Verification of Installation and Performance of ACIP Piles for Bridges

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ABSTRACT: The DFI ACIP Pile Committee, in conjunction with the Florida DOT, completed an ACIP Pile installation monitoring and performance test program in late 2016 to advance the inclusion of ACIP piles in future specifications for bridges by state agencies. Piles of different diameters were installed for compression, tension and lateral testing, and one pile was extracted for visual inspection. This paper presents the pile installation, non-destructive testing and load test results of the program.

INTRODUCTION

The Deep Foundations Institute (DFI) Augered Cast-In-Place (ACIP) Pile Committee performed a ACIP pile installation and test program in the fall of 2016 to demonstrate a fully monitored installation of 18-in and 24-in diameter ACIP piles. The program included automated and manual installation monitoring, Thermal Integrity Profiling, compression, tension and lateral load testing (including monitoring of strain gages embedded along the compression pile shaft), and post-testing extraction of an installed pile for visual inspection.

PROJECT DETAILS AND FIELD EXPLORATION

A general program location map along with an aerial view of the property in Okahumpka FL is shown in Figure 1. Two Cone Penetration Tests (CPT) were performed at initial reaction pile locations R-6 and R-8 (Figures 2 and 3)

The results from CPT R-6 indicated very loose soil conditions at depths below 55-ft, indicating potential relic sinkhole conditions. The test layout was subsequently rotated and moved south of CPT R-8.

TEST PILE INSTALLATION DETAILS

Seven piles were installed to either 40-ft or 60-ft below grade. Thermal Integrity Profile (TIP) wires were installed in all piles but varied to include one wire each attached to a steel center bar or one wire attached to the steel center bar AND four additional wires (each) attached the steel reinforcing cage installed in these piles. Additionally, the 24-in lateral and compression piles had four steel or PVC casings installed next to the TIP wires for testing by thermal probe and/or wire inserted into the casing.

Vibrating wire strain gages were installed in the 18-in and 24-in diameter compression piles, by attaching the sister-bar mounted gages to the installed steel center bar near the pile-top and bottom and at 10-ft depth intervals throughout the pile.

Figure 4 is a photograph of the project installation platform and installation equipment. A 750-horsepower hydraulic power unit was mounted on the back of the crawler crane. A gearbox with about 75,000 ft-lbs of maximum torque was attached to the swinging leads suspended from the crane boom.

Pile installations were monitored manually and by Automated Monitoring Equipment (AME). Figure 5 is an example AME record for the 18-in compression pile (C-1). Pile volume during grouting was estimated by manual count of the strokes of the grout pump while the AME included volumes calculated by a magnetic flow meter, calculated for each 2-ft increment of the pile shaft, for comparison.

COMPRESSION LOAD TESTS

Compression tests were performed in general accordance with ASTM D-1143-07. Load was applied by a hydraulic jack and monitored by (1) electronic load cell between the pile and reaction frame and (2) a gage on the jack. Piles were loaded in increments of about 15 tons at approximately 5-minute intervals. The applied load was increased to or above the target load for each increment. Piles were allowed to come to equilibrium during the interval such that the applied load was not decreasing due to either pile-head deflection or reaction frame deflection. The piles were loaded to geotechnical failure; that is until there was continuous vertical movement of the pile-head with the application of no additional load.

Pile-head deflections were recorded from four dial gages at approximately equal spacing around the pile. Figures 6 and 7 are plots of applied load vs. pile-head deflection.

Strain gage data was collected immediately prior to the second dial gage readings just before the end of the load increment. Figure 8 is an estimated of the load distribution with depth of 18-in diameter pile C-1. Figure 9 is a comparison of the measured and predicted unit shaft resistance in pile C-1. Similar unit shaft resistances were measured in 24-in diameter pile C-2.

TENSION LOAD TESTS

Tension tests were performed in general accordance with ASTM D3689-07. Load was manually applied by a hydraulic jack and monitored by (1) electronic load cell between the pile and reaction frame and (2) a gage on the jack. Piles were loaded in increments of about 10 tons (18-in diameter pile T-1) or 15 tons (24-in diameter pile T-2) at approximately 5-minute intervals.

The applied load was increased to or above the target load for each increment. No additional load was applied during the interval between readings. Piles were allowed to come to equilibrium during the interval such that the applied load was not decreasing due either pile-head deflection or reaction frame deflection. The piles were loaded to geotechnical failure; that is until there was continuous vertical movement of the pile-head with the application of no additional load.

Pile-head deflections were recorded from four dial gages at approximately equal spacing around the pile. Figures 10 and 11are plots of applied load vs. pile-head deflection are presented after the text of this report. The steel center bars inserted into the test piles and to which the uplift test load was applied, were not sleeved to keep them from bonding to the grout of the piles. It is considered that the pile grout probably cracked with a few ft below the ground surface and that the recorded deflections are likely a result of a small section of grout moving with the center bar as it stretched as load was applied. It is estimated that about an inch of the observed pile-head deflections is from the stretch of the center-bar and not the movement of the pile.

LATERAL LOAD TESTS

Lateral tests were performed in general accordance with ASTM D3966-07. Target loads above 50% of the estimated free-head capacity were adjusted and a sequence developed to ensure the piles were tested until the head deflection was at least 1-in. Load was applied by a hydraulic jack and monitored by (1) electronic load cell between the pile and reaction frame and (2) a gage on the jack. Hold times were in general accordance with ASTM D3966-07, however, the adjusted sequence incorporated 20-min hold times for the latter portion of the test.

The applied load was increased to or above the target load for each increment. No additional load was applied during the interval between readings. Piles were allowed to come to equilibrium during the interval such that the applied load was not decreasing due either pile-head deflection or reaction frame deflection. The piles were loaded until at least 1-in of pile-head deflection was observed at the level of load application.

Pile-head deflections were recorded from two dial gages at and above the level of application of the load from the hydraulic jack. Figures 12 and 13 are plots of applied load vs. pile-head deflection.

PILE EXTRACTION

One 18-in diameter pile was extracted to manually measure circumference. The pile was pressure-washed as it was extracted, laid horizontally for inspection and circumference was measured at 1-ft intervals (Figure 14). The average interpreted diameter was calculated as 19.2-in. For comparison, the TIP results from the extraction pile are presented in Figure 15. In addition to showing a relatively uniform temperature, indicative of a uniform pile diameter, the interpreted diameters with depth, when adjusted for the volume of grout observed coming out of the ground during installation, show excellent agreement with the manually calculated diameters. A full report of the TIP program for this project will be published by 31 August 2017.

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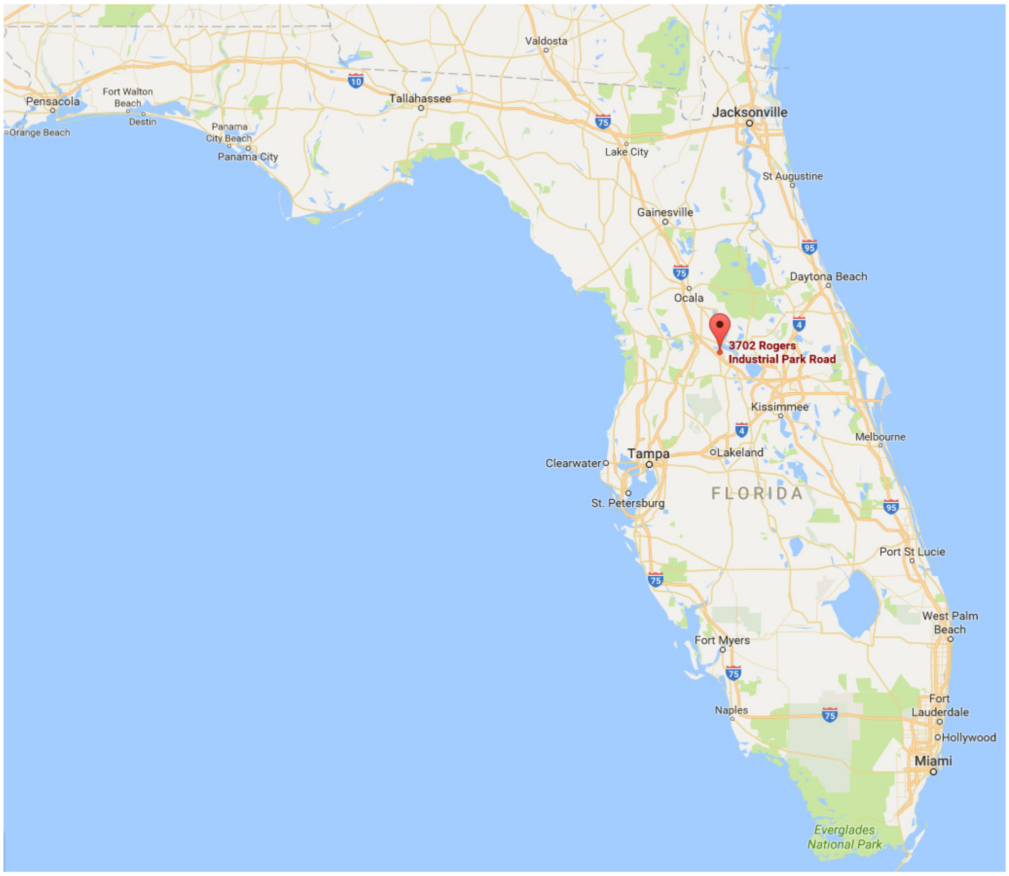

Figure 1. Test Site Location

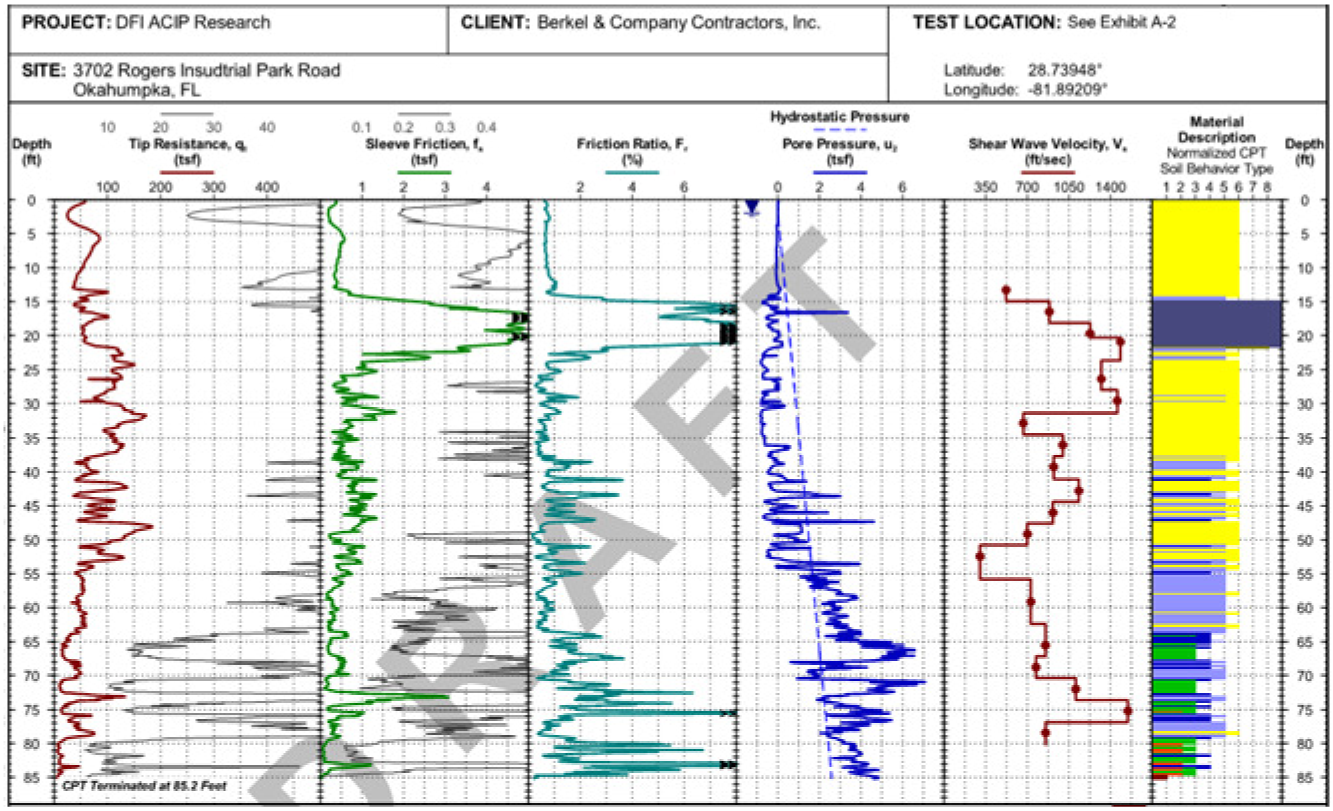

Figure 2 – CPT R-6

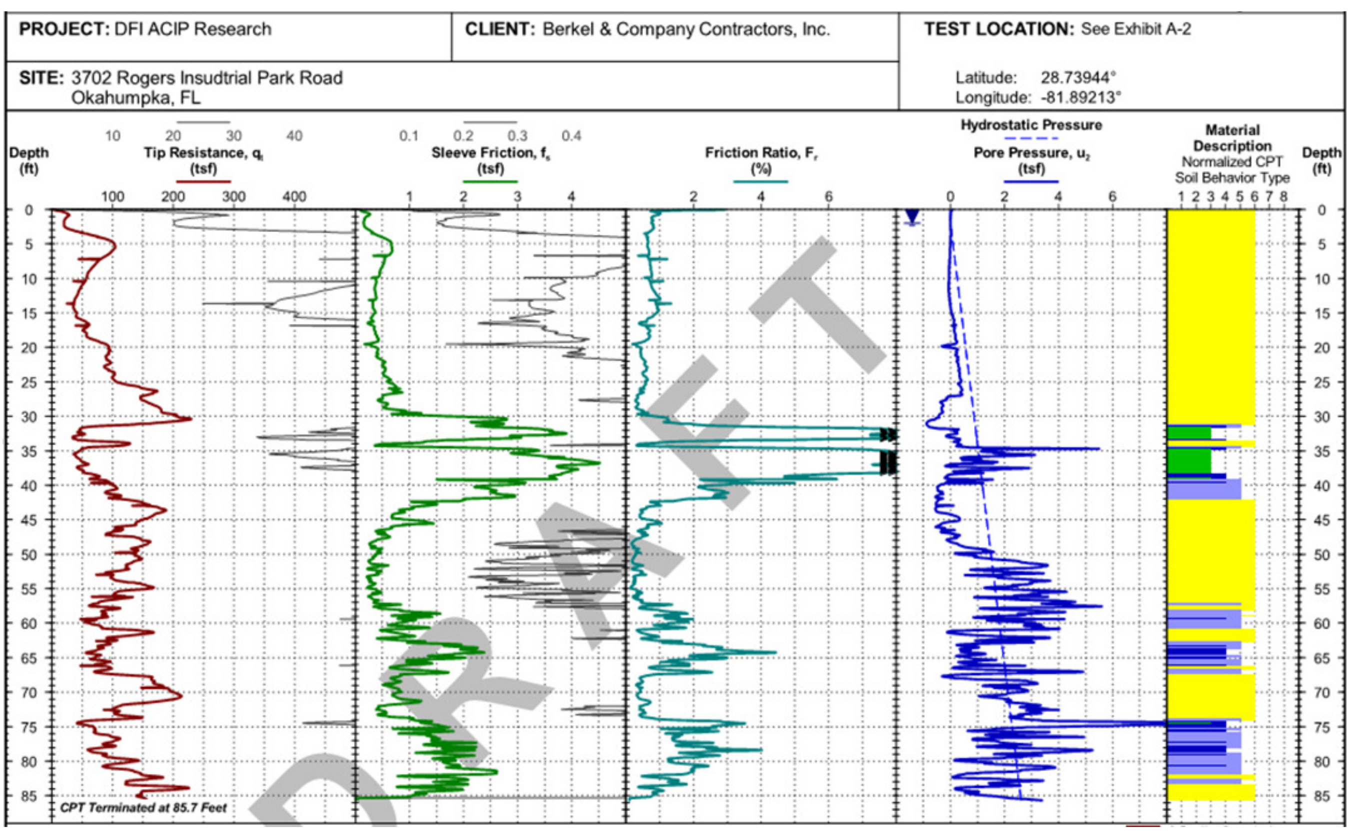

Figure 3- CPT R-8

Figure 4 – Installation Platform and ACIP Pile Drilling Equipment

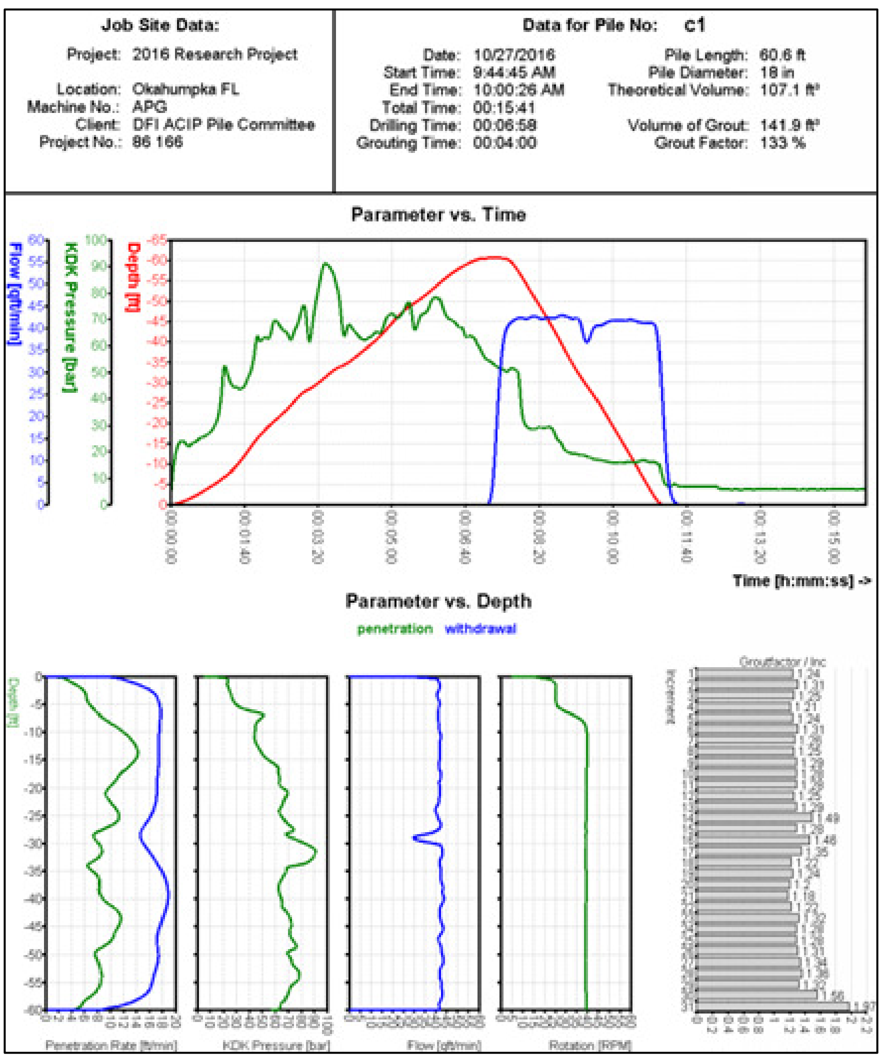

Figure 5 – AME Record for Pile C-1

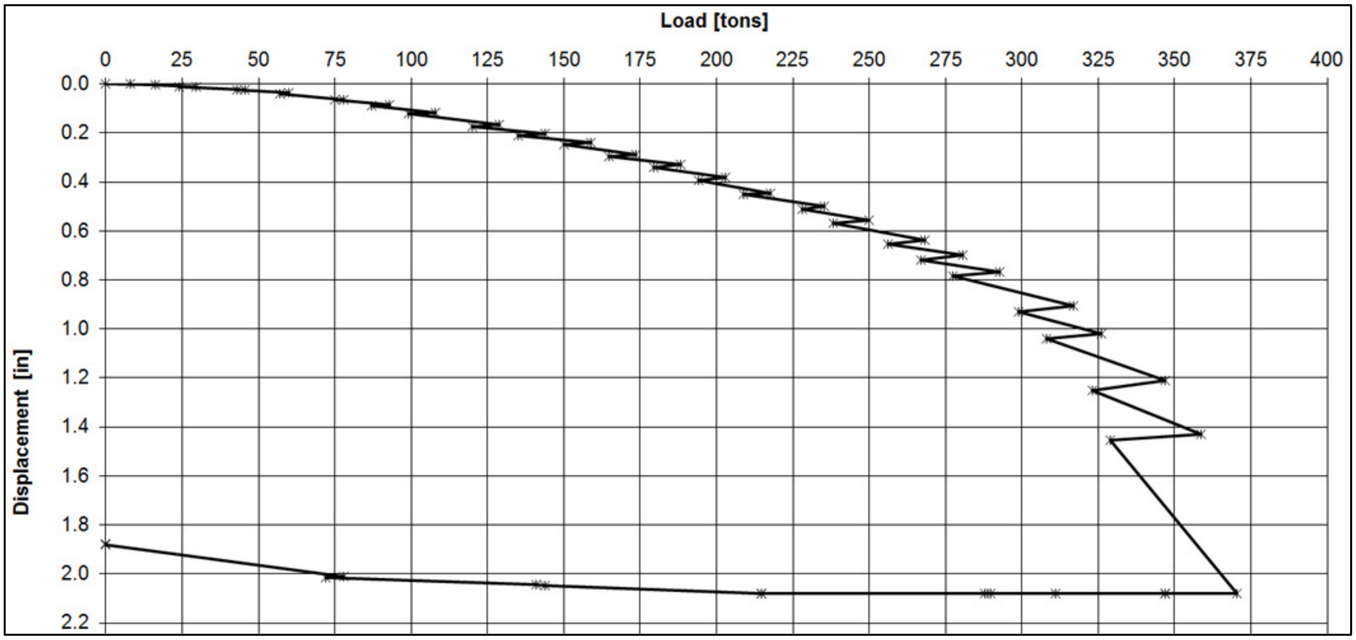

Figure 6 – Applied Load vs Pile-head Deflection – C-1 – 18-in diameter ACIP Pile (60-ft long)

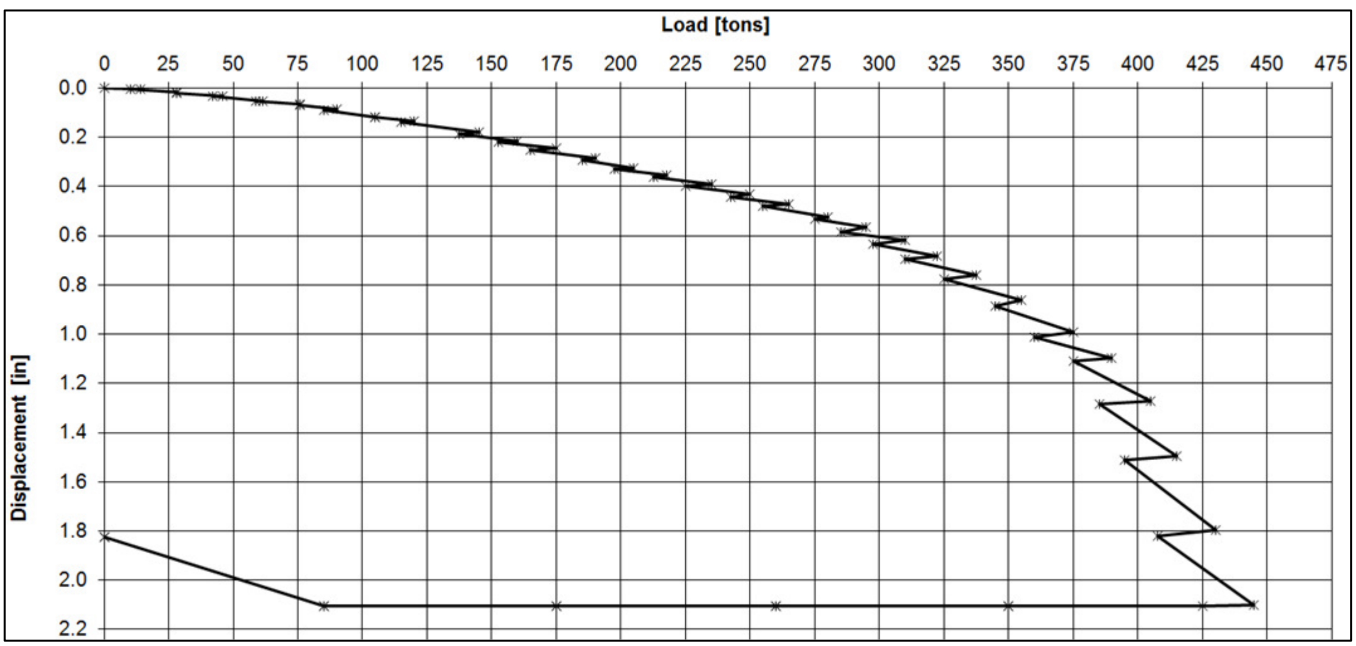

Figure 7 – Applied Load vs Pile-head Deflection – C-2 – 24-in diameter ACIP Pile (60-ft long)

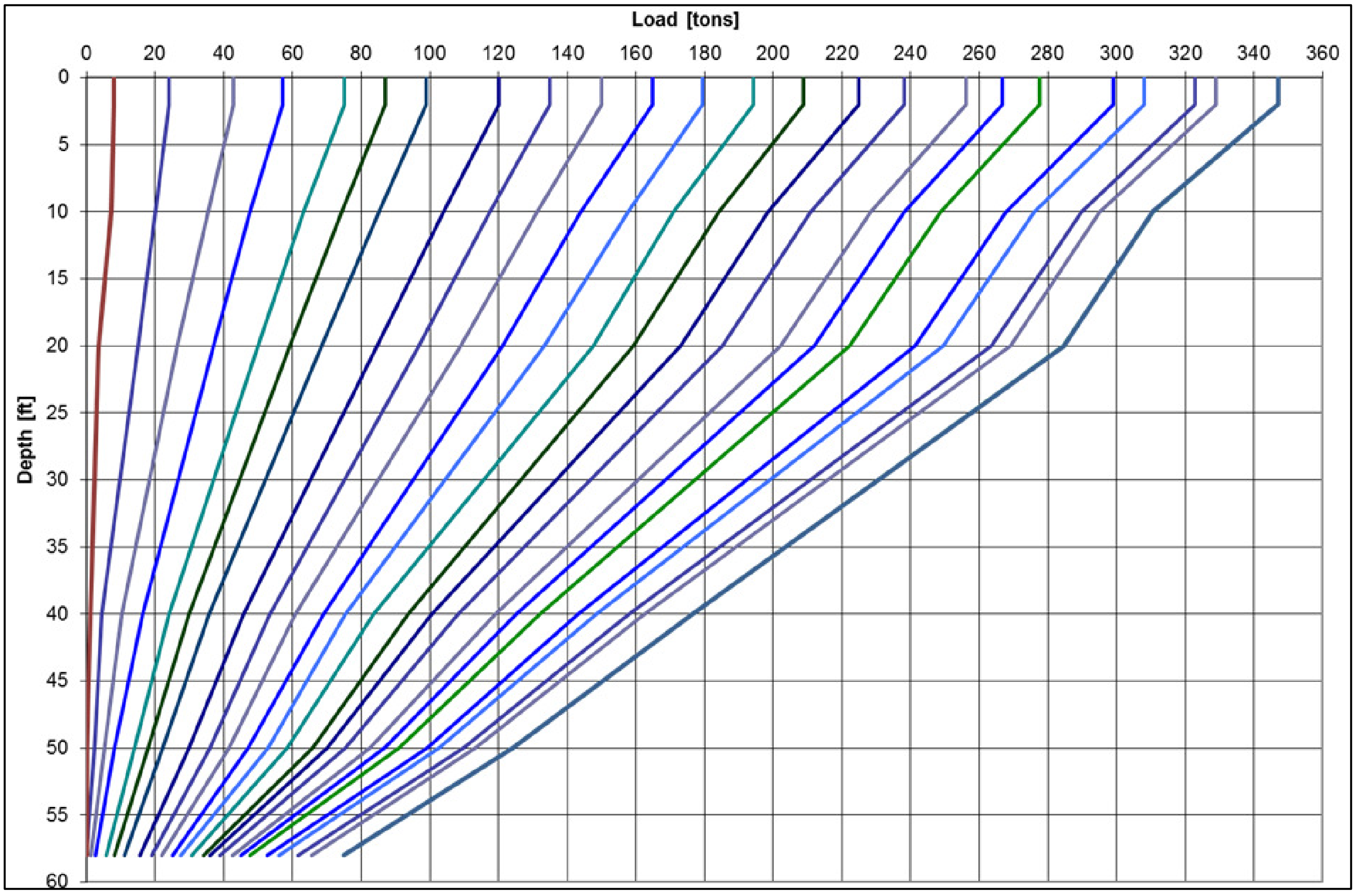

Figure 8 – Load Distribution with Depth in Pile C-8 – 18-in diameter ACIP Pile

Measured						
Gage Depth (ft)	2	10	20	40	50	58
diff (ft)		8	10	20	10	8
Load @ Gage (tons)	347	311	285	177	124	75
Shaft Resistance (tons)		36	26	108	53	49
Unit Resistance (tsf)		0.966129	0.551737	1.145686	1.116632	1.303183
Predicted						
Gage Depth (ft)	2	10	20	40	50	58
diff (ft)		8	10	20	10	8
Load @ Gage (tons)	0	27	54	144	194	234
Shaft Resistance (tons)		27	27	90	50	40
Unit Resistance (tsf)		0.716197	0.572958	0.95493	1.061033	1.061033

Figure 9 – Measured and Predicted Unit Shaft Resistance in Pile C-8

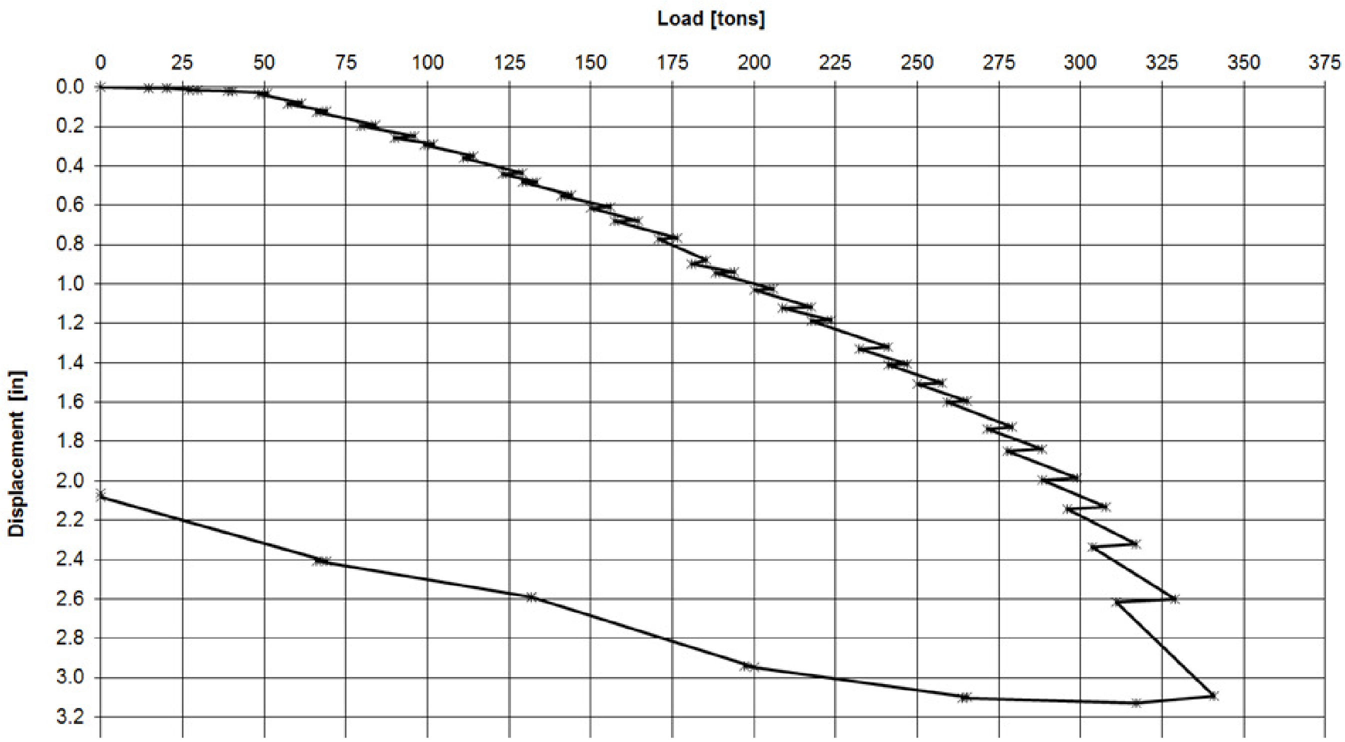

Figure 10 – Applied Load vs Pile-head Deflection – T-1 – 18-in diameter ACIP Pile (60-ft long)

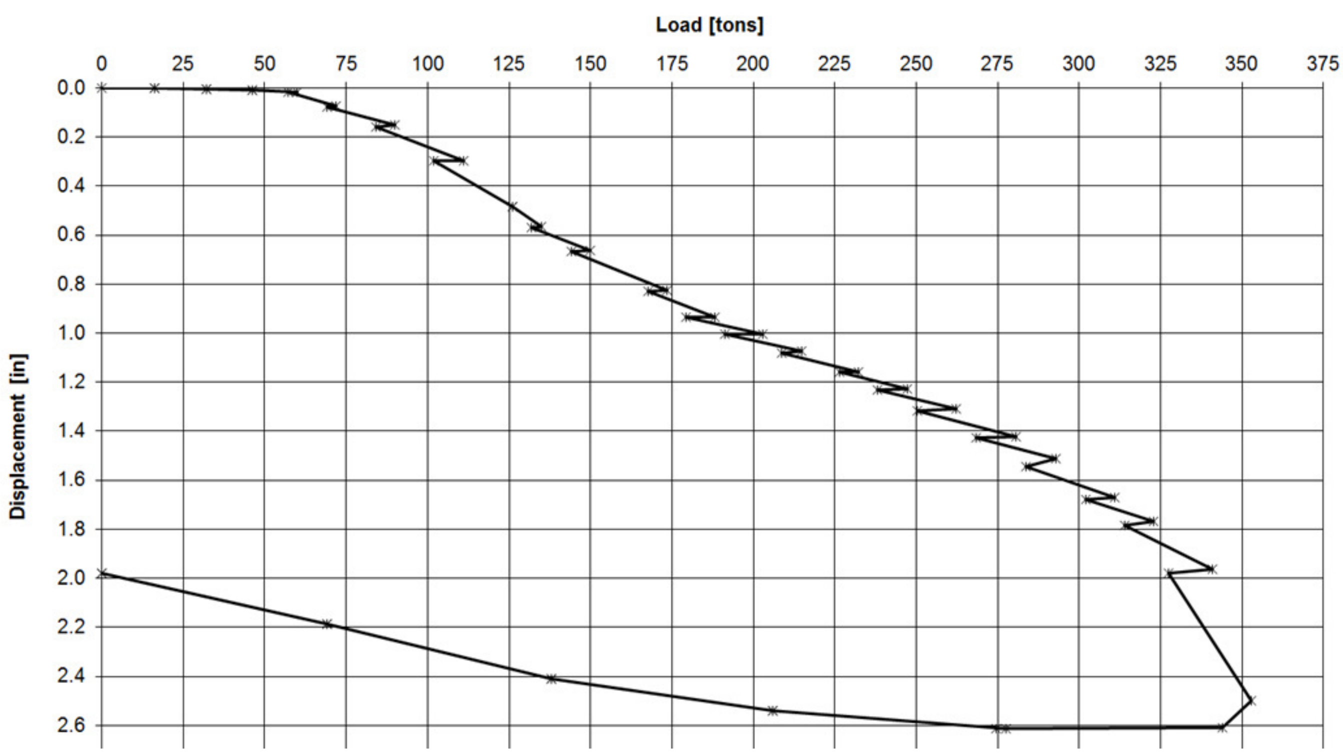

Figure 11 – Applied Load vs Pile-head Deflection – T-2 – 24-in diameter ACIP Pile (60-ft long)

Figure 12 – Applied Load vs Pile-head Deflection – L-1 – 18-in diameter ACIP Pile (40-ft long)

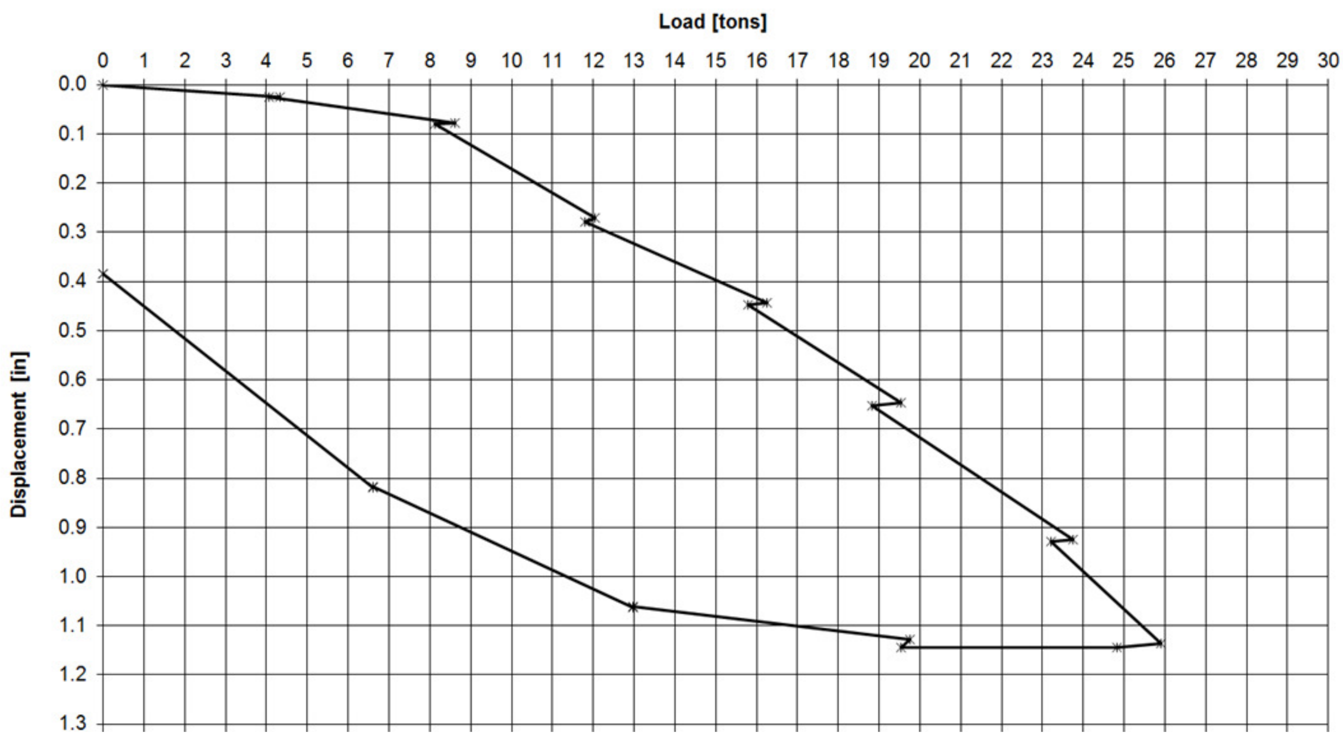

Figure 13 - – Applied Load vs Pile-head Deflection – L-2 – 24-in diameter ACIP Pile (40-ft long)

Figure 14 – Extracted 18-in diameter ACIP Pile for Manual Circumference Readings

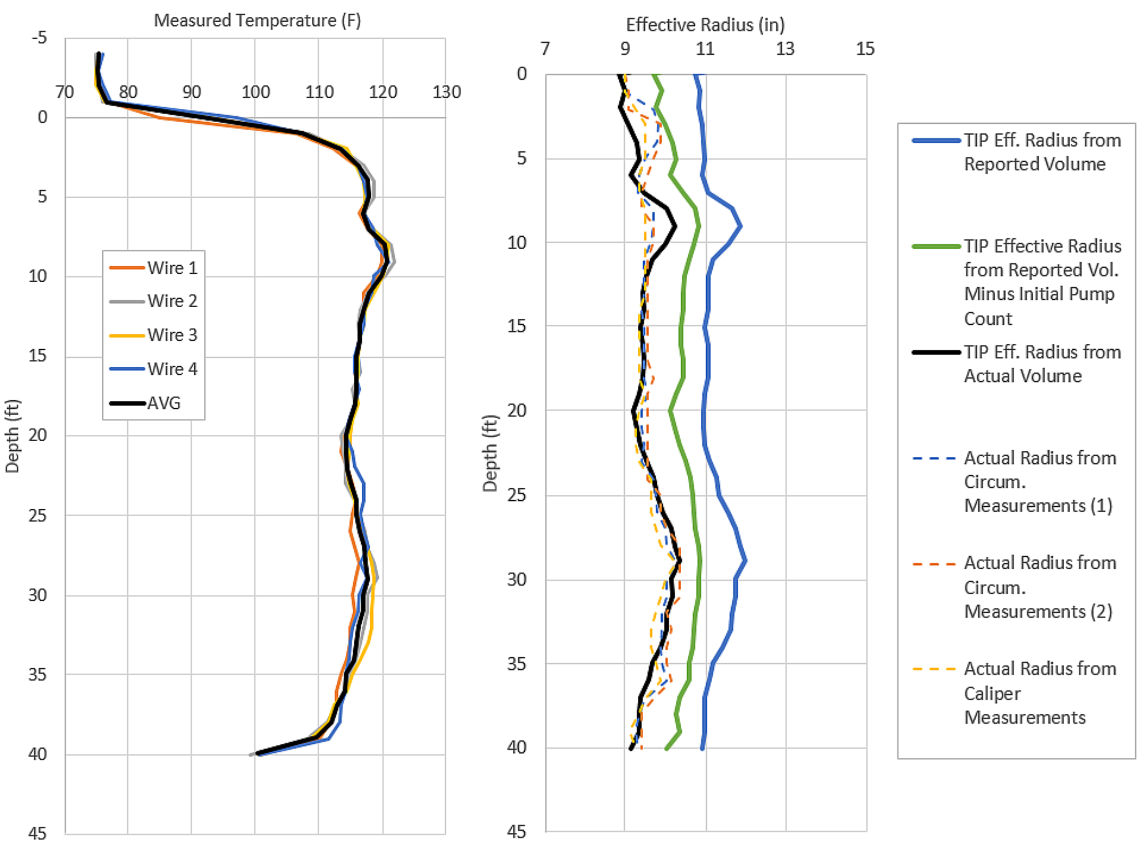

Figure 15 – Temperature Measurements and Interpreted Radius of Extracted Pile