concrete construction: flat spanning systems

Reinforced Concrete Design

- 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 ~ L/20
  - 8”–60” deep

- 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

**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

- 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>
<thead>
<tr>
<th>Table 4-6 Two-Way Beam-Supported Slab</th>
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<tbody>
<tr>
<td><strong>Span</strong></td>
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<tr>
<td><strong>Total Moment</strong></td>
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<tr>
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<td>1.0</td>
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<td>2.0</td>
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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

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
  – $b_w$ & $b_r$ for $T$
  – to fit reinforcement + stirrups
• slab design, $t$
  – deflection control & shear

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

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
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