Breaking Things is Fun!
Incorporating Structural Testing into a Design Course

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Problems with Reinforced Concrete Design

• Structural concepts difficult to visualize
  – Non-linear behavior
• Many students have never seen structural concrete being constructed
• Students have little or no awareness of:
  – Formwork
  – Rebar installation
  – Tolerances
  – Concrete placement
Reinforced Concrete Beam Project

• “the Midterm”
• Spread over several weeks
• Just-in-time delivery of course material
• Teams of 4 students
• Project Components
  – Design
  – Build
  – Test
  – Report

Reinforced Concrete Beam Design

• Each team has a different set of specifications and constraints
  – Load
  – Max Height
• Design Considerations
  – Flexure
    • Formwork and rebar detailing
  – Shear
  – Development Length
  – Deflection
Typical Beam Elevation

Shear Strength

Shear failure
Flexural capacity
Inclined cracking
Inclined cracking and failure

Shear Span/Depth Ratio
Typical Beam Specs

<table>
<thead>
<tr>
<th>Span ft</th>
<th>Span inches</th>
<th>Shear height to rebar inches</th>
<th>Span to depth inches</th>
<th>Predicted ratio</th>
<th>Failure Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>36</td>
<td>4</td>
<td>3</td>
<td>12.0</td>
<td>Flexure</td>
</tr>
<tr>
<td>6</td>
<td>36</td>
<td>6</td>
<td>4.75</td>
<td>7.6</td>
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<tr>
<td>6</td>
<td>36</td>
<td>8</td>
<td>6.75</td>
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<tr>
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<td>36</td>
<td>10</td>
<td>8.75</td>
<td>4.1</td>
<td>Shear</td>
</tr>
</tbody>
</table>

Typical Beam Cross-Sections
Reinforced Concrete Beam Construction

- Build forms
- Cut and install rebar
- Mix concrete
- Place concrete
- Construct beam
- Cure beam
- Remove beam from forms
Slump Test Results

What Slump Test SHOULD Look Like
Form Repair
Reinforced Concrete Beam Testing

• Determine concrete compressive strength
• Test beam to failure
  – record applied loads and midspan deflections
  – Take pictures
  – Take more pictures
Beam 1

b = 12"
h =  4"
d =  3"
Beam 4

b = 5.5"
h = 10.0"
d = 8.8"

Beam 4

b = 5.5"
h = 10.0"
d = 8.8"
**Beam 3**

- $b = 6.0''$
- $h = 8.0''$
- $d = 6.9''$

**Beam 3 (different year)**

- $b = 6.0''$
- $h = 8.0''$
- $d = 6.9''$
Beam 2 (different year)

\[ b = 8.0" \]
\[ h = 6.0" \]
\[ d = 5.0" \]
Reinforced Concrete Beam Report

- Determine if capacity was controlled by Shear, Flexural, or reinforcement.

- Plot measured and predicted Load Vs. Deflection information

- Compare results to predictions
Summary

• Student comments usually mention this project

• Have done this project in classes with over to 50 students