TIP Testing Drilled Shafts

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Why Do We Test Integrity?

c/o Pile Dynamics, Inc.
Drilled Shaft Construction Common Problems

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

c/o FHWA GEC 10, after Baker et al., 1993; O’Neil, 1991
Drilled Shaft Construction Common Problems

- Bulge or necking in shaft – not casing soft zones, pulling temp. casing w/ concrete adhering
- Caving of shaft wall – improper casing or slurry
- Horizontal 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

c/o FHWA GEC 10, after Baker et al., 1993; O’Neil, 1991
Drilled Shaft Size

Drilled Shaft Diameter:

Borehole theoretical diameter and cross section is estimated based on diameter of the drilling tools used. When more accurate measurements are needed (load test or to check for cavities), check profile with calipers.

Borehole Caliper and Logs:

Borehole caliper measurements are recommended for primarily test shafts. Can be mechanical type with outreaching arms, or modern sonic caliper which senses the wall sides from a suspended probe.
Types of Concrete Anomalies

- Low strength concrete
- Slurry mixed concrete
- Semi-cemented material
- Soil-concrete mixtures
- Soil and sediment
Concrete with low cement fraction will not reach the strength anticipated and designed for.

Do not forget the effect of additives.
Conventional Methods

- External - Sonic Echo Testing / Pulse Echo
- Internal - Cross-hole sonic logging (CSL)
- Internal - Gamma Gamma (GGL)
Crosshole Sonic Logging (CSL)

![CSL Diagram]

- Testing Coverage vs. Shaft Diameter
- 6 ft diameter replacement shaft on I-35W in Minneapolis

Source: c/o FHWA and Pile Dynamics, Inc.
Gamma Gamma Logging (GGL)

[Graph showing testing coverage vs. shaft diameter (ft).]

Sample (Gamma Gamma Log)

[Graph showing density deviation from mean (lb/ft³) vs. depth (ft).]
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)
Newer Method - TIP

- 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

- 9010 psi
- 4520 psi
- 2650 psi

C/o Pile Dynamics, Inc.
Special Specification 4021

Thermal Integrity Profiler (TIP) Testing of Drilled Shafts

1. DESCRIPTION

Perform the nondestructive testing (NDT) method termed Thermal Integrity Profiler (TIP) testing by obtaining

- Heat generated by curing cement with DS
- Colder than normal indicates necking, inclusions, or poor quality concrete
- Warmer than normal indicates bulges
- ASTM D 7949
ASMT D 7949

Standard Test Methods for Thermal Integrity Profiling of Concrete Deep Foundations

1. Scope

1.1 These test methods provide procedures for measuring the temperature profile within a deep foundation element constructed using cast-in-place concrete, such as bored piles, (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.6 Units—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this

- Method B – multiple (at least 4) embedded thermal sensors attached to the reinforced cage (around perimeter) installed during construction

- Method A – access ducts running length of shaft
Contractor Notes / 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.

May or may not include Load Testing
Method B – Thermal Wires on Rebar Cage

Thermocouple Wire
Method B – Thermal Wires on Rebar Cage
Method B – TAPS Connection Boxes are Protected

c/o Washington DOT
Method B – Thermal Wires on Rebar Cage

- Thermal Wire cable had 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
Most vendors start testing ~12hrs following concrete placement.

TIP Testing Timeframe

Thermal Testing Timeframe
4000-P Mix Design

- Optimal Testing Window
- Acceptable Testing Window

Most vendors start testing ~12hrs following concrete placement

C/o Washington DOT
Method A – Probes in CSL existing tubes

- Remove water from tube, if applicable
- Insert IR probe into tube
- Collect data (top to bottom)
- Repeat IR scan in all tubes
Effects at Ends

For uniform shaft, temperature is constant, except 1 diameter at top and bottom roll-off.
Correction of Temperature at Toe – Bottom Roll Off

Soil temp

Temperature (F)

70 | 80 | 90 | 100 | 110 | 120 | 130 | 140

c/o Pile Dynamics, Inc.
Example TIP Results

- Results from multiple wires interpolated to produce 3 dimensional result
TIP Tests Can Supplement Concrete Volumes Poured in Field

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

![Graph showing Florida Tampke temperature and effective diameter from concrete logs with reference to TIP Results and 3D profile calibrated from thermal profile and recorded concrete volumes.](attachment:image.png)
Rebar Cage Centered and Good Cementing

Shaft Heat Signature

Temperature ↑

c/o Pile Dynamics, Inc.
Rebar Cage Off Center

Shaft Heat Signature

Temperature

-40° C to +10° C

S46 S37 S28 S19 S10 S1

c/o Pile Dynamics, Inc.
Thermal Integrity Profiling (TIP) Testing

Level 1 Reporting : Field / Direct Obs.

- Verify shaft length
- Confirm cage alignment
- Locate changes in diameter, immediate areas of concern

Level 2 Reporting : Add Field Records

- Correlate concrete records to temperate profile
- Compare to planned radius, shape and cover
- Reporting and identify anomalies
- Qualify shafts for acceptance based on radius and cage cover
Typical Reporting and Classification

• From: avg/local shaft radius & cover; and the rebar cage alignment
• 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

Concrete cover per contract plan. Typical minimum cover – 3”

Ultimate decision should be made by the Engineer.
# Example project

## Table of Estimated Quantities

<table>
<thead>
<tr>
<th>Bridge Element</th>
<th>0405 6003</th>
<th>0416 6006</th>
<th>0420 6023</th>
<th>0426 6037</th>
<th>0421 6001</th>
<th>0427 6001</th>
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</thead>
<tbody>
<tr>
<td>Foundation (10’ x 4’ x 20’ x 4’ x 12’)</td>
<td>EA</td>
<td>LF</td>
<td>CY</td>
<td>CY</td>
<td>EA</td>
<td>LS</td>
<td></td>
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<tr>
<td>ZI - Approach Bank Modifications</td>
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<td>3214</td>
<td>913.5</td>
<td>13.0</td>
<td>11</td>
<td></td>
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<tr>
<td>Overall Totals</td>
<td>2</td>
<td>3214</td>
<td>913.5</td>
<td>13.0</td>
<td>11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Foundation Notes:

Contractor’s attention is drawn to the water bearing layer in the borings. There is also the possibility of aridic granular sediments as described in the borings. The Contractor is responsible for stability of the drilled shaft holes.

Per Section C.2.1.2, casing is required at all drilled shaft locations. Casing will be fabricated to item 439, Drilled Shafts. Prior permission casing to extend from the top elevation to the bottom elevation shown in the Drilled Shaft Casing Table below.

- Thermal Integrity Provider (TIP) Testing of Drilled Shaft (55-4922).
- Conduct the load-sustaining testing (LST) method specified in TIP testing to check the integrity of designated production drilled shafts as shown in the table below. Stand-alone 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 (HSD) Testing

- High Strain Dynamic testing may be performed on any production drilled shafts to be fabricated in by a designated dynamic testing and TIP testing result under shaft installation record. Furnish all materials, equipment, and labor necessary to conduct the High Strain Dynamic testing to drilled shafts. Coordinate testing with the Engineer a minimum of one week prior to the desired testing date. TIP testing parameters will be provided during testing.
• Bulged radius from 27 to 35.5 inches (48 in Diameter Drilled Shaft)
TIP Testing Drilled Shafts

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

- TIP testing should be considered for use under the following conditions:
  - Monoshafts
  - Large Diameter Shaft (60 inches diameter or greater)
  - Drilled Shafts with diameter > 24 inches encountering water bearing sands & on critical roadways such as interstate systems, high ADT, emergency routes, evacuation routes, etc.
Drilling in Water Bearing Sand

- Cohesionless sand generally requires slurry, casing or both.
- Clean sand drilling below the water table is difficult, and stability is critical.
- Without hole stability, oversized excavation are more likely to produce anomalies in the shaft, and inadequate capacity
• Review borings carefully

• Design conservatively when considering areas of water bearing sands for shaft resistance

• Item 416 (Drilled Shafts), 2014 spec now requires a Drilled Shaft Installation Plan to be submitted by the drilling contractor. Approval or notification of changes will be with in 14 days of submission

• Consider adding TIP Testing (SS 4021) when drilling shafts such as: Large Diameter, monoshafts, in water bearing, or critical roadways

• Consider adding Foundation Load Testing (Item 405), to use alongside TIP
When anomalies occur and integrity is questionable..

Questionable Drilled Shaft?
TIP Testing DS – When Finding Questionable Shaft?

Next Steps

- Check New Capacities on Current Effective dimensions
- Static or Dynamic Load Test with PDA to test performance and check if it is in range of the shaft service load
  - Dynamic Load Testing
- Recheck with CSL (if access tubes are present) and/or sonic pulse echo to check if defects are located with other form of NDT
- Core the shaft and check the quality of the concrete, use downhole video to check concrete

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

- Drill extra shafts (often most feasible)
- Micropiles or sister shafts to support weak capacity DS
  (Know what you are still tipping into and consider reductions for close spacing)
Remediation – Fix Compromised Shaft

• When redesign, replacement and/or schedule is of concern
• Anomalies can be high pressure cleaned through hydro-demolition (bad concrete and/or soil in void is forced out) and pressure grouting used through the cored (access) holes
Advantages

• Evaluate concrete quality and rebar cover/alignment
• Complete cross section of the shaft
• Test early after casting (12 to 100hr) with immediate results

Disadvantages

• Must plan and install wires or access tubes before installation
• Must test during early curing of foundation
FOR ASSISTANCE CONTACT:

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