Evaluating the Effect of Temporary Casing on Rock Socket Resistance

GRIP 2018
Presented by: Gray Mullins, Ph.D., P.E.
Rock Socket Resistance

- Often designed as a function of the parent rock properties and characteristics:
  - Unconfined Compression Strength
  - Split Tensile Strength
  - Recovery
  - RQD
Ultimate Side Resistance

  \[ f_{max} = 0.65 p_a \sqrt{\frac{q_u}{p_a}} \quad \text{and} \quad q_u \leq f'c \]

- Kulhawy et al. (2005) – Basis of FHWA (2010)
  \[ f_{max} = C \times p_a \sqrt{\frac{q_u}{p_a}} \quad \text{and} \quad q_u \leq f'c \quad (C = 0.63 \text{ to } 1.00) \]

  \[ f_{max} = \frac{1}{2} \sqrt{q_u} \sqrt{q_t} \quad \text{and} \quad q_u \leq f'c \]
Construction Effects

_ not addressed by design_

- Excavation Equipment
- Reinforcement Bar Size and Cage Spacing
- Concrete properties
- Cased or Slurry Supported
- Temporary or Permanent Casing
- Vibrated or Oscillated Casing
- Slurry Type
- Slurry Exposure
Problem Statements

- Construction methods affect drilled shaft side shear resistance which is not fully addressed by design.
- The effects from full length or partial length temporary casing can present the same concern.
- The effects of prolonged polymer slurry exposure are not clearly defined in literature.
Objectives

Quantify the effects of temporary casing on rock socket capacity

Quantify the effects of slurry exposure on side shear in wet construction
455-15.7 Casings. Ensure casings are metal . . .

. . . . **If temporary casing is advanced deeper than** the minimum top of rock socket elevation shown in the **Plans** or actual top of rock elevation is deeper, withdraw the casing from the rock socket and overream the shaft. If the temporary casing cannot be withdrawn from the rock socket before final cleaning, **extend the length of rock socket** below the authorized tip elevation one-half of the distance between the minimum top of rock socket elevation or actual elevation if deeper, and the temporary casing tip elevation.
Quantifying the Effects

- How does temporary casing affect the resulting side shear?
- Does concrete flow out and form intimate bond with surrounding rock?
  or
- Do residual fragments of crushed rock remain and get squeezed/trapped between outward flowing concrete?
Research Approach

- Find / create simulated limestone parent material
- Construct rock socketed shafts
- Perform pull out tests
- Evaluate results

- Small scale and full scale test program
Target Limestone Strength

$100\text{psi} - 600\text{psi}$ ($SPT-N < 60$)

- Miami limestone (Saxena, 1982)
- Key Largo limestone (Saxena, 1982)
- Fort Thompson limestone (Saxena, 1982)

Miami limestone typical ranges (Frizzi and Meyer, 2000; Prieto-Portar, 1982)
Fort Thompson limestone typical ranges (Frizzi and Meyer, 2000; Prieto-Portar, 1982)

Unconfined Compression Strength (psi) vs. Porosity
Develop Simulated Limestone (small-scale)

- Target UCS 60 psi – 800 psi
- Porous texture
  - Mixing materials
    - Cement (0-800 pcy)
    - Lime (100-500 pcy)
    - Sand
    - Coquina and Oyster shells (increased porosity)
- Over 200 UCS tests
Cast Test Beds

- 6 simulated limestone beds cast
- 42 in. diameter, 23 in. tall.
- UCS 60-850psi
- Cement Content 170 – 680 pcy (1 – 4 bags)
- Cement / Lime = 1
- w/c 1.6 - 3
Simulated Limestone Beds
Small Scale Tests

![Diagram showing small scale tests with labeled points A, B, C, D, and E, and categories Coarse, Fine, Driven, and Insp.]

![Image of experimental setup with labeled Coarse and Fine.]
Casing Types

Coarse-tooth

Fine-tooth

Driving Shoe

Large annulus

Small annulus

No annulus
<table>
<thead>
<tr>
<th>Bed I.D.</th>
<th>Specimen Position I.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>1 (502.78 psi)</td>
<td>Coarse</td>
</tr>
<tr>
<td>2 (885.02 psi)</td>
<td>Coarse</td>
</tr>
<tr>
<td>3 (487.42 psi)</td>
<td>Coarse</td>
</tr>
<tr>
<td>4 (64.78 psi)</td>
<td>Coarse</td>
</tr>
<tr>
<td>5 (163.40 psi)</td>
<td>Coarse</td>
</tr>
<tr>
<td>6 (685.6 psi)</td>
<td>Coarse</td>
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</table>
Pullout Tests
Results (low strength limestone)

- UCS 65psi

Graph showing the following:
- Side Shear (tsf) on the y-axis
- Displacement (in) on the x-axis

Lines represent:
- Driven Temp
- Driven Inspect
- Fine-Tooth Temp
- Fine-Tooth Inspect
- Coarse-Tooth Temp
Results (higher strength limestone)

UCS 885 psi

Side Shear (tsf) vs. Displacement (in)

- Coarse Control
- Fine
- Driven Control
- Coarse
- Driven

Lines:
- Black: Driven Temp
- Brown: Driven Inspect
- Green: Fine-Tooth Temp
- Red: Coarse-Tooth Temp
- Light Green: Coarse-Tooth Inspect
# Temporary / Control Ratio

<table>
<thead>
<tr>
<th>Bed ID</th>
<th>Casing Type</th>
<th>Ultimate Stress Ratio</th>
<th>Residual Stress Ratio</th>
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<tbody>
<tr>
<td>Bed 1</td>
<td>Driven Casing</td>
<td>0.67</td>
<td>0.49</td>
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<tr>
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<td>Fine-Tooth Casing</td>
<td>0.69</td>
<td>0.54</td>
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<td>Bed 2</td>
<td>Driven Casing</td>
<td>0.65</td>
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<td>Coarse-Tooth Casing</td>
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<td>Bed 3</td>
<td>Driven Casing</td>
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<td>0.59</td>
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<tr>
<td>Bed 4</td>
<td>Driven Casing</td>
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<td>0.66</td>
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<tr>
<td></td>
<td>Fine-Tooth Casing</td>
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<td>Bed 5</td>
<td>Driven Casing</td>
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<td>Coarse-Tooth Casing</td>
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<td>0.61</td>
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<td>Bed 6</td>
<td>Driven Casing</td>
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<tr>
<td></td>
<td>Fine-Tooth Casing</td>
<td>0.81</td>
<td>0.37</td>
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## Small-Scale Average Stress Ratios

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<tr>
<th>Casing Type</th>
<th>Ultimate Stress Ratio</th>
<th>Avg Stress Ratio</th>
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<tbody>
<tr>
<td>Driven</td>
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<tr>
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<tr>
<td>Fine</td>
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<td>0.75</td>
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Full-scale Tests

24in diameter
10ft long rock socket
Cast in Miami
Weathered limestone at surface

Control (no casing)

Temporary casing
Full Scale
Cased/uncased stress ratio = 0.83
Conclusions

- Temporary casing can affect side shear in rock sockets
- Small annulus rotated casing had least effect
- Driven casing with no annulus caused damage making it more affected
- Large annulus casing was most affected.
- Present specification reducing side shear to 50% is reasonable, no specimen fell below that level.