ARCHITECTURAL STRUCTURES:
FORM, BEHAVIOR, AND DESIGN
ARCH 331
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FALL 2018

lecture
twenty five

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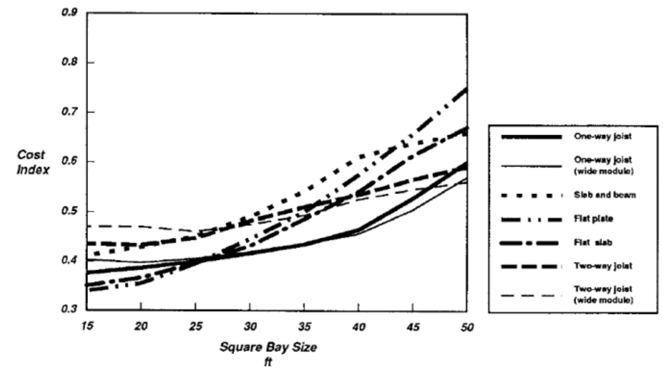
concrete construction:
flat spanning systems

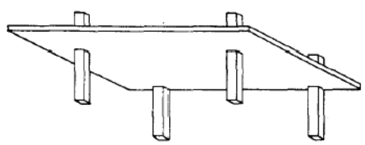
Reinforced Concrete Design

- economical & common
- resist lateral loads

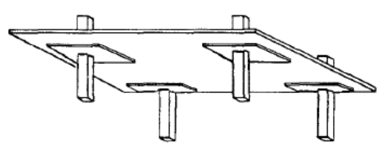


Reinforced Concrete Design

- flat plate
  - 5”-10” thick
  - simple formwork
  - lower story heights

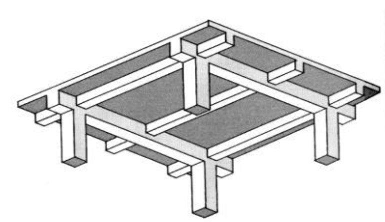


- flat slab
  - same as plate
  - 2 ¼”–8” drop panels



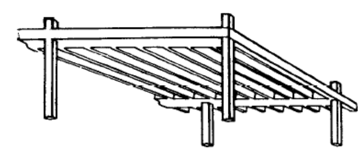
Reinforced Concrete Design

- beam supported
  - slab depth ~ L/20
  - 8”–60” deep



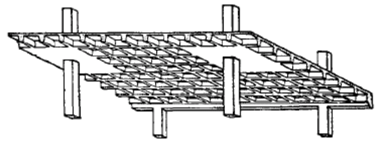
The Architect’s Studio Companion

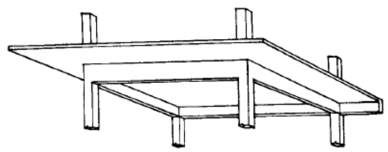
- one-way joists
  - 3”–5” slab
  - 8”–20” stems
  - 5”-7” webs



Reinforced Concrete Design

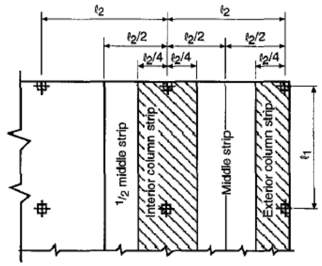
- two-way joist
  - “waffle slab”
  - 3”-5” slab
  - 8”-24” stems
  - 6”-8” webs
- beam supported slab
  - 5”-10” slabs
  - taller story heights



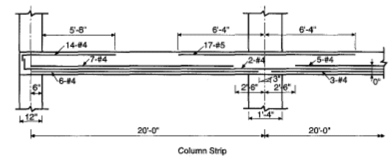


Reinforced Concrete Design

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



(a) Column strip for $\ell_2 \leq \ell_1$



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 $L/D \leq 3$
  - ℓ_n is clear span (+M) or average of adjacent clear spans (-M)

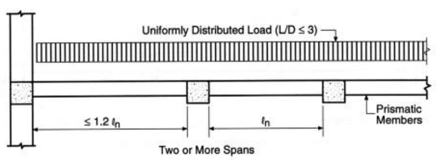


Figure 2-2 Conditions for Analysis by Coefficients (ACI 8.3.3)

Reinforced Concrete Design

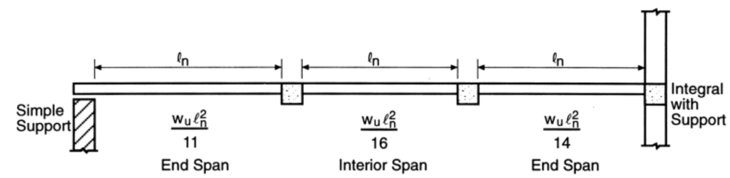


Figure 2-3 Positive Moments—All Cases

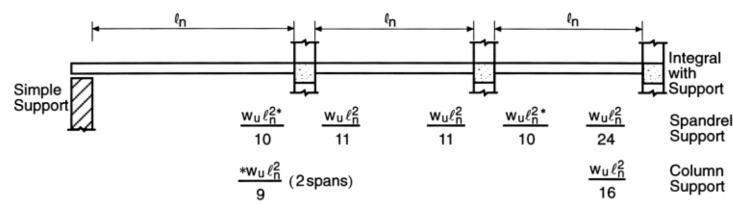
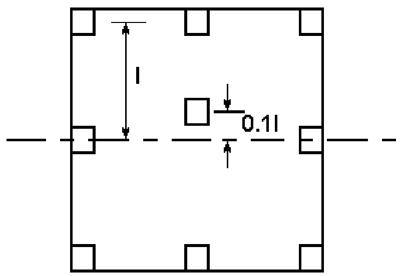


Figure 2-4 Negative Moments—Beams and Slabs

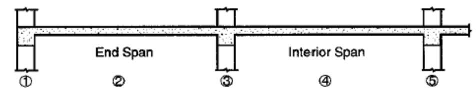
Reinforced Concrete Design

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



Reinforced Concrete Design

Table 4-6 Two-Way Beam-Supported Slab

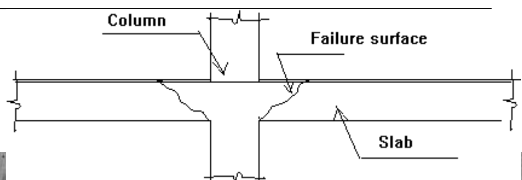


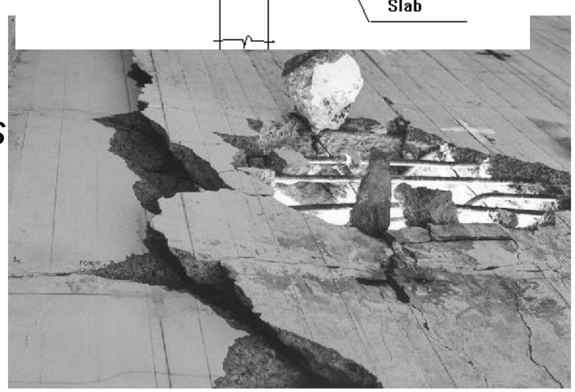
Span ratio	Slab Moments	End Span: 1 Exterior Negative	End Span: 2 Positive	End Span: 3 First Interior Negative	Interior Span: 4 Positive	Interior Span: 5 Interior Negative
ℓ_2/ℓ_1	Total Moment	0.16 M_o	0.57 M_o	0.70 M_o	0.35 M_o	0.65 M_o
0.5	Column Strip Beam	0.12 M_o	0.43 M_o	0.54 M_o	0.27 M_o	0.50 M_o
	Column Strip Slab	0.02 M_o	0.08 M_o	0.09 M_o	0.05 M_o	0.09 M_o
	Middle Strip	0.02 M_o	0.06 M_o	0.07 M_o	0.03 M_o	0.06 M_o
1.0	Column Strip Beam	0.10 M_o	0.37 M_o	0.45 M_o	0.22 M_o	0.42 M_o
	Column Strip Slab	0.02 M_o	0.06 M_o	0.08 M_o	0.04 M_o	0.07 M_o
	Middle Strip	0.04 M_o	0.14 M_o	0.17 M_o	0.09 M_o	0.16 M_o
2.0	Column Strip Beam	0.06 M_o	0.22 M_o	0.27 M_o	0.14 M_o	0.25 M_o
	Column Strip Slab	0.01 M_o	0.04 M_o	0.05 M_o	0.02 M_o	0.04 M_o
	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: $\alpha_1\ell_2/\ell_1 \geq 1.0$ 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

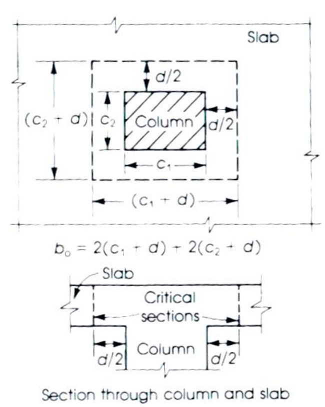
- at columns
- want to avoid stirrups
- can use shear studs or heads

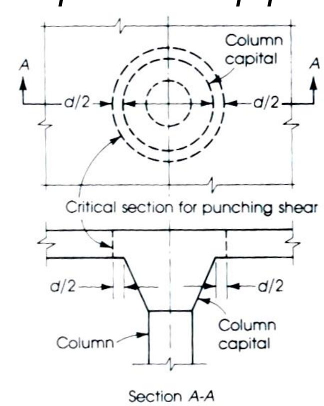




Shear in Concrete

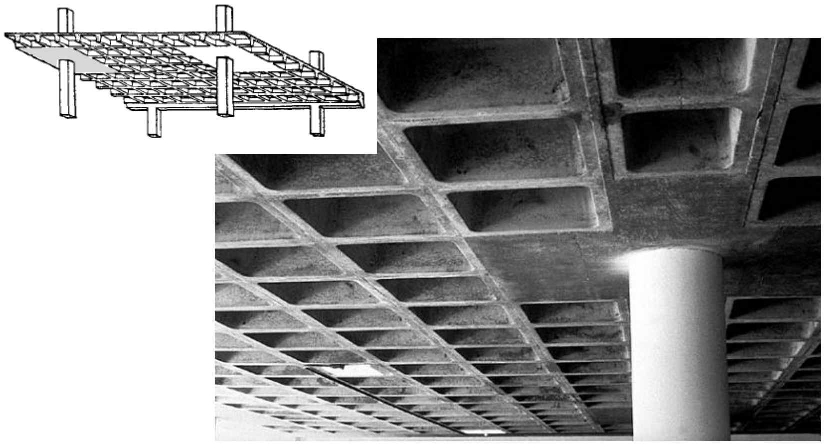
- critical section at d/2 from
  - column face, column capital or drop panel





Shear in Concrete

- at columns with waffle slabs



Openings in Slabs

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

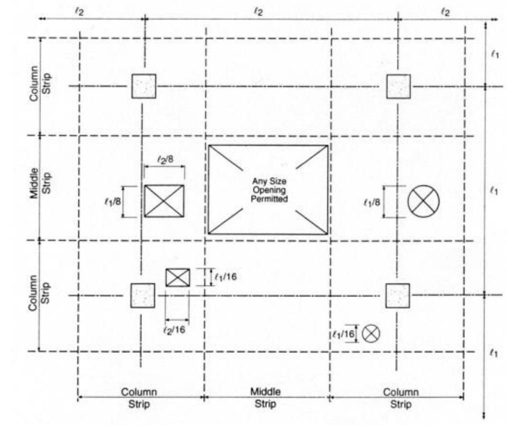


Figure 18-11 Openings in Slab Systems without Beams

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

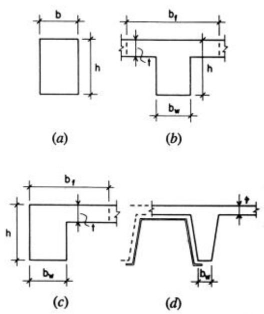
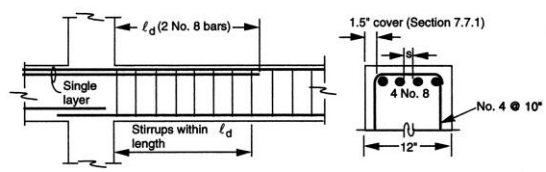


Figure 14.5 Common shapes for beams.

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

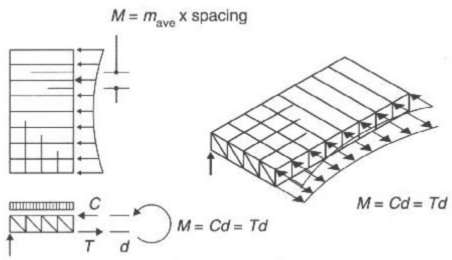
General Beam Design (cont'd)

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



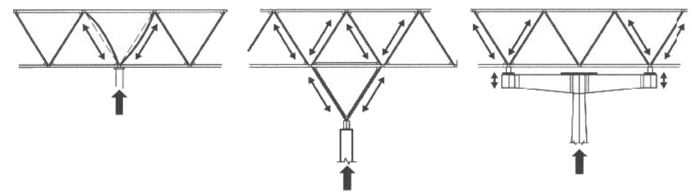
Space "Frame" Behavior

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



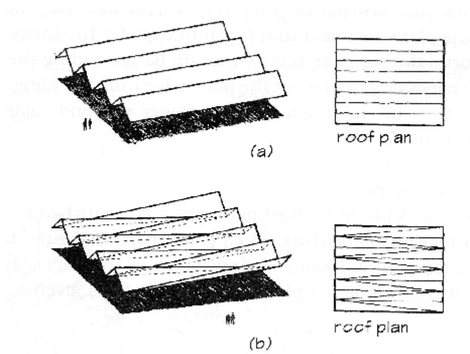
Space "Frame" Behavior

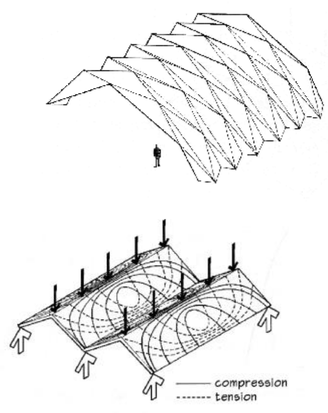
- *shear at columns*
- *support conditions still important*
  - *point supports not optimal*
- *fabrication/construction can dominate design*



Folded Plates

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





Folded Plates

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

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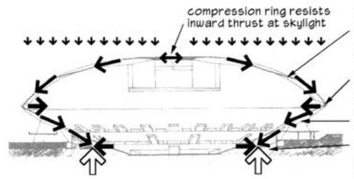
Folded Plates



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