ARCHITECTURAL STRUCTURES: FORM, BEHAVIOR, AND DESIGN
ARCH 331
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SPRING 2015

lecture twenty three

concrete construction: T-beams & slabs
Systems

- beams separate from slab
- beams integral with slab
  - close spaced
- continuous beams
- no beams
T sections

- two areas of compression in moment possible
- one-way joists
- effective flange width
**T sections**

- **negative bending:** min $A_s$, larger of:

$$A_s = \frac{6\sqrt{f'_c}}{f_y} (b_w d)$$

$$A_s = \frac{3\sqrt{f'_c}}{f_y} (b_f d)$$

- **effective width (interior)**
  - $L/4$
  - $b_w + 16t$
  - center-to-center of beams
T sections

- usual analysis steps
  1. assume no compression in web
  2. design like a rectangular beam
  3. needs reinforcement in slab too
  4. also analyze for negative moment, if any

\[ a = \beta_1 x \]

![Diagram of T section beam](image-url)
One-Way

- **Joists**
  - standard stems
  - 2.5” to 4.5” slab
  - ~30” widths
  - reusable forms

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**FLANGEforms**

FLANGEforms are available in standard 2- and 3-foot modules. These forms are among the most popular because of their flexibility to accommodate various layouts and joist widths where required. They are efficient for projects with heavy superimposed loads and provide a two-hour fire rating by using a 4 1/2-inch hard-rock concrete topping. They are efficient for projects of smaller size and for moderate size projects with irregular layouts or unusual building shapes. They are also efficient for projects where the structure is not required to provide a two-hour fire rating by using 3-inch or 3 1/2-inch top slab.

The varying depths provide flexibility to meet a wide range of spans and loads. Further, they will accommodate in-the-floor raceway electrical and communication distribution systems. Ceco FLANGEforms are capable of producing sound structural concrete, but are incapable of producing tight tolerances and smooth finishes. This form is a segmented steelform and the concrete will have irregular joists, a rough finish, and offsets at both the laps and flanges.

If a higher quality finish is required, you may wish to consider Ceco LONGforms (please see page 6). The additional cost of higher quality forms is often offset by finishing costs. Contact your Ceco representative for assistance.

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**Concrete Quantities/30” Widths**

<table>
<thead>
<tr>
<th>Depth of Steelform</th>
<th>Width of Slab</th>
<th>Cubic ft. of concrete per square foot by skin-thickness*</th>
</tr>
</thead>
<tbody>
<tr>
<td>14&quot;</td>
<td>5”</td>
<td>.408</td>
</tr>
<tr>
<td></td>
<td>6”</td>
<td>.394</td>
</tr>
<tr>
<td></td>
<td>7”</td>
<td>.379</td>
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</table>

* Apply only for areas over FLANGEforms and joints between them. Bridging, joints, special headers, beam toes, etc., not included. 10” and 12” depths are also available. Contact your Ceco Concrete Construction Engineer.

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**Concrete Quantities/20” Widths**

<table>
<thead>
<tr>
<th>Depth of Steelform</th>
<th>Width of Slab</th>
<th>Cubic ft. of concrete per square foot for various skin thicknesses*</th>
</tr>
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<tr>
<td>14&quot;</td>
<td>5”</td>
<td>.616</td>
</tr>
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<td>6”</td>
<td>.605</td>
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<td></td>
<td>7”</td>
<td>.590</td>
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</tbody>
</table>

* Apply only for areas over FLANGEforms and joints between them. Bridging, joints, special headers, beam toes, etc., not included. 10” and 12” depths are also available. Contact your Ceco Concrete Construction Engineer.

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**Voids Created by Various Size FLANGEforms**

Shaded areas below indicate standard fill sizes

<table>
<thead>
<tr>
<th>Depth of Steelform</th>
<th>Cubic ft. of void created per linear foot by width of flange (inch)</th>
<th>Vaulted Cft. of Concrete pre Tapered Condition</th>
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<tbody>
<tr>
<td>10”</td>
<td>3.823</td>
<td>.802</td>
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<td>12”</td>
<td>2.614</td>
<td>1.185</td>
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<td>14”</td>
<td>2.608</td>
<td>1.195</td>
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<td>16”</td>
<td>3.183</td>
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<td>20”</td>
<td>3.853</td>
<td>1.610</td>
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<tr>
<td>24”</td>
<td>4.867</td>
<td>3.000</td>
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</table>

**Dimensions**

- SLOPE 1” in 12
- SLOPE 1” in 12
- SLOPE 1” in 12
- FILLER SIZES

**Total void width**

- From 30” to 25” or 20” to 16” in
One-Way

- Joists
  - wide pans
  - 5’, 6’ up
  - light loads & long spans
  - one-leg stirrups
Compression Reinforcement

- doubly reinforced
- negative bending
- two compression forces
- bigger $M_n$
- control deflection
- increase ductility
- needs ties because of buckling
Compression Reinforcement

- **analysis**
  - $A_s$ & $A_s'$
  - $T = C_c + C_s$
  - $T = A_s f_y$
  - $C_s = A_s' (f_s' - 0.85 f_c')$
  - $C_c = 0.85 f_c' ba$ with $a = \beta_1 x$
  - $f_s'$ not known, so solve for $x$ (n.a.)
  - $f_s' < f_y$?
  - $M_n = T(d-a/2) + C_s(d-d')$
Slabs

- one way behavior – like beams
- two way behavior – more complex
Slab Design

- **one unit wide “strip”**
- **with uniform loads**
  - like “wide” beams
  - moment / unit width
  - uniform curvature
- **with point loads**
  - resisted by stiffness of adjacent strips
  - more curvature in middle
Slab Design

- min thickness by code
- reinforcement
  - bars, welded wire mesh
  - cover
- minimum by steel grade
  - 40-50:
    \[ \rho = \frac{A_s}{bt} = 0.002 \]
  - 60:
    \[ \rho = \frac{A_s}{bt} = 0.0018 \]
One-Way Slabs

• $A_s$ tables
• max spacing
  – $\leq 3(t)$ and 18”
  – $\leq 5(t)$ and 18” – temp & shrinkage steel
• no room for stirrups

<table>
<thead>
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<th>Bar size</th>
<th>Bar spacing (in.)</th>
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<td>#9</td>
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</tr>
<tr>
<td>#10</td>
<td></td>
</tr>
<tr>
<td>#11</td>
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Table 3-7 Areas of Bars per Foot Width of Slab—$A_s$ (in.²/ft)
**Precast**

- **prestressed**
  - PCI Design Handbook
  - double T’s
  - hollow core
  - L’s
- **topping**
- **load tables**

### Table of safe superimposed service load (psf) and cambers (in.)

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<th>( y_{(end)} ) in.</th>
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<th>44</th>
<th>46</th>
<th>50</th>
<th>52</th>
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<th>62</th>
<th>64</th>
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</table>

Key:
- 142 - Safe superimposed service load, psf
- 14 - Estimated camber at erection, in.
- 18 - Estimated long-time camber, in.

\( f_c = 5,000 \text{ psi} \)
\( f_{pu} = 270,000 \text{ psi} \)