Purdue Geotechnical Society Workshop and 4th Leonards Lecture

CONSTRUCTION FAILURE OR FLAW, THE ROLE OF ENGINEERING JUDGEMENT IN DECISION MAKING

Presented by:
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Geotechnical Engineering Top 10

1. You are more likely to own “Holtz and Kovacs” than “Dolce & Gabbana
2. You want to name your kids Sandy, Clay, and Peat
3. You want to put your dog house on piles
4. You care about the difference between “dirt” and “soil”
5. You are willing to work on dam problems for days on end
6. Your vacation photos always include retaining walls and slope failures
7. You know that SPT doesn’t stand for Stupid Penetration Test
8. You build sand castles with seaweed tiebacks
9. You recommend boring plans to your client as part of your job
10. You put the word ”Geo” in front of everything
Workshop Theme: *Coping with Disasters Large and Small*
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Presentation Outline

• Background – set the stage!
• Medley of example projects
• Practice area needs
Presentation Outline

• Background – set the stage!

• Medley of example projects

• Practice area needs
Over all, the group found that the 17th Street Canal floodwall “appears to reflect an overall pattern of engineering judgment inconsistent with that required for critical structures.”
Where does engineering judgment come from?

Good judgment comes from Experience

Experience comes from Bad judgment
Where does engineering judgment come from?
Where does engineering judgment come from?
When I hear the words “engineering judgment,” I know they are just going to make up numbers. (Feynman, 1993)
Background

The Code of Hammurabi:

- If a builder build a house for some one, and does not construct it properly, and the house which he built fall in and kill its owner, then that builder shall be put to death.
  - If it kill the son of the owner the son of that builder shall be put to death.
  - If it kill a slave of the owner, then he shall pay slave for slave to the owner of the house.
  - If it ruin goods, he shall make compensation for all that has been ruined, and inasmuch as he did not construct properly this house which he built and it fell, he shall re-erect the house from his own means.
- If a builder build a house for some one, even though he has not yet completed it; if then the walls seem toppling, the builder must make the walls solid from his own means.
Background

Metro construction site collapse

- Lijia Station on Metro line 3
- TBM excavation
- Heavy rainfall

Guangzhou capital of Guangdong Province
Background

Maumee River Crossing

- Single pylon cable stayed bridge
- Tower height ≈ 380 ft
- Foundations: Drilled shafts
  - 256
  - Diameter 7-8 ft.
- Construction ≈ $220 mil

At 15%, foundation costs are ≈ $33 million
Background

Systems perspective

- Quality assurance
- Quality control
- Planning
- Design
- Construction
- Observation

CONSTRUCTED SYSTEM
Presentation Outline

• Background – set the stage!

• Medley of example projects

• Practice area needs
Perry Street Crossing

Foundation system: Drilled shafts
- Diameter: 72 inches
- Length: 35 feet
- Unconfined comp. strength: 4,500 psi
- Reinforcing steel: 60 ksi
- Integrity testing: Cross hole sonic logging
Cross hole sonic logging

Integrity testing:
- In accordance with ASTM 6760
- Defect analysis and impact
- Foundation design
- Inspection
- Construction engineering
- Mitigation planning and design
Cross hole sonic logging
Perry Street Crossing

**Figure A-0**

- **Tube Spacing**: 20.00 inches
- **Input Data**: 200
- **Threshold**: 1.50
- **At Depth of**: 30.00 ft
- **Voltage**: 1400 VAC
- **First Arrival Time**: 174 sec
- **Signal Range**: 500 mV

- **Shelf Name**: 44
- **Depth Range**: 2 - 6
- **Number of Tubes**: 6
- **Tube Spacing**: 60.5 inches
Maumee River Crossing

Foundation system: Drilled shafts
- Diameter: 7-8 ft.
- Length: 100 ft.
- Number: 256
- Unconfined comp. strength: 5000 psi
- Integrity testing: Cross hole sonic logging
Maumee River Crossing
Maumee River Crossing
Research: Defect and acceptance criteria

- Soft Soil
  Load = 860 kN
  No Capacity Reduction

- Medium Stiff Soil
  Load = 2960 kN
  9% Capacity Reduction

- Very Stiff Soil
  Load = 3030 kN
  53% Capacity Reduction
Example project: “Traditional Geotech”

- Existing Casino 48,000 sq. ft.
- Expansion includes:
  - 23,360 sq. ft. of New Construction
  - 6-Story Cast-in-Place Concrete Hotel
  - 60,000 Gallon Water Tank
  - Grading/Landscaping/Parking
Example project: “Traditional Geotech”

- Fill
- SP & SM-SM Liquefiable Sand (Improved with Stone Columns)
- SP & SP-SM Liquefiable Sand
- CL; Soft Clay
- CL; Very Soft to Med Stiff Clay
- CL; Very Soft to Med Stiff Clay
- CL; Med Stiff to Stiff Clay
- CL; Very Stiff to Hard Clay

Existing Casino

60’ 100’
Example project: “Traditional Geotech”

Recommendations to owner

• Expect settlement 18 to 24 inches of

• Expect settlement to take 20 years

• Install stone columns to a depth of 35 ft.

• Foundations:
  • Deep piles
  • Compensating foundation

• Build somewhere else
Example project: “Traditional Geotech”

- At least three episodes of previous grading
- Fill thickness varies from 0 to 10 feet
- No settlement monitoring performed following mass grading

This Project

- Grey contour lines Phase I grading
- Pink Contour lines Phase II grading
- Orange contour lines Phase III Grading
Example project: “Traditional Geotech”

- Developed a judgment based soil profile
- Selected reasonable soil properties based on available lab test results
- Refine selected soil properties to “predict” previously observed settlement thereby verifying FEM Model.
- Compare results with tolerable settlement performance criteria.
- Refine as required
Example project: “Traditional Geotech”

- Past fill
- Consolidation
- Stone columns

- Drains
- Fill
- Consolidation
## Example project: “Traditional Geotech”

<table>
<thead>
<tr>
<th>Phase</th>
<th>Phase No.</th>
<th>Start phase</th>
<th>Calculation type</th>
<th>Load input</th>
<th>Time (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial phase</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Casino stone columns</td>
<td>1</td>
<td>0</td>
<td>Consolidation</td>
<td>Staged Construction</td>
<td>25</td>
</tr>
<tr>
<td>Phase1 and 2 fill</td>
<td>2</td>
<td>1</td>
<td>Consolidation</td>
<td>Staged Construction</td>
<td>25</td>
</tr>
<tr>
<td>Wait 90 days</td>
<td>3</td>
<td>2</td>
<td>Consolidation</td>
<td>Staged Construction</td>
<td>90</td>
</tr>
<tr>
<td>Casino load</td>
<td>4</td>
<td>3</td>
<td>Consolidation</td>
<td>Staged Construction</td>
<td>90</td>
</tr>
<tr>
<td>Wait 1000 days</td>
<td>5</td>
<td>4</td>
<td>Consolidation</td>
<td>Staged Construction</td>
<td>1000</td>
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<tr>
<td>Hotel stone columns and wicks</td>
<td>6</td>
<td>5</td>
<td>Consolidation</td>
<td>Staged Construction</td>
<td>60</td>
</tr>
<tr>
<td>Preload 60 days</td>
<td>7</td>
<td>6</td>
<td>Consolidation</td>
<td>Staged Construction</td>
<td>60</td>
</tr>
<tr>
<td>Preload additional 120 days</td>
<td>8</td>
<td>7</td>
<td>Consolidation</td>
<td>Staged Construction</td>
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<tr>
<td>Switch soil properties</td>
<td>9</td>
<td>8</td>
<td>Consolidation</td>
<td>Staged Construction</td>
<td>2</td>
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<tr>
<td>Remove preload</td>
<td>10</td>
<td>9</td>
<td>Consolidation</td>
<td>Staged Construction</td>
<td>21</td>
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<tr>
<td>Excav, add hotel load, no expansion</td>
<td>11</td>
<td>10</td>
<td>Consolidation</td>
<td>Staged Construction</td>
<td>180</td>
</tr>
<tr>
<td>Final consolidation</td>
<td>12</td>
<td>11</td>
<td>Consolidation</td>
<td>Minimum pore pressure</td>
<td>53</td>
</tr>
</tbody>
</table>
Example project: “Traditional Geotech”
Example project: “Traditional Geotech”
Example project: “Traditional Geotech”

<table>
<thead>
<tr>
<th>Distance from hotel mat foundations</th>
<th>Settlement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Predicted</td>
</tr>
<tr>
<td>30</td>
<td>4.5</td>
</tr>
<tr>
<td>45</td>
<td>2</td>
</tr>
<tr>
<td>60</td>
<td>2</td>
</tr>
<tr>
<td>75</td>
<td>0.25</td>
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<tr>
<td>90</td>
<td>&lt; 0.25</td>
</tr>
<tr>
<td>105</td>
<td>&lt; 0.25</td>
</tr>
</tbody>
</table>
Example project: “Traditional Geotech”
Presentation Outline

- Background – set the stage!
- Medley of example projects
- Practice area needs
Practice area needs

**The Direction of Our Profession**

“Construction deserves more attention in design.” (Peck, 1973)
Practice area needs

Construction focus

Sound transit

Tacoma narrows

Benicia

Tren Urbano
Practice area needs

Construction focus

• Code evolution (LRFD)
• Project delivery systems
  – Traditional – Design/Bid/Build
  – Performance/financial
    • Design build
    • BOOT
    • DBOM
    • PPP
• Performance specifications
Practice area needs

• Implement “hands-on” construction
• Greater emphasis on structural foundation engineering
• Introduce uncertainty and variability into widely used simple models
• Earlier introduction of simple models and numerical analysis to reinforce theory and construction
• Material property estimation
• Regional model needs
• Practitioner training
Practice area needs

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Questions