concrete construction: flat spanning systems

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

- economical & common
- resist lateral loads

Reinforced Concrete Design

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

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

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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

Reinforced Concrete Design

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

Shear in Concrete

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

Reinforced Concrete Design

Table 4-6 Two-Way Beam-Supported Slab

<table>
<thead>
<tr>
<th>Span ratio</th>
<th>Slab Moments</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9</td>
<td>0.91 M₀ 0.37 Mₚ 0.35 M₀</td>
<td>0.45 Mₚ 0.37 M₀</td>
<td>0.61 Mₚ 0.37 M₀</td>
<td>0.65 M₀ 0.36 Mₚ</td>
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<tr>
<td>1.0</td>
<td>0.92 M₀ 0.36 Mₚ 0.36 M₀</td>
<td>0.37 M₀ 0.37 Mₚ</td>
<td>0.60 Mₚ 0.36 M₀</td>
<td>0.61 M₀ 0.36 M₀</td>
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<tr>
<td>2.0</td>
<td>0.96 M₀ 0.36 Mₚ 0.36 M₀</td>
<td>0.25 M₀ 0.25 Mₚ</td>
<td>0.27 M₀ 0.27 Mₚ</td>
<td>0.14 M₀ 0.14 Mₚ</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1. Beams and slab stiffness coefficients: ay/h ≥ 1.0 and f₀ ≥ 2 ft.
2. Interpolate between values shown for different ay/h 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

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

- at columns with waffle slabs

Openings in Slabs

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

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
Concrete Spans
Lecture 25
Foundations Structures
ARCH 331
F2008abn

Space “Frame” Behavior

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

• 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

• common for roofs
• edges need stiffening

http://nisee.berkeley.edu/godden
Folded Plates

- 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