Texas Department of Transportation

September 19, 2024

Welcome to Bridge Briefings

We will begin at 11:30 AM

Reminders

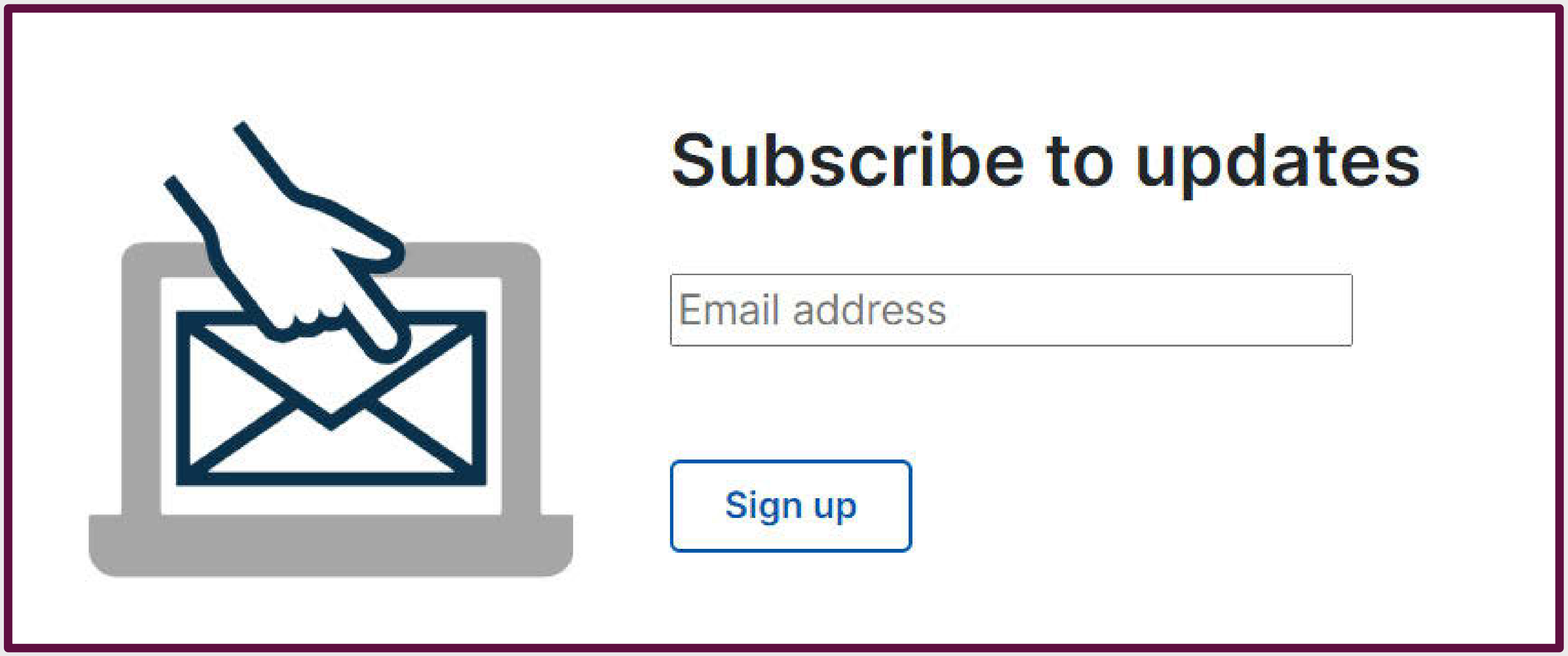
- Chat is turned off, please use the Q&A box
- Slides will be posted on the Bridge Website:

  https://www.txdot.gov/business/resources/highway/bridge/webinar-presentations/bridge-briefings.html

- Please submit additional questions to ryan.eaves@txdot.gov

Don’t miss out on other updates!

https://www.txdot.gov/about/divisions/bridge-division.html



Don’t miss out on other updates!

Subscription Topics

- Discover Texas
- **Do business**
- Explore projects
- About

Bridge

- Construction
- **Design Policy or Standards Release**
- Foundation Design and Construction
- Geotechnical
- Inspection
- Maintenance
- Preservation
- Retaining Wall Design and Construction
- Steel Quality Council
- Superheavy Review
- Texas Ancillary Structures Interest Group

PDH

- Please remember Bridge Division does not provide documentation for TX Board PDH approval. Each engineer should exercise personal judgement when counting webinar topics for their professional development hours. For more info on what qualifies for Continuing Education, please visit https://pels.texas.gov/CEPInfo.htm

TIP Testing and Load Testing Drilled Drilled Shaft Guidance

Ryan L. Eaves P.E., Bridge Division – Geotechnical Branch Manager

Texas Department of Transportation

September 19, 2024

Table of Contents

Why Do We Test Integrity?

Common Problems During Construction

- Bulge or necking in shaft
- Caving of shaft wall
- Horizonal sand lens in concrete
- Soft shaft bottom
- Voids outside of cage
- Rebar cage shifting
- Concrete defects
- Etc.

Construction Control Issues

- Bulge or necking in shaft – not casing soft zones, pulling temp. casing w/ concrete adhering
- Caving of shaft wall – improper casing or slurry
- Horizonal sand lens in concrete – improper tremie in wet hole, water bearing sands
- Soft shaft bottom – incomplete bottom cleaning, side sloughing or cuttings from slurry
- Voids outside of cage – low concrete slump, aggregate too large, rebar too closely spaced
- Rebar cage shifting – missing/inadequate spacers/centralizers, cage stiffness, tremie pump
- Concrete defects – tremie joints not sealed, and problems with placement, slump inadequate
- Etc., excessive sediment in slurry

Shaft Integrity Testing and Load Testing

- Shaft Integrity Testing
  - Concrete yield log
  - Crosshole Sonic Logging (CSL)
  - Thermal Integrity Profiling (TIP)
- Load Testing
  - Static top-down load test
  - (High-strain) Dynamic load testing

Integrity Testing – TxDOT Geotechnical Manual

Drilled Shaft Integrity Testing

Various testing methods are available to determine the integrity of drilled shafts, which are Crosshole Sonic Logging (CSL), Gamma-Gamma testing, and Thermal Integrity Profiling (TIP). TIP is the preferred testing method, as it is done during the curing of the concrete and does not delay construction. Other methods are approved based on the priorities of the project. Bridge Division has developed a Special Specification for TIP testing titled "Thermal Integrity Profiler (TIP) Testing of Drilled Shafts."

TIP or other integrity testing should be considered for use under one or more of the following conditions:

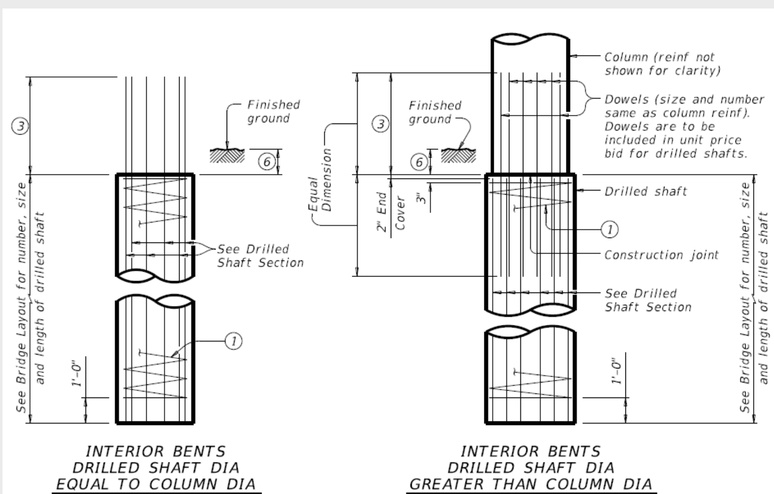
- Mono-shafts;
- Large diameter shafts (60" diameter, or greater);
- Drilled shafts with a diameter > 24 inches encountering water bearing sands in the soil profile and on critical roadways, such as interstate systems, high ADT roadways, emergency routes, evacuation routes, etc.

Number and frequency of tests is at discretion of foundation engineer and dependent on site specific conditions and redundancy designed into the foundation system.

Consult with the TxDOT Bridge Division Geotechnical Branch to determine if a specific project might be considered a candidate for TIP or other integrity testing.

Single Column Bent with Monoshaft Foundations

- Monoshaft
  - single drilled shaft supporting an individual column
  - Typically large diameter shaft (> 5’)



Monoshaft Considerations

- Design Considerations
  - Less Redundancy – Single Shaft Per Bent
  - End Bearing – Larger Displacement Needed to Mobilize
  - Lateral Loading – May Control Design
- Construction Considerations
  - Mass Concrete Pour – Managing Cure Temperature
  - Construction Time – Takes longer to drill and pour than smaller shafts
  - Hole Stability – Can be difficult to stabilize

Large Diameter Shaft Considerations

- Increased construction time
  - Shafts are often deep
  - Cage is larger
    - May also need to be spliced
  - Shaft takes longer to pour
  - More difficult to inspect

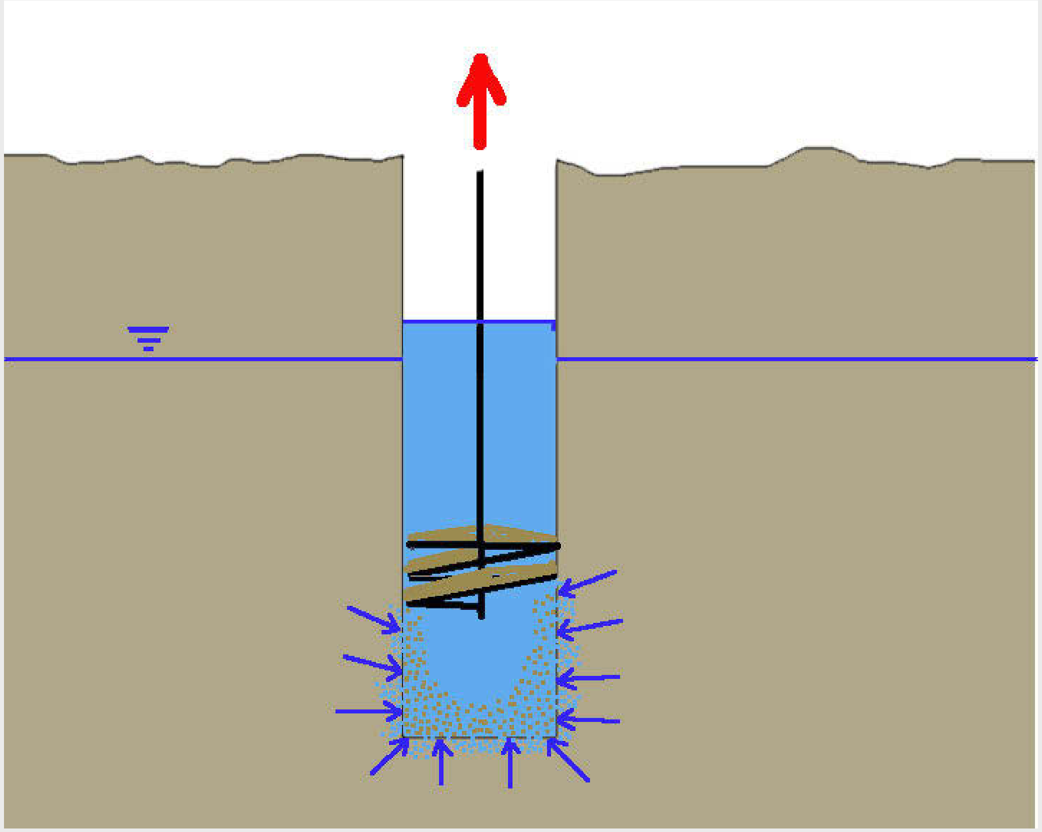
Sand Properties

- Derives most strength from particle contact
  - Confinement is critical
- Loss of confinement can loosen sands
  - Especially when accompanied by water flow
- Loose sand is weak sand
- Quick condition can be created by excavating below water table and reducing water level in excavation
- Withdrawing auger too quickly can destabilize sidewalls

Drilled Shaft Construction

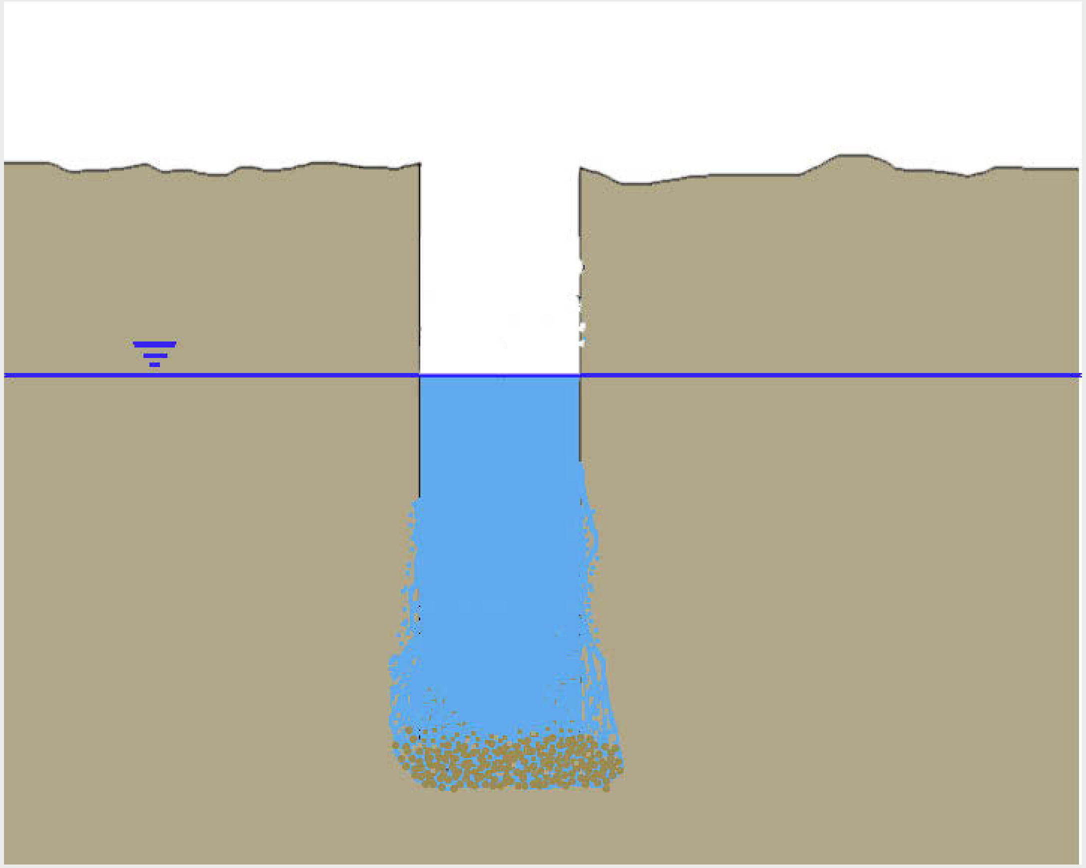
- Design Considerations
  - If relying primarily on water bearing sand for skin friction capacity, design conservatively
  - End bearing in water bearing sand is more difficult to control in construction
- Construction Considerations
  - Installing shafts into cohesionless sand generally requires slurry, casing, or both.
  - Excavation into clean sands located below the water table is especially difficult. Careful attention to hole stability is critical.
  - Failure to maintain hole stability will result in oversized excavations, loss of strength, and inadequate capacity.

Auger Creating Suction



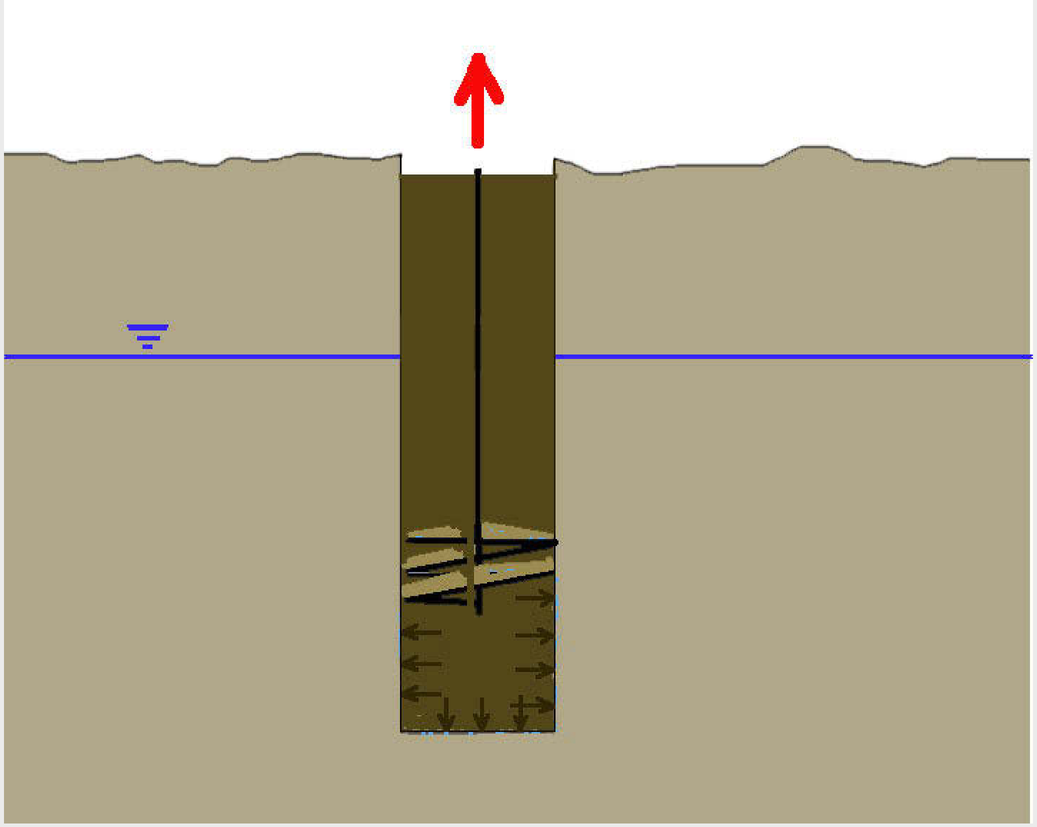
Soil Filled Auger

Resulting Excavation

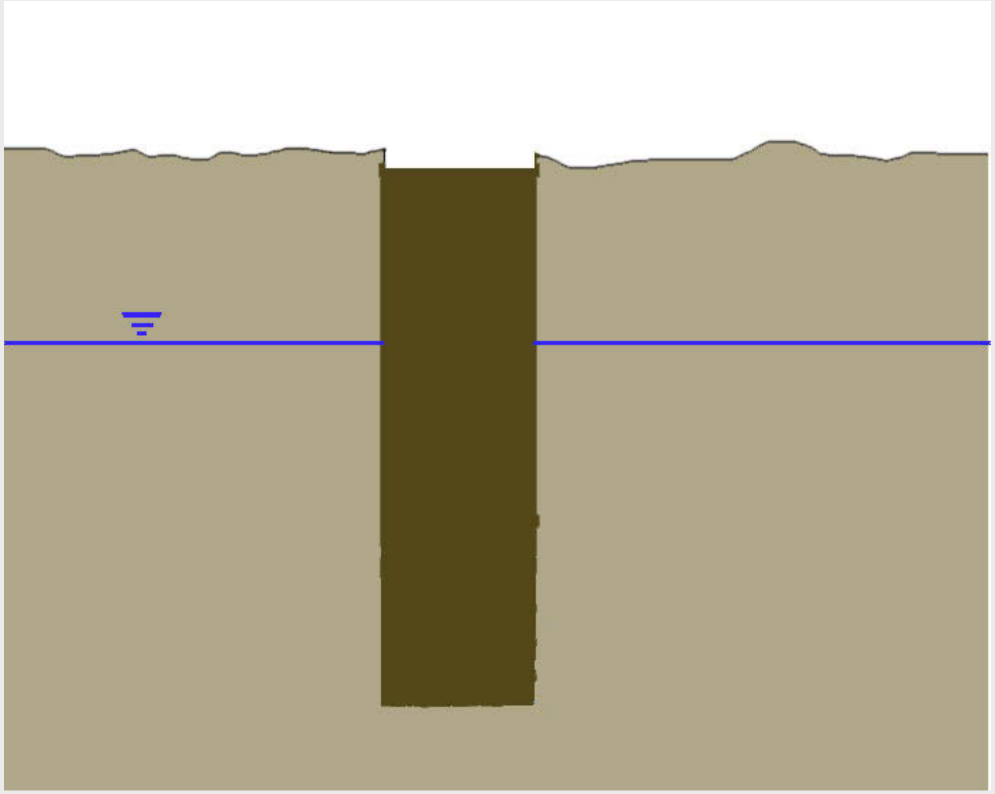


Drilling Slurry

Slurry Providing Positive Head



Resulting Excavation



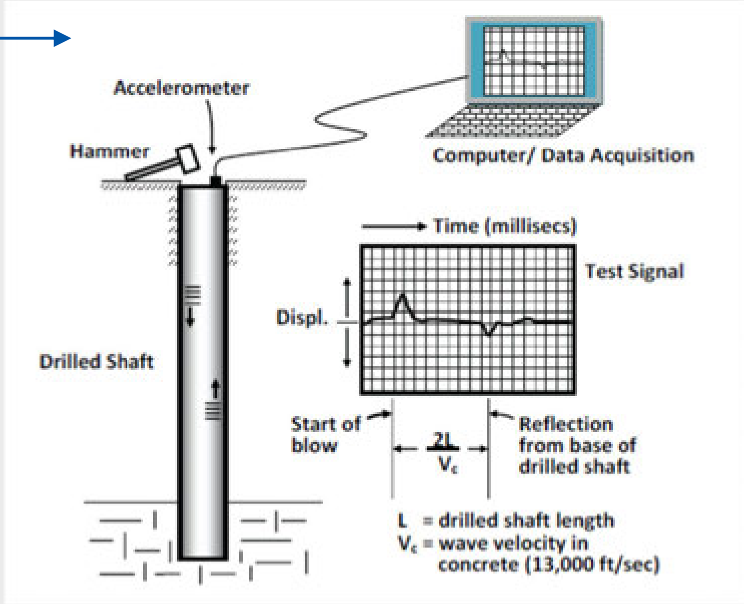
Checking Plumbness & Sounding the Bottom

Types of Concrete Anomalies

- Low strength concrete
- Slurry mixed concrete
- Voids
- Soil-concrete mixtures
- Soil and sediment

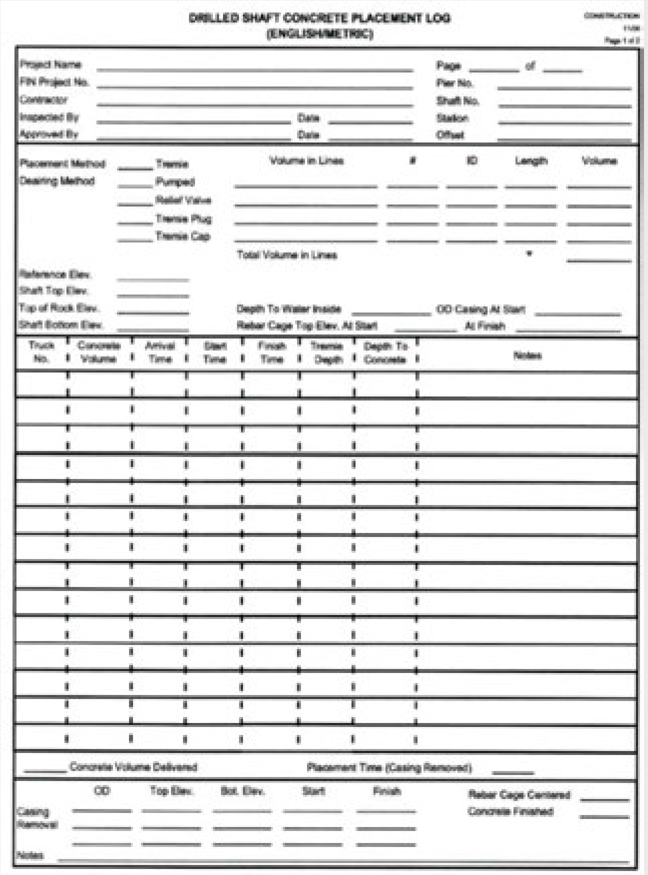
Integrity Testing – Conventional Methods

- External - Sonic Echo Testing / Pulse Echo



- Internal - Cross-hole sonic logging (CSL)
- Internal - Gamma Gamma (GGL)
- Concrete Yield Log

Concrete Yield Log



DRILLED SHAFT CONCRETE PLACEMENT LOG
(ENGLISH/METRIC)

Project Name ____ Page ____ of ____
FIN Project No. ____ Pier No. ____
Contractor ____ Shaft No. ____
Inspected By ____ Date ____ Station ____
Approved By ____ Date ____ Offset ____

Placement Method ____ Tremie
Clearing Method ____ Pumped
____ Relief Valve
____ Tremie Plug
____ Tremie Cap

Volume in Lines # ID Length Volume
Total Volume in Lines

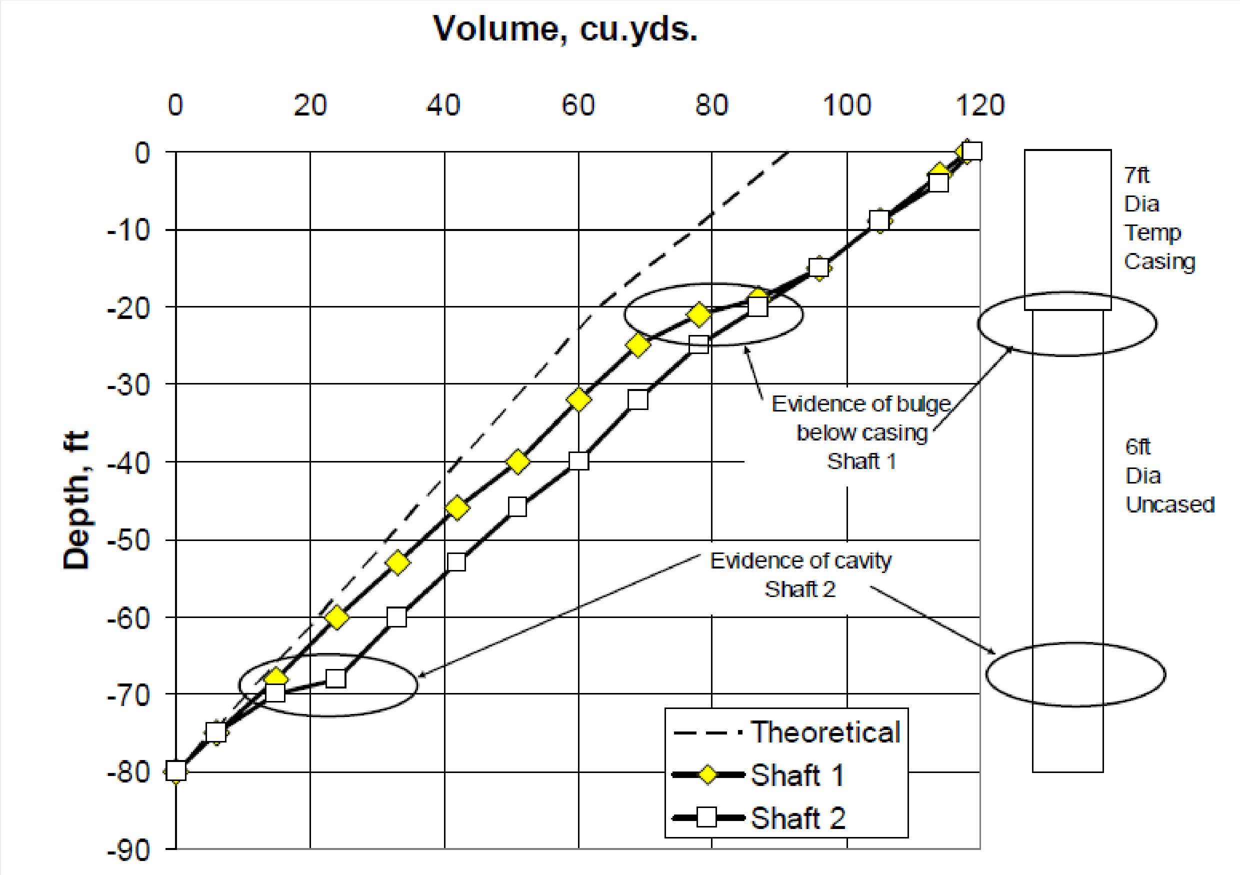
Reference Elev. ____
Shaft Top Elev. ____
Top of Rock Elev. ____ Depth To Water Inside ____ OD Casing At Start ____
Shaft Bottom Elev. ____ Rebar Cage Top Elev. At Start ____ At Finish ____

Truck No.	Concrete Volume	Arrival Time	Start Time	Finish Time	Tremie Depth	Depth To Concrete	Notes

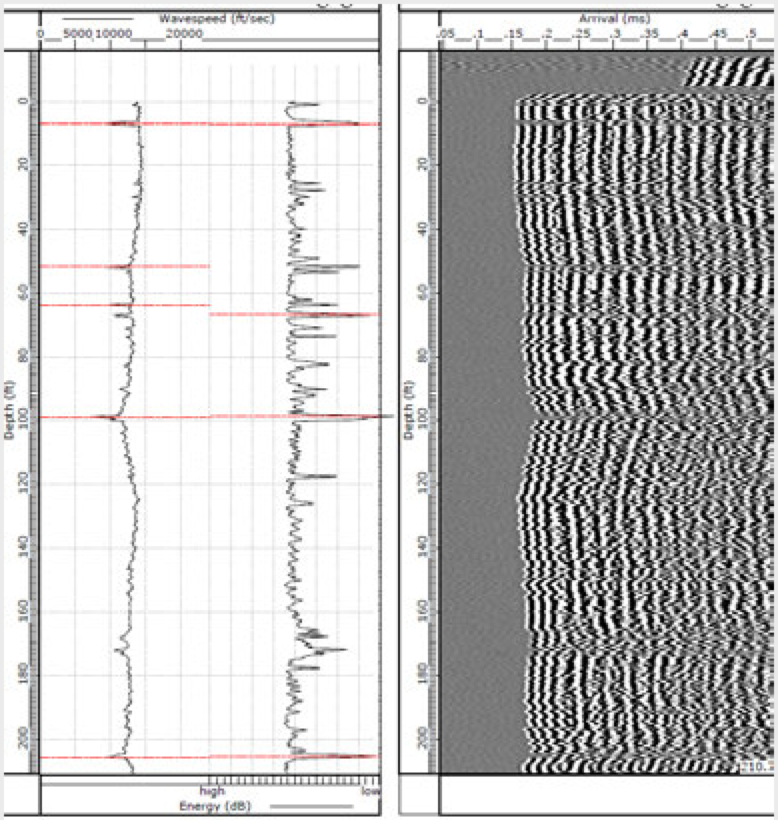
____ Concrete Volume Delivered Placement Time (Casing Removed) ____

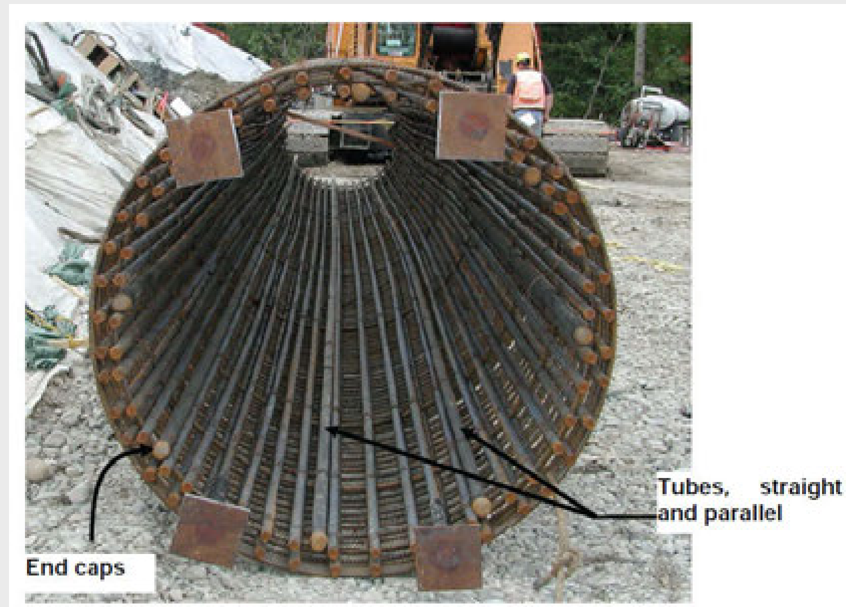
Casing Removal: OD ____ Top Elev. ____ Bot. Elev. ____ Start ____ Finish ____
Rebar Cage Centered ____
Concrete Finished ____

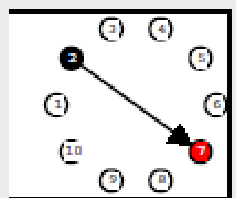
Notes ____



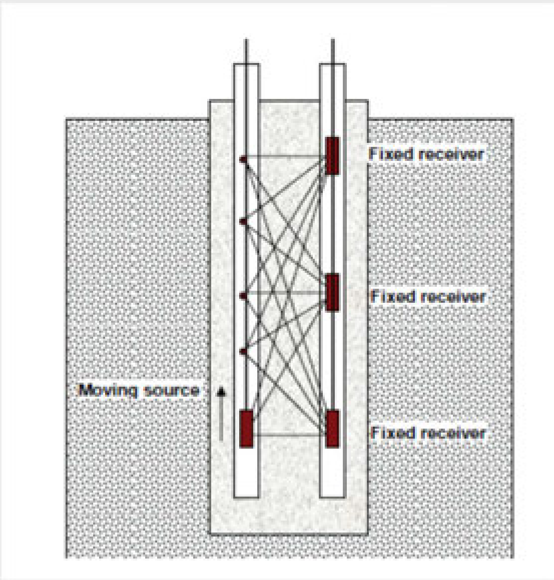
Crosshole Sonic Logging (CSL)

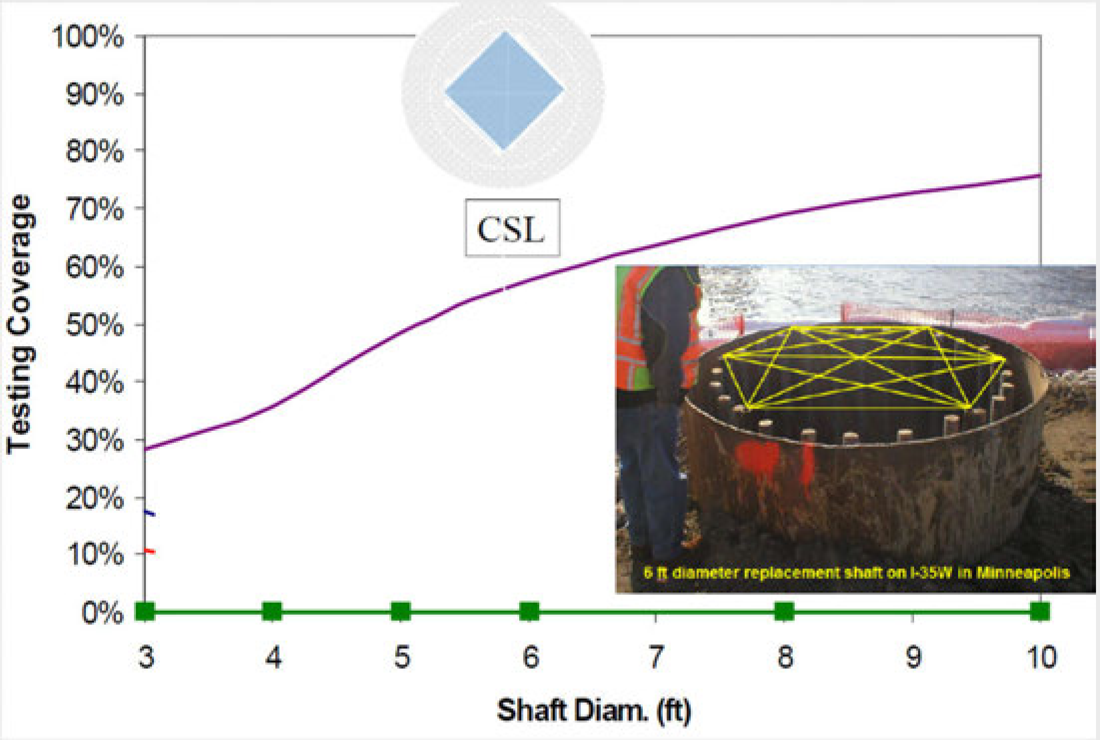






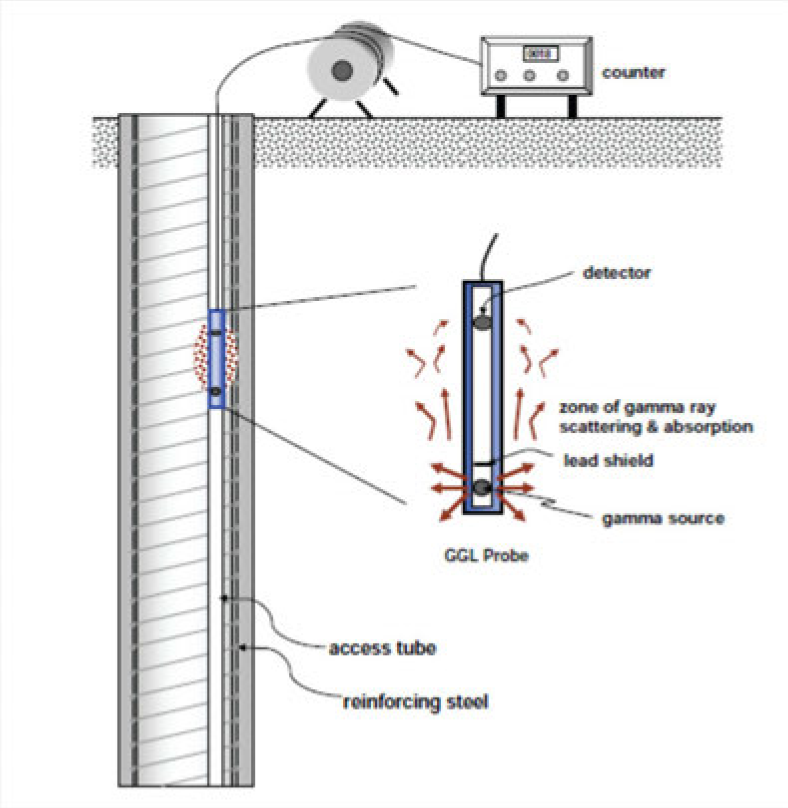
Crosshole Sonic Logging (CSL)



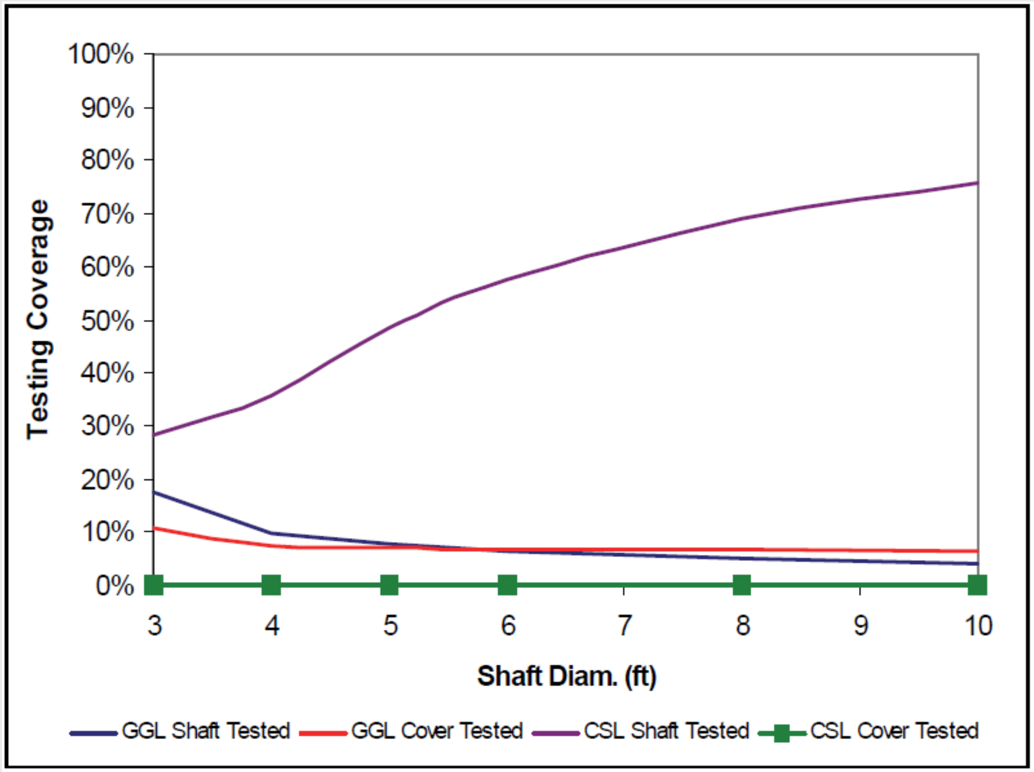


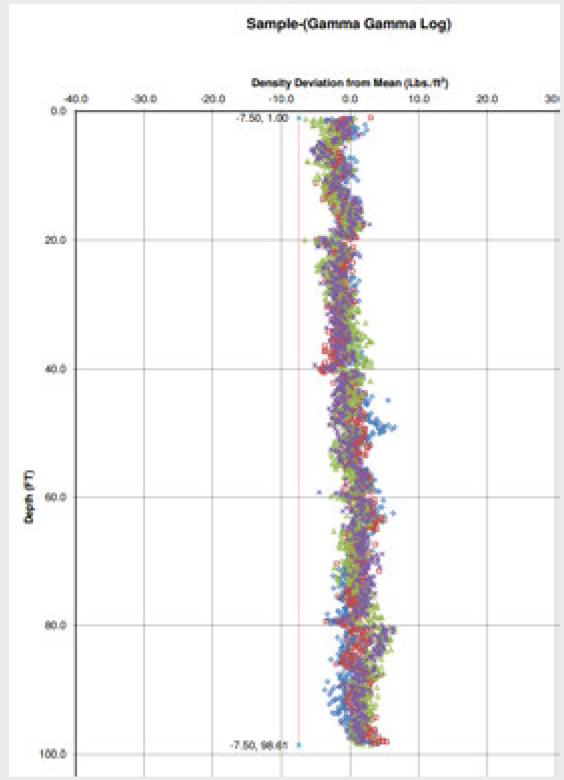
Gamma Gamma Logging (GGL)

- Radioactive Cesium-137 lowered into tubes
- Gamma ray counter determines the density of concrete that backscatters the gamma radiation
- Sensor range is 3-4 inches from access tubes (perimeter of the shaft)



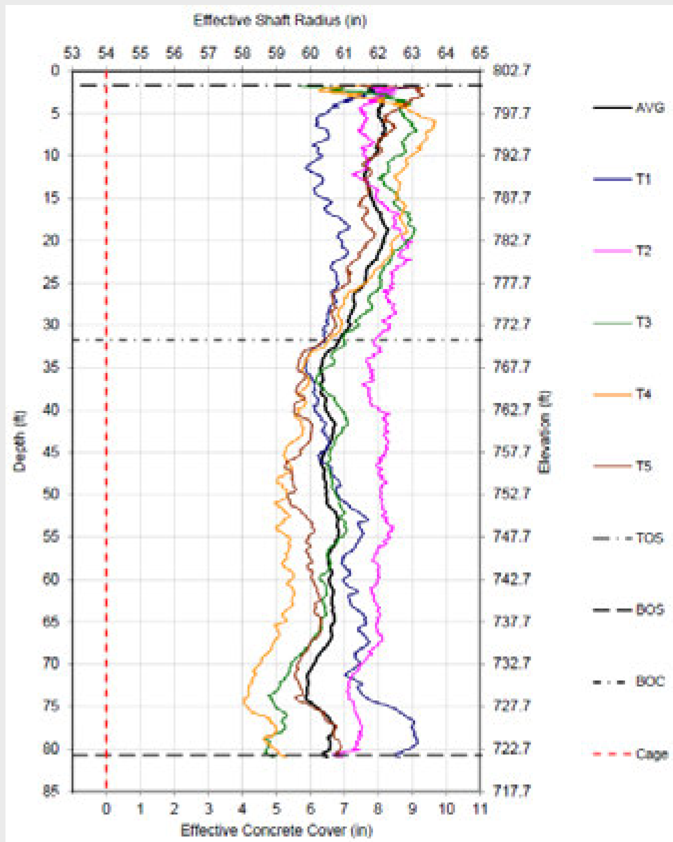
Gamma Gamma Logging (GGL)

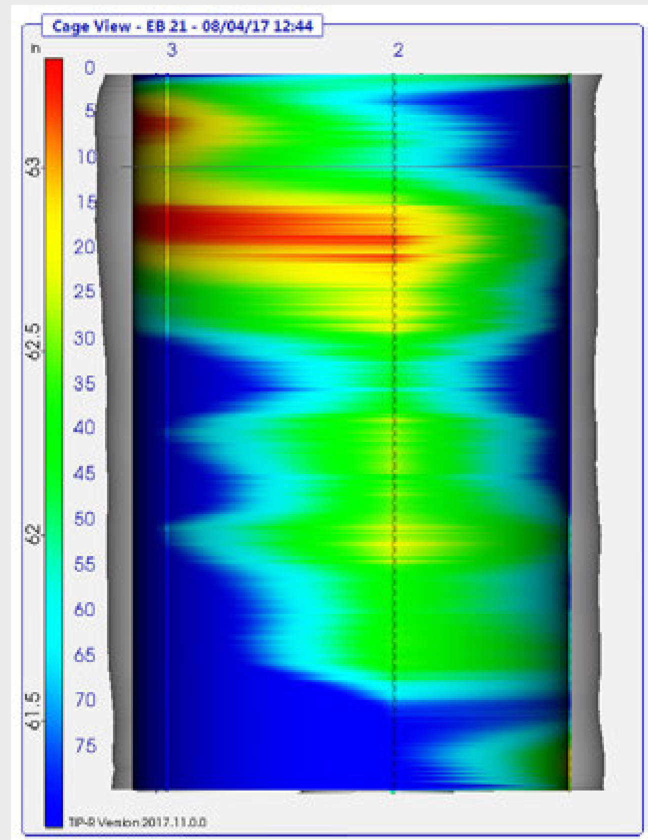




Thermal Integrity Profiling (TIP) Testing

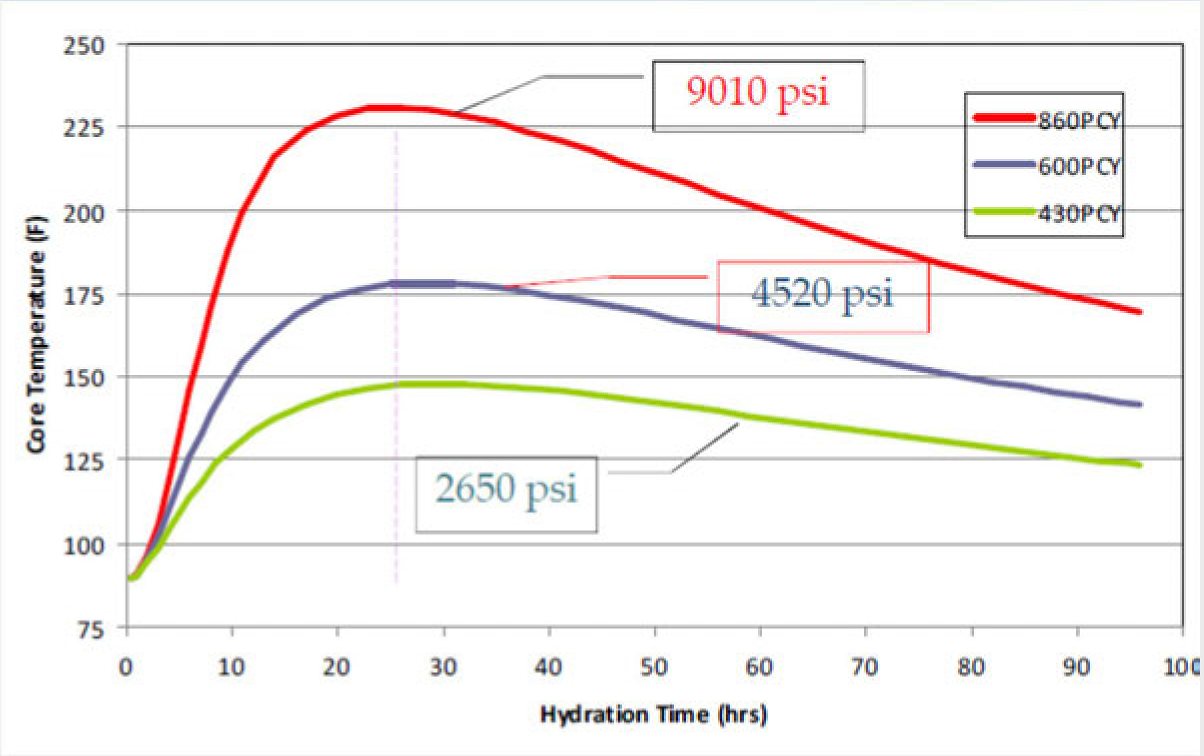
- Use heat generation by curing cement to assess the quality of drilled shafts.
- Developed at University of South FL (2003-2010)





Cement Content Effect on Core Temperature

- Heat generated by curing cement with DS
- Colder than normal indicates necking, inclusions, or poor quality concrete
- Warmer than normal indicates bulges



2024 Special Specification 4003

2024 Specifications 4003

Special Specification 4003

Thermal Integrity Profiler (TIP) Testing of Drilled Shafts

Texas Department of Transportation

- Statewide Special Specification
  - Report requirements
  - Testing procedure
  - Equipment requirements
  - Pay items

2024 Special Specification 4003

2. EQUIPMENT

Supply all materials and equipment required to perform TIP tests. Equipment to perform the test must have the following minimum requirements.

2.1. **Probe or Wire Option**. A computer-based TIP data acquisition system for display of signals during data acquisition (probe only option) or to monitor temperature versus time after casting (wire only option).

2.2. **Probe Only Option**. Thermal probe with four infrared sensors equally spaced at 90° around the perimeter that read temperatures of the tube wall to within 1°F accuracy. The probes must be less than 1-1/4 in. in diameter and must freely descend through the full depth of properly installed access tubes in the drilled shafts; have one depth encoder sensor to determine probe depths; and be capable of collecting data at user-specified depth increments.

2.3. **Wire Only Option**. Ability to collect data at user-defined time intervals (typically 15–60 min.).

3. TESTING PROCEDURE

Conform to testing procedures in accordance with ASTM D7949.

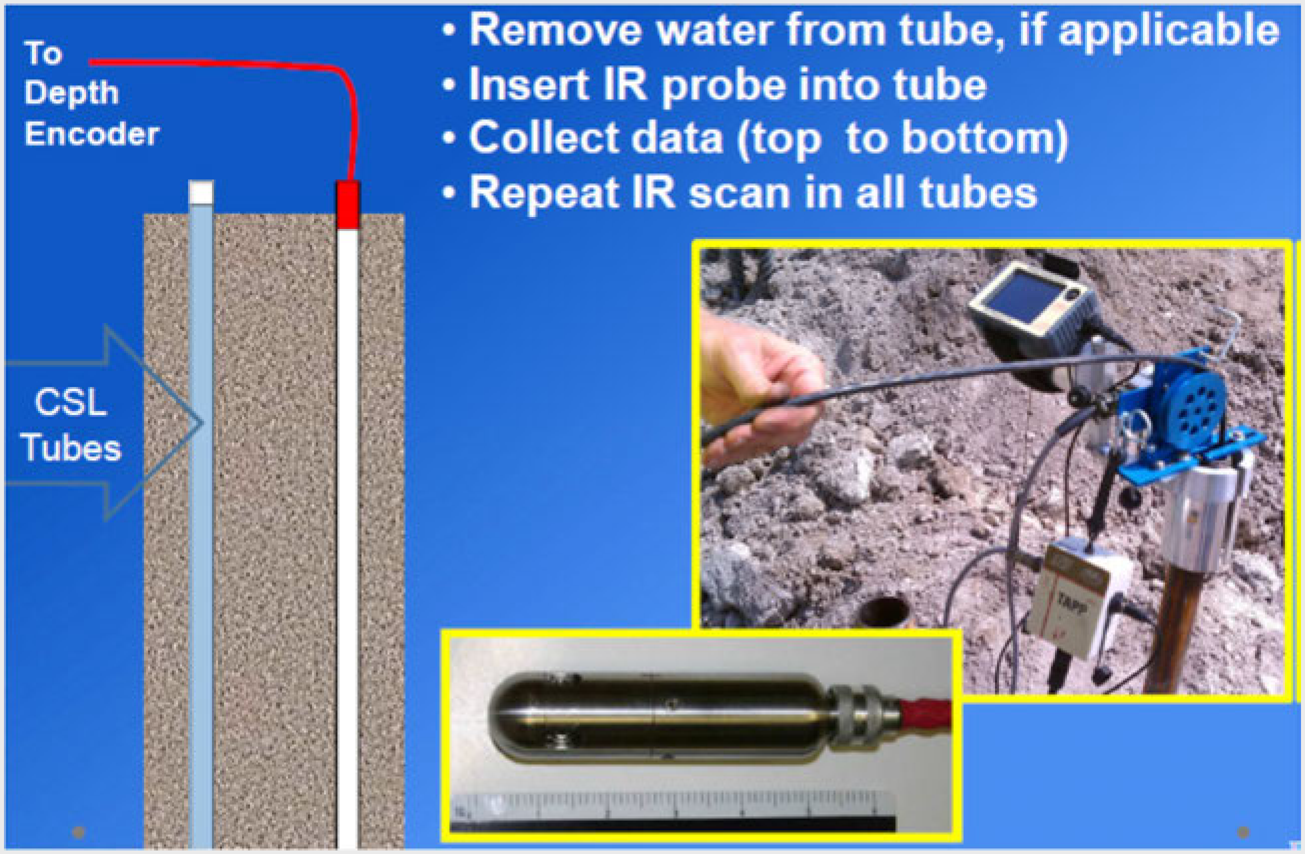
ASTM 7949

Designation: D7949 – 14

Standard Test Methods for Thermal Integrity Profiling of Concrete Deep Foundations[1]

- Heat generated by curing cement with DS
- Method A – access ducts running length of shaft
- Method B – multiple (at lease 4) embedded thermal sensors attached to the reinforced cage (around perimeter) installed during construction

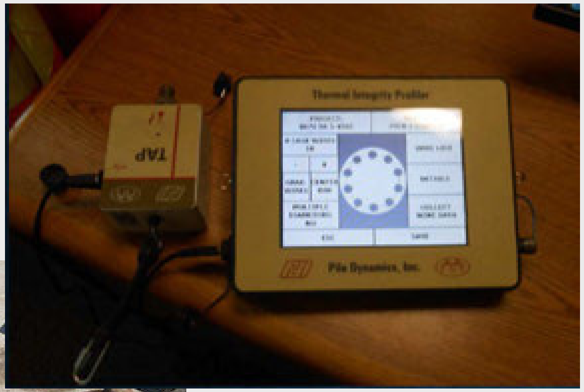
Method A – Probes in CSL tubes



c/o Pile Dynamics, Inc.

Method B – Thermal Wires on Rebar Cage

- Thermal Wire cable ha sensors every 1ft, along full length, typically 4 wires or more evenly spaced on cage
- Thermal Acquisition Ports (TAP) box attached to each wire
- Temperature recorded every 15min, using TIP tablet or computer



Method B – Wire Placement

4. TEST RESULT REPORTING

Submit a written report within 5 working days of completion of testing. The report must present results of TIP tests by including the following.

4.1. **Graphical Displays**. Provide graphical displays of all temperature measurements (probes or wires) versus depth.

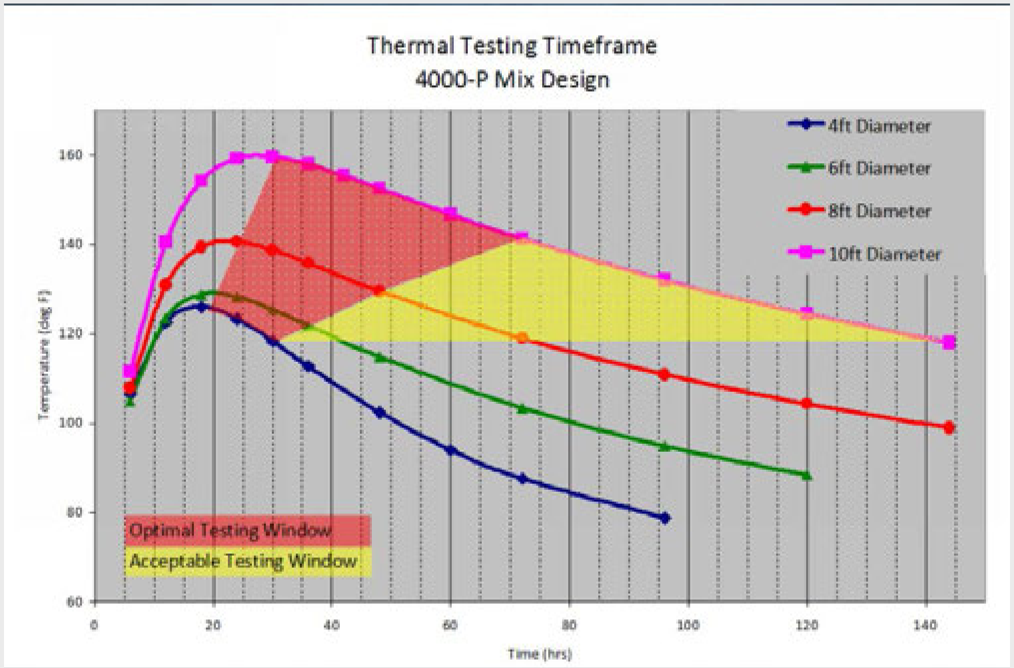
4.2. **Significant Temperature Deviations**. Report indication of unusual temperatures, particularly significantly cooler local deviations of the average at any depth from the overall average over the entire length, in either probe or thermal wire measurements.

4.3. **Overall Average Temperature**. This temperature is proportional to the average radius computed from the actual total concrete volume installed (assuming a consistent concrete mix throughout). Radius at any point can then be determined from the temperature at that point compared to the overall average temperature.

4.4. **Temperature Variation**. Report variations in temperature between tubes (at each depth) that in turn correspond to variations in cage alignment. Where concrete volume is known, report the cage alignment or offset from center.

4.5. **Shaft-Specific Information**. Report shaft-specific construction information (e.g., elevations of the top of shaft, bottom of casing, and bottom of shaft) when available. These values must be noted on all pertinent graphical displays.

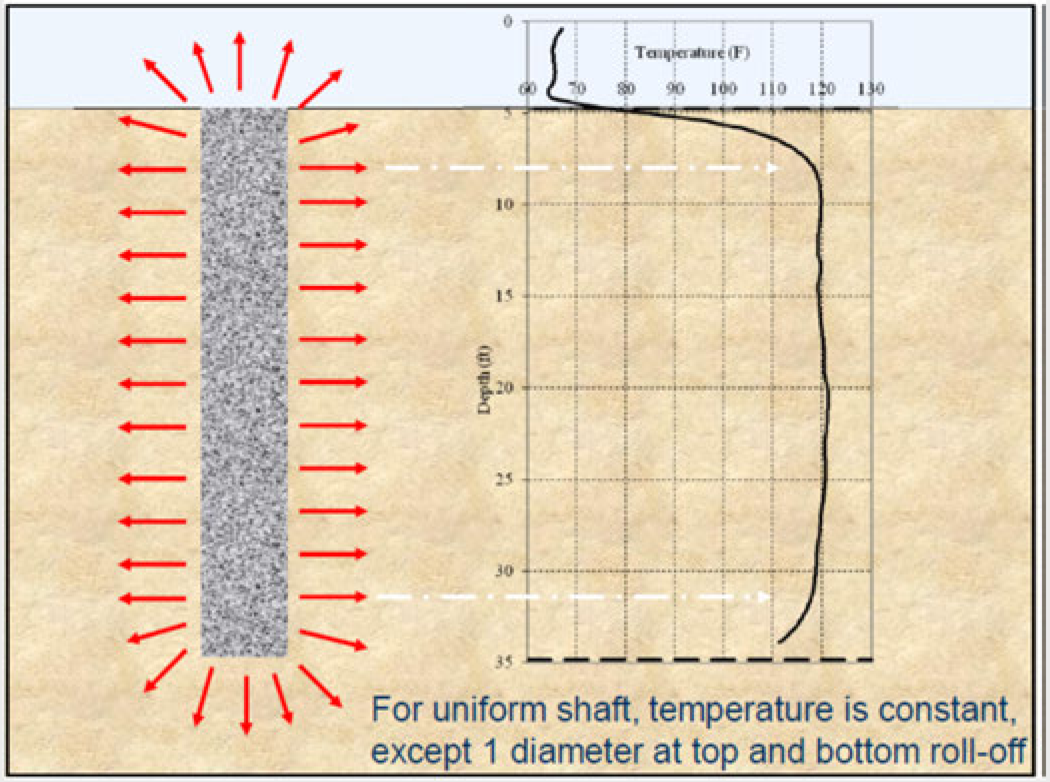
TIP Testing Timeframe



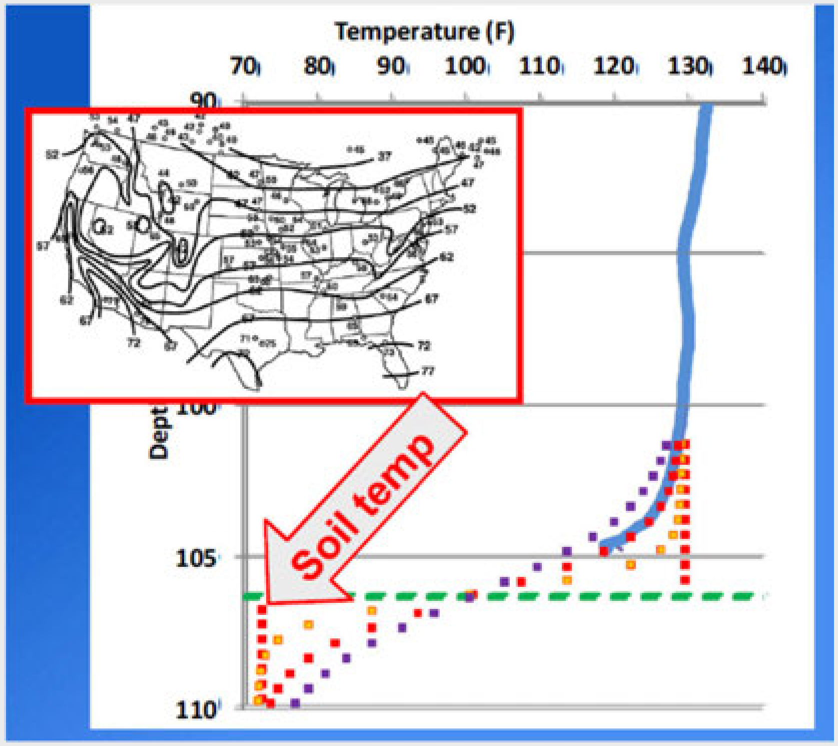
c/o Washington DOT

Most vendors start testing ~12hrs following concrete placement

Effects at Ends

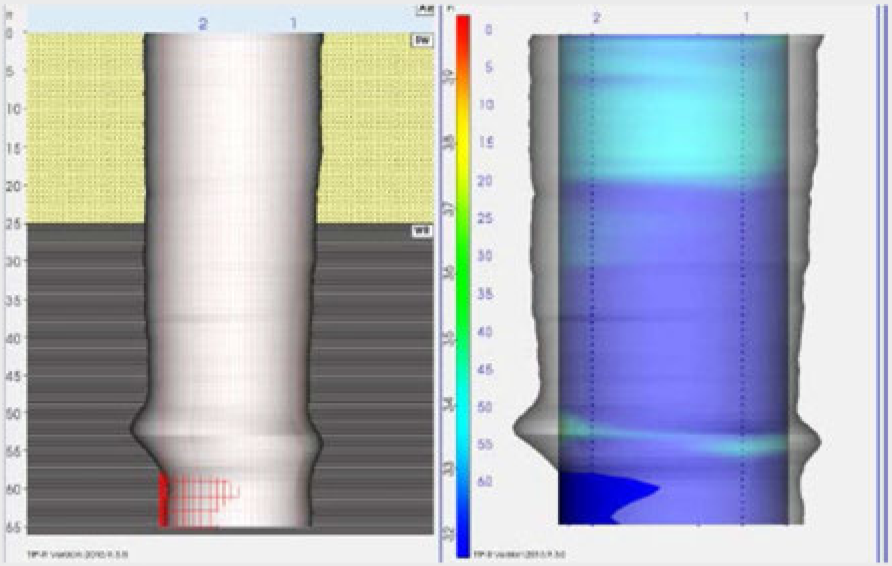


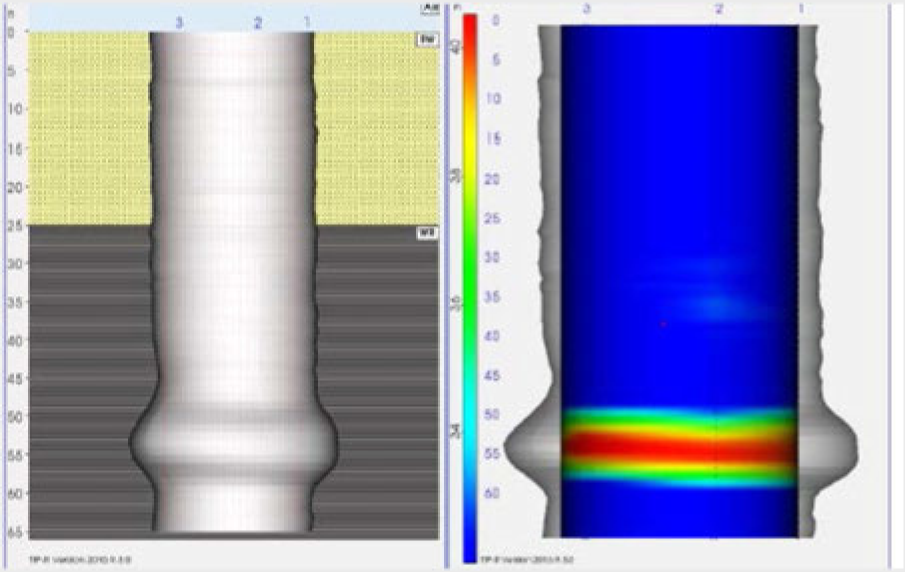
Correction of Temperature at Toe – Bottom Roll Off



Example TIP Results

- Results from multiple wires interpolated to produce 3 dimensional result

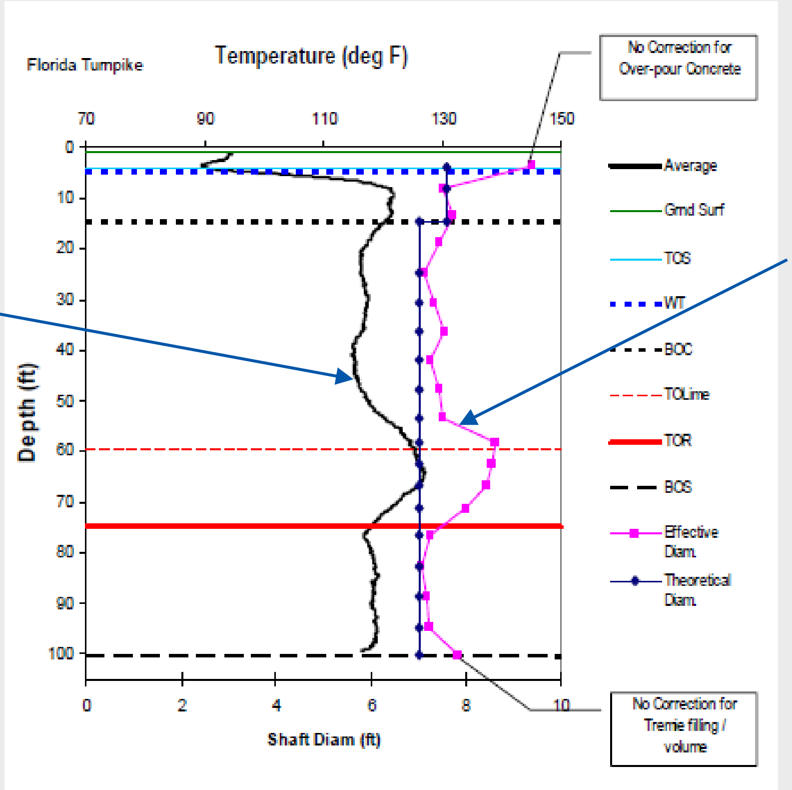




TIP Tests Compared to Concrete Volumes

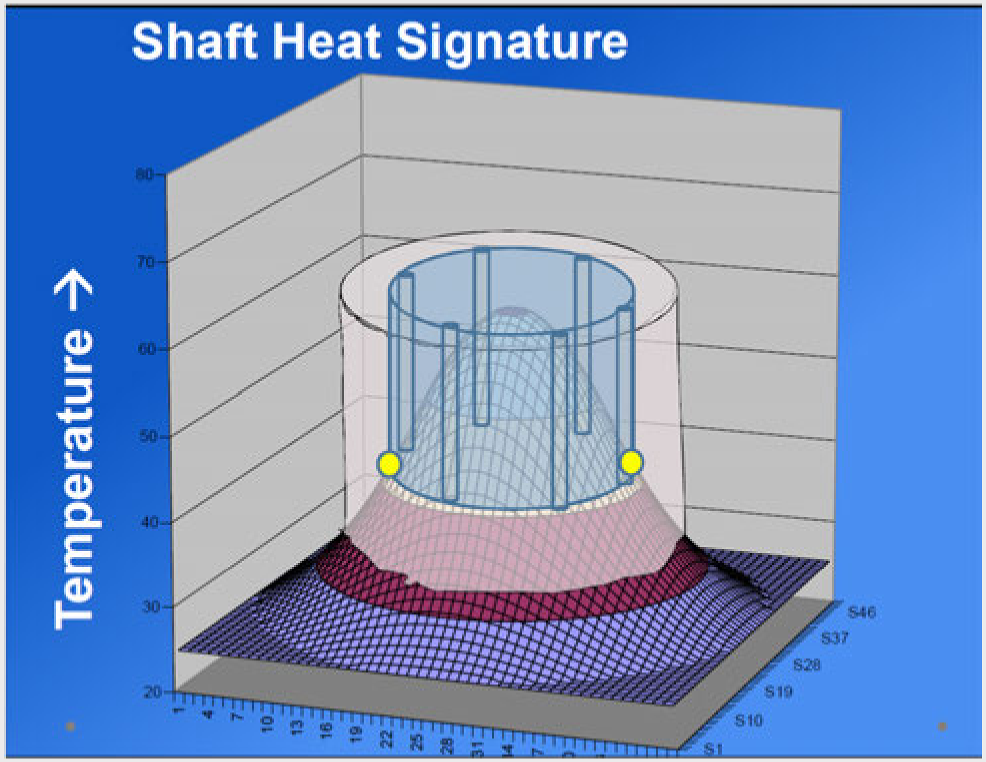
- 3-D profile calibrated from thermal profile and recorded concrete volumes

TIP Results

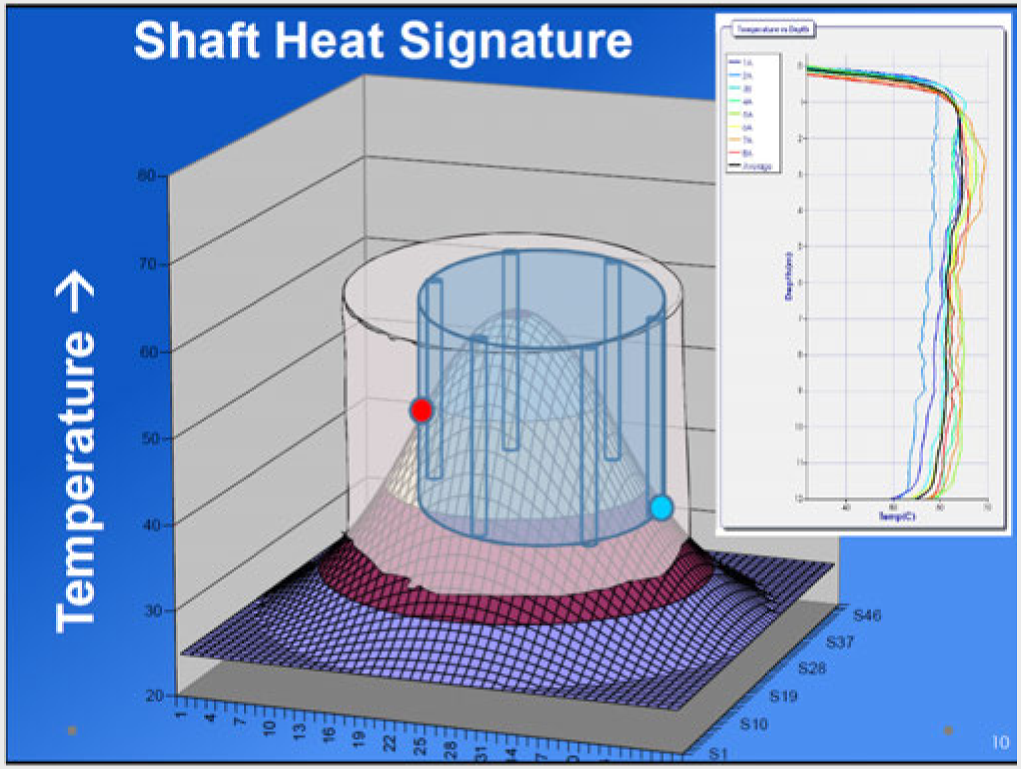


Effective Diameter From Concrete Logs

Rebar Cage Centered



Rebar Cage Off-Center



Shaft Acceptance Criteria

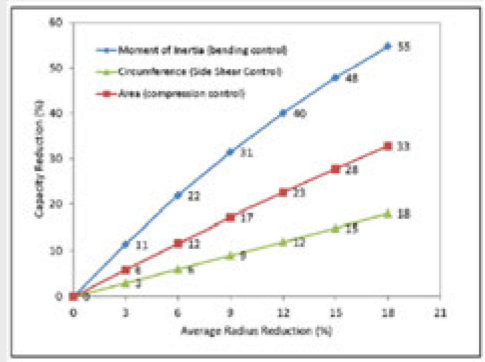
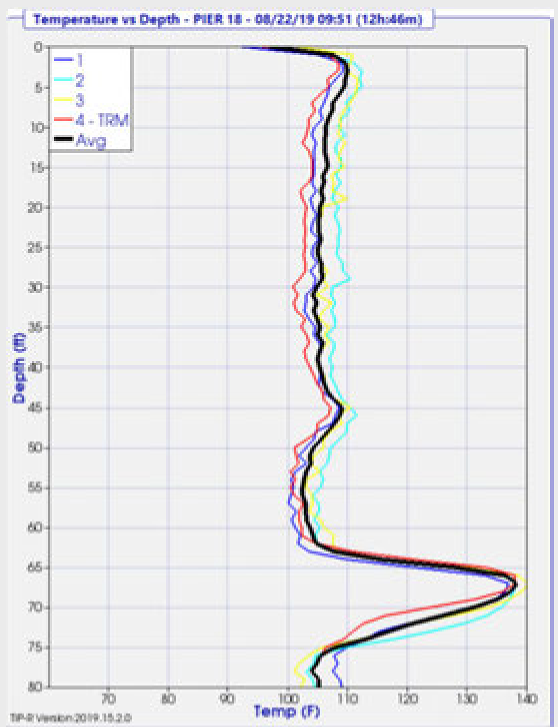


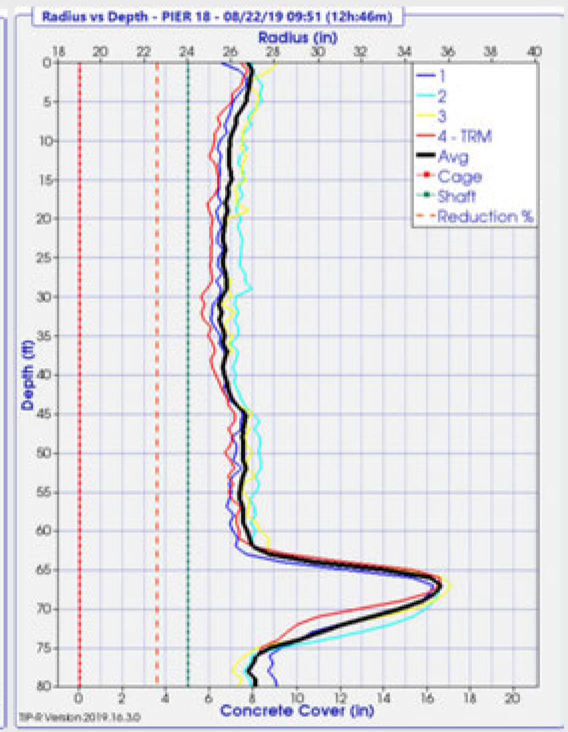
Figure H. Effects of average shaft radius reduction on capacity.

- Average shaft radius and cover
- Local shaft radius and cover
- Geometry Criteria
  - Satisfactory (S) : If, 0 to 6% Effective Radius Reduction and Cover Criteria Met
  - Questionable (Q) : If, Effective Local Radius Reduction > 6% or Effective Local Average Diameter Reduction > 4% or Cover Criteria is NOT Met
- The ultimate decision should be made by the Engineer of Record

TIP Testing Examples

- Bulged radius from 27 to 35.5 inches (48 in Diameter Drilled Shaft)





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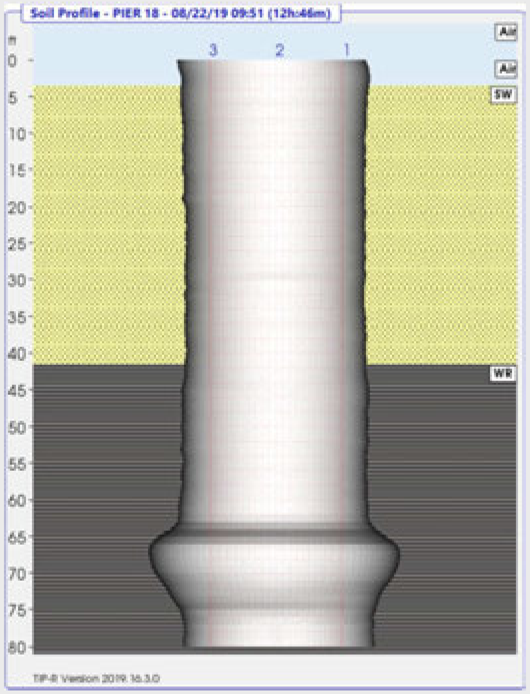
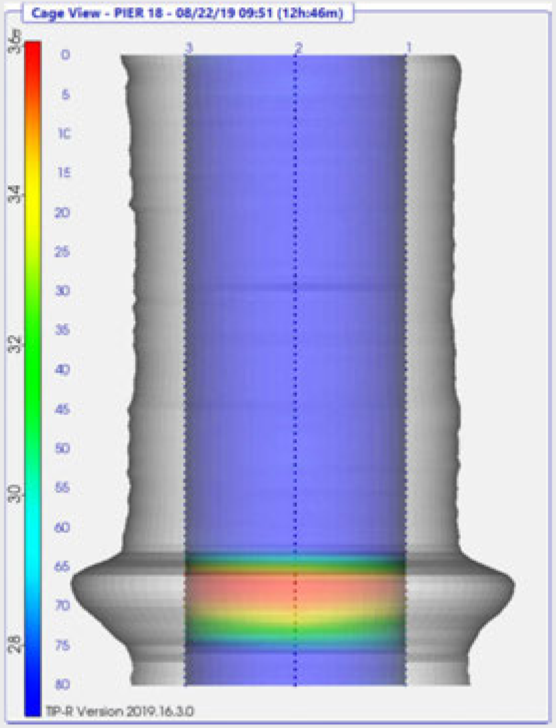


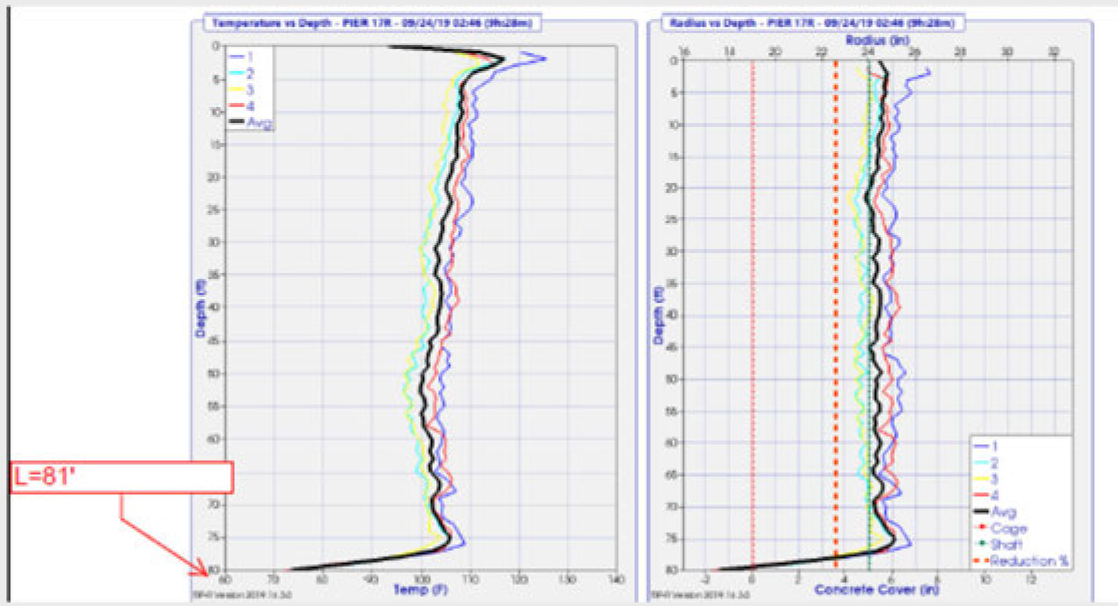


TIP Testing Examples

- Concrete volume placed of 39 CY is ~103% theoretical

- Bottom 2 feet of shaft, reductions of > 6% of the nominal radius (48 in Diameter Drilled Shaft), minimum effective radii is 17.5 inches

- Classified as Questionable (Q), slice of effective area estimates 962 sq.in. from nominal 1809 sq.in.



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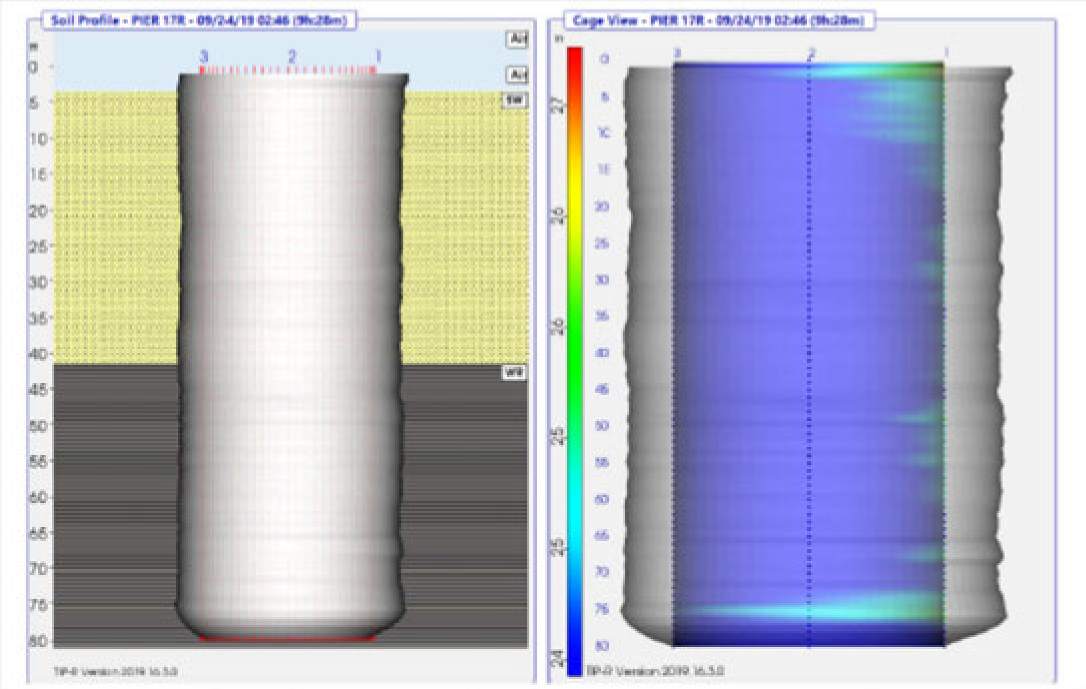

TIP Testing Examples

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Effective Diameter

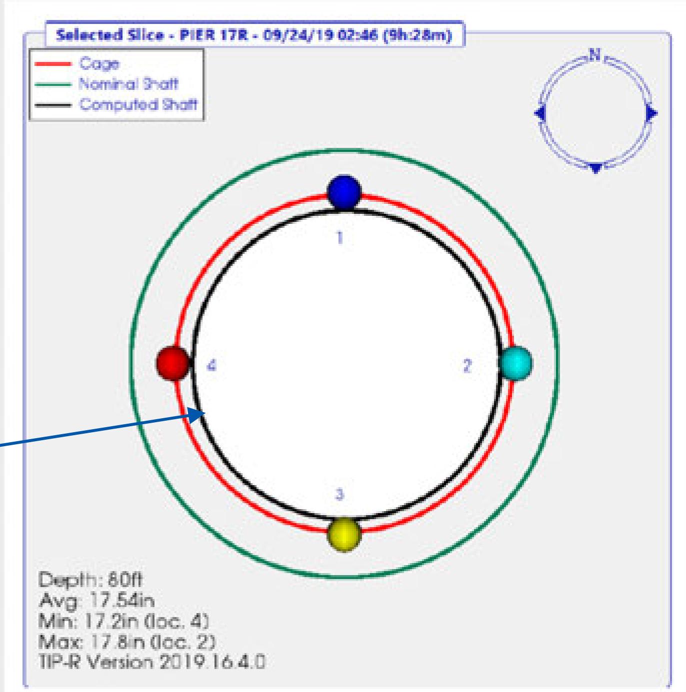


Figure 7: Selected Slice at a Depth of 80 Feet

Drilled Shaft Design Considerations

- Review the borings carefully
- Design conservatively when dealing with water bearing sand
- Consider adding TIP testing (SS 4003) with the following three criteria
  - Monoshafts
  - Large-diameter shafts
  - Water-bearing sands
- Consider adding Foundation Load Testing (Item 405) to use alongside TIP

TIP Testing Usage Considerations

- TIP testing is a construction quality control
- Usage variables
  - Difficulty to install
  - Redundancy
  - Quantity
  - Site variability
- TIP testing is more effective earlier on a project
  - Verify Contractor’s procedure is producing an acceptable result

TIP Testing Usage Considerations

- Testing frequency – project specific decision
  - Monoshafts
    - High-frequency
  - Large-diameter shafts
    - Depends on soil and water indications from borings
    - Depends on depth
  - Water-bearing sands
    - Depends on variability of soil

Contractor Notes - Testing

- May or may not include load testing

Testing Notes:

1. Thermal Integrity Profiler (TIP) Testing of Drilled Shaft (SS 4021): Perform the nondestructive testing (NDT) method termed Thermal Integrity Profiler (TIP) testing to check the integrity of designated production drilled shafts as shown in the table below. Testing shall be coordinated with the Engineer a minimum of one week prior to the desired testing date. The Engineer will choose the drilled shafts to be tested.

2. High Strain Dynamic Testing of Drilled Shaft (Item 405 Foundation Load Test): High Strain Dynamic Testing may be performed on the production drilled shaft suspected to be a deficient drilled shaft based on TIP testing result and/or shaft installation record. Furnish all materials, equipment, and labor necessary to conduct the high strain dynamic testing of drilled shaft. Testing shall be coordinated with the Engineer a minimum of one week prior to the desired testing date. TxDOT personnel shall be present during testing.

Example Project

TABLE OF ESTIMATED QUANTITIES

BID ITEM DESCRIPTION / BRIDGE ELEMENT	0405 6003	0416 6006	0420 6031	0420 6037	4021 6001	4027 6001
	FOUNDATON LOADTEST(D49 45)(DRILLD SHAFT)	DRILL SHAFT (48 IN)	CL C CONC (CAP)(MASS)	CL C CONC (COLUMN)	TIP TESTING(DRILL SHAFT)	TEMP CONSTRUCTION ACCESS
	EA	LF	CY	CY	EA	LS
21 ~ Approach Bent Rehabilitations	2	3214	913.5	13.0	11	
OVERALL TOTALS:	2	3214	913.5	13.0	11	1

FOUNDATION NOTES:

Contractor's attention is drawn to the water bearing sand in the borings. There is also the possibility of artesian water conditions as described in the borings. The Contractor is responsible for stability of the drilled shaft holes.

Permanent casing is required at all drilled shaft locations. Casing will be subsidiary to Item 416, "Drilled Shafts." Final permanent casing to extend from the top elevation to the bottom elevation shown in the Drilled Shaft Casing Table below.

Thermal Integrity Profiler (TIP) Testing of Drilled Shaft (SS 4021): Perform the nondestructive testing (NDT) method termed TIP testing to check the integrity of designated production drilled shafts as shown in the table below. Coordinate testing with the Engineer a minimum of one week prior to the desired testing date. The Engineer will choose the drilled shafts to be tested.

High Strain Dynamic Testing of Drilled Shaft (Item 405 – Foundation Load Test): High Strain Dynamic Testing may be performed on any production drilled shaft suspected to be a deficient drilled shaft based on TIP testing result and/or shaft installation record. Furnish all materials, equipment, and labor necessary to conduct the high strain dynamic testing of drilled shaft. Coordinate testing with the Engineer a minimum of one week prior to the desired testing date. TxDOT personnel will be present during testing.

Questionable Shaft – Next Steps

- Reevaluate capacity with tested dimensions
- Performance check with static or dynamic load test
- Recheck with CSL or sonic pulse echo
- Core the shaft to check for quality

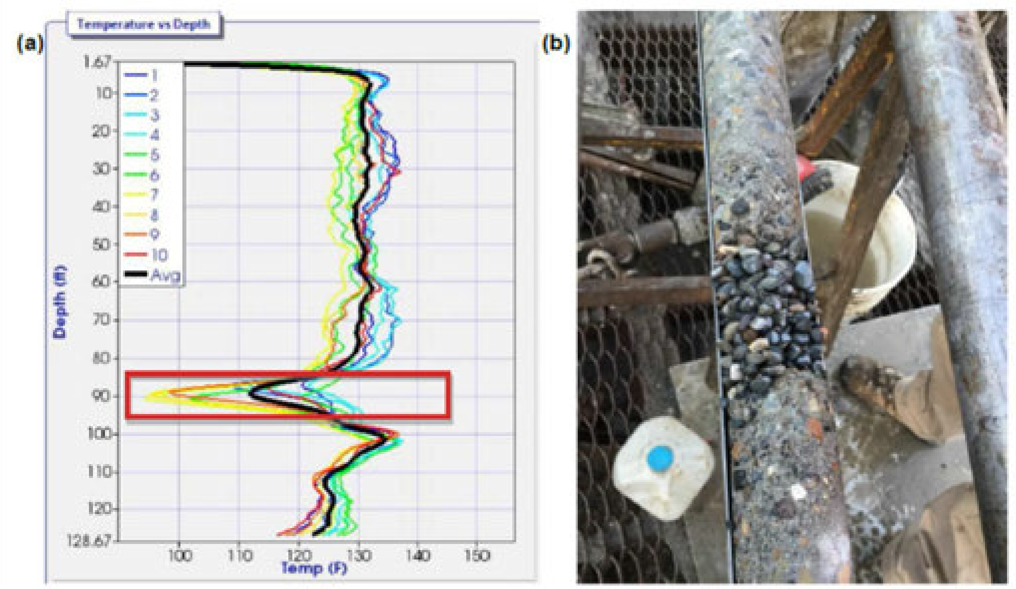


Figure 4: Example TIP result from Piscalko et al. (2016): (a) TIP record and (b) core photograph from a depth of 90 ft.

Piscalko, G., G. Likins, and G. Mullins (2016), "Drilled Shaft Acceptance Criteria Based Upon Thermal Integrity Profiling," Proceedings of the 41st Annual Conference on Deep Foundations: New York, NY, Deep Foundations Institute, 10 p.

Dynamic Testing

- Alternative to Static Load tests
  - Less Expensive
  - Less Time Consuming

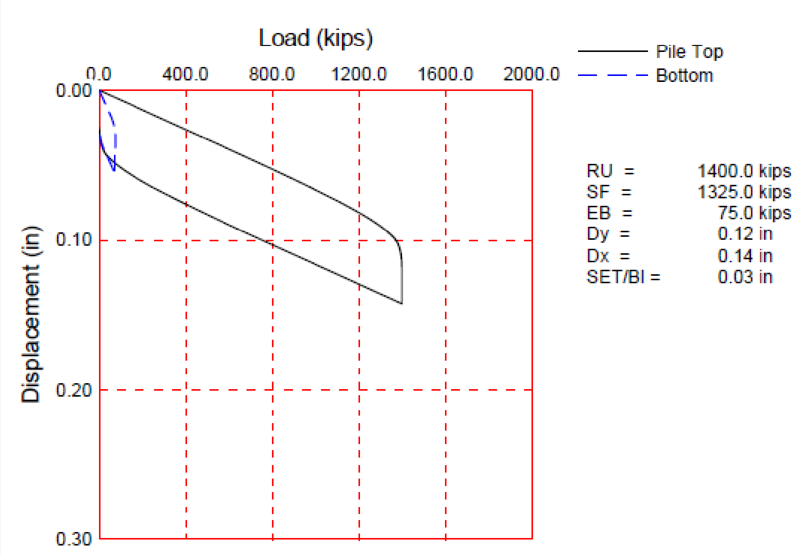
Drilled Shaft Load Testing

- Uses same concept and equipment as PDA testing method for Piling
  - Drop hammer apparatus on installed drilled shaft
  - Drop Weight is 2%-5% of target ultimate capacity
  - Able to provide shaft integrity information as well as predicted capacity

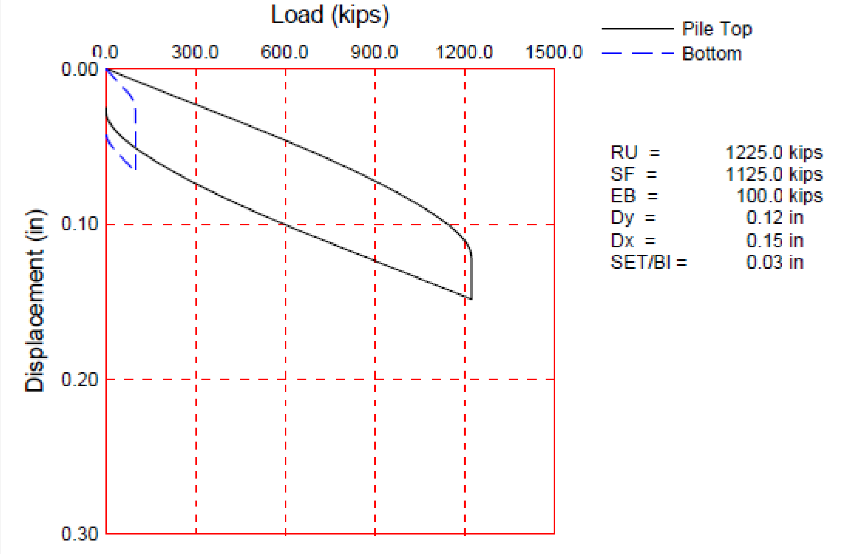
Test Results

- Nearly 2x ultimate capacity and minimal movement

Bent 17



Bent 27

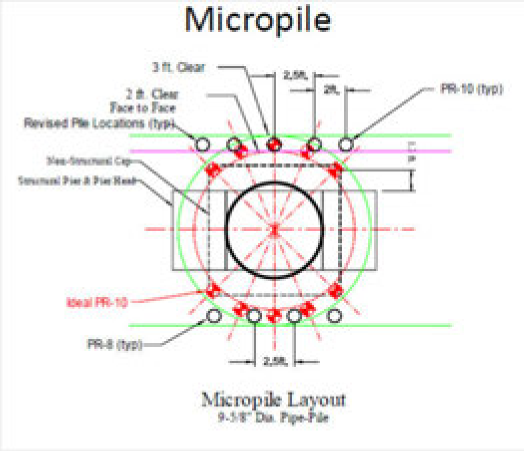


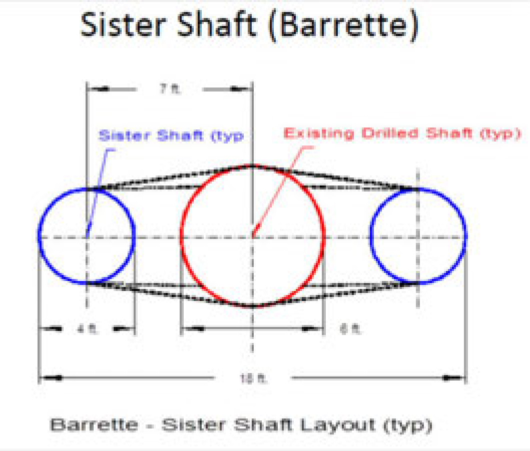
Results

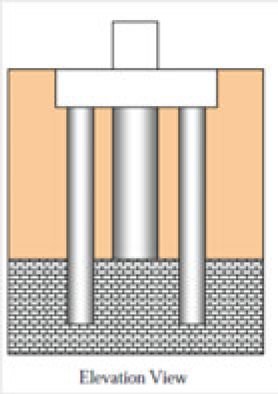
- Able to verify in place capacity exceeded ultimate capacity

Remediation Options

- Design evaluation
  - Capacity
  - Long-term durability
- Shaft Repair
- Shaft Abandonment
  - Drilling sister shafts or micropiles







TIP Testing Overview

- Advantages
  - Evaluate concrete quality and rebar cover/alignment
  - Complete cross section of the shaft
  - Test early after casting (12 to 100hr) w immediate results
- Disadvantages
  - Must plan and install wires or access tubes before installation
  - Must test during early curing of foundation

Conclusions

- Evaluate need and frequency for integrity testing based on:
  - Drilling difficulty and soil
  - Redundancy
  - Soil Variability
  - Number of different elements
  - Drilled shaft geometry
    - Diameter
    - Length

Questions?

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Questions:

What is the best testing method to help us understand the reduction in capacity due to an abandoned shaft (collapsed on top of the auger) 6" away from the proposed shaft?

Better to specify load testing if there are concerns about capacity. Any integrity test methods would help you understand if the proposed shaft is constructed correctly.

Do you expect to require TIP testing for any specific situations in the near future, or will the requirement remain as determined by the engineer?

(Standard Bridges) Determined by the engineer with recommendations for use found in the geotechnical manual. Railroad bridges have more strict guidance for requiring the testing on those projects.

Would you recommend TIP testing for large monoshafts for hammerhead bents? What if those shafts are in very hard rock?

Yes, but quantity of the testing is project specific. Monoshafts, especially 60" or greater in diameter have no redundacy in design and have a high level of complexity to install. Integrity testing is a reliable means to QC the contractors end product that is 'hidden' underground. Socketing in hard rock? This would build more trust that hole would note collapse and EOR would be justified to use 50% less testing than sites installing shafts into unfavorable soils.

What percentage of drilled shafts should be tested (assuming not monoshaft)?

For shafts meeting criteria in Geotech manual for recommending integrity testing, opt for at least 2 shafts per bridge. Depending on how critical the shafts are in design or how bad the subsurface is, often a good idea to spec 1test/bent.

Does division have a preferred drilled shaft testing method (TIP, CSL, etc)?

TIP is preferred but CSL is also approved

Do you have any guidance to correlate the number of CSL tubes to the shaft diameter?

Min. 4 tubes per shaft. And use minimum number of tubes equal or greater than the shaft diameter in Feet. i.e., 5ft shafts; use 5 or more tubes. And make sure tubes are equally spaced along the perimeter of the cage.

Is there a maximum drilled shaft length for Sonic Echo Testing to still be effective?

Have seen reliable results in precast piles and drilled shafts down to 50-60ft.. But sensitivity of the receivers and uniformity of the soil you are embedding piles/shafts into would allow for deeper. Depending on project.
Vendor specific guidance claims it can be reliably used to a depth of 20xDiameter.. In other words, 60' on a 3ft shaft, or 80' on a 4ft shaft.