Bottom Side Grouting of Drilled Shafts Prior to Tip Grouting

Civil & Coastal Engineering

FDOT Contract No.: BDK-75-977-46

Project Managers:
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SCOPE

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- Increase Axial Skin and Tip Resistance of Drilled Shafts by Develop Cylindrical & Spherical Cavity Expansion Stresses Alongside and Below Shaft Tip with Side and Subsequent Tip Grouting.
- Tasks:
  - Design Side Grouting System
  - Small Scale Shaft Test to Evaluate Side Grout System
  - Larger Scale Test Shaft (3'x25') FDOT Test Chamber
    - Monitor Soil and Shaft Stresses and Load Transfer
    - Excavate and evaluate side and tip grouting process
  - Test and Excavate Full Scale Test Shaft at Keystone Heights Location
  - Develop Design Approach For Side and Tip Grouted Drilled Shafts

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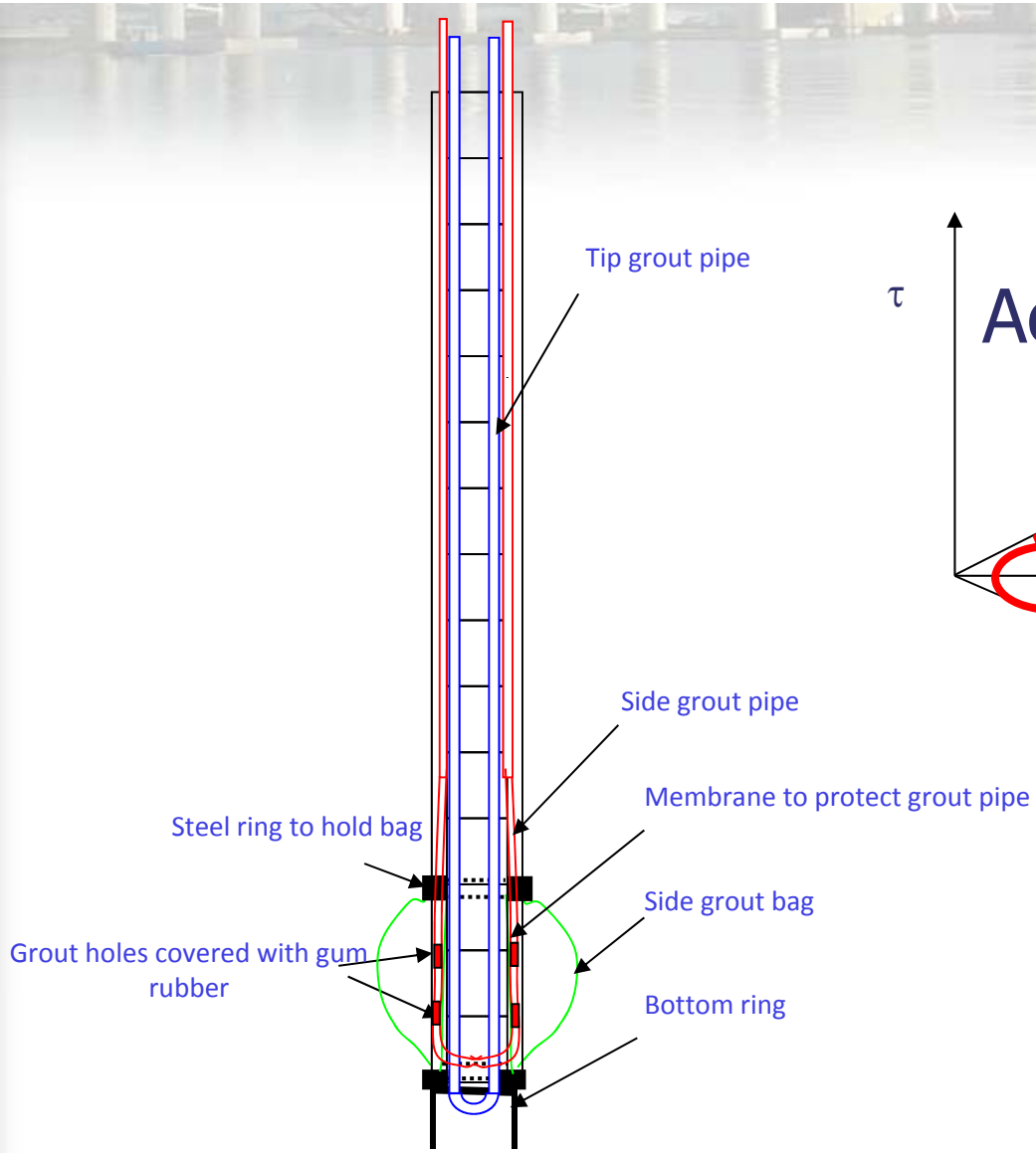
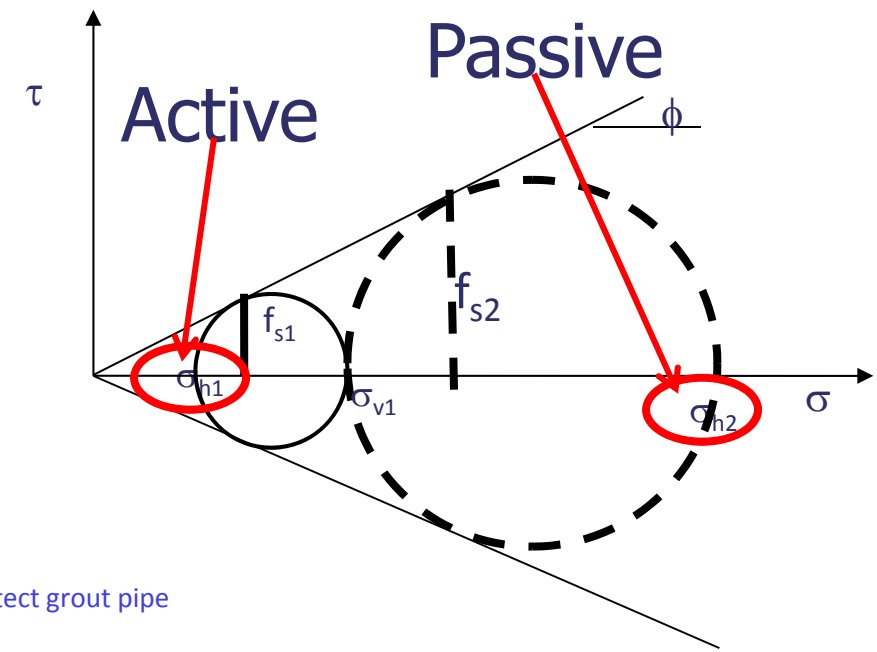
Side Grouting Prior to Tip Grouting





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Tip Grout Flow

No Tip Grout Bulb at Bottom

Tip Grouted Drilled Shafts

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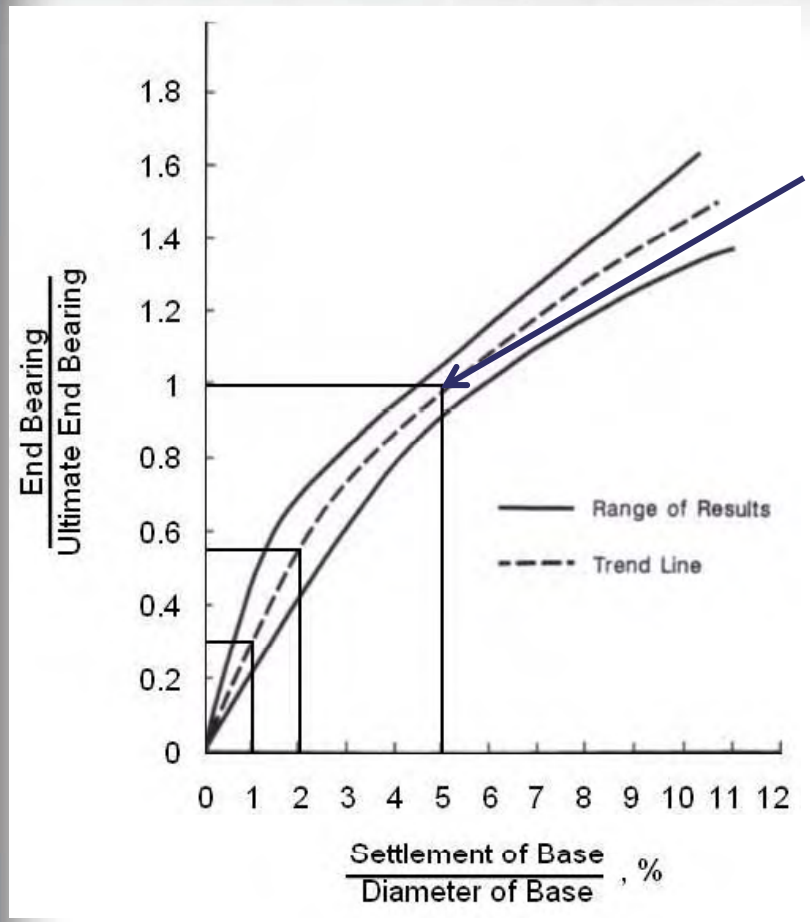
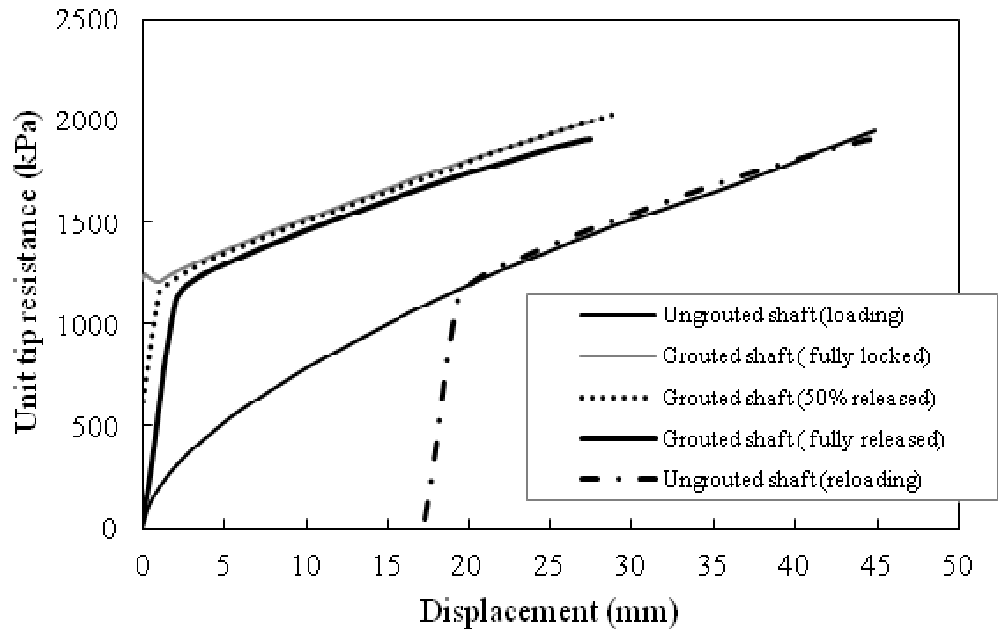
FHWA: Reese – Drilled Shaft Tip Resistance in Sands



q_T = 0.6 x SPT N (tsf)



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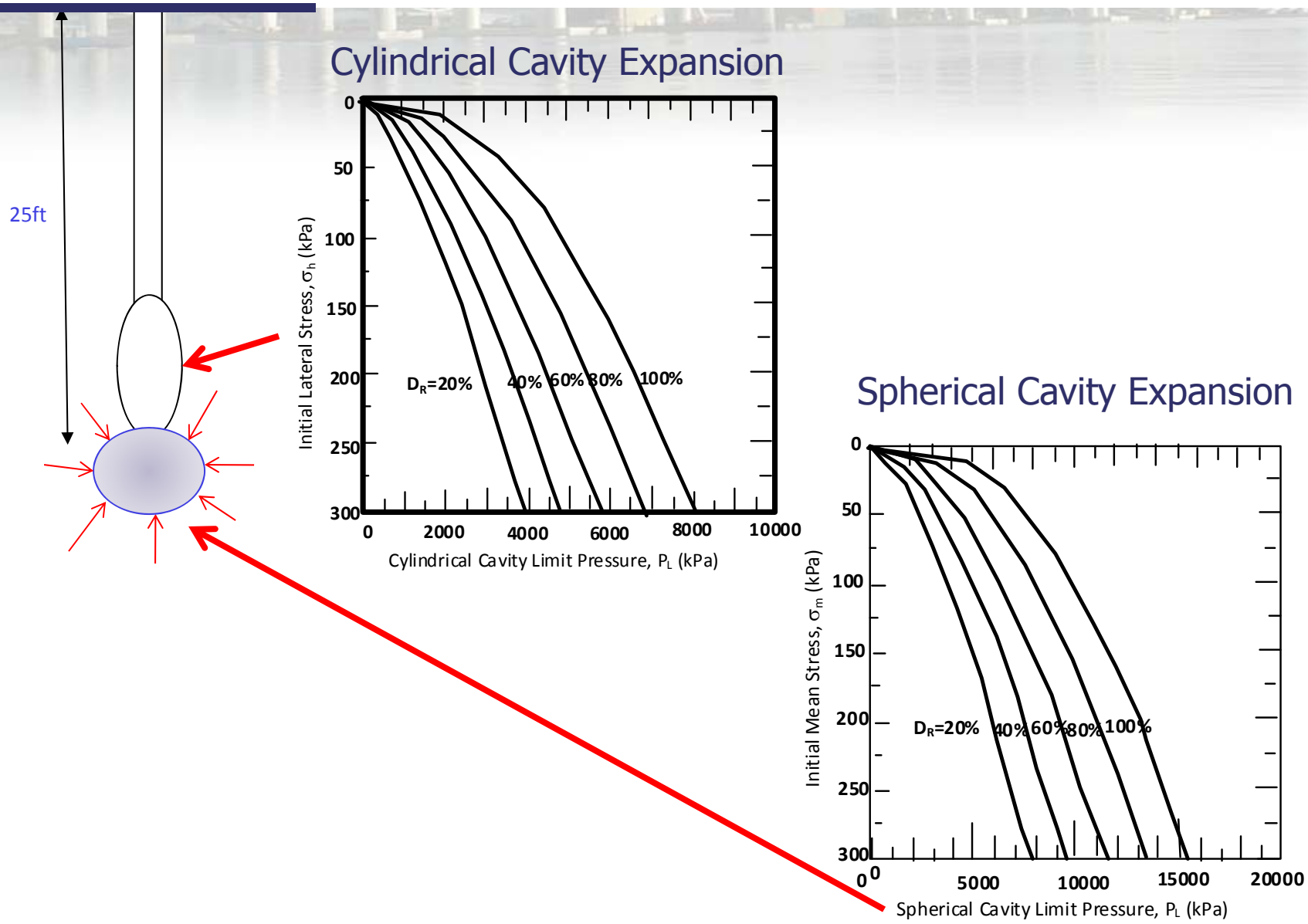
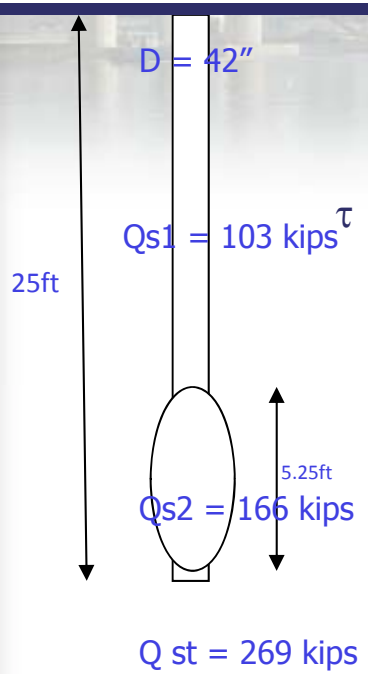
Soil Stresses from Side & Tip Grouting

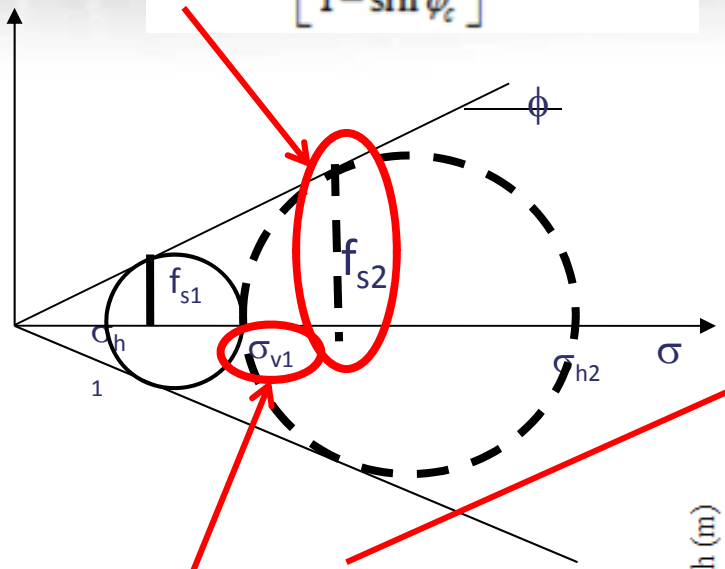
Expected Grout Pressures, Salgado, 2001



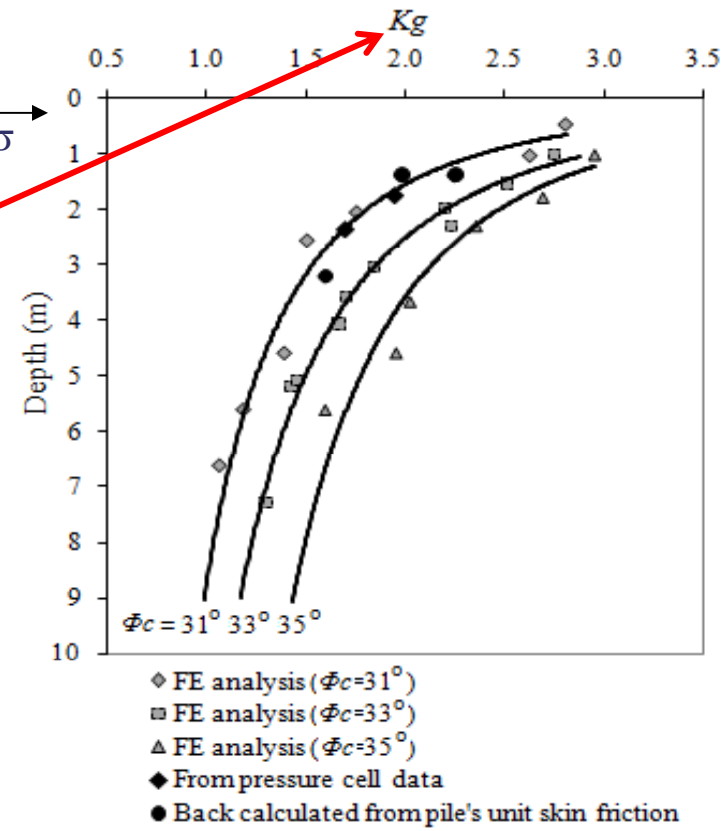
Skin Resistance After Side Grouting



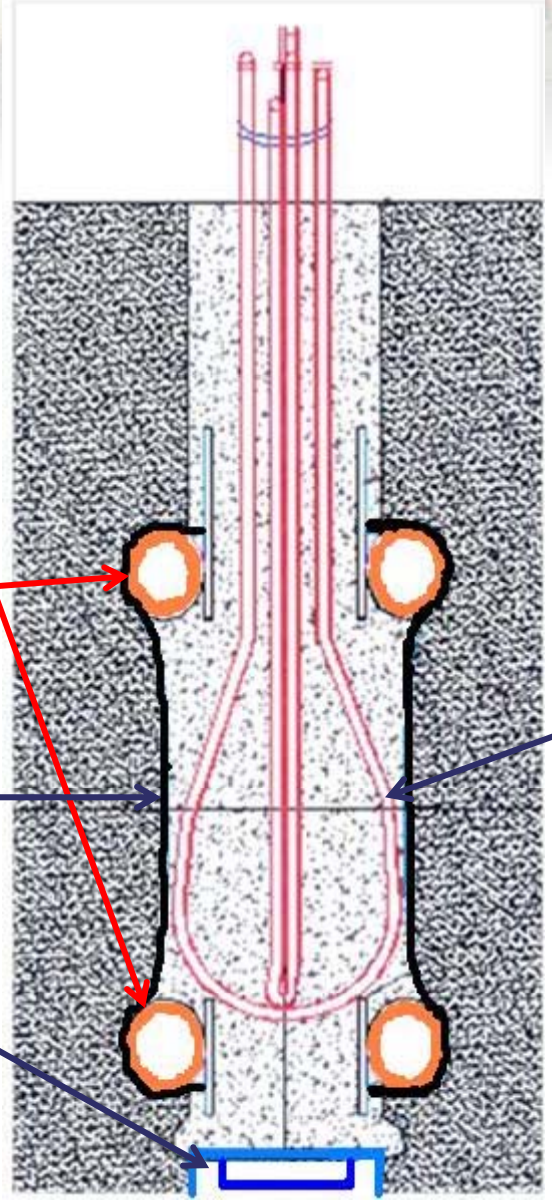
$$f_s = \sigma'_{vg}\left[\frac{\sin\phi_c}{1-\sin\phi_c}\right]\sin(90-\phi_c)$$



$$\sigma_{vg} = K_g\,\sigma_v$$



Design of New Side Grouting System For Drilled Shafts



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Membrane Seal Design

Testing Design using Water – Over 100 psi with NO LEAK!

Construction of Small Scale Test Shaft Grout System

Side Grouting Small Scale Test Shaft:

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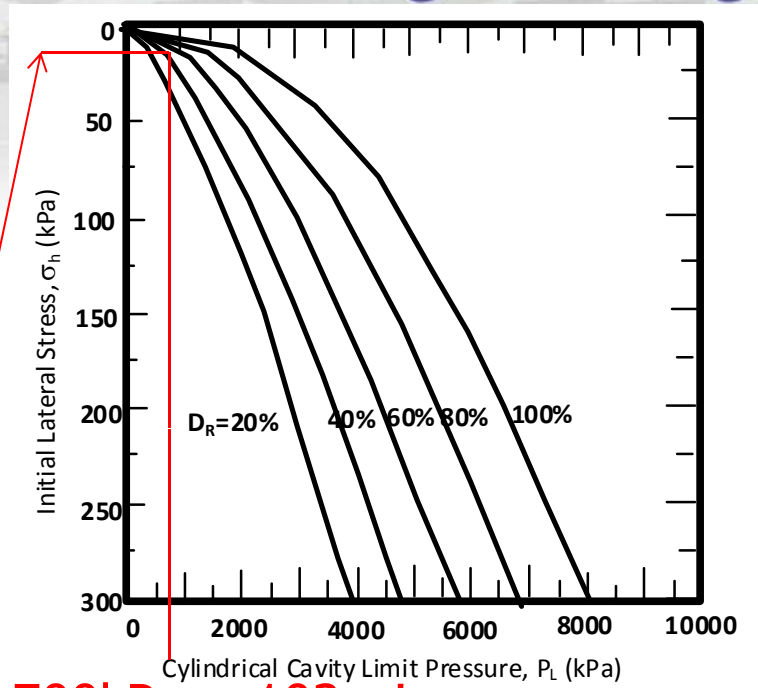
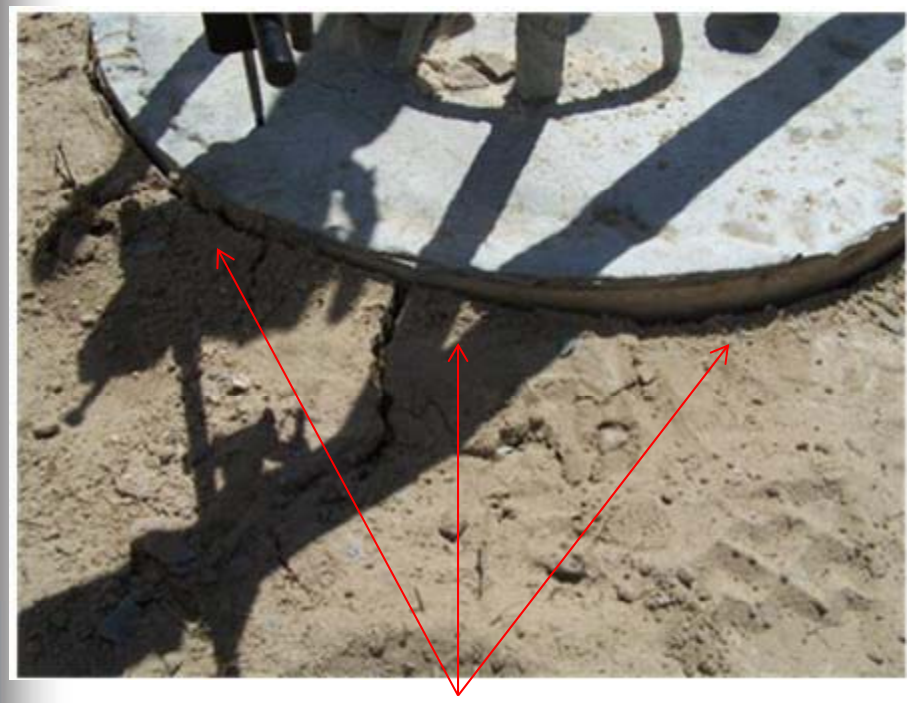
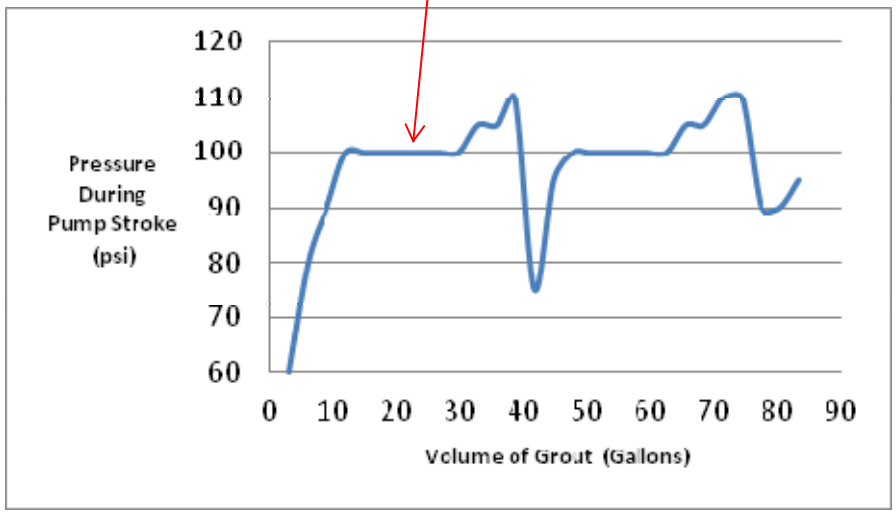
3′ x 6′ Shaft
Average Depth of Side Grout Zone = 5′
Initial Lateral Stress, $\sigma_h = \sigma_v * K_0 \approx 1.9$ psi
or 13 KPa



700kPa = 102psi

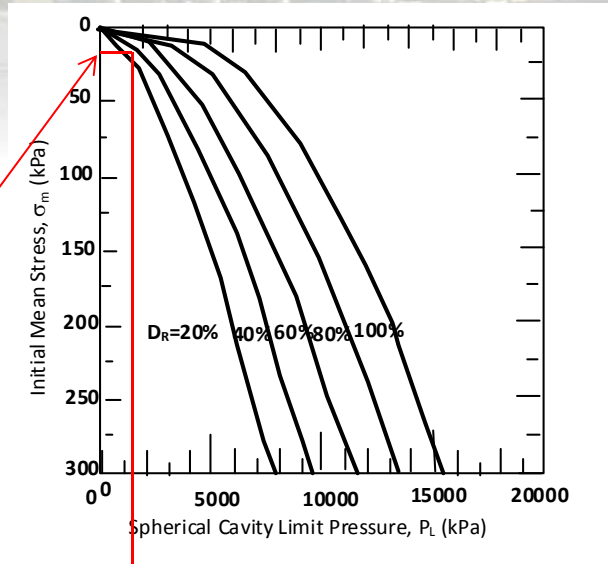


No Upward Grout Flow



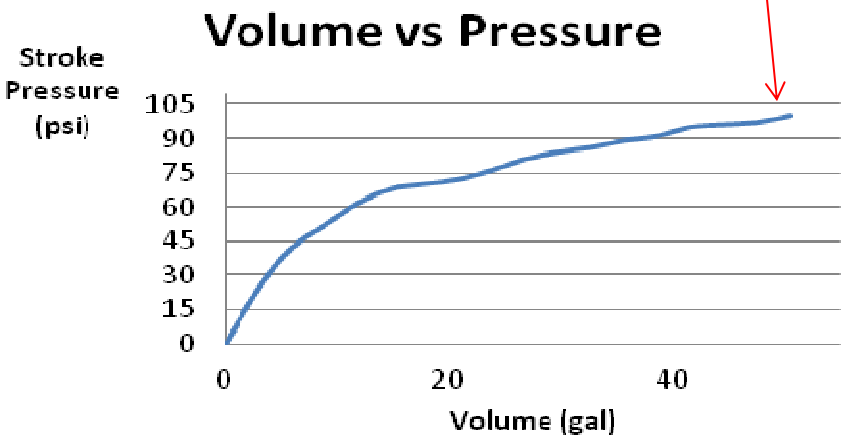
Side and Tip Grouted Small Scale Test Shaft

3′ x 6′ Shaft
Depth of Tip Grout Zone = 6′
Initial Mean Stress, $\sigma_m = \frac{(2*\sigma_h)+\sigma_v}{3} \approx 3$psi
or 20 KPa



1100 kPa=155 psi max

Spherical Cavity Expansion!



Construction of Large Scale Test Shaft Grout System

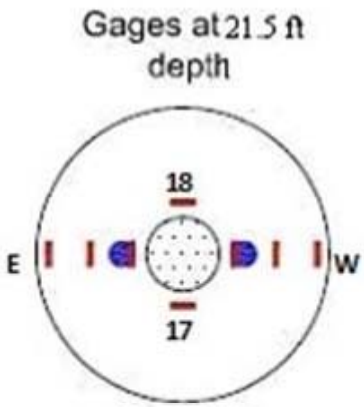
Casing Construction and Placement

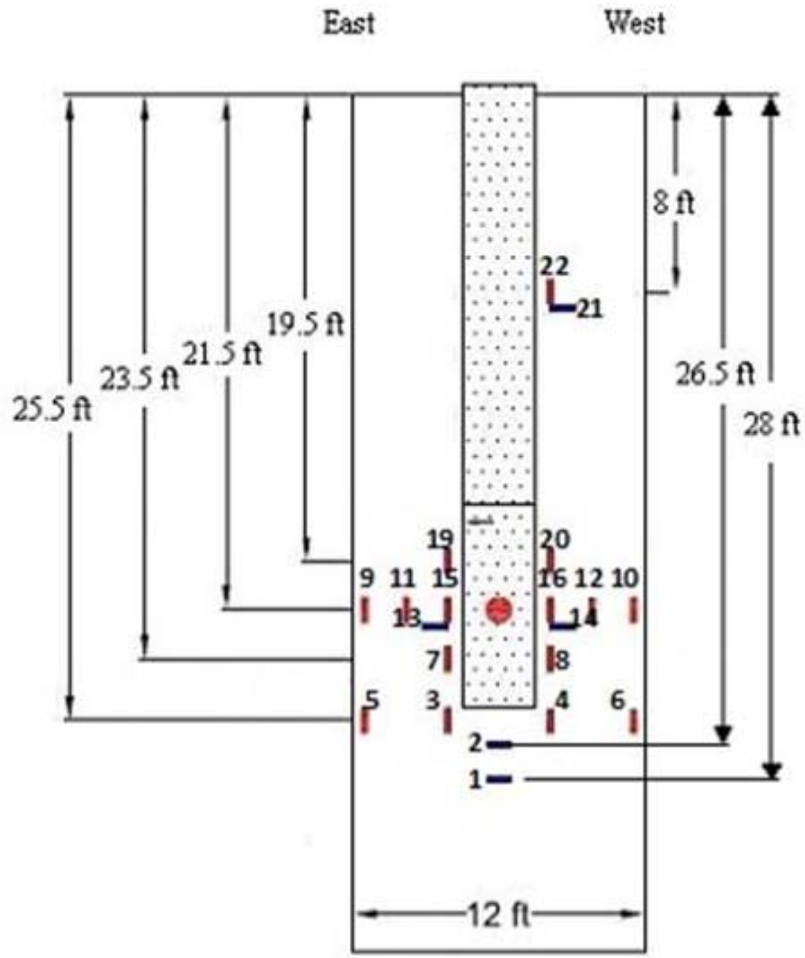
Casing Construction and Placement

Soil and Soil Pressure Cell Placement

18 Inch Soil Lifts
8% Moisture Content
50% Relative Density
$\gamma \approx 110$ lb/ft^3 & $\Phi' \approx 33°$

SPT Blow Counts:
3 – 5 at 8 ft Depth
15 at 21.5 ft Depth





Side Grouting Test Shaft

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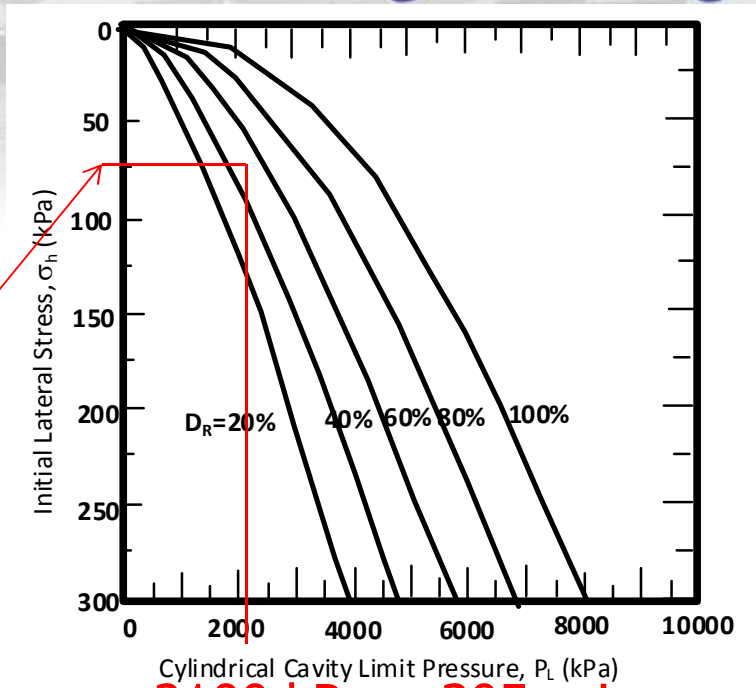
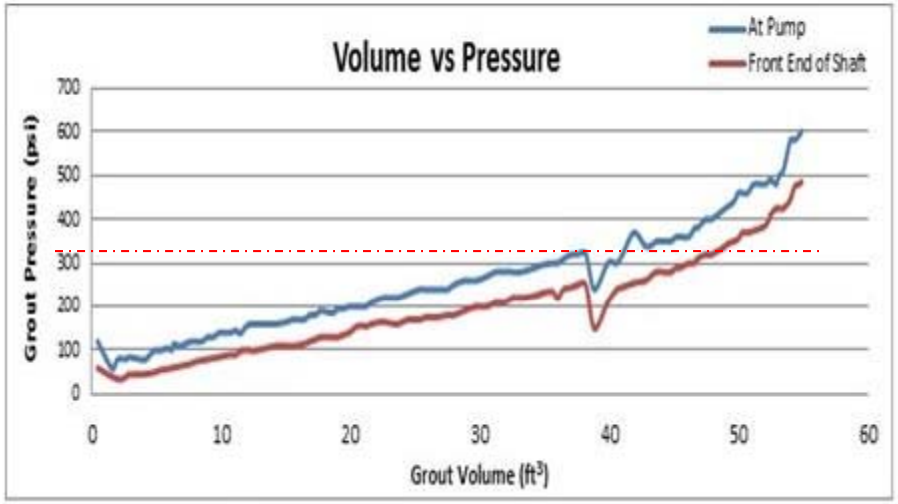
3′ x 25′ Shaft
Average Depth of Side Grout Zone = 21.5′
Initial Lateral Stress, $\sigma_h \approx 10$ psi
or 69 KPa



2100 kPa ≈ 305 psi

No Upward Grout Flow



Side Grouting Test Shaft

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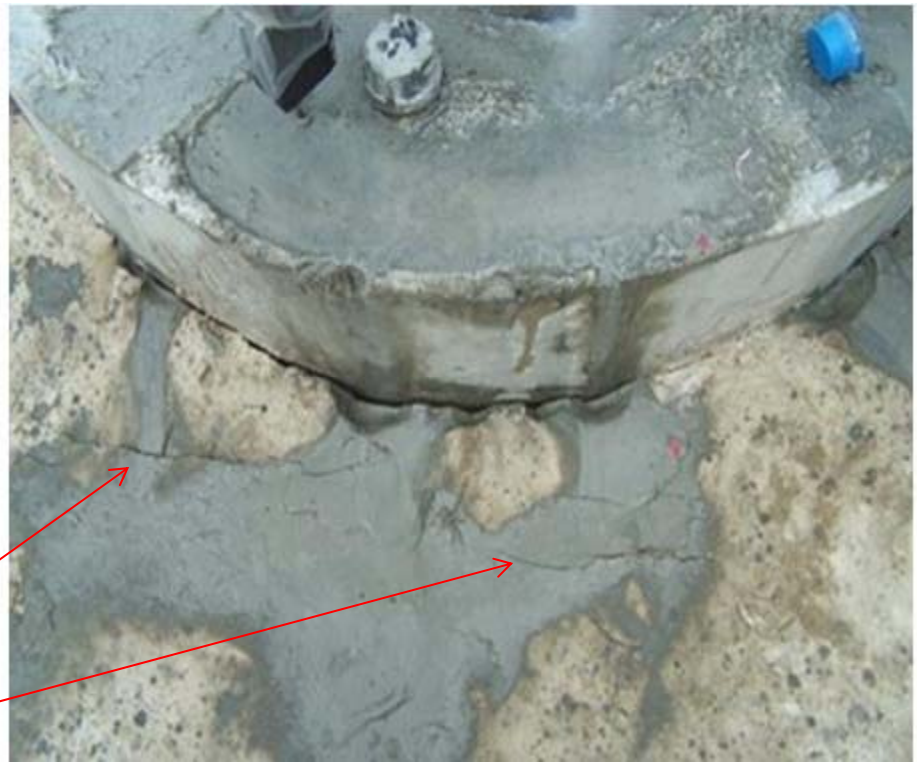
Total Shaft Displacement was ≈ 0.72"
or 2% of Shaft Diameter



Circular Soil Cracks during Side Grouting
No Upward Grout Flow!!!

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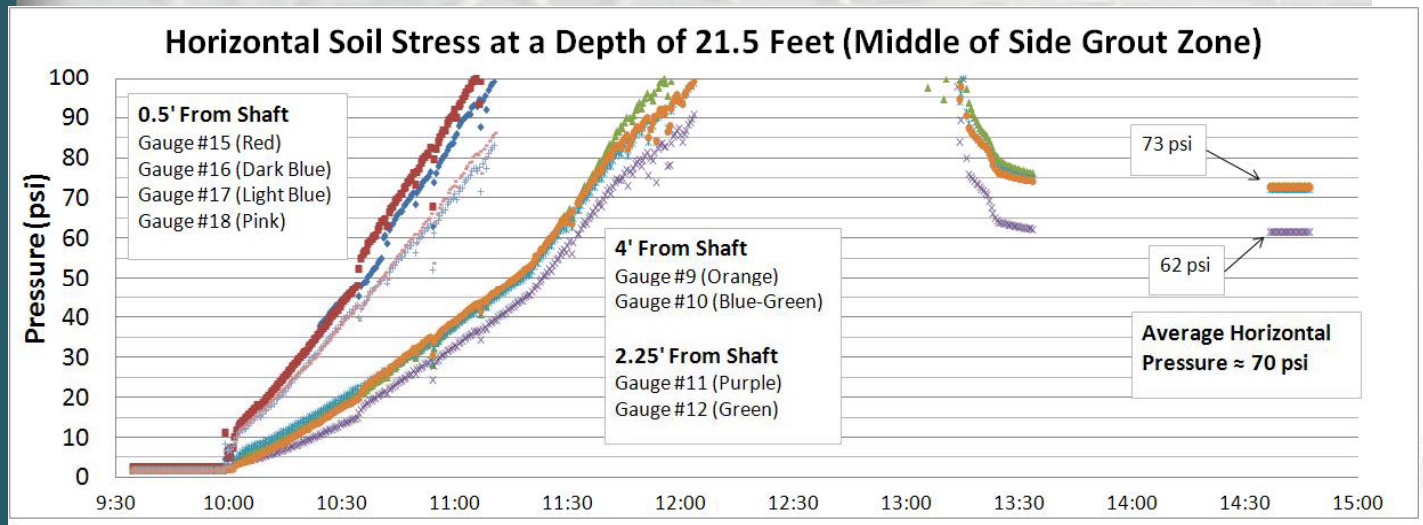
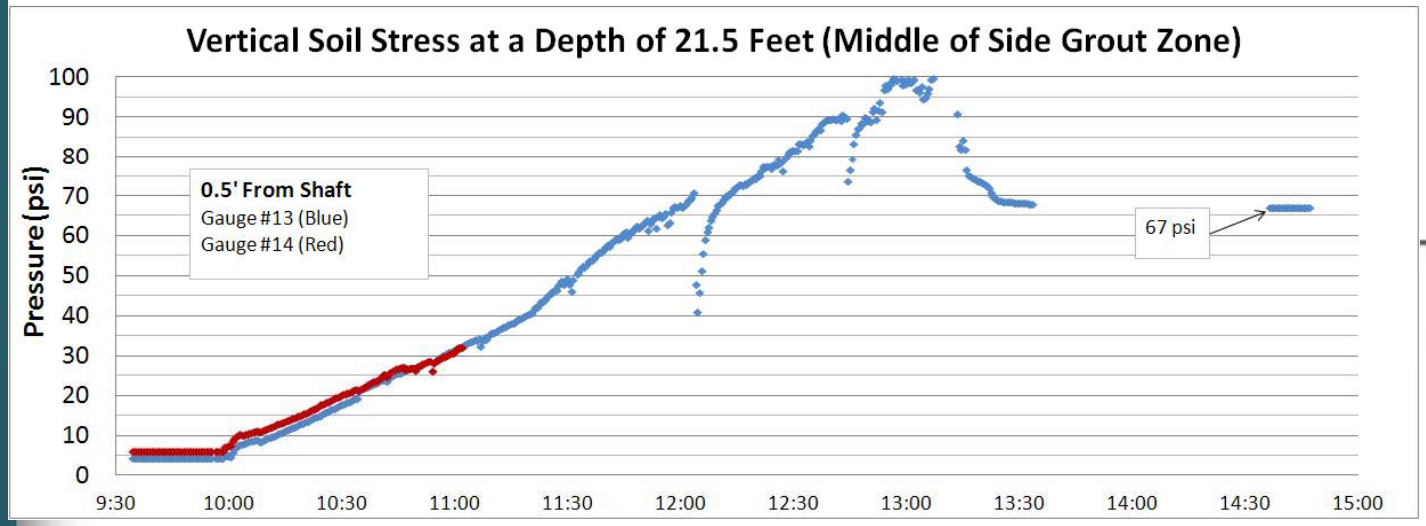
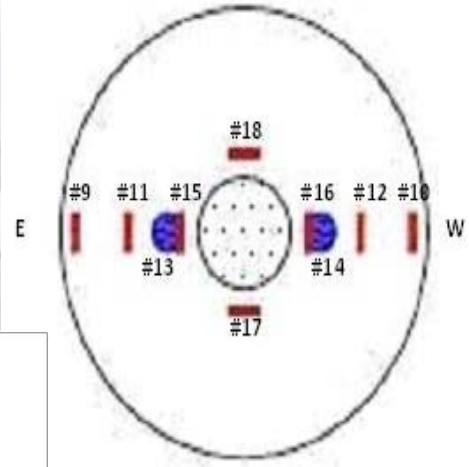
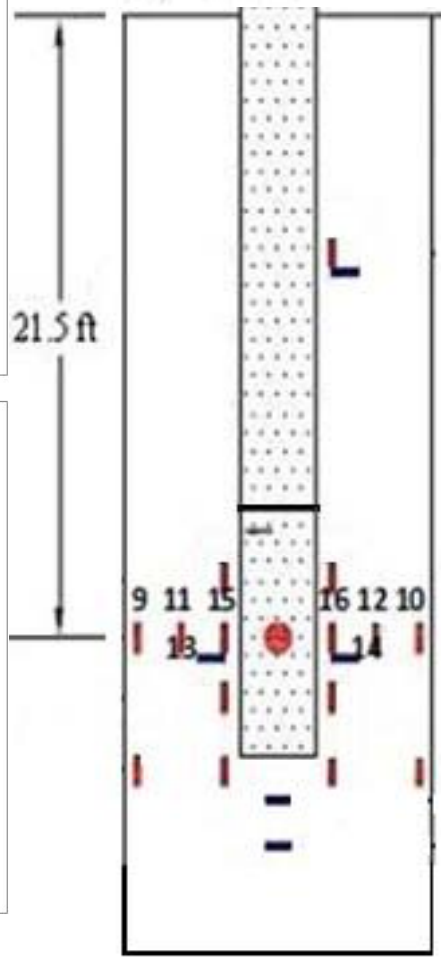
Side Grouting Test Shaft: Pressure Cell Data









Tip Grouting Test Shaft

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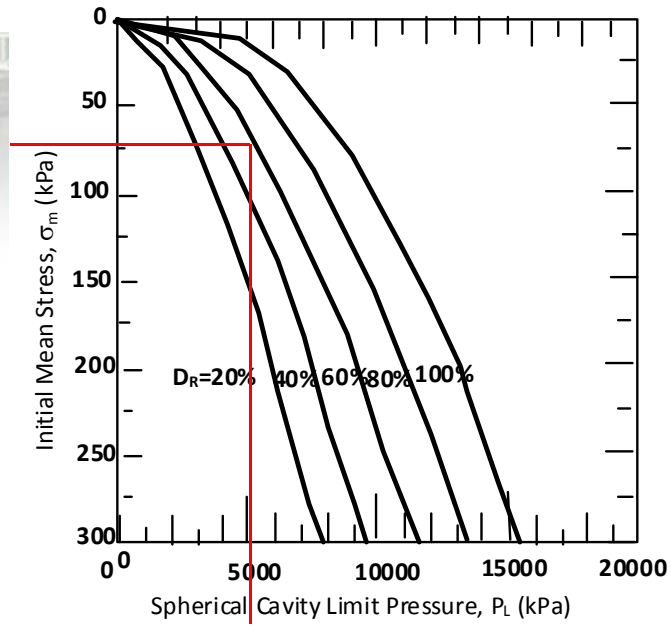
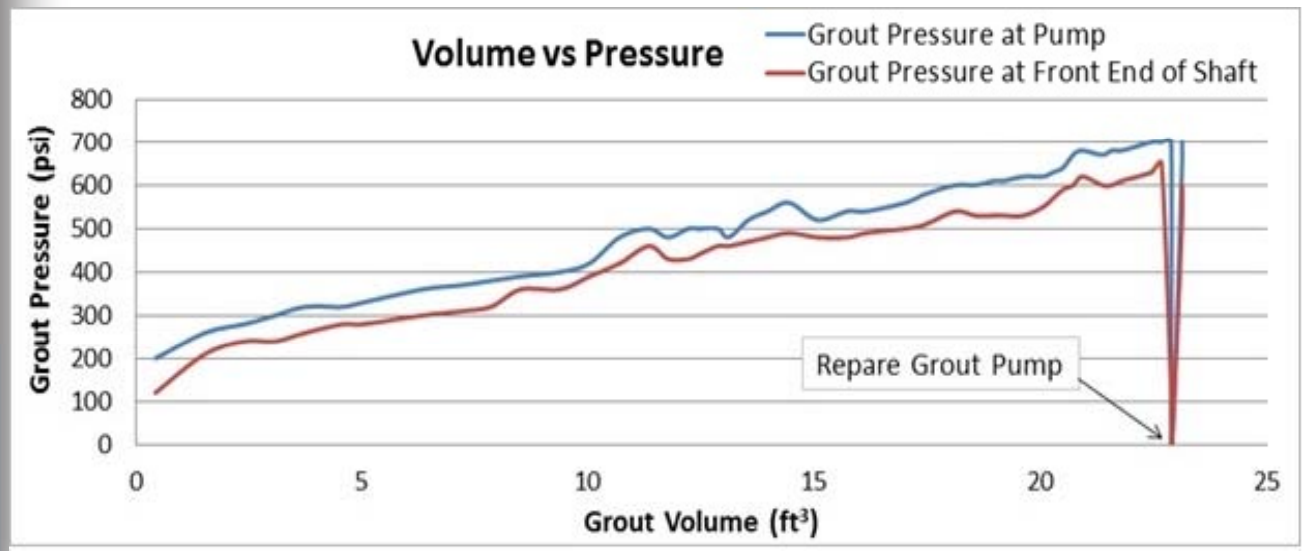
10.9 psi
≈ 75 kPa



Soil Cracks due to Upward Movement of Shaft

5000 kPa ≈ 725 psi



Total Upward Shaft Movement was Approximately 0.4”

Differential Movement of Shaft & Soil was Approximately 0.2”

Tip Grouting Test Shaft

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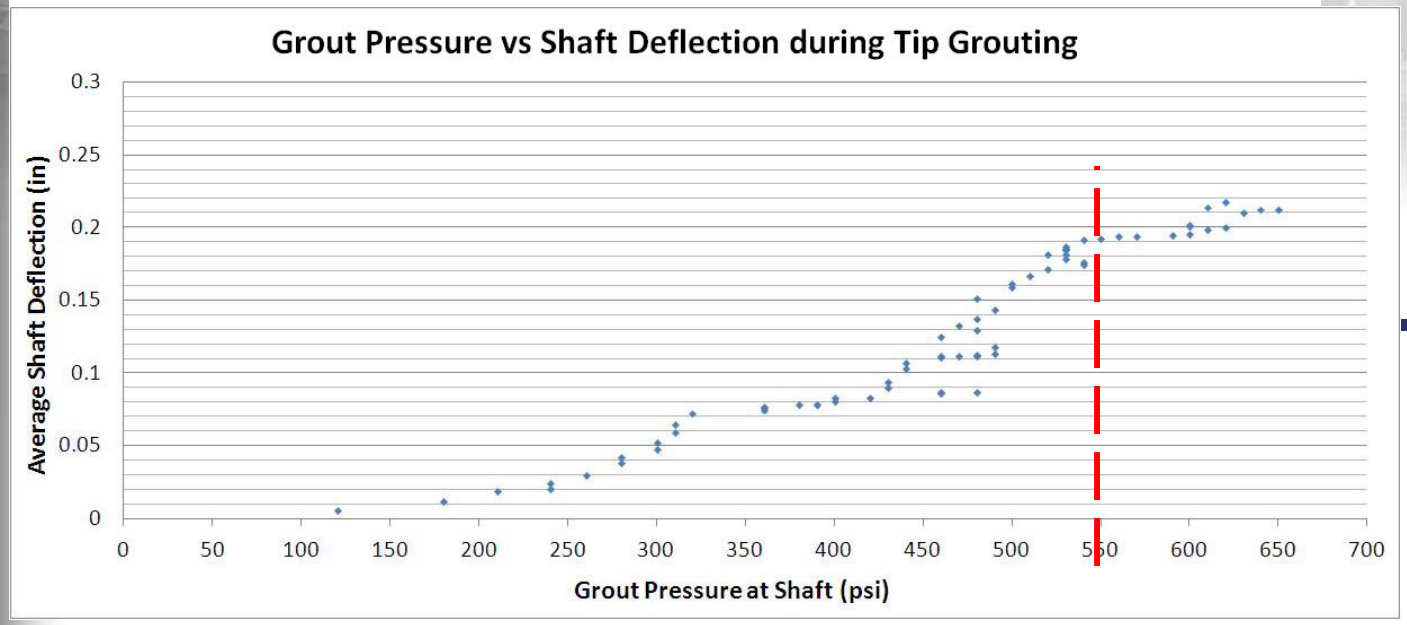

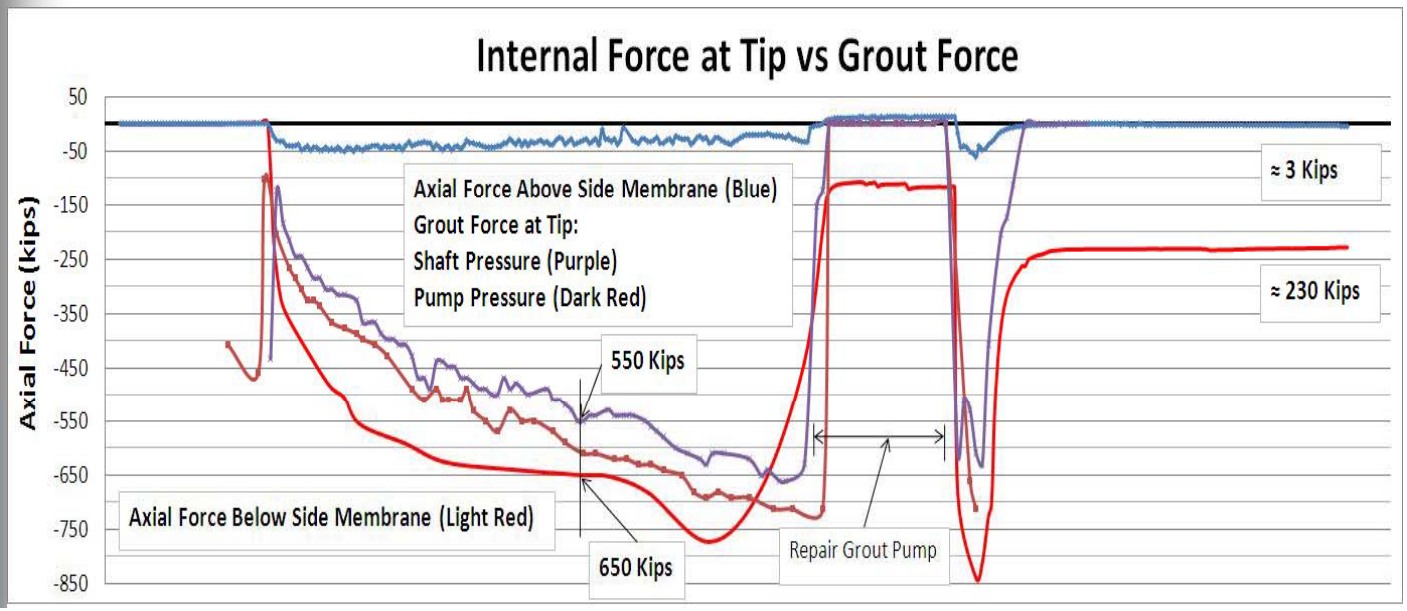

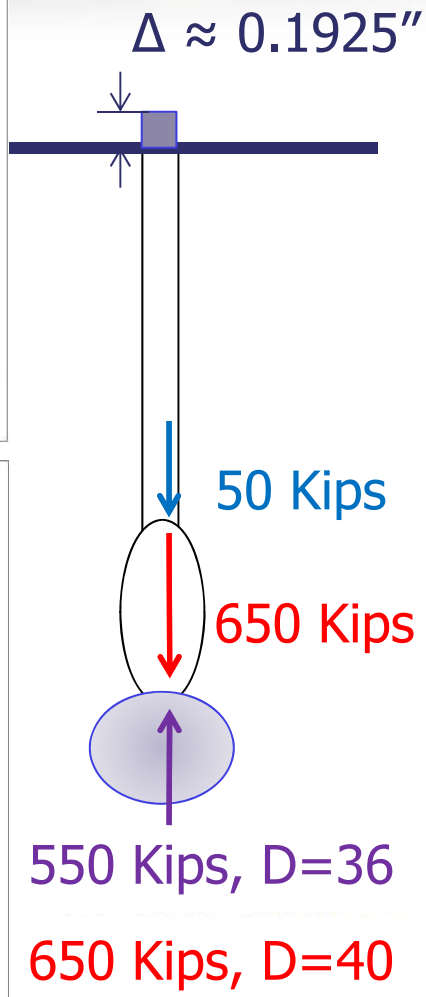

Completed Top-Down Test

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Completed Top-Down Test

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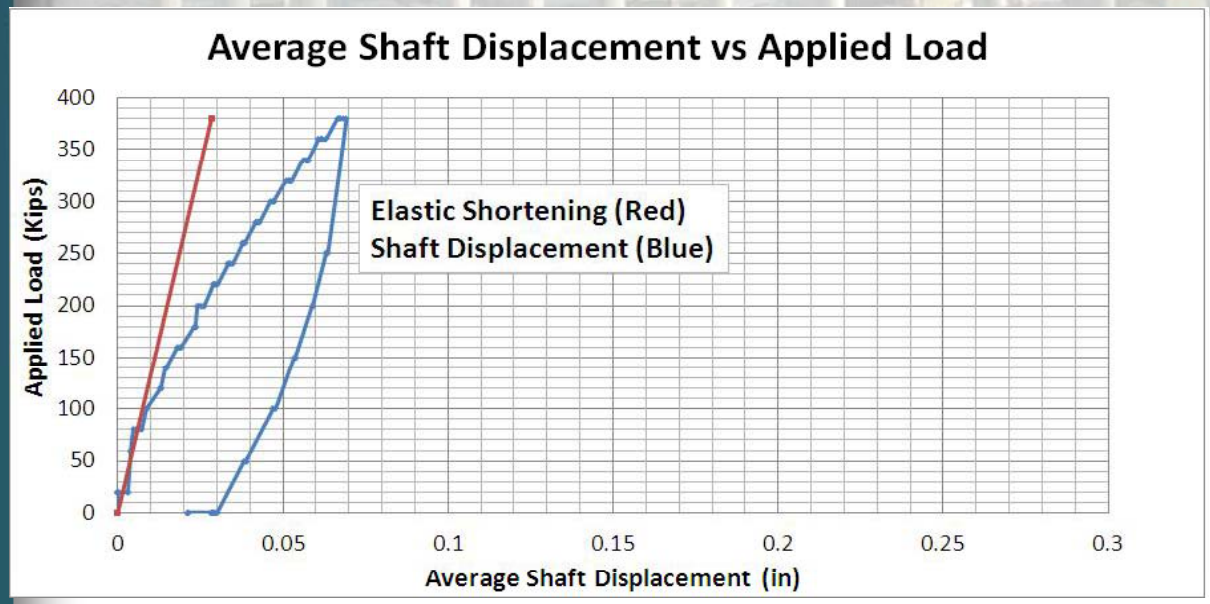

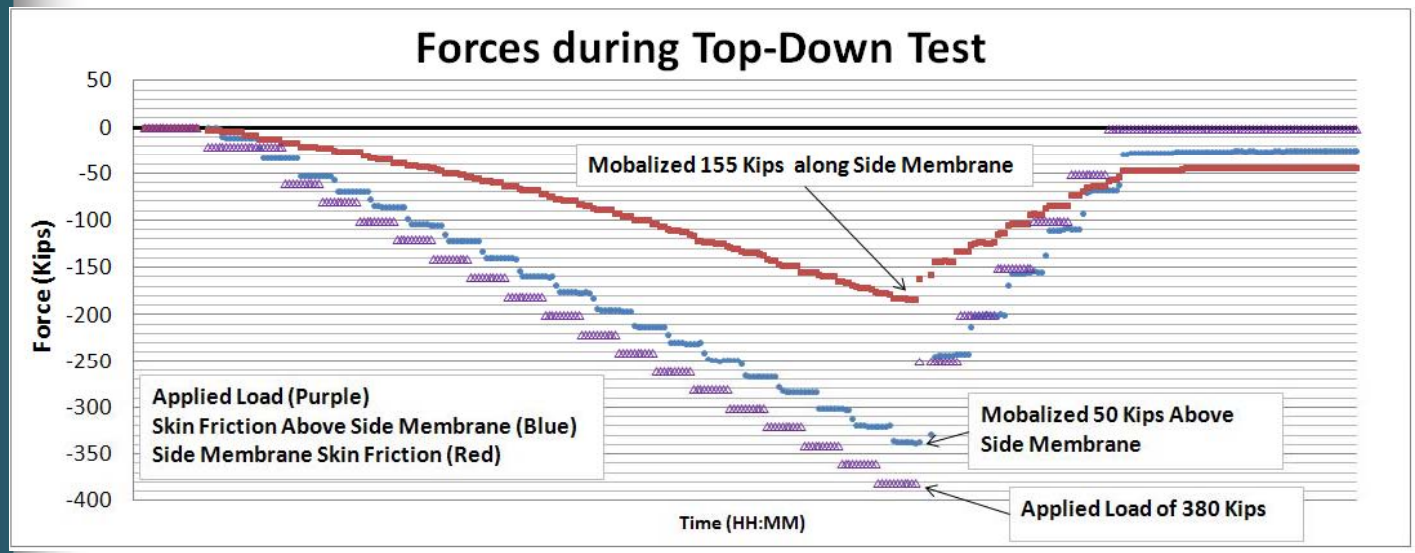

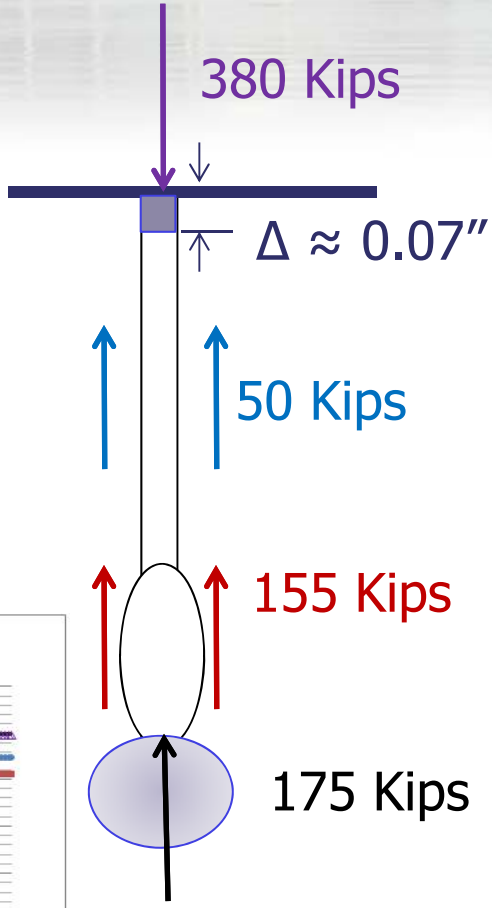

40% of Applied Load Carried by Side Grouted Zone!!!

Side and Tip Grouted Large Scale Test Shaft

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Spherical Cavity Expansion!!!
No Upward Grout Flow!!!

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Side and Tip Grouted Large Scale Test Shaft

Max Diameter of Side Grout Bulb is ≈ 4.5 ft (1.5*Diameter of Shaft)

Average Diameter of Side Grout Bulb ≈ 4 ft (33% Diameter Increase)

Diameter of Tip Grout Bulb ≈ 5 ft (60% Diameter Increase)

Schedule for Full Scale Field Testing

Tasks	Location	Duration
Task 1: Construct Rebar Cage and Three Stage Grout System for Full Scale Field Test	Coastal Engineering Laboratory in Gainesville	2 Months
Task 2: Install 42" x 25 ft Shaft, Side & Tip Grout, Monitor Soil Stresses	Keystone Heights Site	2 Months
Task 3: Axial Top Down Test, Monitor Strains& Stresses	Keystone Heights Site	2 Months
Task 4: Excavated Shaft & Evaluate Load Transfer	Keystone Heights & Office	2 Months

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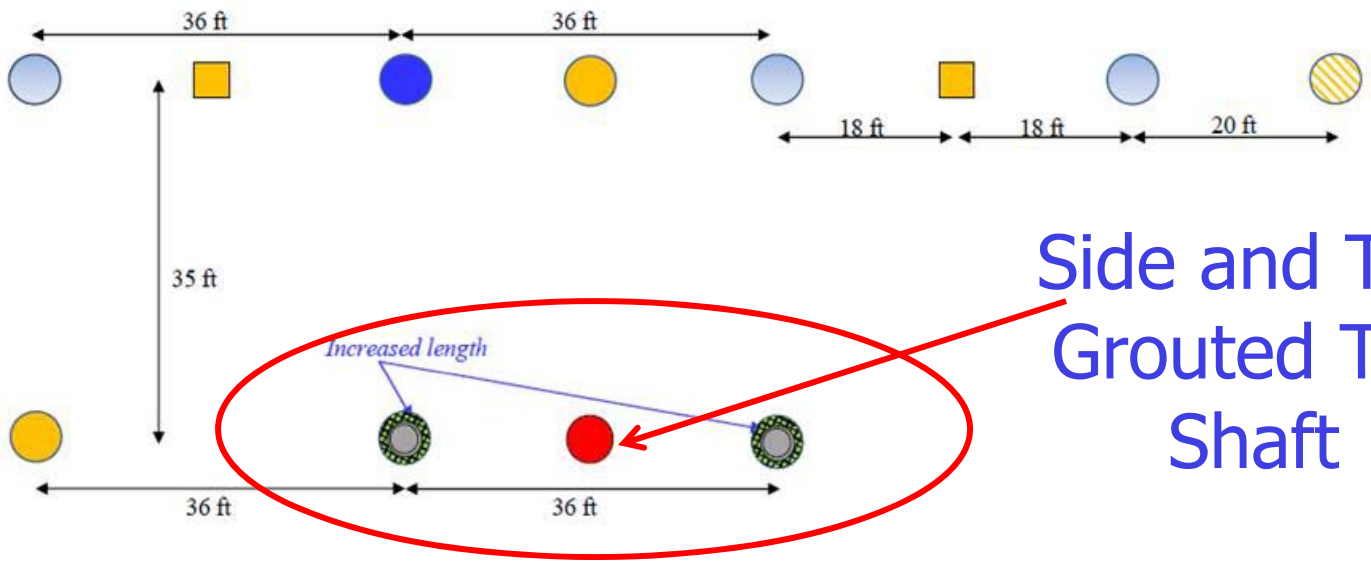
Full Scale Testing at Keystone Heights



Side and Tip Grouted Test Shaft

Shafts/Piles Layout

Shaft dimensions, reinforcement details & test details

Two, 4-ft diameter, 19-ft long test drilled shaft (depth of embedment -18ft and projection above ground – 1ft)
Reinforcement: Longitudinal – 1% of gross C.S area, Lateral ties (stirrups) - # 5 bars @ 5-in spacing, clear cover -3-in
Test details: 1 static top down test, 2 torsion tests, 1 lateral load test, 1 dynamic top down test, 1 dynamic lateral load test

One, 4-ft diameter, 13-ft long test drilled shaft (depth of embedment -12ft and projection above ground – 1ft)
Reinforcement: Longitudinal – 1% of gross C.S area, Lateral ties (stirrups) - # 5 bars @ 5-in spacing, clear cover -3-in
Test details: 1 torsion test

Three, 4-ft diameter, 41-ft long reaction drilled shaft (depth of embedment - 40ft and projection above ground – 1ft)
Reinforcement: Longitudinal – 1% of gross C.S area, Lateral ties (stirrups) - # 5 bars @ 5-in spacing, clear cover -3-in
Test details: Only for reaction

One, 4-ft diameter, 41-ft long reaction drilled shaft (depth of embedment - 40ft and projection above ground – 1ft)
Reinforcement: Longitudinal – 1.5% of gross C.S area, Lateral ties (stirrups) - # 5 bars @ 5-in spacing, clear cover -3-in
Test details: To provide reaction for lateral load test and axial load test

Two, 4-ft diameter, 56-ft long reaction drilled shafts (depth of embedment -55ft and projection above ground – 1ft)
Reinforcement: Longitudinal – 1% of gross C.S area, Lateral ties (stirrups) - # 5 bars @ 5-in spacing, clear cover -3-in
Test details: For supporting pole for torsion test and later to provide reaction for testing of bottom side grouted shafts)

One, 3.5-ft (42") diameter, 26-ft long test drilled shaft
(depth of embedment -25ft & projection above ground – 1ft)
Reinforcement:
Longitudinal – 1% of gross C.S area,
Lateral ties (stirrups) - # 5 bars @ 5-in spacing,
Clear cover - 3-in
Test details: Top down test after bottom side grouting and tip grouting
(To be cast after 6 months: Oct-Nov 2011)

Two, 28 in square, 20 ft long jet grouted pile
Test Details: 2 top down tests, 2 torsion tests, 1 lateral load test

Testing & Instrumentation

- 42” x 25 ft Side and Tip Grouted Shaft will be Instrumented with Vibrating Wire Strain Gages at the Shaft Tip and Above the Side Grout Zone.

- During Side and Tip Grouting, Strain Gages will be Read to Separate Skin friction (Above and Within the Grout Zone) From Tip Resistance
- During Top Down Compression Test, Shaft Side Friction (Above & Within Grout Zone) and Mobilized Tip Resistance as function of top displacements

Testing & Instrumentation

- Place PVC pipe for Telltale at Tip of the Shaft
- Develop Tip Resistance vs. Displacement (Tip Telltale Measurement)
- Geokon Model 4830 Push-In Pressure Cells will be used to Monitor Stresses with in the Soil around the Shaft

- Read Pressure Cells During Shaft Cast and all Three Grout Stages – Monitor the Change in Soil Stress and Better Asses Effects of Side and Tip Grouting Processes
- Validate Design – Using Equations & Pressuremeter Testing

Thank You

Questions?

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