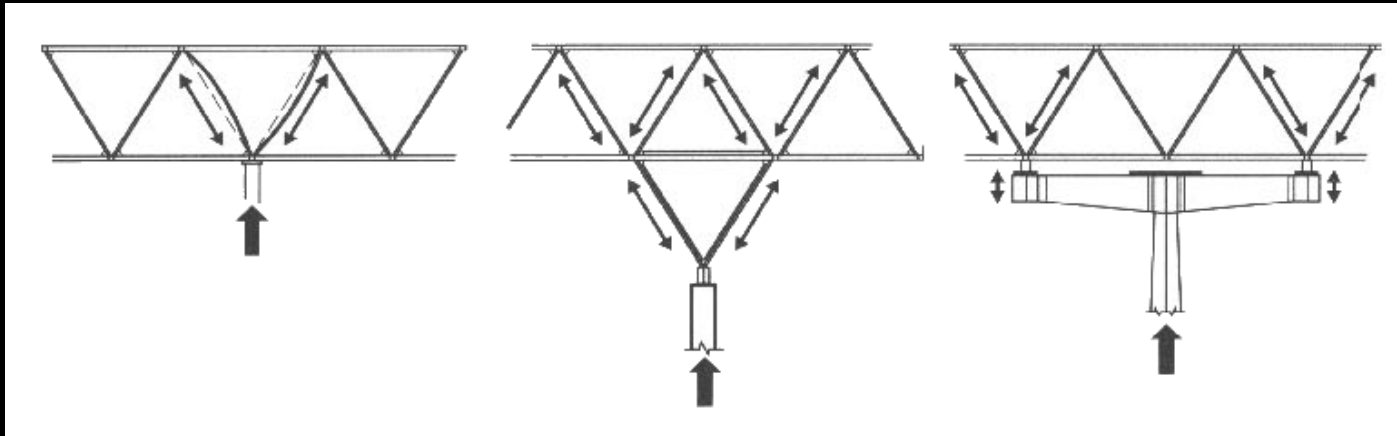
# Space “Frame” Behavior

- *handle uniformly distributed loads well*
- *bending moment*
  - *tension & compression “couple” with depth*
  - *member sizes can vary, but difficult*



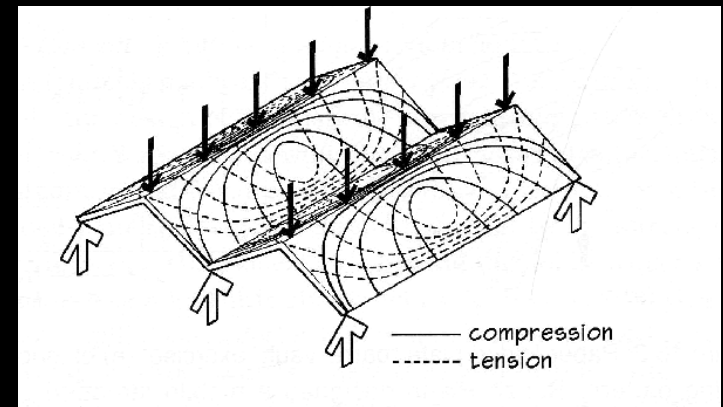
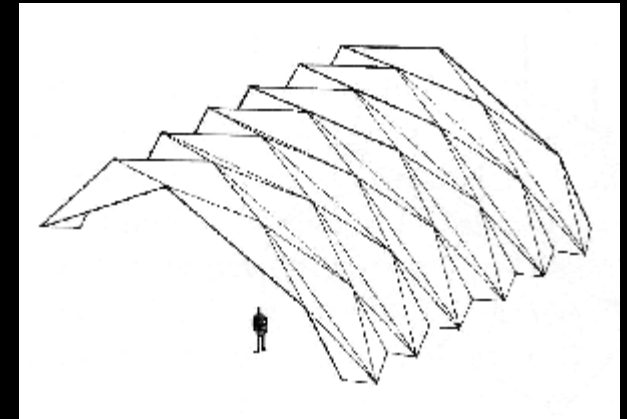
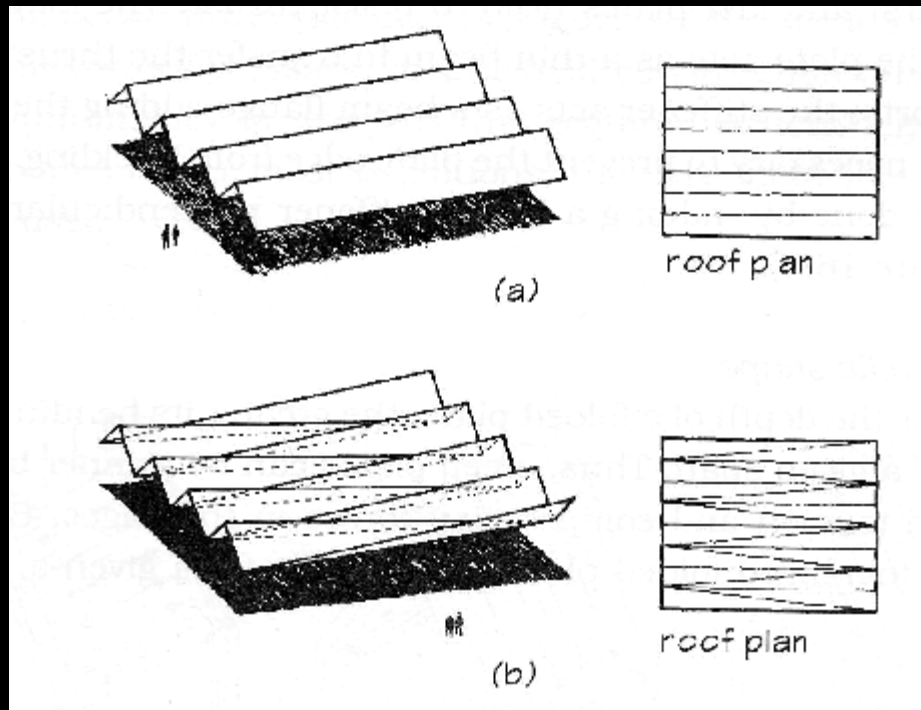
# Space “Frame” Behavior

- *shear at columns*
- *support conditions still important*
  - *point supports not optimal*
- *fabrication/construction can dominate design*



# Folded Plates

- *increased bending stiffness with folding*
- *lateral buckling avoided*



# *Folded Plates*

- *common for roofs*
- *edges need stiffening*

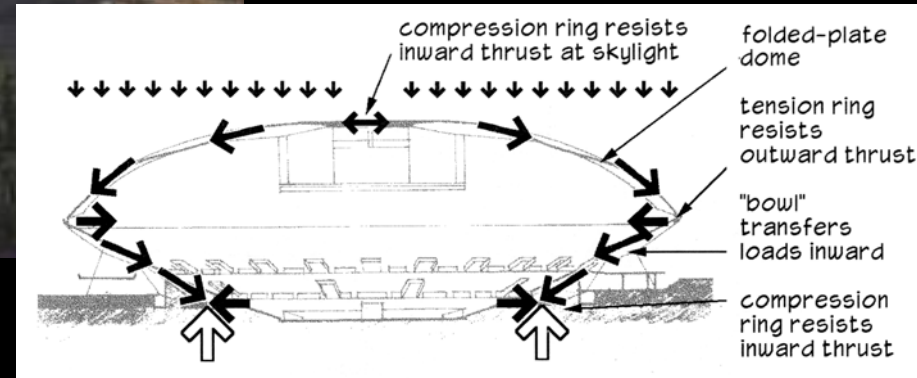


[http:// nisee.berkeley.edu/godden](http://nisee.berkeley.edu/godden)

# Folded Plates



[www.library.illinois.edu](http://www.library.illinois.edu)



- *Assembly Hall, University of Illinois*
- *Harrison & Abramovitz 1963*
- *Edge-supported dome spanning 400 feet wound with 614 miles of one-fifth inch steel wire*