Final Report

Investigation of Carbon Fiber Composite Cables (CFCC) in Prestressed Concrete Piles

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Approximate conversion to SI units

Symbol	When you know	Multiply by	To find	Symbol
		Length		
in.	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		Area		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		Volume		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		Mass		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		Temperature		
°F	Fahrenheit	$\frac{5}{9}(F-32)$	Celsius	°C
		Illumination		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$\frac{\text{candela}}{m^2}$	$\frac{cd}{m^2}$
		Force/Stress/Pressure		
lbf	poundforce	4.45	newtons	N
k	kips	4.45	kilonewtons	kN
$\frac{lbf}{in^2}$ (or psi)	$\frac{\text{poundforce}}{\text{square inch}}$	6.89	kilopascals	kPa
$\frac{k}{in^2}$ (or ksi)	$\frac{\text{kips}}{\text{square inch}}$	6.89	megapascals	MPa

Approximate conversion to imperial units

Symbol	When you know	Multiply by	To find	Symbol
		Length		
mm	millimeters	0.039	inches	in.
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		Area		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		Volume		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		Mass		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg	megagrams	1.103	short tons (2000 lb)	T
		Temperature		
°C	Celsius	$\frac{9}{5}\mathrm{C}+32$	Fahrenheit	°F
		Illumination		
lx	lux	0.0929	foot-candles	fc
$\frac{cd}{m^2}$	$\frac{\text{candela}}{\mathrm{m}^2}$	0.2919	foot-Lamberts	fl
		Force/Stress/Pressure		
N	newtons	0.225	poundforce	lbf
kN	kilonewtons	0.225	kips	k
kPa	kilopascals	0.145	$\frac{\text{poundforce}}{\text{square inch}}$	$\frac{\mathrm{lbf}}{\mathrm{in}^2}$ (or psi)
MPa	megapascals	0.145	$\frac{\text{kips}}{\text{square inch}}$	$\frac{\mathrm{k}}{\mathrm{in}^2}$ (or ksi)

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16. Abstract

The Florida Department of Transportation (FDOT) commonly uses prestressed concrete piles in bridge foundations. These piles are prestressed with steel strands that, when installed in aggressive or marine environments, are subject to corrosion and therefore rapid degradation. Many solutions may address this issue, but they are not long-term. Hence, it would be desirable to use advanced materials that do not corrode. The goal of this research was to assess the suitability of using carbon fiber composite cables (CFCC), which do not corrode, in lieu of conventional steel prestressing strands.

Five (5) 24-in. square prestressed concrete piles, three (3) 40-ft long and two (2) 100-ft long, were cast using 0.6-in. diameter CFCC strands produced by Tokyo Rope Manufacturing Company. A special anchoring system was used because CFCC strands cannot be conventionally gripped using wedges and a jack. The techniques employed to prestress these strands were documented, as well as the unique aspects involved in constructing and precasting CFCC-prestressed piles. During strand detensioning, stresses were monitored in the concrete at the piles' ends to determine the transfer length of CFCC strands, as a means of evaluating their bond characteristics.

Development length tests and flexural tests were performed on two (2) of the 40-ft piles at the FDOT Marcus H. Ansley Structures Research Center to further assess the performance of the CFCC strands. Lastly, the two (2) 100-ft piles were driven at a bridge construction site, adjacent to standard steel-prestressed concrete piles. During driving operations, the behavior of the piles was monitored using embedded data collectors and a Pile Driving Analyzer®.

The precasting efforts and test results show that the performance of piles prestressed with CFCC strands is comparable to those prestressed with steel. Using CFCC strands in prestressed concrete piles for bridge foundations, particularly in harsh environments, could potentially result in bridges that require less maintenance and have longer lifespans.

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EXECUTIVE SUMMARY

The Florida Department of Transportation (FDOT) commonly uses prestressed concrete piles in bridge foundations. These piles are prestressed with steel strands that, when installed in aggressive or marine environments, are subject to corrosion and therefore rapid degradation. Many solutions may address this issue, but they are not long–term. Hence, it would be desirable to use advanced materials that do not corrode. The goal of this research was to assess the suitability of using carbon fiber composite cables (CFCC), which do not corrode, in lieu of conventional steel prestressing strands.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 General

Durability, low maintenance, and safety of bridge structures are top priorities for any owner, including the Florida Department of Transportation (FDOT). Failure of a bridge component can cause the entire structure to fail, especially when it occurs in the foundation. In Florida, many bridge foundations are subjected to harsh marine environments, which can result in expensive maintenance issues and shortened bridge life. In particular, prestressed concrete pile foundations degrade quickly when their steel prestressing strands corrode.

Replacement of pile foundations is difficult because of the superstructure resting on them; outrigger piles can be placed instead, but they are expensive and unsightly. Alternatives to replacing the piles include protecting the pile with shielding or wrapping the pile with anti-corrosive material, but these alternatives are also expensive and do not provide a long–term solution.

Current research is testing the performance of advanced materials as an alternative to steel reinforcement or prestressing. These materials are, more specifically, fiber reinforced plastics (FRP). One of the potential alternatives is carbon fiber composite cables, as they have high resistance to corrosion. The material is a relatively new technology, and research is needed so that designers can gain confidence in this material as a substitute for steel reinforcement or prestressing.

1.2 Problem Statement

Prestressed concrete piles are a common foundation type for Florida bridges due to their economy of design, fabrication, and installation. The piles are prestressed with high-strength, prestressing steel strands and are fabricated under controlled conditions in a casting yard. However, they are often exposed to salt water (aggressive) environments, which results in rapid degradation. The major area of concern is near the water level, also called the "splash zone" (Figure 1.1). In this area, the concrete

Figure 1.1: Splash zone corrosion

experiences periodic wet and dry spells. Consequently, salt deposits on the concrete surface and slowly penetrates the concrete, resulting in corrosion of the prestressed steel strands. This causes loss of concrete material surrounding the strand due to spalling of the concrete and a loss of the steel cross–sectional area. The bridge may no longer be usable, or may require major retrofitting to strengthen the piles, which is very expensive.

A potentially good alternative to prestressed steel strands, especially for piles in aggressive environments, would be carbon fiber composite cables (CFCC). CFCC strands are highly resistant to corrosion and are reported by manufacturers to have higher bond strength to concrete than steel strands. The cost of CFCC is currently higher than steel strands; however, the cost of prestressing strand materials is a relatively small percentage of a bridge's overall cost. Also, the higher initial cost of CFCC would likely be paid back with the long-term benefit of prolonged maintenance-free bridge life.

The use of CFCCs in marine environments holds much promise. For FDOT and bridge designers to use CFCC piles in lieu of conventionally-prestressed concrete piles, some study and testing are needed.

1.3 Research Objectives

The goal of this study was to assess the suitability of using CFCC strands in Florida Department of Transportation (FDOT) bridge construction projects where piles are used, and to determine if CFCC strands are a viable alternative to conventional steel strands. Positive results would benefit FDOT and bridge designers by providing empirical evidence and by giving them confidence in CFCC-prestressed pile designs. Most importantly, the use of CFCC piles, due to their non-corrosive properties, would require less maintenance than steel-stranded piles and would result in bridges with longer lifespans.

The objectives of this research were as follows:

1. To determine the transfer length of the CFCC strands
2. To determine the development length of the CFCC strands
3. To investigate the flexural capacity of CFCC-prestressed piles
4. To investigate the driveability of CFCC piles

To accomplish the objectives, several tasks were completed. Three (3) 40–ft–long and two (2) 100–ft–long, 24-in. square prestressed concrete piles were cast, using CFCC for the prestressing strands and spiral reinforcement. Precasting operations were observed and documented. The 40–ft piles were monitored for transfer length while the strands were cut during prestressing operations. They were also tested in flexure in a laboratory to measure the CFCC strand's development length and the pile's flexural capacity. Later, the 100–ft piles were driven at a bridge construction site.

1.4 Report Organization

This report is organized into chapters as follows. A review of literature is presented in Chapter 2. The material properties, anchorage system, and instrumentation are described in Chapter 3. Chapter 4 is a documentation of the construction of the test piles. The test program and results are presented in Chapters 5 and 6, respectively, for transfer length measurements, development length tests, flexural strength tests, and pile driving tests. The results are discussed in Chapter 7, followed by a summary and conclusions in Chapter 8.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Many studies, both analytical and experimental, have reported on strand bond properties, transfer length, development length, flexural strength of prestressed members, and prestressing losses in concrete members. This chapter will describe the general properties of advanced materials recently introduced as an alternative to steel for overcoming the major issue of corrosion. The advanced materials described in this chapter are Fiber Reinforced Plastics (FRP), one of which is used in this study to prestress five (5) precast concrete piles. Included in this chapter is recent work that has been conducted to test FRPs on the above-mentioned properties.

2.2 Fiber Reinforced Plastic (FRP)

Fiber Reinforced Plastic materials are extensively used and have revolutionized the construction industry. They offer an alternative to steel as reinforcement for concrete structures. FRPs are composite materials consisting of synthetic or organic high–strength fibers that are impregnated within a resin material. They can be manufactured in the form of rods, grids, and cables of various sizes and shapes. The fiber portion of these materials can be made of aramid, glass fibers, or carbon with each having different material properties. However, there are disadvantages of using the fiber-reinforced polymer, including:

1. High cost (5 to 15 times that of steel)

2. Low modulus of elasticity (for aramid and glass FRP)

3. Low ultimate failure strain

4. High ratio of axial–to–lateral strength, causing concern for anchorages for FRP used as prestressing

5. Long-term strength can be lower than the short-term strength for reinforcement due to creep rupture phenomenon (for FRP reinforcement).

6. Susceptibility of FRP to damage by ultra-violet radiation

7. Aramid fibers can deteriorate due to water absorption.

8. High transverse thermal expansion coefficient, compared to concrete

Tensile properties of reinforcement made from Carbon Fiber Reinforced Plastic (CFRP), Aramid Fiber Reinforced Plastic (AFRP), and Glass Fiber Reinforced Plastic (GFRP) are compared to steel in Figure 2.1. Steel exhibits ductile behavior, while the other materials do not.

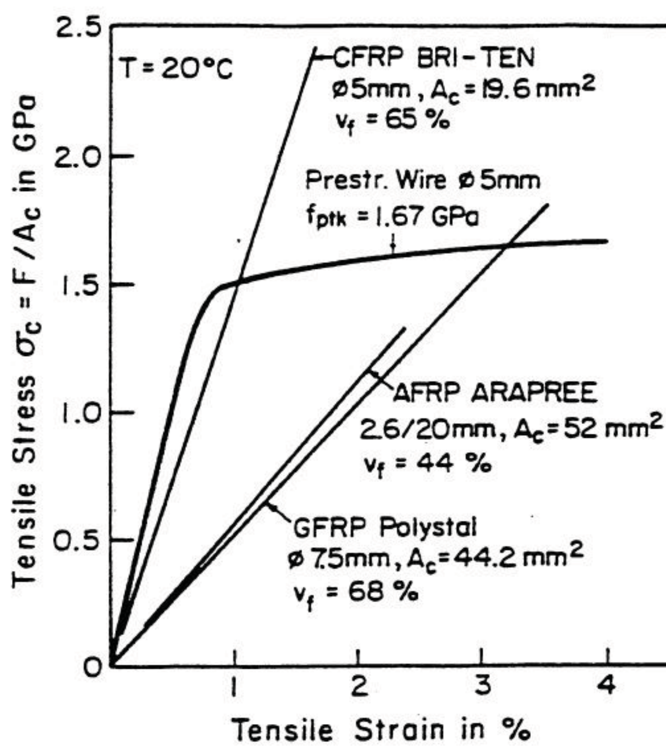


Figure 2.1: FRP stress-strain relationships (Domenico, 1995)

2.3 Carbon Fiber Composite Cables (CFCC)

Carbon fibers can be produced from two (2) materials. The most common textile material is poly–acrylonitrile based (PAN–based). The other is a pitch–based material, which is a by–product of petroleum refining or coal coking. Carbon fibers have exceptionally high tensile strength–to–weight ratios, with a strength ranging from 1970 to 3200 MPa (286 to 464 ksi) and a tensile modulus ranging from 270 to 517 GPa (39,160 ksi to 74,984 ksi). These fibers also have a low coefficient of linear expansion, on the order of 0.2x10^{-6} m/m/degree Celsius, and high fatigue strength. However, disadvantages are their low impact resistance, high electrical conductivity, and high cost.

Commercially–available CFRP prestressing tendons are available under the brand names of Carbon Fiber Composite Cable (CFCC) by Tokyo Rope (Japan), Leadline by Mitsubishi Kasai (Japan), Jitec by Cousin Composites (France), and Bri-Ten by British Ropes (United Kingdom).

Carbon Fiber Composite Cables (CFCC), currently patented in ten (10) countries in the world, are reinforcing cables formed using carbon fibers and thermosetting resins. Made in Japan by Tokyo Rope Manufacturing Company, Ltd. (Tokyo Rope), CFCCs use PAN–type carbon fibers supplied by Toho Rayon. A roving prepreg process manufactures individual wires where the epoxy resin is heat cured. The prepreg is twisted to create a fiber core and is then wrapped with synthetic yarns. The purpose of the yarn is to protect the fibers from ultra-violet radiation and mechanical abrasion, and to improve the bond properties of the wire to concrete.

Tokyo Rope currently produces cables with diameters ranging from 5 to 40 mm and in any length up to 600 meters. Cables are then made from one (1), seven (7), 19, or 37 wires and are twisted to allow better stress distribution through the cross section (Table 2.1). See Appendix A for product information. The tensile strength of a 12.5–mm diameter CFCC is 2.69 kN/mm^2, and the tensile elastic modulus is 155 GPa. The thermal coefficient of expansion is approximately 0.62x10^{-6}/degrees Celsius which is about $1/20^{th}$ that of steel. The relaxation is about 3.5% after 30 years at 80% of the ultimate load; this is about 50% less than that of steel. Also, from the technical data on CFCC provided by Tokyo Rope, pull-out tests show that CFCC has bond strength to concrete of 6.67 MPa, which is more than twice that of steel.

CFCC is lightweight and has very high corrosion resistance. The cable's twisted strands make it easy to handle, as it can be coiled. These features of CFCC make it useful for various applications such as:

1. Reinforcement of structures in corrosive environments
2. Corrosion–resistant ground anchors (Figure 2.2)

Table 2.1: CFCC standard specification (Source: Tokyo Rope)

New Standard specification of CFCC 標準仕様

Designation (Configuration diameter) 呼称	Diameter 直径 (mm)	Effective cross sectional area 有効断面積 (mm²)	Guaranteed capacity 保証破断荷重 (kN)	Nominal mass density* 単位長さ質量 (g/m)	Tensile elastic modulus* 弾性係数 (kN/mm²)
U 5.0φ	5.0	15.2	38	30	167
1×7 7.5φ	7.5	31.1	76	60	155
1×7 10.5φ	10.5	57.8	141	111	155
1×7 12.5φ	12.5	76.0	184	145	155
1×7 15.2φ	15.2	115.6	270	221	155
1×7 17.2φ	17.2	151.1	350	289	155
1×19 20.5φ	20.5	206.2	316	410	137
1×19 25.5φ	25.5	304.7	467	606	137
1×19 28.5φ	28.5	401.0	594	777	137
1×37 35.5φ	35.5	591.2	841	1,185	127
1×37 40.0φ	40.0	798.7	1,200	1,529	145

*Reference value

3. Reinforcement of non-magnetic structures
4. Cables where reduced sag from self–weight is desired
5. Applications that benefit from low linear expansion
6. Structures and construction that benefit from lightweight materials

As illustrated by Figure 2.3, CFCC does not yield before failing like steel does, but fails immediately once it reaches the maximum capacity.

Figure 2.2: Corrosion-resistant ground anchors made of CFCC (Source: Tokyo Rope)

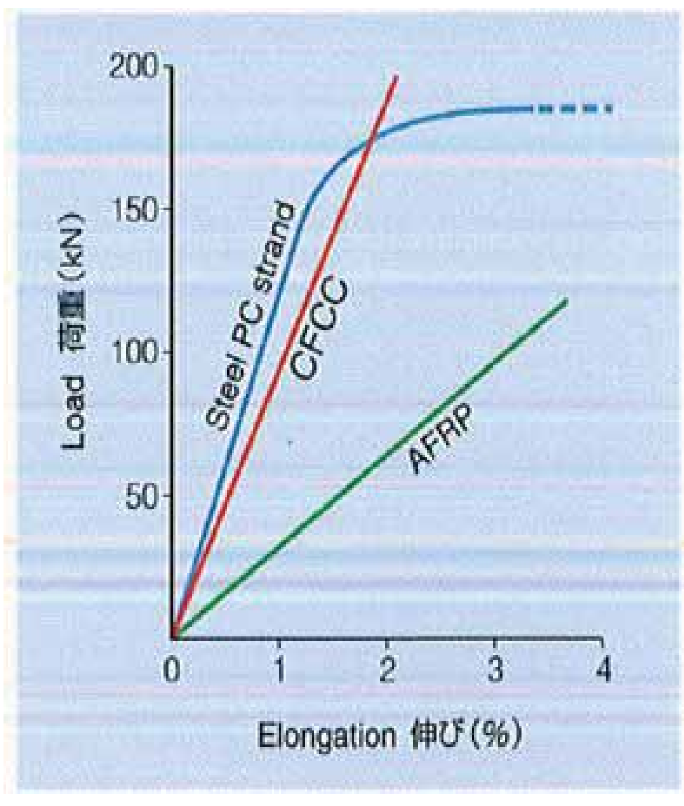


Figure 2.3: Load and elongation diagram (Source: Tokyo Rope)

2.4 Transfer Length and Development Length Background

The transfer length is the length of the strand over which the prestressing force is fully transferred to the concrete. In other words, it is the distance along the member in which the effective prestressing force is developed. The transfer length of a prestressing strand is influenced by the Hoyer effect, which is caused by swelling of the strand in the transfer zone after release as a result of Poisson's ratio. During transfer, the induced confining stresses normal to the tendon enhance the bond strength at the interface, since the lateral deformation is resisted by the surrounding concrete.

The additional length required to develop the strand strength from the effective prestressing stage to the ultimate stage is called the flexural bond length. The sum of these two lengths is called the development length. These lengths are explained by Cousins et al. (1990) and shown in Figure 2.4.

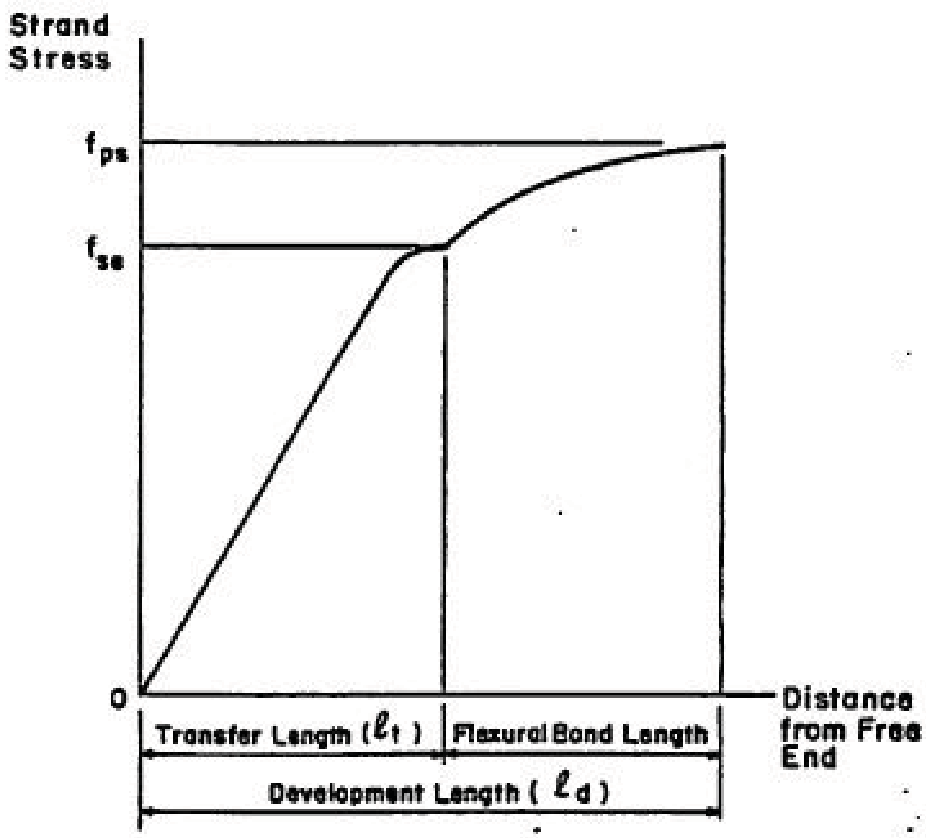


Figure 2.4: Variation of strand stress within the development length (Cousins et al., 1990)

Different tests have been standardized to examine these aspects of prestressing in concrete, including flexural bond tests and transfer length tests. The American Concrete Institute (ACI) suggests that the transfer length of any FRP varies with the condition of the FRP, the stress in the FRP, the strength and cover of the concrete, and the method used to transfer the FRP force to the concrete. In general, a prestressing rod having a smooth surface will require a longer transfer length than a rod with a rough, irregular surface. The transfer length also varies with the method used to release the initial prestress. For example, a greater transfer length will be observed if the release of tension is sudden rather than gradual, and higher initial prestress will require greater transfer length. In general, the bond of FRP tendons is influenced by the following parameters as given by ACI (2004):

1. Tensile strength [600 to 3000 MPa ($87,000$ to $435,000$ psi)]
2. Hoyer effect
3. Cross-sectional shape
4. Surface preparation (braided, deformed, smooth)
5. The method of force transfer
6. Concrete strength and cover

The American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factor Design (LRFD) Bridge Design Specifications (AASHTO, 2011) state that the transfer length for a steel strand should not exceed 60 times its diameter, while the flexural design guidelines in Section 12.9 of ACI 318-11 recommend using Equation 2.1 for estimating the transfer length.

$$L_t = \frac{1}{3} f_{se} d_b \tag{2.1}$$

where
L_t = transfer length (in.)
f_{se} = effective stress after losses (ksi)
d_b = strand diameter (in.)

Even though there are many factors affecting the transfer length, according to AASHTO LRFD and ACI, the transfer length is primarily governed by either one or two parameters.

Development length is the total embedment length of the strand that is required to reach a member's full design strength at a section. According to ACI 318-11 and

AASHTO LRFD, development length may be calculated using Equation 2.2:

$$L_d = \frac{1}{3} f_{se} d_b + (f_{ps} - f_{se}) d_b \tag{2.2}$$

where
L_d = development length (in.)
f_{ps} = prestress in steel at the time for which the nominal resistance of the member is required (ksi)

In Equation 2.2, the first term is the ACI expression for the transfer length of the prestressing strand, while the second term is its flexural bond length.

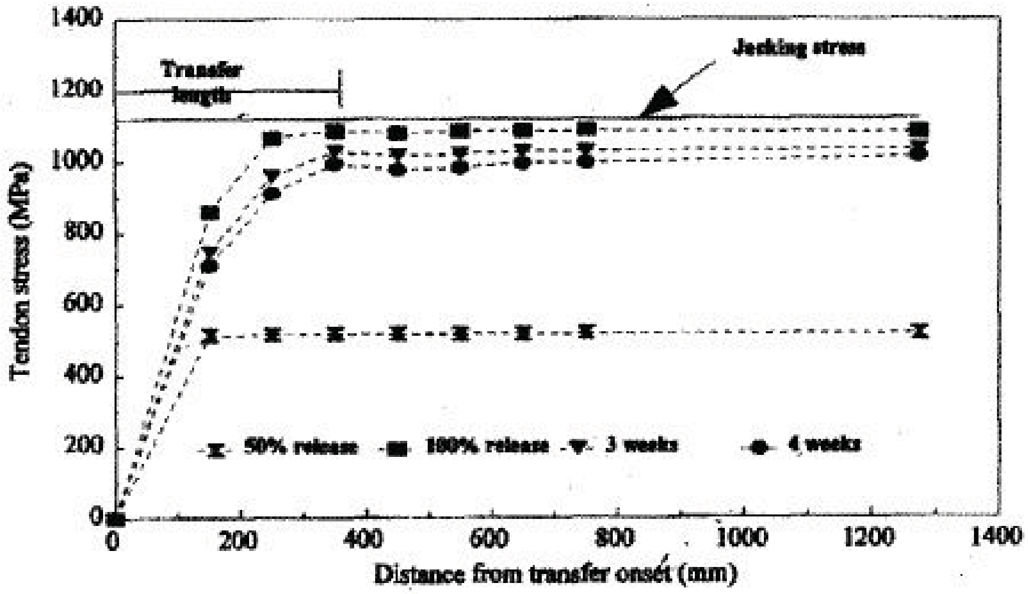
2.5 Research Performed on Transfer and Development Lengths of CFRP Strands

Mahmoud et al. (1999) tested 52 concrete beams which were pretensioned using three (3) different types of prestressing. The tests were performed to observe the behavior of the three (3) materials with respect to transfer and development length. The materials used were lead line bars, CFCC strands, and steel strands. The researchers tested the simply–supported beams in flexure, by applying a one–point load and by varying the shear spans. The results showed that the strand diameter d_b, the initial prestressing level f_{pi}, and the concrete compressive strength at transfer f'_{ci} directly affect the transfer length of the CFRP prestressing strand. Equation 2.3 was proposed to predict transfer length.

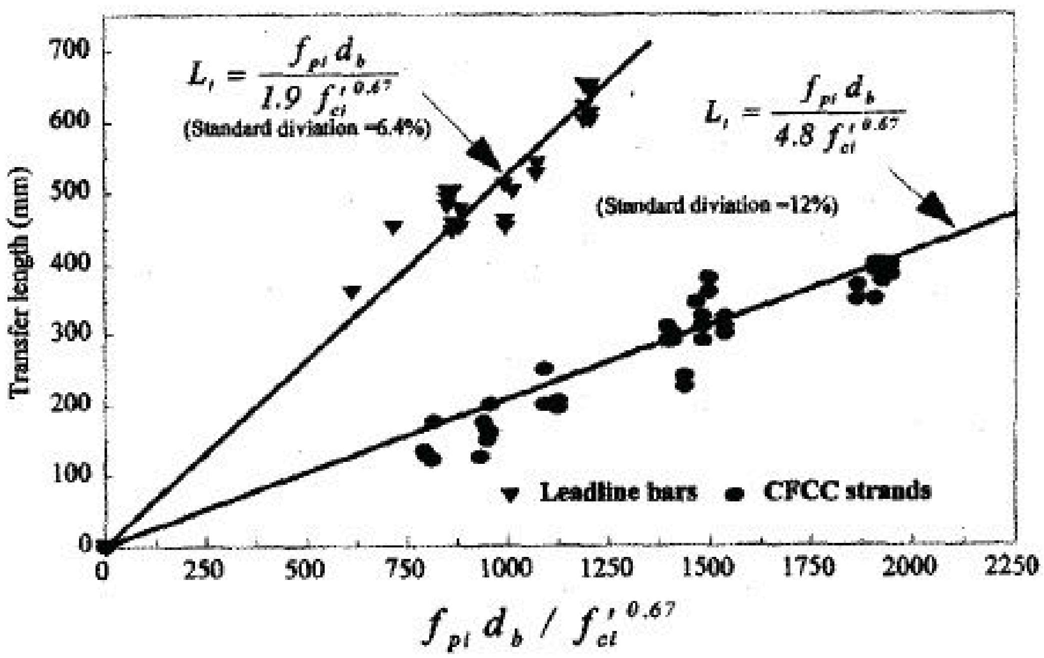
$$L_t = \frac{f_{pi} d_b}{\alpha_t {f'_{ci}}^{0.67}} \tag{2.3}$$

A regression analysis of the test data was performed and resulted in a value of 4.8 (using MPa and mm units) or 25.3 (using psi and in. units) for the constant α_t for CFCC. The researchers concluded that the characteristics of the CFRP cause reduction of the transfer length in comparison with a 7-wire or equivalent number of steel strands (Figure 2.5). In particular, the modulus of elasticity for CFCC is about 79% of that for steel strands which causes more friction between the strand and the concrete during prestress release. This friction arises from the lateral strains caused by the longitudinal strains that occur in the prestressing.

The researchers also studied the effects of confinement on the transfer length and on the flexural bond length by testing six (6) beams that were pretensioned with CFCC, had no shear reinforcement, and provided a concrete cover of four times the strand



(a) Concrete strain profile along transfer length



(b) Transfer length correlation for Leadline bars and CFCC strands

Figure 2.5: Transfer length test results (Mahmoud et al., 1999)

diameter. They compared the results with other beams reinforced with steel, and the results showed that, although there were no splitting cracks within the transfer zone, the transfer length of the CFCC increased by 17% while the flexural bond length increased by 25% (Mahmoud et al., 1999). The concrete cover of four (4) times the strand diameter, without any shear reinforcement, clearly affects the bond characteristics of the CFCC.

Research by **Mahmoud and Rizkalla (1996)** on 24 rectangular-shaped pretensioned concrete beams was conducted to determine the transfer and development lengths of CFRP. Out of the 24 beams, 16 were reinforced with a single CFCC strand. The beams were tested in flexure under the MTS (Mechanical Testing System) machine by applying a point load, at the designated embedment length (as illustrated in Figure 2.6) and at the mid span of the beam. From the test results, they proposed a development length equation for CFRP prestressing strands:

$$L_d = \frac{f_{pi} d_b}{\alpha_t {f'_{ci}}^{0.67}} + \frac{(f_{pu} - f_{se}) d_b}{\alpha_f {f'_c}^{0.67}} \tag{2.4}$$

where
f_{pi} = initial prestressing stress
f'_{ci} = concrete strength during release
f'_{c} = concrete strength at time of loading
f_{pu} = ultimate tensile strength of the CFCC
f_{pe} = effective prestressing stress
α_f = 2.8 (MPa and mm units) or 14.8 (psi and in. units) for CFCC

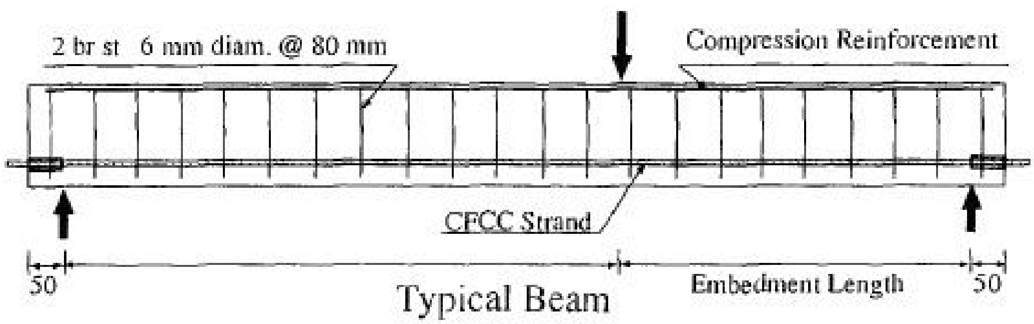


Figure 2.6: Experimental setup (Mahmoud et al., 1999)

It was observed that the beams with embedment length less than the development length failed after flexure and shear cracking, due to slippage of the strand at one or both ends of the beam. Beams with sufficient embedment length failed due to strand rupture at the location of the load point. The beams displayed extensive flexural cracking extending up to the compression zone at the top surface (Figure 2.7). They showed that the transfer length of CFCC strand was about 50% of the ACI prediction for an equivalent steel strand for concrete strength of 35 MPa at transfer.

The test setup used by the researchers was used in our study to assess the development length of CFCC via flexural tests. From their proposed model, it is evident that the transfer length is a function of f'_{ci}, as the increase in concrete strength gives a shorter transfer length due to the improved bond characteristics.

Figure 2.7: Crack pattern observed by Zaki (Mahmoud and Rizkalla, 1996)

Issa et al. (1993) performed transfer length testing on GFRP strands. The researchers used 6–in. x 4–in. specimens for two concentric 3/8–in. diameter S-2 glass epoxy strands. The strands were prestressed to 50% of their ultimate strength. The transfer length observed was 10 to 11 in., or, in other words, 28 times the nominal diameter of the tendons. This demonstrates that the transfer length for FRP strands is much shorter than for steel strands.

Taerwe et al. (1992) used transfer prisms to determine the transfer length of Aramid composite prestressing bars embedded in concrete prisms. Arapree AFRP bars with a sand coating were used in the program. The bars were 7.5 and 5.3 mm in diameter. The concrete strength used for the specimen construction was varied between 71.6 and 81.5 MPa, and the strands were stressed to 50% of the ultimate tensile capacity. The transfer lengths measured in these tests were 16 to 38 times the bar diameter, depending on the type of coating on the bars. The study showed that the transfer length is affected by the finish on the prestressing strands.

The *Transfer Prism* is a test used to determine bond characteristics of reinforcements. This test can be used to measure the transfer length only, and its utility to determine the flexural bond length is questionable (Domenico, 1995). In a typical transfer prism, specimens are made by prestressing the tendons and casting concrete prisms of considerably small cross-sectional area, usually long with a square cross section.

The *End Slip Method*, also referred to as the "draw-in method", is another technique commonly used to evaluate the transfer length of prestressing strands (Logan, 1997). This method is based on relating the amount of slippage measured at the end of the strand upon the release of the prestressing force. First, the strand draw-in Δ_d is calculated as follows:

$$\Delta_d = \delta_s - \delta_c \tag{2.5}$$

where
δ_s = the change in the strand's length in the stress transfer zone due to prestress

release
δ_c = the elastic shortening of the concrete in the stress transfer zone due to prestress release

By integrating the strains of the strand and the concrete along the transfer length, δ_s and δ_c can be calculated as follows:

$$\Delta_d = \int_{L_t} (\Delta\varepsilon_s - \Delta\varepsilon_c)dx \tag{2.6}$$

In Equation 2.6, $\Delta\varepsilon_s$ is the change in the strand strain due to prestress release, and $\Delta\varepsilon_c$ is the change in the concrete strain due to prestress release. If the change in the strand and concrete strain is linear, Equation 2.6 can be expressed in the following, simpler form:

$$\Delta_d = \frac{f_{si}}{\alpha E_{ps}} L_t \tag{2.7}$$

In Equation 2.7, f_{si} is the initial stress in the strand, E_{ps} is the Elastic Modulus of the strand, α is the stress distribution constant, and L_t is the transfer length. Balazs (1993) reported a value of 2 for parameter α in the case of constant stress distribution and a value of 3 in the case of linear stress distribution. Typically, the stress distribution is assumed to be constant. Thus, the transfer length as given by Andrawes et al. (2009) can be calculated as follows:

$$L_t = \frac{2E_{ps}\Delta_d}{f_{si}} \tag{2.8}$$

Domenico (1995) performed research on transfer length and bond characteristics of CFCC strands by testing T–shaped concrete beams in flexure. The variables used were the diameter of the CFCC tendons, concrete cover and strength, and prestressing level. Domenico found that the measured transfer length was proportional to the diameter of the CFCC strands and the prestressing level applied. The transfer length of the CFCC strand was found to be in the range of 140 to 400 mm (5.5 to 15.7 in.), which is much lower than the transfer length determined by using the ACI and AASHTO equations. The author also proposed an equation for transfer length which is given by Equation 2.9:

$$L_t = \frac{f_{pe} A_p}{80\sqrt{f'_{ci}}} \tag{2.9}$$

Grace (2003) designed and used CFRP as the primary reinforcing material in Bridge Street Bridge, the first bridge in the USA to use CFRP. The span that uses the CFRP material as reinforcement spans the Rouge River in Southfield, Michigan. This span was constructed as shown in Figure 2.8, with one side using conventional girders, and the other side using special carbon fiber reinforced beams to provide a side–by–side comparison.

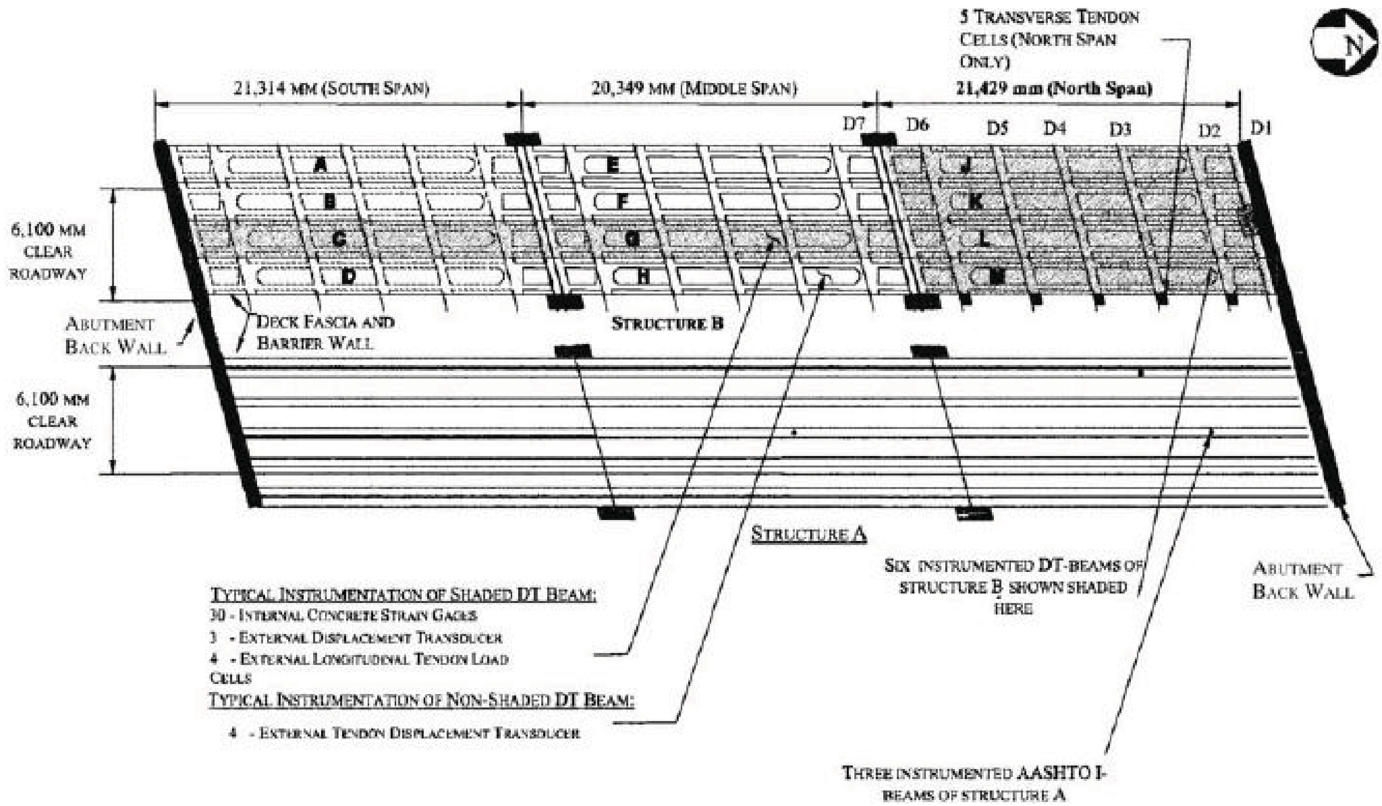


Figure 2.8: Bridge Street Bridge plan view showing conventional span A next to CFRP span B (Grace 2003)

The CFRP–reinforced bridge section consists of four (4) modified double-T girders, designed by Lawrence Technological University (LTU) and Hubbell, Roth and Clark, Inc. (HRC). The study involved long-term monitoring to evaluate the performance of the CFRP reinforcement. Monitoring devices were installed during construction of the span. The cross section of the double-T beam is shown in Figure 2.9.

Instead of steel, each web was reinforced with the following: ten (10) rows of three (3) 10–mm bonded pretensioned CFRP tendons; six (6) rows of two (2) 12.5–mm non-prestressed CFCC strands; and one (1) row of three (3) 12.5–mm non-prestressed strands in each web. The external longitudinal and transverse unbonded CFCC strands provide post-tensioning. The longitudinal 40–mm CFCC strands are externally draped, and 60% of the final post-tensioning force was applied to the longitudinal strands before transporting the beam. Flexure testing was done on the beam before the bridge span was constructed. The researchers observed that all 60 pre-

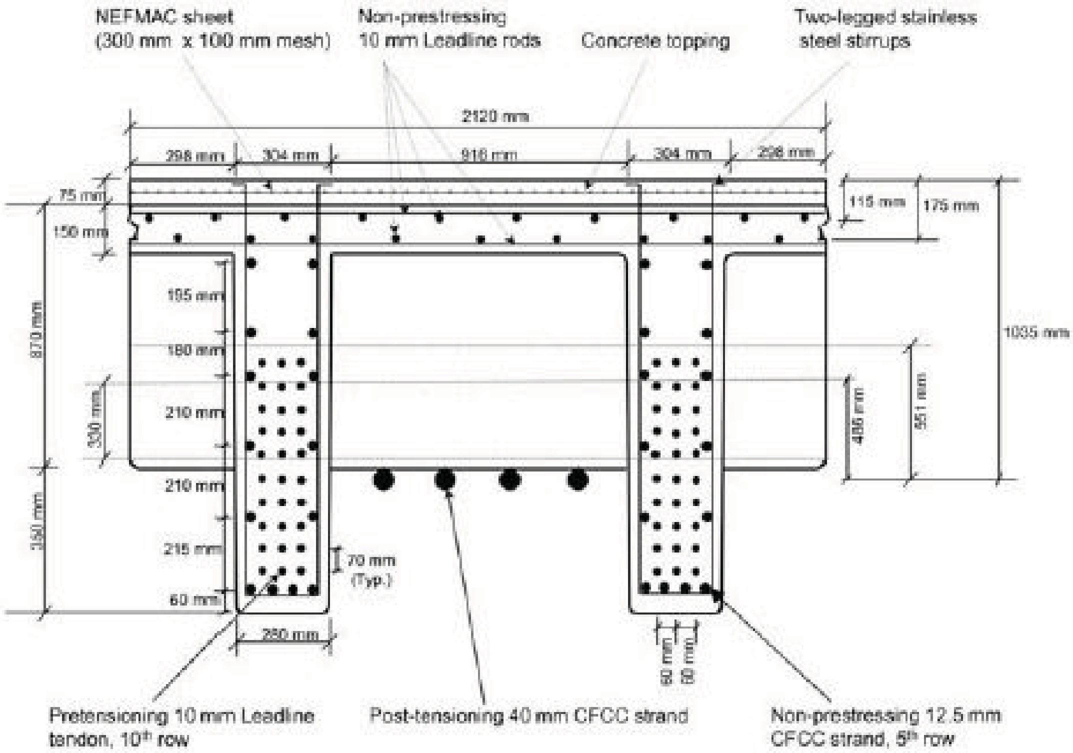


Figure 2.9: Carbon fiber reinforced double-T beam cross section (Grace, 2003)

tensioning strands failed, while the post-tensioning strands did not. At failure, the post-tensioned strands were within 60% of their tensile capacity, and the ultimate load was 5.3 times the service load. The span was used for long–term monitoring of pretension load, concrete strain in the cross section, girder camber and deflection, external strand integrity, and strain of longitudinal external strands.

Grace (2007) presented the data obtained from monitoring the Bridge Street Bridge span with CFRP reinforcement for a period of five (5) years (April 2001-July 2006), where it was concluded that the bridge spans were performing as expected. To monitor the temperature distribution in the beams, thermistors were used in the embedded vibrating wire strain gages. In addition to the data from the monitoring devices, manually–collected data was also obtained.

Significant fluctuations in the measured deflections have been observed, including erratic behavior by some of the sensors. The average mid-span deflections for Beams C and G, after allowing for the flow of traffic, were observed to be about 23 and 14 mm (0.98 and 0.55 in.), respectively. The researchers found that that the temperature has no significant effect on the deflection of the beams. Furthermore, the study concluded that no discernible deviations had occurred beyond the variations due to seasonal temperature changes in the concrete strain and forces in the post-tensioned strands over the five-year monitoring period. The successful implementation and the performance of the CFCC in the Bridge Street Bridge show that CFCC is comparable to steel strands and holds a promising future as reinforcement in a bridge superstructure. However, the performance of CFCC in a bridge substructure has yet to be assessed.

Three (3) single decked bulb-T beams were constructed and tested to failure by **Grace et al. (2012)**. One beam, used as a control specimen, was prestressed and reinforced with steel strands. The second and third beams were prestressed and reinforced with CFCC and CFRP, respectively. The performance of the beams reinforced with CFCC and CFRP was found to be comparable with the performance of the control specimen. The prestressing force in the reinforcements was to a level of approximately 43, 37, and 57% of the ultimate strength of steel, CFCC, and CFRP, respectively. The stress level attributed to the CFCC and the CFRP strands was less than the maximum allowed by American Concrete Institute (ACI) 440.4R, which is 65%. The beams were cast one (1) day after the prestressing was complete. A special mechanical device, explained in Section 3.3, was used to facilitate the stressing of the CFCC strands without damaging the ends of the strand. A hydraulic pump was used to tension the strands (Figure 2.10).

The anchorage or coupling system provided with the CFCC strands was tested for creep under joint research between Lawrence Technological University (LTU) and Tokyo Rope. The release took place 14 days after concrete casting, and the release of the prestressing forces in the CFCC beam was performed by further pulling the strand above the prestressing force and then untying the mechanical device. The CFCC beam was designed to fail in compression by concrete crushing. The load was applied with a hydraulic actuator (Figure 2.11) and a two-point loading frame.

The performance of the beam was monitored through recording the deflection at the mid span, strain readings in concrete and reinforcement, crack propagation, crack width, and crack pattern. The performance of the CFCC prestressed beams was found to be comparable to that of steel, as shown in Figure 2.12. Grace et al. (2012) concluded that the flexural load carrying capacity and the corresponding deflection of the CFCC beam were 107% and 94% of those of the steel beam, respectively.

Although the research suggests that the performance of the CFCC strands was comparable to steel strands, the prestressing level was below the recommended ACI prestress level (65% of Guaranteed Ultimate Tensile Strength (GUTS)). In the new study presented herein, the CFCC was prestressed to 65% of GUTS.

2.6 Other CFCC Coupling Method

Rohleder et al. (2008) introduced the use of CFCC strands as cables as an emergency replacement for the Waldo–Hancock Bridge. The new bridge used an innovative

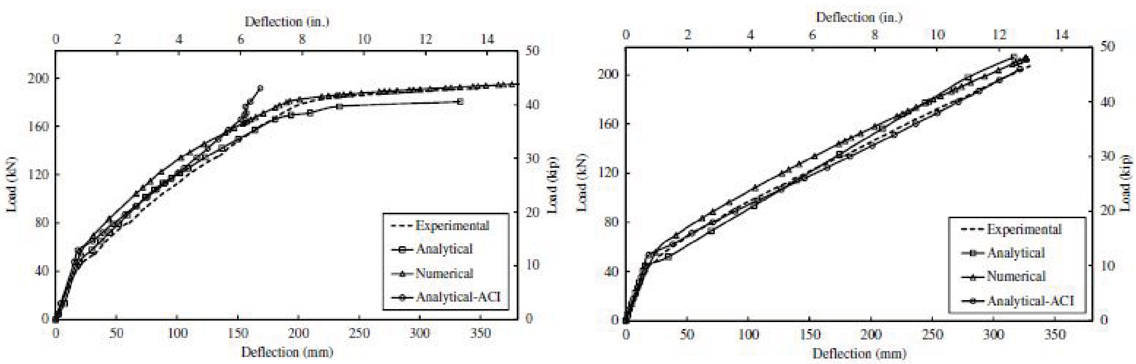
(a) Applying pretension to longitudinal strands

(b) Steel Couplers

Figure 2.10: Pretensioning using steel couplers by Grace et al. (2012)

cradle system to carry the stays from the bridge deck through the pylon and back to the bridge deck. CFRP strands were installed for assessing performance in a service condition and for evaluation of possible use on future bridges. As CFRP strands are low in shear strength and subject to brittle fracture when stressed with biting wedges, in this project the carbon strands were bonded in a threaded socket using

Figure 2.11: Load setup for decked bulb-T beams (Grace et al., 2012)



(a) Steel-prestressed beam

(b) CFCC-prestressed beam

Figure 2.12: Behavior of CFCC in comparison with steel strands. Load-Deflection curves for midspan shown. (Grace et al., 2012)

highly expansive grout (Figure 2.13). The annular spacing in between the socket wall and the strand was filled with a cementitious–based Highly Expansive Material (HEM), which exhibits a high degree of expansion during curing. The expansion of the material produces a confining pressure of approximately 11 ksi (75.85 MPa), locking the strand end and socket together.

Grace et al. (2003) showed that this confining pressure from the HEM is valuable for avoiding creep concerns as might be found if an epoxy agent had been used to anchor the strand in the socket. For the research presented herein, the method used by Grace et al. (2012) was followed to anchor the CFCC strands (Figure 2.10b), as it is also the anchoring method recommended by Tokyo Rope.

(a) Anchor sleeve with nut and strand

(b) Anchor sleeve with HEM

Figure 2.13: HEM coupling method (Rohleder et al., 2008)

2.7 Flexure Test

A flexure test can be used to determine the development length in prestressed concrete members. The test is an iterative process wherein it is often required to evaluate the position of the applied load. The distance between the applied load and the end of the beam can be varied to determine the development length. If the beam fails due to failure of the bond between the strand and the concrete, then this distance is increased, and the test is repeated. Otherwise, if the beam fails in flexure, this distance is decreased. This process is repeated until bond failure and flexure failure occur simultaneously. When this scenario occurs, this distance is considered to be the development length.

Figure 2.14 shows a general setup of a three–point bending test used by Andrawes et al. (2009). If the beam fails in flexure, the load is moved to the left (direction i), and if the beam fails due to bond failure, the load is moved to the right (direction ii).

Abalo et al. (2010) performed testing at the FDOT Marcus H. Ansley Structures Research Center to evaluate the use of CFRP mesh in place of spiral ties or conventional reinforcement spirals for a 24–in. square prestressed concrete pile. A control pile was cast along with the test pile for comparison. Figure 2.15 shows the cross sections of the control and CFRP piles. The control pile was tested earlier to compare the actual capacity to the theoretical capacity of the CFRP pile. The control pile was also a 24–in. square prestressed concrete pile; however, it had 16 0.6–in. diameter low-relaxation strands in a square pattern with W3.4 spiral ties. Both piles were 40–ft long. Strain gages were used to measure concrete strain on the top fiber towards the center of the pile, and ten (10) displacement gages were placed along the length of the pile. The control and CFRP pile test setups were similar except for the number of strain gages used.

A single point load was applied to a spreader beam that consisted of two (2) steel I-beams whose reactions provided the two (2) point loads applied to the pile. The

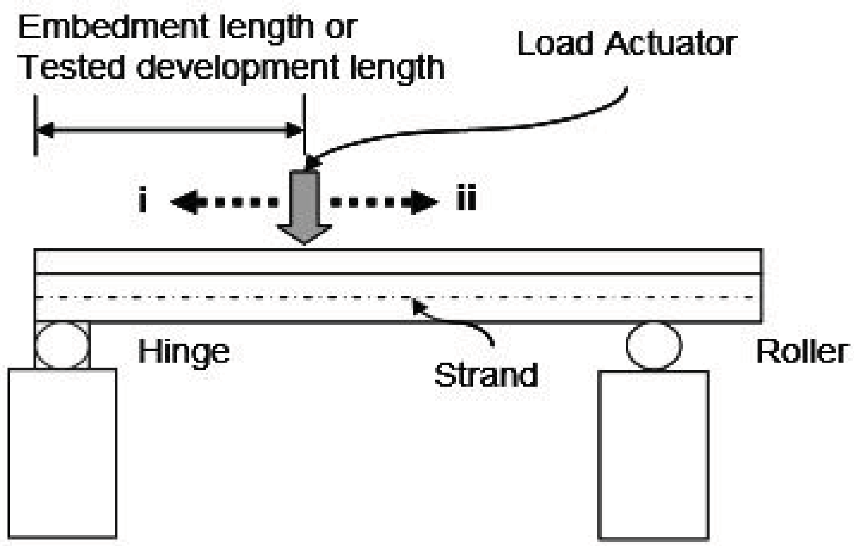
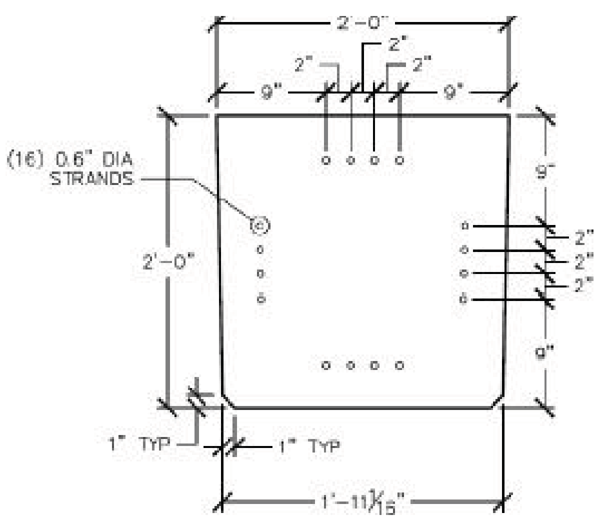
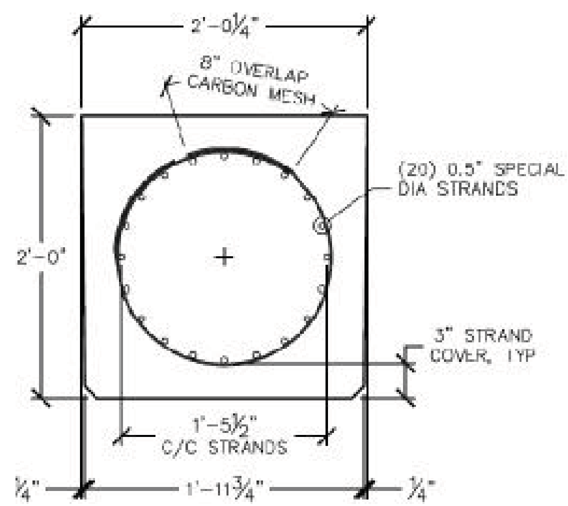


Figure 2.14: Flexure test used to evaluate development length (Andrawes et al., 2009)



(a) Control pile



(b) CFRP pile

Figure 2.15: Pile sections (Abalo et al., 2010)

load was applied until failure, and the CFRP pile experienced a compressive failure at the top. The ratio of actual-to-theoretical moment capacity for the CFRP pile was 1.27, compared to 1.21 for the control pile.

Based on the research, a conclusion can be made that the performance of the pile using CFRP meshing was higher than that of the control pile. A similar test setup was used in the study presented herein to assess the flexural behavior of CFCC–prestressed piles.

To summarize, there has been a lot of research on the performance of CFRP strands in beams. The purpose of the research presented herein was to investigate the performance of CFCC strands in 24–in. square piles, so as to evaluate the feasibility of replacing the steel in conventional piles used in Florida Department of Transportation bridge construction projects.

CHAPTER 3

MATERIALS AND INSTRUMENTATION

3.1 Introduction

This research involved the precasting and testing of five (5) CFCC–prestressed concrete piles having a cross section of 24 in. x 24 in., with three (3) piles being 40–ft long and two (2) piles being 100–ft long. The piles were precast at Gate Precast Company (GATE) in Jacksonville, Florida. The various tests were performed at GATE, FDOT Marcus H. Ansley Structures Research Center, and at a bridge construction site in Volusia County, Florida. This chapter describes the characteristics and properties of the materials used to construct the piles and the instrumentation used to test them.

3.2 Prestressing Strands

CFCC, manufactured by Tokyo Rope, was used as the prestressing material in the piles. CFCC is a composite of fiber and a fiber bond; the fiber used to provide bond is usually epoxy. Care must be taken to protect the strands from damage, deformation, and sudden shocks caused by heavy or hard objects. Strand diameters of 12.5 mm (0.5 in.) and 15.2 mm (0.6 in.) were used for longitudinal prestressing in the initial and final precasting attempts, respectively, and a CFCC wire with diameter 5.0 mm (0.2 in.) was used for transverse spiral reinforcement. As reported by the manufacturer, the strands and wire have effective cross–sectional areas of 76.0 mm^2 (0.118 in^2), 115.6 mm^2 (0.179 in^2), and 15.2 mm^2 (0.0236 in^2), respectively. The GUTS is 184 kN (41.4 k) for the 12.5–mm diameter strands, 270 kN (60.7 k) for the 15.2–mm strands, and 38 kN (8.54 k) for the 5.0–mm wire. The strands' modulus of elasticity 155 GPa (22,480 ksi), and the ultimate tensile strain is 1.6%; the modulus of elasticity for the wire is 167 GPa (24,221 ksi). The stress-strain relationship of CFCC strand is linear up to failure. Other characteristics of CFCC are mentioned in Section 2.3 and in Appendix A.

For the final precasting attempt, conventional 0.6–in. diameter steel strands were coupled with the CFCC to facilitate stressing. They were seven–wire, 270–ksi (1.86–GPa), low–relaxation strands conforming to ASTM A416 specifications. Their nominal cross–sectional area is 0.217 in^2 (140 mm^2), and the modulus of elasticity is 28,500 ksi (196 GPa).

3.3 Coupling Device Anchorage System

Figure 3.1 shows the conventional method of stressing strands in a casting bed. The steel strand is held by chucks on both ends and is tensioned using a jack. The chuck most commonly used at the non–stressing end of the bed is a Bayonet grip that comprises a barrel and a wedge. On the stressing end of the bed, the most commonly used grip is an open grip (Figure 3.2), where the wedges are held together by an O-ring.

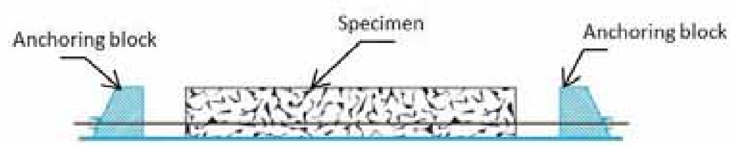


Figure 3.1: A typical stressing bed schematic (Access Science website)

Because CFCC is brittle and susceptible to abrasion, the conventional method of anchoring it for prestressing operations was not allowed. Instead, an anchoring device was used to couple the CFCC with the conventional steel strands. The steel strands were then gripped using the bayonet grips and the open grips at the precasting bed non–stressing end and stressing end, respectively.

The anchoring device was a stainless steel coupler (Figure 3.3) that is produced by Tokyo Rope. It consists of a stainless steel sleeve for the CFCC and an attached joint coupler in which to anchor the steel strand. Before Tokyo Rope manufactured this coupler, Mahmoud et al. (1999) wrapped synthetic yarns around each strand because the CFCC is vulnerable to objects gripping on it directly. Recently, Tokyo Rope introduced a steel mesh sheet (Figure 3.4) and a steel braid grip that provide friction between the CFCC and the stainless steel sleeve and also to avoid direct

Figure 3.2: Open grip (Source: CCL pretensioning systems website)

contact of the wedges with the CFCC, thus avoiding mechanical abrasion. The mesh sheet comprises interlocked layers of stainless steel sheets and Polinet sheets. This provides adequate buffer to the CFCC strands and resists the bite from the wedges during seating, thus protecting the strand from getting damaged. The braided grip provides a second layer of buffering while creating frictional forces against the wedges. To anchor the conventional steel strand to the coupler, a chuck is used.

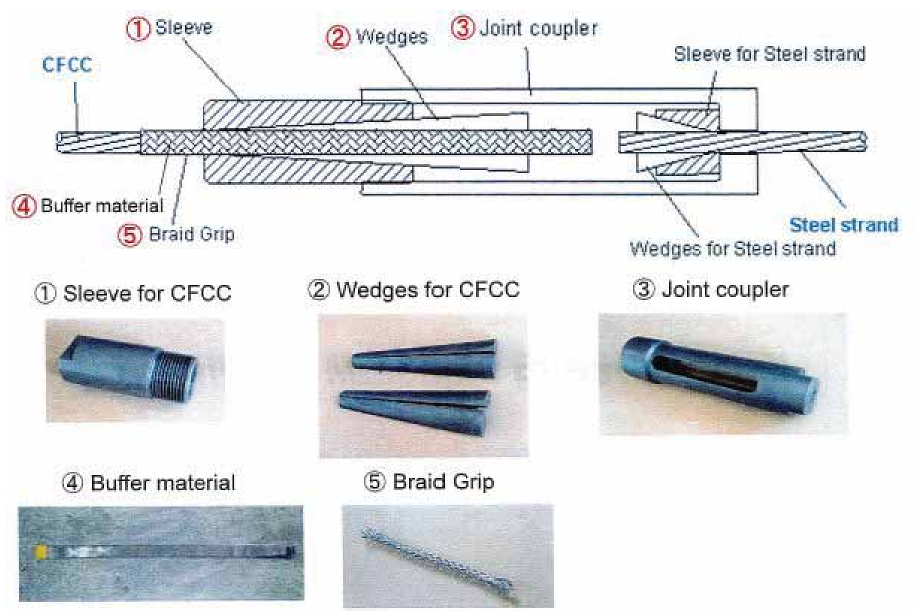


Figure 3.3: Tokyo Rope coupling device (Tokyo Rope CFCC handling manual)

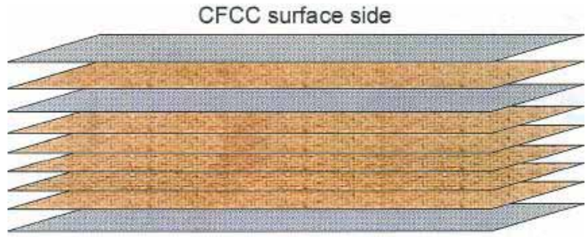


Figure 3.4: Construction of buffer material (Tokyo Rope)

Tokyo Rope currently produces couplers for 0.6–in. diameter strands. This newly–developed anchoring device was tested for creep under joint research between Lawrence Technological University (LTU) and Tokyo Rope. The installation procedure for the anchoring device is explained in Chapter 4, and Tokyo Rope's installation instructions are included in Appendix A.

3.4 Concrete

Self–consolidating concrete (SCC) was used in this research program. SCC is a highly–workable concrete that flows under its own weight through densely–reinforced or complex structural elements. The benefits of using SCC include:

1. Improved constructability
2. A smooth finished surface
3. Eliminated need for mechanical vibration
4. It easily fills complex-shaped formwork.

For a concrete mix to be considered as self–consolidating concrete, the Precast/Prestressed Concrete Institute (PCI) suggests a minimum of three physical properties:

1. Flowability
2. Passing ability
3. Resistance to segregation

To achieve the high flowability and stability characteristics of SCC, typical mixes have a higher paste volume, less or smaller coarse aggregate, and higher sand-to-coarse aggregate ratios than conventional mixtures. Figure 3.5 compares the volume percentage of the constituents used in SCC and those used in traditional concrete.

Previous studies have demonstrated that hardened SCC shares similar mechanical properties with conventional concrete in terms of strength and modulus of elasticity (Persson, 2001). However, SCC has greater concrete shrinkage because of its higher paste or fines content.

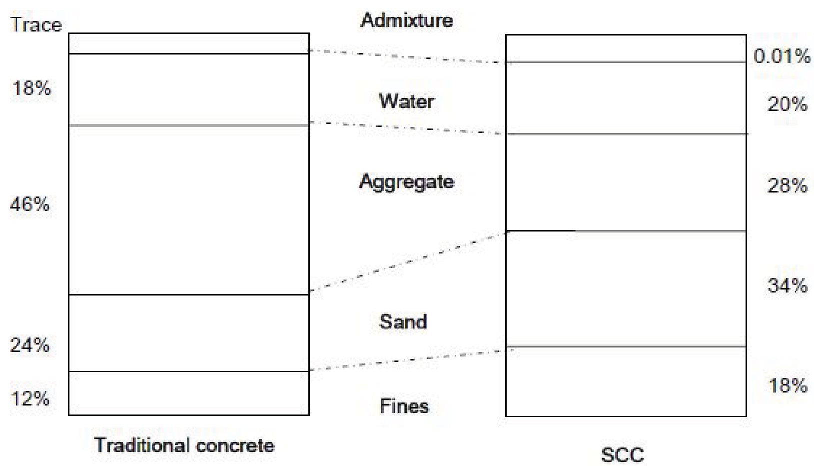


Figure 3.5: Typical volume percentage of constituents in SCC and traditional concrete (Andrawes et al., 2009)

Andrawes et al. (2009) researched the bond of SCC with steel strand, and he concluded that SCC does not affect the strand's transfer or development length and is comparable to conventional concrete and its strength.

GATE mixed the SCC for the piles, and they measured the 28-day cylinder strength to be 8640 psi (59.6 MPa). The aggregates in the mix design were 67 Rock, Sand, STI Flyash, and Glenium 7700. The water–to–cement ratio was 0.34, and the density was 142.3 lb/ft^3. The concrete mix properties are in Appendix B.

3.5 Instrumentation

3.5.1 Strain Gages

This research involved concrete strain measurement during transfer and during flexural and development length tests. For this purpose, strain gage model KC–60–120–A1–11 (L1M2R), manufactured by KYOWA Electronic Instruments Co., Ltd., was used (see Figure 3.6),

where

60 = length of the strain gage (mm)
120 = resistance of the gage (Ω)
L1M2R = 2 lead wires of length 1 m each

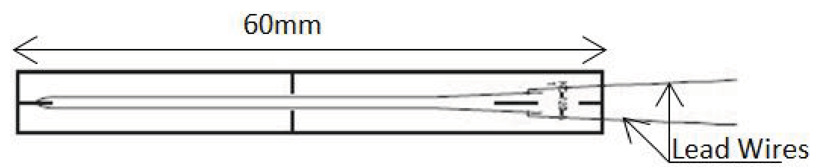


Figure 3.6: Strain gage schematic (Kyowa Strain Gage Manual)

The two (2) lead wires come connected to the strain gage from the supplier, for ease of connecting the gages to the data acquisition system. Otherwise, the lead wires have to be soldered to the gage, which is a time–consuming process. This type of strain gage can be easily adhered to concrete by using glue, and some initial preparation is required before application, which is explained in Section 5.1. Chapter 5 provides details on the strain gage layout for each stage of testing and type of test performed.

3.5.2 Deflection Gages

Non–contact displacement gages, provided by the FDOT Structures Research Center, were used for the flexural and development length tests on the 40–ft piles. The displacement gages are easy to install and can project the laser in areas where contact displacement gages cannot reach. Chapter 5 provides details on the displacement gage layout for each type of test performed.

3.5.3 Embedded Data Collectors (EDC)

To monitor the two (2) 100–ft–long piles during driving operations, Embedded Data Collectors (EDC), shown in Figure 3.7, were pre-installed in the piles before they were cast at GATE. The EDC system was provided and installed by Applied Foundation Testing, Inc. (AFT). AFT also provided personnel on site during pile driving and interpreted the results. The installation procedure is explained in Chapter 4.

Embedded Data Collectors are strain transducers and accelerometers that are embedded in a concrete member. The EDC system was developed as a result of the FDOT project, "Estimating Driven Pile Capacities during Construction" (Herrera et al., 2009). Before EDC was developed, pile monitoring during driving was done

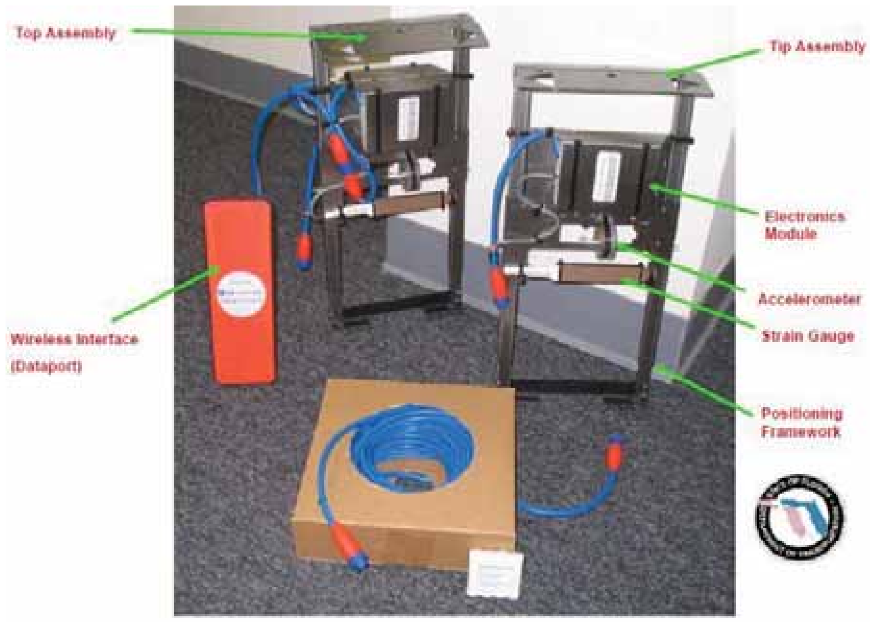


Figure 3.7: Typical EDC set of instruments (Source: FDOT)

with a Pile Driving Analyzer® (PDA). Because the PDA requires the user to assume a constant damping factor for static resistance estimates in the field, and because signal matching analyses (CAPWAP) do not produce unique solutions, FDOT sought an alternative method to calculate static resistance from dynamic load test results. Hence, the FDOT studies were conducted on the use of EDC as a standard method to monitor piles during driving. The EDC system estimates soil damping for every blow during driving. The ability to monitor the pile specimen over a long period of time (several months or years) is another advantage of EDC. In the research by Herrera et al. (2009), EDC performance was compared to PDA and CAPWAP on a database compiled by FDOT. Herrera observed that the EDC provides results that are on an average within 15 percent of PDA and CAPWAP estimated static resistance.

3.5.4 Pile Driving Analyzer® (PDA)

The Pile Driving Analyzer® (PDA) system was used to monitor the two (2) 100–ft–long piles during driving operations. The PDA uses accelerometers and strain transducers to continuously measure pile-top forces and velocities. It is used to monitor stresses in the pile during driving; accordingly, adjustments can be made to the cushion and hammer impact force to prevent damage to the pile. Measurements recorded during driving are also used to calculate the pile driving resistance, as well as the pile's static bearing capacity. FDOT provided and installed the PDA system and interpreted the results. GRL Engineers, Inc. (GRL) was also on site to provide an analysis and expertise.

CHAPTER 4

TEST SPECIMEN PRODUCTION

4.1 Introduction

This research involved the precasting and testing of five (5) CFCC-prestressed concrete piles. This chapter describes the casting setup and the different methods used to stress the strands, and comparisons to conventional methods are made.

Tokyo Rope's coupler installation procedure, as well as stressing procedures and coupler arrangements similar to those used by Grace et al. (2012), was used for this research. This was the first instance that couplers were used by FDOT, and hence an initial session was conducted at the Marcus H. Ansley Structures Research Center to demonstrate the installation procedure for the coupling device. This session also illustrated to the precaster, Gate Precast Company, the techniques for installing and tensioning a CFCC strand.

Later, on July 22–26, 2013, the research team from the FAMU-FSU College of Engineering joined with Tokyo Rope at GATE's precasting yard in Jacksonville, Florida, to precast the five (5) pile specimens. There, Tokyo Rope installed the 40 couplers — 20 at each end of the precasting bed. GATE stressed the set of 20 CFCC strands, tied CFCC spiral reinforcement, and cast the concrete. FAMU-FSU provided assistance whenever needed and oversaw the efforts for accordance with the design and research goals.

This chapter provides details of these efforts, and Appendix H includes several photos of the coupler installation, CFCC strand stressing, CFCC spiral installation, and pile casting.

4.2 Coupling at the FDOT Lab

For the initial demonstration session, 4–ft lengths of 0.5–in. diameter CFCC strands were stressed using couplers supplied by the CFCC manufacturer, Tokyo Rope. The coupler connects the CFCC strand to a conventional steel strand. A small mock-up of the precasting bed was built by FDOT to simulate the procedures that would be used during the actual pretensioning of the pile specimens at GATE's precasting yard (Figure 4.1).

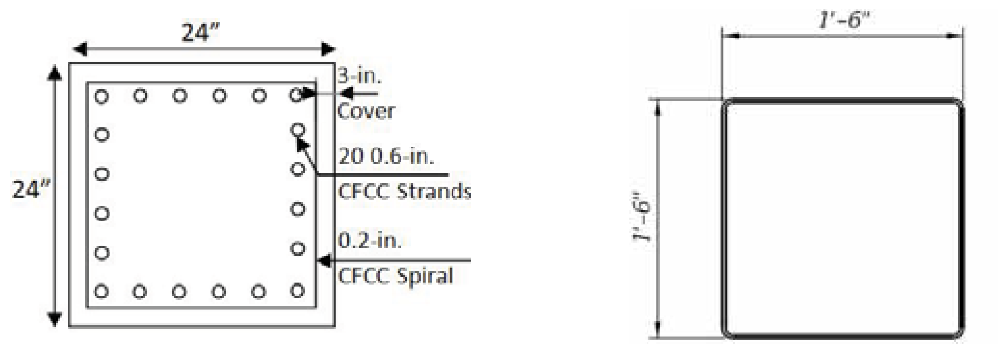
Figure 4.1: Setup for coupling demonstration

Tokyo Rope demonstrated how to install the coupling devices. After they were installed, markings were made at the junctions of the coupler and the CFCC and steel strands, to measure any strand slip that would occur during stressing and to verify that it would slip as predicted by Tokyo Rope. Load was applied using a monostrand jack until the pressure was 3400 psi, which equates to 27,030 lb in the strand. The stress was applied gradually to minimize slippage. At 3400 psi, it was observed that the wedges had seated in the coupler sleeve. When the strand was released, the jack pressure was recorded as 2300 psi, equating to 16,606 lb in the strand. The strand was removed, and the test was repeated on a different strand with similar results.

4.3 Pile Specimen Configuration

The prestressing force was designed so that the pile would have the minimum desired compression of 1 ksi on its cross section to overcome tensile stresses during driving.

The prestressing strand pattern was based on FDOT's standard details for a 24–in. square pile with 20 0.6–in. diameter (15.2–mm) strands (Figure 4.2a). The 20–strand option was chosen because of GATE's casting bed strand template. The spirals were 5.0–mm diameter (0.2–in.) CFCC, with approximate dimensions shown in Figure 4.2b. The number of turns and pitches for the CFCC spirals was based on FDOT standards for conventional steel spirals (Figure 4.3), which is designed to provide confinement to the concrete core and to avoid premature failure at the ends due to prestress release and impact load during driving. More details of the piles are provided in Appendix C.



(a) Section

(b) Spirals

Figure 4.2: Section view of the pile specimens. (See Appendices A and C for manufactured dimensions.)

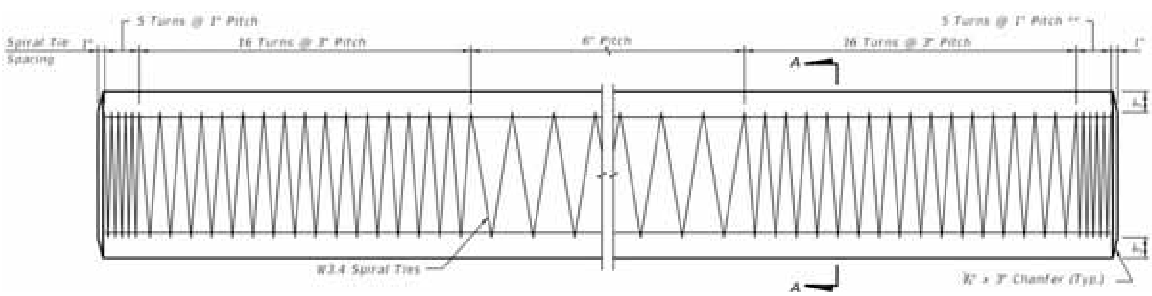


Figure 4.3: FDOT standard pile details

4.4 Prestressing Losses

PCI Design Handbook (PCI, 2010) edition, Chapter 5, explains the prestressing loss calculations for a prestressed concrete member. This enables the designer to estimate the prestressing losses rather than using a lump–sum value. The equations provide realistic values for normal design conditions. These equations were applied to calculate the prestress losses for the five (5) pile specimens and resulted in a total prestress loss of 8.8% for each of the 16 strands. The four (4) corner strands that were initially stressed to only 5 k had much greater losses (61.6%) because the elastic shortening, creep, and shrinkage losses due to all the strands being stressed were disproportional to the small initial stress (See Appendix D). The calculations for the various losses are described below.

The total losses are due to elastic shortening (ES), creep of concrete (CR), shrinkage of concrete (SH) and relaxation of the strands (RE):

$$TL = ES + CR + SH + RE \tag{4.1}$$

Losses due to elastic shortening, in psi, are calculated as:

$$ES = \frac{K_{es} E_{ps} f_{cir}}{E_{ci}} \tag{4.2}$$

where
K_{es} = 1.0 for pretensioned components
E_{ps} = modulus of elasticity of prestressing strands (psi)
E_{ci} = modulus of elasticity of concrete at the time prestress is applied (psi)
f_{cir} = net compressive stress in concrete at center of gravity of prestressing force immediately after the prestress has been applied to the concrete (psi)

where

$$f_{cir} = K_{cir}(\frac{P_i}{A_g} + \frac{P_i e^2}{I_g}) - \frac{M_g e}{I_g} \tag{4.3}$$

where
K_{cir} = 0.9 for pretensioned components
P_i = initial prestress force (lb)
e = eccentricity of center of gravity of tendons with respect to center of gravity of concrete at the cross section considered (in.)
A_g = area of gross concrete section at the cross section considered (in^2)
I_g = moment of inertia of gross concrete section at the cross section considered (in^4)
M_g = bending moment due to dead weight of prestressed component and any other permanent loads in place at the time of prestressing (lb-in.)

Losses due to creep of concrete, in psi, are calculated as:

$$CR = K_{cr}(\frac{E_{ps}}{E_c}(f_{cir} - f_{cds})) \tag{4.4}$$

where
K_{cr} = 2.0 normal–weight concrete
f_{cds} = stress in concrete at center of gravity of prestressing force due to all superimposed, permanent dead loads that are applied to the member after it has been prestressed (psi)
E_c = modulus of elasticity of concrete at 28 days (psi)

where

$$f_{cds} = \frac{M_{sd}(e)}{I_g} \tag{4.5}$$

where
M_{sd} = moment due to all superimposed, permanent dead load and sustained load applied after prestressing (lb-in.)

Losses due to shrinkage of concrete, in psi, are calculated as:

$$SH = (8.2 * 10^{-6}) K_{sh} E_{ps} (1 - \frac{0.06V}{S})(100 - RH) \tag{4.6}$$

where
K_{sh} = 1.0 for pretensioned components
$\frac{V}{S}$ = volume-to-surface ratio
RH = average ambient relative humidity

Losses due to relaxation of strands, in psi, are calculated as:

$$RE = [K_{re} - J(SH + CR + ES)]C \tag{4.7}$$

where values of K_{re} and J are taken from Table 5.7.1 in PCI (2010), and values of coefficient C are taken from Table 5.7.2.

4.5 Pile Casting Bed Setup

4.5.1 Stressing Forces

According to the ACI specifications for CFRP strands, CFCC should be stressed to no more than 65% of GUTS. For the 15.2–mm diameter strands, GUTS is equal to 270 kN (60.7 kips). However, GATE's casting bed was designed to hold a maximum compressive force of 684 kips, which is not enough strength if all 20 strands were stressed to 65% of GUTS. To keep the total compressive force under the capacity of the casting bed, one of the options considered was to stress all the strands to less than 65%. The option chosen, however, was to stress the four (4) corner strands to 8.2% of GUTS and to stress the remaining 16 strands to 65% of GUTS. This would permit the CFCC's performance to be assessed at ACI's recommended maximum stress level. Hence, the jacking force for each of the 16 strands was 39.45 kips (65% of GUTS), and the jacking force for each of the four (4) corner strands was 5 kips (8.2% of GUTS) — for a total compressive force of 651.2 kips.

4.5.2 Wooden Headers

CFCC strands are not as strong in shear as steel strands, approximately half as much, and are susceptible to damage from hard-edged objects in abrasion. To avoid damaging the CFCCs, GATE's conventional steel headers were replaced with wooden (0.5–in.–thick plywood) headers that were built at the casting yard (Figure 4.4). Twenty (20) holes of 0.7–in. diameter were drilled in the headers to accommodate the CFCC strands. The wooden headers were placed at every pile–end location. Additional headers were placed at each end (at the stressing and non–stressing ends) of the bed, to be used for casting 5–ft–long concrete blocks that would secure the strands as a measure of safety after stressing.

(a) Conventional Steel Header

(b) Wooden Header

Figure 4.4: Steel header replaced with wooden header

4.5.3 Prestressing Bed Layout

The prestressing bed was a self-stressing form, with a total length of 440 feet. A schematic is shown in Figure 4.5. The distance between the concrete block at the stressing end and Pile ′1′ was 1 ft, and similarly the distance between the concrete block at the non–stressing end and Pile ′5′ was 1 ft. The end–to–end distance between adjacent piles was 1 ft, to provide enough room to cut the CFCCs. Because of the coupling devices that were used, additional length of CFCC strands was considered, which is explained in the next section.

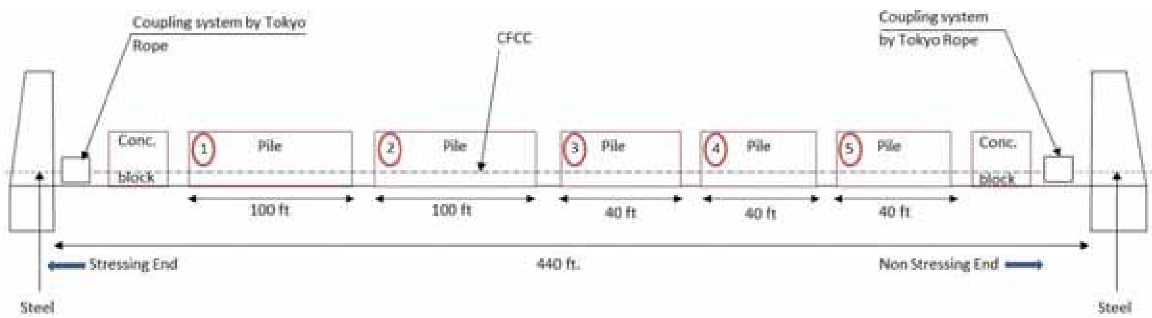


Figure 4.5: Stressing bed schematic at Gate Precast Company

4.6 Strand Installation

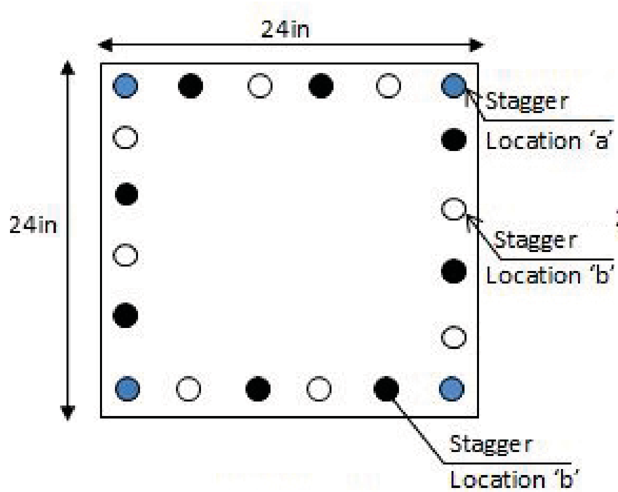
The 5–mm diameter CFCC spirals were delivered in five (5) bundles, one (1) for each pile. The bundles were placed at each pile location, to be put in the final position once the prestressing operations were complete. The CFCC strands were delivered to GATE in spools (Figure 4.6). They were pulled from the spool and along the length of the casting bed, while being fed through the headers. GATE used typical procedures to pull the strands, with the exception of their pulling one strand at a time by hand instead of machine-pulling several at a time.

Each strand was cut to a length of 360 ft before another one was pulled from the spool. This length accounted for the prestressing bed setup, so the strand would be long enough for the total pile length, the concrete blocks, the headers, and the additional length needed to avoid coupler interaction during stressing (as discussed in the next section).

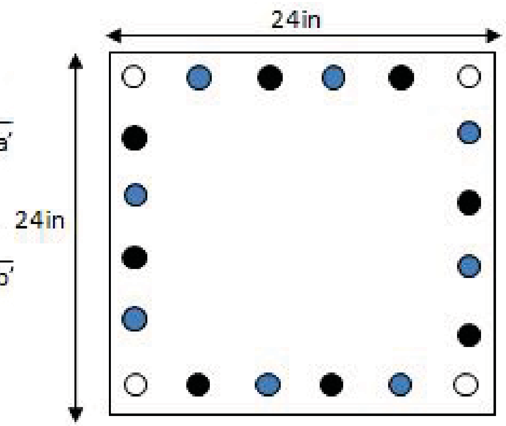
Figure 4.6: Assembly to lay strands

4.7 Coupler Staggering

Before the couplers were installed, it was necessary to consider the CFCC strand elongation and the seating losses in the coupler as explained in Section 4.2. The couplers were installed in a staggered pattern, to avoid any coupler interaction that could result from the strands elongating during tensioning. The couplers were staggered at 3–ft increments. The strands were stressed starting with the coupler closest to the stressing jack and extending 8 ft from the end of the pile, proceeding to the couplers extending 5 ft, and finally to the couplers extending 2 ft. Figure 4.7 shows the stagger pattern at the stressing and non–stressing ends of the prestressing bed, and Figure 4.8 shows a plan view at each end.

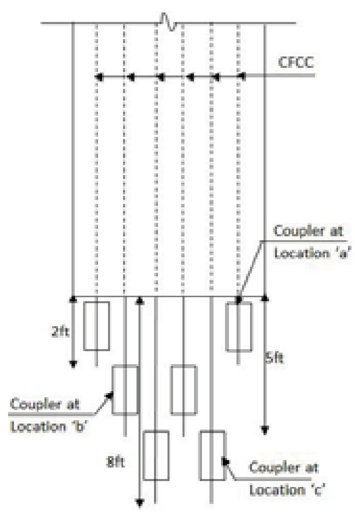


(a) Stressing End View

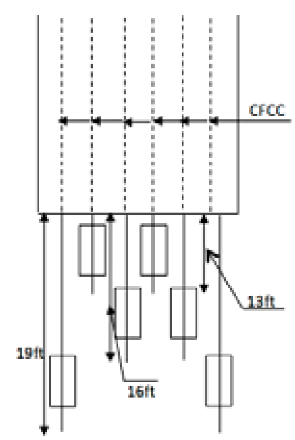


(b) Non-Stressing End View

Figure 4.7: CFCC strand stagger pattern, viewed from both ends



(a) Stressing End View



(b) Non-Stressing End View

Figure 4.8: Coupler stagger pattern, plan view of both ends

The basic elongation of the CFCC strands due to the initial prestressing force was calculated using Equation 4.8.

$$\Delta = \frac{PL}{AE} \tag{4.8}$$

where
P = prestressing force applied (kips)
L = length of the CFCC strand (ft)
A = cross–sectional area of the CFCC strand (in^2)

E = modulus of elasticity of the strand (ksi)

In addition to the basic elongation, an abutment rotation of 0.25 in., anchor sets of 0.125 in. and 0.375 in. for the non-stressing end and stressing end, respectively, along with seating losses of the steel strand's and CFCC's wedges in the coupler, were taken into account. The seating in each coupler was assumed to be 0.125 in. for the steel strand and 2.165 in. for the CFCC strand per the manufacturer. The elongation of the steel strands were also considered.

4.8 Coupler Installation Procedures

The couplers were installed by Tokyo Rope. Tokyo Rope's full instructions are included in Appendix A and are summarized below.

4.8.1 Setting the Anchoring Device

1. Wrapping the Buffer Material

   The buffer material explained in Chapter 3 was wrapped over the end of the CFCC strand to be anchored. The wrapping was spiraled over the strand, carefully following the CFCC's direction of twist, so that during tensioning, the strand and the buffer material would act homogeneously (see Figure 4.9).

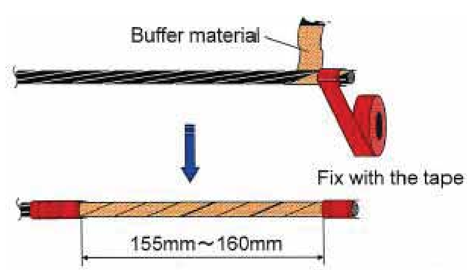


Figure 4.9: Wrapping the buffer material (Source: Tokyo Rope)

   According to Tokyo Rope specifications, the buffer material should extend up to 160 mm from the end of the CFCC to be anchored so as to provide enough area for the wedges to seat.

2. Spray Molybdenum

The sleeve was lubricated with molybdenum spray (Figure 4.10) to reduce the friction between the wedges and the sleeve during wedge seating. Although

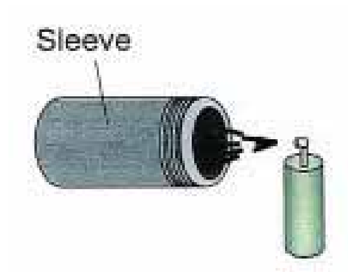


Figure 4.10: Spraying molybdenum on the sleeves (Source: Tokyo Rope)

the amount of molybdenum to be sprayed on the sleeve was specified by Tokyo Rope, the sleeves were sprayed until the inside surface was fully covered. The molybdenum spray is an air–drying, solid film lubricant containing molybdenum disulfide and a binder, so it adheres to many surfaces and does not easily rub off. It forms a thin, dry but "slippery" film of solid lubricants and performs under extremely heavy loads up to 10,000 psi. The molybdenum spray for this research was supplied by Tokyo Rope.

3. Insert the Sleeve and Install the Braided Grip

   After spraying the sleeve with the molybdenum lubricant and letting it dry (usually less than a minute), the CFCC strand (which is wrapped with the mesh sheet) was inserted into the sleeve. The mesh sheet buffer material was then covered with the braided grip (Figure 4.11).

Figure 4.11: Installing sleeve and the braided grip

The braided grip was first compressed manually, such that the grip's diameter increased for the ease of sliding it over the mesh sheet. Once it enveloped the mesh sheet, the braided grip was drawn tightly towards the end of CFCC to eliminate the excess diameter if any, such that the braided grip wrapped the mesh sheet without any wrinkles. An electrical tape was fixed to both the ends of the braided grip and mesh sheet to protect the installer from any sharp edges.

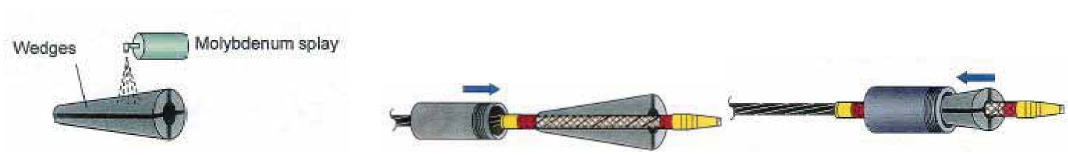
4. Check the Installation

   It was ensured that the wrapping of the buffer material followed the specifications provided by Tokyo Rope:

   - Tape–to–tape length needs to be over 155 mm because the length of the wedge is 155 mm
   - Check if the braided grip has no wrinkles and is tightly wrapped
   - The spiral wrapping of the mesh sheet should not have any gap between the spirals

4.8.2 Setting Wedges and Sleeve Toward CFCC

Figure 4.12 shows the steps to set the wedges and sleeve for the CFCC. Once the



(a) Step 1 **(b)** Step 2 **(c)** Step 3

Figure 4.12: Wedge setup

checks for the buffer material were verified, the molybdenum spray was applied on the outer surface of the wedges until they were completely covered with a thin film of the lubricant, to provide ease of wedge seating. The wedges were placed on the CFCC strand wrapped with the buffering material, such that 60 mm of the strand end was extending beyond the larger diameter of the wedge. The wedges were provided with an O-ring so that they remained in place.

The wedge position was checked for the following:

1. The wedge position should not overlap with the electrical tape that is wrapped around the ends of the buffer material.
2. The wedges should not have any gaps between them.

The wedges were inserted into the sleeve:

A pneumatic jack provided by Tokyo Rope was used to provide a consistent penetration of all four (4) parts of the wedge into the sleeve, as shown in Figure 4.13. A 55–mm mark was made on the wedge from the larger end of the wedge, and that is the point to which the wedge was penetrated in to the sleeve. If the wedges are inconsistently installed in the sleeve, there are chances of improper seating of the wedges, thus providing an uneven grip on the CFCC strand. After the mark was made, the pneumatic jack (Figure 4.13) was used to push the wedges into the sleeve, with a pressure of about 20 MPa (3 ksi).

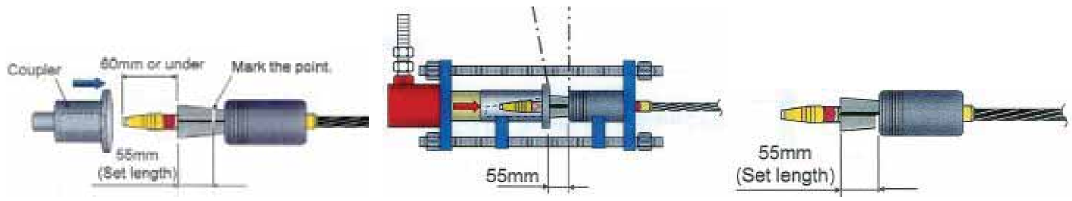


Figure 4.13: Wedge installation

4.8.3 Finishing the Coupler Installation

The coupler installation was finished in the two steps described below.

1. Attaching the wedges and the coupler to the steel strand:

   A standard open grip, shown in Figure 3.2, was used to wedge the steel strand in the coupler. The coupler is provided with a hole which allows the steel strand to be inserted in one end (Figure 4.14). After the steel strand was inserted into the coupler, the open grip was installed on it and was pulled back inside the coupler, so that anchoring of the steel strand was complete.

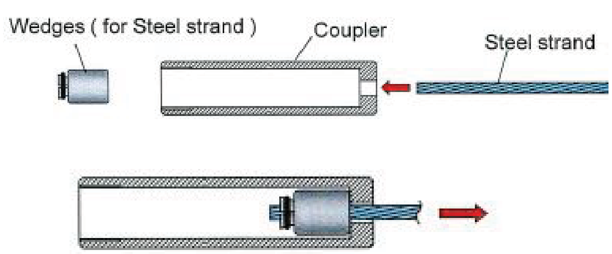


Figure 4.14: Steel strand installation

2. Joining the CFCC to the steel strand:

The CFCC strand end with installed wedges and buffer materials was coupled to the steel strand end by twisting together the threaded ends of the sleeve and the coupler (Figure 4.14). The coupler was turned until it was taut and then drawn out by a thread, so that there would be no damage to the coupler while tensioning. Figure 4.15 is a photo of the completed installation of a coupler. Note that there should be no interaction between the CFCC and the steel strand within the coupler.

Figure 4.15: CFCC coupled with steel strand

After the coupler installation was complete, the slack in the CFCC strands that occurred while laying the strands was removed by pulling the strands taut at the non–stressing end. The steel strands at the non–stressing end were anchored by using the standard bayonet grips. Figure 4.16 shows the coupler arrangement after the couplers were installed. Location $'a'$ represents the couplers extending 2 ft from the end of the pile, location $'b'$ represents the couplers extending 5 ft from the end of the pile, and location $'c'$ represents the couplers extending 8 ft from the end of the pile.

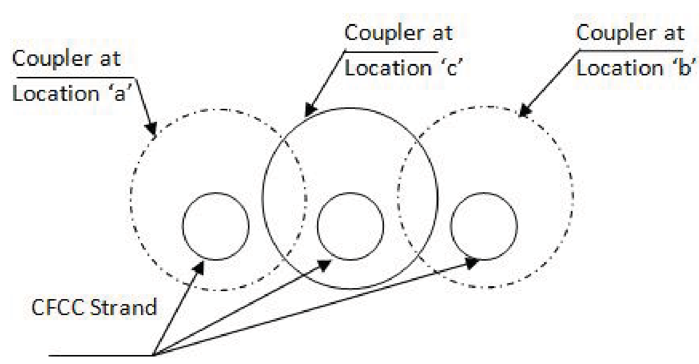


Figure 4.16: Coupler view after stagger

4.9 Stressing the Strands

The stressing pattern was different than for conventional steel strand stressing. All the strands were stressed to a force of 5 k during the initial prestressing, and the corner strands were not stressed more thereafter. The remaining 16 strands were stressed in the sequence shown in Figure 4.17. GATE measured the stressing force during all pretensioning operations and recorded it after each strand was fully stressed.

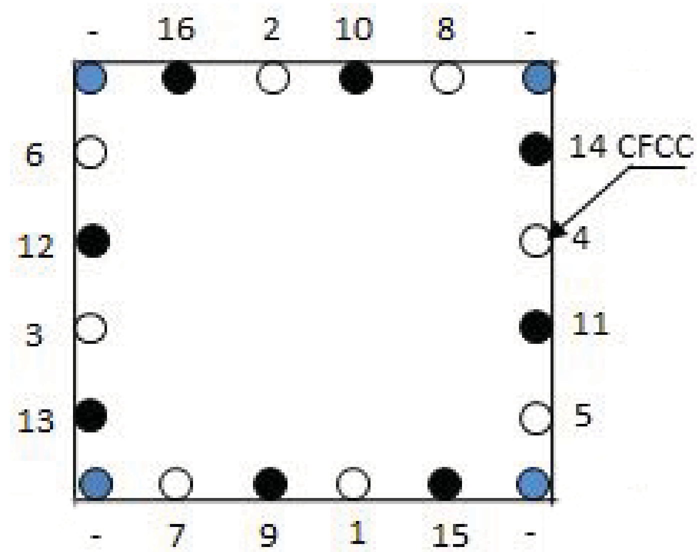


Figure 4.17: Stressing sequence, at stressing end, looking towards pile

The expected combined elongation of the CFCC strands and steel strands was less than 50 in. The hydraulic jack had a stroke capacity of 72 in. and therefore would not need to be repositioned to complete the stressing. Hence, there was no need to cut any steel strand ends during the stressing operation. Because the CFCC was coupled with the steel strand, Tokyo Rope advised the precaster to stress each strand gradually. The suggested approximate time to stress one strand to a force of 39.45 k was 3 minutes. This would allow the wedges in the coupler to seat without causing any slippage of the strands.

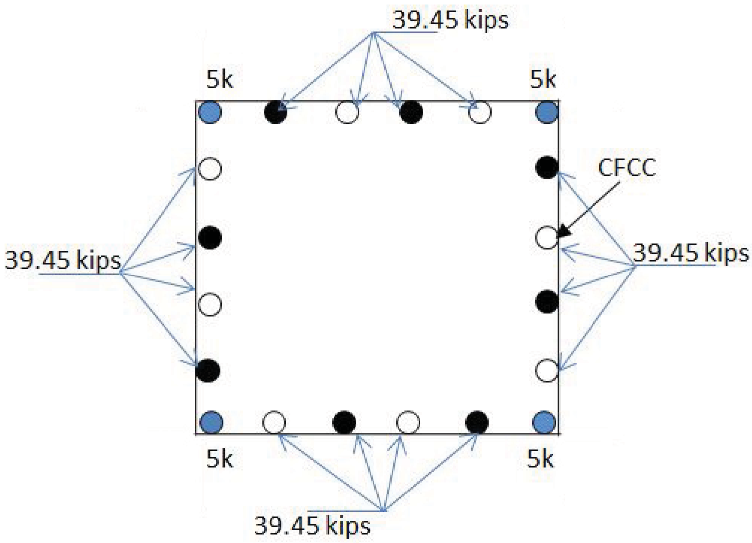
The prestressing force was applied using a hydraulic monostrand jack, and the strands were locked using open grips at the stressing end so that the force would be maintained after jacking. For the initial stressing, all 20 strands were stressed to a force of 5 k, and the corner strands were not stressed more thereafter. After the initial stressing was complete, the CFCC strands were checked to ensure that there was not excess slack, and the integrity of the coupler device was checked. Markings were made on the CFCC strands at the edge of the couplers to denote any slippage. Figure 4.18

illustrates the coupler stagger pattern after the completion of initial stressing.

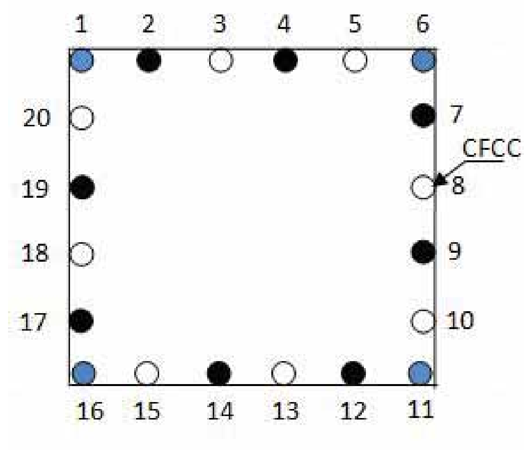
Figure 4.18: Staggered couplers after initial pretensioning

Figure 4.19 shows the target force for each strand, and Table 4.1 shows the measured force and elongation for each strand. During the stressing process, after each strand tensioning was complete, elongation of strands was recorded by measuring from a pre–marked spot on the strand to the end of the jack. The measured elongations ranged from $46\frac{3}{4}$ in. to 50 in., which was close to the expected $47\frac{1}{4}$ in. The elongations of strands 2, 3, and 4 were higher than the calculated elongation, likely because of initial excess slack in the strand due to the weight of the coupler.

After the completion of stressing, self–consolidating concrete was used to cast the concrete blocks between the pile ends and casting bed ends. This was a measure of safety to secure the stressed strands. The concrete was mixed at GATE and was supplemented with an accelerating agent, so that the concrete blocks would cure faster.



(a) Target forces



(b) Strand numbers

Figure 4.19: Target forces and strand numbers at stressing end

Table 4.1: Force and elongation measurements

Strand No.	Force in Strand lb	Calculated Elongation in.	Observed Elongation in.
1	5000	NA	NA
2	39460	$47\frac{1}{4}$	50
3	39490	$47\frac{1}{4}$	$49\frac{3}{4}$
4	39460	$47\frac{1}{4}$	48
5	39430	$47\frac{1}{4}$	$47\frac{1}{2}$
6	5000	NA	NA
7	39460	$47\frac{1}{4}$	$47\frac{3}{4}$
8	39460	$47\frac{1}{4}$	$46\frac{3}{4}$
9	39460	$47\frac{1}{4}$	$47\frac{1}{4}$
10	39440	$47\frac{1}{4}$	$47\frac{1}{2}$
11	5000	NA	NA
12	39450	$47\frac{1}{4}$	$47\frac{1}{4}$
13	39450	$47\frac{1}{4}$	$46\frac{3}{4}$
14	39450	$47\frac{1}{4}$	$47\frac{1}{4}$
15	39470	$47\frac{1}{4}$	$46\frac{3}{4}$
16	5000	NA	NA
17	39460	$47\frac{1}{4}$	48
18	39440	$47\frac{1}{4}$	$46\frac{3}{4}$
19	39470	$47\frac{1}{4}$	$47\frac{1}{4}$
20	39510	$47\frac{1}{4}$	$47\frac{1}{4}$

4.10 Installation of Spirals and EDC

The CFCC spirals, which were placed near their respective locations in the piles before the stressing operations began, were tied in their final position to the CFCC strands with plastic zip ties (Figure 4.20). The spirals at the locations where Embedded Data Collectors were to be installed were temporarily left untied, to provide enough space to install the EDC, after which the spirals were tied. Lifting hooks were installed in accordance with FDOT standards.

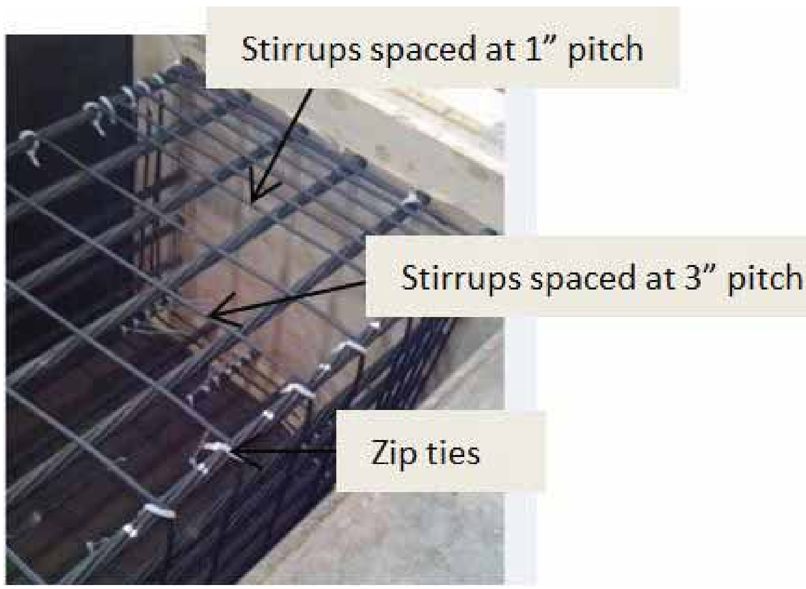


Figure 4.20: Installation of stirrups (Source: ACI)

Embedded Data Collectors were installed in the two (2) 100–ft piles, for the purpose of monitoring the piles during driving. Applied Foundation Testing, Inc. (AFT) provided and installed the Embedded Data Collectors, as follows:

1. EDCs were installed at two (2) pile widths (48 in.) from the head of the pile and at one pile width (24 in.) from the tip of the pile.
2. An additional EDC was installed at the center of the other two (2) EDCs to monitor the strain in the mid span during driving.
3. Cables were run through the piles for enabling the connection between the three (3) sets of EDCs.
4. The cables were tied to the strands using zip ties, making sure that the cables would not be subjected to any damage while placing concrete.

The instrument set located in the center was kept clear of the lifting hooks, at 48 in. and 51 in. from the pile head for Pile No. 1 and Pile No. 2, respectively (refer to Figure 4.5 for casting bed layout). The spirals in the vicinity of the EDCs were tied to the CFCC strands after the EDC installation was complete. Figure 4.21 shows the EDC secured to the CFCC strands. The EDC was fixed using a rubber material to prevent the hard edge of the steel frame from interacting with the strands and to minimize any steel and carbon interaction. The entire setup was checked for quality

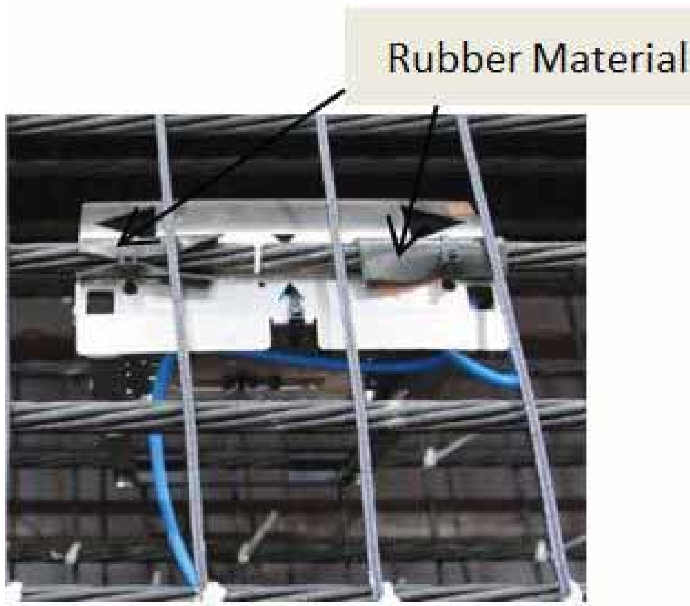


Figure 4.21: EDC clamped with a rubber material

by GATE and the researchers before the concrete was placed. Once the piles were cast and cured as described in the next section, the battery for the EDC system was disconnected. The battery was reconnected several months later, when the piles were driven at the construction site.

4.11 Concrete Placement

Not typically used for piles, a self–consolidating concrete mix was used to avoid the need to use a mechanical vibrator. This was desired because the CFCC strands are susceptible to abrasion and damage if a conventional mechanical vibrator is used. As per Tokyo Rope's standards, a vibrator with a rubber tip can be used to consolidate the concrete in a member that contains CFCC, or a mechanical vibrator with no rubber wrapping can be used in cases where the spacing between the CFCCs is larger than the diameter of the vibrator head so that there is no interaction between the vibrator head and the CFCC strands. Instead, self–consolidating concrete was used so that a vibrator would not be needed during placement operations (Figure 4.22). This would avoid altogether the potential of impacting the CFCC with a vibrator.

Figure 4.22: Casting using SCC

Accelerants were added to the concrete for faster curing. To cast all five (5) piles, four (4) truckloads of concrete were placed. The top surface of the concrete was leveled to a smooth finish. Once the casting was complete, a plastic cover was placed over the bed to facilitate a uniform curing temperature, as shown in Figure 4.23. Steam curing was not allowed because the temperature could have affected the couplers. According to Tokyo Rope, slippage of a strand in the coupler occurs at around 140°F.

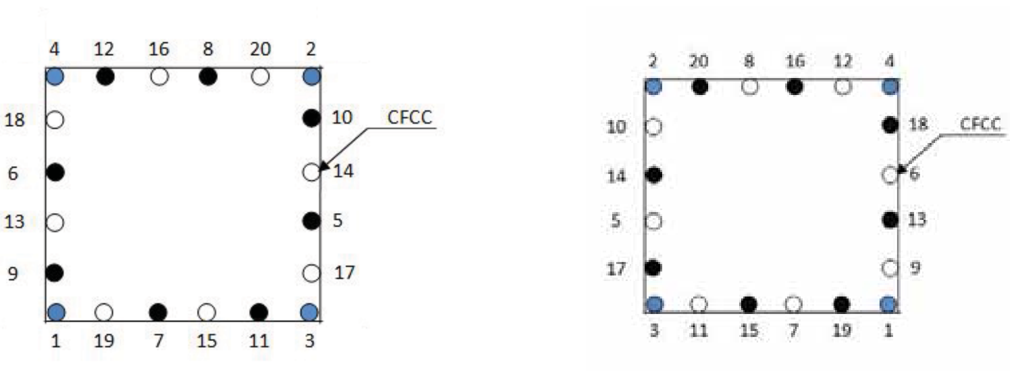
Seven (7) 4-in. x 8-in. cylinders were made, to test for concrete strength after 24 hours (to determine if the strands could be released) and at the times of the flexure tests and pile driving tests. The next day, the strain gages were installed for the purpose of the transfer length tests described in the next chapter.

4.12 Stress Release

To release the strand force into the piles, the strands were then cut in the sequence shown in Figure 4.24. Figure 4.25 shows the tools used to cut the steel and CFCC strands, respectively.

(a) Steel strand concave (b) Plastic Cover

Figure 4.23: Curing



(a) Stressing End (b) Non-stressing End

Figure 4.24: Strand cutting sequence

For a typical pile, the precaster cuts the strands in a routine, customary pattern. However, in this study, the strand cutting sequence was governed by the position of the installed couplers. The cutting sequence was designed such that there would be no coupler interaction during release of prestressing force, as the couplers would tend to pull in towards the pile when the strands were cut (refer to Figure 4.8 for the coupler stagger pattern). In accordance with a typical cutting sequence, the cuts were alternated in a symmetrical pattern about the axes of the cross section, to not cause unnecessary (although temporary) tension on the pile's outer surfaces.

Before the strands were cut, markings were made at 2 in. from the header locations on the CFCC strands to measure any amount of strand slip during stress release. From Figure 4.24a, the corner strands that extended 2 ft from the end of the pile were cut first, and then the strands (marked in black) that extended 5 ft from the end of the

(a) Torching the steel

(b) Cutting the CFCC

Figure 4.25: Different strand cut method

pile were cut, followed by the strands (marked in white) that extended 8 ft.

Conventionally, torches were used to cut the steel strands at both the stressing and non-stressing ends simultaneously (Figure 4.25a). After the 20 strands had been cut at each end, the CFCC strands between the pile headers were cut using a side grinder (Figure 4.25b), because CFCCs are bonded with epoxy and it is recommended to not torch them. The distance in the headers between the pile ends was only about 1 ft, but this distance could be increased so that the operator cutting the strands will have a greater space in which to lower the grinder for cutting the strands at the bottom.

The EDCs monitored concrete strains, during stress release, in the two (2) 100–ft piles. Similarly, electrical strain gages were used to monitor the concrete strains in the three (3) 40–ft piles. The experimental program and instrumentation setup are explained in the next chapter.

CHAPTER 5

EXPERIMENTAL PROGRAM

5.1 Transfer Length Tests

5.1.1 Introduction

As mentioned in Chapter 2, the transfer length is the distance from the end of the prestressing strand to the point where the effective stress in the strand is developed. In a pretensioned member, this stress is transferred from the strand to the surrounding concrete through bond. The length over which the stress is transferred is inversely proportional to the bond strength. For design, it is necessary to predict this length, so that it is known where the effective prestress has been fully transferred to the member's cross section.

This section describes the experimental program designed to measure the CFCC's transfer length in this study. Monitoring the piles was done at Gate Precast Company on July 26, 2013, while the piles were in their casting bed. Concrete strains were continuously monitored at the ends of the piles while the steel strands were being torch cut and while the CFCC strands were being cut with a side grinder. This data shows the gradual transfer of prestress to the surrounding concrete throughout the strand cutting operations.

5.1.2 Test Setup and Instrumentation

The three (3) 40–ft piles were equipped with electrical resistance strain gages on the tops of the piles, so that concrete strains could be measured during stress release. The strain gage application was started after the concrete was allowed to cure for 24 hours. The strain gages had an effective length of 60 mm (2.36 in.) and were installed at the ends of the piles and at mid span.

On all three (3) pile specimens, the strain gage locations were kept similar, as shown in Figure 5.1. One end of the pile was instrumented with eight (8) strain gages along the centerline of the pile, and the other end had 18 strain gages installed approximately along the top corner strands.

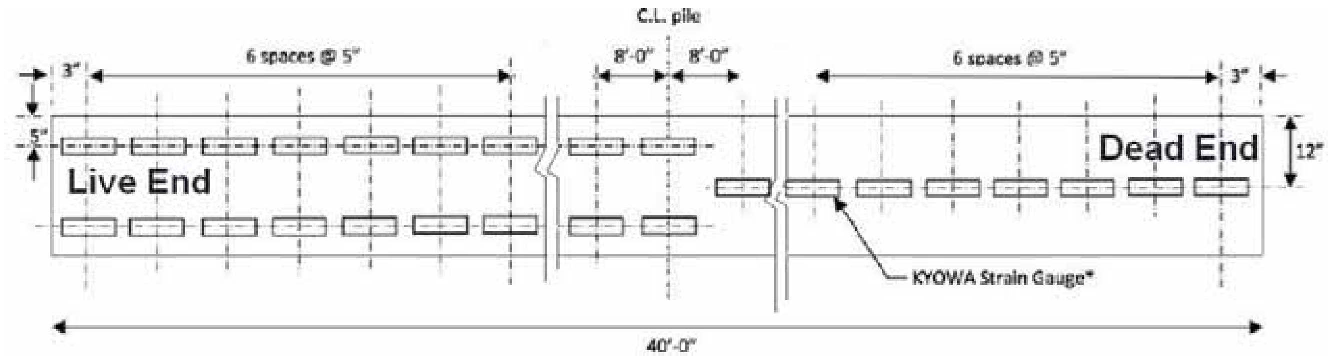


Figure 5.1: Strain gage layout on top of pile for transfer length test (Not to scale)

Strain gage application was done as follows:

1. The concrete at the strain gage locations was smoothed with a grinder.
2. The smooth surface was cleared of dust by spraying it with acetone and wiping it clean.
3. Centerline location markings were made on the smoothened surface.
4. Strain gages were applied using Zap gel glue.
5. The strain gage lead wires were secured by taping them to the concrete with duct tape.

The strain gages on a given pile were connected to a channel which in turn was connected to the data acquisition system located adjacent to the center of the three (3) 40–ft piles. The system was provided and controlled by FDOT. The strain gages were checked for weak bond with the concrete by looking for violent jumps in the strain readings, and gages with irregular readings were replaced. The strain gages were numbered as shown in Figure 5.2, starting from the stressing end of the bed. For example, for strain gage number S103, S represents a strain gage, and 103 represents the first pile and the third strain gage on the pile. Similarly, the gage numbers on the second and third piles started with S201 and S301, respectively. After the installation was complete, the concrete strains were monitored throughout the stress release process. The results are discussed in Chapter 6.

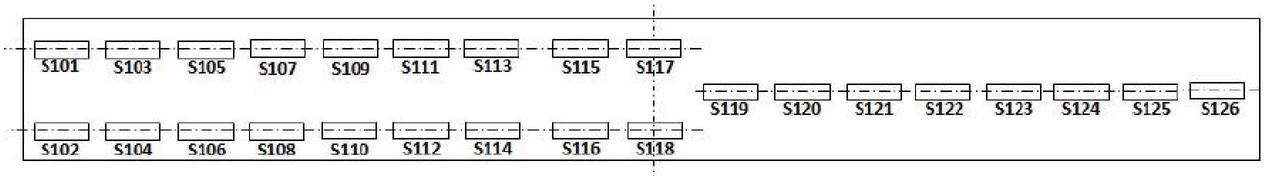


Figure 5.2: Strain gage numbering for transfer length test (Top view of pile in casting bed)

The two (2) 100–ft piles were instrumented with Embedded Data Collectors, as previously discussed. As shown in Figures 5.3 and 5.4, the data collector steel frames were placed at a distance of two (2) pile widths from the head of the pile and one (1) pile width from the bottom of the pile.

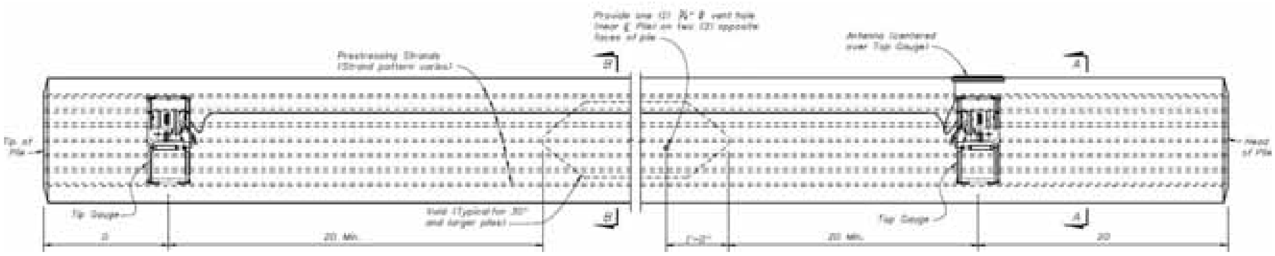


Figure 5.3: Typical EDC layout (FDOT)

Figure 5.4: EDC installation

After the concrete was cast, the strains were recorded through a wireless receiver; this continued throughout the strand cutting operations. EDC installation and data monitoring was done by Applied Foundation Testing, Inc. The results from the EDC monitoring are discussed in Chapter 6. The EDCs were also used to monitor the two (2) 100–ft piles during driving.

5.2 Development Length and Flexure Tests

5.2.1 Introduction

For design, it is necessary to predict the length required to develop the strand's ultimate strength. This development length is the length at which the failure mode changes from bond slippage failure to rupture of the tendons. The design of pile foundations also requires calculation of the pile's flexural capacity.

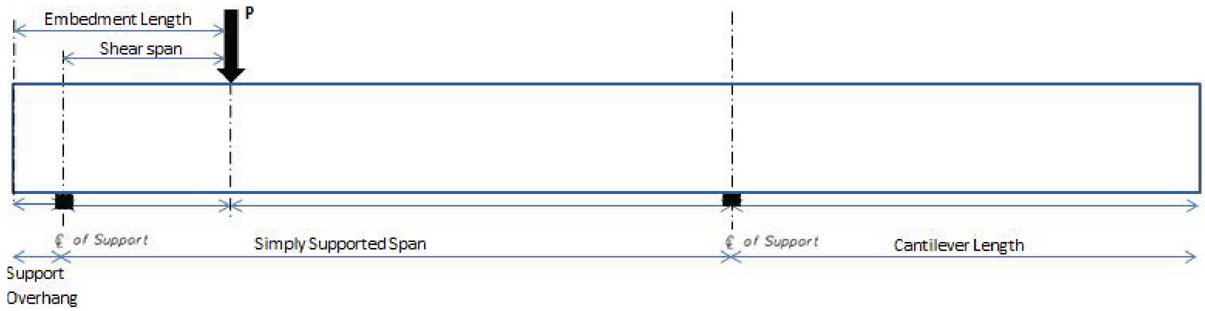
This section explains the experimental setup, instrumentation layout, and test procedures used for development length and flexure tests in this study. The shear span length was varied to determine the development length of the CFCC strands. An additional test was performed to determine the flexural capacity of the pile. The two development length tests were performed on September 6 and 10, 2013. The flexure test was performed on September 12, 2013.

5.2.2 Test Matrix and Setup

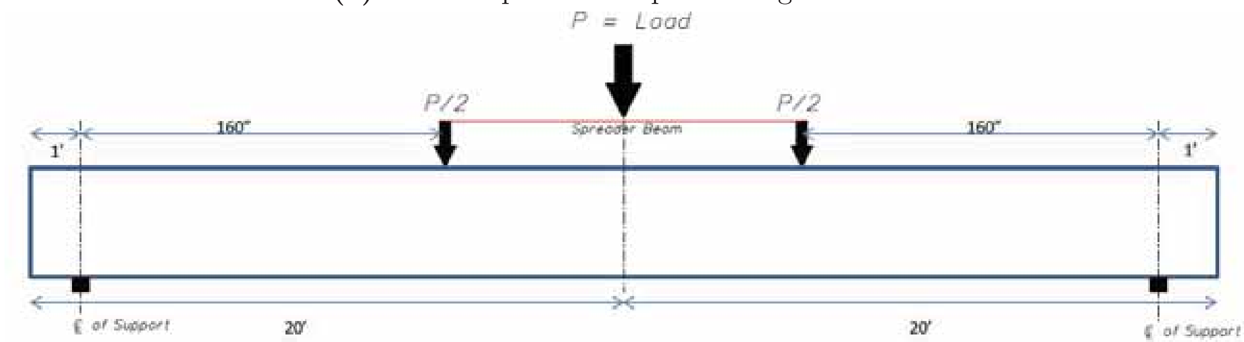
Two (2) of the 40–ft piles were used for experimentation purpose at the FDOT Structures Research Center in Tallahassee, Florida, 45 days after casting. (The third 40–ft pile that had been cast was kept for possible future testing.) The piles were placed in a test setup, similar to the one presented by Gross and Burns (1995). For each test setup, the pile was simply supported. Two (2) development length tests were performed on the first pile, which had a cantilevered end (Figure 5.5a). One (1) flexure test was performed on the second pile, with supports on the ends (Figure 5.5b).

The piles were supported by two (2) steel I–beams. The I–beams were leveled and grouted to the lab's concrete floor with quick-setting anchoring cement. Depending on the span length of the simply–supported section of the pile, the supports were moved into position, and hence the supports were grouted two (2) times for the three (3) tests performed. The curing time for the grout was about 4 hours. Elastomeric bearing pads were placed between the supports and the pile. The height of the support gave the piles about a 2-ft clearance above the testing floor.

A point load was applied to the pile by an Enerpac actuator. As the predicted



(a) Test setup for development length tests



(b) Test setup for flexure test

Figure 5.5: Test setups

development length was less than 10 ft, the point load was applied close to the support for the development length tests on the first pile. This load arrangement, along with the cantilever length at the other end, "preserved" the other pile end for an additional test. Load was measured with a load cell and was initially applied on the pile specimen at a rate of 250 lb per second. An elastomeric pad was used under a steel loading plate with a groove that fit the tip of the actuator, as seen in Figure 5.6.

Parameters that were varied for each test are as follows:

1. Length of the simply–supported span (S.S. Span)
2. Length of the cantilever overhang
3. Length of the shear span
4. Embedment length of the strand

Test parameters are summarized in Table 5.1. For the development length tests, parameters were chosen to ensure the structural integrity of the cantilever end of the beam, so that two (2) experiments could be performed on one (1) pile specimen. Test P-6–22 Dev, for example, indicates a pile specimen tested for development length of strands, having an embedment length of 6 ft and a cantilever length of 17 ft. After the first test was completed, approximately 6.5 ft of the pile's tested/damaged end

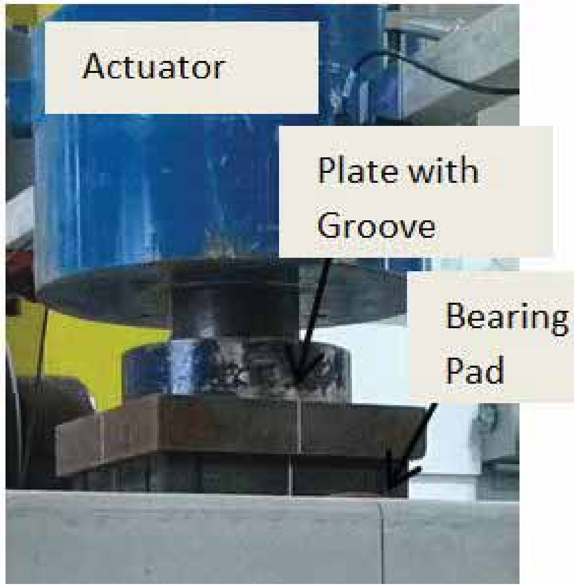


Figure 5.6: Loading setup

was separated from the specimen and discarded. The remaining 33.5–ft length was used for the second test. The damaged end was cantilevered approximately 5.5 ft (see Figure 5.5a), and the undamaged, opposite end of the pile was loaded.

Table 5.1: Test matrix

Test No.	Test Designation	Pile No.	Simple-Supp. Span ft	Shear Span ft	Cantilever Length ft	Embedment Length ft
1	P-6–22 Dev	1	22	5	17	6
2	P-10–27 Dev	1	27	9	5.5	10
3	P-38 Flex	2	38	13.3	*N.A.*	14.3

5.2.3 Instrumentation for the Development Length Tests

Instrumentation for each development length test was planned to monitor the following:

1. Applied load
2. Vertical deflections at several points
3. Concrete top fiber strains around the load point

4. Strand end slip

The instrumentation layout for the first development length test is shown in Figure 5.7. Six (6) deflection gages were mounted along the length of the pile to monitor vertical deflections. The two (2) adjacent deflection gages placed at the load point location were averaged in the data analysis. Four (4) electrical resistance strain gages were installed to monitor the top fiber strains in the concrete around the load point (Figure 5.7). Strand end slip measurements were made during testing using linear variable displacement transducers (LVDTs). The devices were anchored with clamps to four CFCCs in the bottom of the pile (Figure 5.8). Strand slips, monitored throughout the tests, reflected the displacement of the strand relative to the beam. The test setup is shown in Figure 5.9.

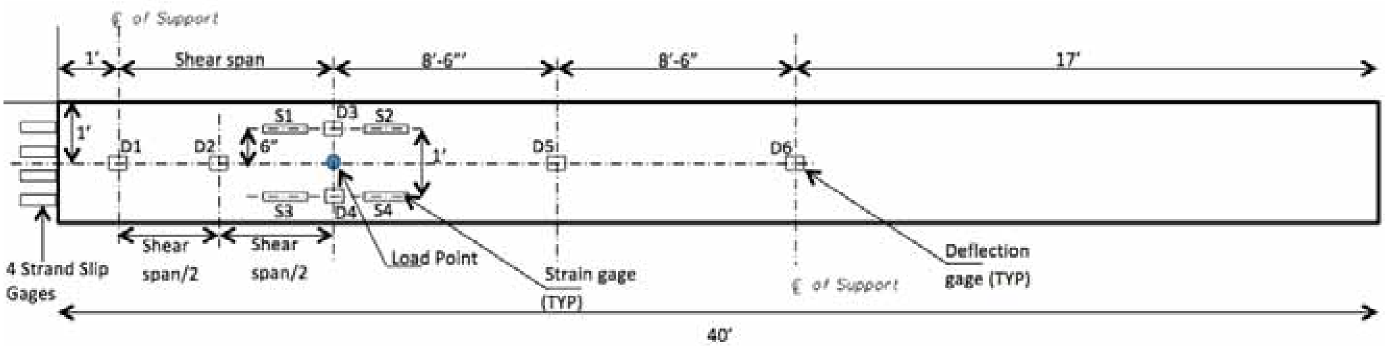


Figure 5.7: Gage layout for first development length test (Plan view) (Not to scale)

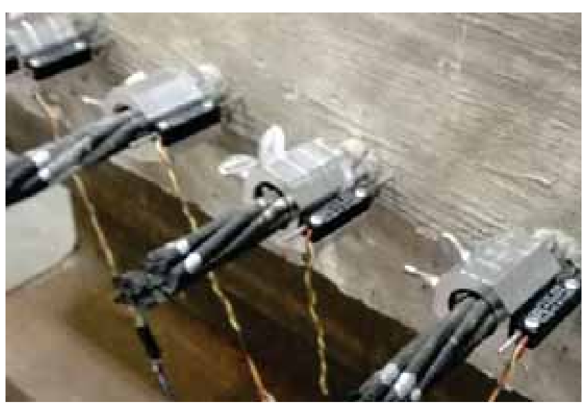


Figure 5.8: Strand slip measurement device

Figure 5.9: A pile being tested for development length

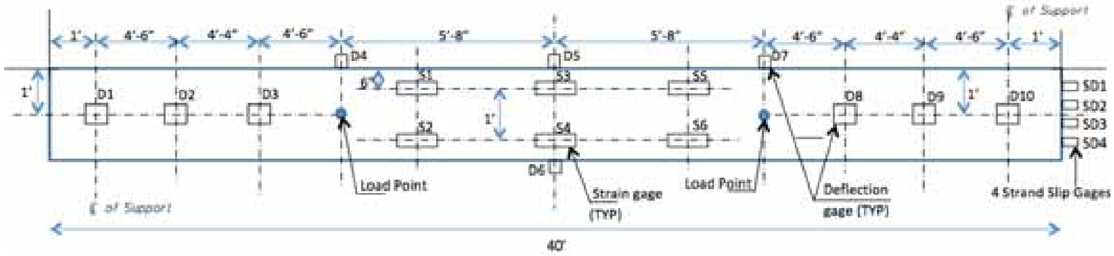
5.2.4 Instrumentation for Flexure Test

The flexure test used instruments to measure the following:

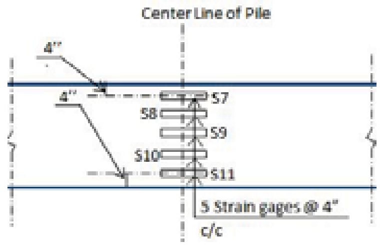
1. Applied load
2. Vertical deflections at several points
3. Concrete top fiber strains in the constant–moment region
4. Strand end slip

Fourteen (14) strain gages and ten (10) non–contact deflection gages were installed on the specimen, as shown in Figure 5.10.

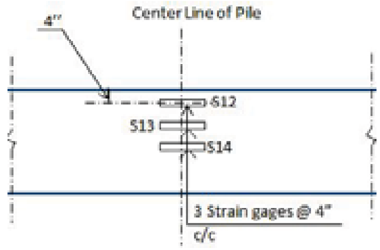
Two (2) strain gages were located on the concrete surface at mid span (under the actuator location) to measure the top fiber compressive strain. Two (2) other strain gages were placed at 8 in. from the center. Angles were anchored to the side face by drilling holes in the concrete, and then the lasers from the displacement gages were projected on to the angle face (Figure 5.11) to measure the displacement. In addition to these gages, four (4) strand slip gages were installed to measure any strand slip during flexure (Figure 5.8). A single point load was transferred to a spreader beam, which was formed of two (2) steel I-beams. The spreader beam supports caused two (2) point loads to be applied to the pile and thereby a constant-moment region in approximately the middle third of the pile. The weight of the spreader beam and its bearing plates was approximately 3000 lb. The setup is shown in Figure 5.12.



(a) Plan view



(b) Elevation view – east face



(c) Elevation view – west face

Figure 5.10: Gage layout for flexure test (Not to scale)

Figure 5.11: Laser device setup for measuring displacement

Figure 5.12: Test setup for flexural test

5.2.5 Test Procedure for Development Length and Flexure Tests

For safety purposes, wooden logs were placed under the load point, where the maximum deflection was expected. Load was then applied at a rate of 250 pounds per second until the formation of the first flexural cracks. After that, the rate was changed to 200 pounds per second. The test continued until a bond or flexural failure occurred. A substantial loss in the member's load capacity would be the result of a bond failure, which would be accompanied by strand slippage of one or more strands. Flexure failure is evidenced by vertical cracks in the bottom of the pile and extending upward as the load is increased. When failure was achieved, the pile was unloaded. Crack propagations on the concrete surface were marked after the failure, and a detailed crack pattern was then sketched. A similar procedure was followed for the second test on the first pile, and again for the third test, varying the parameters given in Table 5.1. The results from the tests are discussed in Chapter 6.

5.3 Pile Driving Test Setup

The two (2) 100–ft piles were stored at GATE until a suitable bridge construction project on which to drive them was found. In late January 2014, the piles were delivered to Deer Crossing Bridge (Bridge No. 790207) being constructed on Interstate 4 near milepost 127, west of U.S. Highway 92. This is located in Volusia County between Daytona and Deland. The piles were installed by the contractor, The de Moya Group, Inc., on January 23 and 24, 2014. They were driven adjacent to production piles on End Bent 3-1 located at Station 1177+48.0 on the westbound bridge. The piles were installed on the west end of the bent, near Boring DC-1. See Appendix E for a plan view of the bridge and soil boring logs. See Appendix H for photos of the site and pile driving activities.

The purpose of these pile driving tests was to "test the limits" of the piles. The first pile was driven as a normal pile would be, as determined by FDOT personnel on site, and was then subjected to hard driving during the latter part of installation. The second pile was installed under hard driving conditions to test the limits more and to test for repeatable behavior. Both piles were driven to refusal. After testing, the pile tops were to be cut off to 2 ft below grade, and the piles were to be covered by soil and abandoned in place.

Both EDC and PDA were used to monitor the stresses in the piles while they were being driven. During the installation of piles, high impact forces imposed by the pile driver hammer occur. The hammer blow causes a compression wave that travels at about the speed of sound. When it reaches the pile tip, it reflects. Depending on the soil resistance, the reflecting wave can cause compressive or tensile stresses in the pile. This wave can cause damage to the concrete, high stresses in the prestressing strands, and possible rupturing of the bond between the steel and concrete.

Additional details regarding the tests (for example, the pile driving hammer and cushion details) are provided in a test summary report prepared by FDOT (see Appendix E).

CHAPTER 6

EXPERIMENTAL TEST RESULTS

6.1 Introduction

One purpose of this experimental program was to determine the transfer length of CFCC strands by way of measuring concrete strains at the ends of the piles while the strands were being detensioned in the casting bed. Another purpose was to determine the development length of the CFCC strands, in addition to determining the flexural strength of the pile. Lastly, the purpose was to test the behavior of the pile while it was being driven into the ground as part of a bridge foundation. This chapter reports the results that were obtained from all of these tests.

6.2 Transfer Length Measurements

6.2.1 General

The concrete strength at 24 hours after casting was 5370 psi. This is an average of two (2) cylinder strengths, 5320 and 5420 psi, as determined by GATE. As explained in Section 5.1, three (3) 40–ft prestressed concrete piles were monitored during release of prestressing. Both ends of each pile were instrumented with strain gages and were designated as follows: 3N, 3S, 4N, 4S, 5N, and 5S, where the numbers 3 through 5 represent the pile number as per the bed layout shown in Figure 4.5. ’N’ represents the North end, which was the stressing end of the bed, and ’S’ represents the South end, which was the non–stressing end. The strain gage layout is shown in Figure 5.1, and a photo of the strain gages near the stressing end is in Figure 6.1.

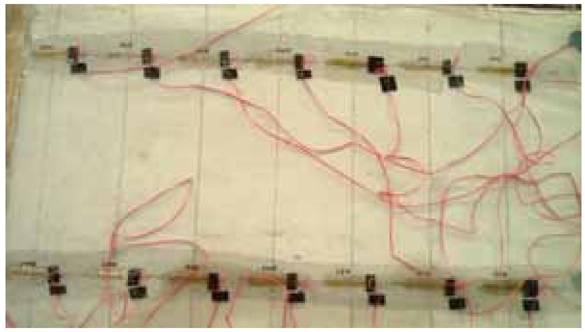


Figure 6.1: Strain gage layout at stressing end

6.2.2 Measured Strains at Transfer

Figure 6.2 shows the strain profile along the length of pile '3', with each line representing the strains after a strand was cut. This demonstrates the increasing compressive stress on the pile as the force in each strand was released. The strain profiles for all six (6) pile ends after 75% and 100% release are shown in Figures 6.3 through 6.14. Here, 75% release refers to 15 strands being released, and 100% release refers to all strands being released. In these figures, the strain is shown from the pile end to the mid span. The strains reported in Figures 6.2–6.4, 6.7–6.8, and 6.11–6.12 for the stressing ends are average readings of pairs of strain gages located at the top corners of the pile specimen. For example, the plotted strain at 3 in. from the pile end is the average of the strains in strain gages S101 and S102 (Figure 5.2).

There are two commonly–used methods to measure the transfer length of a strand: (1) the 95% Average Maximum Strain (AMS) method (Russell and Burns, 1996) which uses the measured strains along the transfer zone of a prestressed member and (2) the "draw–in" or "end–slip" method. The AMS method was used in this study. The idealized theoretical strain profile as explained by Mahmoud and Rizkalla (1996) would show a linear increase in strain in the transfer zone, followed by a uniform strain plateau. However, for the pile end '4N', the data shows a linear increase in strain in the transfer zone, but a uniform strain plateau was difficult to define. Therefore, for this pile end, the transfer length was estimated by a visual analysis.

For all other pile ends, the 95% AMS method was used to determine the transfer length of CFCC. The procedure as explained by Russell and Burns (1996) is as follows:

1. Strains after the prestress release are recorded and used to determine the strain profile within the transfer zone.

2. Data may be smoothed if required, by taking the strain at any point 'b' as the average of the strains at three adjacent points centered at 'b'.

3. The strain plateau region, or the distance over which strain is at a nearly constant maximum, is estimated visually. The average strain within the plateau is calculated. A line corresponding to 95% of this average strain is superimposed on the strain profile.

4. The intersection of the 95% AMS and the strain profile defines the transfer length.

The transfer lengths determined from the AMS method for the 75% and 100% stress release measurements were averaged. These average transfer lengths for each pile end are given in Table 6.1.

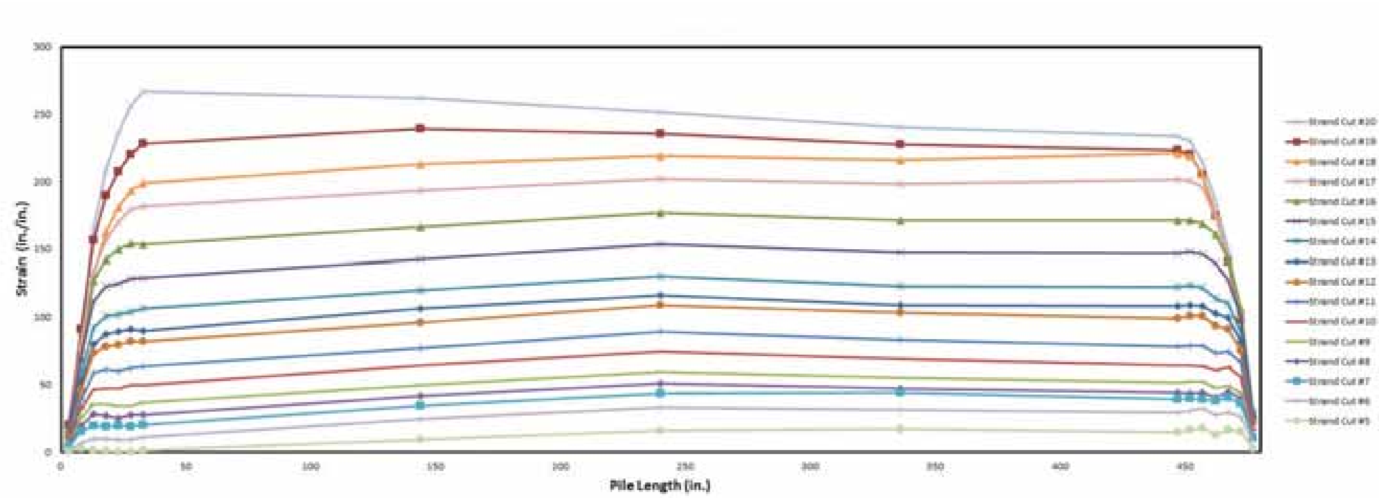


Figure 6.2: Strain profile for pile 3 at release

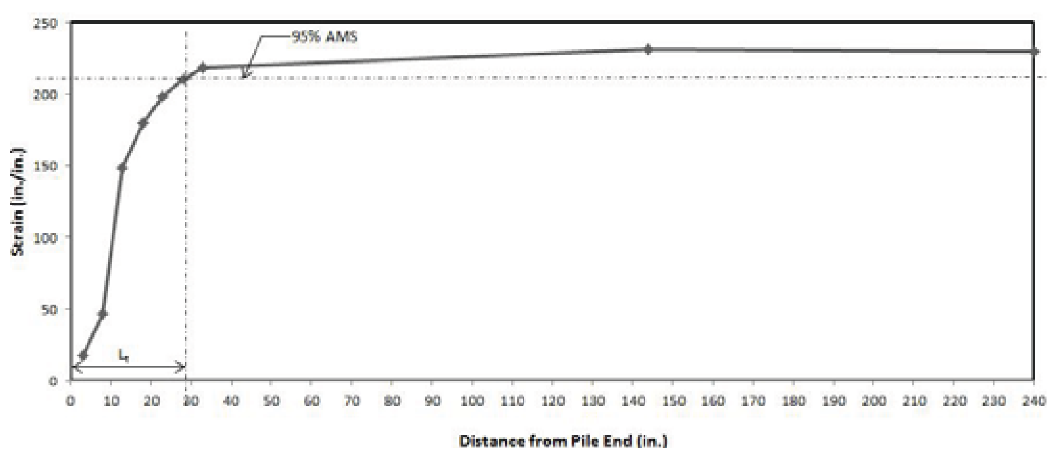


Figure 6.3: Strain profile for pile end $3N$ at 75% stress release

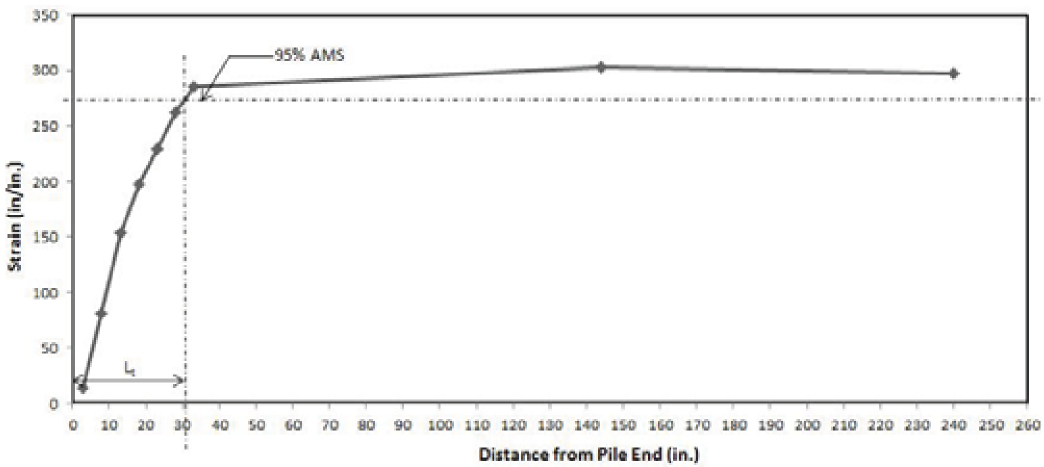


Figure 6.4: Strain profile for pile end 3N at 100% stress release

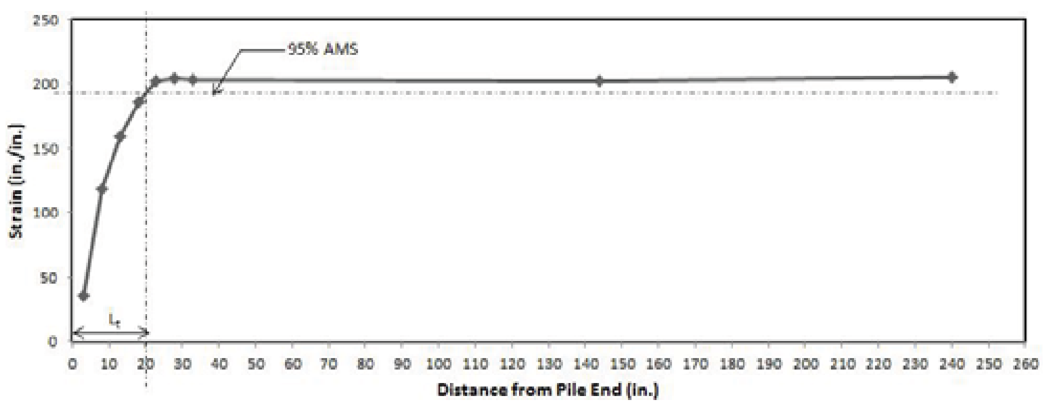


Figure 6.5: Strain profile for pile end 3S at 75% stress release

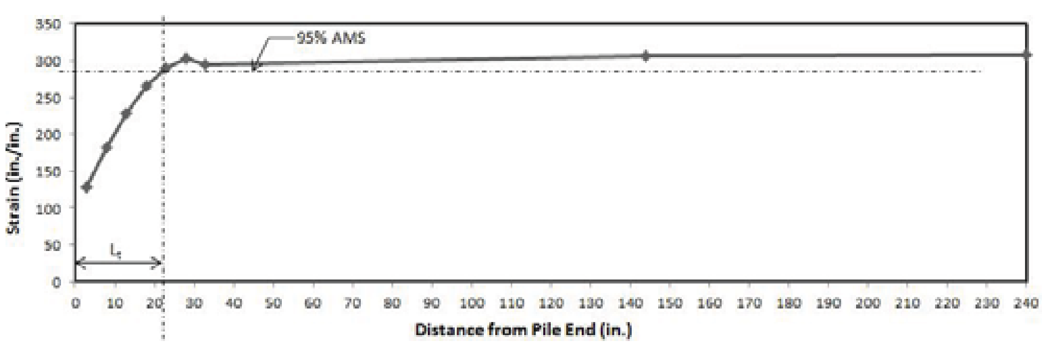


Figure 6.6: Strain profile for pile end 3S at 100% stress release

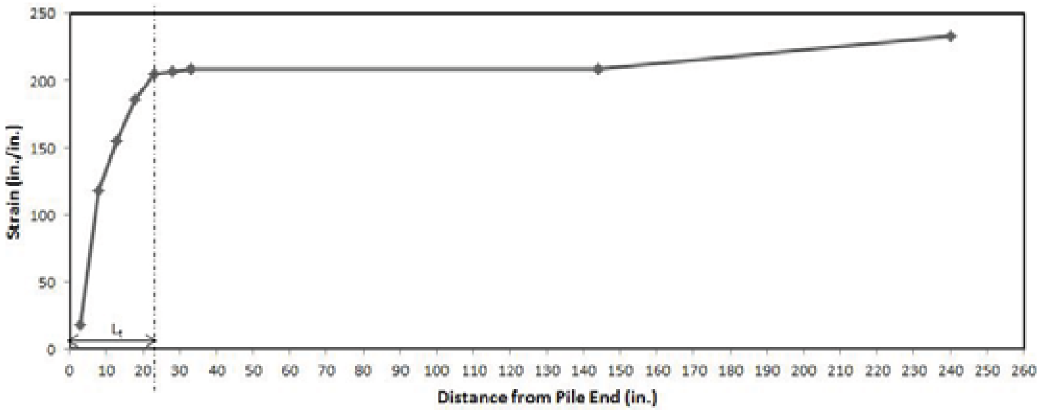


Figure 6.7: Strain profile for pile end $4N$ at 75% stress release

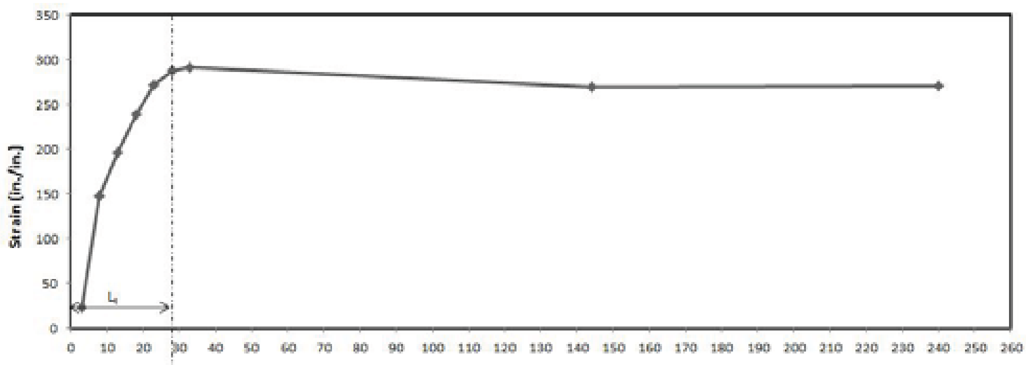


Figure 6.8: Strain profile for pile end $4N$ at 100% stress release

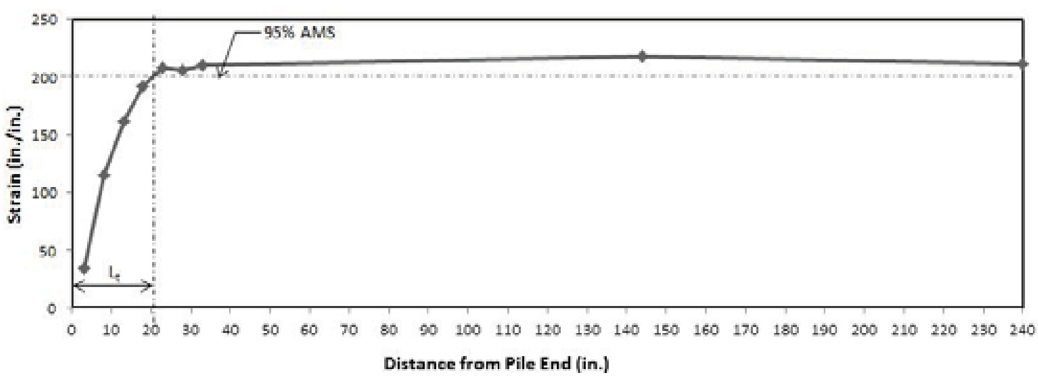


Figure 6.9: Strain profile for pile end $4S$ at 75% stress release

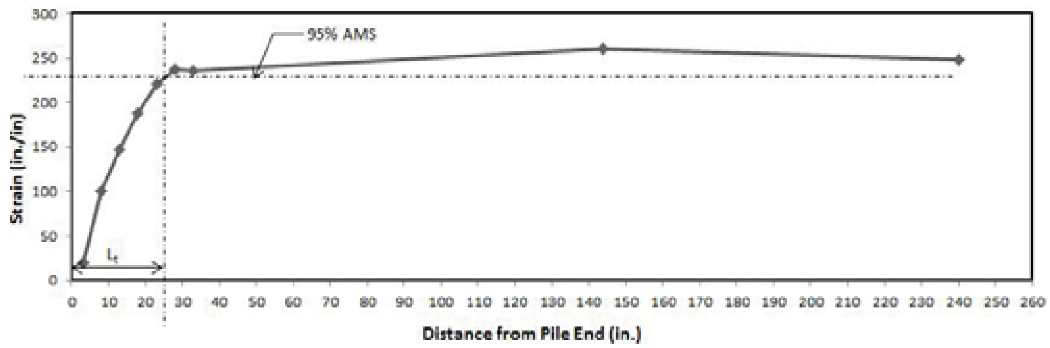


Figure 6.10: Strain profile for pile end $4S$ at 100% stress release

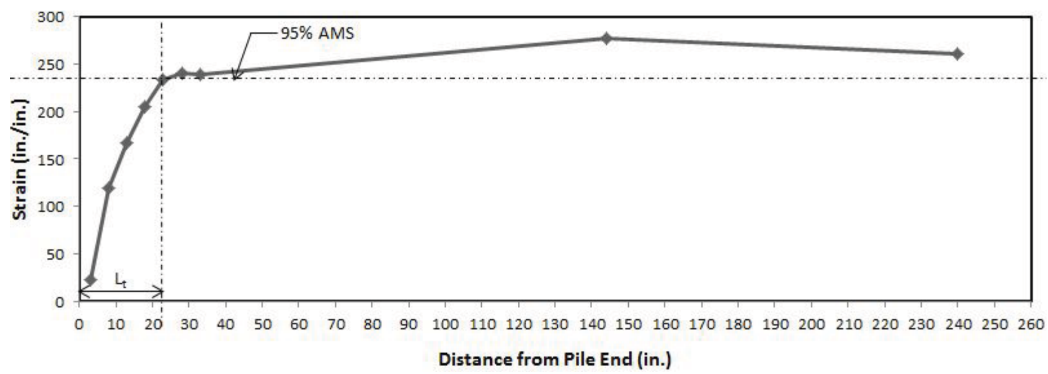


Figure 6.11: Strain profile for pile end $5N$ at 75% stress release

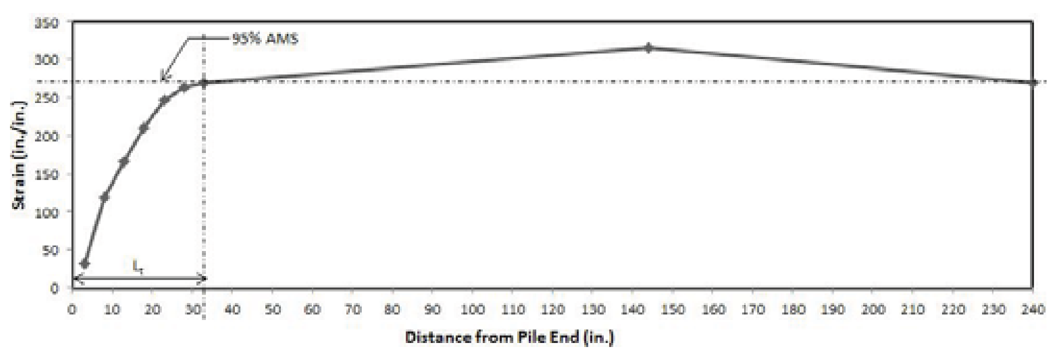


Figure 6.12: Strain profile for pile end $5N$ at 100% stress release

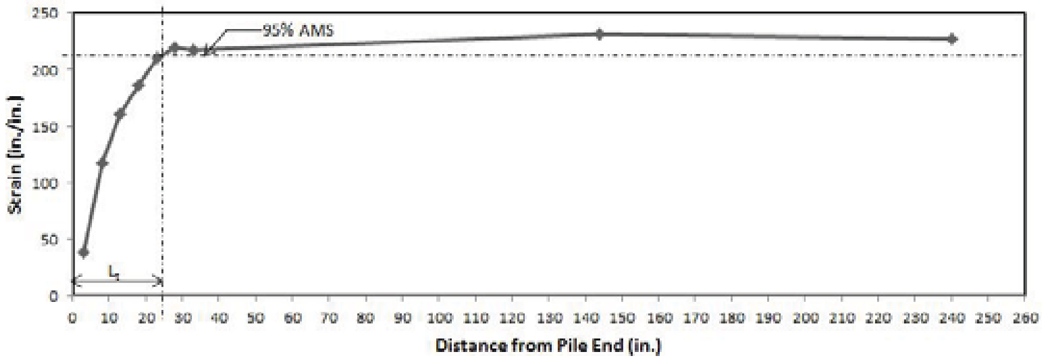


Figure 6.13: Strain profile for pile end $5S$ at 75% stress release

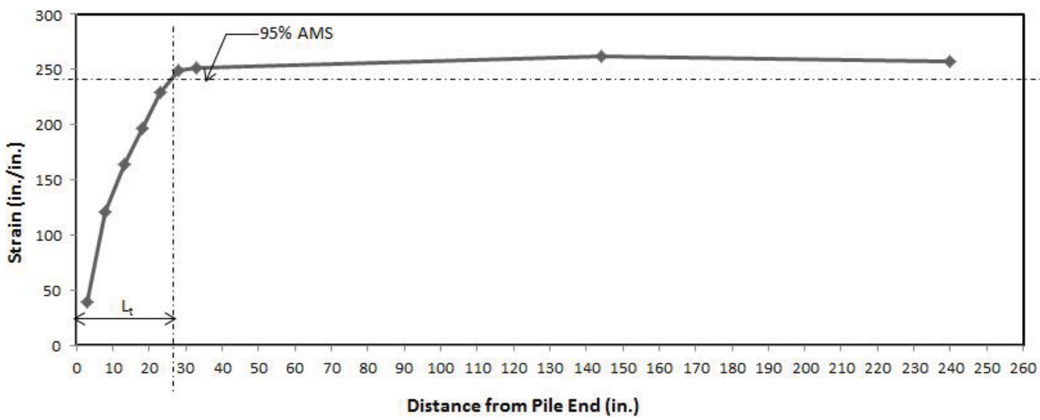


Figure 6.14: Strain profile for pile end $5S$ at 100% stress release

Table 6.1: Transfer length for specimen pile ends

Pile End	Transfer Length (in.)
$3N$	29.0
$3S$	21.5
$4N$	25.5
$4S$	22.0
$5N$	28.0
$5S$	24.5
Average Transfer Length	25.0

6.3 Development Length Test Results

Two (2) development length tests on one (1) 40–ft pile specimen were conducted. The test results are presented in this section, including load versus deflection plots, as well as sketches of cracking patterns that occurred.

6.3.1 Test 1

The pile specimen was prepared for testing as explained in Chapter 4. For the first test, the embedment length was 6 ft, the simply–supported span length was 22 ft, and the cantilever length was 17 ft. The plot of applied load versus deflection, calculated from the average of deflection gages D3 and D4 adjacent to the applied load, is shown in Figure 6.15. The first flexural crack was observed at a load of 175 kips and extended up to 2 ft from the load point to the free end of the pile. The flexural cracks had propagated to 4 in. from the top fiber. The load was applied until failure occurred at 205 kips. The final crack pattern is shown in Figures 6.16 and 6.17. The maximum top fiber strain in the vicinity of the load point at failure was 0.0012. The applied load versus the average strain in the four (4) gages around the load point (Figure 5.7) is shown in Figure 6.18. During loading, one of the strain gages next to the load point location gave erroneous data at 40 kips, but after 43 kips, both the strain gages gave similar readings. There was no observable strand end slip on any of the four (4) instrumented CFCC strands throughout the test.

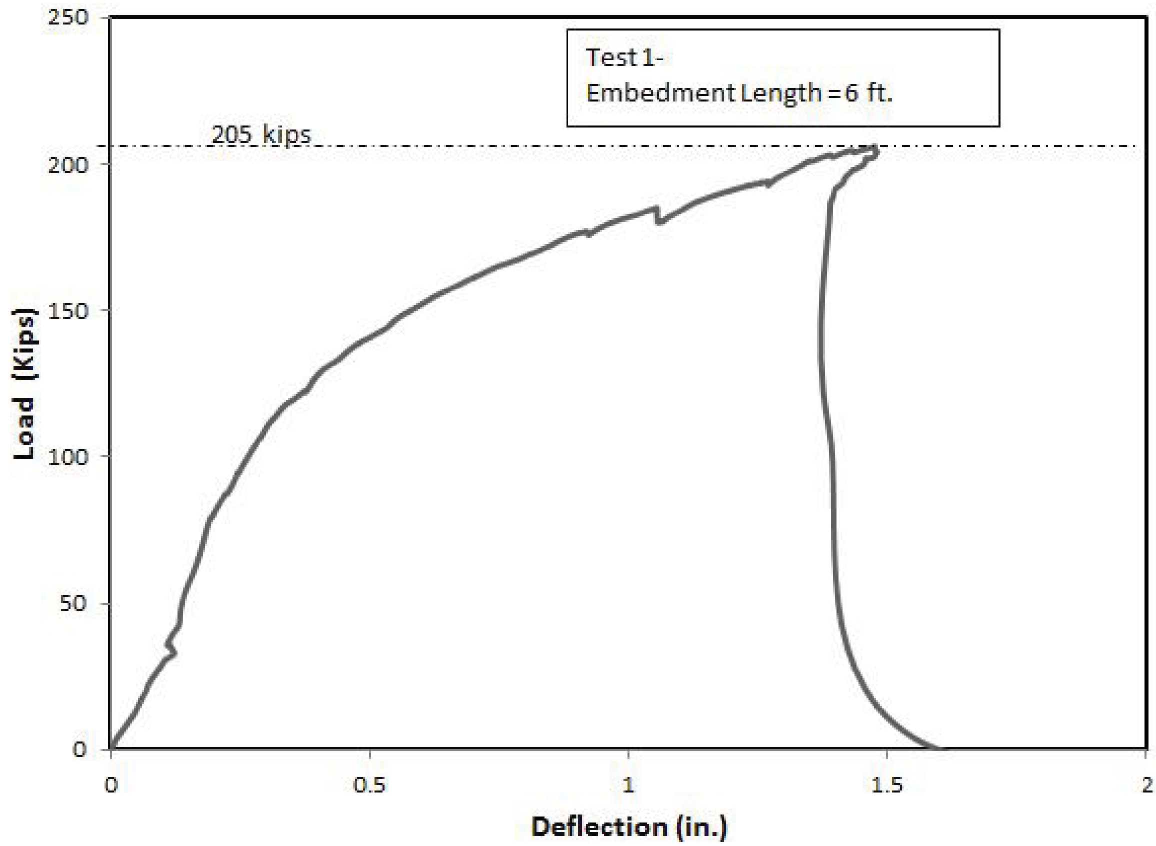


Figure 6.15: Load vs. Deflection for Test 1

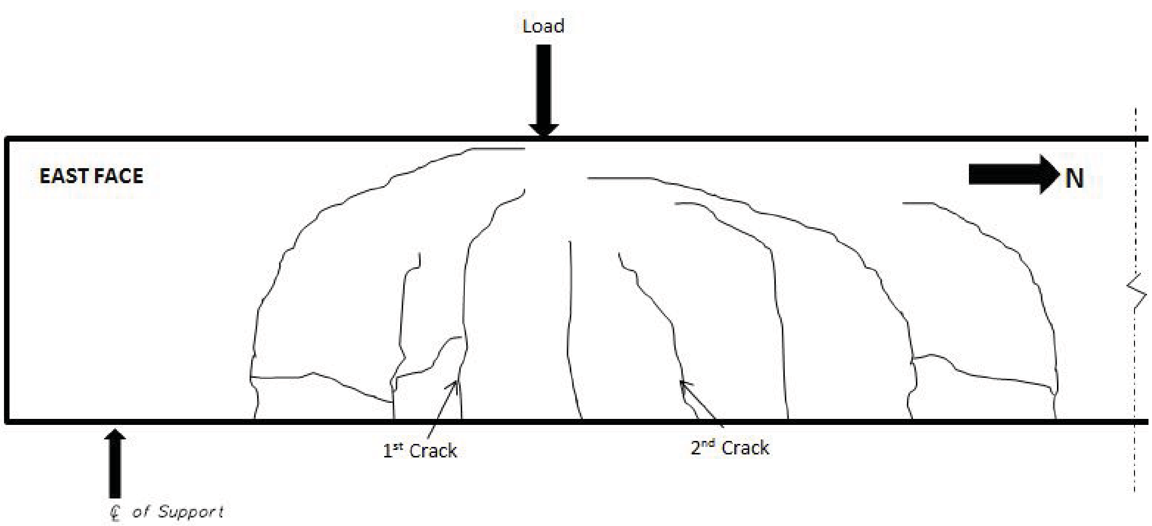


Figure 6.16: Failure crack pattern on east face for Test 1

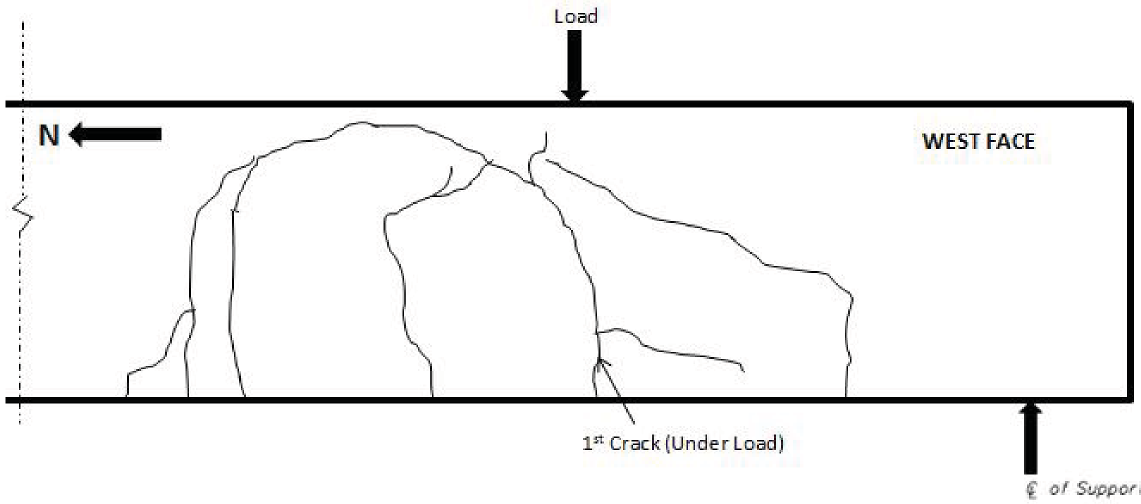


Figure 6.17: Failure crack pattern on west face for Test 1

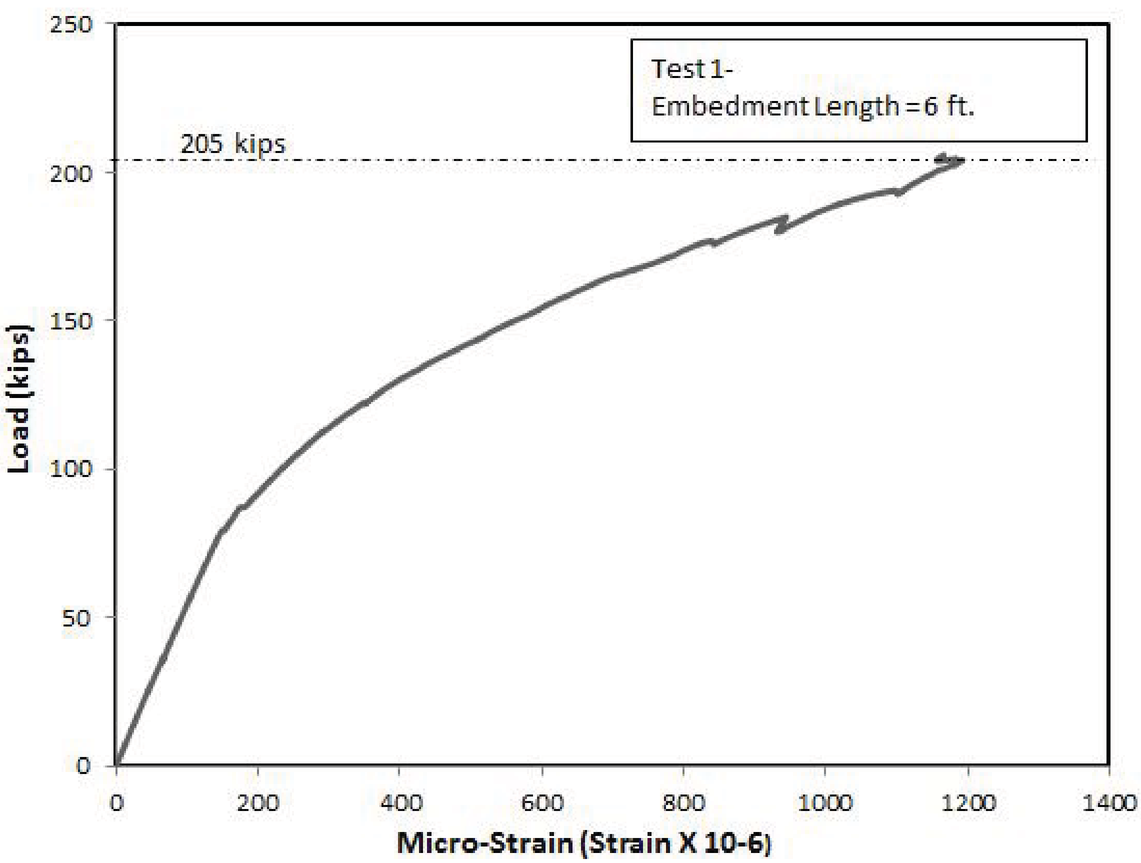


Figure 6.18: Load vs. Strain for Test 1

6.3.2 Test 2

The pile specimen from Test 1 was used again for Test 2. The structural integrity of the cantilevered end from the Test 1 setup remained undisturbed throughout Test 1, so this pile end (opposite the tested end from Test 1) was used to perform Test 2. For this second test, the embedment length was 10 ft, the simply–supported span length was 27 ft, and the cantilever length was approximately 5.5 ft. The loading procedure was similar to Test 1, as were the strain gage and deflection gage layouts. A plot of applied load versus deflection, calculated from the average of deflection gages D3 and D4 adjacent to the applied load, is shown in Figure 6.19.

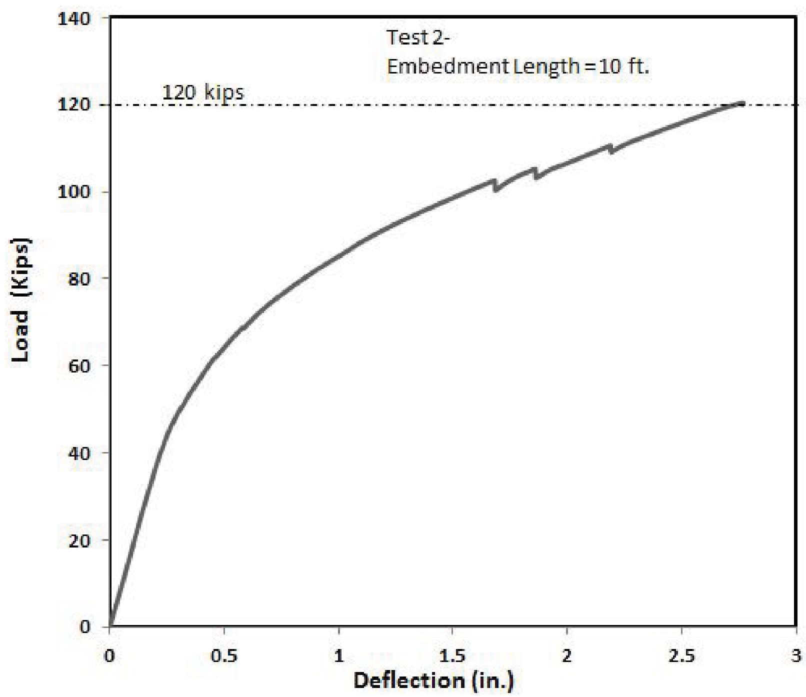


Figure 6.19: Load vs. Deflection for Test 2

The first flexural crack occurred at a load of 101 kips, on the bottom of the pile under the load application point. The cracks propagated up to 3 in. from the top fiber and extended up to 3 ft from the load point towards the free end of the pile. The test resulted in a flexural failure at a load of 120 kips and a deflection of 2.8 in. The maximum strain in the top fiber in the vicinity of the load point at failure was 0.00138. Local concrete crushing occurred on the top of the pile near the load point at failure (Figure 6.20). Sketches of the crack patterns on the east and west faces are shown in Figures 6.21 and 6.22. There was no observable strand slip in any of the four (4) instrumented CFCC strands throughout the test.

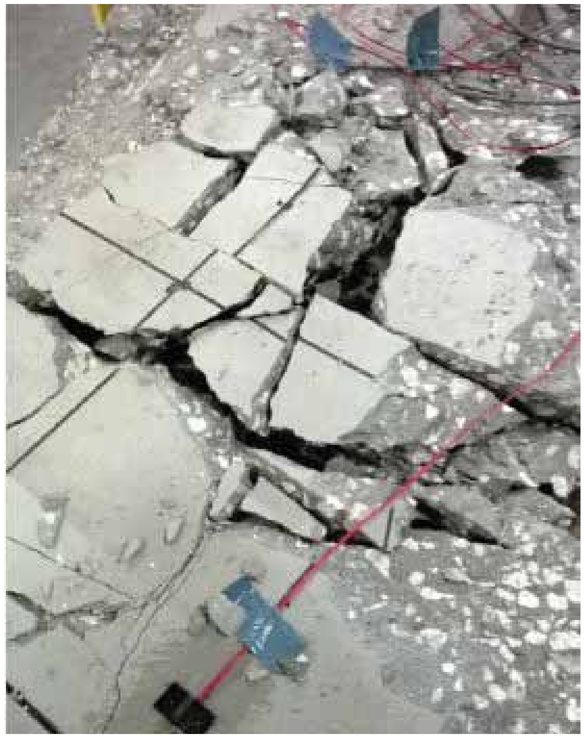


Figure 6.20: Concrete crushing at top in Test 2

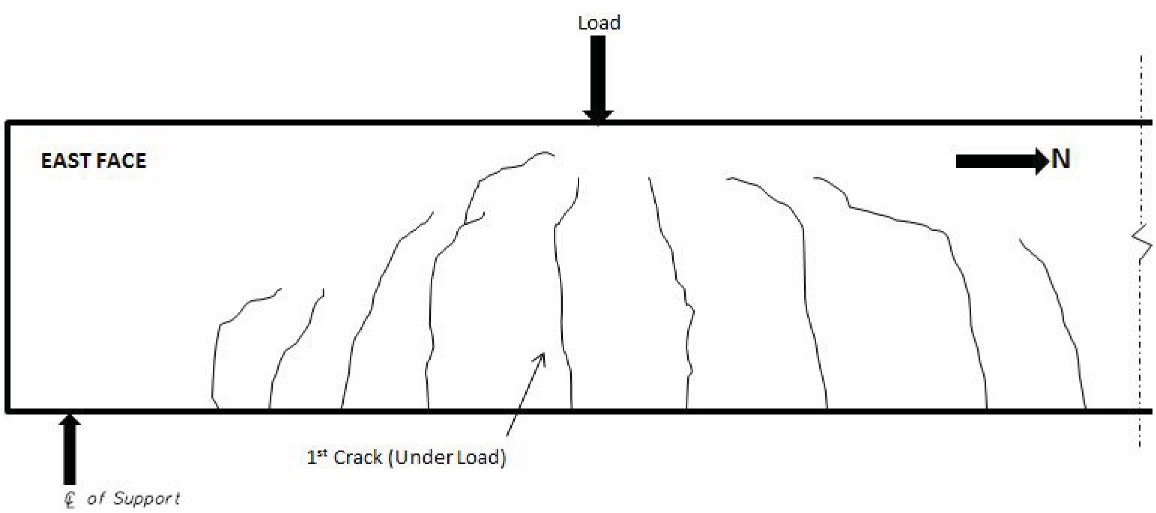


Figure 6.21: Failure crack pattern on east face for Test 2

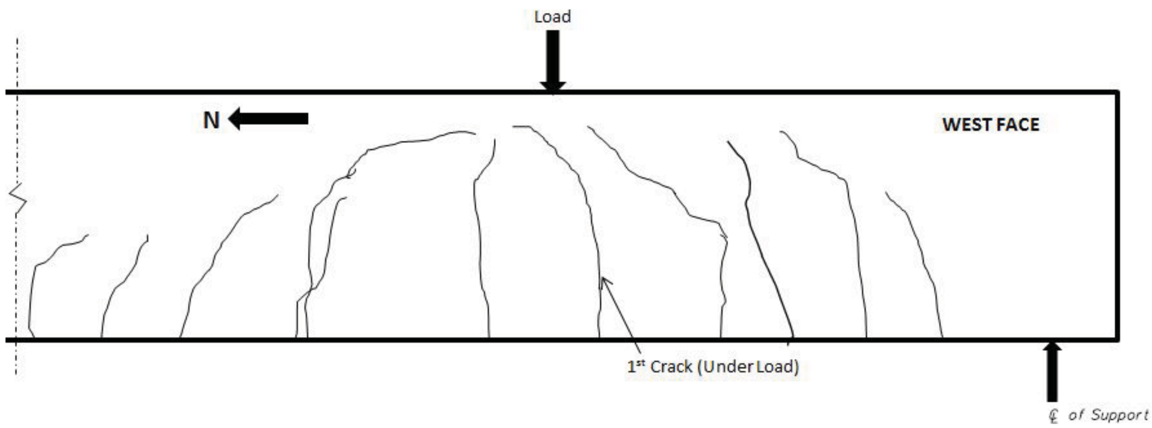


Figure 6.22: Failure crack pattern on west face for Test 2

6.4 Flexural Strength Test Results

Three (3) 4–in. x 8–in. concrete cylinders were tested on the day of the flexural strength test and had an average compressive strength of 9500 psi. The applied load versus deflection is plotted in Figure 6.23, where the plotted deflections are averages of gages D5 and D6 at mid span. Failure occurred at a load of 113 kips and a mid-span deflection of 9.63 in. (Figure 6.23). This does not include the effects due to the self weight of the pile or the spreader beam weight. The maximum concrete strain recorded was 1300 microstrains, from strain gages S3 and S4 at mid span. There was no strand end slip observed in any of the four (4) instrumented strands throughout the test. Sketches of the crack pattern on the east and west faces are shown in Figures 6.24 and 6.25. The cracks were uniformly distributed in the constant-moment region and extended up to 5 ft from the load points toward the ends of the pile. At the maximum load, the flexural cracks propagated to about 3 in. from the top fiber. Failure of the pile occurred under one of the load transfer points on the spreader beam shown in Figure 6.26.

As previously stated, the pile specimen failed at an applied load of 113 kips, which equates to a calculated moment of 753 kip–ft. This generated a total calculated test moment of 875 kip–ft, including an initial calculated moment of 122 kip–ft due to the self weight of the pile and the spreader beam weight of approximately 3000 lb. The theoretical pile capacity was calculated to be 809 kip–ft (see Appendix F), for a test–to–theoretical moment ratio of 1.08 (Table 6.2).

The results obtained from the transfer length, development length and flexural tests are discussed in Chapter 7.

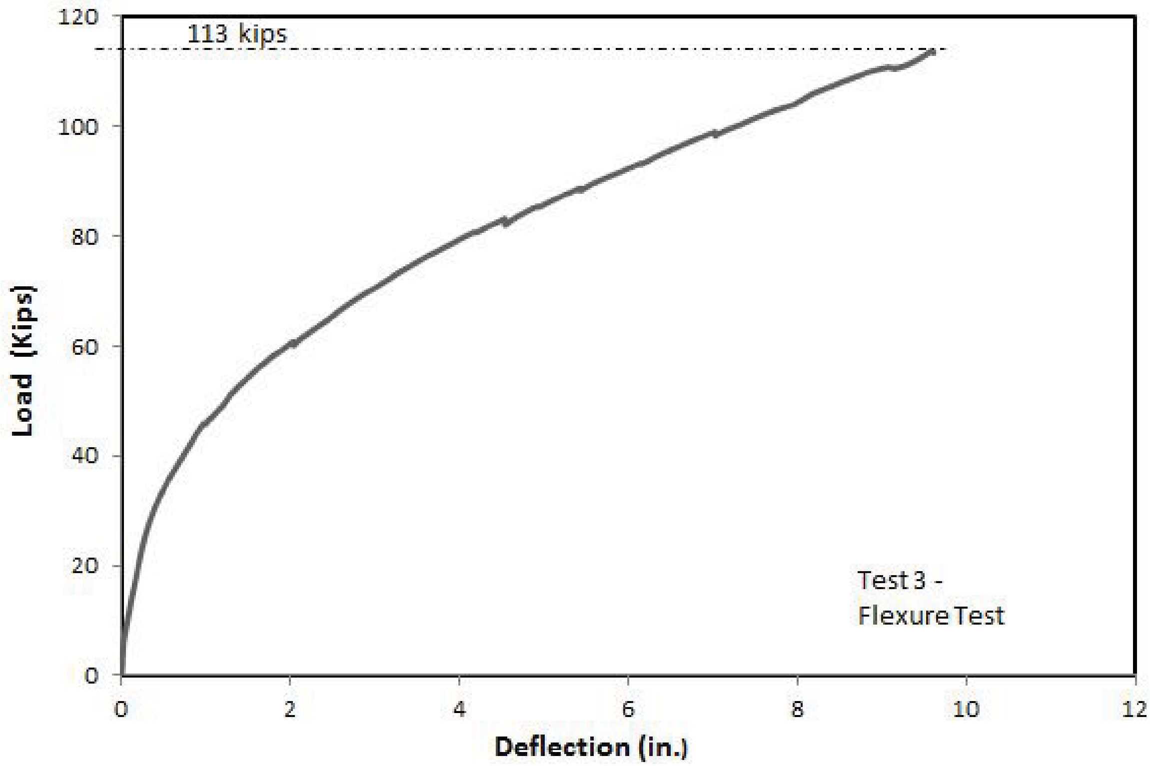


Figure 6.23: Load vs. Deflection for flexure test

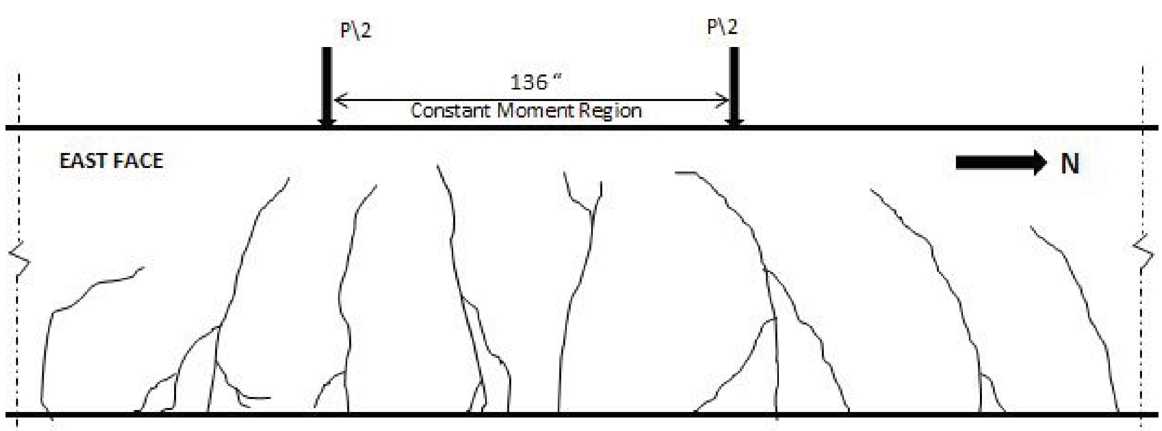


Figure 6.24: Failure crack pattern on east face for flexure test

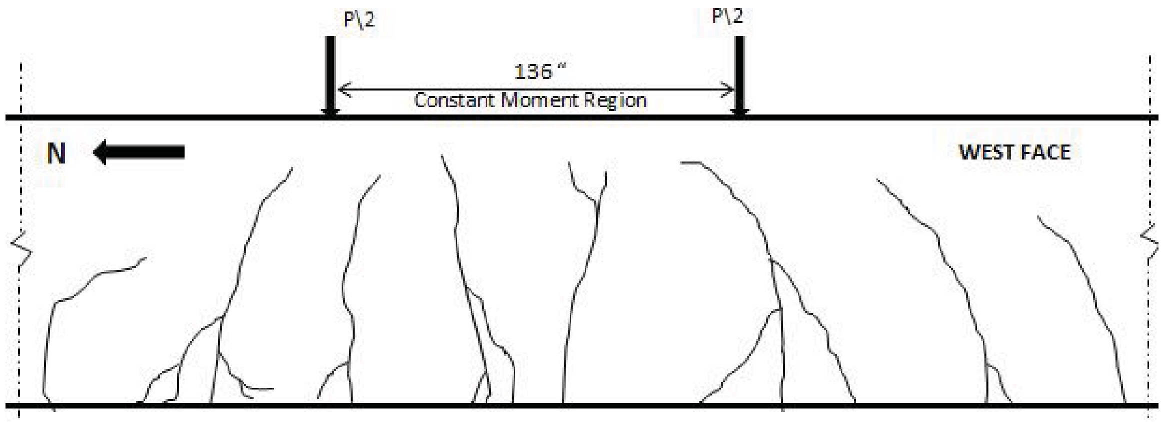


Figure 6.25: Failure crack pattern on west face for flexure test

Figure 6.26: Failure under one of the load points

Table 6.2: Theoretical vs. test moment capacity

	Moment Capacity (kip–ft)
Theoretical	809
Test	875
Ratio (Test/Theoretical)	1.08

6.5 Pile Driving Test Results

6.5.1 Introduction

Both EDC and PDA were used to monitor the piles during driving. FDOT also provided geotechnical expertise and assessed the performance of the pile through observations and EDC and PDA test results. Data and reports are included in Appendix E, and selected photos are in Appendix H. With the researchers, representatives from FDOT Structures Research Center and FDOT Central Office were on site during driving of the first pile on January 23, 2014. For the second pile, driven on January 24, FDOT representatives were not able to attend.

The piles were designed to have a permanent compression of 1000 psi at the effective prestress level, after losses. The piles were subjected to 2765 and 3139 hammer blows for Piles 1 and 2, respectively. See Chapter 7 for a discussion of the test results.

Two (2) 4-in. x 8-in. cylinders were tested at the FDOT Structures Research Center on January 28, 2014. The compressive strengths were 9,849 and 10,313 psi, for an average of 10,080 psi.

6.5.2 Embedded Data Collectors (EDC) Results

EDC data was gathered and reported by Applied Foundation Testing, Inc. (AFT). The Embedded Data Collector was unable to connect to the second pile, so data was collected only for the first pile driven on January 23. EDC results and the report prepared by AFT are provided in Appendix E.

6.5.3 Pile Driving Analyzer® (PDA) Results

PDA data was gathered for both piles and reported by GRL Engineers, Inc. GRL's report on the results, including the pile driving logs kept by the field inspector, is provided in Appendix E.

6.5.4 FDOT Summary Report

FDOT's Assistant State Geotechnical Engineer, Rodrigo Herrera, P.E., evaluated the test results and prepared a summary report on the pile driving activities and pile performance. The report is in Appendix E. It provides a chronicle of the driving operations, including details about the pile cushions that were used and when they were replaced. The report also notes cracking that was observed and comments on the pile integrity.

Herrera calculated maximum stress limits and compared them to the stresses to which the piles were subjected. Although driving and subsurface conditions prevented the development of maximum compression stresses of 6.25 ksi, per FDOT Specification 455-5.11.2 (FDOT, 2014a) and based on *measured* concrete compressive strength, the stresses in the piles *did* exceed the typical limit used in production pile driving (which is 3.6 ksi, assuming a *nominal* 6000 psi concrete strength and 1000 psi for initial prestress). In addition, the theoretical limit on *tension stress*, 1.38 ksi based on *measured* concrete compressive strength, was exceeded during driving.

The pile heads were locally damaged; the concrete spalled, likely due to the intentional use of thin cushions and hard driving. Other than to the pile heads, there was no major pile damage. As noted by Herrera, the piles' resistances were well beyond the 900-kip suggested driving resistance per FDOT's Structures Design Guidelines (FDOT, 2014b).

CHAPTER 7

DISCUSSION

7.1 Introduction

The results obtained from the experimental program were reported in Chapter 6. In this chapter, the findings will be discussed. Also, the challenges associated with precasting CFCC–prestressed piles, as well as the differences between using CFCC and steel prestressing, will be explained.

7.2 Transfer Length of CFCC

The strain gage data taken during prestress release was analyzed using the 95% AMS method for five (5) pile ends out of six (6). The end '4N' did not show a distinct strain plateau and hence the strain profile was evaluated visually for the transfer length. The strain profiles for all six (6) transfer length locations are presented in Figures 6.3 through 6.14, and the values of the transfer lengths are shown in Table 6.1.

The transfer length values are consistently lower than Equation 7.1 recommended by ACI 440.4R–04.

$$L_t = \frac{f_{pi} d_b}{\alpha_t {f'_{ci}}^{0.67}} \tag{7.1}$$

The factor α_t was determined by Grace (2000) to be 11.2 (for psi and in. units) or 2.12 (for MPa and mm units); this results in a predicted transfer length of 37.3 in. from Equation 7.1 for f_{pi} of 220 ksi. The observed transfer length was 25 in., which is 33% lower than predicted. Mahmoud et al. (1999) proposed for α_t a value of 25.3 (for psi and in. units) or 4.8 (for MPa and mm units) to predict the transfer length of a CFCC tendon. This results in a predicted transfer length of 16.5 in., which is 34% lower than observed.

From Table 6.1, the transfer lengths at the stressing ends, denoted by 'N', are higher than the transfer lengths at the non–stressing ends, denoted by 'S'. The average ratios of non–stressing to stressing end transfer lengths ranged from 0.74 for pile '3' to 0.86 for piles '4' and '5'. According to Pozolo (2010), transfer lengths might be influenced by factors such as concrete casting location, cutting location, and the use of multiple batches of concrete. However, the strain gage locations (offsets from the pile's longitudinal axis) were different for the non–stressing ends than for the stressing ends, which could explain the different transfer length results.

Furthermore, the transfer length observed in this study was 31% less than the AASHTO provision of $60d_b$ (36 in.). In ACI 318-11, the transfer length of a prestressing strand is as follows:

$$L_t = \frac{f_{se} d_b}{3} \tag{7.2}$$

This results in a predicted transfer length of 40.2 in., using an effective prestress f_{se} of 201 ksi after all prestress losses, as calculated per PCI (2010). Note that the equation does not account for the concrete compressive strength at the time of release. The observed transfer length was 38% less than that predicted by Equation 7.2.

7.3 Development Length Tests

A crack is termed as "flexural" if it originates as a vertical crack that propagates upwards from the bottom surface. Tests 1 and 2, performed on the two (2) ends of one (1) 40–ft pile, failed in flexure. The shortest embedment length used in these two (2) test setups was 72 in. Development length is the shortest embedment length that develops the strand's flexural capacity without any bond slip, so these tests indicate that the strand was developed in less than 72 in.

Table 7.1 provides development length predictions per equations from ACI (2011), AASHTO (2011), Mahmoud and Rizkalla (1996), and Lu et al. (2000). The equation by Lu et al. (2000) for predicting development length is as follows:

$$L_d = \frac{1}{3} f_{se} d_b + \frac{3}{4}(f_{pu} - f_{se}) d_b \tag{7.3}$$

Equation 7.3 results in a predicted development length of 102 in., which is 42% higher than the shortest embedment length tested in this study.

See Chapter 2 for the equations by others.

The predicted development length according to ACI and AASHTO is 123 in., which is 71% higher than the shortest embedment length tested. The low value of the

Table 7.1: Development length predictions

	Predicted Length (*in.*)
Lu et al. (2000)	102
ACI 318-11 and AASHTO LRFD	123
Mahmoud and Rizkalla (1996)	29
Mahmoud and Rizkalla (1996) with Grace (2000) α_t	49

development length might be due to the characteristic properties of CFCC and also might be a result of using high–strength, self–consolidating concrete. For a more accurate prediction of the development length, more testing would be needed.

7.4 Flexural Strength Tests

Table 6.2 shows that the flexural strength of the concrete pile prestressed with CFCC is 8% higher than the theoretically-predicted strength. Furthermore, the mid span deflection at failure was 9.26 in., which indicates high ductility. In research conducted by Abalo et al. (2010), tests were performed on a 24–in. diameter circular concrete pile, prestressed with 20 0.5–in. diameter strands which were wrapped with a CFRP mesh in lieu of spiral ties. The performance of this specimen was compared to a control pile, a 24–in. square prestressed concrete pile prestressed with 16 0.6–in. diameter steel strands. The results of the tests on the control pile can be compared to the 24–in. square pile tested in the current study, although a direct comparison should not be made. The pile in the current study contained 20 0.6–in. diameter CFCC strands instead of 16 steel strands, and the strand layout and stressing forces were different. Table 7.2 compares the flexure test results on the control pile from Abalo et al. (2010) to the results of the CFCC pile test in this study.

Table 7.2: Moment capacity comparison

Moment Capacity	Abalo et al. (2010) Control Pile kip-ft	CFCC-Prestressed Pile Specimen kip-ft
Theoretical	625	809
Test	759	875
Ratio (Test/Theoretical)	1.21	1.08

The CFCC-prestressed pile capacity was greater than the theoretical capacity and greater than the control pile from Abalo et al. (2010). There was no strand end slip throughout the tests, which demonstrates that the CFCC has a good bond with concrete.

7.5 Pile Driving Tests

Both piles performed well during installation at the Interstate 4 bridge construction site, even though they were subjected to hard driving conditions and high levels of stress. There was no major damage to the piles, other than concrete spalling at the pile heads, which was likely due to the intentional use of thin driving cushions.

Pile capacities calculated by PDA were approximately twice the value of FDOT's suggested driving resistance for a conventional 24-in. prestressed pile. The data also suggests that there was no significant loss of prestress.

7.6 Lessons Learned from First Attempt to Prestress

Before September 2012, plans were made to precast five (5) concrete piles prestressed with 20 0.5–in. diameter CFCC strands. The casting setup and layout were similar to that described in Chapter 4. On September 10-12, 2012, the first attempt was made to cast the piles using 0.5–in. diameter strands. The only difference between the piles that were attempted in September 2012 and the piles that were successfully cast in Summer 2013, about which the results in this report are based, is that 0.5–in. diameter strands were used instead of 0.6–in. diameter strands. The coupler dimensions also differed because of the different strand diameters.

In the first attempt, after the CFCC strands, spirals, and couplers were installed in the precasting bed, the stressing operations began. Initially, all strands were partially stressed in the sequence shown in Figure 7.1. Thereafter, full stressing to 29 k began. While the third strand was about to be fully stressed, the first CFCC strand that had been fully stressed slipped from the coupling device. All prestressing operations were stopped.

The researchers summarized the efforts in a short presentation, which is included in Appendix G.

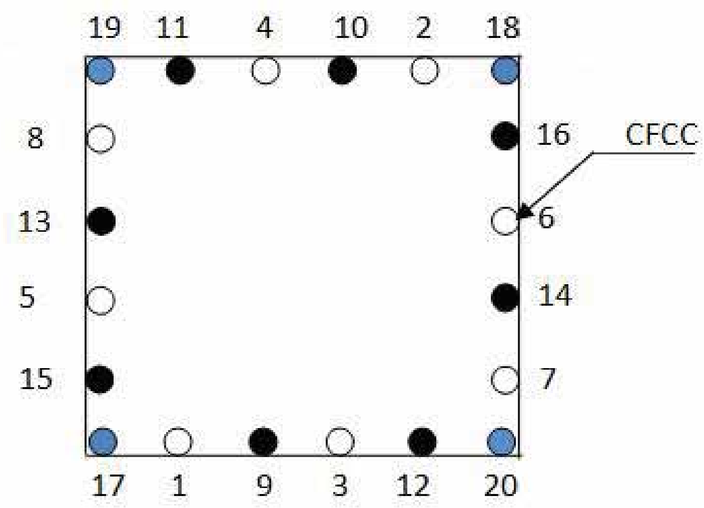


Figure 7.1: Stressing sequence for first casting attempt

The CFCC coupling device from which the strand had slipped was locally investigated by the researchers, CFCC manufacturer, and precasting personnel at GATE, and possible reasons for the slippage were speculated as follows:

1. Hoyer Effect
   During the prestressing operation, the strand might have reduced in diameter, thus reducing the frictional forces between the wrapping mechanism and the coupler sleeve.

2. Length of the wedges
   The length of the wedges gripping the CFCC strand after the seating was achieved might not have been adequate.

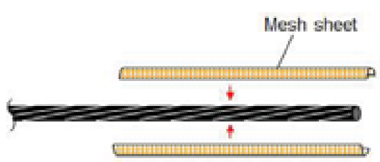
3. Twisting of the CFCC strands
   It was observed that the strand had twisted during the stressing operation. This might have resulted in loss of contact between the wrapping material and the CFCC strand.

The CFCC manufacturer, Tokyo Rope, took several couplers (with short extensions of strands attached) to Japan and performed an investigation of the failed coupler as well as other couplers that had been installed. They concluded that the molybdenum lube spray that was used was not able to seat the wedges completely due to lack of lubrication and hence the seated length of the wedges was inadequate to generate the frictional forces required to grip the CFCC strand. To remedy this at the next attempt, in Summer 2013, Tokyo Rope provided their own special molybdenum spray.

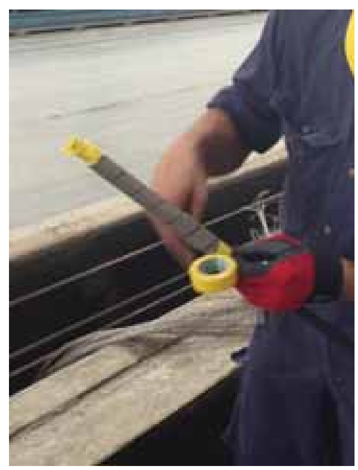
Tokyo Rope also noted that the seating of the wedges was not consistent from coupler to coupler. To remedy this, they developed the coupler installation procedure described in Chapter 4 and Appendix A. The main differences between the previous installation procedure (which was used for prestressing the 0.5–in. diameter strands in Summer 2012) and the new technique used in Summer 2013 are given below:

1. The Mesh Sheet Wrapping

   The earlier technique of wrapping the mesh sheet to the strand employed two (2) separate mesh sheets (Figure 7.2a). This may not provide complete wrapping on the CFCC strand. The new technique (Figure 7.2b) involved wrapping the CFCC strand uniformly with a continuous mesh sheet and provides a better and more uniform grip on the strand.



(a) Earlier Technique (2012)



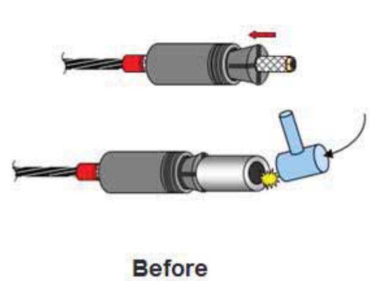
(b) New Technique (2013)

Figure 7.2: Mesh sheet installation technique

2. Wedge Installation

   In the new technique, the wedges were marked at 55 mm from the larger end of the wedges. A pneumatic jack was used to install the wedges into the sleeve. The previous method was to hammer the wedges into the sleeve. The new method provided a uniform and consistent installation of the wedges (Figure 7.3).

The new techniques used to install the couplers were successful in prestressing the strands and are now a standard used by Tokyo Rope.



(a) Earlier Technique (2012)

(b) New Technique (2013)

Figure 7.3: Wedge installation method

CHAPTER 8

SUMMARY AND CONCLUSIONS

8.1 Summary

This study investigated the following: installation procedures for CFCC strands and stressing couplers; CFCC bond characteristics (transfer length and development length); and the flexural capacity of a pile that is prestressed with CFCC strands. In addition, the behavior of a CFCC-prestressed pile during driving operations was observed and analyzed.

To meet the research objectives, piles were cast and several tests were performed. The research activities and tests were as follows:

1. Five (5) 24–in. square prestressed concrete piles were cast using 20 0.6–in. diameter CFCC prestressing strands, manufactured by Tokyo Rope Manufacturing Company. Produced at Gate Precast Company in Jacksonville, Florida, these five (5) piles included two (2) 100–ft and three (3) 40–ft specimens.

2. Transfer length tests were performed at GATE on the three (3) 40–ft piles.

3. Two (2) development length tests were performed on one (1) of the 40–ft piles at the FDOT Marcus H. Ansley Structures Research Center in Tallahassee, Florida.

4. One (1) of the 40–ft piles was tested for flexural strength at the FDOT Marcus H. Ansley Structures Research Center. The third 40–ft pile is stored at the laboratory for future studies, if needed.

5. The two (2) 100–ft piles were driven at an Interstate 4 bridge construction site in Volusia County, Florida, to monitor the static resistance of the piles and the pile behavior during driving.

8.2 Conclusions

8.2.1 Transfer Length of CFCC

An analysis of the transfer length tests, particularly of the data obtained from the electrical resistance strain gages, suggests that the CFCC strands have a 25–in. transfer length, which is 38% and 31% less than that predicted by ACI and AASHTO, respectively, for steel strands. The observed transfer length is 33% lower than the transfer length calculated from ACI 440.4R–04 and using the alpha factor by Grace (2000). Testing of more pile specimens could be performed to determine an alpha factor for CFCC strand transfer length predictions. Nonetheless, the observed transfer length is conservative, in that it is less than the predicted values.

The strain variation at the pile ends shows that the transfer lengths observed at the stressing ends were higher than those at the non–stressing ends. This could be due to the differing strain gage layouts at the ends: pairs of gages were placed near the corners at the stressing ends, whereas a single line of gages was placed along the pile centerline at the non–stressing ends.

8.2.2 Development Length of CFCC

The Test 1 pile had an embedment length of 72 in. Because the pile failed in flexure, rather than by failure of the strand–to–concrete bond, the development length could not be determined in this study. However, it can be concluded that the development length of CFCC is less than 72 in. and therefore also less than the AASHTO prediction of 123 in. for steel strands and with CFCC's value for GUTS.

8.2.3 Flexural Strength of CFCC–Prestressed Pile

The flexural strength of the CFCC–prestressed concrete pile was 8% higher than theoretical. The test results suggest that the flexural performance of piles with CFCC strands is comparable to that of piles with steel strands. The cracking pattern in all three (3) tests (the two (2) development length tests and the flexural test) was as anticipated for a flexural failure. In all tests, there was no end slip in any of the strands, which indicates a good bond characteristic of the CFCC with concrete. In addition, the pile's mid span had deflected over 9 in. at failure, which indicates good ductility. This is consistent with the approximate 10–in. deflection of concrete piles with similar dimensions that were prestressed with steel and tested by Abalo et al. (2010).

8.2.4 Pile Driving

Two (2) 100–ft piles were subjected to hard driving conditions and high internal compressive and tensile stresses. They both performed well, with no major damage or loss of prestress.

8.2.5 Specimen Production

There are unique challenges associated with using CFCC strands in a prestressed concrete pile. The precaster has to adapt to a new technique of stressing the strand with respect to:

1. Coupler installation
2. Proper handling of the CFCC to prevent damage
3. Concrete consolidation during placement, preferably without a vibrator to prevent damage to strand
4. The stressing method of CFCC strands, with regard to a slower–than–normal stressing rate recommended by the manufacturer
5. Use of a different header material (e.g., wood instead of steel) to prevent damage to CFCC strands while installing them in the precasting bed

8.3 Suggestions for Future Research

Suggestions for future research are as follows:

1. More testing could be performed to better estimate the value of the alpha factor in the ACI 440.4R–04 equation, by varying parameters such as the diameter of the CFCC, the prestressing force, and the concrete strength.
2. More tests could be performed to evaluate the development length of CFCC in prestressed concrete piles. The conclusions reported herein are based on only two (2) tests, for which the pile failed in flexure rather than the CFCC failing in bond.
3. Research should be conducted to further improve the anchorage system for the CFCC strands, with the goal being to make installation easier and faster for the precaster.

4. Specifications need to be developed for the CFCC material, if it is to be specified for use on future FDOT bridge construction projects. For example, necessary precautions or restrictions on the handing and storage of CFCC strands need to be specified. This includes acceptable levels of incidental damage.

5. Long–term properties should be further evaluated as part of specifications development.

6. Because the CFCC material does not corrode, it is possible that the 3–in. concrete cover could be reduced. Testing could be done to verify this, for example, to make sure that an adequate amount of concrete surrounds the strand to develop it. However, a reduced concrete cover would result in the need for precasters' standard templates to be modified.

7. In this test program, standard steel lifting loops to handle the piles were installed. An alternative lifting loop, made of a non-corrosive material, could be designed and tested if a pile completely devoid of steel were desired.

8. Other uses of CFCC strands should be investigated, particularly for structures that normally utilize steel prestressing strands in harsh or marine environments. For example, using CFCC instead of steel strands in sheet piles could be beneficial and cost effective in the long term.

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Appendices

APPENDIX A

CFCC PRODUCT INFORMATION

CFCC MATERIAL PROPERTIES

CARBON FIBER COMPOSITE CABLE (CFCC)

by Tokyo Rope Manufacturing Co., Ltd.

MATERIAL CHARACTERISTICS & PROPERTIES

	for 1x7 12.5ϕ strand	
High Tensile Strength	2.69 kN/mm^2	*Equal to steel strands*
High Tensile Modulus	155 kN/mm^2	*Similar to steel strands*
Lightweight	1.6 specific gravity	*About 1/5th of steel strand weight*
Low Linear Expansion	0.6x10^{-6}/°C	*About 1/20th of steel*
High Corrosion Resistance		*High acid resistance and alkali resistance*
Non Magnetic Interact		
Flexible		*Can be coiled*
Low Relaxation Loss	1.3% at 70% guar. cap. at 1000 hours	*Similar to steel strands*

STRAND PROPERTIES

Designation (Configuration diameter)	Diameter (mm)	Effective cross-sectional area (mm^2)	Guaranteed capacity (kN)	Nominal mass density (g/m)	Tensile elastic modulus (kN/mm^2)
U 5.0ϕ	5.0	15.2	38	30	167
1x7 7.5ϕ	7.5	31.1	76	60	155
1x7 10.5ϕ	10.5	57.8	141	111	155
1x7 12.5ϕ	12.5	76.0	184	145	155
1x7 15.2ϕ	15.2	115.6	270	221	155
1x7 17.2ϕ	17.2	151.1	350	289	155
1x19 20.5ϕ	20.5	206.2	316	410	137
1x19 25.5ϕ	25.5	304.7	467	606	137
1x19 28.5ϕ	28.5	401.0	594	777	137
1x37 35.5ϕ	35.5	591.2	841	1185	127
1x37 40.0ϕ	40.0	798.7	1200	1529	145

CFCC SPECIFICATION FROM TOKYO ROPE / CABLE TECHNOLOGIES

No. CTCF13-002A

CFCC SPECIFICATION

FOR

24" SQUARE

PRESTRESSED CONCRETE PILE

May 21, 2013

Cable Technologies North America, Inc.

26200 Town Center Drive, Novi, MI 48375

Contents

1 General

1.1 Scope

This specification covers shop fabrication, test, inspection and packing of the CFCC Strands and CFCC Ties for the 24” SQUARE PRESTRESSED CONCRETE PILE.

1.2 Specifications to be applied

The CFCC Strands and Ties shall be manufactured based upon the requirements documented by drawings and statements in the following specifications.

(1) FDOT DESIGN STANDARDS FY 2012/2013
40’-0” 24” SQUARE PRESTRESSED CONCRETE PILE (SHEET NO.1)
100’-0” 24” SQUARE PRESTRESSED CONCRETE PILE (SHEET NO.1)

All CFCC for the Strands and Ties shall have the performance stated in the following data manual.

(2) *Technical Data on CFCC, 2012 Tokyo Rope*

The CFCC strands and ties shall be processed and manufactured using the following standards and recommendations.

(3) *JIS Japanese Industrial Standards, the latest version*

(4) *Recommendation for Design and Construction of Concrete Structures Using Continuous Reinforcing Materials, 1997 Japan Society of Civil Engineers*

(5) *Manufacturing Standard of CFCC, Tokyo Rope, the latest version.*

The codes and standards specified in the tender documents are in general to be applied.
The manufacture may use other codes / standards in the alternative results in a final structure with equal or improved standard.

1.3 Contact line

Cable Technologies North America, Inc.

TOKYO ROPE
TCT Division

TOKYO ROPE
Gamagori CFCC Plant

Information Office

Name and Position	TEL No.	FAX No.
Noriyoshi Inoue **Cable Technologies North America, Inc.**	919-767-4965	919-767-4965
Kenichi Ushijima **Cable Technologies North America, Inc** Senior Engineer	248-449-8470	248-449-8471

2 Quality and quantity of product

2.1 CFCC Strands

(1) Construction of CFCC Strands

The CFCC Strands shall consist of the CFCC 1×7 15.2 ϕ . The properties of the CFCC 1×7 15.2 ϕ and their material shall be in accordance with section 3.1 and chapter 4.

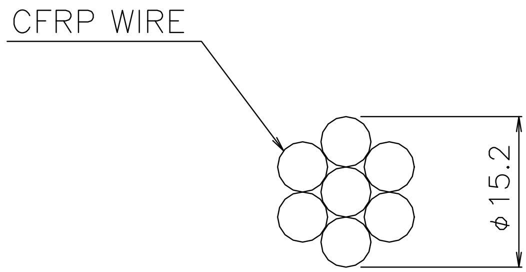


Fig. 2-1 Cross section of CFCC 1×7 15.2 ϕ

(2) Length and number of CFCC Strands

Table 2-1 Length and number of pieces of CFCC Strands

Length of one coil	Number of coils	Total length
1,174m (3,850ft)	2	2,348m (7,700ft)

2.2 Anchoring devices

(1) Details of Anchoring devices

The anchoring device shall consist of the wedge, sleeve and coupler in Fig. 2-2. The details of the wedge, sleeve and coupler shall be as shown in Fig. 2-3. The configuration of the mesh sheet shall be as shown in Fig. 2-4. The appearance of the braid grip shall be as shown in Pic. 2-1. The properties of the wedge, sleeve and coupler shall be in accordance with chapter 4.

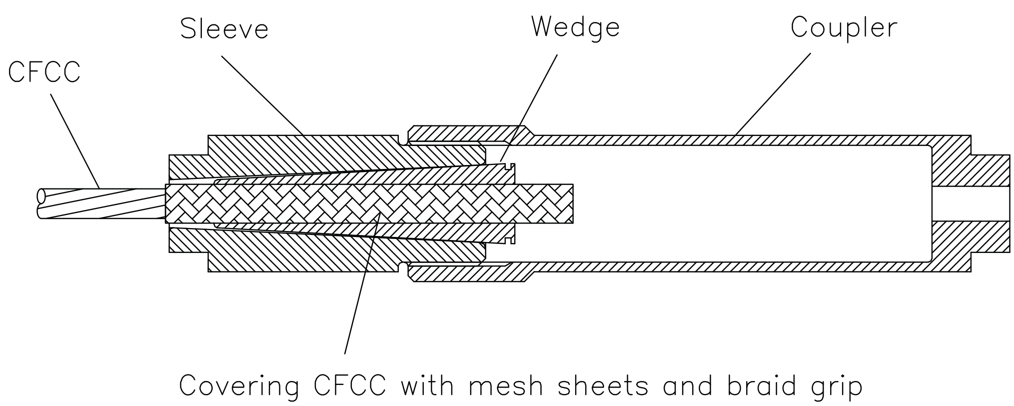
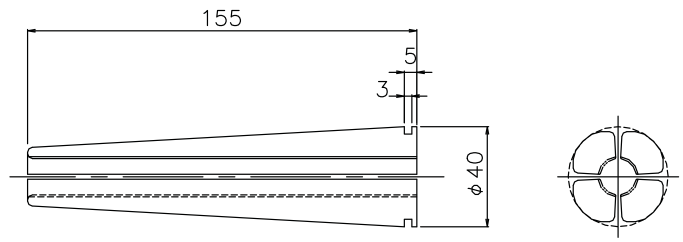
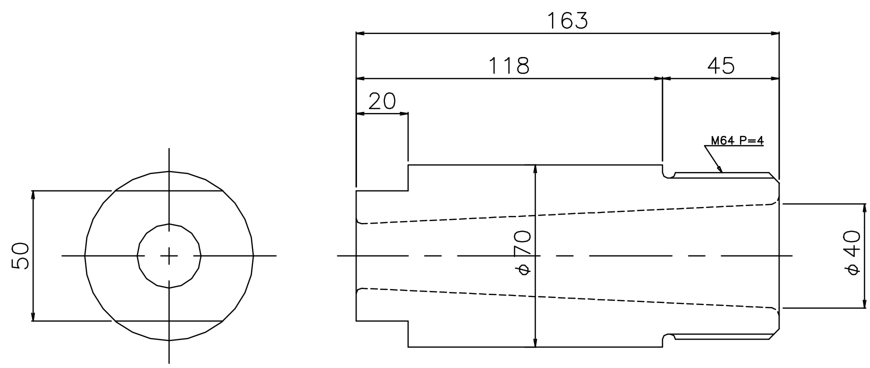


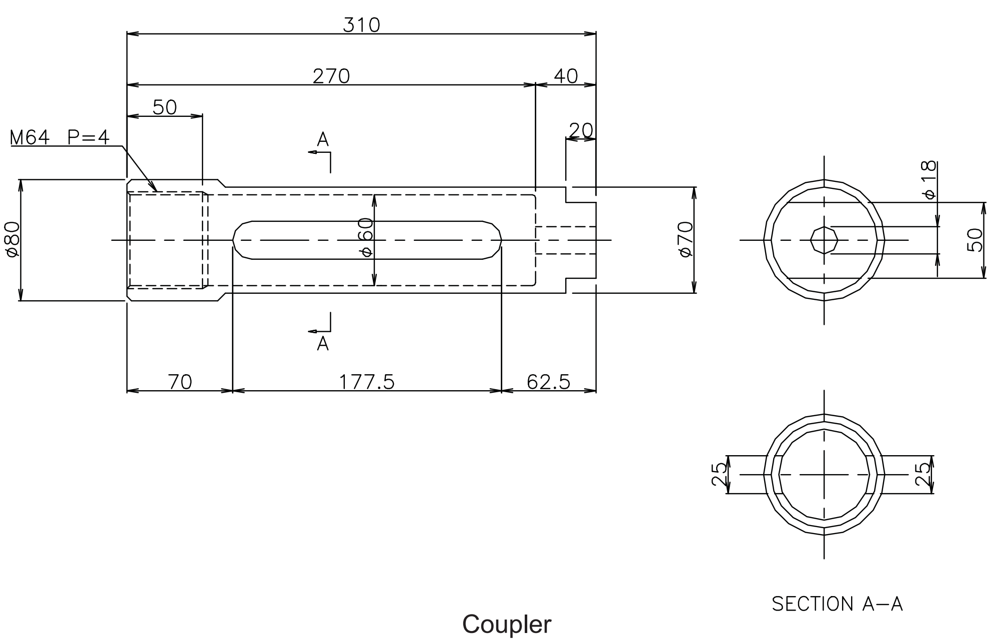
Fig. 2-2 Schematic of anchoring devices



Wedge (4 pieces in 1 set)



Sleeve



Coupler

Fig. 2-3 Shapes of the anchoring wedge, sleeve and coupler (Unit: mm)

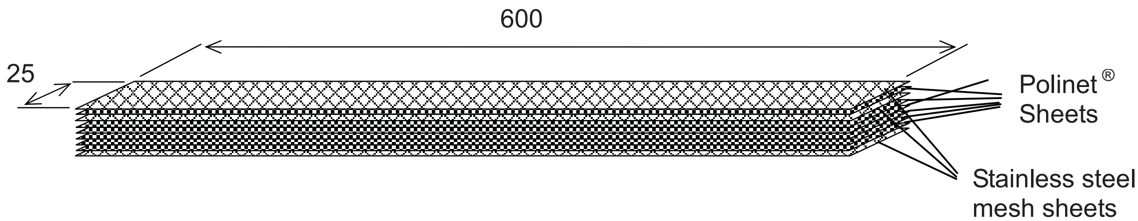


Fig. 2-4 Configuration of the mesh sheets (Unit: mm)

Pic. 2-1 Appearance of the braid grip

(2) Number of Anchoring devices

Table 2-2 Number of anchoring devices

Item	Number of items	Extra amount	Total
Wedge	40 sets	–	40 sets
O ring	40 pieces	10 pieces	50 pieces
Sleeve	40 pieces	–	40 pieces
Coupler	40 pieces	–	40 pieces
Mesh sheet	40 sets	10 sets	50 sets
Braid grip ※	14 pieces	3 pieces	17 pieces

※One braid grip is divided into three. Therefore, 17 braid grips are equivalent to 51

2.3 CFCC Ties

(1) Construction of CFCC Ties

The CFCC Ties shall consist of the CFCC U 5.0 ϕ. The properties of the CFCC U 5.0 ϕ and their material shall be in accordance with section 3.3 and chapter 4.

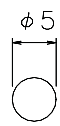


Fig. 2-5 Cross section of CFCC U 5.0 ϕ

(2) Shapes and number of CFCC Ties

The radius of inscribed circle of bent part R is planed to be 10.85 mm.
Tolerances of the dimensions are +0.5”, -0.0”.

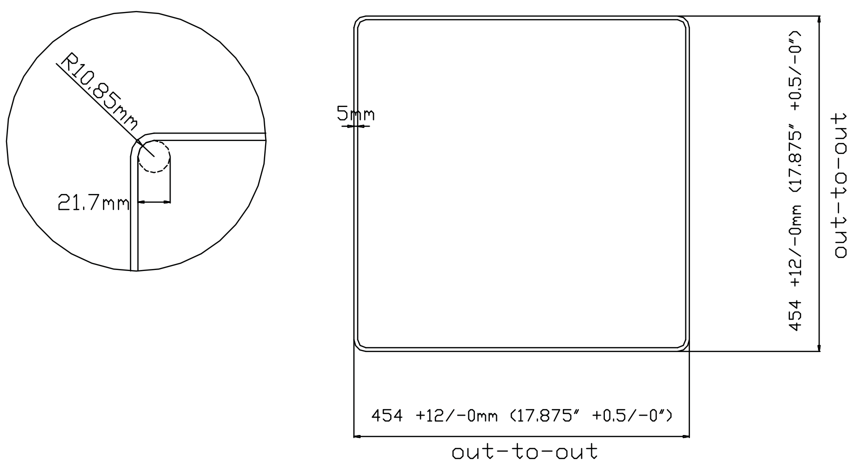


Fig. 2-6 Bending detail of CFCC Ties

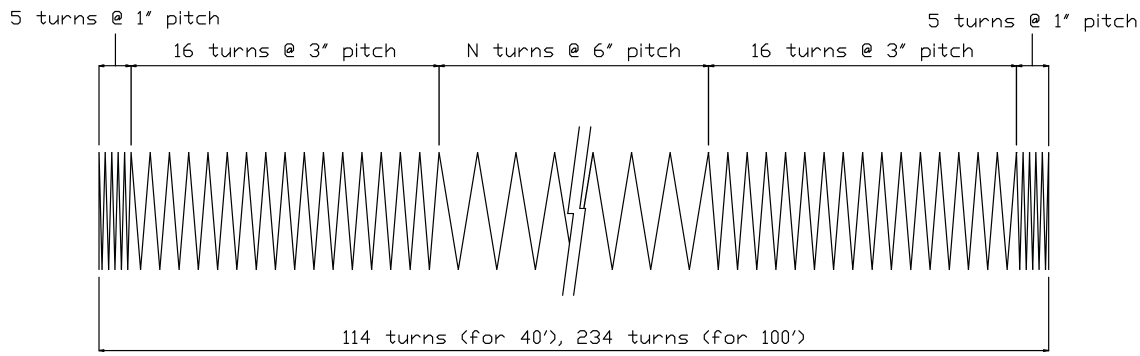


Fig. 2-7 Turning detail of CFCC Ties

Table 2-3 Number of CFCC Ties

Type	Total number of turns	Length of CFCC	Number of pieces
40' pile	114 turns	207 m (679 ft)	3
100' pile	234 turns	425 m (1,394 ft)	2

3 Specifications

3.1 CFCC Strands

The CFCC Strands shall comply with the specifications as shown in Table 3-1.

Table 3-1 Specifications of CFCC Strands of CFCC 1×7 12.5 ϕ

	Unit	Nominal	Tolerance
Construction	—	1×7	—
Diameter	mm	15.2※	—
Effective cross sectional area	mm^2	115.6※	—
Linear density	g/m	221※	—
Breaking load	kN	270	270 or above
Tensile modulus	kN/mm^2	155※	—

※ Standard value

According to the ACI committee reports (ACI 440.4R-04), the recommended maximum jacking stresses for CFRP tendons are 65% of their ultimate strength, but in this project, the CFCC strands shall be stressed to 75% of their breaking loads.

3.2 Anchoring devices

While the CFCC strands are stressed, the temperature of the anchoring devices shall not exceed 50 degrees Celsius (122 degrees Fahrenheit).

3.3 CFCC Ties

The CFCC Ties shall comply with the specifications as shown in Table 3-2.

Table 3-2 Specifications of CFCC Ties of CFCC U 5.0 ϕ

	Unit	Nominal	Tolerance
Construction	—	U	—
Diameter	mm	5.0※	—
Effective cross sectional area	mm^2	15.2※	—
Linear density	g/m	30※	—
Breaking load	kN	38	38 or above
Tensile modulus	kN/mm^2	167※	—

※ Standard value

4 Material

4.1 Carbon fiber prepregnation

The prepreg shall be PAN carbon fiber (for example: grade T700) impregnated with epoxy resin and amin hardener. Properties of the carbon fiber are shown in Table 4-1.

Table 4-1 Properties of the carbon fiber (in the case of T700)

Properties		Unit	Value
Carbon fiber	Filament count (Nominal)	—	12,000 or 24,000
	Yield without size	tex	800 or 1,650
	Strand tensile strength	kN/mm^2	4.90
	Strand tensile modulus	kN/mm^2	230

4.2 Wrapping fiber

The each string of CFCC shall be wrapped with the fiber. The polyester filament yarn shall be used for wrapping.

4.3 Wedges, sleeves and couplers for CFCC Strands

The wedges shall be made of steels (SCM415 according to JIS G 4053), with machining and heat treatment.
The sleeves and couplers shall be made of steels (S45CH according to JIS G 4051), with machining and heat treatment.

4.4 Polinet sheets and stainless steel meshes

The mesh sheets shall consist of polinet sheets and stainless meshes. The polinet sheets shall be made of open meshed synthetic fiber cloth with abrasive grains. (#400, Aluminium oxide)
The stainless steel meshes shall be made of stainless steels (SUS304 according to JIS G 3555).

4.5 Braid grips

The braid grips shall be made of wire of stainless steels (SUS403 W1 according to JIS G 4309).

5 Test and inspection

5.1 Items and number of sampling

The test and inspection shall be subjected on the items and the numbers of sampling as shown in Table 5-1.

Table 5-1 Items and number of sampling for test and inspection

	Item		Number of sampling
Acceptance inspection	Carbon fiber	Type, quantity	Each acceptance
	Resin	Type, quantity	Each acceptance
	Wrapping fiber	Type, quantity	Each acceptance
	Wedge, sleeve, coupler	Type, quantity	Each acceptance
	Polinet sheet	Type, quantity	Each acceptance
	Stailess steel mesh	Type, quantity	Each acceptance
	Braid grip	Type, quantity	Each acceptance
In-process inspection	CFCC 1×7 15.2 ϕ	Diameter, pitch, linear density	Five for each lot
		Tensile test	Five for each lot
	CFCC U 5.0 ϕ CFCC tie	Diameter, linear density	Five for each lot
		Tensile test	Five for each lot
		Shape	Earch piece
		Dimension	Earch piece
		Appearance	Earch piece
Shipping inspection	CFCC strand	Length	Every cable
		Quantity	Each package
		Shipping mark	Each package
	CFCC tie	Quantity	Each package
		Shipping mark	Each package

5.2 Method of test and inspection of CFCC

Test for CFCC 1×7 15.2 ϕ and CFCC U 5.0 ϕ

① Five 1.5 m long test pieces shall be cut from each lot of CFCC 1 x 7 15.2 ϕ and CFCC U 5.0 ϕ to measure the diameter, pitch, and linear density. Each terminal of test pieces shall be fixed into a socket with filling HEM (Highly expansive material) to conduct the tensile test.

② The tensile modulus shall be calculated according to the slope of the load . The length of the gauge of the extensometer shall be 500 mm.

③ The elongation at break shall be calculated by extrapolation of the load - elongation curve up to the breaking point.

④ The method of tensile test shall conform to JSCE-E531.

6 Packing and indication

(1) Packing detail

Table 6-1 Packing List

Pack -age No.	Description		Quantity		Dimention (mm)	Weight (kg)	
			m	pieces		Net	Gross
1	CFCC strands	CFCC 1×7 15.2 ϕ	1174	2	1802×1802×1185	520	1005
2	CFCC ties “40’ pile”	CFCC U 5.0 ϕ	207	3	900×650×735	19	30
3	CFCC ties “100’ pile”	CFCC U 5.0 ϕ	425	2	1100×650×735	26	38
4	Anchoring devices	Wedges	-	40	950×850×480	302	314
		Sleeves	-	40			
		Coupler	-	40			
		Mesh sheets	-	50			
		Braid grip	1.5	17			
		O ring	-	50			
		Jig	-	2			

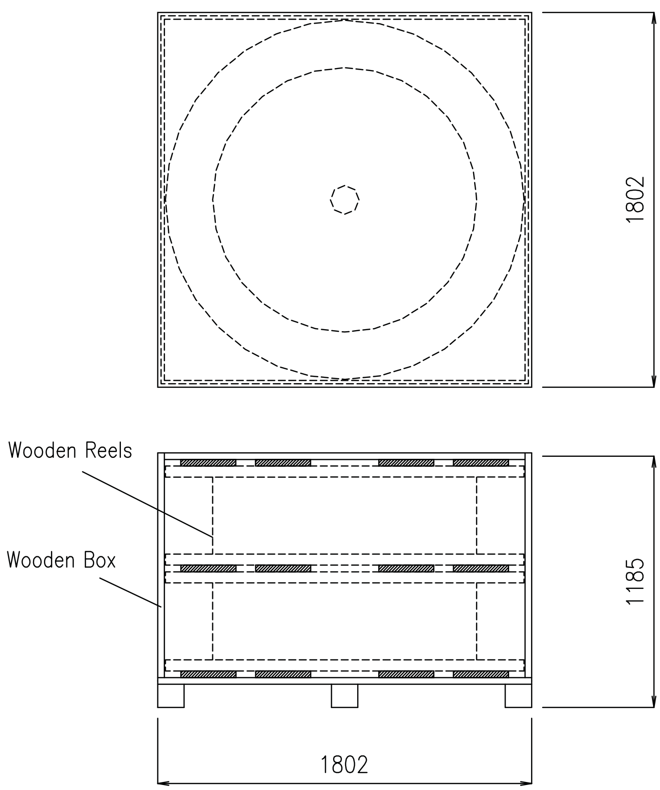


Fig. 6-1 Detail of Package No.1

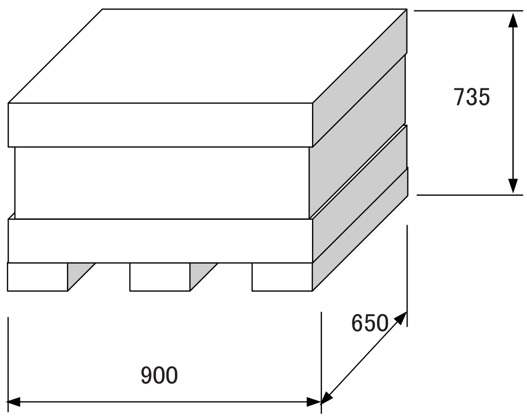


Fig. 6-2　Detail of Package No.2

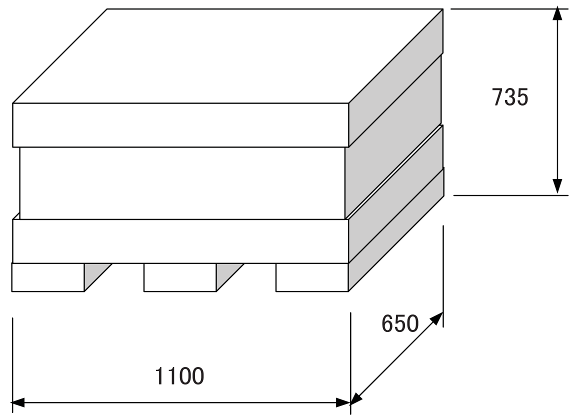


Fig. 6-3　Detail of Package No.3

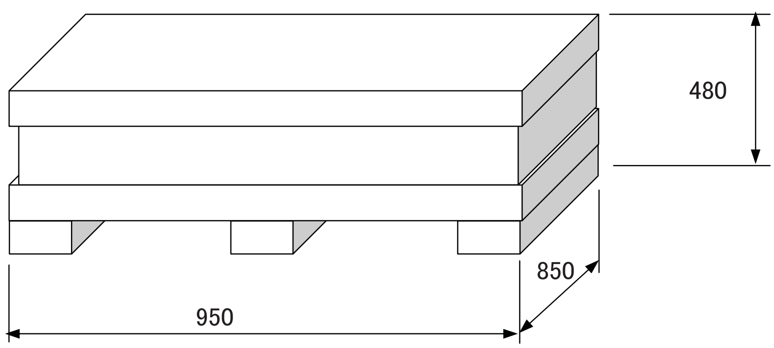


Fig. 6-4　Detail of Package No.4

(2) Indication

The label shall be attached on the each product. And as the following, the indication shall be attached on the each packing.

<table>
<tr><td>Name of Products</td><td colspan="2"></td></tr>
<tr><td>Quantity</td><td colspan="2"></td></tr>
<tr><td rowspan="2">Weight</td><td>N.W.T</td><td></td></tr>
<tr><td>G.W.T</td><td></td></tr>
<tr><td>Check Mark</td><td colspan="2"></td></tr>
<tr><td colspan="3">Manufacturing Company :
Tokyo Rope Mfg. Co., Ltd.</td></tr>
<tr><td colspan="3">Manufacturing Factory :
Tokyo Rope Mfg. Co., Ltd. Gamagori CFCC Factory</td></tr>
</table>

7 Documents to be submitted

Tokyo Rope shall submit the test report for CFCC. The test report shall include the following documents.

(1) Test results of CFCC

The test results of CFCC 1×7 15.2 ϕ and CFCC U 5.0 ϕ shall include the following:

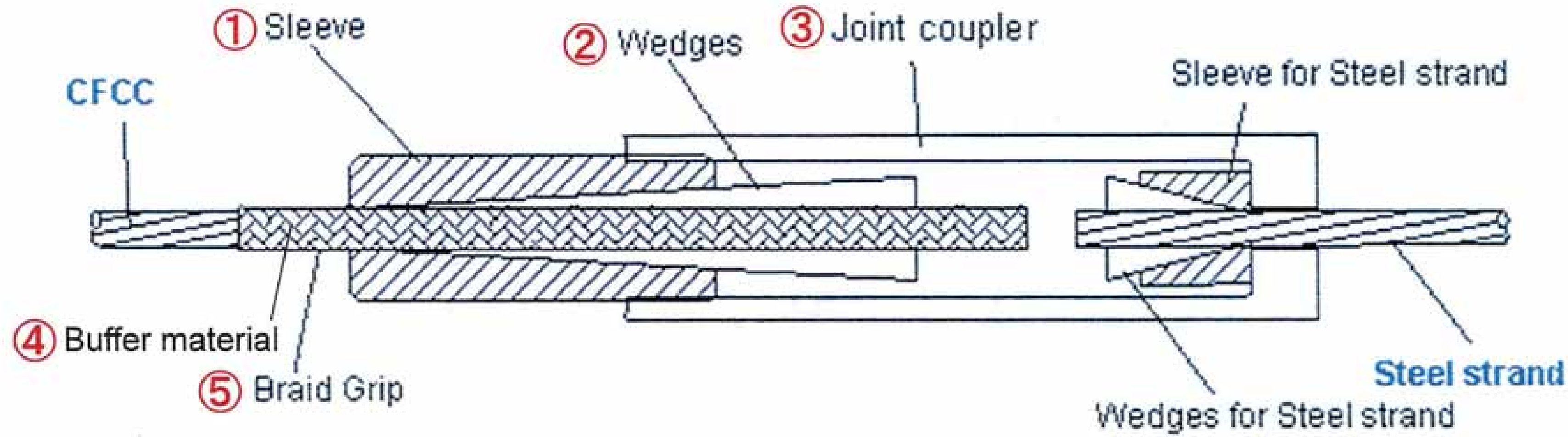
Diameter;
Direction and pitch of lay (only CFCC 1×7 15.2 ϕ);
Linear density;
Breaking load;
Tensile modulus;
Elongation at break;

COUPLING DEVICE MANUAL FROM TOKYO ROPE

Manual for wrapping Buffer material

TOKYO ROPE MFG.CO.,LTD.

1. Parts list

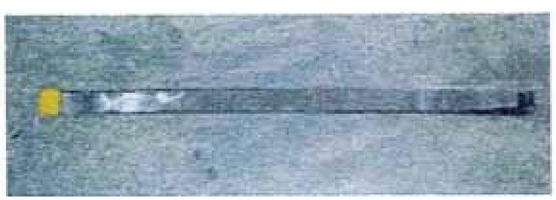


① Sleeve for CFCC

② Wedges for CFCC

③ Joint coupler

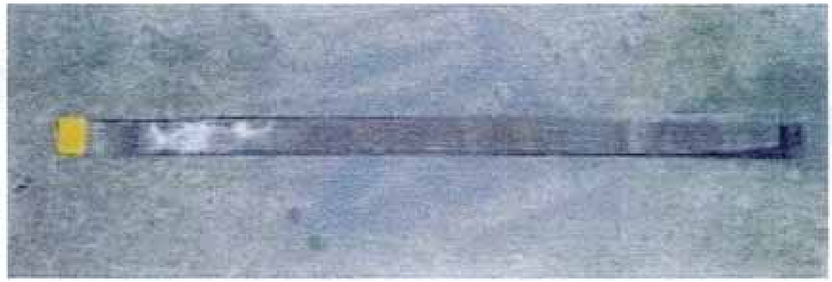
④ Buffer material

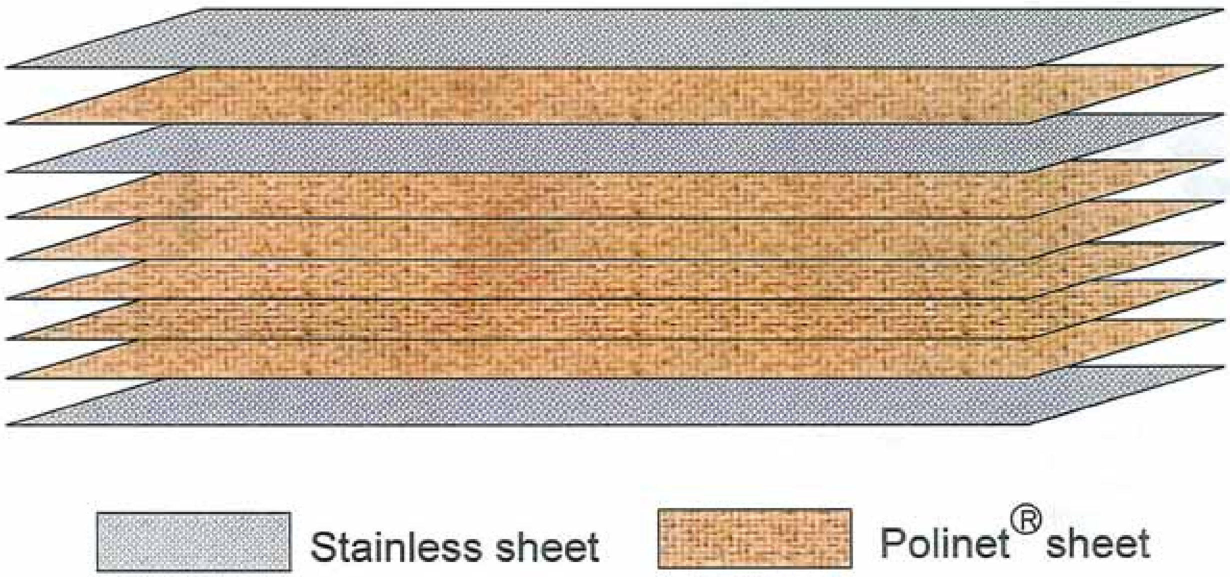


⑤ Braid Grip

TOKYO ROPE MFG.CO.,LTD.

2. Detail of Buffer material





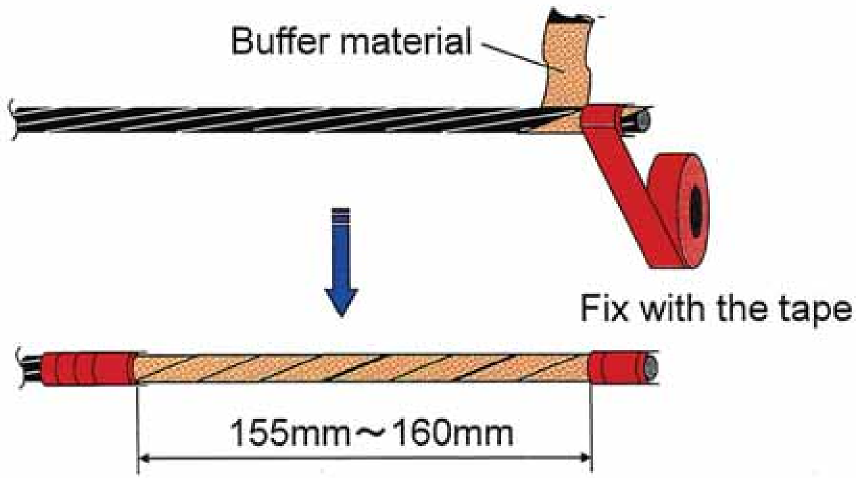
Construction of Buffer material

TOKYO ROPE MFG.CO.,LTD.

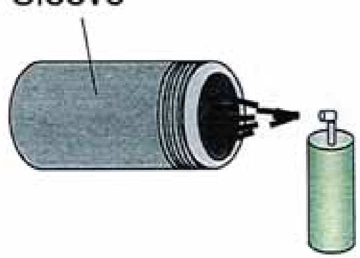
3. Setting the anchoring devices

3-1. Wrapping the Buffer material

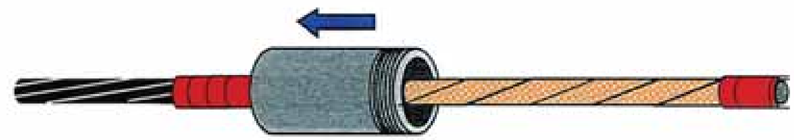
① Wrap spirally the anchoring part of CFCC with the Buffer material. Spiral direction of the Buffer material is CFCC's lay direction.



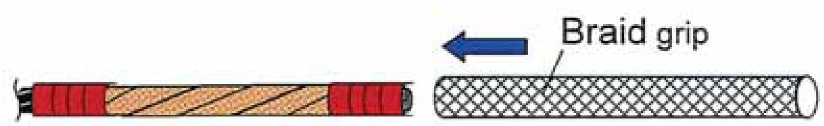
② Spray molybdenum on the inside of sleeve .



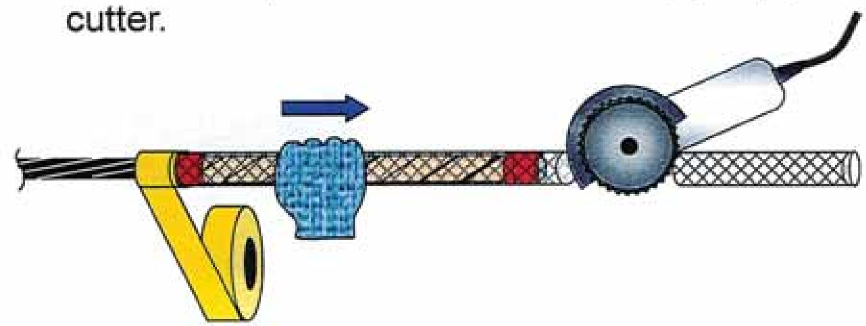
③ Insert the sleeve to CFCC.



④ Insert the Braid grip to CFCC, and cover the Buffer material.



⑤ Draw the Braid grip tightly in the direction of the arrow through your hand in order to eliminate the wrinkles, and then cut the Braid grip by grinder cutter.



TOKYO ROPE MFG.CO.,LTD.

Check point for wrapping Buffer material.

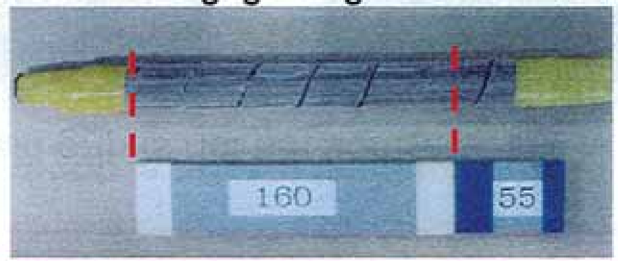
① Tape to tape length needs to be over 155mm.
（155mm is wedge length)

② Wrap tightly.

③ Spiral wrapping has no gap between spirals.

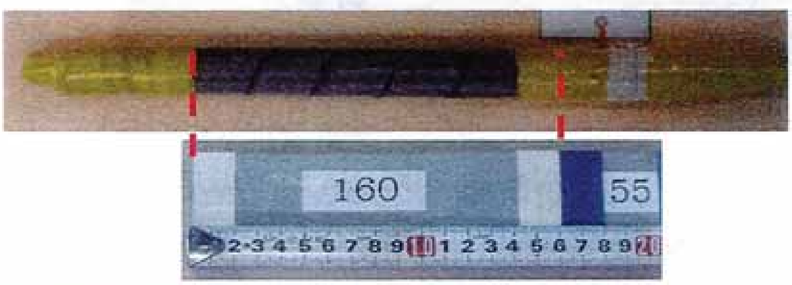
Check with the gage

The gage length is 160mm

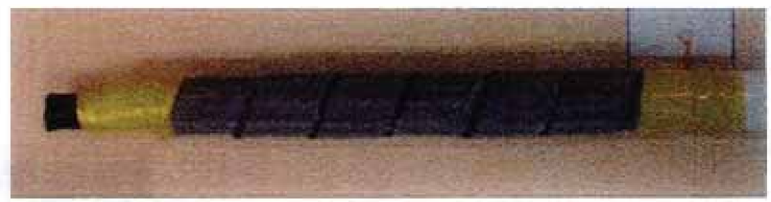


Warning

① Tape to tape length is under the gage length(160mm).



② Wrapping is loose.

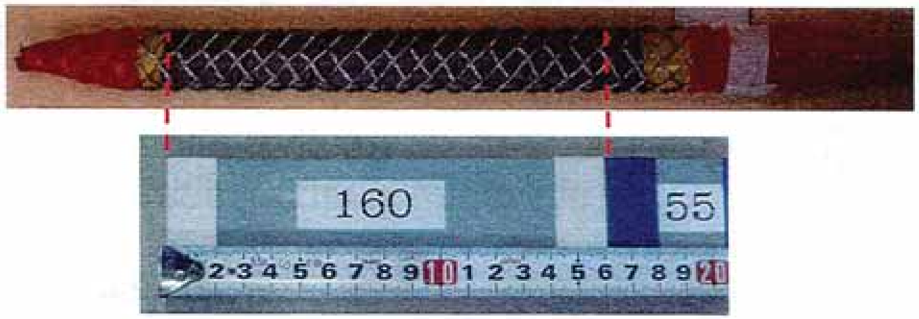


③ Spiral wrapping has gap between spirals.

TOKYO ROPE MFG.CO.,LTD.

Check point for covering Braid gripe.

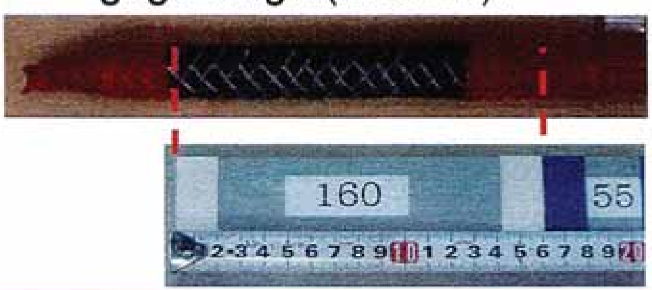
① Tape to tape length needs to be over 155mm.
(155mm is wedge length)
Check with the gage



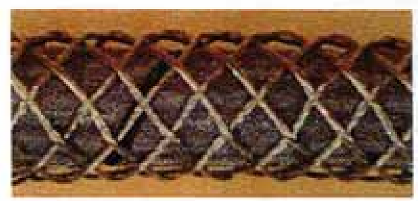
② The Braid grip must be set tightly in order to eliminate the wrinkles.

Warning

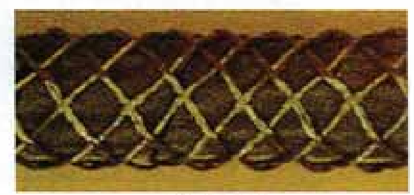
① Tape to Tape length is under the gage length(160mm).



② The Braid grip is not set tightly.



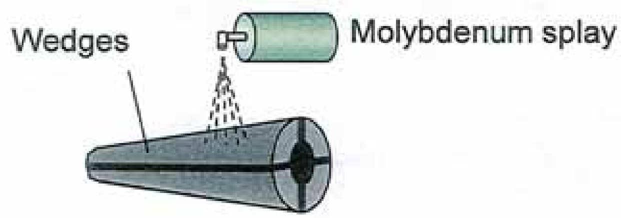
Warning
The Braid grip is not set tightly (Loose).



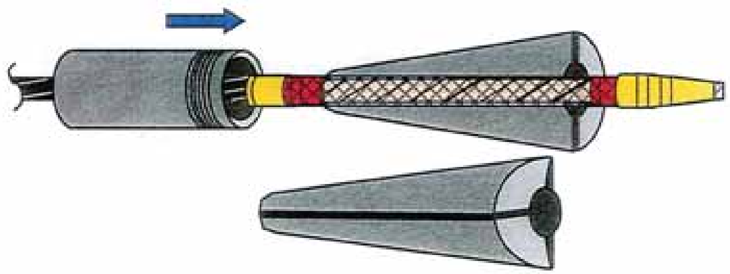
Good
The Braid grip is set tightly.

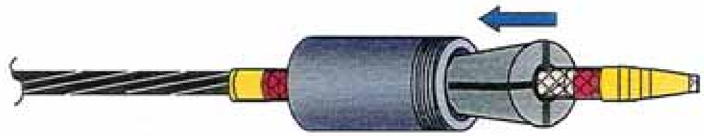
3-2. Setting wedges and sleeve toward CFCC

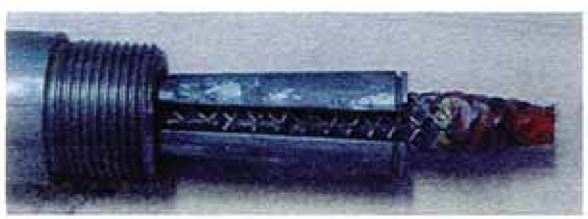
① Spray molybdenum on the outside of wedges.



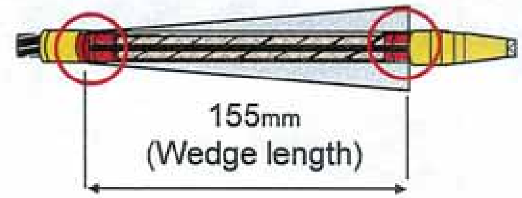
② Set the wedges.





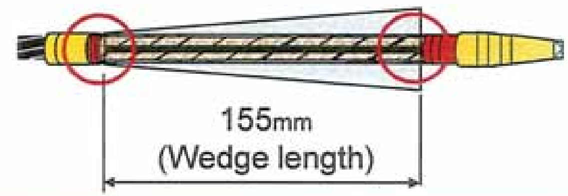


Notice
Do not set the wedges on any tape which fixed the mesh sheet and Braid grips.



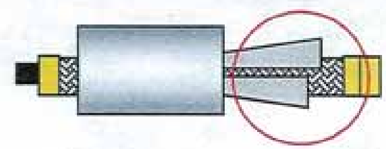
Warning

Set the wedges between the fixed tapes.



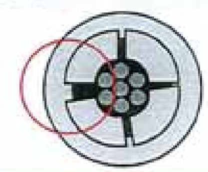
Good

Notice
Be careful so that the end face of the wedges does not become uneven.



Warning

Do not become uneven the gaps between wedges.

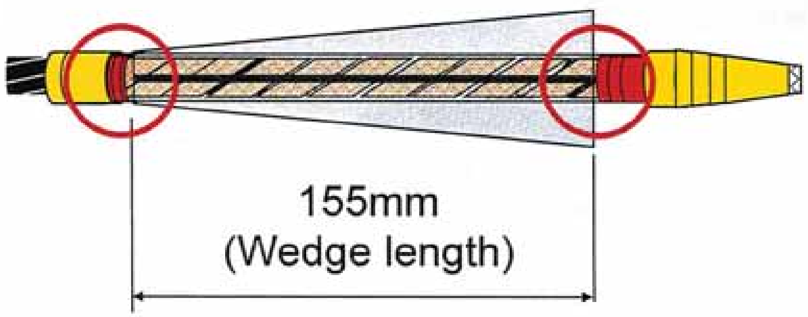


Warning

TOKYO ROPE MFG.CO.,LTD.

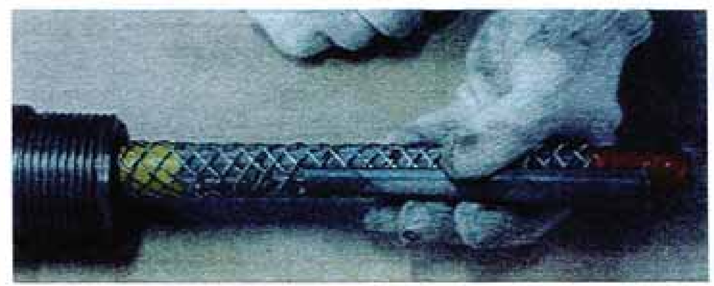
Check point for wedge position.

① Set the wedges between the fixed tapes (Do not put on the tape) .



Warning

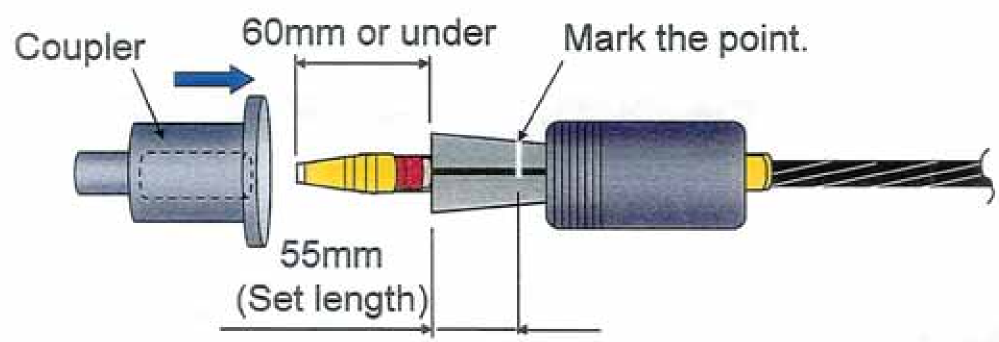
Set the wedges on the tape.



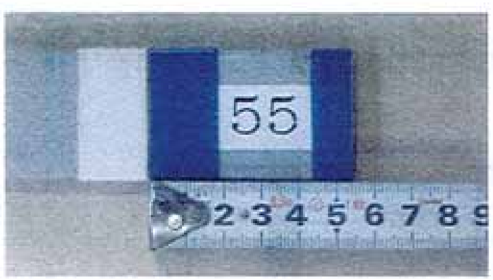
TOKYO ROPE MFG.CO.,LTD.

3-3. Inserting the wedges into the sleeve by using the push equipment.

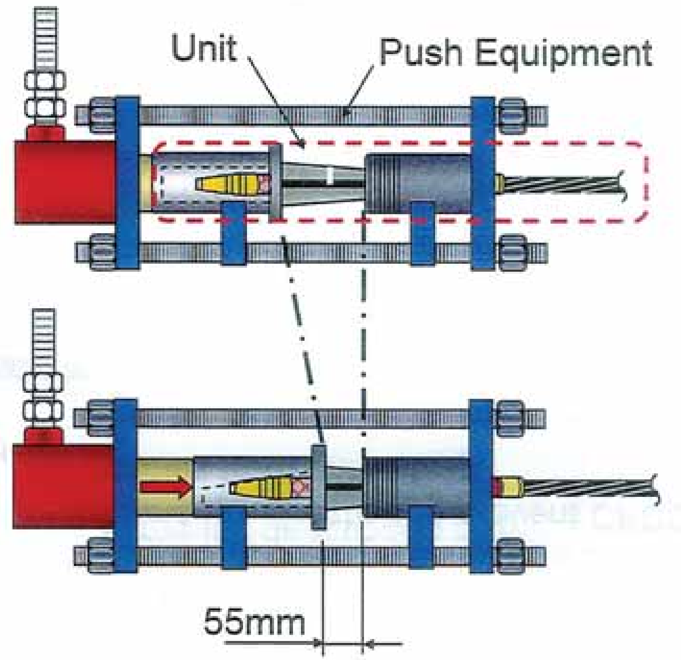
① Mark the point at 55mm (Set length) from the edge of the wedges.



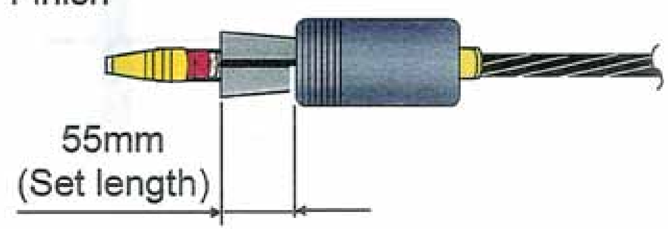
Check with the gage



② Set the above unit into the Push Equipment.



③ Finish



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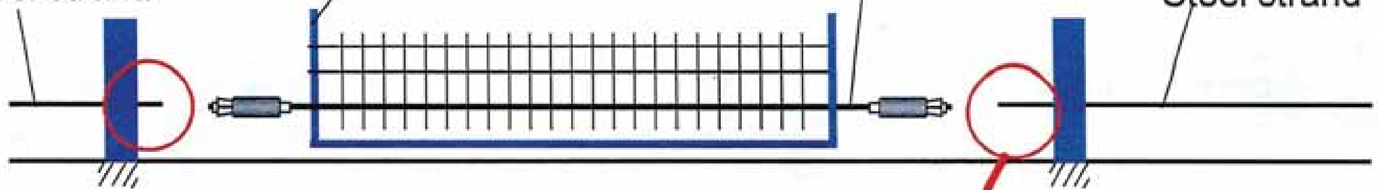
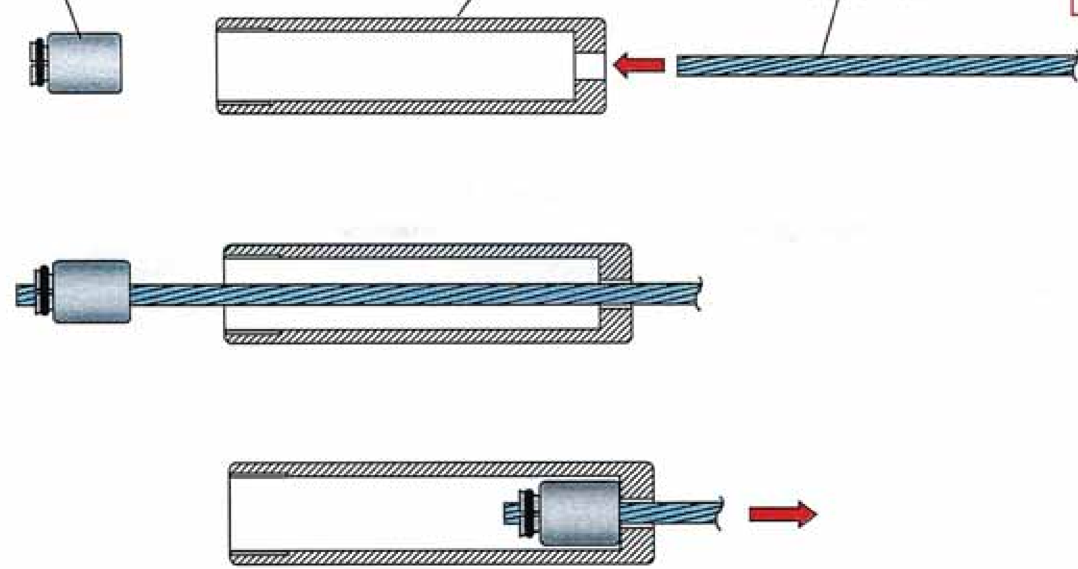
4. Setting the tensioning devices



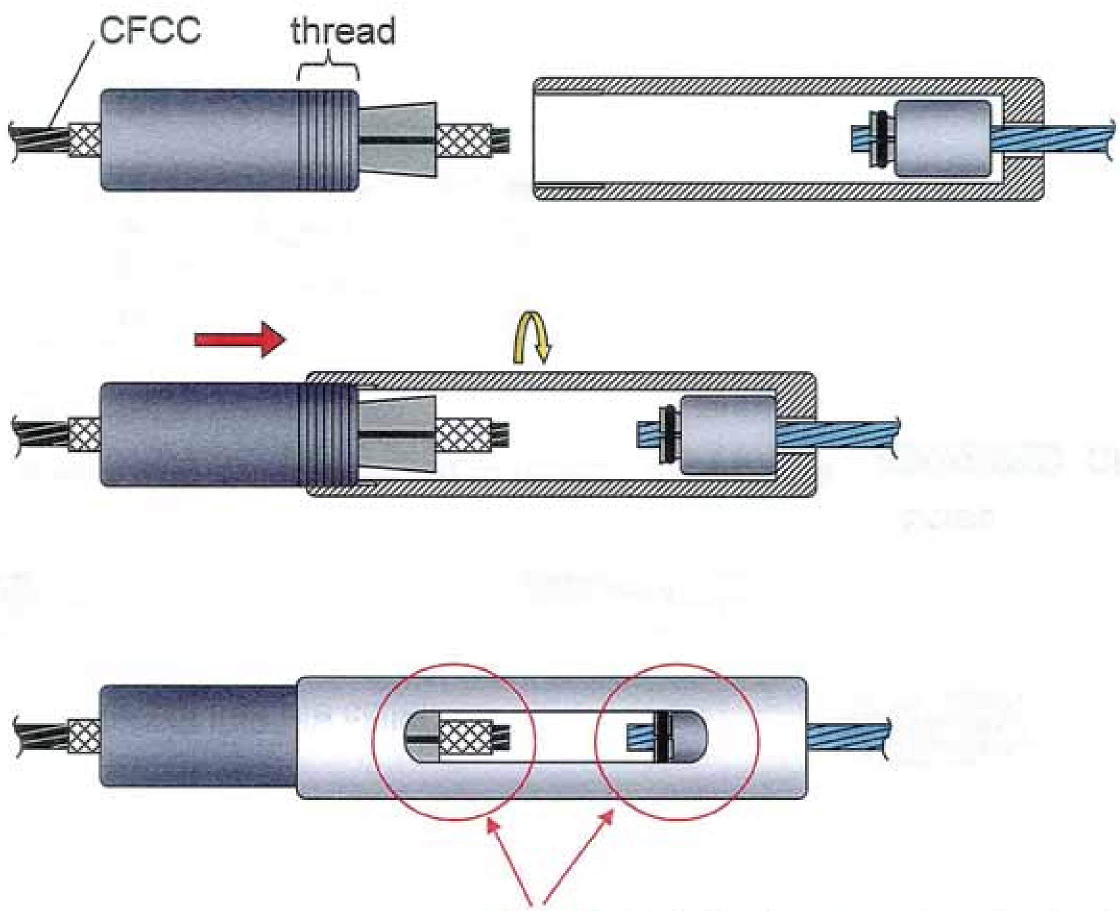
4-1. Attaching the wedges and a coupler to steel strand.



Notice
Use CFCC and steel strand of same lay direction to prevent CFCC cables from untwisting.

TOKYO ROPE MFG.CO.,LTD.

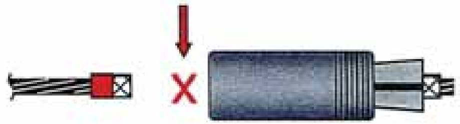
4-2. Joining CFCC to steel strand while turning a coupler



Check :CFCC should not touch steel strand.

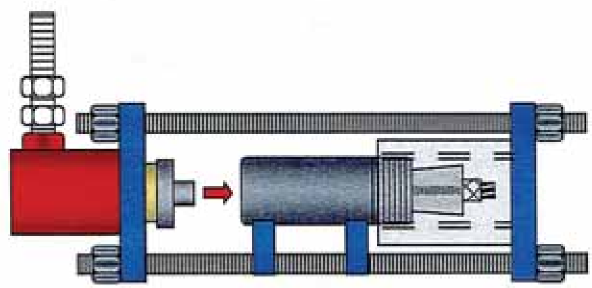
5. Removing the wedges from Sleeve

① Cut off surplus CFCC.

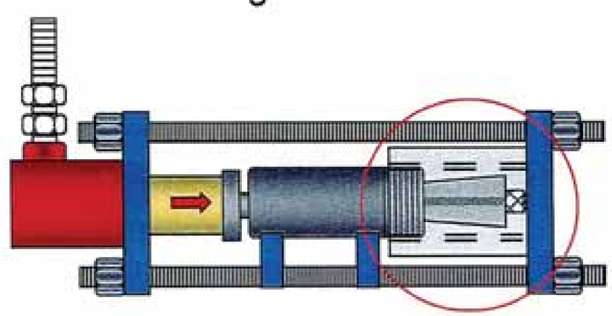


② Screw a sleeve into the collar.

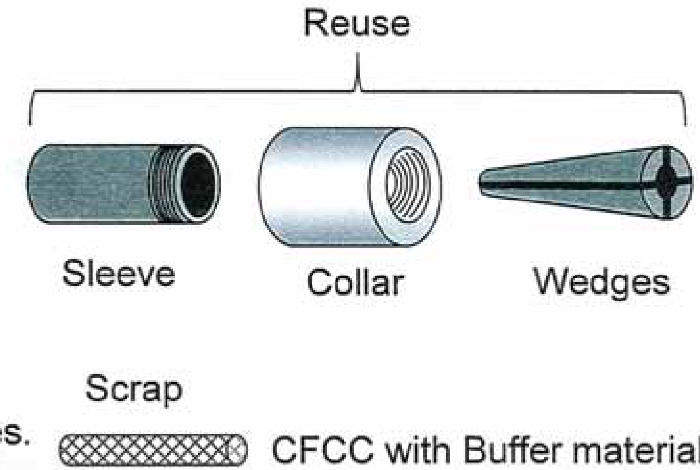
③ Set sleeve with collar at device to release the wedges.



④ Push out the wedges.



⑤ Remove the wedges from CFCC for reuse.



TOKYO ROPE MFG.CO.,LTD.

APPENDIX B

CONCRETE MIX DESIGN

Note: The first two pages in this appendix contain compression strength test data and the concrete mix design that were provided by Gate before the piles were cast, to help in deciding to use the SCC mix design. This data is NOT on the specific batches used in the casting of the piles for this research.

The third (3rd) through sixth (6th) pages are copies of the batch tickets for the mix that was used for this research.

GATE PRECAST COMPANY

Self-Consolidating Concrete
28-Day Compression Strength Test Results

CAST DATE	TEST RESULTS
05/31/13	9150 9160/9140psi
06/03/13	8875 8790/8960psi
06/04/13	9290 9370/9210psi
06/05/13	8955 9160/8770psi
06/07/13	9220 9270/9170psi
06/10/13	8770 8330/9210psi
06/11/13	9005 9090/8920psi
06/12/13	9085 8890/9280psi
06/13/13	8625 8700/8550psi
06/17/13	8445 8500/8390psi
06/18/13	8145 8220/8070psi
06/19/13	8240 8570/7910psi
06/20/13	8660 8620/8700psi

Avg = 8805

Gate Precast Company – 402 Heckscher Dr. – Jacksonville, FL 32226 - Phone (904) 757-0860 – Fax (904) 751-5435

CONCRETE MIX DESIGN

ISSUED: 02/07/12

REVIEWED: B. Hunter

MIX NO.: SCC -1

CONCRETE SUPPLIER: Gate Concrete Products

ADDRESS: 402 Zoo Parkway

PLANT LOCATION: Jacksonville, FL 32226 TELEPHONE NO.: (904) 757-0860

DEPT. ASSIGNED PLANT NO.: 72-055 PROJECT NO.: General

ORIGINAL ISSUE DATE: 04/07/07

CLASS CONCRETE: V (7500)

SOURCES OF MATERIALS

Coarse Aggregate Titan/Tarmac Pennsuco	Grade 67 S.G. (SSD) 2.430
Fine Aggregate Florida Rock Industries	F.M. 2-28 S.G. (SSD) 2.630
Pit No. (Coarse) 87-145	Type Crushed Limestone
Pit No. (Fine) 71-132	Type Silica Sand
Cement Suwannee	Spec AASHTO M-85 Type I/II
Air Entr. Admix AE-90 MB/BASF	Spec AASHTO M-154
1st Admixture Glenium 7700 MB/BASF	Spec AASHTO M-194
2nd Admixture Pozz NC534	Spec AASHTO M-194
3rd Admixture Z60/BASF	Spec ASTM C 494-99 Type B
Fly Ash STI/Pro-Ash	Spec ASTM C-618 Class F
Cement (lbs) 714	*SPREAD RANGE: 25 TO 31 INCHES
Coarse Aggregate (lbs) 1375	AIR CONTENT: 3.0 % TO 8.0 %
Fine Aggregates (lbs) 1200	UNIT WEIGHT (WET): 136.33 PCF
Air Entr. Admix (oz) 4.5	WATER CEMENT RATIO (LBS/LB): .36 (incl. 1 gal for NC534)
1st Admixture (oz) 30	MAX. ALLOWABLE W/C (FIELD) : .38
2nd Admixture (oz) 128	THEORETICAL YIELD: 27 (cu. ft.)
3rd Admixture (oz) 16.0	
Water (gals.) 36.0	
Water (lbs) 300	
Fly Ash (lbs.) 126	

****

PRODUCER TEST DATA

*Spread: 28 INCHES

Air Conctent: 4.2 %

Temperature: 86 deg. F.

Compressive strength P. S. I.

1 Day 4390

14 Day 8120

28 Day 9855

*NOTE: Spread determined by using the Slump Cone in the inverted position.

GATE CONCRETE JACKSONVILLE FLORIDA **FDOT PLANT 72055** **Ticket No:** 21989

Printed On: 7/24/2013

Operator Certificate s334420592140 **Truck Number:** 1

Recipe Name: MIX2SCCNCR534

Recipe Description: jobs#13146/13147/13137

Created: 7/24/2013 3:33:41 PM **Created By:** jansen

Recipe Class : class v [7500] **Start Time:** 3:26:27 PM **Completed Time:** 3:33:34 PM

Mix Time: 121.25 Secs

W/C Ratio:	0.34	**Holdback:**	6 %
Slump Adjust:	0.00 Gal	**Prewet:**	0 %
Tot. Water Deduct:	0.00 Gal	**Temper Water:**	1.00 Gal
Batch Size:	6.000 Yds ^{3}	**Ice:**	0.0 lbs

Scale 1	Agg #1-4	Starting Wgt:	-1.3	lbs	Ending Wgt:	0.0	lbs
Scale 2	Cem #1-4	Starting Wgt:	-3.7	lbs	Ending Wgt:	0.4	lbs
Scale 3		Starting Wgt:	0.0	lbs	Ending Wgt:	0.0	lbs

Prod. Name:	Product Source	Target:	Actual:	Final Moisture:	Deviation:	%	Accp'td	Tolerance Over/Under	
67 Rock	87-145	8537.3 lbs	8467.6 lbs	3.4 %	-69.62 lbs	-0.82	0	2.0	2.0
Sand	71-132	7415.6 lbs	7302.3 lbs	2.9 %	-113.34 lbs	-1.53	0	2.0	2.0
STI FLYASH	STI	756.0 lbs	767.6 lbs	0.0 %	11.62 lbs	1.54	1	1.0	1.0
Suwannnee American	TYPE I,II	4284.0 lbs	4281.8 lbs	0.0 %	-2.25 lbs	-0.05	0	1.0	1.0
MBAE 90	BASF	48.0 Oz	48.0 Oz	0.0 %	0.00 Oz	0.00	0	3.0	3.0
Z-60	BASF	144.0 Oz	144.0 Oz	0.0 %	0.00 Oz	0.00	0	3.0	3.0
Glenium 7700	BASF /F	180.0 Oz	180.0 Oz	0.0 %	0.00 Oz	0.00	0	3.0	3.0
POZZ NC534	BASF	768.0 Oz	768.0 Oz	0.0 %	0.00 Oz	0.00	0	3.0	3.0
Cold Water	Not Entered	143.5 Gal	144.0 Gal	0.0 %	0.54 Gal	0.38	0	1.0	1.0

Issuance of this ticket constitutes certification that the batched concrete was produced and information recorded is in compliance with the 'Specification' and other 'Contract Document' requirenments for Structural Concrete. FDOT-GDOT-N/C

Signature on this ticket constitutes certification that the maximum specified water cementitious materials ratio was not exceeded and the batch was deliverd and placed in compliance with 'Specification' and other 'Contract Document' requirements.

Certified Signature: ______________________

B15 Carbon
42
90%

GATE CONCRETE JACKSONVILLE FLORIDA

FDOT PLANT 72055 **Ticket No:** 21988

Printed On: 7/24/2013

Operator Certificate s334420592140 **Truck Number:** 2

Recipe Name: MIX2SCCNCR534

Recipe Description: jobs#13146/13147/13137

Created: 7/24/2013 3:28:08 PM **Created By:** jansen

Recipe Class : class v [7500] **Start Time:** 3:19:17 PM **Completed Time:** 3:28:01 PM

Mix Time: 124.26 Secs

W/C Ratio:	0.34	**Holdback:**	6 %
Slump Adjust:	0.00 Gal	**Prewet:**	0 %
Tot. Water Deduct:	0.00 Gal	**Temper Water:**	1.00 Gal
Batch Size:	6.000 Yds^3 =	**Ice:**	0.0 lbs

Scale 1	Agg #1-4	Starting Wgt:	3.8 lbs	Ending Wgt:	0.0	lbs
Scale 2	Cem #1-4	Starting Wgt:	4.9 lbs	Ending Wgt:	0.4	lbs
Scale 3		Starting Wgt:	0.0 lbs	Ending Wgt:	0.0	lbs

Prod. Name:	Product Source	Target:	Actual:	Final Moisture:	Deviation:	%	Accp'td	Tolerance Over	Tolerance Under
67 Rock	87-145	8541.4 lbs	8451.4 lbs	3.4 %	-89.97 lbs	-1.05	0	2.0	2.0
Sand	71-132	7417.1 lbs	7393.6 lbs	2.9 %	-23.52 lbs	-0.32	0	2.0	2.0
STI FLYASH	STI	756.0 lbs	762.0 lbs	0.0 %	6.00 lbs	0.79	0	1.0	1.0
Suwannnee American	TYPE I,II	4284.0 lbs	4278.4 lbs	0.0 %	-5.63 lbs	-0.13	0	1.0	1.0
MBAE 90	BASF	48.0 Oz	48.0 Oz 3 lbs	0.0 %	0.00 Oz	0.00	0	3.0	3.0
Z-60	BASF	144.0 Oz	144.0 Oz 9 lbs	0.0 %	0.00 Oz	0.00	0	3.0	3.0
Glenium 7700	BASF /F	180.0 Oz	180.0 Oz 11.25 lbs	0.0 %	0.00 Oz	0.00	0	3.0	3.0
POZZ NC534	BASF	768.0 Oz	768.0 Oz 48 lbs	0.0 %	0.00 Oz	0.00	0	3.0	3.0
Cold Water	Not Entered	142.6 Gal	142.0 Gal 1182.81 lbs	0.0 %	-0.57 Gal	-0.40	0	1.0	1.0

22139.51 lbs

Issuance of this ticket constitutes certification that the batched concrete was produced and information recorded is in compliance with the 'Specification' and other 'Contract Document' requirenments for Structural Concrete. FDOT-GDOT-N/C

Signature on this ticket constitutes certification that the maximum specified water cementitious materials ratio was not exceeded and the batch was deliverd and placed in compliance with 'Specification' and other 'Contract Document' requirements.

Certified Signature: ______________________

B15 carbon
3f
9.0%

GATE CONCRETE JACKSONVILLE FLORIDA **FDOT PLANT 72055** **Ticket No:** 21987

Printed On: 7/24/2013

Operator Certificate s334420592140 **Truck Number:** 1

Recipe Name: MIX2SCCNCR534

Recipe Description: jobs#13146/13147/13137

Created: 7/24/2013 3:20:59 PM **Created By:** jansen

Recipe Class : class v [7500] **Start Time:** 3:10:16 PM **Completed Time:** 3:20:52 PM

Mix Time: 327.91 Secs

W/C Ratio:	0.34	**Holdback:**	6 %
Slump Adjust:	0.00 Gal	**Prewet:**	0 %
Tot. Water Deduct:	0.00 Gal	**Temper Water:**	1.00 Gal
Batch Size:	6.000 Yds^3	**Ice:**	0.0 lbs

Scale 1	Agg #1-4	Starting Wgt:	-1.3	lbs	Ending Wgt:	8.8	lbs
Scale 2	Cem #1-4	Starting Wgt:	-1.5	lbs	Ending Wgt:	13.1	lbs
Scale 3		Starting Wgt:	0.0	lbs	Ending Wgt:	0.0	lbs

Prod. Name:	Product Source	Target:	Actual:	Final Moisture:	Deviation:	%	Accp'td	Tolerance Over/Under	
67 Rock	87-145	8541.8 lbs	8456.4 lbs	3.4 %	-85.45 lbs	-1.00	0	2.0	2.0
Sand	71-132	7416.8 lbs	7413.6 lbs	2.9 %	-3.27 lbs	-0.04	0	2.0	2.0
STI FLYASH	STI	756.0 lbs	752.6 lbs	0.0 %	-3.38 lbs	-0.45	0	1.0	1.0
Suwannnee American	TYPE I,II	4284.0 lbs	4278.4 lbs	0.0 %	-5.63 lbs	-0.13	0	1.0	1.0
MBAE 90	BASF	48.0 Oz	48.0 Oz	0.0 %	0.00 Oz	0.00	0	3.0	3.0
Z-60	BASF	144.0 Oz	144.0 Oz	0.0 %	0.00 Oz	0.00	0	3.0	3.0
Glenium 7700	BASF /F	180.0 Oz	180.0 Oz	0.0 %	0.00 Oz	0.00	0	3.0	3.0
POZZ NC534	BASF	768.0 Oz	768.0 Oz	0.0 %	0.00 Oz	0.00	0	3.0	3.0
Cold Water	Not Entered	142.4 Gal	143.0 Gal	0.0 %	0.55 Gal	0.39	0	1.0	1.0

Issuance of this ticket constitutes certification that the batched concrete was produced and information recorded is in compliance with the 'Specification' and other 'Contract Document' requirenments for Structural Concrete. FDOT-GDOT-N/C

Signature on this ticket constitutes certification that the maximum specified water cementitious materials ratio was not exceeded and the batch was deliverd and placed in compliance with 'Specification' and other 'Contract Document' requirements.

Certified Signature: ______________________________

15/5 Carbon
30
90%

GATE CONCRETE JACKSONVILLE FLORIDA **FDOT PLANT 72055** **Ticket No:** 21986

Printed On: 7/24/2013

Operator Certificate s334420592140 **Truck Number:** 2

Recipe Name: MIX2SCCNCR534

Recipe Description: jobs#13146/13147/13137

Created: 7/24/2013 3:12:11 PM **Created By:** jansen

Recipe Class : class v [7500] **Start Time:** 3:04:52 PM **Completed Time:** 3:12:04 PM

Mix Time: 126.37 Secs

W/C Ratio:	0.34	**Holdback:**	6 %
Slump Adjust:	0.00 Gal	**Prewet:**	0 %
Tot. Water Deduct:	0.00 Gal	**Temper Water:**	3.00 Gal
Batch Size:	6.000 Yds ^{3}	**Ice:**	0.0 lbs

Scale 1	Agg #1-4	Starting Wgt:	-1.3	lbs	Ending Wgt:	-1.3	lbs
Scale 2	Cem #1-4	Starting Wgt:	4.5	lbs	Ending Wgt:	12.0	lbs
Scale 3		Starting Wgt:	0.0	lbs	Ending Wgt:	0.0	lbs

Prod. Name:	**Product Source**	**Target:**	**Actual:**	**Final Moisture:**	**Deviation:**	**%**	**Accp'td**	**Tolerance Over**	**Tolerance Under**
67 Rock	87-145	8548.9 lbs	8472.6 lbs	3.5 %	-76.24 lbs	-0.89	0	2.0	2.0
Sand	71-132	7416.5 lbs	7377.3 lbs	2.9 %	-39.22 lbs	-0.53	0	2.0	2.0
STI FLYASH	STI	756.0 lbs	763.5 lbs	0.0 %	7.50 lbs	0.99	0	1.0	1.0
Suwannnee American	TYPE I,II	4284.0 lbs	4277.6 lbs	0.0 %	-6.38 lbs	-0.15	0	1.0	1.0
MBAE 90	BASF	48.0 Oz	48.0 Oz	0.0 %	0.00 Oz	0.00	0	3.0	3.0
Z-60	BASF	144.0 Oz	144.0 Oz	0.0 %	0.00 Oz	0.00	0	3.0	3.0
Glenium 7700	BASF /F	180.0 Oz	180.0 Oz	0.0 %	0.00 Oz	0.00	0	3.0	3.0
POZZ NC534	BASF	768.0 Oz	768.0 Oz	0.0 %	0.00 Oz	0.00	0	3.0	3.0
Cold Water	Not Entered	141.7 Gal	142.0 Gal	0.0 %	0.26 Gal	0.19	0	1.0	1.0

Issuance of this ticket constitutes certification that the batched concrete was produced and information recorded is in compliance with the 'Specification' and other 'Contract Document' requirenments for Structural Concrete. FDOT-GDOT-N/C

Signature on this ticket constitutes certification that the maximum specified water cementitious materials ratio was not exceeded and the batch was deliverd and placed in compliance with 'Specification' and other 'Contract Document' requirements.

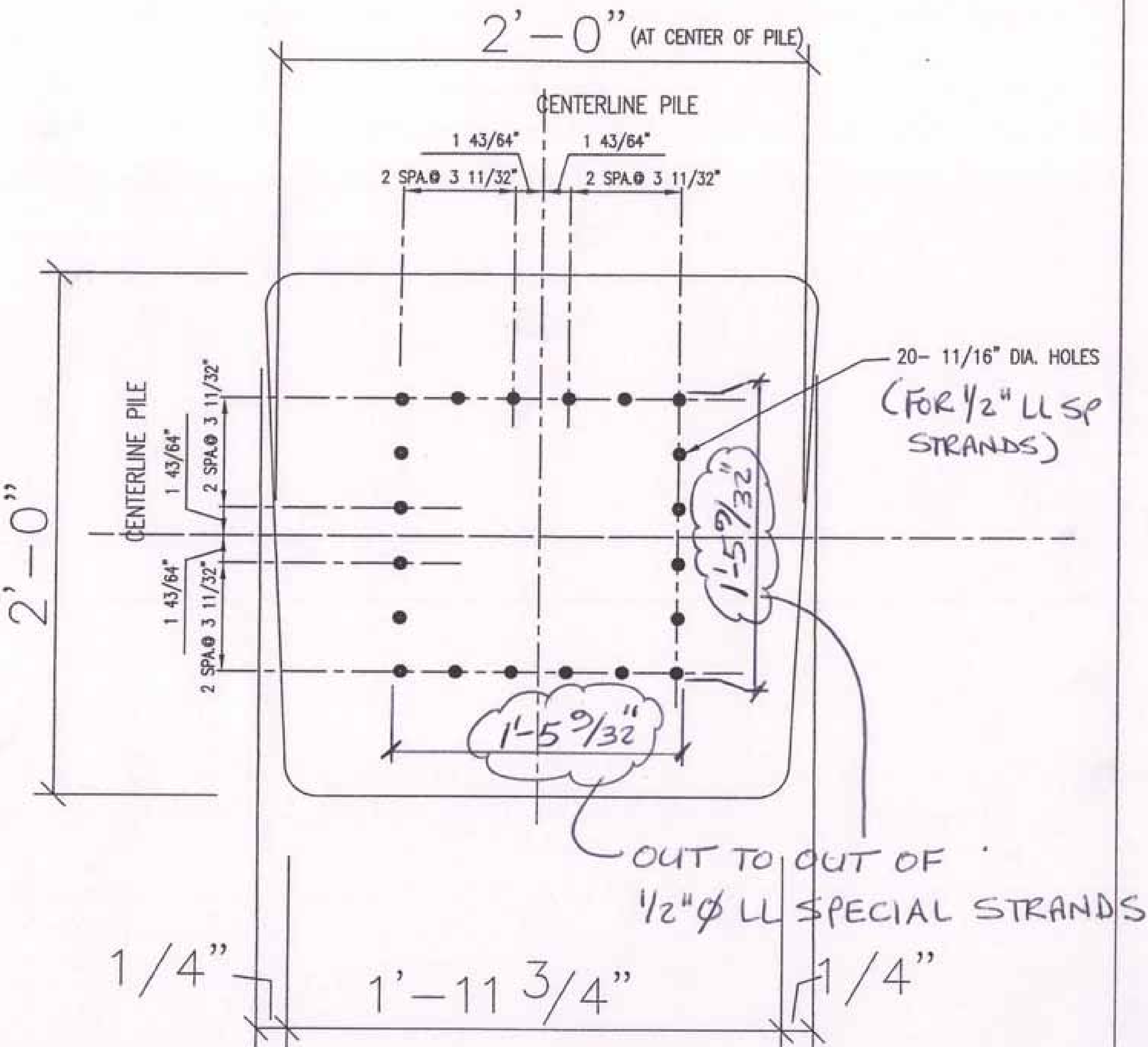
Certified Signature: ______________________

B/S – Carbon 84 90%

APPENDIX C

STRAND TEMPLATE LAYOUT AND PILE DETAILS

Strand Template for Gate Precast Company's Casting Bed



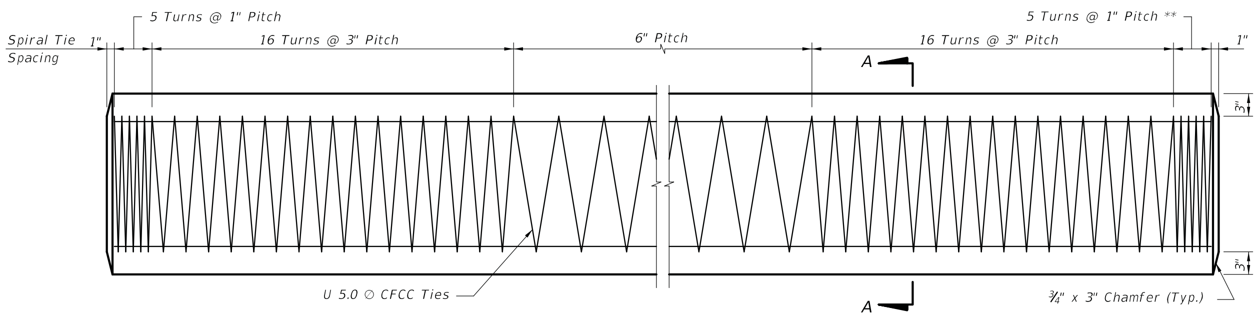
STRAND PATTERN

24" □ PILE

20 STRANDS – F.D.O.T

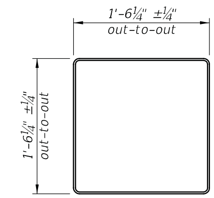
EMS 7-11-01

Plans for 40-ft-long Pile. Markups (in red) are Changes Made from September 2012 to July 2013 Casting

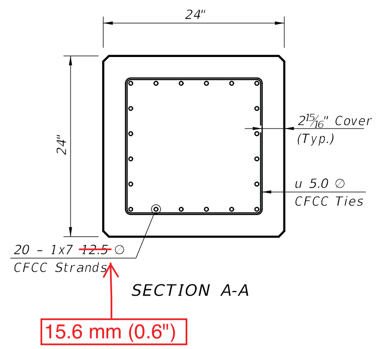


ELEVATION

** See Note No. 4 on Index No. 20601



BENDING DIAGRAM



SECTION A-A

15.6 mm (0.6") 39.45 4 corner bars stressed to 5 k each.

NOTE:
1x7 ~~12.5~~ ⌀ strands stressed to ~~31.0~~ k each.
The strands shall be located as follows:
Place one strand at each corner and place the remaining strands equally spaced between the corner strands.
The total strand pattern shall be concentric with the nominal concrete section of the pile.

NOTE:
Work this Index with Index No. 20600 - Notes and Details for Square Prestressed Concrete Piles.

QUANTITY OF 40'-0" PILES REQUIRED: 3

ESTIMATED QUANTITIES PER PILE

ITEM	UNIT	QUANTITY
24" Sq. Prestressed Concrete Piles	LF	40
U 5.0 ⌀ CFCC Ties	LF	609
1X7 ~~12.5~~ ⌀ CFCC Strands	LF	**

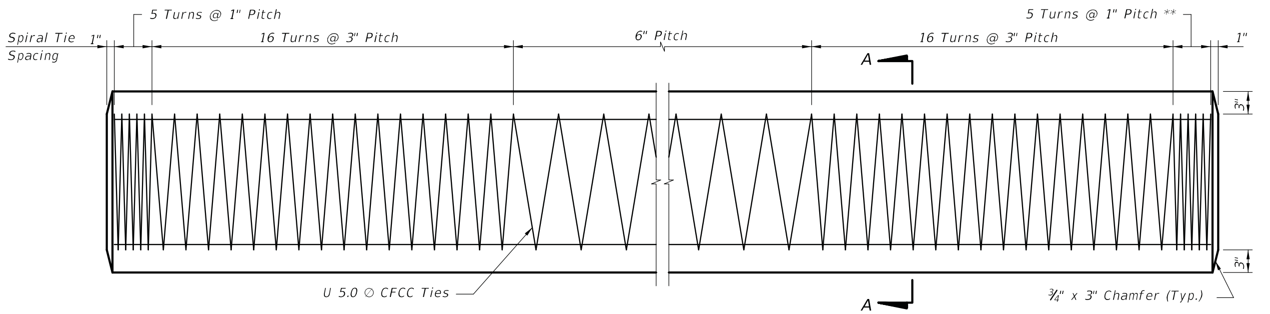
15.6 mm (0.6")

** For total of 5 piles, need 22 (20 + 2 extra) Strands @ 350 ft. each = 7,700 ft. (All piles, 3-40' and 2-100' to be cast with one set of 20 strands).

LAST REVISION	REVISION	DESCRIPTION:		FDOT DESIGN STANDARDS FY 2012/2013	40'-0" 24" SQUARE PRESTRESSED CONCRETE PILE	INDEX NO.	SHEET NO.
01/01/??						?????	1

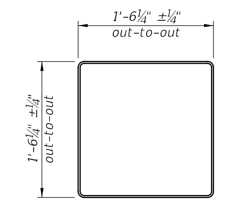
$DATES $TIMES $USERS $FILES

Plans for 100-ft-long Pile. Markups (in red) are Changes Made from September 2012 to July 2013 Casting

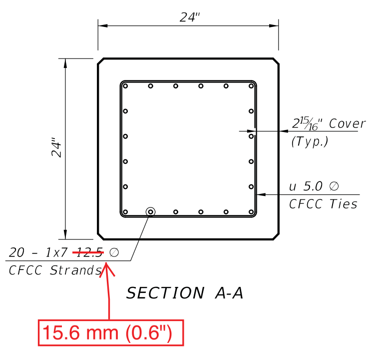


ELEVATION

** See Note No. 4 on Index No. 20601



BENDING DIAGRAM



SECTION A-A

NOTE:
1x7 ~~12.5~~ ⌀ strands stressed to ~~31.0~~ k each.
15.6 mm (0.6")
39.45
4 corner bars stressed to 5 k each.
The strands shall be located as follows:
Place one strand at each corner and place the remaining strands equally spaced between the corner strands.
The total strand pattern shall be concentric with the nominal concrete section of the pile.

NOTE:
Work this Index with Index No. 20600 - Notes and Details for Square Prestressed Concrete Piles.

QUANTITY OF 100'-0" PILES REQUIRED: 2

ESTIMATED QUANTITIES PER PILE

ITEM	UNIT	QUANTITY
24" Sq. Prestressed Concrete Piles	LF	40
U 5.0 ⌀ CFCC Ties	LF	1318
1X7 ~~12.5~~ ⌀ CFCC Strands	LF	**

15.6 mm (0.6")

** For total of 5 piles, need 22 (20 + 2 extra) Strands @ 350 ft. each = 7,700 ft. (All piles, 3-40' and 2-100' to be cast with one set of 20 strands).

LAST REVISION	REVISION	DESCRIPTION:	FDOT DESIGN STANDARDS FY 2012/2013	100'-0" 24" SQUARE PRESTRESSED CONCRETE PILE	INDEX NO.	SHEET NO.
01/01/??					?????	1

$DATES $TIMES $USERS $FILES

APPENDIX D

PRESTRESS LOSS CALCULATIONS

Prestress & Elongation Calculations

P (Pull)	34145	34145	34145
L (Length)	4320	960	3912
A (Area)	0.1792	0.217	0.1792
E (MOE)	22480000	28500000	22480000
Basic Elongation	36.62	5.30	33.16
		steel	CFCC in product Live - dead end
Adjustment Factor	0.375	0.375	
Force Adjustment	349.69	2415.82	
Adjust for this force:	305.47		

Total Pull	39145	39.45 k
Initial Pull	5000	

Enter Green Cells

Outer Wire	39450.47 lb

pull to this force

we want this to be 39450 lb (so that we don't stress the strand past 65% -- ever)

Abutment Rotation	0.25
Dead End	0.125
Live End	0.375
Steel & CFCC Coupler Seating	4.58
Gross Theoretical Elongation	47.25
Net Theoretical Elongation	46.87
Upper Range	49.22
Lower Range	44.53

PRESTRESS LOSS CALCULATIONS (per PCI Design Handbook, 6th Edition)

CFCC Properties:

E_{ps} =	22480060	psi	Initial Force in each of 16 strands =	39.45	kips	65% GUTS = (0.65)(338.6 ksi)(0.1792 in^2)
A_{strand} =	0.1792	sq. in.	Initial Prestress in each of 16 strands =	220145	psi	[(39.45 k)(1000 lb/k)/0.1792 in^2]

Concrete Properties:

			Initial Force in each of 4 corner strands =	5	kips	
f'_{ci} =	5370	psi (@ 24 hrs)	Initial Prestress in each of 4 corner strands =	27902	psi	[(5 k)(1000 lb/k)/0.1792 in^2]
E_{ci} =	4176976.2	psi [57000 $f'_{ci}{}^{0.5}$]				
f'_c =	8640	psi (@ 28 days)				
E_c =	5298241.2	psi [57000 $f'_c{}^{0.5}$]				

---

1) Elastic Shortening

$ES = K_{es} * E_{ps} * f_{cir} / E_{ci}$

where

K_{es} = 1.0 for pretensioned members

E_{ps} = Modulus of Elasticity of prestressing material

E_{ci} = Modulus of Elasticity of concrete at time prestress is applied

f_{cir} = Net compressive stress in concrete at C.G. of prestressing force immediately after prestress is applied to the concrete

f_{cir} = $K_{cir}\,[(P_i / A_g) + (P_i e^2/I_g)] - M_g e/I_g$

where

K_{cir} = 0.9 for pretensioned members

P_i = Initial prestress force (after anchorage seating loss)

e = Eccentricity of the C.G. of tendons with respect to the C.G. of the concrete

A_g = Area of gross concrete section

I_g = Moment of inertia of gross concrete section

M_g = Moment due to dead weight of prestressed member and any other permanent loads in place at the time of prestressing

Therefore,

for 16 strands:				*for 4 strands:*			
K_{es} =	1			K_{es} =	1		
K_{cir} =	0.9			K_{cir} =	0.9		
P_i =	39.45	kips per strand		P_i =	5	kips per strand	
e =	0	in.		e =	0	in.	
A_g =	576	sq. in.	(24 in. x 24 in.)	A_g =	576	sq. in.	(24 in. x 24 in.)
I_g =	27648	in^4		I_g =	27648	in^4	
M_g =	0	No eccentricity		M_g =	0	No eccentricity	
f_{cir} =	986.25	psi (for 16 strands)		f_{cir} =	31.25	psi (for 4 strands)	
ES =	5307.9	psi (for 16 strands)		ES =	168.2	psi (for 4 strands)	

Therefore, ES Losses = **5476.1** psi (for 20 strands)

---

2) Creep of Concrete

$CR = K_{cr} (E_{ps}/E_c) (f_{cir} - f_{cds})$

where

K_{cr} = 2.0 normal weight concrete
1.6 sand lightweight oncrete

f_{cds} = Stress in concrete at C.G. of the prestressing force due to all superimposed permanent loads that are applied to the member after it has been prestressed

f_{cds} = $M_{sd} * e/I_g$

Therefore,

K_{cr} = 2

f_{cds} = 0 No eccentricity

f_{cir} = 1017.5 psi (for 20 strands)

Therefore, CR Losses = **8634.4** psi

---

3) Shrinkage

$SH = (8.2x10^{-6})\ K_{sh}\ E_{ps}\ (1 - 0.06V/S)\ (100 - RH)$

where

K_{sh} =	1.0 for pretensioned members
V/S =	Volume-to-Surface ratio
R.H. =	Average ambient relative humidity

Therefore,

K_{sh} =	1		
E_{ps} =	22480060	psi	
V =	276480	in^3	[(240) (24) (480)]
S =	47232	sq. in.	[(24)(480)(4) + (24)(24)(2)]
V/S =	5.8536585		
R.H. =	75%		

Therefore, SH Losses = **2989.8** psi

---

4) Relaxation

$RE = [K_{re} - J(SH+CR+ES)]\ C$

where K_{re} and J are taken from PCI Table 4.7.3.1
and C is taken from PCI Table 4.7.3.1 or calculated using Eqs. 4.7.3.8 - 4.7.3.12.
Eqs. 4.7.3.11 & 4.7.3.12 are applicable.

$C = (f_{pi}/f_{pu})/0.21)\ (((f_{pi}/f_{pu})/0.9)\text{-}0.55$ when $f_{pi}/f_{pu} > 0.54$

$C = (f_{pi}/f_{pu})/4.25$ when $f_{pi}/f_{pu} < 0.54$

Therefore,

K_{re} =	5000	From PCI Table 4.7.3.1	
J =	0.04	From PCI Table 4.7.3.1	
SH+CR+ES =	17100	psi	
f_{pu} =	338672	psi	[(60.69 k)(1000)/0.1792 in^2]

Therefore,

for 16 strands:

f_{pi} =	220145	psi
f_{pi}/f_{pu} =	0.65	
C =	0.533	
RE =	2301.2	psi

for 4 strands:

f_{pi} =	27902	psi
f_{pi}/f_{pu} =	0.082	
C =	0.0194	
RE =	83.67	psi

Therefore, RE Losses = **2301.2** **psi for each of 16 strands**
83.67 **psi for each of 4 strands**

Total Prestressing Losses = ES + CR + SH + RE

Total Losses =	**19401**	**psi (for each of 16 strands)**
	17184	**psi (for each of 4 corner strands)**
Total % loss =	**8.81**	**% (for each of 16 strands)**
	61.59	**% (for each of 4 corner strands)**

Effective stress in strands after losses = Initial Prestress - Total Losses

Effective Stress =	**200744**	**psi (for each of 16 strands)**
Effective Stress =	**10718**	**psi (for each of 4 corner strands)**

Force in each strand after losses = Effective Stress x A_{strand}

Force in strand =	**35.97**	**kips (for each of 16 strands)**
Force in strand =	**1.92**	**kips (for each of 4 strands)**

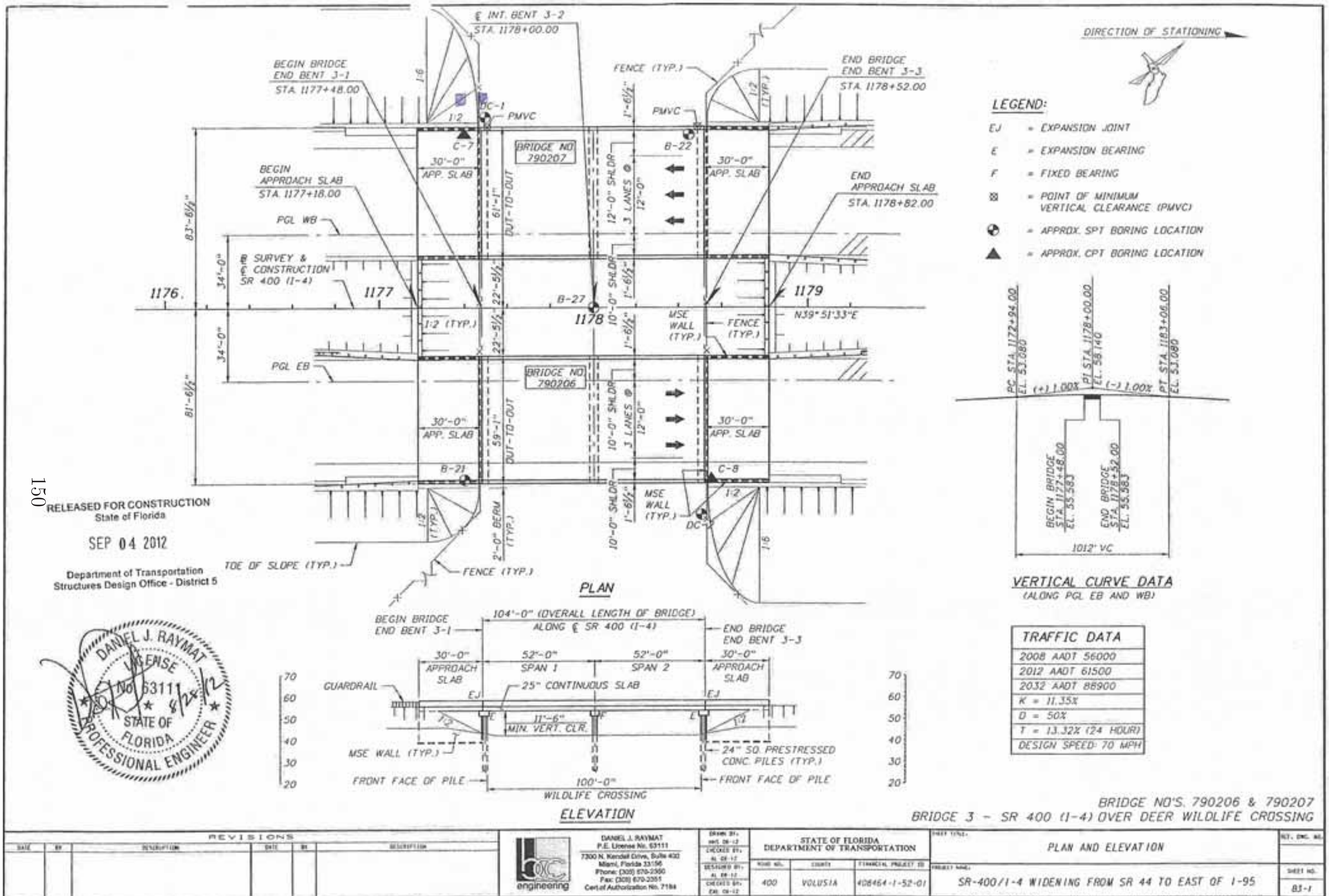
Compressive stress in pile = [16(Force in strand) + 4(Force in strand)] / A_g

Compression in pile = **1.01** **ksi**

APPENDIX E

PILE DRIVING TESTS AND REPORTS

PILE TEST SITE: SOIL BORING DATA AND PLAN & ELEVATION SHEET


DIRECTION OF STATIONING
LEGEND:
EJ = EXPANSION JOINT
E = EXPANSION BEARING
F = FIXED BEARING
= POINT OF MINIMUM VERTICAL CLEARANCE (PMVC)
= APPROX. SPT BORING LOCATION
= APPROX. CPT BORING LOCATION
℄ INT. BENT 3-2
STA. 1178+00.00
BEGIN BRIDGE
END BENT 3-1
STA. 1177+48.00
END BRIDGE
END BENT 3-3
STA. 1178+52.00
BEGIN
APPROACH SLAB
STA. 1177+18.00
END
APPROACH SLAB
STA. 1178+82.00
FENCE (TYP.)
PMVC
C-1
C-7
C-8
B-21
B-22
B-27
DC-1
BRIDGE NO 790207
BRIDGE NO 790206
30'-0" APP. SLAB
61'-1" OUT-TO-OUT
59'-1" OUT-TO-OUT
12'-0" SHLDR
10'-0" SHLDR
3 LANES @ 12'-0"
1'-6½"
22'-5½"
2'-0" BERM (TYP.)
PGL WB
PGL EB
℄ SURVEY & CONSTRUCTION SR 400 (I-4)
83'-6½"
81'-6½"
34'-0"
1176.
1177
1178
1179
N39°51'33"E
MSE WALL (TYP.)
1:2 (TYP.)
TOE OF SLOPE (TYP.)
PLAN
104'-0" (OVERALL LENGTH OF BRIDGE) ALONG ℄ SR 400 (I-4)
BEGIN BRIDGE END BENT 3-1
END BRIDGE END BENT 3-3
30'-0" APPROACH SLAB
52'-0" SPAN 1
52'-0" SPAN 2
25" CONTINUOUS SLAB
GUARDRAIL
11'-6" MIN. VERT. CLR.
24" SQ. PRESTRESSED CONC. PILES (TYP.)
FRONT FACE OF PILE
100'-0" WILDLIFE CROSSING
ELEVATION
PC STA. 1172+94.00 EL. 53.080
PI STA. 1178+00.00 EL. 58.140
PT STA. 1183+06.00 EL. 53.080
(+) 1.00%
(-) 1.00%
BEGIN BRIDGE STA. 1177+48.00 EL. 55.583
END BRIDGE STA. 1178+52.00 EL. 55.583
1012' VC
VERTICAL CURVE DATA
(ALONG PGL EB AND WB)
TRAFFIC DATA
2008 AADT 56000
2012 AADT 61500
2032 AADT 88900
K = 11.35%
D = 50%
T = 13.32% (24 HOUR)
DESIGN SPEED: 70 MPH
RELEASED FOR CONSTRUCTION
State of Florida
SEP 04 2012
Department of Transportation
Structures Design Office - District 5
DANIEL J. RAYMAT
LICENSE No. 53111
STATE OF FLORIDA
PROFESSIONAL ENGINEER
BRIDGE NO'S. 790206 & 790207
BRIDGE 3 - SR 400 (I-4) OVER DEER WILDLIFE CROSSING
REVISIONS
DANIEL J. RAYMAT
P.E. License No. 53111
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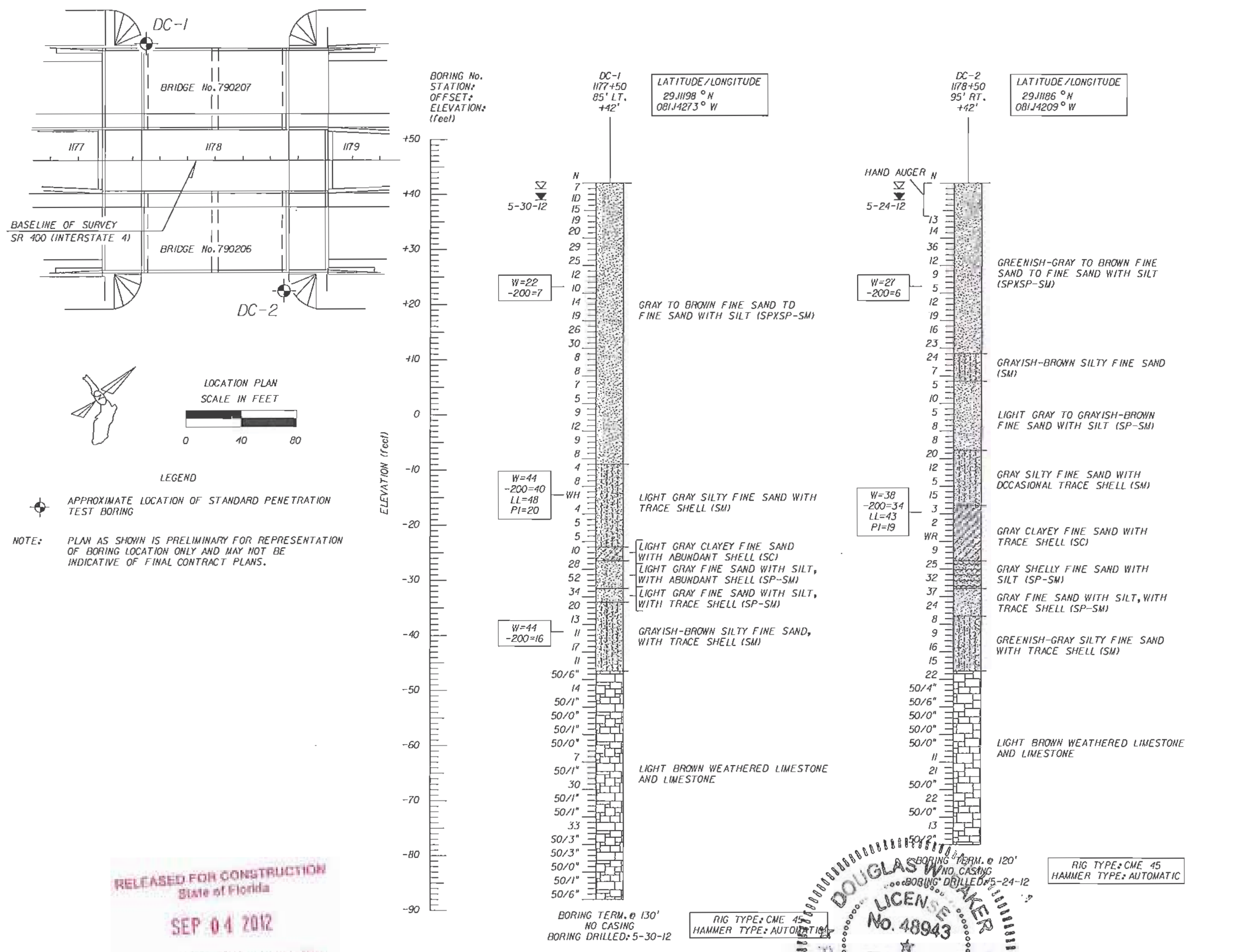
Cert of Authorization No. 7184
engineering
STATE OF FLORIDA
DEPARTMENT OF TRANSPORTATION
400
VOLUSIA
408464-1-52-01
PLAN AND ELEVATION
SR-400/I-4 WIDENING FROM SR 44 TO EAST OF I-95
B3-1



LEGEND

- APPROXIMATE LOCATION OF STANDARD PENETRATION TEST BORING

NOTE: PLAN AS SHOWN IS PRELIMINARY FOR REPRESENTATION OF BORING LOCATION ONLY AND MAY NOT BE INDICATIVE OF FINAL CONTRACT PLANS.

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Department of Transportation
Structures Design Office - District 5

LEGEND

SAND — SILTY SAND
CLAYEY SAND — CLAY
SHELLY SAND — LIMESTONE

(SP)	UNIFIED SOIL CLASSIFICATION GROUP SYMBOL
5-30-12	ENCOUNTERED GROUNDWATER LEVEL DATE NOTED
	ESTIMATED NORMAL SEASONAL HIGH GROUNDWATER LEVEL
W=0	NATURAL MOISTURE CONTENT (%)
-200=0	FINES PASSING No. 200 SIEVE (%)
LL=0	LIQUID LIMIT (%)
PI=0	PLASTICITY INDEX
NP	NON-PLASTIC
N	STANDARD PENETRATION RESISTANCE IN BLOWS PER FOOT UNLESS OTHERWISE NOTED
50/6"	NUMBER OF BLOWS REQUIRED (50) TO ADVANCE SAMPLING SPOON (6) INCHES
WR	WEIGHT OF ROD SUFFICIENT TO ADVANCE SAMPLE SPOON
WH	WEIGHT OF ROD AND HAMMER SUFFICIENT TO ADVANCE SAMPLE SPOON

STANDARD PENETRATION TEST DATA
AUTOMATIC HAMMER

SPOON INSIDE DIA.	1 3/8 in.
SPOON OUTSIDE DIA.	2 in.
ASTM STANDARD AUTOMATIC HAMMER	
AVG. HAMMER DROP	30 in.
HAMMER WEIGHT	140 lbs.

GRANULAR MATERIALS

RELATIVE DENSITY	SPT (BLOWS/FOOT)
VERY LOOSE	LESS THAN 3
LOOSE	3-8
MEDIUM DENSE	8-24
DENSE	24-40
VERY DENSE	GREATER THAN 40

SILTS AND CLAYS

CONSISTENCY	SPT (BLOWS/FOOT)
VERY SOFT	LESS THAN 1
SOFT	1-3
FIRM	3-6
STIFF	6-12
VERY STIFF	12-24
HARD	GREATER THAN 24

ENVIRONMENTAL CLASSIFICATION:

SUPERSTRUCTURE: N/A

SUBSTRUCTURE: CONCRETE: MODERATELY AGGRESSIVE
STEEL: EXTREMELY AGGRESSIVE
pH=5.0

NOTES:

1) SUBSURFACE VARIATIONS BETWEEN BORINGS SHOULD BE ANTICIPATED AS INDICATED IN SECTION 2-4 OF THE STANDARD SPECIFICATIONS.

2) ARTESIAN CONDITIONS WERE NOT NOTED BY THE DRILLER. HOWEVER, BASED ON REVIEW OF THE ST. JOHNS RIVER WATER MANAGEMENT DISTRICT POTENTIOMETRIC MAPS OF THE FLORIDAN AQUIFER FOR THE PROJECT AREA, THE POTENTIAL ARTESIAN HEAD ELEVATION IS ESTIMATED TO BE +25 FEET (NGVD).

3) STATIONS AND OFFSETS REFERENCE THE BASELINE OF SURVEY OF SR 400 (INTERSTATE 4).

BRIDGE NO'S. 790206 & 790207
BRIDGE 3 - SR 400 (I-4) OVER DEER WILDLIFE CROSSING

DOUGLAS W. BAKER, P.E.
P.E. LICENSE NUMBER 48943
NODARSE A TERRACON COMPANY
1675 LEE ROAD
WINTER PARK, FLORIDA 32789
CERTIFICATE OF AUTHORIZATION No. 6174

NODARSE
A Terracon COMPANY

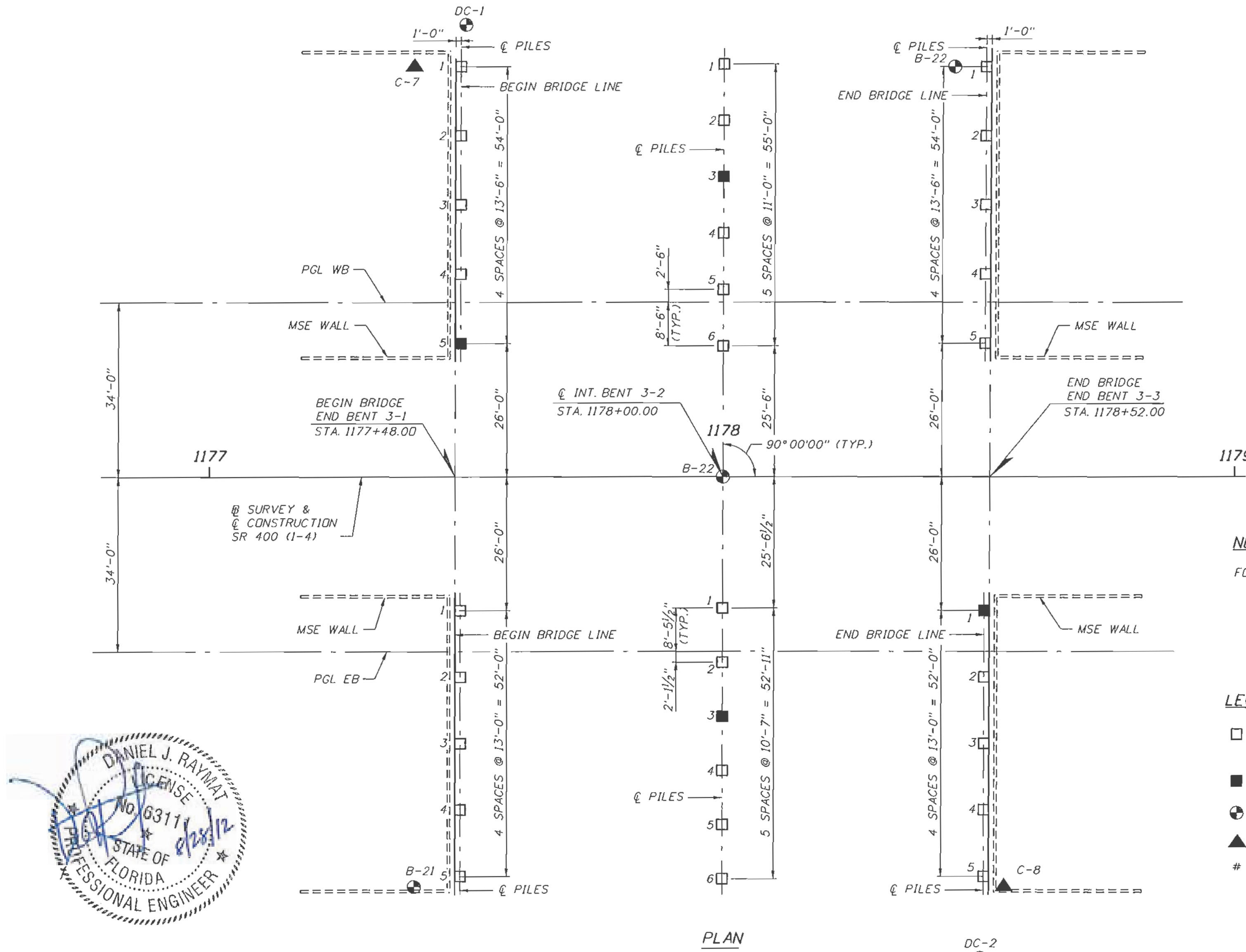
DOUGLAS W. BAKER
LICENSE
No. 48943
STATE OF FLORIDA
PROFESSIONAL ENGINEER

REVISIONS					
DATE	BY	DESCRIPTION	DATE	BY	DESCRIPTION

DRAWN BY:	STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION			SHEET TITLE: REPORT OF SPT BORINGS FOR STRUCTURES	REF. DWG. NO.
CHECKED BY: EHJ 8-23-12	ROAD NO.	COUNTY	FINANCIAL PROJECT ID	PROJECT NAME:	SHEET NO.
DESIGNED BY:	SR 400	VOLUSIA	408464-1-52-01	SR 400/I-4 WIDENING FROM SR 44 TO EAST I-95	B3-5
CHECKED BY:					

NODARSE A TERRACON COMPANY Project No. H112 5034

srwilks 8/23/2012 3:55:51 PM N:\CADD\FDOT-Projects\408464\geotech\b3boring01.dgn



PLAN

DIRECTION OF STATIONING

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Structures Design Office - District 5

NOTE:

FOR FOUNDATION NOTES, SEE SHEET B-8.

LEGEND

- □ PROPOSED 24" SQUARE PRESTRESSED CONCRETE PILE (PLUMB)
- ■ PROPOSED 24" SQUARE PRESTRESSED CONCRETE TEST PILE (PLUMB)
- ◐ APPROXIMATE SPT BORING LOCATION
- ▲ APPROXIMATE CPT BORING LOCATION
- \# PILE NUMBER

BRIDGE NO'S. 790206 & 790207
BRIDGE 3 - SR 400 (I-4) OVER DEER WILDLIFE CROSSING

REVISIONS					
DATE	BY	DESCRIPTION	DATE	BY	DESCRIPTION

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Cert.of Authorization No. 7184

DRAWN BY: HHS 08-12
CHECKED BY: AL 08-12
DESIGNED BY: AL 08-12
CHECKED BY: CXL 08-12

STATE OF FLORIDA
DEPARTMENT OF TRANSPORTATION

ROAD NO.	COUNTY	FINANCIAL PROJECT ID
400	VOLUSIA	408464-1-52-01

SHEET TITLE: FOUNDATION LAYOUT

PROJECT NAME: SR-400/I-4 WIDENING FROM SR 44 TO EAST OF I-95

REF. DWG. NO.

SHEET NO. B3-12

PILE DATA TABLE

PIER OR BENT NUMBER	PILE SIZE (IN.)	NOMINAL BEARING RESISTANCE (TONS)	TENSION RESISTANCE (TONS)	MINIMUM TIP ELEVATION (FT.)	TEST PILE LENGTH (FT.)	REQUIRED JET ELEVATION (FT.)	REQUIRED PREFORM ELEVATION (FT.)	FACTORED DESIGN LOAD (TONS)	DOWN DRAG (TONS)	TOTAL SCOUR RESISTANCE (TONS)	NET SCOUR RESISTANCE (TONS)	100-YEAR SCOUR ELEVATION (FT.)	LONG TERM SCOUR ELEVATION (FT.)	RESISTANCE FACTOR-Φ	PILE CUT-OFF ELEVATIONS
INSTALLATION CRITERIA								DESIGN CRITERIA							
END BENT 3-1	24	247	N/A	*	115	N/A	N/A	160	N/A	N/A	N/A	N/A	N/A	0.65	SEE TABLE BELOW
INT. BENT 3-2	24	377	N/A	-3 **	120	N/A	N/A	245	N/A	N/A	N/A	N/A	N/A	0.65	SEE TABLE BELOW
END BENT 3-3	24	247	N/A	*	115	N/A	N/A	160	N/A	N/A	N/A	N/A	N/A	0.65	SEE TABLE BELOW

* MINIMUM TIP ELEVATION SHALL BE DETERMINED IN ACCORDANCE WITH SECTION 455-5.8 OF THE SPECIFICATIONS.
** MINIMUM TIP ELEVATION REQUIRED FOR LATERAL STABILITY.

PILE CUT-OFF ELEVATIONS TABLE

	LOCATION	PILE 1	PILE 2	PILE 3	PILE 4	PILE 5	PILE 6
WESTBOUND BRIDGE	END BENT 3-1	50.5	50.8	51.1	51.3	51.6	-
	INT. BENT 3-2	50.6	50.8	51.1	51.3	51.5	51.7
	END BENT 3-3	50.5	50.8	51.1	51.3	51.6	-
EASTBOUND BRIDGE	END BENT 3-1	51.6	51.4	51.1	50.8	50.6	-
	INT. BENT 3-2	51.7	51.5	51.3	51.1	50.9	50.7
	END BENT 3-3	51.6	51.4	51.1	50.8	50.6	-

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Department of Transportation
Structures Design Office - District 5

$$\frac{\text{FACTORED DESIGN LOAD + NET SCOUR RESISTANCE + DOWN DRAG}}{\phi} \leq \text{NOMINAL BEARING RESISTANCE}$$

TENSION RESISTANCE - THE ULTIMATE SIDE FRICTION CAPACITY THAT MUST BE OBTAINED BELOW THE 100 YEAR SCOUR ELEVATION TO RESIST PULLOUT OF THE PILE (SPECIFY ONLY WHEN DESIGN REQUIRES TENSION CAPACITY).

TOTAL SCOUR RESISTANCE - AN ESTIMATE OF THE ULTIMATE STATIC SIDE FRICTION RESISTANCE PROVIDED BY THE SCOURABLE SOIL.

NET SCOUR RESISTANCE - AN ESTIMATE OF THE ULTIMATE STATIC SIDE FRICTION RESISTANCE PROVIDED BY THE SOIL FROM THE REQUIRED PREFORMED OR JETTING ELEVATION TO THE SCOUR ELEVATION.

100-YEAR SCOUR ELEVATION - ESTIMATED ELEVATION OF SCOUR DUE TO THE 100 YEAR STORM EVENT.

LONG TERM SCOUR ELEVATION - ESTIMATED ELEVATION OF SCOUR USED IN DESIGN FOR EXTREME EVENT LOADING.

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8/28/12

BRIDGE NO'S. 790206 & 790207
BRIDGE 3 - SR 400 (I-4) OVER DEER WILDLIFE CROSSING

REVISIONS					
DATE	BY	DESCRIPTION	DATE	BY	DESCRIPTION

bcc engineering
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Cert.of Authorization No. 7184

DRAWN BY: IHS 08-12
CHECKED BY: AL 08-12
DESIGNED BY: AL 08-12
CHECKED BY: CXL 08-12

STATE OF FLORIDA
DEPARTMENT OF TRANSPORTATION

ROAD NO.	COUNTY	FINANCIAL PROJECT ID
400	VOLUSIA	408464-1-52-01

SHEET TITLE: PILE DATA TABLE
PROJECT NAME: SR-400/I-4 WIDENING FROM SR 44 TO EAST OF I-95
REF. DWG. NO.
SHEET NO. B3-13

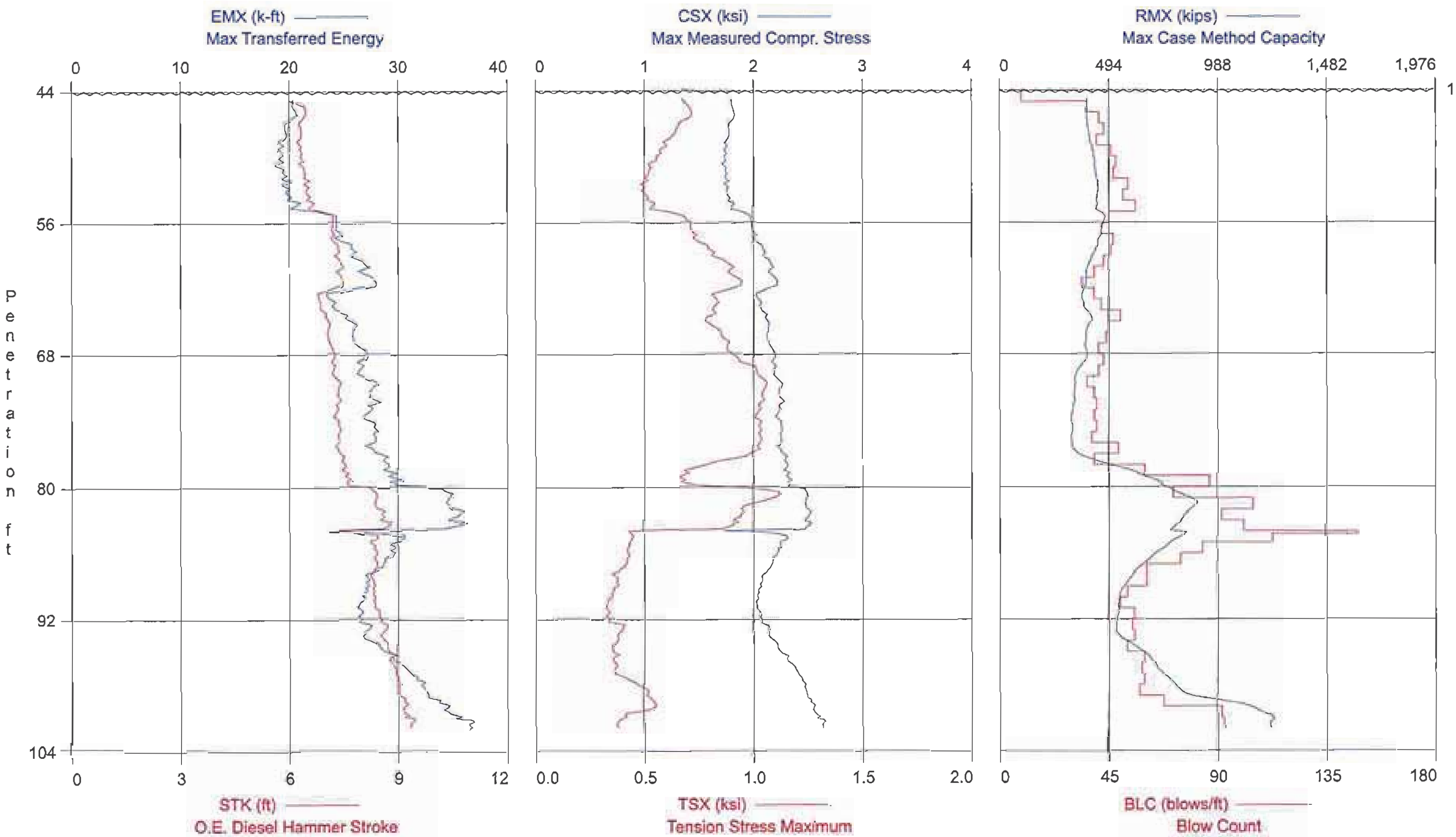
PILE DRIVING DATA FOR PRODUCTION PILES NEAR TEST PILES 1 AND 2 (FOR COMPARISON PURPOSES)

PDIPLOT Ver. 2012.2 - Printed: 3-Oct-2013

Nodarse & Associates Inc - Case Method & iCAP® Results

Test date: 24-Sep-2013

I-4 OVER DEER CROSSING - EB 3-1, P5
RE 52.18, CE 51.6 NBR 494k



1 - Test pile, NBR 594k, GE: 46.18 feet

I-4 OVER DEER CROSSING - EB 3-1, P5
OP: MK

RE 52.18, CE 51.6 NBR 494k
Test date: 24-Sep-2013

AR: 576.00 in^2
LE: 111.00 ft
WS: 14,050.6 f/s

SP: 0.150 k/ft3
EM: 6,392 ksi
JC: 0.50

CSB: Compression Stress at Bottom
CSX: Max Measured Compr. Stress
TSX: Tension Stress Maximum
EMX: Max Transferred Energy
STK: O.E. Diesel Hammer Stroke

RX4: Max Case Method Capacity (JC=0.4)
RMX: Max Case Method Capacity
RX6: Max Case Method Capacity (JC=0.6)
BTA: BETA Integrity Factor

BL# end	depth ft	BLC bl/ft	TYPE	CSB ksi	CSX ksi	TSX ksi	EMX k-ft	STK ft	RX4 kips	RMX kips	RX6 kips	BTA (%)
9	45.00	9	AV9	1.0	1.8	0.7	20.4	6.44	410	392	384	100
45	46.00	36	AV36	1.0	1.8	0.7	20.4	6.43	410	395	387	100
86	47.00	41	AV41	1.0	1.8	0.7	20.4	6.41	413	396	384	100
129	48.00	43	AV43	1.0	1.8	0.6	19.6	6.31	415	401	390	100
169	49.00	40	AV40	1.0	1.8	0.6	19.3	6.28	424	409	397	100
215	50.00	46	AV46	1.0	1.8	0.6	19.4	6.35	438	424	413	100
263	51.00	48	AV48	1.0	1.7	0.5	19.1	6.35	448	430	418	100
310	52.00	47	AV47	1.0	1.7	0.5	19.5	6.43	463	436	423	100
363	53.00	53	AV53	1.1	1.8	0.5	19.9	6.52	474	444	427	100
414	54.00	51	AV51	1.1	1.8	0.5	20.0	6.53	476	441	420	100
470	55.00	56	AV56	1.1	1.8	0.5	20.5	6.60	476	438	425	100
515	56.00	45	AV45	1.1	2.0	0.7	24.2	7.19	487	475	463	100
557	57.00	42	AV42	1.1	2.0	0.7	24.4	7.21	477	463	448	100
604	58.00	47	AV47	1.1	2.0	0.7	24.7	7.23	473	449	433	100
650	59.00	46	AV46	1.1	2.1	0.8	25.9	7.36	468	434	419	100
693	60.00	43	AV43	1.1	2.1	0.9	26.7	7.39	451	413	398	100
732	61.00	39	AV39	1.0	2.2	0.9	26.9	7.40	437	394	379	100
766	62.00	34	AV34	1.0	2.2	0.9	28.0	7.49	424	391	380	100
805	63.00	39	AV39	0.9	2.1	0.8	24.2	6.92	407	374	360	100
847	64.00	42	AV42	0.9	2.1	0.8	24.1	6.86	415	381	368	100
897	65.00	50	AV50	1.0	2.1	0.8	25.2	7.01	451	411	382	100
942	66.00	45	AV45	1.0	2.1	0.8	26.1	7.12	440	402	395	100
986	67.00	44	AV44	0.9	2.1	0.9	26.0	7.09	418	392	391	100
1027	68.00	41	AV41	0.9	2.2	0.9	26.9	7.20	421	391	389	100
1070	69.00	43	AV43	0.8	2.2	0.9	26.8	7.23	419	388	386	100
1111	70.00	41	AV41	0.8	2.2	1.0	26.5	7.23	391	354	336	100
1147	71.00	36	AV36	0.8	2.2	1.1	27.8	7.39	381	341	322	100
1186	72.00	39	AV39	0.8	2.2	1.0	27.5	7.35	377	338	309	100
1226	73.00	40	AV40	0.8	2.3	1.0	27.8	7.38	376	337	306	100
1265	74.00	39	AV39	0.8	2.2	1.0	27.2	7.29	367	327	293	100
1305	75.00	40	AV40	0.8	2.3	1.0	28.0	7.41	373	329	303	100
1343	76.00	38	AV38	0.8	2.3	1.0	27.9	7.38	370	325	304	100
1392	77.00	49	AV49	0.9	2.2	1.0	27.5	7.34	380	336	315	100
1431	78.00	39	AV39	1.1	2.3	0.9	28.9	7.51	471	420	392	100
1491	79.00	60	AV60	1.3	2.3	0.7	29.3	7.57	641	588	567	100
1578	80.00	87	AV87	1.6	2.3	0.7	29.8	7.65	741	717	703	100
1650	81.00	72	AV72	1.8	2.5	1.1	34.8	8.38	824	814	803	100
1755	82.00	105	AV105	2.0	2.5	1.0	34.7	8.40	893	885	879	100
1847	83.00	92	AV92	2.0	2.5	0.9	35.6	8.59	855	844	834	100
1948	84.00	101	AV101	1.9	2.4	0.9	33.9	8.60	815	799	790	100
1985	84.25	148	AV37	1.8	2.1	0.4	26.9	7.93	861	841	834	100
2070	85.00	113	AV85	1.8	2.3	0.4	30.3	8.38	824	808	806	100
2154	86.00	84	AV84	1.7	2.2	0.4	29.6	8.36	756	747	743	100
2229	87.00	75	AV75	1.5	2.2	0.4	29.0	8.40	687	684	683	100

I-4 OVER DEER CROSSING - EB 3-1, P5
OP: MK

RE 52.18, CE 51.6 NBR 494k
Test date: 24-Sep-2013

BL# end	depth ft	BLC bl/ft	TYPE	CSB ksi	CSX ksi	TSX ksi	EMX k-ft	STK ft	RX4 kips	RMX kips	RX6 kips	BTA (%)
2290	88.00	61	AV61	1.4	2.1	0.4	28.1	8.37	628	625	623	100
2351	89.00	61	AV61	1.3	2.1	0.4	27.3	8.32	596	587	586	100
2404	90.00	53	AV53	1.2	2.0	0.4	27.0	8.33	586	553	547	100
2454	91.00	50	AV50	1.1	2.0	0.3	26.5	8.38	585	538	529	100
2510	92.00	56	AV56	1.1	2.1	0.3	26.6	8.49	587	537	530	100
2565	93.00	55	AV55	1.1	2.1	0.4	27.1	8.63	578	529	522	100
2621	94.00	56	AV56	1.2	2.2	0.4	27.0	8.57	598	545	534	100
2674	95.00	53	AV53	1.3	2.2	0.4	28.3	8.72	662	619	606	100
2734	96.00	60	AV60	1.5	2.3	0.4	29.7	8.84	718	683	676	100
2793	97.00	59	AV59	1.6	2.4	0.4	30.8	8.93	762	722	710	100
2853	98.00	60	AV60	1.8	2.4	0.4	31.9	9.02	808	771	741	100
2911	99.00	58	AV58	1.9	2.5	0.5	32.6	9.06	856	824	793	100
2979	100.00	68	AV68	2.2	2.5	0.5	33.8	9.20	1,036	1,016	997	100
3071	101.00	92	AV92	2.4	2.6	0.5	34.9	9.21	1,217	1,196	1,185	100
3164	102.00	93	AV93	2.6	2.6	0.4	36.7	9.40	1,258	1,234	1,217	100
			Average	1.4	2.2	0.7	28.0	7.85	633	606	593	100

Total number of blows analyzed: 3164

BL#	depth (ft)	Comments
1	44.11	Test pile, NBR ~~594k~~ 494k, GE: 46.18 feet
1939	83.91	CHANGE CUSHION

Time Summary

Drive	44 minutes 20 seconds	10:08:11 AM - 10:52:31 AM (9/24/2013) BN 1 - 1939
Stop	13 minutes 17 seconds	10:52:31 AM - 11:05:48 AM
Drive	30 minutes 27 seconds	11:05:48 AM - 11:36:15 AM BN 1940 - 3164

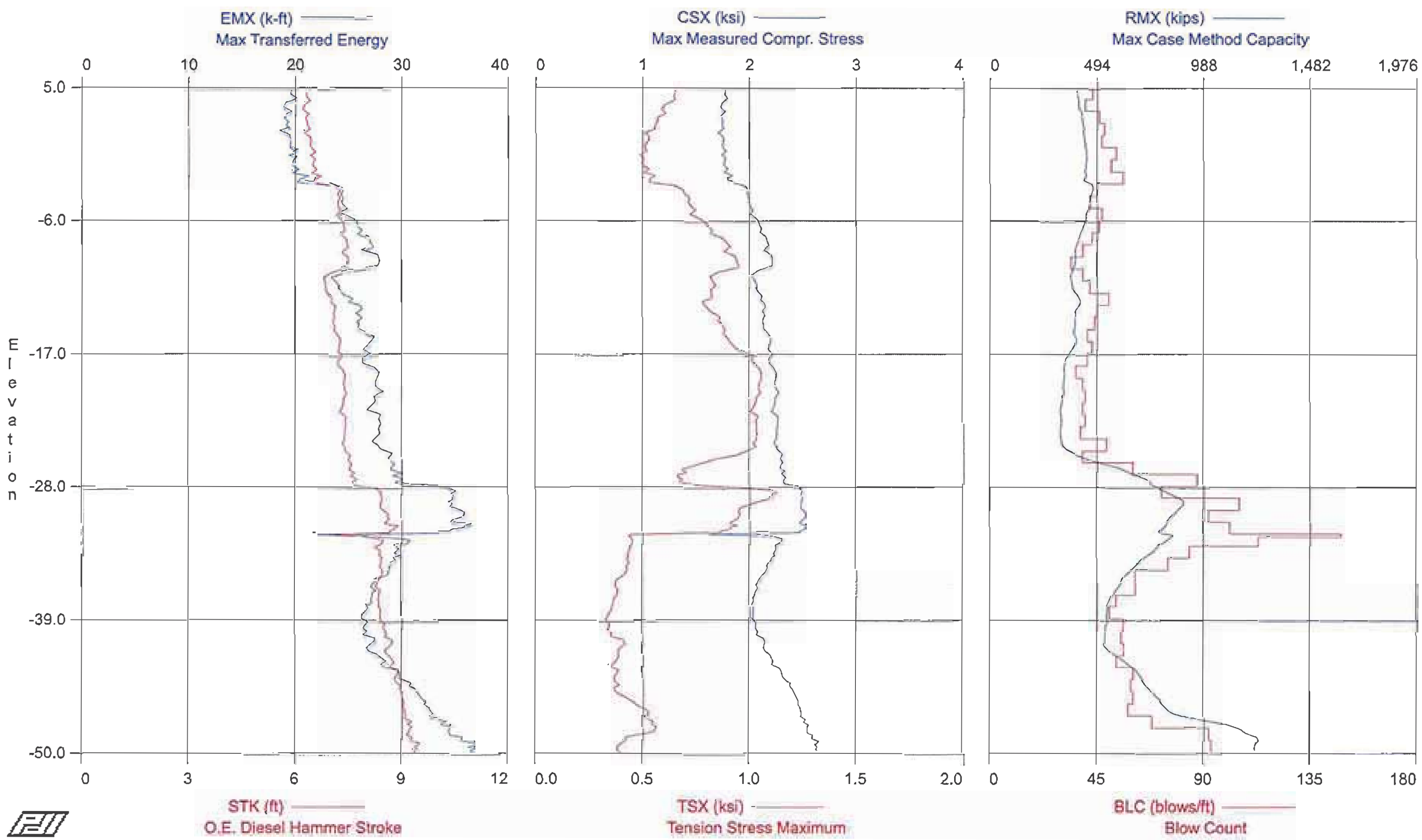
Total time [1:28:04] = (Driving [1:14:47] + Stop [0:13:17])

PDIPLOT Ver. 2012.2 - Printed: 3-Oct-2013

Nodarse & Associates Inc - Case Method & iCAP® Results

Test date: 24-Sep-2013

I-4 OVER DEER CROSSING - EB 3-1, P5
RE 52.18, CE 51.6 NBR 494k



I-4 OVER DEER CROSSING - EB 3-1, P5
OP: MK

RE 52.18, CE 51.6 NBR 494k
Test date: 24-Sep-2013

AR: 576.00 in^2
LE: 111.00 ft
WS: 14,050.6 f/s

SP: 0.150 k/ft3
EM: 6,392 ksi
JC: 0.50

CSB: Compression Stress at Bottom
CSX: Max Measured Compr. Stress
TSX: Tension Stress Maximum
EMX: Max Transferred Energy
STK: O.E. Diesel Hammer Stroke

RX4: Max Case Method Capacity (JC=0.4)
RMX: Max Case Method Capacity
RX6: Max Case Method Capacity (JC=0.6)
BTA: BETA Integrity Factor

BL# end	Elev.	BLC bl/ft	TYPE	CSB ksi	CSX ksi	TSX ksi	EMX k-ft	STK ft	RX4 kips	RMX kips	RX6 kips	BTA (%)
9	7.2	9	AV9	1.0	1.8	0.7	20.4	6.44	410	392	384	100
45	6.2	36	AV36	1.0	1.8	0.7	20.4	6.43	410	395	387	100
86	5.2	41	AV41	1.0	1.8	0.7	20.4	6.41	413	396	384	100
129	4.2	43	AV43	1.0	1.8	0.6	19.6	6.31	415	401	390	100
169	3.2	40	AV40	1.0	1.8	0.6	19.3	6.28	424	409	397	100
215	2.2	46	AV46	1.0	1.8	0.6	19.4	6.35	438	424	413	100
263	1.2	48	AV48	1.0	1.7	0.5	19.1	6.35	448	430	418	100
310	0.2	47	AV47	1.0	1.7	0.5	19.5	6.43	463	436	423	100
363	-0.8	53	AV53	1.1	1.8	0.5	19.9	6.52	474	444	427	100
414	-1.8	51	AV51	1.1	1.8	0.5	20.0	6.53	476	441	420	100
470	-2.8	56	AV56	1.1	1.8	0.5	20.5	6.60	476	438	425	100
515	-3.8	45	AV45	1.1	2.0	0.7	24.2	7.19	487	475	463	100
557	-4.8	42	AV42	1.1	2.0	0.7	24.4	7.21	477	463	448	100
604	-5.8	47	AV47	1.1	2.0	0.7	24.7	7.23	473	449	433	100
650	-6.8	46	AV46	1.1	2.1	0.8	25.9	7.36	468	434	419	100
693	-7.8	43	AV43	1.1	2.1	0.9	26.7	7.39	451	413	398	100
732	-8.8	39	AV39	1.0	2.2	0.9	26.9	7.40	437	394	379	100
766	-9.8	34	AV34	1.0	2.2	0.9	28.0	7.49	424	391	380	100
805	-10.8	39	AV39	0.9	2.1	0.8	24.2	6.92	407	374	360	100
847	-11.8	42	AV42	0.9	2.1	0.8	24.1	6.86	415	381	368	100
897	-12.8	50	AV50	1.0	2.1	0.8	25.2	7.01	451	411	382	100
942	-13.8	45	AV45	1.0	2.1	0.8	26.1	7.12	440	402	395	100
986	-14.8	44	AV44	0.9	2.1	0.9	26.0	7.09	418	392	391	100
1027	-15.8	41	AV41	0.9	2.2	0.9	26.9	7.20	421	391	389	100
1070	-16.8	43	AV43	0.8	2.2	0.9	26.8	7.23	419	388	386	100
1111	-17.8	41	AV41	0.8	2.2	1.0	26.5	7.23	391	354	336	100
1147	-18.8	36	AV36	0.8	2.2	1.1	27.8	7.39	381	341	322	100
1186	-19.8	39	AV39	0.8	2.2	1.0	27.5	7.35	377	338	309	100
1226	-20.8	40	AV40	0.8	2.3	1.0	27.8	7.38	376	337	306	100
1265	-21.8	39	AV39	0.8	2.2	1.0	27.2	7.29	367	327	293	100
1305	-22.8	40	AV40	0.8	2.3	1.0	28.0	7.41	373	329	303	100
1343	-23.8	38	AV38	0.8	2.3	1.0	27.9	7.38	370	325	304	100
1392	-24.8	49	AV49	0.9	2.2	1.0	27.5	7.34	380	336	315	100
1431	-25.8	39	AV39	1.1	2.3	0.9	28.9	7.51	471	420	392	100
1491	-26.8	60	AV60	1.3	2.3	0.7	29.3	7.57	641	588	567	100
1578	-27.8	87	AV87	1.6	2.3	0.7	29.8	7.65	741	717	703	100
1650	-28.8	72	AV72	1.8	2.5	1.1	34.8	8.38	824	814	803	100
1755	-29.8	105	AV105	2.0	2.5	1.0	34.7	8.40	893	885	879	100
1847	-30.8	92	AV92	2.0	2.5	0.9	35.6	8.59	855	844	834	100
1948	-31.8	101	AV101	1.9	2.4	0.9	33.9	8.60	815	799	790	100
1985	-32.1	148	AV37	1.8	2.1	0.4	26.9	7.93	861	841	834	100
2070	-32.8	113	AV85	1.8	2.3	0.4	30.3	8.38	824	808	806	100
2154	-33.8	84	AV84	1.7	2.2	0.4	29.6	8.36	756	747	743	100
2229	-34.8	75	AV75	1.5	2.2	0.4	29.0	8.40	687	684	683	100

I-4 OVER DEER CROSSING - EB 3-1, P5
OP: MK

RE 52.18, CE 51.6 NBR 494k
Test date: 24-Sep-2013

BL# end	Elev.	BLC bl/ft	TYPE	CSB ksi	CSX ksi	TSX ksi	EMX k-ft	STK ft	RX4 kips	RMX kips	RX6 kips	BTA (%)
2290	-35.8	61	AV61	1.4	2.1	0.4	28.1	8.37	628	625	623	100
2351	-36.8	61	AV61	1.3	2.1	0.4	27.3	8.32	596	587	586	100
2404	-37.8	53	AV53	1.2	2.0	0.4	27.0	8.33	586	553	547	100
2454	-38.8	50	AV50	1.1	2.0	0.3	26.5	8.38	585	538	529	100
2510	-39.8	56	AV56	1.1	2.1	0.3	26.6	8.49	587	537	530	100
2565	-40.8	55	AV55	1.1	2.1	0.4	27.1	8.63	578	529	522	100
2621	-41.8	56	AV56	1.2	2.2	0.4	27.0	8.57	598	545	534	100
2674	-42.8	53	AV53	1.3	2.2	0.4	28.3	8.72	662	619	606	100
2734	-43.8	60	AV60	1.5	2.3	0.4	29.7	8.84	718	683	676	100
2793	-44.8	59	AV59	1.6	2.4	0.4	30.8	8.93	762	722	710	100
2853	-45.8	60	AV60	1.8	2.4	0.4	31.9	9.02	808	771	741	100
2911	-46.8	58	AV58	1.9	2.5	0.5	32.6	9.06	856	824	793	100
2979	-47.8	68	AV68	2.2	2.5	0.5	33.8	9.20	1,036	1,016	997	100
3071	-48.8	92	AV92	2.4	2.6	0.5	34.9	9.21	1,217	1,196	1,185	100
3164	-49.8	93	AV93	2.6	2.6	0.4	36.7	9.40	1,258	1,234	1,217	100
			Average	1.4	2.2	0.7	28.0	7.85	633	606	593	100

Total number of blows analyzed: 3164

BL#	Elev.	Comments
1	8.1	Test pile, NBR ~~594k~~ 494k, GE: 46.18 feet
1939	-31.7	CHANGE CUSHION

Time Summary

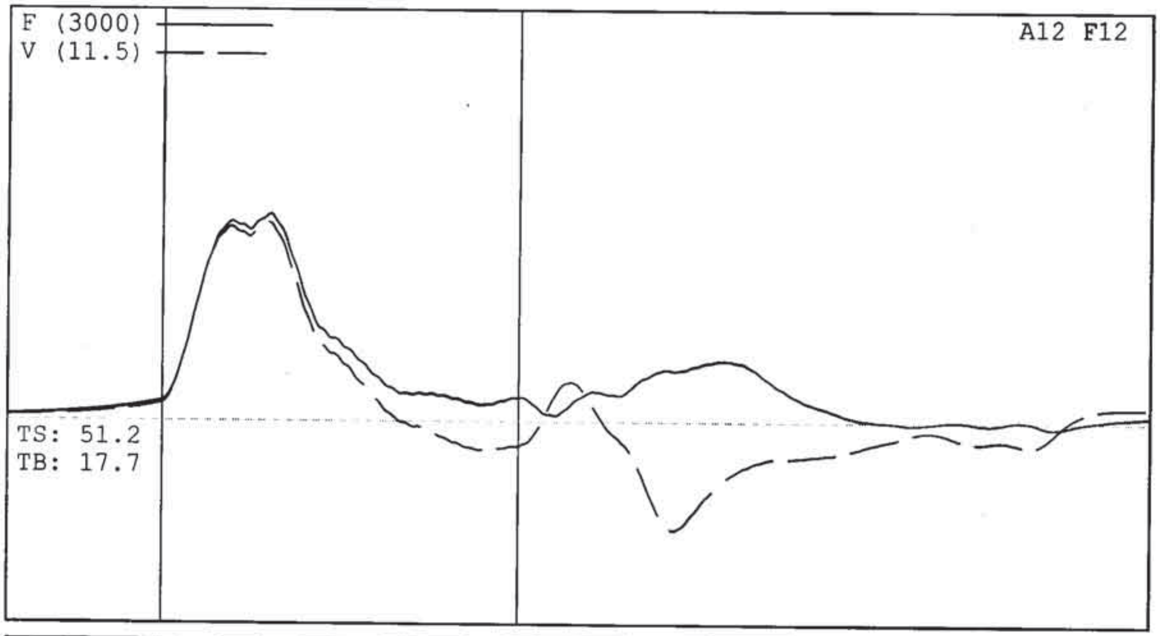
Drive	44 minutes 20 seconds	10:08:11 AM - 10:52:31 AM (9/24/2013) BN 1 - 1939
Stop	13 minutes 17 seconds	10:52:31 AM - 11:05:48 AM
Drive	30 minutes 27 seconds	11:05:48 AM - 11:36:15 AM BN 1940 - 3164

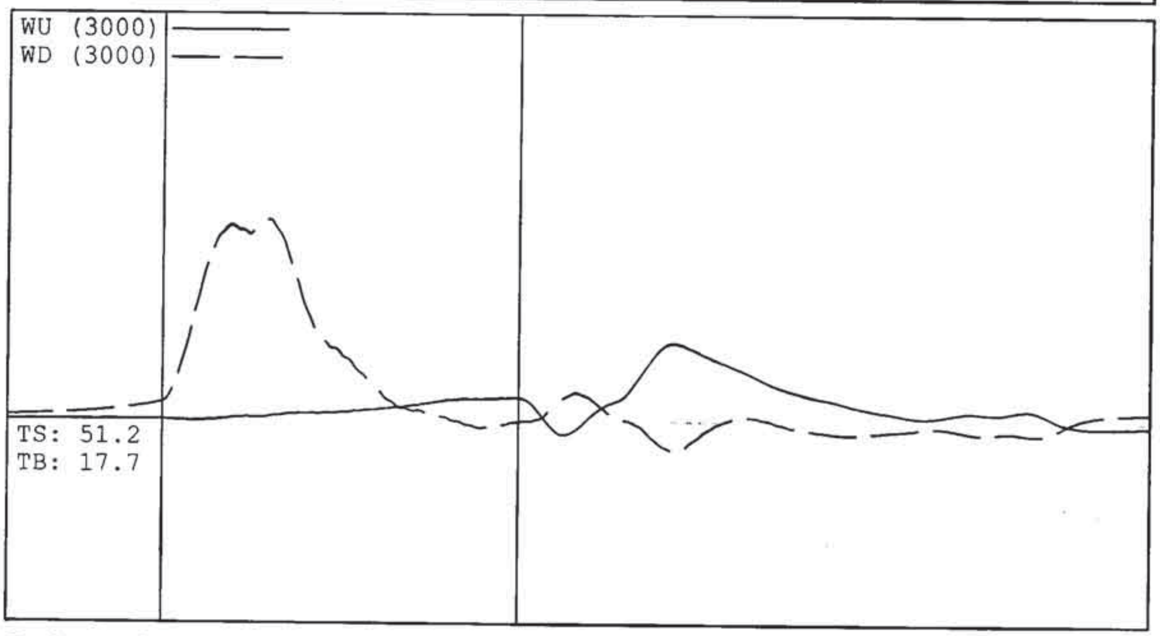
Total time [1:28:04] = (Driving [1:14:47] + Stop [0:13:17])

GRL Engineers, Inc. Pile Driving Analyzer ®

I-4 OVER DEER CROSSING

EB 3-1, P5





Project Information
PROJECT: I-4 OVER DEER CROSSING
PILE NAME: EB 3-1, P5
DESCR: RE 52.18, CE 51.6,NBR 594K
OPERATOR: MK
FILE: Deer Crossing EB 3-1 P5 - MH
9/24/2013 11:36:13 AM
Blow Number 3164

Pile Properties

LE	111.00 ft
AR	576.00 in^2
EM	6346 ksi
SP	0.150 k/ft3
WS	14000.0 f/s
EA/C	261.1 ksec/ft
2L/C	15.90 ms
JC	0.50 []
LP	101.99 ft

Quantity Results

CSX	2.61 ksi
CSI	3.14 ksi
CSB	2.58 ksi
TSX	0.32 ksi
STK	9.22 ft
EMX	35.80 k-ft
BTA	100.0 (%)
RA2	1242 kips
RMX	1231 kips

Sensors
F1: [E583] 93.9 (0.97)
F2: [E631] 95.7 (0.97)
A1: [77664] 1035 g's/v (1.03)
A2: [77662] 1065 g's/v (1.03)
CLIP: OK

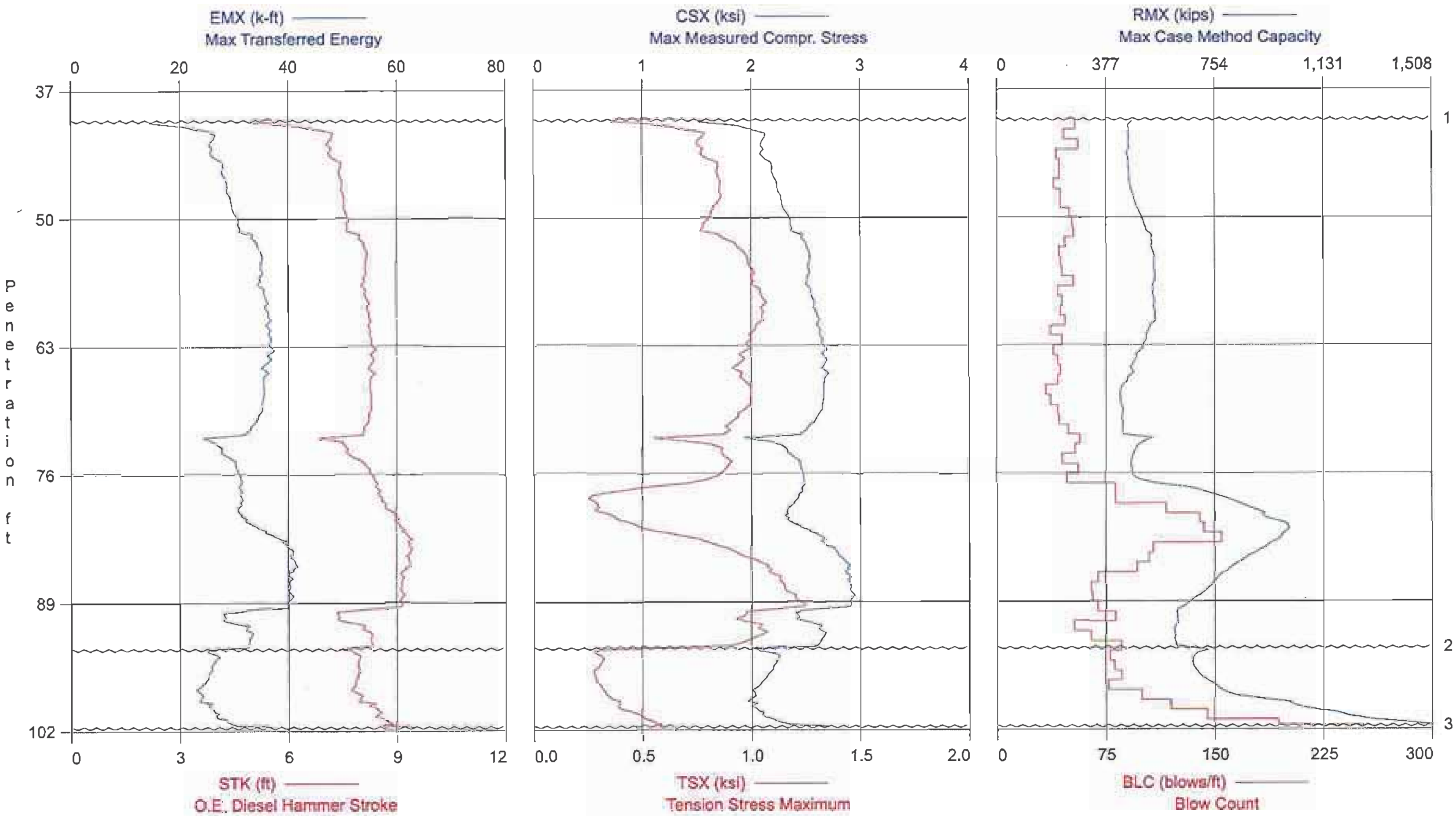
Version 2012.114

PDIPLOT Ver. 2012.2 - Printed: 3-Oct-2013

Nodarse & Associates Inc - Case Method & iCAP® Results

Test date: 20-Sep-2013

I-4 OVER DEER CROSSING - IB 3-2, P1
RE 51.59, GE 42.24, 754K



1 - NBR: 377 tons (754 kips)
2 - CUSHION CHANGE

3 - HIGH CSB, 18 / 19 BPI (21 blows recorded), 101 FT 8 IN

I-4 OVER DEER CROSSING - IB 3-2, P1
OP: MK

RE 51.59, GE 42.24, 754K
Test date: 20-Sep-2013

AR: 576.00 in^2
LE: 116.00 ft
WS: 14,146.3 f/s

SP: 0.150 k/ft3
EM: 6,479 ksi
JC: 0.50

CSB: Compression Stress at Bottom
CSX: Max Measured Compr. Stress
TSX: Tension Stress Maximum
EMX: Max Transferred Energy
STK: O.E. Diesel Hammer Stroke

RX4: Max Case Method Capacity (JC=0.4)
RMX: Max Case Method Capacity
RX6: Max Case Method Capacity (JC=0.6)
BTA: BETA Integrity Factor

BL# end	depth ft	BLC bl/ft	TYPE	CSB ksi	CSX ksi	TSX ksi	EMX k-ft	STK ft	RX4 kips	RMX kips	RX6 kips	BTA (%)
54	41.00	54	AV54	1.2	1.8	0.5	18.8	5.96	471	459	454	100
100	42.00	46	AV46	1.2	2.1	0.8	26.5	7.25	480	457	435	100
156	43.00	56	AV56	1.2	2.1	0.8	25.7	7.13	478	457	437	100
197	44.00	41	AV41	1.2	2.1	0.8	25.9	7.14	474	452	431	100
240	45.00	43	AV43	1.2	2.2	0.8	28.0	7.46	483	457	435	100
283	46.00	43	AV43	1.2	2.2	0.8	28.0	7.42	486	458	439	100
322	47.00	39	AV39	1.2	2.2	0.9	28.8	7.50	488	461	446	100
366	48.00	44	AV44	1.2	2.3	0.9	29.0	7.51	497	471	454	100
410	49.00	44	AV44	1.3	2.3	0.8	29.6	7.56	508	480	459	100
460	50.00	50	AV50	1.3	2.3	0.8	30.2	7.61	522	495	471	100
512	51.00	52	AV52	1.3	2.4	0.8	30.9	7.65	535	509	483	100
565	52.00	53	AV53	1.4	2.4	0.8	32.0	7.79	554	525	499	100
612	53.00	47	AV47	1.4	2.5	0.9	34.2	8.08	569	537	512	100
655	54.00	43	AV43	1.4	2.5	1.0	35.0	8.17	575	541	517	100
699	55.00	44	AV44	1.3	2.5	1.0	35.1	8.16	580	546	523	100
744	56.00	45	AV45	1.3	2.5	1.0	35.1	8.15	579	546	523	100
797	57.00	53	AV53	1.3	2.5	1.0	34.8	8.08	578	546	523	100
839	58.00	42	AV42	1.3	2.5	1.0	35.5	8.12	570	539	514	100
884	59.00	45	AV45	1.3	2.6	1.1	36.1	8.22	575	546	521	100
928	60.00	44	AV44	1.3	2.6	1.1	36.2	8.23	574	547	523	100
975	61.00	47	AV47	1.2	2.6	1.0	36.5	8.26	571	545	523	100
1012	62.00	37	AV37	1.2	2.6	1.0	36.5	8.25	548	523	502	100
1057	63.00	45	AV45	1.2	2.7	1.0	36.7	8.30	539	514	495	100
1096	64.00	39	AV39	1.1	2.7	1.0	36.9	8.37	521	497	480	100
1138	65.00	42	AV42	1.1	2.7	1.0	36.6	8.35	503	480	466	100
1182	66.00	44	AV44	1.1	2.7	0.9	35.8	8.32	498	470	457	100
1224	67.00	42	AV42	1.0	2.7	1.0	35.6	8.29	482	452	441	100
1258	68.00	34	AV34	0.9	2.7	1.0	35.8	8.31	466	431	418	100
1295	69.00	37	AV37	0.9	2.7	1.0	35.3	8.29	471	431	400	100
1337	70.00	42	AV42	1.0	2.6	1.0	35.0	8.29	482	437	399	100
1380	71.00	43	AV43	1.0	2.6	0.9	34.2	8.22	483	436	394	100
1429	72.00	49	AV49	1.0	2.5	0.9	32.8	8.09	486	436	393	100
1486	73.00	57	AV57	0.9	2.2	0.7	27.0	7.70	559	509	461	100
1540	74.00	54	AV54	0.9	2.3	0.9	27.7	7.61	539	484	433	100
1585	75.00	45	AV45	1.0	2.4	0.9	29.8	7.96	528	468	414	100
1641	76.00	56	AV56	1.0	2.5	0.9	30.7	8.24	532	469	413	100
1689	77.00	48	AV48	1.0	2.5	0.8	31.5	8.42	575	491	434	100
1771	78.00	82	AV82	1.2	2.5	0.5	31.3	8.49	787	668	601	100
1853	79.00	82	AV82	1.4	2.4	0.3	31.4	8.61	889	795	756	100
1970	80.00	117	AV117	1.7	2.3	0.3	30.9	8.78	937	887	849	100
2110	81.00	140	AV140	1.9	2.3	0.4	32.1	9.01	987	947	911	100
2253	82.00	143	AV143	2.1	2.5	0.5	35.0	9.15	1,030	1,008	997	100
2408	83.00	155	AV155	2.2	2.6	0.7	38.5	9.35	996	982	973	100
2516	84.00	108	AV108	2.2	2.7	0.9	40.3	9.38	941	928	919	100

I-4 OVER DEER CROSSING - IB 3-2, P1
OP: MK

RE 51.59, GE 42.24, 754K
Test date: 20-Sep-2013

BL# end	depth ft	BLC bl/ft	TYPE	CSB ksi	CSX ksi	TSX ksi	EMX k-ft	STK ft	RX4 kips	RMX kips	RX6 kips	BTA (%)
2621	85.00	105	AV105	2.1	2.8	1.0	40.9	9.35	880	868	861	100
2718	86.00	97	AV97	2.0	2.9	1.1	41.1	9.29	821	815	812	100
2788	87.00	70	AV70	1.9	2.9	1.1	40.2	9.14	773	770	768	100
2853	88.00	65	AV65	1.8	2.9	1.2	40.4	9.15	740	735	732	100
2919	89.00	66	AV66	1.7	2.9	1.2	40.4	9.17	700	692	687	100
2989	90.00	70	AV70	1.6	2.8	1.2	36.4	8.63	654	645	642	100
3071	91.00	82	AV82	1.5	2.4	1.0	28.1	7.39	631	625	620	100
3124	92.00	53	AV53	1.6	2.6	1.0	32.6	8.10	631	621	613	100
3189	93.00	65	AV65	1.6	2.7	1.0	33.2	8.31	627	616	605	91
3275	94.00	86	AV86	1.5	2.4	0.7	29.6	8.13	674	653	632	91
3353	95.00	78	AV78	1.4	2.2	0.3	26.9	7.95	725	686	648	100
3434	96.00	81	AV81	1.4	2.2	0.3	26.1	7.95	719	681	644	100
3520	97.00	86	AV86	1.4	2.1	0.3	25.3	7.94	747	707	669	100
3597	98.00	77	AV77	1.4	2.1	0.3	24.0	7.84	797	756	717	100
3697	99.00	100	AV100	1.5	2.0	0.3	24.1	7.99	884	840	799	100
3817	100.00	120	AV120	1.8	2.0	0.4	25.5	8.30	1,072	1,031	999	100
3962	101.00	145	AV145	2.0	2.1	0.5	27.2	8.55	1,232	1,205	1,179	100
4059	101.50	194	AV97	2.4	2.3	0.6	29.8	8.86	1,422	1,405	1,392	100
4077	101.58	216	AV18	3.1	2.6	0.5	35.4	9.33	1,678	1,620	1,585	100
4098	101.67	252	AV21	3.3	2.7	0.6	37.0	9.48	1,730	1,692	1,664	100
			Average	1.5	2.4	0.7	32.2	8.34	748	716	692	100

Total number of blows analyzed: 4098

BL#	depth (ft)	Comments
1	40.02	NBR: 377 tons (754 kips)
1448	72.33	CUSHION CHANGE
3250	93.71	CUSHION CHANGE
4059	101.50	MARK INCHES
4098	101.67	HIGH CSB, 18 / 19 BPI (21 blows recorded), 101 FT 8 IN

Time Summary

Drive	34 minutes 19 seconds	1:47:15 PM - 2:21:34 PM (9/20/2013) BN 1 - 1448
Stop	19 minutes 44 seconds	2:21:34 PM - 2:41:18 PM
Drive	44 minutes 57 seconds	2:41:18 PM - 3:26:15 PM BN 1449 - 3250
Stop	17 minutes 1 second	3:26:15 PM - 3:43:16 PM
Drive	29 minutes 58 seconds	3:43:16 PM - 4:13:14 PM BN 3251 - 4098

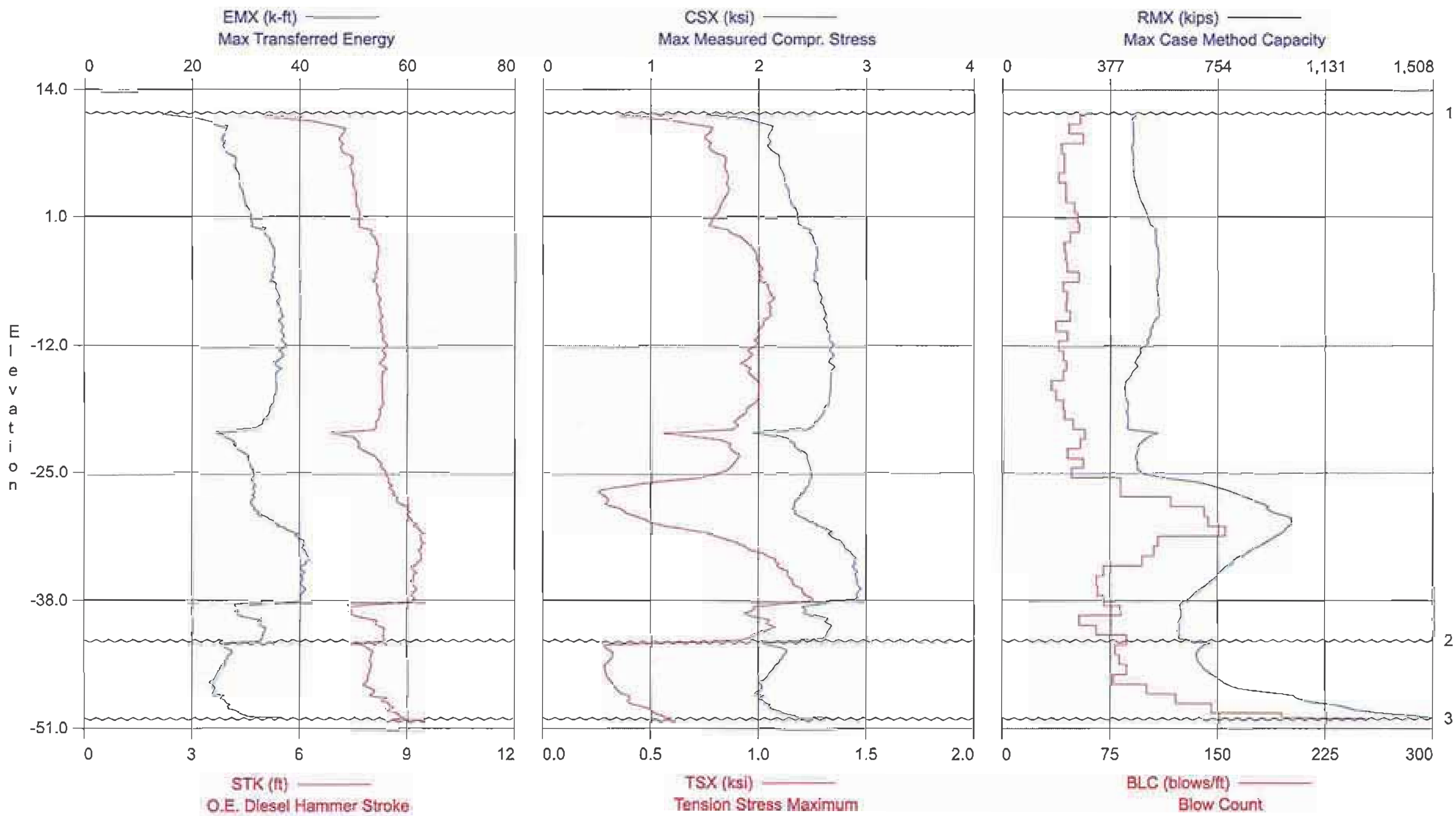
Total time [2:25:59] = (Driving [1:49:14] + Stop [0:36:45])

Nodarse & Associates Inc - Case Method & iCAP® Results

PDIPLOT Ver. 2012.2 - Printed: 3-Oct-2013

Test date: 20-Sep-2013

I-4 OVER DEER CROSSING - IB 3-2, P1
RE 51.59, GE 42.24, 754K



1 - NBR: 377 tons (754 kips)
2 - CUSHION CHANGE
3 - HIGH CSB, 18 / 19 BPI (21 blows recorded), 101 FT 8 IN

I-4 OVER DEER CROSSING - IB 3-2, P1
OP: MK

RE 51.59, GE 42.24, 754K
Test date: 20-Sep-2013

AR: 576.00 in^2
LE: 116.00 ft
WS: 14,146.3 f/s

SP: 0.150 k/ft3
EM: 6,479 ksi
JC: 0.50

CSB: Compression Stress at Bottom
CSX: Max Measured Compr. Stress
TSX: Tension Stress Maximum
EMX: Max Transferred Energy
STK: O.E. Diesel Hammer Stroke

RX4: Max Case Method Capacity (JC=0.4)
RMX: Max Case Method Capacity
RX6: Max Case Method Capacity (JC=0.6)
BTA: BETA Integrity Factor

BL# end	Elev.	BLC bl/ft	TYPE	CSB ksi	CSX ksi	TSX ksi	EMX k-ft	STK ft	RX4 kips	RMX kips	RX6 kips	BTA (%)
54	10.6	54	AV54	1.2	1.8	0.5	18.8	5.96	471	459	454	100
100	9.6	46	AV46	1.2	2.1	0.8	26.5	7.25	480	457	435	100
156	8.6	56	AV56	1.2	2.1	0.8	25.7	7.13	478	457	437	100
197	7.6	41	AV41	1.2	2.1	0.8	25.9	7.14	474	452	431	100
240	6.6	43	AV43	1.2	2.2	0.8	28.0	7.46	483	457	435	100
283	5.6	43	AV43	1.2	2.2	0.8	28.0	7.42	486	458	439	100
322	4.6	39	AV39	1.2	2.2	0.9	28.8	7.50	488	461	446	100
366	3.6	44	AV44	1.2	2.3	0.9	29.0	7.51	497	471	454	100
410	2.6	44	AV44	1.3	2.3	0.8	29.6	7.56	508	480	459	100
460	1.6	50	AV50	1.3	2.3	0.8	30.2	7.61	522	495	471	100
512	0.6	52	AV52	1.3	2.4	0.8	30.9	7.65	535	509	483	100
565	-0.4	53	AV53	1.4	2.4	0.8	32.0	7.79	554	525	499	100
612	-1.4	47	AV47	1.4	2.5	0.9	34.2	8.08	569	537	512	100
655	-2.4	43	AV43	1.4	2.5	1.0	35.0	8.17	575	541	517	100
699	-3.4	44	AV44	1.3	2.5	1.0	35.1	8.16	580	546	523	100
744	-4.4	45	AV45	1.3	2.5	1.0	35.1	8.15	579	546	523	100
797	-5.4	53	AV53	1.3	2.5	1.0	34.8	8.08	578	546	523	100
839	-6.4	42	AV42	1.3	2.5	1.0	35.5	8.12	570	539	514	100
884	-7.4	45	AV45	1.3	2.6	1.1	36.1	8.22	575	546	521	100
928	-8.4	44	AV44	1.3	2.6	1.1	36.2	8.23	574	547	523	100
975	-9.4	47	AV47	1.2	2.6	1.0	36.5	8.26	571	545	523	100
1012	-10.4	37	AV37	1.2	2.6	1.0	36.5	8.25	548	523	502	100
1057	-11.4	45	AV45	1.2	2.7	1.0	36.7	8.30	539	514	495	100
1096	-12.4	39	AV39	1.1	2.7	1.0	36.9	8.37	521	497	480	100
1138	-13.4	42	AV42	1.1	2.7	1.0	36.6	8.35	503	480	466	100
1182	-14.4	44	AV44	1.1	2.7	0.9	35.8	8.32	498	470	457	100
1224	-15.4	42	AV42	1.0	2.7	1.0	35.6	8.29	482	452	441	100
1258	-16.4	34	AV34	0.9	2.7	1.0	35.8	8.31	466	431	418	100
1295	-17.4	37	AV37	0.9	2.7	1.0	35.3	8.29	471	431	400	100
1337	-18.4	42	AV42	1.0	2.6	1.0	35.0	8.29	482	437	399	100
1380	-19.4	43	AV43	1.0	2.6	0.9	34.2	8.22	483	436	394	100
1429	-20.4	49	AV49	1.0	2.5	0.9	32.8	8.09	486	436	393	100
1486	-21.4	57	AV57	0.9	2.2	0.7	27.0	7.70	559	509	461	100
1540	-22.4	54	AV54	0.9	2.3	0.9	27.7	7.61	539	484	433	100
1585	-23.4	45	AV45	1.0	2.4	0.9	29.8	7.96	528	468	414	100
1641	-24.4	56	AV56	1.0	2.5	0.9	30.7	8.24	532	469	413	100
1689	-25.4	48	AV48	1.0	2.5	0.8	31.5	8.42	575	491	434	100
1771	-26.4	82	AV82	1.2	2.5	0.5	31.3	8.49	787	668	601	100
1853	-27.4	82	AV82	1.4	2.4	0.3	31.4	8.61	889	795	756	100
1970	-28.4	117	AV117	1.7	2.3	0.3	30.9	8.78	937	887	849	100
2110	-29.4	140	AV140	1.9	2.3	0.4	32.1	9.01	987	947	911	100
2253	-30.4	143	AV143	2.1	2.5	0.5	35.0	9.15	1,030	1,008	997	100
2408	-31.4	155	AV155	2.2	2.6	0.7	38.5	9.35	996	982	973	100
2516	-32.4	108	AV108	2.2	2.7	0.9	40.3	9.38	941	928	919	100

I-4 OVER DEER CROSSING - IB 3-2, P1
OP: MK

RE 51.59, GE 42.24, 754K
Test date: 20-Sep-2013

BL# end	Elev.	BLC bl/ft	TYPE	CSB ksi	CSX ksi	TSX ksi	EMX k-ft	STK ft	RX4 kips	RMX kips	RX6 kips	BTA (%)
2621	-33.4	105	AV105	2.1	2.8	1.0	40.9	9.35	880	868	861	100
2718	-34.4	97	AV97	2.0	2.9	1.1	41.1	9.29	821	815	812	100
2788	-35.4	70	AV70	1.9	2.9	1.1	40.2	9.14	773	770	768	100
2853	-36.4	65	AV65	1.8	2.9	1.2	40.4	9.15	740	735	732	100
2919	-37.4	66	AV66	1.7	2.9	1.2	40.4	9.17	700	692	687	100
2989	-38.4	70	AV70	1.6	2.8	1.2	36.4	8.63	654	645	642	100
3071	-39.4	82	AV82	1.5	2.4	1.0	28.1	7.39	631	625	620	100
3124	-40.4	53	AV53	1.6	2.6	1.0	32.6	8.10	631	621	613	100
3189	-41.4	65	AV65	1.6	2.7	1.0	33.2	8.31	627	616	605	91
3275	-42.4	86	AV86	1.5	2.4	0.7	29.6	8.13	674	653	632	91
3353	-43.4	78	AV78	1.4	2.2	0.3	26.9	7.95	725	686	648	100
3434	-44.4	81	AV81	1.4	2.2	0.3	26.1	7.95	719	681	644	100
3520	-45.4	86	AV86	1.4	2.1	0.3	25.3	7.94	747	707	669	100
3597	-46.4	77	AV77	1.4	2.1	0.3	24.0	7.84	797	756	717	100
3697	-47.4	100	AV100	1.5	2.0	0.3	24.1	7.99	884	840	799	100
3817	-48.4	120	AV120	1.8	2.0	0.4	25.5	8.30	1,072	1,031	999	100
3962	-49.4	145	AV145	2.0	2.1	0.5	27.2	8.55	1,232	1,205	1,179	100
4059	-49.9	194	AV97	2.4	2.3	0.6	29.8	8.86	1,422	1,405	1,392	100
4077	-50.0	216	AV18	3.1	2.6	0.5	35.4	9.33	1,678	1,620	1,585	100
4098	-50.1	252	AV21	3.3	2.7	0.6	37.0	9.48	1,730	1,692	1,664	100
			Average	1.5	2.4	0.7	32.2	8.34	748	716	692	100

Total number of blows analyzed: 4098

BL#	Elev.	Comments
1	11.6	NBR: 377 tons (754 kips)
1448	-20.7	CUSHION CHANGE
3250	-42.1	CUSHION CHANGE
4059	-49.9	MARK INCHES
4098	-50.1	HIGH CSB, 18 / 19 BPI (21 blows recorded), 101 FT 8 IN

Time Summary

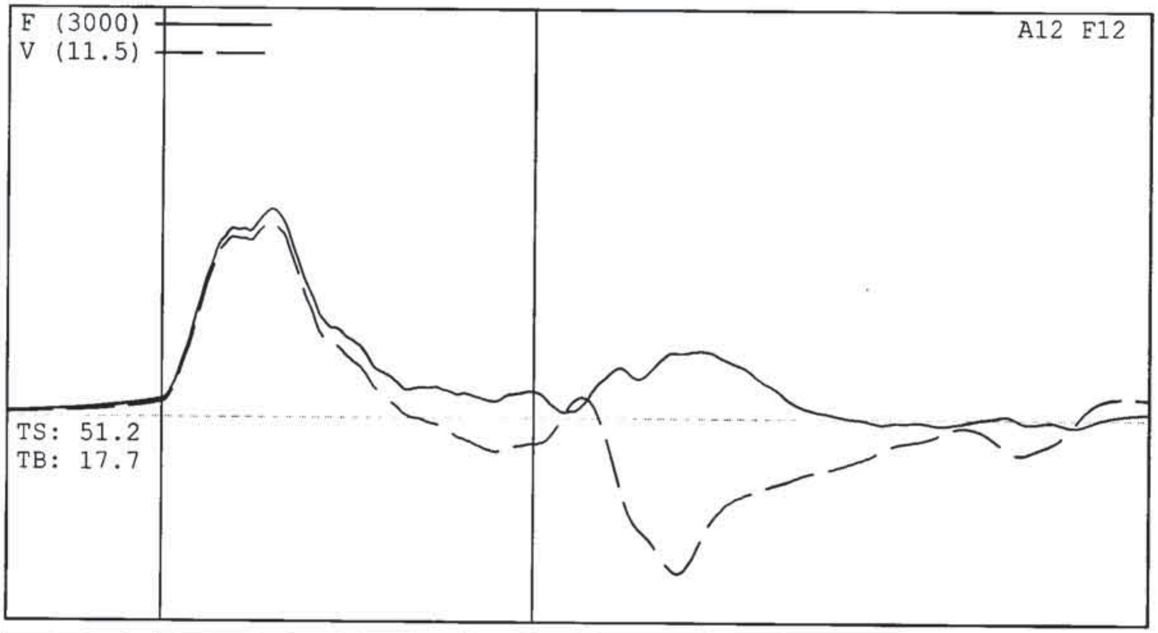
Drive	34 minutes 19 seconds	1:47:15 PM - 2:21:34 PM (9/20/2013) BN 1 - 1448
Stop	19 minutes 44 seconds	2:21:34 PM - 2:41:18 PM
Drive	44 minutes 57 seconds	2:41:18 PM - 3:26:15 PM BN 1449 - 3250
Stop	17 minutes 1 second	3:26:15 PM - 3:43:16 PM
Drive	29 minutes 58 seconds	3:43:16 PM - 4:13:14 PM BN 3251 - 4098

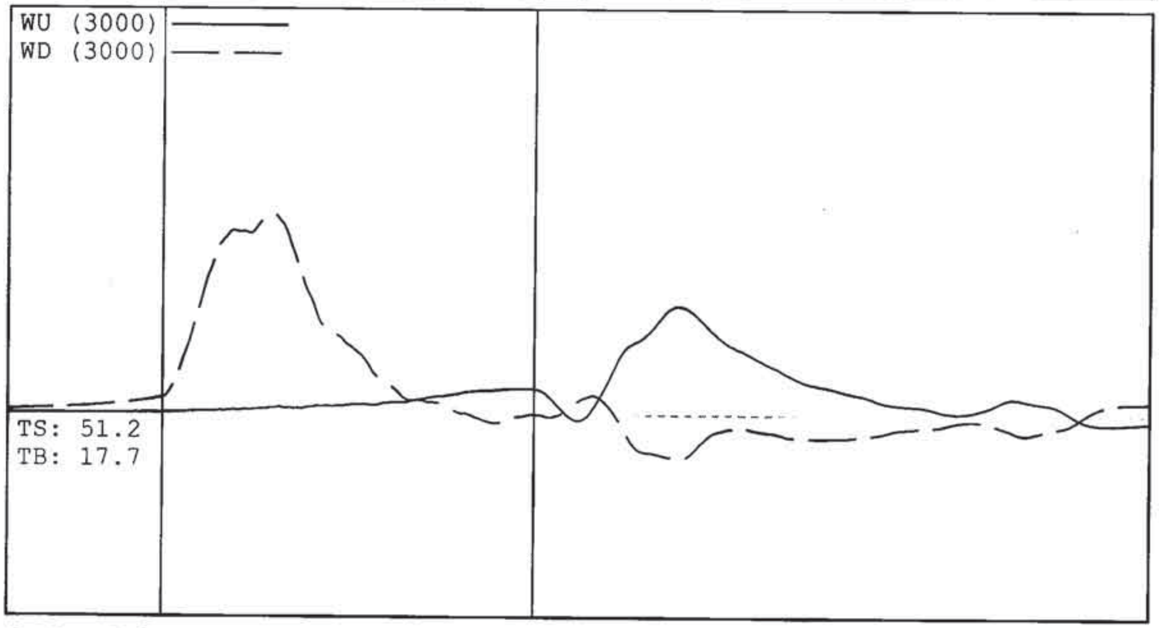
Total time [2:25:59] = (Driving [1:49:14] + Stop [0:36:45])

GRL Engineers, Inc. Pile Driving Analyzer ®

I-4 OVER DEER CROSSING

BENT 3-2 PILE 1





Project Information
PROJECT: I-4 OVER DEER **CROSSING**
PILE NAME: BENT 3-2 PILE 1
DESCR: APE D46-42
OPERATOR: MK
FILE: I-4 Deer Crossing Bent 3-2 Pile 1 DP-MH
9/20/2013 4:13:08 PM
Blow Number 4090

Pile Properties

LE	116.00 ft
AR	576.00 in^2
EM	6346 ksi
SP	0.150 k/ft3
WS	14000.0 f/s
EA/C	261.1 ksec/ft
2L/C	16.60 ms
JC	0.50 []
LP	101.66 ft

Quantity Results

CSX	2.66 ksi
CSB	3.24 ksi
TSX	0.54 ksi
STK	9.37 ft
EMX	35.31 k-ft
BTA	100.0 (%)
RA2	1690 kips
RX5	1713 kips
RX6	1680 kips

Sensors
F1: [E583] 93.9 (0.975)
F2: [E631] 95.7 (0.975)
A1: [77664] 1035 g's/v (1.025)
A2: [77662] 1065 g's/v (1.025)
CLIP: OK

Version 2012.114

Page No. 1/2

700-010-60
Construction
11/11

PILE DRIVING INFORMATION

Structure Number: 790207 I-4 over Deer Crossing

FIN PROJ. ID # 408464-1-52-1 DATE 9-24-13 STATION NO. 1178+00

PILE SIZE 24"SQ ACTUAL/AUTH LENGTH 115' BENT/PIER NO. EB 3-1 PILE NO. 5

HAMMER TYPE APE D46-42 ~~SERIAL# 200605397~~ RATED ENERGY 114,109 FT/LBS OPERATING RATE VARIES

REF. ELEV +52.18 MIN. TIP ELEV -3 PILE CUTOFF ELEV +51.6

DRIVING CRITERIA TEST PILE

PILE CUSHION THICKNESS AND MATERIAL

HAMMER CUSHION THICKNESS AND MATERIAL 3½" MICARTA 2X 1" & ALUM 3 X ½"

WEATHER Cloudy TEMP 70° START TIME 9:43am STOP TIME 11:45am

PILE DATA

PAY ITEM NO. N/A WORK ORDER NO. N/A

MANUFACTURED BY DURASTRESS T.B.M./B.M. ELEV N/A GROUND ROD READ N/A

DATE CAST ROD READ N/A PILE HEAD ROD READ N/A

MANUFACTURER'S PILE NO. H-18 H.I. N/A PILE HEAD ELEV. 65.18'

PILE HEAD CHAMFER 3/4" X 3" PILE TIP ELEV. -49.82'

PILE TIP CHAMFER 3/4" X 3" GROUND ELEV. +46.18'

QUALIFED INSPECTOR'S NAME: Michael Harrington TIN #: H65255860

SPLICE / EACH	PREFORMED HOLE	DYNAMIC LOAD TEST	PAY SET CHECK	NO PAY SET CHECK	REDRIVE	EXTRACTION	DRIVING OF SPLICE	PILE TYPE CODE	BATTER	PILE LENGTH		PENETRATION BELOW GROUND	EXTENSION / BUILD UP	
										ORIGINAL FURNISHED	TOTAL LENGTH WITH EXTENSION		AUTHORIZED	ACTUAL
0.00		1.00	0.00	0.00	0.00	0.00	0.00	1.0	0.000	115'	115'	96'	0.000	0.000

NOTES: (1) FUEL SETTING # 1

(2) FUEL SETTING #2

(3) Fuel setting # 3

(4) Fuel setting # 4

(5) Start Driving

(6) Stop Driving

(7) Stopped to hook up PDA gages @ 9:55am - 10:20am.

(8) Stopped to change cushion

For Trainee experience evidence only:
Name of CTQP Trainee being supervised by the Qualified Inspector:

CTQP Trainee

I certify the Pile Driving Record accuracy and that the named above Trainee has observed the full pile installation:

Allen Brill

Qualified Inspector (Signature)

PILE DRIVING LOG

700-010-60
Construction
11/11

Structure No. 790207 | **Bent/Pier No.** EB 3-1 | **Pile No.** 5

Depth	Blows	Stroke/ Pressure	Note No.	Depth	Blows	Stroke/ Pressure	Note No.	Depth	Blows	Stroke/ Pressure	Note No.	Depth	Blows	Stroke/ Pressure	Note No.
0-1				33-34	24	6.12	① ⑤ 170psi	66-67	44	7.00	160psi	99-100	68	9.07	300psi
1-2				34-35	16	5.57	170psi	67-68	41	7.08	160psi	100-101	92	9.03	300psi
2-3				35-36	26	5.93	170psi	68-69	43	7.15	160psi	101-102	93	9.25	⑥ 300psi
3-4				36-37	31	5.78	170psi	69-70	41	7.16	160psi				
4-5				37-38	73	5.04	170psi	70-71	36	7.11	160psi				
5-6				38-39	43	5.99	170psi	71-72	39	7.28	160psi				
6-7				39-40	54	5.96	170psi	72-73	40	7.28	160psi				
7-8				40-41	51	5.94	170psi	73-74	39	7.22	160psi				
8-9				41-42	64	5.92	170psi	74-75	40	6.74	160psi				
9-10				42-43	50	6.04	170psi	75-76	38	7.30	160psi				
10-11				43-44	51	6.06	170psi	76-77	49	7.25	160psi				
11-12				44-45	53	6.05	⑦ 170psi	77-78	39	7.37	160psi				
12-13				45-46	36	6.34	170psi	78-79	60	7.44	160psi				
13-14				46-47	41	6.35	170psi	79-80	87	7.54	200psi				
14-15				47-48	43	6.20	170psi	80-81	72	8.16	200psi				
15-16				48-49	40	6.23	170psi	81-82	105	8.24	200psi				
16-17				49-50	46	6.23	170psi	82-83	92	8.47	220psi				
17-18				50-51	48	6.26	170psi	83-84	101	8.58	250psi				
18-19				51-52	47	6.34	170psi	84-85	37/85	8.27	⑧ 300psi	84'			
19-20				52-53	53	6.41	170psi	85-86	84	8.21	300psi	1"	12	7.68	
20-21				53-54	51	6.44	170psi	86-87	75	8.30	300psi	2"	13	7.79	
21-22				54-55	56	6.52	170psi	87-88	61	8.26	300psi	3"	12	7.96	
22-23				55-56	45	6.94	190psi	88-89	61	8.22	300psi				
23-24				56-57	42	7.11	190psi	89-90	53	8.23	300psi				
24-25				57-58	47	7.12	190psi	90-91	50	8.27	300psi				
25-26				58-59	46	7.27	190psi	91-92	56	8.37	300psi				
26-27				59-60	43	7.28	190psi	92-93	65	8.52	300psi				
27-28				60-61	39	7.31	190psi	93-94	56	8.47	300psi				
28-29				61-62	34	7.38	190psi	94-95	53	8.53	300psi				
29-30				62-63	39	6.98	160psi	95-96	60	8.72	300psi				
30-31				63-64	42	6.77	160psi	96-97	50	8.8	300psi				
31-32				64-65	50	6.88	160psi	97-98	60	8.91	300psi				
32-33				65-66	45	7.01	160psi	98-99	58	8.94	300psi				

Page No. 1/2

700-010-60
Construction
11/11

PILE DRIVING INFORMATION

Structure Number: E-River Dear Crossing 790207

FIN PROJ. ID # 408464-1-52-1 DATE 9/20/13 STATION NO. 1178+00

PILE SIZE 24" SQ ACTUAL/AUTH LENGTH 120' BENT/PIER NO. 3-2 PILE NO. 1

HAMMER TYPE APE D-46-42 SERIAL# 1107634 RATED ENERGY 114,109 FT/LBS OPERATING RATE VARIES

REF. ELEV 51.59 MIN. TIP ELEV -3.0' PILE CUTOFF ELEV 50.60

DRIVING CRITERIA TEST PILE

PILE CUSHION THICKNESS AND MATERIAL 19" 1/8 X 3/4" Pine Plywood A) 322 Blows compressed 10" B) 1840 Blows 10"

HAMMER CUSHION THICKNESS AND MATERIAL 3½" Micarta 2X 1" & Alum 3 X ½"

WEATHER Clear TEMP 92 START TIME 1:11 PM STOP TIME 4:25 PM

PILE DATA

PAY ITEM NO. N/A WORK ORDER NO. N/A

MANUFACTURED BY Durastress T.B.M./B.M. ELEV N/A GROUND ROD READ N/A

DATE CAST 3/27/13 ROD READ N/A PILE HEAD ROD READ N/A

MANUFACTURER'S PILE NO. B1577 N-6 H.I. N/A PILE HEAD ELEV. 69.9234

PILE HEAD CHAMFER 3/4" X 3" PILE TIP ELEV. -50.08

PILE TIP CHAMFER 3/4" X 3" GROUND ELEV. 42.24

QUALIFED INSPECTOR'S NAME: Michael Harrington TIN #: H65255860

SPLICE / EACH	PREFORMED HOLE	DYNAMIC LOAD TEST	PAY SET CHECK	NO PAY SET CHECK	REDRIVE	EXTRACTION	DRIVING OF SPLICE	PILE TYPE CODE	BATTER	PILE LENGTH		PENETRATION BELOW GROUND	EXTENSION / BUILD UP	
										ORIGINAL FURNISHED	TOTAL LENGTH WITH EXTENSION		AUTHORIZED	ACTUAL
0.00	15.0	1.00	0.00	0.00	0.00	0.00	0.00	1.0	0.000	120.000	120.000	92.320	0.000	0.000

NOTES:
(1) Fuel Pressure 120 PSI
(2) Fuel Pressure 140 PSI
(3) Fuel Pressure 180 PSI
(4) Fuel Pressure 200 PSI
(5) Fuel Pressure 220 PSI
(6) Fuel Pressure 240 PSI
(7) Fuel Pressure 300 PSI
(8) Fuel Pressure 350 PSI
(9) Fuel Pressure 400 PSI
(10) Fuel Pressure 500 PSI
(11) New Pile Cushion
(12) Stopped to attach PDA leads
(13) Stopped to change pile cushion
(14) Stopped to mark inches on pile
(15) Stopped driving @ 101.666 mark on pile

For Trainee experience evidence only:
Name of CTQP Trainee being supervised by the Qualified Inspector:

CTQP Trainee

I certify the Pile Driving Record accuracy and that the named above Trainee has observed the full pile installation:

Qualified Inspector (Signature)

700-010-60
Construction
11/11

PILE DRIVING LOG

9/25

DOZER CROSSING Structure No. 790201	Bent/Pier No. 3-2	Pile No. 1

Depth	Blows	Stroke/ Pressure	Note No.	Depth	Blows	Stroke/ Pressure	Note No.	Depth	Blows	Stroke/ Pressure	Note No.	Depth	Blows	Stroke/ Pressure	Note No.
0-1				33-34	40	5.78	1	66-67	42	8.25	4	99-100	120	8.30	6/7
1-2				34-35	46	5.84	1/2	67-68	34	8.19	4	100-101	145	8.44	7/9
2-3				35-36	46	5.98	2/1	68-69	37	8.22	4	101-101.5	97	8.90	9/14
3-4				36-37	82	5.16	1	69-70	42	8.15	4	101'7"	18	9.40	9
4-5				37-38	101	5.15	1	70-71	43	8.06	4	101'8"	19	9.40	9/5
5-6				38-39	99	5.21	1	71-72	49	8.05	4/13				
6-7				39-40	103	5.34	1/11/2	72-73	57	7.39	11/4				
7-8				40-41	68	6.10	2/3	73-74	54	7.60	4				
8-9				41-42	46	7.10	3	74-75	45	8.03	4				
9-10				42-43	56	7.05	3	75-76	56	8.18	4/5				
10-11				43-44	41	7.15	3/4	76-77	48	8.22	5/6				
11-12				44-45	43	7.32	4	77-78	82	8.30	6/7				
12-13				45-46	43	7.37	4	78-79	82	8.49	7				
13-14				46-47	39	7.38	4	79-80	117	8.71	7/8				
14-15				47-48	44	7.46	4	80-81	140	8.83	8/9				
15-16				48-49	44	7.36	4	81-82	143	8.65	9/10				
16-17				49-50	50	7.52	4	82-83	155	9.26	500				
17-18				50-51	52	7.50	4	83-84	108	9.25	500				
18-19				51-52	53	7.86	4	84-85	105	9.18	10				
19-20				52-53	47	7.93	4	85-86	97	9.12	10				
20-21				53-54	43	8.08	4	86-87	77	9.04	10				
21-22				54-55	44	7.88	4	87-88	65	9.06	10/3				
22-23				55-56	45	8.11	4	88-89	66	9.02	9/3				
23-24				56-57	53	7.96	4	89-90	70	7.73	3/4				
24-25	48	4.7	11/1	57-58	42	8.09	4	90-91	82	7.52	4				
25-26	43	5.0	1	58-59	45	8.10	4	91-92	53	8.62	4				
26-27	49	5.2	1	59-60	44	8.08	4	92-93	65	8.26	4				
27-28	48	5.5	1	60-61	47	7.93	4	93-94	86	7.90	4/13/11				
28-29	24	5.5	1	61-62	37	8.36	4	94-95	78	7.88	4				
29-30	31	5.53	1	62-63	45	8.26	4	95-96	81	7.87	4				
30-31	33	5.64	1	63-64	39	8.24	4	96-97	86	7.81	4				
31-32	32	5.76	1	64-65	42	8.19	4	97-98	77	7.70	4				
32-33	33	5.82	1	65-66	44	8.09	4	98-99	100	7.92	4/6				

START 1:41 PM
AT [illegible] PDA [illegible]
CHANGE PILE CUSHION [illegible] COMPRESSED TO 12" 2322 Blows
CHANGE PILE CUSHION [illegible] COMPRESSED TO 1040 Blows

9/11 9/19 [illegible] Blow

EDC DATA AND REPORT BY APPLIED FOUNDATION TESTING, INC.

SMARTPILE

SmartPile™ EDC REPORT

SmartPile(TM) Review Version 4.041b
Disabled Error Detection Levels: None

FSU Carbon Fiber Research **End Bent 31** **Pile 1**

****Warning: Repeated Mechanical Errors Detected, Seek Further Professional Data Analysis**

User Information

CEI Name Don Robertson
Company Name Applied Foundation Testing
City Green Cove Springs
State Florida
Zip 32043
Certification ID 000FL000001
Phone Number 9042841337

Project Information

Project Name FSU Carbon Fiber Research
City Deland
State Fl
County/District D5
Project Number (DOT) 408464-1-52-01
Project Description FSU Carbon Fiber Research Piles
Structure 790206
Description I-4 Wildlife Crossing
Latitude
Longitude

Notes

174

Drive Duration:From 01-23-2014 14:37:06 to 01-23-2014 16:46:21

Pile Information

Structure	End Bent 31	
Pile Number	1	
Pile Length	100	Feet
Pile Marker Increment	1	Feet
Set Check Marker Increment	1	inches
Top Gage to Pile Top	48	inches
Tip Gage to Pile Tip	24	inches
d Dimension	24	inches
Mid Gage to Pile Tip	588	inches
Top Cross-Section Area	576	inches 2
Tip Cross-Section Area	576	inches 2
Modulus of Elasticity	6046.829992	KSI
Concrete Specific Weight	0.145	K/ft 3
Wave Speed	13900	Feet/sec
Fixed Jc Damping Coefficient	0.4	
Pile Tip UP Soil Rate Factor	0.92	
Air Hammer/Multipeak	FALSE	
Hammer		
Nominal Bearing Resistance	1	Tons
Tension Resistance	1	Tons
Minimum Tip Elevation	1	Feet
Jet/PreForm Elevation	1	Feet
Pile Cut-Off Elevation	1	Feet
Radio 1 ID	00.A0.96.30.2D.43	
Radio 1 FW Version	517	

*****Average at identified displacement unless a single blow or indicated otherwise in header (e.g. Tension)***

Displacement (Feet)	Blow Number	Blows per Foot to Disp	Stroke/BPM (Feet)	Energy (Kips-ft)	Fixed Jc Capacity (Kips)	UF Capacity (Kips)	Wave Speed (Feet/sec)	Top Compression (Ksi)	Tip Compression (Ksi)	Max Tension (Ksi)	MPI	Top Preload Delta (uStrain)	Tip Preload Delta (uStrain)
-22.00	1	10	4.5	19.0	137.6	130.0	14679.9	1.4	0.3	1.1	94.2	-27.4	-54.2
-24.00	17	5	5.7	21.7	197.4	223.8	14487.3	1.7	0.3	1.2	95.8	-2.0	0.6
-25.00	23	6	5.7	22.2	218.7	257.2	14438.4	1.8	0.3	1.2	100.0	-1.6	0.3
-26.00	29	6	5.7	21.8	246.7	287.2	14398.3	1.8	0.3	1.2	98.5	-1.4	-2.4
-27.00	36	7	5.8	23.1	236.4	266.4	14348.7	1.8	0.4	1.3	100.0	-1.9	-5.9
-28.00	43	7	6.0	25.3	218.3	233.0	14325.3	1.9	0.4	1.3	97.3	-1.1	-7.2
-29.00	50	7	5.9	26.1	198.1	212.7	14304.0	1.9	0.4	1.2	97.7	-0.4	-3.9
-30.00	60	10	6.0	27.2	192.0	203.8	14272.7	1.9	0.4	1.3	98.0	-0.5	-5.6
-31.00	70	10	6.0	27.8	170.6	183.0	14237.0	1.9	0.4	1.3	97.9	-0.7	-5.0
-32.00	80	10	6.0	28.6	155.7	176.3	14205.4	2.0	0.5	1.3	98.4	-0.5	-5.1
-33.00	92	12	6.2	30.4	148.3	186.4	14176.8	2.0	0.5	1.3	99.0	-0.5	-4.7
-34.00	105	13	6.2	31.1	151.8	194.7	14163.2	2.0	0.5	1.3	99.0	0.3	-5.1
-35.00	120	15	6.4	31.4	168.9	208.2	14137.9	2.1	0.5	1.3	99.0	0.7	-5.4
-36.00	133	13	6.4	31.6	184.0	208.0	14122.4	2.1	0.6	1.3	99.4	1.0	-3.3
-37.00	149	16	6.5	31.9	188.9	207.3	14116.9	2.1	0.6	1.3	100.0	1.4	-3.7
-38.00	172	21	6.2	29.3	215.7	251.8	14106.9	2.0	0.6	1.2	100.0	2.4	-4.4
-39.00	197	25	6.2	29.6	218.5	305.3	14117.8	2.0	0.7	1.2	100.0	2.7	-6.3
-40.00	223	26	6.4	30.5	229.0	353.5	14124.0	2.1	0.7	1.2	100.0	3.0	-5.4
-41.00	249	26	6.6	31.9	254.1	349.0	14121.7	2.2	0.8	1.2	100.0	3.9	-6.0
-42.00	275	26	7.4	38.3	254.0	417.4	14101.5	2.4	0.8	1.3	100.0	2.8	-8.0
-43.00	305	30	7.4	38.8	251.2	395.8	14106.8	2.4	0.8	1.3	100.0	4.0	-8.1
-44.00	332	27	7.3	37.5	252.5	321.4	14107.6	2.3	0.7	1.2	100.0	3.4	-8.4
-45.00	350	18	7.2	37.5	276.4	248.5	14083.1	2.3	0.6	1.2	100.0	2.9	-5.4

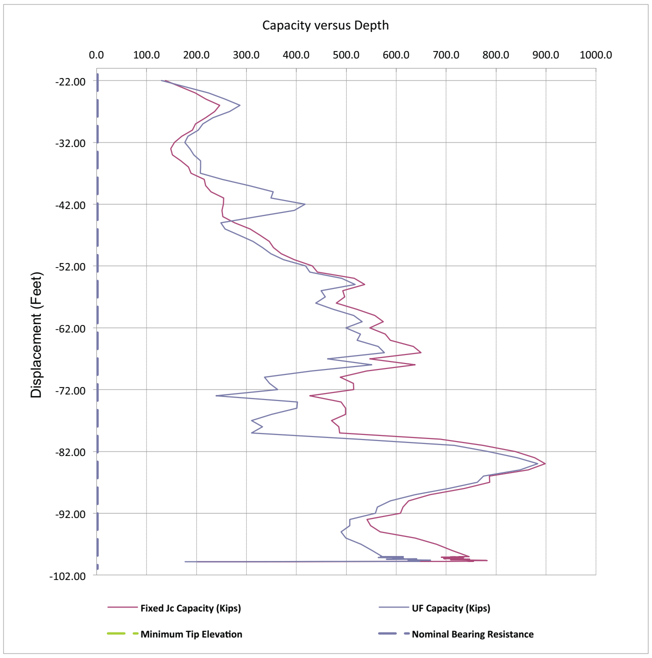
Displacement (Feet)	Blow Number	Blows per Foot to Disp	Stroke/BPM (Feet)	Energy (Kips-ft)	Fixed Jc Capacity (Kips)	UF Capacity (Kips)	Wave Speed (Feet/sec)	Top Compression (Ksi)	Tip Compression (Ksi)	Max Tension (Ksi)	MPI	Top Preload Delta (uStrain)	Tip Preload Delta (uStrain)
-46.00	367	17	7.3	36.9	307.4	257.3	14053.9	2.3	0.6	1.2	100.0	3.0	-5.9
-47.00	389	22	7.4	37.3	327.4	285.5	14058.2	2.4	0.5	1.2	100.0	3.5	-4.5
-48.00	411	22	7.5	36.8	345.9	313.1	14084.3	2.4	0.5	1.2	99.1	3.3	-6.5
-49.00	433	22	7.4	35.4	354.2	332.1	14073.4	2.3	0.5	1.1	97.1	4.0	-5.8
-50.00	455	22	7.7	37.6	370.0	349.2	14038.7	2.4	0.6	1.1	94.7	3.6	-6.2
-51.00	478	23	7.9	39.1	395.9	374.7	14024.2	2.5	0.6	1.1	91.7	3.6	-7.4
-52.00	506	28	8.0	38.4	431.8	418.3	14013.8	2.4	0.6	1.1	88.1	5.0	-5.6
-53.00	536	30	8.4	41.7	442.1	426.7	14022.7	2.6	0.7	1.1	85.2	4.9	-6.5
-54.00	572	36	8.8	44.5	515.8	490.5	14008.5	2.6	0.7	1.2	83.9	4.0	-8.6
-55.00	594	22	8.8	43.4	536.9	517.8	13889.1	2.7	0.7	1.1	84.1	4.7	-6.8
-56.00	626	32	8.7	47.0	492.6	449.6	13905.2	2.7	0.8	1.2	83.1	5.0	-8.7
-57.00	657	31	8.8	48.2	496.9	457.6	13905.5	2.8	0.8	1.3	81.6	5.3	-11.7
-58.00	687	30	8.7	48.2	480.1	438.9	13885.2	2.8	0.8	1.4	81.2	5.8	-11.5
-59.00	719	32	8.7	47.3	521.1	473.9	13899.9	2.9	0.8	1.4	81.0	6.4	-13.0
-60.00	747	28	8.8	48.3	557.2	515.0	13881.1	3.0	0.8	1.3	80.5	5.5	-13.3
-61.00	774	27	8.8	49.1	574.1	531.5	13864.5	3.0	0.8	1.5	80.0	5.6	-13.7
-62.00	804	30	8.8	49.5	546.8	498.9	13869.3	3.0	0.8	1.5	79.5	6.4	-18.2
-63.00	839	35	8.8	48.4	578.1	528.3	13840.8	3.1	0.8	1.4	80.2	7.2	-21.4
-64.00	869	30	8.9	49.7	588.3	521.9	13794.6	3.1	0.8	1.3	81.0	8.0	-23.2
-65.00	899	30	9.0	49.0	634.2	563.9	13769.0	3.2	0.8	1.3	81.7	7.6	-24.6
-66.00	931	32	9.1	48.6	649.6	576.3	13781.4	3.2	0.7	1.3	83.3	8.4	-22.9
-67.00	961	30	9.1	50.4	547.1	462.2	13801.8	3.2	0.7	1.4	84.7	8.8	-27.1
-68.00	986	25	9.2	48.4	637.6	551.2	13779.4	3.2	0.7	1.4	85.4	10.3	-28.4
-69.00	1021	35	9.4	50.4	540.7	430.2	13774.8	3.3	0.6	1.5	85.9	12.5	-30.1
-70.00	1056	35	9.4	51.5	487.5	336.3	13779.7	3.2	0.6	1.5	87.0	14.1	-32.8
-71.00	1092	36	9.3	51.0	514.4	346.1	13753.7	3.2	0.6	1.6	87.7	14.1	-32.8
-72.00	1126	34	9.4	48.7	515.0	362.8	13738.2	3.2	0.5	1.6	88.0	13.9	-32.2
-73.00	1161	35	9.2	48.8	426.9	238.9	13726.4	3.1	0.5	1.4	88.6	14.0	-31.2
-74.00	1203	42	9.3	43.2	489.7	402.1	13713.6	3.0	0.5	1.3	89.0	13.8	-29.9
-75.00	1242	39	9.3	41.0	498.2	401.0	13683.4	3.0	0.5	1.1	89.2	14.2	-29.8
-76.00	1282	40	9.4	40.8	498.4	350.3	13701.0	2.9	0.4	1.0	90.5	13.2	-29.4
-77.00	1320	35	9.2	38.2	470.1	310.1	13675.9	2.7	0.4	1.1	91.6	13.2	-30.8
-78.00	1360	40	8.4	36.7	485.0	332.0	13679.2	2.5	0.4	0.9	92.8	13.7	-21.8
-79.00	1423	63	8.9	42.6	486.5	310.0	13651.6	2.9	0.5	0.9	91.5	13.8	-18.2
-80.00	1493	70	9.0	43.8	687.9	521.3	13806.1	2.9	0.8	0.7	89.0	14.7	-4.3
-81.00	1560	67	9.0	43.9	773.9	715.9	14003.9	2.9	1.1	0.6	86.6	15.6	-2.0
-82.00	1640	80	9.1	45.6	838.4	784.1	14074.3	2.9	1.4	0.6	85.2	12.9	-4.4
-83.00	1720	80	9.2	46.6	877.3	842.6	14149.8	3.0	1.6	0.6	84.9	11.9	-4.9
-84.00	1815	95	9.3	46.5	898.3	883.4	14227.2	3.0	1.6	0.7	84.7	12.2	-4.7
-85.00	1903	88	9.4	47.8	864.2	848.0	14260.2	3.1	1.6	0.9	86.0	12.1	-4.4
-86.00	1987	84	9.4	49.0	786.5	774.8	14178.7	3.2	1.5	1.1	86.1	13.3	-4.4
-87.00	2075	88	9.5	50.2	787.4	762.5	14093.9	3.3	1.4	1.1	87.3	13.6	-5.0
-88.00	2129	54	9.5	50.8	736.4	704.8	14065.2	3.4	1.2	1.1	87.8	14.0	-5.7
-89.00	2188	59	9.5	51.0	667.7	637.9	14027.1	3.4	1.1	1.2	86.4	14.7	-8.4
-90.00	2246	58	9.5	50.4	625.0	587.9	14024.1	3.5	1.1	1.1	86.0	15.5	-11.4
-91.00	2300	54	9.4	49.3	613.4	561.9	14025.1	3.4	0.9	1.3	86.8	16.8	-12.2
-92.00	2351	51	9.5	50.0	608.5	558.4	14022.5	3.4	0.9	1.2	87.0	15.6	-10.0
-93.00	2401	50	9.4	48.7	541.6	506.9	13990.0	3.3	0.9	1.1	87.6	16.4	-10.7
-94.00	2451	50	9.5	46.6	548.6	506.9	14026.9	3.2	0.8	1.0	88.6	18.1	-11.6
-95.00	2509	58	9.5	44.9	567.8	489.7	14058.8	3.1	0.8	0.9	90.3	18.9	-9.1
-96.00	2566	57	9.7	44.3	637.6	499.0	14076.4	3.0	0.8	0.7	93.9	19.3	-6.8
-97.00	2624	58	9.7	42.8	680.6	529.5	14054.8	3.0	0.8	0.5	97.7	18.8	-4.4
-98.00	2690	66	9.8	43.1	711.6	551.2	13994.6	3.2	0.9	0.6	99.4	19.5	-3.1
-99.00	2736	46	9.9	44.3	746.1	572.3	13938.2	3.3	0.9	0.5	100.0	20.8	-1.9
-99.00	2736		9.9	45.0	726.0	572.0	13921.7	3.4	1.0	0.4	100.0	20.1	3.1
-99.02	2737		10.1	46.7	735.0	614.0	13921.9	3.4	1.0	0.5	100.0	20.4	-1.3
-99.04	2738		9.8	47.1	737.0	609.0	13926.7	3.5	1.0	0.5	100.0	21.6	-3.2
-99.07	2739		9.8	45.1	708.0	594.0	13926.7	3.4	1.0	0.5	100.0	23.0	-3.6
-99.09	2740		9.7	45.3	718.0	568.0	13926.7	3.5	1.0	0.4	100.0	21.6	-2.8
-99.11	2741		9.7	43.8	722.0	592.0	13926.7	3.4	1.0	0.5	100.0	23.0	-2.8
-99.13	2742		9.6	46.1	690.0	603.0	13926.7	3.4	1.0	0.4	100.0	23.0	-2.5
-99.15	2743		9.8	45.7	733.0	611.0	13931.6	3.4	0.9	0.4	100.0	22.2	2.7
-99.17	2744		9.7	48.4	730.0	564.0	13931.8	3.6	1.0	0.5	99.0	23.0	1.2
-99.20	2745		9.7	46.7	731.0	614.0	13936.5	3.5	1.0	0.4	99.0	23.0	-0.1

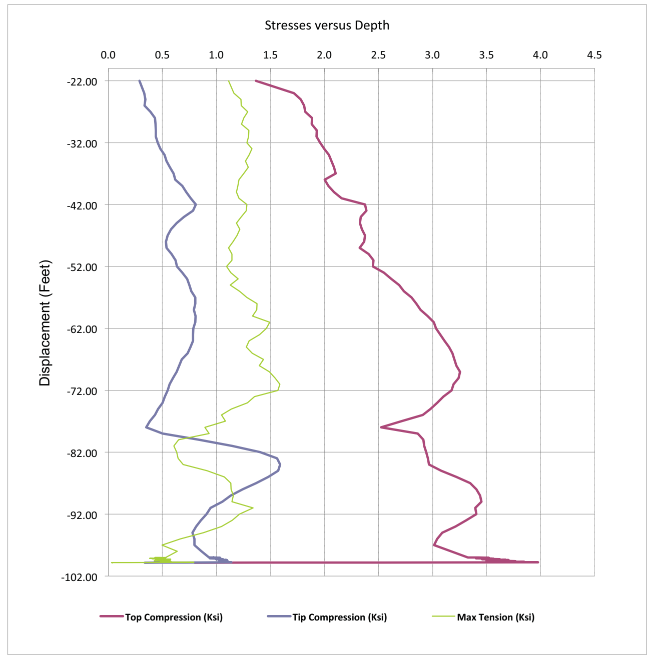
Displacement (Feet)	Blow Number	Blows per Foot to Disp	Stroke/BPM (Feet)	Energy (Kips-ft)	Fixed Jc Capacity (Kips)	UF Capacity (Kips)	Wave Speed (Feet/sec)	Top Compression (Ksi)	Tip Compression (Ksi)	Max Tension (Ksi)	MPI	Top Preload Delta (uStrain)	Tip Preload Delta (uStrain)
-99.22	2746		9.6	47.3	735.0	612.0	13937.0	3.6	1.0	0.5	99.0	24.5	0.1
-99.24	2747		9.9	47.1	713.0	599.0	13936.5	3.5	1.0	0.4	99.0	23.5	-0.5
-99.26	2748		9.8	48.2	700.0	602.0	13937.0	3.6	1.1	0.6	99.0	24.5	0.5
-99.28	2749		9.6	46.3	706.0	604.0	13936.5	3.5	1.0	0.4	99.0	23.6	-0.2
-99.30	2750		9.4	47.8	695.0	593.0	13937.0	3.6	1.0	0.5	99.0	23.0	1.2
-99.33	2751		9.5	47.0	700.0	602.0	13931.6	3.5	1.1	0.5	99.0	23.8	-4.7
-99.35	2752		9.6	48.2	695.0	615.0	13931.8	3.6	1.1	0.5	98.0	24.1	2.3
-99.37	2753		9.6	49.2	720.0	616.0	13931.6	3.7	1.0	0.6	99.0	24.5	-0.6
-99.39	2754		9.7	48.3	729.0	641.0	13931.8	3.6	1.1	0.6	98.0	24.5	-1.6
-99.41	2755		9.8	48.1	747.0	580.0	13931.6	3.7	1.1	0.6	98.0	24.5	0.5
-99.43	2756		9.9	49.3	734.0	637.0	13931.8	3.7	1.1	0.5	98.0	23.0	0.5
-99.46	2757		9.9	48.2	731.0	630.0	13926.7	3.7	1.1	0.5	98.0	24.5	-0.2
-99.48	2758		9.8	47.9	739.0	637.0	13926.7	3.6	1.1	0.5	98.0	24.5	0.5
-99.50	2759		9.7	48.6	739.0	623.0	13926.7	3.7	1.0	0.5	98.0	24.5	1.2
-99.52	2760		9.8	47.4	725.0	625.0	13926.7	3.6	1.0	0.6	98.0	24.5	0.1
-99.54	2761		9.7	46.2	709.0	626.0	13921.8	3.5	1.0	0.4	98.0	24.5	2.3
-99.57	2762		9.6	49.0	746.0	654.0	13921.5	3.7	1.1	0.5	98.0	25.5	1.6
-99.59	2763		9.8	49.9	742.0	661.0	13921.8	3.8	1.1	0.6	98.0	24.5	0.9
-99.61	2764		9.9	48.0	777.0	669.0	13916.4	3.7	1.1	0.6	98.0	27.4	-1.7
-99.63	2765		9.8	49.3	780.0	664.0	13912.0	3.8	1.1	0.6	97.0	28.2	2.0
-99.65	2766		9.8	45.4	782.0	625.0	13911.2	3.7	1.1	0.6	98.0	29.6	2.0
-99.67	2767		9.7	51.5	751.0	638.0	13912.0	3.8	1.1	0.5	97.0	30.4	3.8
-99.70	2768		10.0	54.4	742.0	624.0	13911.2	3.8	1.1	0.5	97.0	30.9	-0.2
-99.72	2769		9.7	54.0	749.0	648.0	13912.0	3.8	1.1	0.5	97.0	30.4	2.7
-99.74	2770		9.7	53.4	744.0	628.0	13911.2	3.8	1.1	0.5	97.0	31.8	2.7
-99.76	2771		9.6	54.3	755.0	647.0	13912.0	3.9	1.1	0.5	97.0	33.3	0.1
-99.78	2772		9.8	51.8	697.0	606.0	13916.4	4.0	1.1	0.8	97.0	34.8	0.9
-99.80	2773		8.5	26.5	595.0	454.0	13912.0	2.5	0.7	0.2	97.0	34.8	-1.4
-99.83	2774		6.5	13.8	393.0	291.0	13911.2	1.4	0.5	0.0	96.0	35.8	-5.0
-99.85	2775	40	4.5	11.3	202.0	177.0	13899.3	0.8	0.3	0.0	96.0	34.8	-4.9

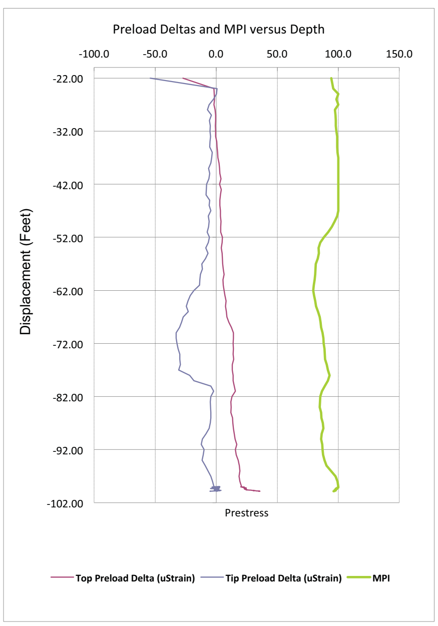
SMARTPILE

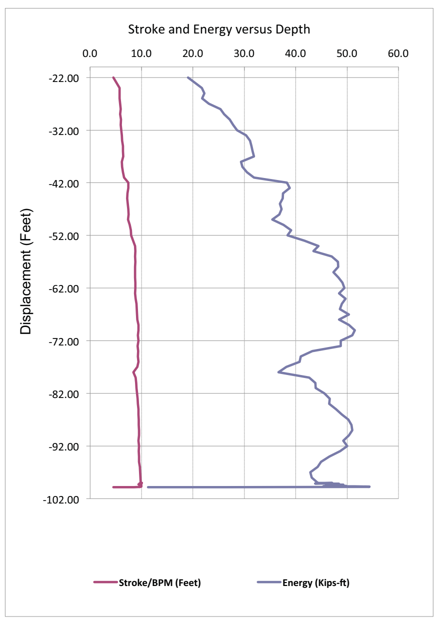
SmartPile™ EDC REPORT

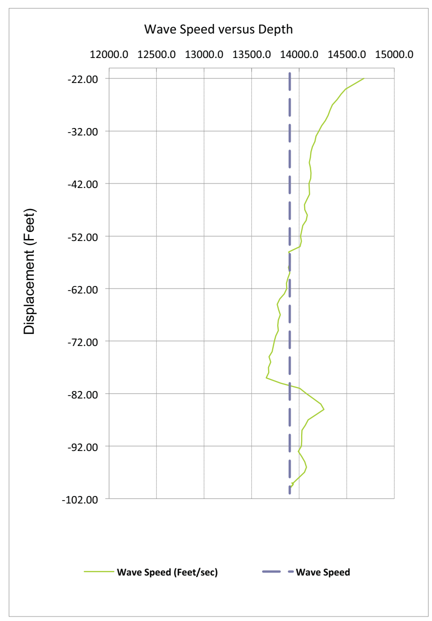
FSU Carbon Fiber Research **End Bent 31** **Pile 1** 2

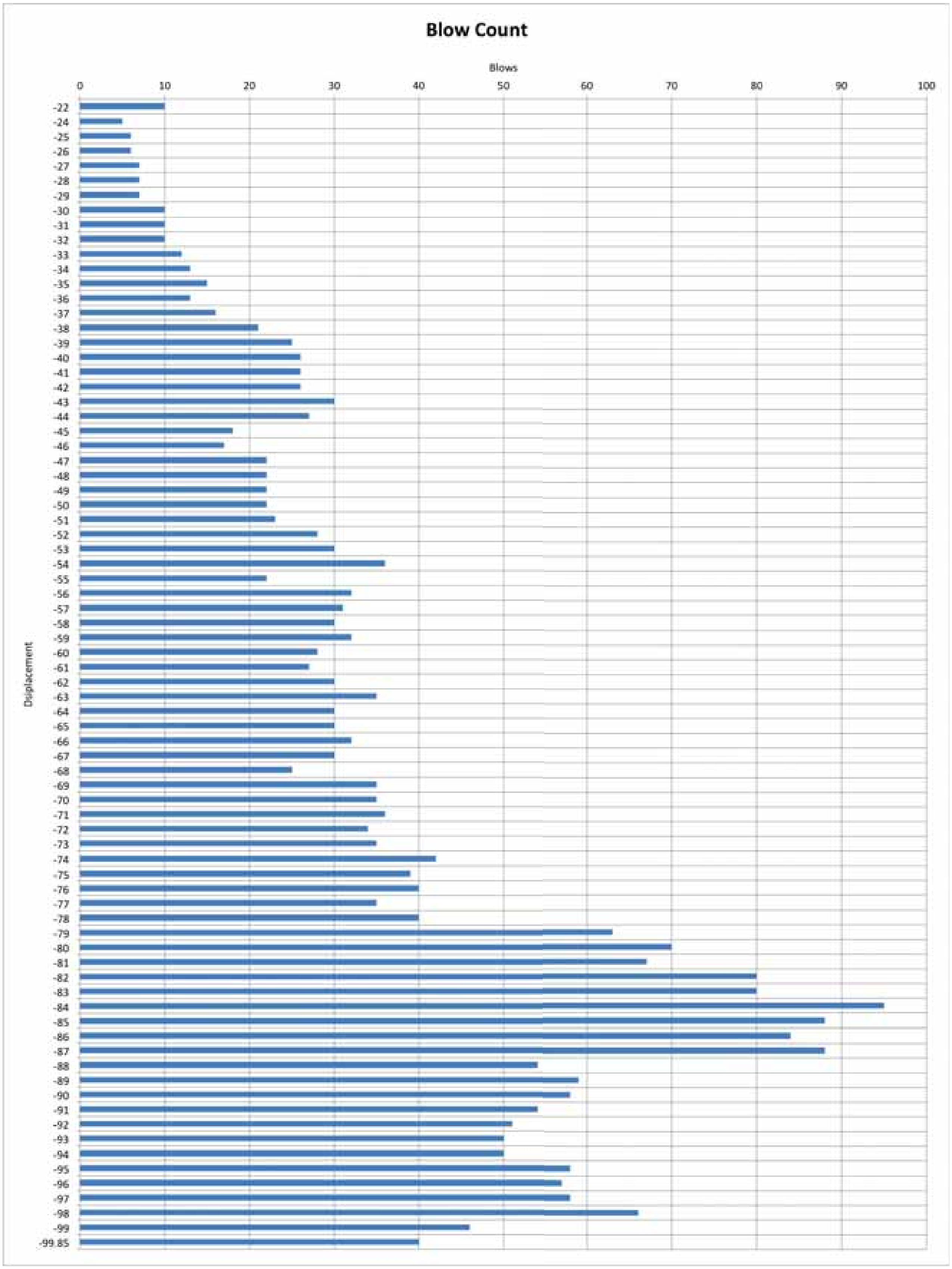











Blow Count
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PDA DATA AND REPORT BY GRL ENGINEERS, INC.

Subject: FW: PDA Testing Results - CFCC Piles
From: "Potter, William" <William.Potter@dot.state.fl.us>
Date: Tue, 28 Jan 2014 16:18:49 +0000
To: Michelle Roddenberry <mroddenberry@fsu.edu>

fyi

Will Potter, P.E.
Florida Department of Transportation
M. H. Ansley Structures Research Center
850-921-7106

From: Herrera, Rodrigo
Sent: Monday, January 27, 2014 8:10 AM
To: Robertson, Robert; Jones, Larry; Fallaha, Sam; Potter, William
Subject: FW: PDA Testing Results - CFCC Piles

FYI

Rodrigo Herrera, P.E.
Asst. State Geotechnical Engineer
Florida Department of Transportation
605 Suwannee Street, MS 33
Tallahassee, FL 32399-0450
Phone: (850) 414-4377

From: MHGRLFL@aol.com [mailto:MHGRLFL@aol.com]
Sent: Sunday, January 26, 2014 10:10 PM
To: Hipworth, Robert; Herrera, Rodrigo
Cc: grl-fl@grlengineers.com
Subject: PDA Testing Results - CFCC Piles

Gentlemen,

This report presents the results of the Pile Driving Analyzer® (PDA) dynamic pile testing performed during the installation of two 24-inch square, 100 feet long, experimental prestressed concrete piles utilizing CFCC (carbon fiber composite cable) prestressing strands and spiral reinforcements. Information regarding the structural pile design and specifics about these research piles may be found in the FDOT's Structures Office documents. Two each reusable strain transducers and accelerometers were bolted on opposite pile sides five feet below each pile top for the PDA data acquisition. An APE D 46-42 open-ended (i.e., single-acting) diesel hammer with a ram weight of 10.1 kips was used to drive and test the piles. A pile driving inspector on site monitored the pile installations and kept pile driving blow count logs. The piles were driven at the I-4 widening project site in District 5 close to the Deer Crossing Bridge No.

790207 near End Bent 3-1 in the vicinity of soil boring DC-1. The two piles were referred to as: CFCC West Pile N1 and CFCC East Pile N2.

The attached pdf file contains the PDA testing results, along with copies of the inspector's pile driving logs (as provided to us) and the soil boring. The PDA w01 data files are too large to attach here and can be obtained by the following weblinks:

CFCC EAST PILE N2-MH.w01

https://grlfl.pile.com:5001/fbsharing/60kPljez

CFCC WEST PILE N1-MH.w01

https://grlfl.pile.com:5001/fbsharing/u1eivlO0

These links will be available for one month. The server will ask for a password, which is fdot (all lowercase).

The PDA results in the attached file are presented in table and graph forms as functions of hammer blow number, pile "penetration" depth below the template reference used by the inspector in recording the pile driving blow counts, and pile tip elevations. The references had reported elevations of approximately +53 feet, and were approximately seven feet above existing ground surface. The results include:

CSX: maximum measured pile compressing stress at the gages (averaged from the two transducers at opposite pile faces) located five feet below pile top, ksi,

CSI: maximum measured pile compressing stress by the higher of the two individual gages located five feet below pile top, ksi,

CSB: maximum computed pile toe compression stresses, ksi,

TSX: maximum computed pile tension stress throughout pile length, ksi,

STK: hammer ram stroke height, ft,

EMX: maximum energy transferred to the pile top at the gages location, kip-ft,

BTA: pile integrity assessment factor,

RX0: total soil resistance to pile driving (static and dynamic), kips,

RX5: pile static ultimate load bearing capacity computed with a Case Damping Factor Jc = 0.5 based on correlations with CAPWAP data analyses with the RMX Case Method equation obtained from the Test Piles driving program for the production work for the bridge construction, kips.

The data indicated a pile material one-dimensional stresswave speed of 14,050 feet/second, which corresponds to a dynamic elastic modulus of 6,178 ksi assuming a material unit weight of 145 lbs/ft3.

Pile N1 was driven on January 23rd afternoon. Pile top cushion consisted of sheets of plywood with an initial total thickness of 8.75 inches. The pile cushion was changes when the pile had a “penetration” 77 feet below reference. The pile was driven to a final tip elevation of -47 feet. Pile driving was stopped due to concrete spalling at pile top. The pile was subjected to a total of 2,765 hammer blows.

Pile N2 was driven during the morning of January 24th. Pile top cushion consisted of sheets of plywood with a total thickness of 6 inches. The pile cushion was changed at pile “penetrations” below reference of 70, 84, and 93 feet. The pile was driven to a final tip elevation of -51 feet. Pile driving was stopped due to concrete spalling at pile top. The pile was subjected to a total of 3,139 hammer blows. When the pile was at “penetration” below reference of approximately 55 feet, two small cracks (a few feet apart along pile length) were observed in the pile at about mid pile length. These minor cracks evidently did not produce stresswave reflections of the type that would've been characteristically typically present in the test records within the first time cycle of strtesswave travel in the pile. Their presence in the pile may possibly be surmised from the data by the minor distortion to the 2L/c reflection characteristics, reduction in the overall stresswave speed, and overall trend and characteristics in the wave-up records. The pile was subjected to about 2500 additional hammer blows with high stroke heights and pile stress levels after the cracks were observed in the pile without further indications of pile damage.

We appreciate the opportunity to provide our PDA field testing services during the field pile driving phase of these interesting experimental piles. Please confirm receipt of this e-mail and the successful downloading of the data files by the provided weblinks, and let us know if you have any questions or if we may be of further assistance.

Regards,

Mohamad Hussein, P.E.
Marty Bixler, P.E.
GRL Engineers, Inc.

Attachments:
PileDrivingAnalyzerPDATestingResultsPilesN1andN2.pdf 797 KB

GRL Engineers, Inc.

Pile Driving Analyzer® (PDA) Dynamic Pile Testing Results
Pile Driving Logs (as provided to us by the field inspector)
Site Layout and Soil Boring

24-inch square precast concrete piles with CFCC strands and spirals

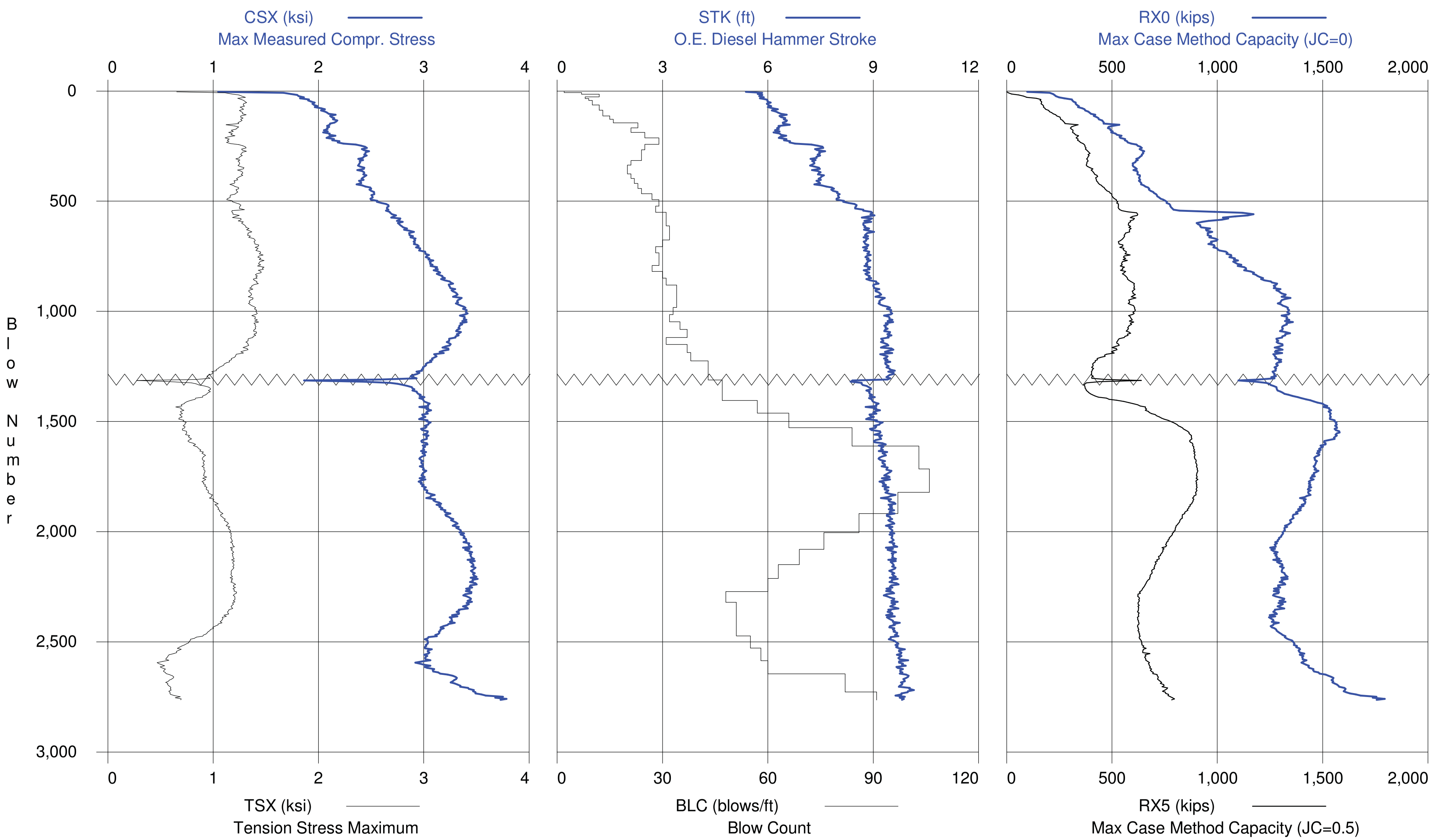
Pile N1
Pile N2

PDIPLOT Ver. 2014.1 - Printed: 25-Jan-2014

GRL Engineers, Inc. - Case Method & iCAP® Results

Test date: 23-Jan-2014

I-4 DEER CROSSING Bridge No. 790207 - CFCC WEST PILE N1



CHANGE PILE 1 - ON

I-4 DEER CROSSING Bridge No. 790207 - CFCC WEST PILE N1 APE D46-42 HAMMER
OP: GRL-MGB Test date: 23-Jan-2014

AR: 576.00 in^2 SP: 0.145 k/ft3
LE: 95.00 ft EM: 6,178 ksi
WS: 14,050.0 f/s JC: 0.50

CSX: Max Measured Compr. Stress
CSI: Max F1 or F2 Compr. Stress
CSB: Compression Stress at Bottom
TSX: Tension Stress Maximum
STK: O.E. Diesel Hammer Stroke
EMX: Max Transferred Energy
BTA: BETA Integrity Factor
RX0: Max Case Method Capacity (JC=0)
RX5: Max Case Method Capacity (JC=0.5)

BL# end	BLC bl/ft	TYPE	CSX ksi	CSI ksi	CSB ksi	TSX ksi	STK ft	EMX k-ft	BTA (%)	RX0 kips	RX5 kips
5	2	AV5	1.05	1.27	0.17	0.65	5.37	19.77	81.6	97	0
10	7	AV5	1.67	1.93	0.34	1.11	5.83	22.45	93.8	204	8
15	12	AV5	1.74	2.01	0.37	1.18	5.72	21.77	98.0	220	23
20	12	AV5	1.80	2.07	0.38	1.25	5.84	22.30	100.0	227	57
25	12	AV5	1.81	2.09	0.39	1.27	5.75	22.07	100.0	233	81
30	8	AV5	1.86	2.14	0.42	1.31	5.88	22.57	96.0	249	95
35	9	AV5	1.82	2.04	0.46	1.23	5.77	21.60	97.8	273	141
40	9	AV5	1.91	2.14	0.52	1.27	5.95	24.04	95.2	310	163
45	10	AV5	1.90	2.14	0.52	1.29	5.99	22.60	100.0	312	159
50	10	AV5	1.93	2.17	0.52	1.31	5.99	22.71	100.0	317	166
55	10	AV5	1.96	2.20	0.54	1.32	6.08	23.55	100.0	328	166
60	10	AV5	1.94	2.18	0.54	1.29	5.97	22.79	100.0	327	163
65	12	AV5	1.96	2.20	0.54	1.29	6.01	22.79	100.0	334	171
70	12	AV5	1.99	2.22	0.56	1.30	6.10	23.57	100.0	343	176
75	12	AV5	1.96	2.19	0.55	1.26	6.00	22.63	100.0	339	175
80	12	AV5	2.03	2.24	0.59	1.28	6.14	24.57	100.0	359	182
85	12	AV5	2.06	2.28	0.61	1.29	6.28	25.56	100.0	370	185
90	13	AV5	2.02	2.24	0.61	1.25	6.12	24.15	100.0	374	200
95	13	AV5	2.06	2.28	0.64	1.27	6.23	25.43	100.0	388	204
100	13	AV5	2.08	2.31	0.64	1.28	6.29	25.45	100.0	393	214
105	13	AV5	2.10	2.33	0.65	1.28	6.38	25.89	100.0	400	221
110	13	AV5	2.16	2.43	0.69	1.31	6.54	27.77	100.0	420	233
115	15	AV5	2.11	2.35	0.68	1.26	6.33	26.15	100.0	414	238
120	15	AV5	2.13	2.39	0.70	1.26	6.38	26.29	100.0	428	253
125	15	AV5	2.15	2.43	0.71	1.28	6.50	26.70	100.0	435	255
130	16	AV5	2.14	2.41	0.72	1.26	6.46	26.30	100.0	438	256
135	16	AV5	2.18	2.46	0.74	1.27	6.54	27.12	100.0	454	267
140	16	AV5	2.17	2.45	0.75	1.26	6.53	27.07	100.0	457	269
145	23	AV5	2.15	2.44	0.76	1.24	6.43	26.68	100.0	461	276
150	23	AV5	2.11	2.37	0.76	1.24	6.43	25.50	100.0	461	277
155	23	AV5	2.11	2.31	0.90	1.12	6.62	25.44	100.0	536	339
160	23	AV5	2.08	2.30	0.86	1.21	6.31	25.31	100.0	501	319
165	23	AV5	2.10	2.34	0.83	1.24	6.33	25.78	100.0	484	308
170	21	AV5	2.08	2.32	0.81	1.23	6.26	25.13	100.0	480	303
175	21	AV5	2.09	2.34	0.84	1.22	6.31	25.34	100.0	492	308
180	21	AV5	2.05	2.32	0.84	1.17	6.20	24.40	100.0	493	316
185	21	AV5	2.09	2.35	0.86	1.19	6.33	25.24	100.0	504	315
190	25	AV5	2.05	2.30	0.84	1.15	6.16	24.06	100.0	497	313
195	25	AV5	2.11	2.36	0.88	1.18	6.34	25.42	100.0	518	322
200	25	AV5	2.10	2.35	0.89	1.17	6.37	25.37	100.0	524	326
205	25	AV5	2.16	2.41	0.93	1.21	6.53	26.56	100.0	546	341
210	25	AV5	2.10	2.33	0.91	1.14	6.36	24.82	100.0	536	335
215	29	AV5	2.08	2.32	0.92	1.11	6.31	24.43	100.0	539	330

I-4 DEER CROSSING Bridge No. 790207 - CFCC WEST PILE N1 APE D46-42 HAMMER
OP: GRL-MGB Test date: 23-Jan-2014

BL#	BLC	TYPE	CSX	CSI	CSB	TSX	STK	EMX	BTA	RX0	RX5
end	bl/ft		ksi	ksi	ksi	ksi	ft	k-ft	(%)	kips	kips
220	29	AV5	2.15	2.39	0.96	1.15	6.53	26.15	100.0	562	339
225	29	AV5	2.13	2.39	0.96	1.13	6.46	25.56	100.0	562	337
230	29	AV5	2.20	2.47	0.97	1.15	6.63	26.59	100.0	572	345
235	29	AV5	2.18	2.45	0.97	1.13	6.62	26.16	100.0	575	350
240	29	AV5	2.24	2.51	1.00	1.17	6.77	27.48	100.0	592	363
245	25	AV5	2.36	2.62	1.04	1.24	7.24	30.58	100.0	617	369
250	25	AV5	2.41	2.68	1.04	1.28	7.43	31.86	100.0	623	372
255	25	AV5	2.44	2.73	1.08	1.30	7.56	33.02	100.0	635	372
260	25	AV5	2.46	2.74	1.09	1.31	7.57	33.30	100.0	642	377
265	25	AV5	2.41	2.69	1.07	1.27	7.35	31.82	100.0	631	375
270	24	AV5	2.43	2.71	1.08	1.28	7.40	32.30	100.0	639	380
275	24	AV5	2.48	2.78	1.11	1.31	7.63	33.95	100.0	653	385
280	24	AV5	2.45	2.75	1.10	1.28	7.46	32.88	100.0	647	391
285	24	AV5	2.45	2.75	1.10	1.27	7.48	32.81	100.0	649	396
290	24	AV5	2.43	2.73	1.09	1.26	7.42	32.54	100.0	641	387
295	24	AV5	2.46	2.76	1.07	1.28	7.49	32.90	100.0	642	391
300	24	AV5	2.43	2.74	1.07	1.26	7.39	32.54	100.0	634	386
305	24	AV5	2.42	2.72	1.06	1.25	7.39	32.32	100.0	628	384
310	24	AV5	2.38	2.67	1.04	1.22	7.21	31.32	100.0	616	380
315	21	AV5	2.42	2.73	1.06	1.25	7.36	32.58	100.0	623	385
320	21	AV5	2.39	2.70	1.04	1.23	7.26	31.63	100.0	614	386
325	21	AV5	2.40	2.72	1.03	1.25	7.32	31.92	100.0	611	382
330	21	AV5	2.39	2.71	0.97	1.25	7.32	31.17	100.0	599	382
335	21	AV5	2.39	2.71	1.00	1.25	7.28	31.53	100.0	600	379
340	20	AV5	2.38	2.70	1.01	1.24	7.21	31.50	100.0	598	378
345	20	AV5	2.39	2.73	1.01	1.26	7.32	31.95	100.0	602	384
350	20	AV5	2.43	2.78	1.02	1.29	7.45	32.75	100.0	611	396
355	20	AV5	2.43	2.80	1.02	1.29	7.48	32.53	100.0	618	410
360	20	AV5	2.37	2.75	0.99	1.23	7.25	30.68	100.0	602	401
365	20	AV5	2.42	2.81	1.02	1.26	7.43	32.24	100.0	620	407
370	20	AV5	2.43	2.82	1.02	1.28	7.50	32.71	100.0	623	411
375	20	AV5	2.43	2.82	1.01	1.28	7.45	32.42	100.0	621	415
380	21	AV5	2.43	2.81	1.00	1.27	7.42	32.18	100.0	622	419
385	21	AV5	2.46	2.85	1.01	1.28	7.60	32.97	100.0	633	428
390	21	AV5	2.44	2.83	1.00	1.25	7.53	32.35	100.0	632	432
395	21	AV5	2.42	2.83	1.00	1.24	7.50	32.09	100.0	628	423
400	22	AV5	2.41	2.81	1.00	1.22	7.45	31.59	100.0	630	424
405	22	AV5	2.43	2.84	1.01	1.23	7.51	32.21	100.0	634	426
410	22	AV5	2.39	2.79	1.00	1.20	7.39	31.15	100.0	628	426
415	22	AV5	2.40	2.81	1.01	1.21	7.45	31.62	100.0	635	432
420	23	AV5	2.41	2.81	1.02	1.20	7.49	31.70	100.0	639	436
425	23	AV5	2.36	2.76	1.01	1.16	7.32	30.27	100.0	638	441
430	23	AV5	2.41	2.80	1.03	1.19	7.53	31.73	100.0	651	451
435	23	AV5	2.45	2.82	1.05	1.21	7.66	32.69	100.0	659	454
440	23	AV5	2.49	2.86	1.07	1.24	7.82	33.88	100.0	671	463
445	24	AV5	2.50	2.87	1.08	1.24	7.89	34.37	100.0	677	466
450	24	AV5	2.48	2.86	1.08	1.22	7.81	33.72	100.0	676	470
455	24	AV5	2.50	2.88	1.09	1.22	7.86	34.23	100.0	684	476
460	24	AV5	2.53	2.90	1.11	1.23	7.99	34.87	100.0	696	489
465	24	AV5	2.53	2.91	1.11	1.22	7.97	34.69	100.0	700	491
470	27	AV5	2.53	2.84	1.09	1.21	8.04	34.13	100.0	710	501
475	27	AV5	2.50	2.71	1.10	1.16	7.99	33.84	100.0	713	499

I-4 DEER CROSSING Bridge No. 790207 - CFCC WEST PILE N1 APE D46-42 HAMMER
OP: GRL-MGB Test date: 23-Jan-2014

BL#	BLC	TYPE	CSX	CSI	CSB	TSX	STK	EMX	BTA	RX0	RX5
end	bl/ft		ksi	ksi	ksi	ksi	ft	k-ft	(%)	kips	kips
480	27	AV5	2.51	2.68	1.12	1.16	8.00	34.31	100.0	716	501
485	27	AV5	2.51	2.68	1.13	1.16	8.03	34.33	100.0	725	506
490	27	AV5	2.49	2.72	1.13	1.13	7.96	33.78	100.0	731	511
495	29	AV5	2.50	2.74	1.14	1.13	7.96	33.89	100.0	743	520
500	29	AV5	2.56	2.82	1.16	1.18	8.16	35.15	100.0	754	521
505	29	AV5	2.56	2.82	1.15	1.18	8.15	34.41	100.0	761	528
510	29	AV5	2.60	2.88	1.17	1.22	8.30	36.20	100.0	759	523
515	29	AV5	2.64	2.96	1.19	1.25	8.47	37.58	100.0	773	530
520	29	AV5	2.66	3.00	1.19	1.26	8.53	38.23	100.0	776	530
525	28	AV5	2.67	2.99	1.19	1.26	8.51	38.02	100.0	778	531
530	28	AV5	2.65	2.98	1.19	1.25	8.48	37.95	100.0	781	530
535	28	AV5	2.65	2.98	1.20	1.25	8.48	37.95	100.0	786	532
540	28	AV5	2.66	3.19	1.20	1.30	8.71	39.39	100.0	793	538
545	28	AV5	2.64	3.30	1.24	1.18	8.72	38.75	100.0	821	546
550	31	AV5	2.68	3.36	1.49	1.18	8.94	40.11	100.0	987	575
557	31	AV5	2.70	3.34	1.73	1.19	9.01	41.40	100.0	1,145	623
562	31	AV5	2.68	3.25	1.75	1.19	8.88	40.32	100.0	1,151	618
567	31	AV5	2.74	3.25	1.71	1.25	9.02	40.75	100.0	1,138	615
572	31	AV5	2.72	3.21	1.61	1.21	8.86	39.78	100.0	1,075	596
577	31	AV5	2.72	3.21	1.55	1.22	8.77	39.79	100.0	1,034	595
582	31	AV5	2.77	3.29	1.57	1.26	8.92	40.57	100.0	1,051	605
587	31	AV5	2.76	3.25	1.49	1.25	8.85	40.26	100.0	1,005	599
592	31	AV5	2.74	3.19	1.39	1.24	8.74	39.87	100.0	946	583
597	31	AV5	2.81	3.12	1.36	1.30	8.96	41.41	100.0	926	589
602	31	AV5	2.75	3.04	1.33	1.27	8.70	39.61	100.0	900	577
607	31	AV5	2.77	3.09	1.35	1.29	8.72	40.27	100.0	910	578
612	32	AV5	2.78	3.07	1.36	1.30	8.73	40.21	100.0	922	579
617	32	AV5	2.80	3.12	1.37	1.31	8.79	40.84	100.0	925	587
622	32	AV5	2.81	3.13	1.38	1.32	8.77	40.76	100.0	927	582
627	32	AV5	2.83	3.18	1.41	1.33	8.83	40.01	100.0	963	590
632	32	AV5	2.82	3.19	1.41	1.32	8.75	40.59	100.0	943	580
637	32	AV5	2.87	3.25	1.45	1.35	8.91	42.18	100.0	957	585
642	32	AV5	2.91	3.28	1.48	1.37	9.02	42.91	100.0	974	581
647	32	AV5	2.87	3.24	1.46	1.34	8.86	41.84	100.0	959	566
652	32	AV5	2.86	3.21	1.46	1.32	8.77	41.23	100.0	953	559
657	32	AV5	2.86	3.21	1.46	1.32	8.75	41.24	100.0	953	559
662	32	AV5	2.89	3.25	1.50	1.35	8.82	42.00	100.0	968	560
667	32	AV5	2.88	3.25	1.49	1.35	8.75	41.69	100.0	966	557
672	32	AV5	2.92	3.29	1.52	1.39	8.85	42.45	100.0	990	547
677	30	AV5	2.92	3.28	1.53	1.40	8.81	41.54	100.0	1,011	550
682	30	AV5	2.92	3.27	1.52	1.40	8.79	42.05	100.0	991	538
687	30	AV5	2.90	3.20	1.48	1.38	8.71	41.75	100.0	965	528
692	30	AV5	2.92	3.17	1.49	1.40	8.78	42.34	100.0	973	531
697	30	AV5	2.91	3.11	1.47	1.40	8.79	42.41	100.0	963	541
702	30	AV5	2.94	3.17	1.49	1.43	8.87	42.83	100.0	985	553
707	28	AV5	2.94	3.19	1.49	1.41	8.77	42.34	100.0	980	544
712	28	AV5	2.91	3.17	1.47	1.39	8.67	41.74	100.0	974	539
717	28	AV5	2.98	3.25	1.52	1.44	8.90	43.24	100.0	1,010	559
722	28	AV5	2.97	3.24	1.51	1.42	8.80	42.51	100.0	1,008	555
727	28	AV5	2.96	3.23	1.51	1.41	8.76	42.36	100.0	1,015	560
732	28	AV5	3.02	3.29	1.54	1.46	8.90	43.59	100.0	1,043	570
737	29	AV5	3.01	3.27	1.52	1.44	8.84	42.86	100.0	1,046	562

I-4 DEER CROSSING Bridge No. 790207 - CFCC WEST PILE N1 APE D46-42 HAMMER
OP: GRL-MGB Test date: 23-Jan-2014

BL#	BLC	TYPE	CSX	CSI	CSB	TSX	STK	EMX	BTA	RX0	RX5
end	bl/ft		ksi	ksi	ksi	ksi	ft	k-ft	(%)	kips	kips
742	29	AV5	3.01	3.27	1.51	1.43	8.83	42.87	100.0	1,044	563
747	29	AV5	3.05	3.31	1.53	1.48	8.94	43.98	100.0	1,071	588
752	29	AV5	3.03	3.27	1.51	1.44	8.82	42.96	100.0	1,065	557
757	29	AV5	3.03	3.27	1.49	1.42	8.78	42.72	100.0	1,061	555
762	29	AV5	3.05	3.29	1.49	1.45	8.87	42.61	100.0	1,084	564
767	29	AV5	3.06	3.30	1.49	1.45	8.84	42.75	100.0	1,084	557
772	29	AV5	3.09	3.32	1.50	1.49	8.94	43.97	100.0	1,097	573
777	29	AV5	3.04	3.24	1.44	1.43	8.80	42.47	100.0	1,071	544
782	29	AV5	3.07	3.29	1.44	1.45	8.85	42.80	100.0	1,091	548
787	29	AV5	3.06	3.29	1.42	1.43	8.80	41.87	100.0	1,098	545
792	27	AV5	3.09	3.31	1.44	1.45	8.83	42.50	100.0	1,111	549
797	27	AV5	3.06	3.27	1.41	1.42	8.72	42.04	100.0	1,095	537
802	27	AV5	3.14	3.37	1.45	1.50	8.97	43.73	100.0	1,139	565
807	27	AV5	3.10	3.33	1.42	1.46	8.81	42.60	100.0	1,128	545
812	27	AV5	3.14	3.36	1.44	1.48	8.91	43.76	100.0	1,143	554
817	27	AV5	3.10	3.31	1.42	1.43	8.73	42.40	100.0	1,131	545
822	30	AV5	3.14	3.35	1.46	1.45	8.82	42.80	100.0	1,161	563
827	30	AV5	3.14	3.35	1.47	1.44	8.83	42.69	100.0	1,170	554
832	30	AV5	3.13	3.34	1.45	1.41	8.79	41.91	100.0	1,173	551
837	30	AV5	3.17	3.39	1.47	1.42	8.91	42.88	100.0	1,192	563
842	30	AV5	3.16	3.38	1.46	1.40	8.84	42.83	100.0	1,184	563
847	30	AV5	3.19	3.41	1.49	1.41	8.90	42.90	100.0	1,208	571
852	31	AV5	3.19	3.42	1.51	1.41	8.92	43.07	100.0	1,219	575
857	31	AV5	3.18	3.40	1.48	1.39	8.84	42.12	100.0	1,214	577
862	31	AV5	3.21	3.43	1.51	1.39	8.94	43.04	100.0	1,230	583
867	31	AV5	3.24	3.46	1.55	1.41	9.06	44.02	100.0	1,252	590
872	31	AV5	3.27	3.48	1.55	1.42	9.12	44.52	100.0	1,268	602
877	31	AV5	3.28	3.49	1.56	1.43	9.14	43.68	100.0	1,284	605
882	34	AV5	3.22	3.43	1.53	1.37	8.96	42.10	100.0	1,270	602
887	34	AV5	3.24	3.45	1.52	1.37	9.00	42.77	100.0	1,273	607
892	34	AV5	3.25	3.45	1.51	1.36	9.02	43.02	100.0	1,271	606
897	34	AV5	3.28	3.50	1.53	1.37	9.13	44.07	100.0	1,280	605
902	34	AV5	3.27	3.49	1.54	1.35	9.09	43.48	100.0	1,289	606
907	34	AV5	3.28	3.49	1.53	1.35	9.10	43.67	100.0	1,287	603
912	34	AV5	3.27	3.48	1.53	1.33	9.05	43.39	100.0	1,288	596
917	34	AV5	3.31	3.52	1.56	1.35	9.18	44.49	100.0	1,305	600
922	34	AV5	3.32	3.54	1.56	1.36	9.21	44.70	100.0	1,304	600
927	34	AV5	3.33	3.55	1.57	1.37	9.25	43.92	100.0	1,336	612
932	34	AV5	3.30	3.52	1.54	1.34	9.13	43.54	100.0	1,312	596
937	34	AV5	3.28	3.50	1.53	1.33	9.07	43.04	100.0	1,310	598
942	34	AV5	3.36	3.58	1.59	1.38	9.33	44.85	100.0	1,345	612
947	34	AV5	3.34	3.57	1.59	1.37	9.27	44.45	100.0	1,319	587
952	34	AV5	3.33	3.57	1.56	1.35	9.21	43.99	100.0	1,303	577
957	34	AV5	3.33	3.60	1.57	1.35	9.20	44.29	100.0	1,308	585
962	34	AV5	3.30	3.59	1.54	1.33	9.14	43.79	100.0	1,290	579
967	34	AV5	3.32	3.61	1.55	1.34	9.18	43.92	100.0	1,295	581
972	34	AV5	3.33	3.63	1.54	1.35	9.21	44.33	100.0	1,303	591
977	34	AV5	3.35	3.64	1.55	1.36	9.26	44.94	100.0	1,310	602
982	33	AV5	3.41	3.71	1.62	1.41	9.51	46.38	100.0	1,337	609
987	33	AV5	3.39	3.69	1.58	1.40	9.46	45.59	100.0	1,336	610
992	33	AV5	3.38	3.68	1.58	1.39	9.40	44.81	100.0	1,335	606
997	33	AV5	3.40	3.71	1.59	1.41	9.50	46.31	100.0	1,336	610

I-4 DEER CROSSING Bridge No. 790207 - CFCC WEST PILE N1 APE D46-42 HAMMER
OP: GRL-MGB Test date: 23-Jan-2014

BL# end	BLC bl/ft	TYPE	CSX ksi	CSI ksi	CSB ksi	TSX ksi	STK ft	EMX k-ft	BTA (%)	RX0 kips	RX5 kips
1002	33	AV5	3.41	3.73	1.60	1.42	9.53	46.34	100.0	1,342	608
1007	33	AV5	3.39	3.71	1.59	1.40	9.45	45.77	100.0	1,327	598
1012	33	AV5	3.41	3.74	1.59	1.42	9.54	46.15	100.0	1,342	605
1017	32	AV5	3.39	3.72	1.57	1.40	9.49	45.62	100.0	1,336	597
1022	32	AV5	3.35	3.67	1.52	1.38	9.34	44.77	100.0	1,312	581
1027	32	AV5	3.38	3.72	1.56	1.39	9.43	45.62	100.0	1,326	587
1032	32	AV5	3.38	3.71	1.55	1.39	9.44	45.33	100.0	1,325	588
1037	32	AV5	3.40	3.74	1.59	1.42	9.54	46.23	100.0	1,343	596
1042	32	AV5	3.38	3.72	1.56	1.40	9.48	45.66	100.0	1,330	591
1047	35	AV5	3.38	3.71	1.53	1.40	9.46	45.33	100.0	1,331	587
1052	35	AV5	3.39	3.71	1.54	1.42	9.54	45.32	100.0	1,353	602
1057	35	AV5	3.35	3.68	1.52	1.39	9.37	44.45	100.0	1,331	587
1062	35	AV5	3.36	3.69	1.51	1.40	9.39	44.74	100.0	1,327	590
1067	35	AV5	3.34	3.66	1.51	1.40	9.33	44.41	100.0	1,316	583
1072	35	AV5	3.32	3.65	1.50	1.39	9.32	44.33	100.0	1,304	575
1077	35	AV5	3.34	3.65	1.49	1.41	9.39	44.57	100.0	1,308	576
1082	37	AV5	3.33	3.65	1.49	1.40	9.37	44.51	100.0	1,309	574
1087	37	AV5	3.33	3.65	1.50	1.39	9.38	44.66	100.0	1,311	578
1092	37	AV5	3.31	3.63	1.46	1.38	9.32	44.15	100.0	1,297	567
1097	37	AV5	3.37	3.70	1.53	1.43	9.53	45.48	100.0	1,336	585
1102	37	AV5	3.33	3.65	1.49	1.40	9.44	43.92	100.0	1,342	586
1107	37	AV5	3.32	3.64	1.48	1.39	9.45	44.47	100.0	1,321	574
1112	37	AV5	3.31	3.62	1.48	1.39	9.45	44.38	100.0	1,316	571
1117	37	AV5	3.31	3.62	1.48	1.39	9.44	44.71	100.0	1,311	564
1122	31	AV5	3.28	3.58	1.44	1.36	9.39	44.11	100.0	1,300	551
1127	31	AV5	3.25	3.54	1.42	1.33	9.23	43.56	100.0	1,281	535
1132	31	AV5	3.25	3.53	1.42	1.33	9.28	43.55	100.0	1,284	529
1137	31	AV5	3.24	3.52	1.45	1.33	9.29	43.42	100.0	1,292	527
1142	31	AV5	3.23	3.50	1.43	1.31	9.25	43.23	100.0	1,285	524
1147	31	AV5	3.23	3.50	1.43	1.32	9.30	43.58	100.0	1,288	522
1152	37	AV5	3.25	3.50	1.46	1.33	9.38	43.67	100.0	1,308	530
1157	37	AV5	3.25	3.49	1.44	1.34	9.44	43.83	100.0	1,310	536
1162	37	AV5	3.21	3.44	1.41	1.31	9.30	43.24	100.0	1,294	514
1167	37	AV5	3.18	3.41	1.39	1.29	9.26	42.93	100.0	1,274	503
1172	37	AV5	3.24	3.46	1.45	1.33	9.56	44.86	100.0	1,299	524
1177	37	AV5	3.23	3.42	1.44	1.33	9.58	44.14	100.0	1,310	523
1182	37	AV5	3.18	3.38	1.38	1.29	9.41	43.56	100.0	1,275	506
1187	38	AV5	3.15	3.35	1.40	1.26	9.34	43.00	100.0	1,275	497
1192	38	AV5	3.17	3.36	1.41	1.28	9.47	43.18	100.0	1,300	505
1197	38	AV5	3.09	3.26	1.35	1.21	9.16	41.69	100.0	1,263	470
1202	38	AV5	3.12	3.28	1.39	1.22	9.35	42.72	100.0	1,276	467
1207	38	AV5	3.13	3.28	1.38	1.22	9.47	43.35	100.0	1,278	466
1212	38	AV5	3.10	3.24	1.39	1.19	9.36	42.68	100.0	1,278	442
1217	38	AV5	3.08	3.21	1.40	1.18	9.35	42.26	100.0	1,285	431
1222	38	AV5	3.07	3.19	1.40	1.17	9.38	41.75	100.0	1,302	428
1227	43	AV5	3.05	3.16	1.39	1.14	9.32	41.77	100.0	1,286	421
1232	43	AV5	3.07	3.15	1.42	1.15	9.47	42.48	100.0	1,303	419
1237	43	AV5	3.04	3.11	1.39	1.13	9.36	42.04	100.0	1,286	412
1242	43	AV5	3.01	3.05	1.38	1.10	9.34	41.84	100.0	1,279	408
1247	43	AV5	3.03	3.06	1.40	1.11	9.45	42.52	100.0	1,289	411
1252	43	AV5	3.01	3.01	1.40	1.08	9.44	41.73	100.0	1,282	408
1257	43	AV5	2.99	3.02	1.37	1.05	9.39	41.59	100.0	1,274	406

I-4 DEER CROSSING Bridge No. 790207 - CFCC WEST PILE N1 APE D46-42 HAMMER
OP: GRL-MGB Test date: 23-Jan-2014

BL#	BLC	TYPE	CSX	CSI	CSB	TSX	STK	EMX	BTA	RX0	RX5
end	bl/ft		ksi	ksi	ksi	ksi	ft	k-ft	(%)	kips	kips
1262	43	AV5	2.99	3.07	1.36	1.05	9.47	41.69	100.0	1,276	412
1267	43	AV5	2.99	3.10	1.37	1.04	9.53	42.06	100.0	1,280	409
1272	43	AV5	2.95	3.11	1.35	1.01	9.51	41.63	100.0	1,269	403
1277	43	AV5	2.95	3.15	1.34	1.00	9.51	41.70	100.0	1,265	403
1282	43	AV5	2.95	3.20	1.33	0.99	9.56	42.28	100.0	1,268	403
1287	43	AV5	2.92	3.23	1.35	0.98	9.53	41.77	100.0	1,268	400
1292	43	AV5	2.90	3.28	1.33	0.96	9.50	41.06	100.0	1,276	405
1297	43	AV5	2.87	3.29	1.32	0.93	9.36	39.38	100.0	1,276	410
1302	43	AV5	2.91	3.31	1.32	0.96	9.45	41.00	100.0	1,257	402
1307	43	AV5	2.93	3.34	1.35	0.97	9.47	40.56	100.0	1,274	406
1312	47	AV5	2.31	2.67	1.17	0.70	9.14	30.99	100.0	1,164	563
1317	47	AV5	2.01	2.20	0.97	0.30	8.39	27.57	97.8	1,108	563
1322	47	AV5	2.49	2.59	1.09	0.65	8.43	33.13	100.0	1,196	424
1327	47	AV5	2.70	2.80	1.19	0.81	8.70	36.76	100.0	1,235	379
1332	47	AV5	2.76	2.85	1.25	0.84	8.66	37.48	100.0	1,252	371
1337	47	AV5	2.82	2.93	1.30	0.88	8.71	38.71	100.0	1,254	367
1342	47	AV5	2.85	2.99	1.35	0.93	8.82	39.57	100.0	1,269	371
1347	47	AV5	2.88	3.03	1.38	0.96	8.88	40.16	100.0	1,281	372
1352	47	AV5	2.90	3.06	1.41	0.97	8.93	40.77	100.0	1,281	375
1357	47	AV5	2.91	3.07	1.42	0.98	8.93	40.93	100.0	1,285	377
1362	47	AV5	2.91	3.06	1.43	0.96	8.84	40.62	100.0	1,292	380
1367	47	AV5	2.94	3.08	1.47	0.97	8.92	41.30	100.0	1,304	386
1372	47	AV5	2.92	3.05	1.49	0.93	8.82	40.37	100.0	1,308	392
1377	47	AV5	2.97	3.09	1.51	0.95	8.97	41.70	100.0	1,325	400
1382	47	AV5	2.97	3.10	1.54	0.92	8.95	41.45	100.0	1,341	409
1387	47	AV5	2.96	3.09	1.60	0.90	8.90	41.29	100.0	1,362	422
1392	47	AV5	3.00	3.12	1.65	0.89	9.05	41.99	100.0	1,388	443
1397	47	AV5	2.95	3.06	1.66	0.83	8.84	40.73	100.0	1,400	477
1402	47	AV5	3.00	3.05	1.71	0.82	8.99	42.13	100.0	1,427	493
1407	57	AV5	3.01	3.06	1.75	0.79	9.00	42.04	100.0	1,449	526
1412	57	AV5	2.99	3.10	1.78	0.74	8.95	41.13	100.0	1,457	565
1417	57	AV5	3.05	3.20	1.81	0.74	9.11	42.64	100.0	1,485	582
1422	57	AV5	3.05	3.20	1.85	0.71	9.12	42.60	100.0	1,500	607
1427	57	AV5	3.05	3.20	1.86	0.71	9.11	42.75	100.0	1,512	622
1432	57	AV5	3.02	3.15	1.86	0.69	9.01	42.08	100.0	1,517	641
1437	57	AV5	2.97	3.09	1.83	0.65	8.84	40.83	100.0	1,510	658
1442	57	AV5	3.07	3.17	1.87	0.72	9.18	43.11	100.0	1,536	657
1447	57	AV5	3.02	3.10	1.88	0.69	9.01	42.17	98.0	1,531	664
1452	57	AV5	3.05	3.12	1.89	0.71	9.12	42.89	98.0	1,536	663
1457	57	AV5	3.04	3.11	1.87	0.69	9.06	42.23	98.0	1,530	675
1462	66	AV5	3.03	3.13	1.90	0.70	9.04	42.26	93.8	1,536	678
1467	66	AV5	3.02	3.10	1.90	0.70	9.03	42.07	93.6	1,536	691
1472	66	AV5	2.99	3.03	1.90	0.68	8.91	41.50	93.4	1,537	707
1477	66	AV5	2.99	3.00	1.89	0.69	8.91	41.44	100.0	1,535	715
1482	66	AV5	3.01	3.02	1.92	0.70	8.98	41.81	96.0	1,537	726
1487	66	AV5	2.99	3.03	1.93	0.69	8.90	41.26	94.0	1,539	740
1492	66	AV5	2.96	3.00	1.91	0.68	8.83	40.92	100.0	1,538	752
1497	66	AV5	3.02	3.06	1.96	0.71	9.06	42.45	98.0	1,555	766
1502	66	AV5	3.04	3.08	1.99	0.73	9.15	42.93	94.0	1,559	780
1507	66	AV5	3.08	3.10	2.01	0.75	9.31	43.79	96.0	1,569	794
1512	66	AV5	3.03	3.05	2.02	0.72	9.12	42.56	96.0	1,560	799
1517	66	AV5	3.03	3.06	2.00	0.73	9.14	42.80	98.0	1,565	809

I-4 DEER CROSSING Bridge No. 790207 - CFCC WEST PILE N1 APE D46-42 HAMMER
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BL#	BLC	TYPE	CSX	CSI	CSB	TSX	STK	EMX	BTA	RX0	RX5
end	bl/ft		ksi	ksi	ksi	ksi	ft	k-ft	(%)	kips	kips
1522	66	AV5	3.02	3.06	1.99	0.72	9.07	42.37	100.0	1,563	819
1527	66	AV5	3.03	3.08	2.03	0.73	9.09	42.57	100.0	1,568	827
1532	84	AV5	3.02	3.07	2.03	0.73	9.07	42.23	100.0	1,569	838
1537	84	AV5	2.96	3.00	1.99	0.70	8.86	40.75	100.0	1,553	838
1542	84	AV5	2.99	3.01	2.03	0.71	8.97	41.39	100.0	1,565	851
1547	84	AV5	3.05	3.06	2.08	0.75	9.25	42.94	100.0	1,584	862
1552	84	AV5	3.03	3.04	2.06	0.75	9.20	42.74	100.0	1,580	867
1557	84	AV5	3.00	3.01	2.07	0.74	9.08	42.10	100.0	1,565	867
1562	84	AV5	3.02	3.04	2.06	0.75	9.15	42.39	100.0	1,565	874
1567	84	AV5	3.04	3.09	2.06	0.77	9.24	43.00	100.0	1,566	877
1572	84	AV5	3.01	3.07	2.09	0.76	9.13	42.34	100.0	1,551	875
1577	84	AV5	3.03	3.09	2.08	0.78	9.21	43.08	100.0	1,555	879
1582	84	AV5	3.03	3.10	2.09	0.79	9.22	43.33	100.0	1,553	879
1587	84	AV5	2.98	3.05	2.05	0.77	9.06	42.18	100.0	1,529	871
1592	84	AV5	2.97	3.03	2.02	0.76	8.98	41.40	100.0	1,500	867
1597	84	AV5	3.00	3.06	2.04	0.79	9.10	42.27	100.0	1,514	876
1602	84	AV5	3.04	3.10	2.06	0.82	9.34	43.33	98.0	1,515	883
1607	84	AV5	3.02	3.07	2.04	0.83	9.30	43.01	100.0	1,508	883
1612	103	AV5	2.99	3.03	2.01	0.82	9.15	42.08	100.0	1,492	883
1617	103	AV5	3.02	3.07	2.06	0.85	9.32	43.06	100.0	1,503	889
1622	103	AV5	2.99	3.05	2.03	0.86	9.23	42.55	100.0	1,489	887
1627	103	AV5	2.99	3.06	2.05	0.87	9.21	42.51	100.0	1,484	889
1632	103	AV5	3.00	3.08	2.03	0.88	9.26	42.92	100.0	1,483	891
1637	103	AV5	2.99	3.07	2.06	0.88	9.23	43.26	100.0	1,484	889
1642	103	AV5	3.02	3.11	2.08	0.91	9.41	43.90	100.0	1,486	895
1647	103	AV5	2.98	3.07	2.07	0.89	9.25	43.20	100.0	1,472	889
1652	103	AV5	3.01	3.10	2.11	0.92	9.32	44.17	100.0	1,487	893
1657	103	AV5	3.00	3.08	2.08	0.92	9.31	43.68	100.0	1,471	892
1662	103	AV5	2.98	3.06	2.09	0.91	9.25	43.49	100.0	1,469	892
1667	103	AV5	2.96	3.04	2.08	0.90	9.17	42.85	100.0	1,461	893
1672	103	AV5	2.97	3.05	2.09	0.90	9.17	42.91	100.0	1,463	895
1677	103	AV5	2.97	3.06	2.10	0.90	9.22	43.04	100.0	1,465	898
1682	103	AV5	2.99	3.07	2.09	0.92	9.31	43.53	100.0	1,471	899
1687	103	AV5	2.99	3.08	2.12	0.92	9.31	43.79	100.0	1,472	899
1692	103	AV5	2.98	3.07	2.12	0.90	9.27	43.65	100.0	1,470	900
1697	103	AV5	2.98	3.07	2.10	0.91	9.30	43.33	100.0	1,460	902
1702	103	AV5	2.99	3.07	2.11	0.91	9.33	43.59	100.0	1,461	903
1707	103	AV5	2.98	3.08	2.13	0.90	9.32	43.72	100.0	1,465	904
1712	103	AV5	2.98	3.08	2.13	0.90	9.36	43.65	100.0	1,459	903
1717	106	AV5	3.00	3.10	2.13	0.92	9.41	44.10	100.0	1,468	906
1722	106	AV5	3.00	3.10	2.13	0.91	9.40	44.10	100.0	1,464	905
1727	106	AV5	3.03	3.14	2.17	0.93	9.56	45.02	100.0	1,478	908
1732	106	AV5	3.00	3.11	2.18	0.92	9.45	44.50	100.0	1,471	905
1737	106	AV5	2.99	3.09	2.15	0.91	9.41	43.93	100.0	1,458	903
1742	106	AV5	2.99	3.07	2.15	0.92	9.38	43.92	100.0	1,457	902
1747	106	AV5	2.97	3.06	2.14	0.91	9.30	43.24	100.0	1,448	901
1752	106	AV5	3.01	3.10	2.16	0.93	9.48	44.55	100.0	1,464	904
1759	106	AV5	2.98	3.06	2.15	0.91	9.32	43.39	100.0	1,446	902
1764	106	AV5	2.99	3.08	2.15	0.92	9.39	43.82	100.0	1,451	905
1769	106	AV5	2.98	3.07	2.17	0.92	9.35	43.48	100.0	1,446	902
1774	106	AV5	2.94	3.03	2.15	0.89	9.15	42.50	100.0	1,432	898
1779	106	AV5	2.98	3.07	2.17	0.91	9.30	43.44	100.0	1,441	901

I-4 DEER CROSSING Bridge No. 790207 - CFCC WEST PILE N1 APE D46-42 HAMMER
OP: GRL-MGB Test date: 23-Jan-2014

BL#	BLC	TYPE	CSX	CSI	CSB	TSX	STK	EMX	BTA	RX0	RX5
end	bl/ft		ksi	ksi	ksi	ksi	ft	k-ft	(%)	kips	kips
1784	106	AV5	2.97	3.07	2.18	0.91	9.29	43.30	100.0	1,436	900
1789	106	AV5	3.01	3.11	2.19	0.93	9.40	43.91	100.0	1,445	904
1794	106	AV5	2.99	3.10	2.19	0.93	9.31	43.53	100.0	1,438	902
1799	106	AV5	3.01	3.13	2.21	0.94	9.42	44.29	100.0	1,447	905
1804	106	AV5	3.00	3.11	2.19	0.93	9.33	43.62	100.0	1,434	901
1809	106	AV5	2.99	3.12	2.18	0.93	9.29	43.19	100.0	1,426	899
1814	106	AV5	3.03	3.16	2.22	0.95	9.43	44.41	100.0	1,444	905
1819	106	AV5	3.03	3.16	2.20	0.96	9.40	43.95	100.0	1,432	900
1824	97	AV5	3.03	3.16	2.21	0.96	9.39	44.29	100.0	1,435	899
1829	97	AV5	3.03	3.16	2.21	0.95	9.36	44.12	100.0	1,432	897
1834	97	AV5	3.10	3.23	2.22	0.99	9.62	45.55	100.0	1,440	899
1839	97	AV5	3.08	3.21	2.22	0.99	9.56	45.19	100.0	1,431	892
1844	97	AV5	3.07	3.19	2.20	0.99	9.46	44.59	100.0	1,421	889
1849	97	AV5	3.03	3.15	2.16	0.97	9.25	42.97	100.0	1,394	883
1854	97	AV5	3.09	3.22	2.20	1.00	9.46	44.70	100.0	1,418	889
1859	97	AV5	3.08	3.21	2.19	0.99	9.41	44.17	100.0	1,407	883
1864	97	AV5	3.12	3.25	2.21	1.01	9.49	45.11	100.0	1,421	886
1869	97	AV5	3.13	3.27	2.20	1.02	9.53	45.48	100.0	1,416	881
1874	97	AV5	3.18	3.32	2.21	1.05	9.67	46.47	100.0	1,421	881
1879	97	AV5	3.13	3.26	2.18	1.02	9.47	44.95	100.0	1,401	871
1884	97	AV5	3.14	3.28	2.19	1.03	9.47	45.15	100.0	1,404	871
1889	97	AV5	3.16	3.30	2.17	1.04	9.51	45.09	100.0	1,395	866
1894	97	AV5	3.17	3.31	2.17	1.05	9.52	45.17	100.0	1,397	865
1899	97	AV5	3.17	3.31	2.16	1.05	9.50	44.96	100.0	1,387	860
1904	97	AV5	3.19	3.34	2.17	1.05	9.53	45.57	100.0	1,394	860
1909	97	AV5	3.19	3.34	2.15	1.06	9.49	45.23	100.0	1,381	853
1914	97	AV5	3.22	3.37	2.16	1.08	9.55	45.82	100.0	1,384	850
1919	86	AV5	3.23	3.38	2.14	1.08	9.53	45.72	100.0	1,376	844
1924	86	AV5	3.21	3.36	2.12	1.08	9.42	45.03	100.0	1,363	837
1929	86	AV5	3.21	3.35	2.12	1.07	9.39	44.85	100.0	1,359	833
1934	86	AV5	3.24	3.38	2.12	1.08	9.48	45.14	100.0	1,360	834
1939	86	AV5	3.25	3.40	2.11	1.10	9.48	45.38	100.0	1,362	834
1944	86	AV5	3.28	3.43	2.10	1.12	9.57	45.67	100.0	1,358	829
1949	86	AV5	3.26	3.41	2.09	1.10	9.43	44.94	100.0	1,346	823
1954	86	AV5	3.28	3.42	2.09	1.11	9.45	45.21	100.0	1,345	822
1959	86	AV5	3.30	3.45	2.10	1.13	9.55	46.14	100.0	1,353	821
1964	86	AV5	3.32	3.47	2.09	1.14	9.59	46.13	100.0	1,345	816
1969	86	AV5	3.30	3.45	2.08	1.13	9.49	45.49	100.0	1,336	812
1974	86	AV5	3.28	3.43	2.06	1.13	9.40	44.98	100.0	1,325	806
1979	86	AV5	3.33	3.50	2.08	1.15	9.54	46.05	100.0	1,332	804
1984	86	AV5	3.31	3.48	2.06	1.15	9.47	45.31	100.0	1,320	802
1989	86	AV5	3.33	3.48	2.05	1.15	9.48	45.45	100.0	1,317	800
1994	86	AV5	3.34	3.48	2.06	1.16	9.50	45.95	100.0	1,321	800
1999	86	AV5	3.35	3.49	2.05	1.16	9.54	46.07	100.0	1,317	796
2004	76	AV5	3.36	3.50	2.04	1.16	9.54	45.72	100.0	1,314	792
2009	76	AV5	3.38	3.52	2.04	1.17	9.60	46.16	100.0	1,312	788
2014	76	AV5	3.35	3.49	2.03	1.17	9.47	45.56	100.0	1,308	787
2019	76	AV5	3.38	3.53	2.03	1.18	9.56	46.12	100.0	1,309	786
2024	76	AV5	3.37	3.51	2.02	1.16	9.50	45.77	100.0	1,302	778
2029	76	AV5	3.39	3.53	2.01	1.17	9.55	45.77	100.0	1,295	773
2034	76	AV5	3.39	3.53	2.00	1.17	9.54	45.87	100.0	1,292	771
2039	76	AV5	3.41	3.56	2.00	1.18	9.62	46.24	100.0	1,291	768

I-4 DEER CROSSING Bridge No. 790207 - CFCC WEST PILE N1 APE D46-42 HAMMER
OP: GRL-MGB Test date: 23-Jan-2014

BL# end	BLC bl/ft	TYPE	CSX ksi	CSI ksi	CSB ksi	TSX ksi	STK ft	EMX k-ft	BTA (%)	RX0 kips	RX5 kips
2044	76	AV5	3.40	3.54	1.99	1.18	9.51	45.87	100.0	1,286	766
2049	76	AV5	3.38	3.52	1.97	1.17	9.46	45.21	100.0	1,277	760
2054	76	AV5	3.41	3.56	1.98	1.18	9.56	46.03	100.0	1,280	761
2059	76	AV5	3.44	3.58	1.97	1.19	9.62	46.48	100.0	1,279	755
2064	76	AV5	3.42	3.56	1.96	1.18	9.54	45.98	100.0	1,272	756
2069	76	AV5	3.46	3.61	1.97	1.20	9.73	47.30	100.0	1,282	760
2074	76	AV5	3.38	3.52	1.92	1.17	9.39	44.39	100.0	1,253	738
2079	76	AV5	3.41	3.55	1.94	1.18	9.49	45.43	100.0	1,261	745
2084	69	AV5	3.42	3.56	1.95	1.18	9.51	45.65	100.0	1,268	742
2089	69	AV5	3.41	3.54	1.94	1.18	9.48	45.44	100.0	1,266	743
2094	69	AV5	3.46	3.60	1.97	1.20	9.66	46.71	100.0	1,287	743
2099	69	AV5	3.42	3.55	1.93	1.18	9.51	45.42	100.0	1,266	735
2104	69	AV5	3.44	3.57	1.95	1.18	9.53	45.78	100.0	1,277	732
2109	69	AV5	3.45	3.59	1.95	1.19	9.59	45.78	100.0	1,284	728
2114	69	AV5	3.44	3.58	1.94	1.18	9.52	45.65	100.0	1,276	724
2119	69	AV5	3.45	3.60	1.95	1.19	9.55	45.81	100.0	1,282	723
2124	69	AV5	3.49	3.63	1.98	1.20	9.67	46.59	100.0	1,300	726
2129	69	AV5	3.43	3.57	1.93	1.18	9.47	44.89	100.0	1,272	711
2134	69	AV5	3.47	3.62	1.96	1.19	9.58	46.03	100.0	1,292	717
2139	69	AV5	3.45	3.59	1.94	1.19	9.53	45.10	100.0	1,286	706
2144	69	AV5	3.46	3.58	1.94	1.19	9.54	45.21	100.0	1,294	710
2149	63	AV5	3.47	3.60	1.95	1.19	9.57	45.24	100.0	1,308	706
2154	63	AV5	3.47	3.61	1.95	1.19	9.57	45.29	100.0	1,304	705
2159	63	AV5	3.46	3.60	1.94	1.19	9.55	44.77	100.0	1,303	703
2164	63	AV5	3.48	3.62	1.95	1.20	9.61	45.69	100.0	1,309	702
2169	63	AV5	3.49	3.63	1.96	1.20	9.65	45.85	100.0	1,319	700
2174	63	AV5	3.47	3.61	1.94	1.18	9.56	45.24	100.0	1,309	693
2179	63	AV5	3.44	3.58	1.91	1.17	9.45	44.05	100.0	1,302	689
2184	63	AV5	3.45	3.59	1.91	1.17	9.48	44.32	100.0	1,302	689
2189	63	AV5	3.50	3.65	1.95	1.18	9.66	45.47	100.0	1,326	690
2194	63	AV5	3.46	3.60	1.91	1.16	9.49	44.44	100.0	1,313	687
2199	63	AV5	3.49	3.64	1.94	1.18	9.61	44.97	100.0	1,327	682
2205	63	AV5	3.49	3.64	1.94	1.18	9.61	45.12	100.0	1,328	682
2210	63	AV5	3.46	3.61	1.91	1.17	9.52	44.59	100.0	1,314	678
2215	60	AV5	3.50	3.66	1.93	1.18	9.64	45.65	100.0	1,326	681
2220	60	AV5	3.48	3.65	1.92	1.18	9.60	45.20	100.0	1,315	672
2225	60	AV5	3.45	3.62	1.90	1.17	9.49	44.50	100.0	1,303	671
2230	60	AV5	3.43	3.60	1.87	1.16	9.43	43.95	100.0	1,289	665
2235	60	AV5	3.49	3.69	1.93	1.20	9.65	45.56	100.0	1,324	663
2240	60	AV5	3.51	3.73	1.92	1.21	9.75	46.07	100.0	1,324	659
2245	60	AV5	3.45	3.67	1.87	1.19	9.53	44.83	100.0	1,291	656
2250	60	AV5	3.43	3.66	1.86	1.19	9.47	44.48	100.0	1,286	653
2255	60	AV5	3.48	3.71	1.89	1.22	9.62	45.41	100.0	1,313	653
2260	60	AV5	3.42	3.64	1.83	1.19	9.43	44.04	98.0	1,275	646
2265	60	AV5	3.41	3.62	1.83	1.19	9.41	43.66	100.0	1,276	641
2270	60	AV5	3.40	3.61	1.82	1.20	9.37	43.40	98.0	1,272	637
2275	48	AV5	3.47	3.69	1.87	1.23	9.59	45.30	100.0	1,301	634
2280	48	AV5	3.43	3.65	1.83	1.21	9.52	44.66	100.0	1,279	635
2285	48	AV5	3.39	3.60	1.82	1.20	9.39	43.53	100.0	1,269	624
2290	48	AV5	3.40	3.55	1.82	1.20	9.40	43.36	100.0	1,278	625
2295	48	AV5	3.40	3.51	1.81	1.20	9.36	43.25	100.0	1,274	624
2300	48	AV5	3.41	3.55	1.81	1.20	9.43	43.35	100.0	1,284	627

I-4 DEER CROSSING Bridge No. 790207 - CFCC WEST PILE N1 APE D46-42 HAMMER
OP: GRL-MGB Test date: 23-Jan-2014

BL# end	BLC bl/ft	TYPE	CSX ksi	CSI ksi	CSB ksi	TSX ksi	STK ft	EMX k-ft	BTA (%)	RX0 kips	RX5 kips
2305	48	AV5	3.44	3.59	1.84	1.21	9.55	43.98	100.0	1,310	630
2310	48	AV5	3.46	3.62	1.87	1.21	9.64	44.33	100.0	1,329	627
2315	48	AV5	3.41	3.55	1.81	1.19	9.49	43.44	98.0	1,291	628
2320	51	AV5	3.47	3.61	1.87	1.21	9.74	44.81	100.0	1,328	631
2325	51	AV5	3.41	3.54	1.82	1.19	9.51	43.61	100.0	1,290	623
2330	51	AV5	3.44	3.57	1.85	1.20	9.63	44.33	98.0	1,312	625
2335	51	AV5	3.40	3.54	1.82	1.18	9.52	43.41	96.0	1,299	629
2340	51	AV5	3.38	3.52	1.80	1.17	9.53	43.21	98.0	1,289	624
2345	51	AV5	3.41	3.54	1.82	1.18	9.60	44.09	96.0	1,297	627
2350	51	AV5	3.41	3.57	1.83	1.18	9.70	43.98	100.0	1,312	629
2355	51	AV5	3.34	3.51	1.77	1.16	9.46	42.46	96.0	1,283	622
2360	51	AV5	3.35	3.52	1.77	1.15	9.54	42.81	94.0	1,281	626
2365	51	AV5	3.29	3.46	1.73	1.13	9.34	41.62	94.0	1,252	620
2370	51	AV5	3.34	3.52	1.77	1.14	9.53	42.64	94.0	1,282	629
2375	51	AV5	3.33	3.52	1.76	1.14	9.56	42.69	93.8	1,281	629
2380	51	AV5	3.27	3.44	1.71	1.11	9.35	41.38	89.8	1,251	624
2385	51	AV5	3.32	3.50	1.75	1.13	9.61	42.97	90.0	1,277	626
2390	51	AV5	3.28	3.46	1.72	1.10	9.49	41.97	90.0	1,259	621
2395	51	AV5	3.26	3.44	1.71	1.09	9.44	41.76	89.6	1,254	624
2400	51	AV5	3.25	3.43	1.71	1.08	9.46	41.82	89.6	1,257	623
2405	51	AV5	3.27	3.46	1.71	1.08	9.54	42.50	89.6	1,263	624
2410	51	AV5	3.25	3.44	1.70	1.07	9.56	42.27	89.6	1,264	626
2415	51	AV5	3.29	3.49	1.74	1.08	9.75	43.46	89.6	1,289	629
2420	51	AV5	3.23	3.43	1.69	1.04	9.55	42.10	89.4	1,264	627
2425	51	AV5	3.26	3.45	1.71	1.06	9.71	42.88	89.4	1,277	627
2430	51	AV5	3.17	3.34	1.67	1.02	9.44	41.10	89.6	1,248	619
2435	51	AV5	3.17	3.33	1.68	1.00	9.46	40.95	89.2	1,258	622
2440	51	AV5	3.19	3.36	1.70	1.00	9.59	41.94	89.0	1,270	624
2445	51	AV5	3.17	3.33	1.71	0.98	9.60	41.85	89.2	1,278	627
2450	51	AV5	3.15	3.31	1.71	0.97	9.58	41.46	89.2	1,282	625
2455	51	AV5	3.13	3.29	1.71	0.95	9.53	41.17	89.2	1,283	625
2460	51	AV5	3.15	3.29	1.73	0.95	9.69	41.88	88.6	1,293	629
2465	51	AV5	3.15	3.29	1.75	0.94	9.72	42.08	89.0	1,306	632
2470	51	AV5	3.10	3.25	1.74	0.91	9.60	41.07	88.8	1,308	631
2475	55	AV5	3.12	3.27	1.77	0.90	9.72	41.85	88.6	1,322	633
2480	55	AV5	3.07	3.20	1.76	0.86	9.58	40.44	88.2	1,323	631
2485	55	AV5	3.04	3.18	1.77	0.83	9.50	39.84	88.4	1,326	629
2490	55	AV5	3.02	3.15	1.78	0.79	9.46	39.41	88.2	1,337	634
2495	55	AV5	3.02	3.16	1.80	0.78	9.53	39.91	88.2	1,349	637
2500	55	AV5	3.04	3.17	1.81	0.78	9.62	40.35	88.2	1,359	640
2505	55	AV5	3.04	3.16	1.81	0.76	9.68	40.38	88.4	1,363	643
2510	55	AV5	3.03	3.14	1.82	0.74	9.69	40.44	88.0	1,367	642
2515	55	AV5	3.02	3.11	1.80	0.73	9.63	39.80	88.0	1,361	642
2520	55	AV5	3.03	3.13	1.82	0.71	9.72	40.20	88.4	1,374	647
2525	55	AV5	3.01	3.10	1.82	0.69	9.64	39.84	87.8	1,379	651
2530	58	AV5	3.02	3.11	1.81	0.67	9.75	39.85	87.6	1,384	656
2535	58	AV5	3.04	3.12	1.84	0.67	9.81	40.52	88.0	1,392	654
2540	58	AV5	3.05	3.10	1.83	0.68	9.78	40.20	87.4	1,388	649
2545	58	AV5	3.04	3.10	1.85	0.66	9.75	40.52	88.4	1,388	645
2550	58	AV5	3.07	3.13	1.85	0.66	9.84	41.02	88.0	1,396	645
2555	58	AV5	3.03	3.10	1.82	0.62	9.74	39.16	87.0	1,407	676
2560	58	AV5	3.01	3.07	1.83	0.60	9.70	39.28	87.4	1,396	661

I-4 DEER CROSSING Bridge No. 790207 - CFCC WEST PILE N1 APE D46-42 HAMMER
OP: GRL-MGB Test date: 23-Jan-2014

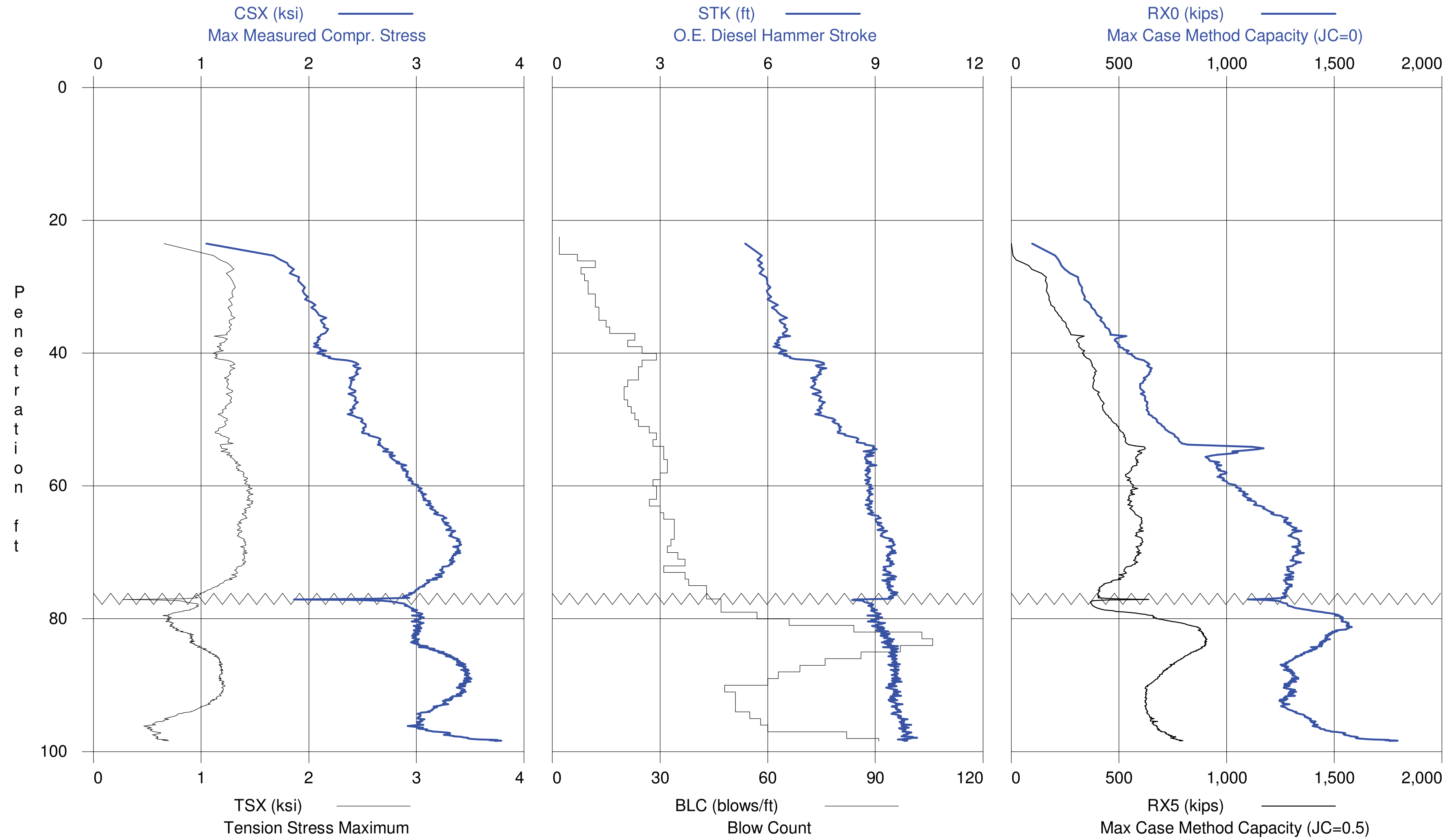
BL#	BLC	TYPE	CSX	CSI	CSB	TSX	STK	EMX	BTA	RX0	RX5
end	bl/ft		ksi	ksi	ksi	ksi	ft	k-ft	(%)	kips	kips
2565	58	AV5	3.04	3.10	1.88	0.57	9.81	40.66	88.4	1,410	662
2570	58	AV5	3.02	3.08	1.86	0.57	9.76	39.91	88.2	1,404	655
2575	58	AV5	3.01	3.07	1.86	0.55	9.71	39.63	87.8	1,401	656
2580	58	AV5	3.02	3.09	1.86	0.55	9.74	39.66	87.8	1,407	662
2585	58	AV5	3.06	3.17	1.90	0.57	9.96	41.17	88.4	1,420	661
2590	60	AV5	3.00	3.15	1.87	0.54	9.80	39.49	87.8	1,414	669
2595	60	AV5	2.93	3.13	1.84	0.48	9.75	37.93	87.0	1,402	676
2600	60	AV5	2.96	3.20	1.87	0.48	9.83	38.93	87.6	1,410	675
2605	60	AV5	3.00	3.23	1.88	0.51	9.81	38.99	87.6	1,417	674
2610	60	AV5	3.04	3.26	1.91	0.52	9.92	40.01	88.0	1,431	679
2615	60	AV5	3.01	3.19	1.90	0.50	9.67	38.57	88.0	1,430	680
2620	60	AV5	3.05	3.21	1.92	0.52	9.74	39.14	88.4	1,441	681
2625	60	AV5	3.08	3.24	1.93	0.53	9.78	39.64	88.4	1,450	688
2630	60	AV5	3.10	3.28	1.95	0.55	9.82	39.87	88.4	1,458	682
2635	60	AV5	3.08	3.34	1.95	0.52	9.74	39.29	88.6	1,455	688
2640	60	AV5	3.14	3.45	1.98	0.56	9.89	39.91	88.8	1,481	694
2645	60	AV5	3.14	3.42	1.99	0.54	9.72	39.32	88.6	1,481	693
2650	82	AV5	3.21	3.50	2.01	0.57	9.88	40.33	88.6	1,505	711
2655	82	AV5	3.28	3.57	2.05	0.62	10.04	41.38	88.6	1,531	717
2660	82	AV5	3.27	3.55	2.05	0.61	9.91	40.61	88.4	1,531	716
2665	82	AV5	3.34	3.63	2.10	0.64	10.02	41.74	88.4	1,558	720
2670	82	AV5	3.30	3.61	2.09	0.60	9.85	40.78	88.0	1,548	718
2675	82	AV5	3.30	3.65	2.09	0.60	9.92	40.90	88.2	1,545	720
2680	82	AV5	3.28	3.67	2.09	0.58	9.91	40.60	88.0	1,549	728
2685	82	AV5	3.25	3.66	2.07	0.55	9.79	39.51	87.2	1,548	737
2690	82	AV5	3.28	3.66	2.10	0.56	9.78	39.99	87.6	1,549	727
2695	82	AV5	3.32	3.69	2.11	0.58	9.87	40.54	87.2	1,568	745
2700	82	AV5	3.34	3.71	2.13	0.58	9.76	40.36	87.4	1,573	743
2705	82	AV5	3.37	3.73	2.14	0.60	9.80	40.67	86.6	1,583	746
2710	82	AV5	3.39	3.77	2.16	0.59	9.94	41.49	86.8	1,595	757
2715	82	AV5	3.45	3.87	2.19	0.61	10.10	42.26	87.2	1,616	764
2720	82	AV5	3.44	3.89	2.18	0.58	10.07	41.57	87.2	1,598	752
2725	82	AV5	3.45	3.89	2.19	0.57	9.96	40.54	87.4	1,596	738
2730	91	AV5	3.50	3.90	2.20	0.59	10.02	40.86	87.0	1,611	751
2735	91	AV5	3.51	3.82	2.22	0.60	9.89	39.85	86.8	1,632	758
2740	91	AV5	3.52	3.73	2.23	0.59	9.78	39.30	86.6	1,648	765
2745	91	AV5	3.58	3.66	2.27	0.62	9.66	39.18	87.0	1,670	766
2750	91	AV5	3.73	3.74	2.42	0.68	9.84	41.39	88.6	1,751	778
2755	91	AV5	3.69	3.77	2.40	0.65	9.76	40.75	88.4	1,736	782
2760	91	AV5	3.78	3.96	2.49	0.69	9.90	41.61	91.0	1,792	799
2765	91	AV5	3.73	3.82	2.48	0.69	9.81	42.42	89.8	1,756	783

GRL Engineers, Inc. - Case Method & iCAP® Results

PDIPLOT Ver. 2014.1 - Printed: 25-Jan-2014

Test date: 23-Jan-2014

I-4 DEER CROSSING Bridge No. 790207 - CFCC WEST PILE N1



CHANGE PILE 1 - ON

I-4 DEER CROSSING Bridge No. 790207 - CFCC WEST PILE N1 APE D46-42 HAMMER
OP: GRL-MGB Test date: 23-Jan-2014

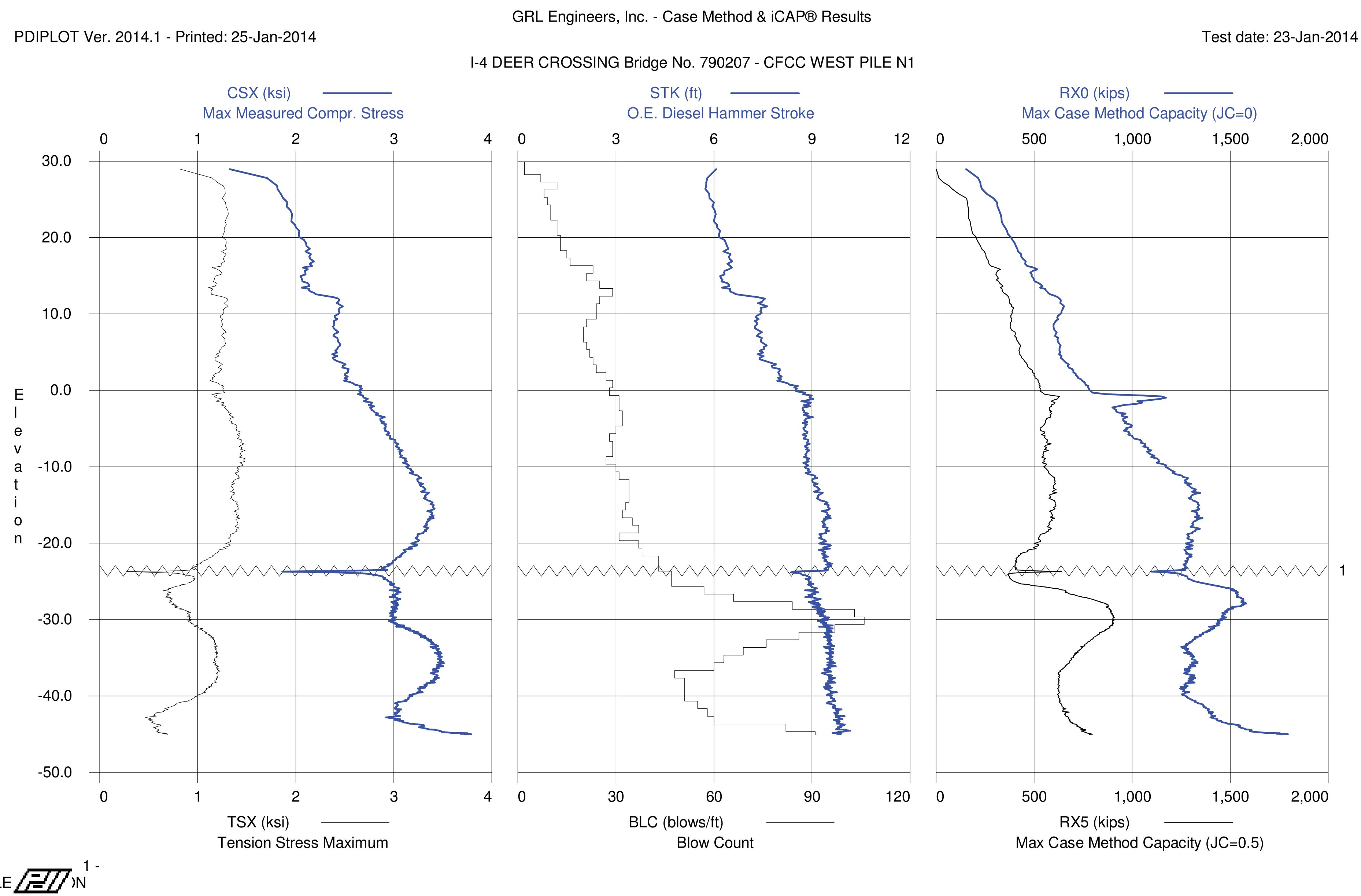
AR: 576.00 in^2 SP: 0.145 k/ft3
LE: 95.00 ft EM: 6,178 ksi
WS: 14,050.0 f/s JC: 0.50

CSX: Max Measured Compr. Stress
CSI: Max F1 or F2 Compr. Stress
CSB: Compression Stress at Bottom
TSX: Tension Stress Maximum
STK: O.E. Diesel Hammer Stroke
EMX: Max Transferred Energy
BTA: BETA Integrity Factor
RX0: Max Case Method Capacity (JC=0)
RX5: Max Case Method Capacity (JC=0.5)

BL# end	depth ft	BLC bl/ft	TYPE	CSX ksi	CSI ksi	CSB ksi	TSX ksi	STK ft	EMX k-ft	BTA (%)	RX0 kips	RX5 kips
2	23.00	2	AV2	0.96	1.09	0.09	0.69	3.73	12.14	82.0	53	0
4	24.00	2	AV2	0.85	1.04	0.14	0.47	3.06	16.75	80.0	81	0
6	25.00	2	AV2	1.63	1.99	0.34	1.03	7.73	35.07	86.5	197	0
13	26.00	7	AV7	1.70	1.96	0.35	1.14	5.77	20.79	95.7	213	14
25	27.00	12	AV12	1.80	2.07	0.39	1.24	5.77	22.36	100.0	230	63
33	28.00	8	AV8	1.84	2.09	0.43	1.28	5.83	22.09	96.1	254	110
42	29.00	9	AV9	1.90	2.13	0.51	1.27	5.95	23.35	97.3	305	159
52	30.00	10	AV10	1.92	2.16	0.52	1.30	5.98	22.68	100.0	317	165
62	31.00	10	AV10	1.96	2.20	0.54	1.30	6.04	23.24	100.0	331	165
74	32.00	12	AV12	1.97	2.20	0.55	1.28	6.04	22.96	100.0	338	175
86	33.00	12	AV12	2.03	2.25	0.59	1.27	6.17	24.63	100.0	362	183
99	34.00	13	AV13	2.06	2.28	0.63	1.27	6.23	25.16	100.0	386	207
112	35.00	13	AV13	2.13	2.37	0.67	1.29	6.42	26.69	100.0	410	227
127	36.00	15	AV15	2.13	2.40	0.70	1.27	6.42	26.37	100.0	428	251
143	37.00	16	AV16	2.16	2.44	0.74	1.25	6.48	26.78	100.0	452	267
166	38.00	23	AV23	2.11	2.35	0.83	1.21	6.42	25.65	100.0	493	308
187	39.00	21	AV21	2.07	2.33	0.84	1.19	6.25	24.86	100.0	492	310
212	40.00	25	AV25	2.10	2.35	0.90	1.16	6.36	25.21	100.0	527	329
241	41.00	29	AV29	2.18	2.44	0.97	1.15	6.61	26.43	100.0	572	346
266	42.00	25	AV25	2.42	2.69	1.06	1.28	7.43	32.16	100.0	630	373
290	43.00	24	AV24	2.45	2.75	1.10	1.28	7.49	32.95	100.0	647	388
314	44.00	24	AV24	2.42	2.72	1.06	1.25	7.36	32.27	100.0	628	385
335	45.00	21	AV21	2.39	2.71	1.01	1.25	7.31	31.66	100.0	607	382
355	46.00	20	AV20	2.41	2.75	1.02	1.27	7.36	32.18	100.0	607	392
375	47.00	20	AV20	2.41	2.80	1.01	1.26	7.41	32.01	100.0	616	409
396	48.00	21	AV21	2.44	2.83	1.00	1.26	7.52	32.39	100.0	629	426
418	49.00	22	AV22	2.41	2.81	1.01	1.21	7.45	31.65	100.0	633	428
441	50.00	23	AV23	2.43	2.81	1.04	1.20	7.59	32.21	100.0	655	451
465	51.00	24	AV24	2.51	2.88	1.09	1.23	7.90	34.35	100.0	687	479
492	52.00	27	AV27	2.51	2.74	1.12	1.17	8.02	34.20	100.0	721	505
521	53.00	29	AV29	2.59	2.88	1.17	1.21	8.27	36.00	100.0	762	526
549	54.00	28	AV28	2.66	3.13	1.24	1.23	8.63	38.64	100.0	818	541
580	55.00	31	AV29	2.72	3.26	1.66	1.21	8.91	40.39	100.0	1,101	608
611	56.00	31	AV31	2.77	3.14	1.39	1.27	8.79	40.33	100.0	943	586
643	57.00	32	AV32	2.84	3.19	1.41	1.33	8.84	41.22	100.0	948	584
675	58.00	32	AV32	2.88	3.24	1.49	1.35	8.80	41.72	100.0	969	557
705	59.00	30	AV30	2.92	3.19	1.49	1.41	8.79	42.27	100.0	978	540
733	60.00	28	AV28	2.97	3.23	1.51	1.42	8.80	42.64	100.0	1,009	555
762	61.00	29	AV29	3.03	3.28	1.51	1.44	8.85	42.99	100.0	1,062	565
791	62.00	29	AV29	3.07	3.29	1.45	1.45	8.84	42.72	100.0	1,092	553
818	63.00	27	AV27	3.11	3.33	1.43	1.46	8.83	42.87	100.0	1,127	549
848	64.00	30	AV30	3.15	3.37	1.47	1.42	8.85	42.68	100.0	1,183	561
879	65.00	31	AV31	3.23	3.45	1.53	1.41	9.01	43.33	100.0	1,248	589

I-4 DEER CROSSING Bridge No. 790207 - CFCC WEST PILE N1 APE D46-42 HAMMER
OP: GRL-MGB Test date: 23-Jan-2014

BL#	depth	BLC	TYPE	CSX	CSI	CSB	TSX	STK	EMX	BTA	RX0	RX5
end	ft	bl/ft		ksi	ksi	ksi	ksi	ft	k-ft	(%)	kips	kips
913	66.00	34	AV34	3.26	3.48	1.53	1.36	9.07	43.37	100.0	1,282	604
947	67.00	34	AV34	3.32	3.54	1.56	1.36	9.20	44.11	100.0	1,319	601
981	68.00	34	AV34	3.33	3.62	1.56	1.36	9.23	44.45	100.0	1,305	588
1014	69.00	33	AV33	3.40	3.71	1.59	1.41	9.48	45.82	100.0	1,336	606
1046	70.00	32	AV32	3.38	3.71	1.56	1.40	9.45	45.51	100.0	1,328	589
1081	71.00	35	AV35	3.35	3.68	1.51	1.40	9.40	44.71	100.0	1,323	585
1118	72.00	37	AV37	3.32	3.64	1.49	1.40	9.42	44.51	100.0	1,318	574
1149	73.00	31	AV31	3.24	3.52	1.43	1.33	9.28	43.52	100.0	1,288	529
1186	74.00	37	AV37	3.21	3.43	1.42	1.31	9.41	43.65	100.0	1,293	517
1224	75.00	38	AV38	3.11	3.26	1.39	1.21	9.37	42.51	100.0	1,284	458
1267	76.00	43	AV43	3.02	3.08	1.39	1.09	9.42	41.99	100.0	1,284	411
1310	77.00	43	AV43	2.92	3.25	1.34	0.97	9.48	41.13	100.0	1,269	404
1357	78.00	47	AV47	2.65	2.79	1.25	0.79	8.71	36.35	99.8	1,230	417
1404	79.00	47	AV47	2.96	3.08	1.57	0.90	8.92	41.30	100.0	1,353	427
1461	80.00	57	AV57	3.03	3.14	1.85	0.71	9.05	42.23	98.9	1,510	631
1527	81.00	66	AV66	3.02	3.05	1.96	0.71	9.04	42.20	96.9	1,551	762
1611	82.00	84	AV84	3.01	3.06	2.05	0.77	9.14	42.39	99.9	1,545	869
1714	83.00	103	AV103	2.99	3.07	2.09	0.90	9.28	43.36	100.0	1,474	895
1820	84.00	106	AV104	2.99	3.10	2.17	0.92	9.37	43.81	100.0	1,448	903
1917	85.00	97	AV97	3.13	3.26	2.19	1.02	9.49	44.99	100.0	1,408	876
2003	86.00	86	AV86	3.29	3.44	2.09	1.12	9.49	45.54	100.0	1,341	816
2079	87.00	76	AV76	3.40	3.54	1.99	1.18	9.54	45.86	100.0	1,287	766
2148	88.00	69	AV69	3.45	3.58	1.95	1.19	9.55	45.68	100.0	1,283	725
2211	89.00	63	AV62	3.47	3.61	1.93	1.18	9.56	44.96	100.0	1,312	692
2271	90.00	60	AV60	3.45	3.66	1.88	1.19	9.54	44.74	99.7	1,299	657
2319	91.00	48	AV48	3.43	3.59	1.84	1.21	9.51	44.00	99.8	1,295	628
2370	92.00	51	AV51	3.38	3.53	1.80	1.17	9.54	43.23	96.7	1,290	625
2421	93.00	51	AV51	3.28	3.46	1.72	1.09	9.54	42.32	90.1	1,266	625
2472	94.00	51	AV51	3.16	3.32	1.71	0.97	9.59	41.62	89.1	1,282	626
2527	95.00	55	AV55	3.04	3.15	1.80	0.77	9.62	40.16	88.2	1,353	640
2585	96.00	58	AV58	3.03	3.10	1.85	0.61	9.78	40.12	87.9	1,400	657
2645	97.00	60	AV60	3.04	3.26	1.92	0.52	9.79	39.26	88.1	1,439	682
2727	98.00	82	AV82	3.33	3.70	2.11	0.59	9.92	40.86	87.7	1,564	734
2765	98.42	91	AV38	3.63	3.79	2.34	0.64	9.82	40.60	88.2	1,703	773


GRL Engineers, Inc. - Case Method & iCAP® Results
PDIPLOT Ver. 2014.1 - Printed: 25-Jan-2014
Test date: 23-Jan-2014
I-4 DEER CROSSING Bridge No. 790207 - CFCC WEST PILE N1
CSX (ksi)
Max Measured Compr. Stress
STK (ft)
O.E. Diesel Hammer Stroke
RX0 (kips)
Max Case Method Capacity (JC=0)
Elevation
TSX (ksi)
Tension Stress Maximum
BLC (blows/ft)
Blow Count
RX5 (kips)
Max Case Method Capacity (JC=0.5)
CHANGE PILE

I-4 DEER CROSSING Bridge No. 790207 - CFCC WEST PILE N1 APE D46-42 HAMMER
OP: GRL-MGB Test date: 23-Jan-2014

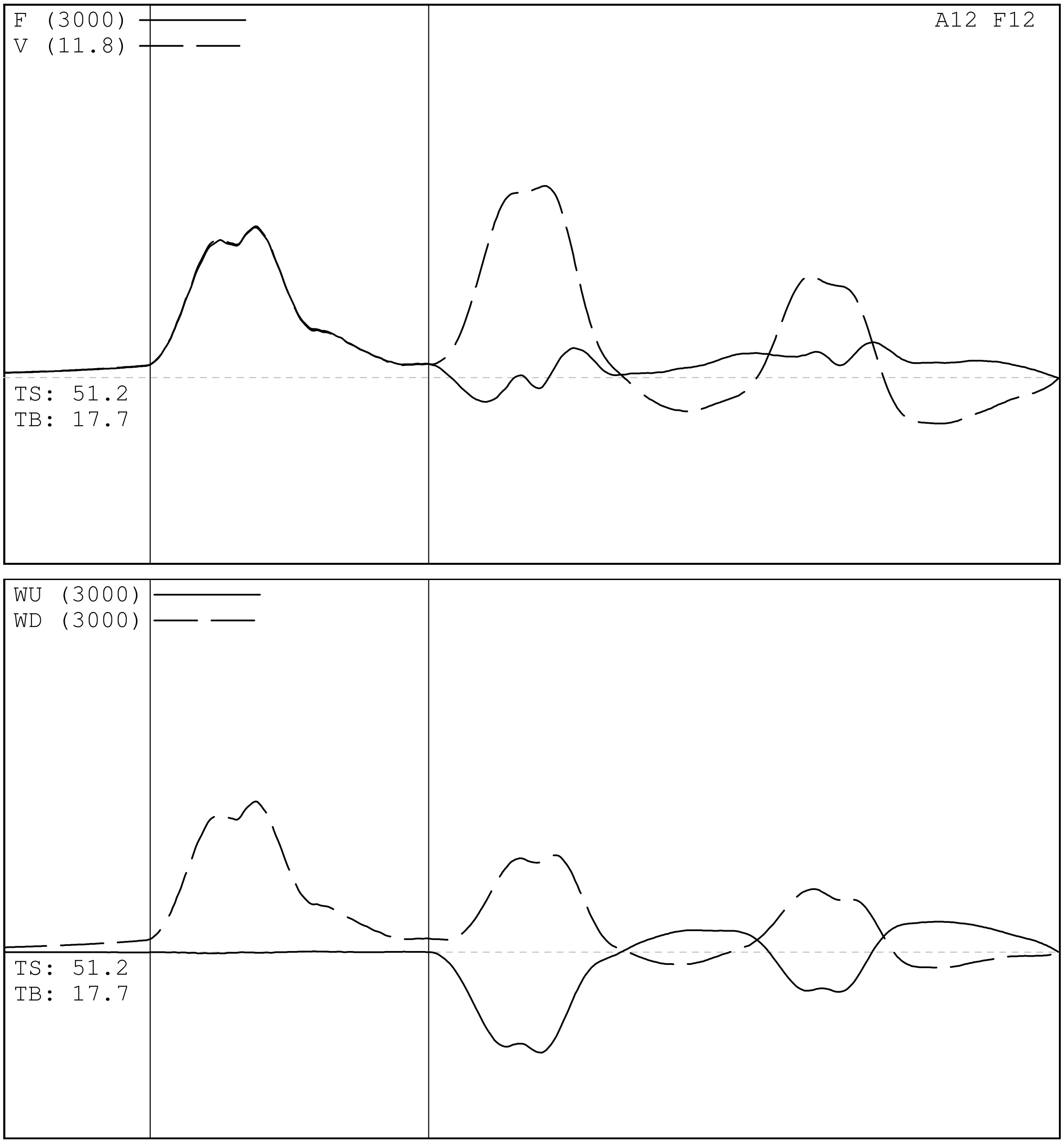
AR: 576.00 in^2 SP: 0.145 k/ft3
LE: 95.00 ft EM: 6,178 ksi
WS: 14,050.0 f/s JC: 0.50

CSX: Max Measured Compr. Stress EMX: Max Transferred Energy
CSI: Max F1 or F2 Compr. Stress BTA: BETA Integrity Factor
CSB: Compression Stress at Bottom RX0: Max Case Method Capacity (JC=0)
TSX: Tension Stress Maximum RX5: Max Case Method Capacity (JC=0.5)
STK: O.E. Diesel Hammer Stroke

BL# end	Elev.	BLC bl/ft	TYPE	CSX ksi	CSI ksi	CSB ksi	TSX ksi	STK ft	EMX k-ft	BTA (%)	RX0 kips	RX5 kips
2	30.4	2	AV2	0.96	1.09	0.09	0.69	3.73	12.14	82.0	53	0
4	29.4	2	AV2	0.85	1.04	0.14	0.47	3.06	16.75	80.0	81	0
6	28.4	2	AV2	1.63	1.99	0.34	1.03	7.73	35.08	86.5	197	0
13	27.4	7	AV7	1.70	1.96	0.35	1.14	5.77	20.79	95.7	213	14
25	26.4	12	AV12	1.80	2.07	0.39	1.24	5.77	22.36	100.0	230	63
33	25.4	8	AV8	1.84	2.09	0.43	1.28	5.83	22.09	96.1	254	110
42	24.4	9	AV9	1.90	2.13	0.51	1.27	5.95	23.35	97.3	305	159
52	23.4	10	AV10	1.92	2.16	0.52	1.30	5.98	22.69	100.0	317	165
62	22.4	10	AV10	1.96	2.20	0.54	1.30	6.04	23.25	100.0	331	165
74	21.4	12	AV12	1.97	2.20	0.55	1.28	6.04	22.97	100.0	338	175
86	20.4	12	AV12	2.03	2.25	0.59	1.27	6.17	24.64	100.0	362	183
99	19.4	13	AV13	2.06	2.28	0.63	1.27	6.23	25.08	100.0	386	208
112	18.4	13	AV13	2.13	2.37	0.67	1.29	6.42	26.69	100.0	410	227
127	17.4	15	AV15	2.13	2.40	0.70	1.27	6.42	26.38	100.0	428	251
143	16.4	16	AV16	2.16	2.44	0.74	1.25	6.48	26.79	100.0	452	267
166	15.4	23	AV23	2.11	2.35	0.83	1.21	6.42	25.66	100.0	493	308
187	14.4	21	AV21	2.07	2.33	0.84	1.19	6.25	24.82	100.0	492	310
212	13.4	25	AV25	2.10	2.35	0.90	1.16	6.36	25.22	100.0	527	329
241	12.4	29	AV29	2.18	2.44	0.97	1.15	6.61	26.44	100.0	572	346
266	11.4	25	AV25	2.42	2.69	1.06	1.28	7.43	32.16	100.0	630	373
290	10.4	24	AV24	2.45	2.75	1.10	1.28	7.49	32.96	100.0	647	388
314	9.4	24	AV24	2.42	2.72	1.06	1.25	7.36	32.27	100.0	628	385
335	8.4	21	AV21	2.39	2.71	1.01	1.25	7.31	31.67	100.0	607	382
355	7.4	20	AV20	2.41	2.75	1.02	1.27	7.36	32.19	100.0	607	392
375	6.4	20	AV20	2.41	2.80	1.01	1.26	7.41	32.02	100.0	616	408
396	5.4	21	AV21	2.44	2.83	1.00	1.26	7.52	32.40	100.0	629	425
418	4.4	22	AV22	2.41	2.81	1.01	1.21	7.45	31.66	100.0	633	428
441	3.4	23	AV23	2.43	2.81	1.04	1.20	7.59	32.22	100.0	655	451
465	2.4	24	AV24	2.51	2.88	1.09	1.23	7.90	34.36	100.0	687	479
492	1.4	27	AV27	2.51	2.74	1.12	1.17	8.02	34.20	100.0	721	505
521	0.4	29	AV29	2.59	2.88	1.17	1.21	8.27	36.00	100.0	762	526
549	-0.6	28	AV28	2.66	3.13	1.24	1.23	8.63	38.62	100.0	818	541
580	-1.6	31	AV29	2.72	3.26	1.66	1.21	8.91	40.39	100.0	1,100	608
611	-2.6	31	AV31	2.77	3.14	1.39	1.27	8.79	40.33	100.0	942	586
643	-3.6	32	AV32	2.84	3.19	1.41	1.33	8.84	41.23	100.0	948	584
675	-4.6	32	AV32	2.88	3.24	1.49	1.35	8.80	41.72	100.0	969	557
705	-5.6	30	AV30	2.92	3.19	1.49	1.41	8.79	42.27	100.0	978	540
733	-6.6	28	AV28	2.97	3.23	1.51	1.42	8.80	42.65	100.0	1,009	555
762	-7.6	29	AV29	3.03	3.28	1.51	1.44	8.85	42.99	100.0	1,062	564
791	-8.6	29	AV29	3.07	3.29	1.45	1.45	8.84	42.72	100.0	1,091	553
818	-9.6	27	AV27	3.11	3.33	1.43	1.46	8.83	42.88	100.0	1,127	549
848	-10.6	30	AV30	3.15	3.37	1.47	1.42	8.85	42.68	100.0	1,183	561
879	-11.6	31	AV31	3.23	3.45	1.53	1.41	9.01	43.32	100.0	1,248	589

I-4 DEER CROSSING Bridge No. 790207 - CFCC WEST PILE N1 APE D46-42 HAMMER
OP: GRL-MGB Test date: 23-Jan-2014

BL# end	Elev.	BLC bl/ft	TYPE	CSX ksi	CSI ksi	CSB ksi	TSX ksi	STK ft	EMX k-ft	BTA (%)	RX0 kips	RX5 kips
913	-12.6	34	AV34	3.26	3.48	1.53	1.36	9.07	43.36	100.0	1,281	604
947	-13.6	34	AV34	3.32	3.54	1.56	1.36	9.20	44.10	100.0	1,319	601
981	-14.6	34	AV34	3.33	3.62	1.56	1.36	9.23	44.45	100.0	1,305	588
1014	-15.6	33	AV33	3.40	3.71	1.59	1.41	9.48	45.82	100.0	1,336	606
1046	-16.6	32	AV32	3.38	3.71	1.56	1.40	9.45	45.52	100.0	1,328	589
1081	-17.6	35	AV35	3.35	3.68	1.51	1.40	9.40	44.71	100.0	1,323	585
1118	-18.6	37	AV37	3.32	3.64	1.49	1.40	9.42	44.51	100.0	1,318	574
1149	-19.6	31	AV31	3.24	3.52	1.43	1.33	9.28	43.52	100.0	1,288	529
1186	-20.6	37	AV37	3.21	3.43	1.42	1.31	9.41	43.65	100.0	1,293	517
1224	-21.6	38	AV38	3.11	3.26	1.39	1.21	9.37	42.51	100.0	1,284	458
1267	-22.6	43	AV43	3.02	3.08	1.39	1.09	9.42	41.98	100.0	1,283	411
1310	-23.6	43	AV43	2.92	3.25	1.34	0.97	9.48	41.13	100.0	1,269	404
1357	-24.6	47	AV47	2.65	2.79	1.25	0.79	8.71	36.35	99.8	1,230	417
1404	-25.6	47	AV47	2.96	3.08	1.57	0.90	8.92	41.30	100.0	1,353	427
1461	-26.6	57	AV57	3.03	3.14	1.85	0.71	9.05	42.23	98.9	1,510	631
1527	-27.6	66	AV66	3.02	3.05	1.96	0.71	9.04	42.20	96.9	1,551	762
1611	-28.6	84	AV84	3.01	3.06	2.05	0.77	9.14	42.38	99.9	1,545	869
1714	-29.6	103	AV103	2.99	3.07	2.09	0.90	9.28	43.36	100.0	1,474	895
1820	-30.6	106	AV104	2.99	3.10	2.17	0.92	9.37	43.82	100.0	1,448	902
1917	-31.6	97	AV97	3.13	3.26	2.19	1.02	9.49	45.00	100.0	1,408	876
2003	-32.6	86	AV86	3.29	3.44	2.09	1.12	9.49	45.55	100.0	1,341	816
2079	-33.6	76	AV76	3.40	3.54	1.99	1.18	9.54	45.86	100.0	1,287	766
2148	-34.6	69	AV69	3.45	3.58	1.95	1.19	9.55	45.69	100.0	1,282	725
2211	-35.6	63	AV62	3.47	3.61	1.93	1.18	9.56	44.95	100.0	1,312	692
2271	-36.6	60	AV60	3.45	3.66	1.88	1.19	9.54	44.74	99.7	1,299	657
2319	-37.6	48	AV48	3.43	3.59	1.84	1.21	9.51	43.99	99.8	1,294	628
2370	-38.6	51	AV51	3.38	3.53	1.80	1.17	9.54	43.23	96.7	1,290	625
2421	-39.6	51	AV51	3.28	3.46	1.72	1.09	9.54	42.32	90.1	1,266	625
2472	-40.6	51	AV51	3.16	3.32	1.71	0.97	9.59	41.62	89.1	1,282	626
2527	-41.6	55	AV55	3.04	3.15	1.80	0.77	9.62	40.16	88.2	1,353	640
2585	-42.6	58	AV58	3.03	3.10	1.85	0.61	9.78	40.11	87.9	1,400	657
2645	-43.6	60	AV60	3.04	3.26	1.92	0.52	9.79	39.25	88.1	1,439	682
2727	-44.6	82	AV82	3.33	3.70	2.11	0.59	9.92	40.85	87.7	1,564	734
2765	-45.0	91	AV38	3.63	3.79	2.34	0.64	9.82	40.59	88.2	1,703	773



Project Information

PROJECT: I-4 DEER CROSSING
PILE NAME: CFCC WEST PILE N1
DESCR: APE D46-42 HAMMER
OPERATOR: GRL-MGB
FILE: CFCC WEST PILE N1-MH
1/23/2014 2:44:51 PM
Blow Number 159

Pile Properties

LE	95.00	ft
AR	576.00	in^2
EM	6178	ksi
SP	0.145	k/ft3
WS	14050.0	f/s
EA/C	253.3	ksec/ft
2L/C	13.50	ms
JC	0.50	[]
LP	37.70	ft

Quantity Results

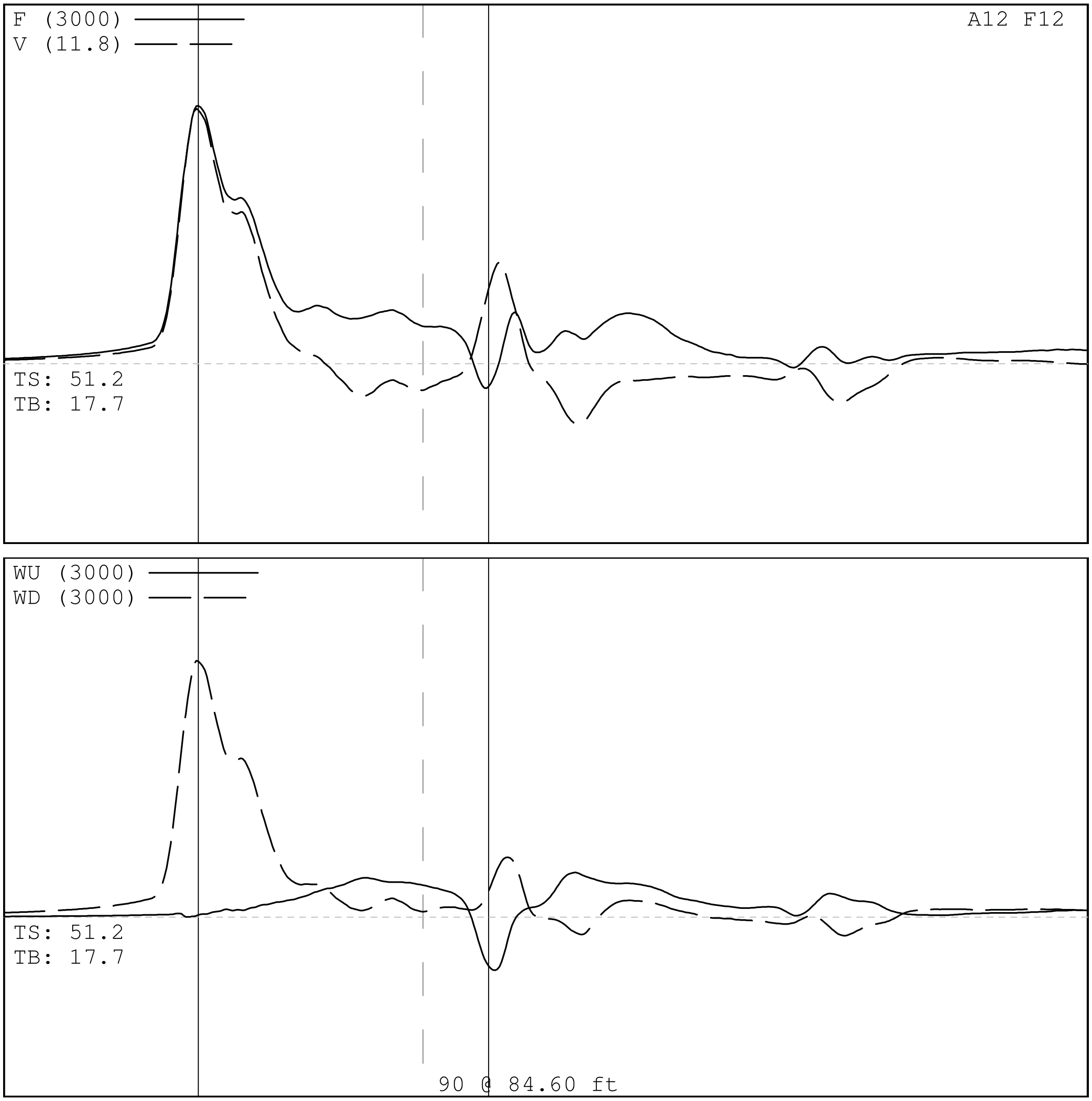
CSX	2.09	ksi
CSI	2.34	ksi
CSB	0.87	ksi
TSX	1.23	ksi
STK	6.40	ft
EMX	25.72	k-ft
BTA	100.0	(%)
RX0	509	kips
RX5	319	kips

Sensors

F1: [F978] 94.4 (0.98)
F2: [A407] 99.3 (0.98)
A1: [19932] 1020 g's/v (1.02)
A2: [29018] 1150 g's/v (1.02)
CLIP: OK

Version 2012.114

I-4 DEER CROSSING CFCC WEST PILE N1



Project Information
PROJECT: I-4 DEER CROSSING
PILE NAME: CFCC WEST PILE N1
DESCR: APE D46-42 HAMMER
OPERATOR: GRL-MGB
FILE: CFCC WEST PILE N1-MH
1/23/2014 4:40:53 PM
Blow Number 2761

Pile Properties

LE	95.00	ft
AR	576.00	in^2
EM	6178	ksi
SP	0.145	k/ft3
WS	14050.0	f/s
EA/C	253.3	ksec/ft
2L/C	13.70	ms
JC	0.50	[]
LP	98.37	ft

Quantity Results

CSX	3.73	ksi
CSI	3.76	ksi
CSB	2.42	ksi
TSX	0.69	ksi
STK	9.78	ft
EMX	42.70	k-ft
BTA	90.0	(%)
RX0	1725	kips
RX5	783	kips

Sensors
F1: [F978] 94.4 (1)
F2: [A407] 99.3 (1)
A1: [19932] 1020 g's/v (1)
A2: [29018] 1150 g's/v (1)
CLIP: OK

700-010-60
Construction
11/11

PILE DRIVING INFORMATION

Structure Number: Expermental Pile No 1

FIN PROJ. ID # 488464-1-5201 DATE 1-23-14 STATION NO. ______

PILE SIZE 24" ACTUAL/AUTH LENGTH 100' BENT/PIER NO. / PILE NO. N-1

HAMMER TYPE D46-42 RATED ENERGY 114,109 Ft/lbs OPERATING RATE varies

REF. ELEV 53.37' MIN. TIP ELEV / PILE CUTOFF ELEV /

DRIVING CRITERIA Experimental Pile 24" Square Concrete Pile

PILE CUSHION THICKNESS AND MATERIAL Pine Plywood 8 3/4"

HAMMER CUSHION THICKNESS AND MATERIAL 3 1/2" (2-1", Micarta / 3-1/2" Aluminum)

WEATHER Clear TEMP 57° START TIME 2:36 pm STOP TIME 4:46 pm

PILE DATA

PAY ITEM NO. N/A WORK ORDER NO. N/A

MANUFACTURED BY ______ T.B.M./B.M. ELEV N/A GROUND ROD READ N/A

DATE CAST 7-24-13 ROD READ N/A PILE HEAD ROD READ N/A

MANUFACTURER'S PILE NO. N/A H.I. N/A PILE HEAD ELEV. 53.40'

PILE HEAD CHAMFER 3/4" x 3" PILE TIP ELEV. -46.60'

PILE TIP CHAMFER 3/4" x 3" GROUND ELEV. 41.20'

QUALIFED INSPECTOR'S NAME: Gonzalo Silva TIN #: S 41028067

SPLICE / EACH	PREFORMED HOLE	DYNAMIC LOAD TEST	PAY SET CHECK	NO PAY SET CHECK	REDRIVE	EXTRACTION	DRIVING OF SPLICE	PILE TYPE CODE	BATTER	PILE LENGTH		PENETRATION BELOW GROUND	EXTENSION / BUILD UP	
										ORIGINAL FURNISHED	TOTAL LENGTH WITH EXTENSION		AUTHORIZED	ACTUAL
/	20.0'	/	/	/	/	/	/	/	/	100.0'	/	87.80'	/	/

NOTES: Predrilled 20'.
- Experimental Pile No. 1, Pile cushion 8 3/4".
- Fuel setting started at 380 PSI
- Pile PDA and EDC.

For Trainee experience evidence only:
Name of CTQP Trainee being supervised by the Qualified Inspector: ______
CTQP Trainee

I certify the Pile Driving Record accuracy and that the named above Trainee has observed the full pile installation:

[signature]
Qualified Inspector (Signature)

N-1 2

Bridge	Experim. Pile No. 1 1-23-14
End/Bent	
Pile	No. 1
Reference Elevation	53.37'

Depth	Blows	Stroke	Fuel S.		Comments
1.-2					
2.-3					
3.-4					
4.-5					
5.-6					
6.-7					
7.-8					
8.-9					
9.-10					
10.-11	Predrilling				
11.-12					
12.-13					
13-14					
14-15					
15-16					
16-17					
17-18					
18-19					
19-20					
20-21	run				
21-22					
22-23	6	5.71	380		22½ beginning - start
23-24	run		380		
24-25					
25-26	7	5.71			
26-27	12	5.70			
27-28	8	5.76			
28-29	9	5.89			
29-30	10	5.96			
30-31	10	5.92			
31-32	12	6.0			
32-33	12	6.08			
33-34	13	6.22			
34-35	13	6.32			
35-36	15	6.36			
36-37	16	6.31			re-start 2:50 pm
37-38	23	6.13			
38-39	21	6.17			

starting 380

FS 1
2
3
4

2:36 pm

Stop 2:41 check gauges

N-1 (3)

Bridge	Deer Bridge Experimental Pile No 1.				
End/Bent					
Pile	No. 1				1-23-14
Reference Elevation	53.37'				

Depth	Blows	Stroke	Fuel S.		Comments
39-40	25	6.17	380		
40-41	29	6.52	400		
41-42	25	7.33	"		
42-43	24	7.39	"		
43-44	24	7.26	"		
44-45	21	7.21	"		
45-46	20	7.27	"		
46-47	20	7.32	450		
47-48	21	7.42	"		
48-49	22	7.24	"		
49-50	23	7.49	"		
50-51	24	7.79	480		
51-52	27	7.87	"		
52-53	29	8.16	520		
53-54	28	8.28			
54-55	31	8.57			
55-56	31	8.67			
56-57	32	7.91			
57-58	32	8.68			
58-59	30	8.68	540		
59-60	28	8.69	540		
60-61	29	8.73			
61-62	29	8.73			
62-63	27	8.72			
63-64	30	8.74			
64-65	31	8.69			
65-66	34	8.96			
66-67	34	9.09			
67-68	34	9.12			
68-69	33	9.36			
69-70	32	9.32			
70-71	35	9.27			
71-72	37	9.3			
72-73	31	9.17			
73-74	37	9.27			
74-75	38	9.24			Smoke - Born.
75-76	43	8.61			
76-77	43	9.32	650		Stopped 3:49 pm -
77-78	47	8.41	650		Re-started 4:08 p.m.

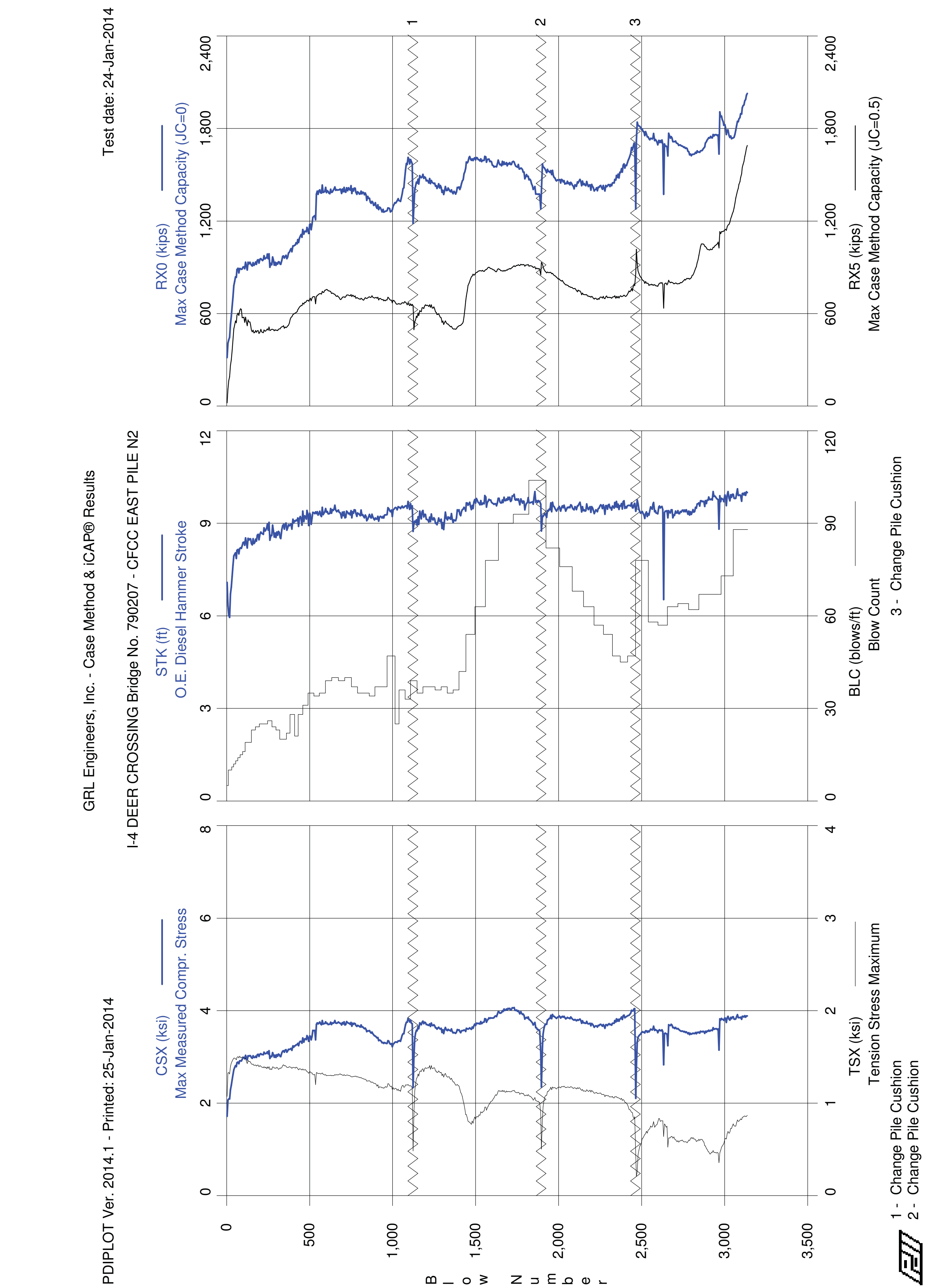
Change cushion. 9"

N-1 (4)

VT REVIEW DRIVING LOG	
Bridge	Deer Bridge - Experimental Pile No. 1
End/Bent	
Pile	No. 1 1-23-14
Reference Elevation	53.37'

Depth	Blows	Stroke	Fuel S.		Comments
78-79	47	8.72	650		
79-80	57	8.93	↓		
80-81	66	8.83			
81-82	84	9.01	680		
82-83	103	9.02	720		
83-84	106	9.18	↓		
84-85	97	9.42			
85-86	86	9.33			
86-88	76	9.42			
87-88	69	9.43			
88-89	63	9.44			
89-90	60	9.33			
90-91	48	9.38			
91-92	51	9.31		Smoke	
92-93	51	9.28		Smoke	
93-94	51	9.47		Smoke	
94-95	55	9.36		Smoke	
95-96	58	9.66			
96-97	60	9.60		- Reference broke	
97-98	82	9.56			
98-99	38	9.55		spall in pile @ 4:46 p.m= 98'-5"	
99-100					

total 2768 blows
- Operation stopped at 4:46 pm. Pile head had a mayor spall.


PDIPLOT Ver. 2014.1 - Printed: 25-Jan-2014
GRL Engineers, Inc. - Case Method & iCAP® Results
I-4 DEER CROSSING Bridge No. 790207 - CFCC EAST PILE N2
Test date: 24-Jan-2014
CSX (ksi)
Max Measured Compr. Stress
TSX (ksi)
Tension Stress Maximum
STK (ft)
O.E. Diesel Hammer Stroke
BLC (blows/ft)
Blow Count
RX0 (kips)
Max Case Method Capacity (JC=0)
RX5 (kips)
Max Case Method Capacity (JC=0.5)
Blow Number
1 - Change Pile Cushion
2 - Change Pile Cushion
3 - Change Pile Cushion

I-4 DEER CROSSING Bridge No. 790207 - CFCC EAST PILE N2 APE D46-42 HAMMER
OP: GRL-MGB Test date: 24-Jan-2014

AR: 576.00 in^2 SP: 0.145 k/ft3
LE: 95.00 ft EM: 6,178 ksi
WS: 14,050.0 f/s JC: 0.50

CSX: Max Measured Compr. Stress
CSI: Max F1 or F2 Compr. Stress
CSB: Compression Stress at Bottom
TSX: Tension Stress Maximum
STK: O.E. Diesel Hammer Stroke
EMX: Max Transferred Energy
BTA: BETA Integrity Factor
RX0: Max Case Method Capacity (JC=0)
RX5: Max Case Method Capacity (JC=0.5)

BL# end	BLC bl/ft	TYPE	CSX ksi	CSI ksi	CSB ksi	TSX ksi	STK ft	EMX k-ft	BTA (%)	RX0 kips	RX5 kips
5	5	AV5	1.71	2.11	0.54	1.07	7.08	29.37	97.6	314	21
10	5	AV5	2.07	2.58	0.70	1.33	6.33	28.75	100.0	408	109
15	10	AV5	2.09	2.54	0.73	1.33	6.02	25.99	100.0	430	167
20	10	AV5	2.09	2.49	0.76	1.32	5.95	25.26	100.0	446	190
25	10	AV5	2.29	2.73	0.90	1.40	6.71	31.50	100.0	530	264
30	10	AV5	2.39	2.82	0.99	1.43	6.93	32.93	100.0	582	300
35	11	AV5	2.50	2.96	1.10	1.45	7.28	35.18	100.0	646	360
40	11	AV5	2.62	3.09	1.20	1.47	7.64	37.73	100.0	708	431
45	12	AV5	2.72	3.23	1.33	1.49	7.94	39.60	100.0	781	500
50	12	AV5	2.77	3.31	1.37	1.49	8.00	39.83	100.0	808	525
55	13	AV5	2.81	3.34	1.42	1.48	8.05	40.66	100.0	839	552
60	13	AV5	2.79	3.30	1.42	1.47	7.86	39.37	100.0	836	540
67	14	AV5	2.87	3.42	1.51	1.50	8.11	40.85	100.0	886	584
72	14	AV5	2.88	3.41	1.50	1.50	8.13	40.92	100.0	881	603
77	14	AV5	2.87	3.38	1.48	1.50	8.06	40.13	100.0	875	596
82	15	AV5	2.91	3.42	1.51	1.50	8.16	40.81	100.0	890	612
87	15	AV5	2.93	3.45	1.52	1.50	8.24	41.40	100.0	895	638
92	15	AV5	2.92	3.45	1.52	1.49	8.19	41.08	100.0	895	630
97	16	AV5	2.97	3.51	1.51	1.51	8.32	41.80	100.0	891	564
102	16	AV5	2.99	3.55	1.53	1.50	8.40	42.21	100.0	903	578
107	16	AV5	2.97	3.54	1.51	1.48	8.32	41.34	100.0	890	567
112	19	AV5	2.98	3.57	1.52	1.48	8.34	41.29	100.0	899	550
117	19	AV5	3.02	3.63	1.57	1.48	8.49	42.32	100.0	926	568
122	19	AV5	2.99	3.60	1.55	1.45	8.36	41.79	100.0	912	546
127	19	AV5	2.96	3.52	1.52	1.44	8.28	41.31	100.0	897	533
133	19	AV5	3.03	3.58	1.58	1.46	8.50	42.35	100.0	930	559
138	19	AV5	3.01	3.57	1.57	1.45	8.45	42.04	100.0	923	541
143	19	AV5	3.01	3.58	1.55	1.44	8.45	41.98	100.0	917	538
148	19	AV5	3.03	3.60	1.58	1.44	8.51	42.19	100.0	934	525
153	23	AV5	2.97	3.53	1.53	1.42	8.29	40.38	100.0	906	483
158	23	AV5	2.99	3.57	1.55	1.42	8.38	40.70	100.0	918	489
163	23	AV5	3.02	3.62	1.57	1.42	8.48	41.35	100.0	927	488
168	23	AV5	2.98	3.57	1.54	1.40	8.32	40.65	100.0	909	476
173	24	AV5	2.99	3.59	1.56	1.41	8.39	40.70	100.0	922	480
178	24	AV5	3.03	3.63	1.59	1.42	8.55	41.63	100.0	944	491
183	24	AV5	2.98	3.58	1.54	1.40	8.39	40.76	100.0	911	479
188	24	AV5	3.07	3.69	1.62	1.42	8.71	42.80	100.0	958	496
193	24	AV5	3.04	3.66	1.59	1.41	8.59	41.86	100.0	944	481
199	25	AV5	3.01	3.64	1.57	1.39	8.46	41.06	100.0	928	472
204	25	AV5	3.06	3.69	1.61	1.41	8.67	41.99	100.0	956	478
209	25	AV5	3.06	3.71	1.60	1.39	8.70	42.53	100.0	947	497
214	25	AV5	3.07	3.73	1.62	1.39	8.73	42.64	100.0	961	487
219	25	AV5	3.05	3.70	1.59	1.38	8.63	42.00	100.0	939	476

I-4 DEER CROSSING Bridge No. 790207 - CFCC EAST PILE N2 APE D46-42 HAMMER
OP: GRL-MGB Test date: 24-Jan-2014

BL#	BLC	TYPE	CSX	CSI	CSB	TSX	STK	EMX	BTA	RX0	RX5
end	bl/ft		ksi	ksi	ksi	ksi	ft	k-ft	(%)	kips	kips
224	25	AV5	3.05	3.70	1.61	1.38	8.66	41.92	100.0	951	479
229	25	AV5	3.10	3.77	1.66	1.40	8.86	43.45	100.0	979	493
234	25	AV5	3.05	3.72	1.60	1.38	8.70	42.33	100.0	949	484
239	25	AV5	3.07	3.75	1.63	1.39	8.80	42.52	100.0	962	491
244	25	AV5	3.10	3.79	1.64	1.38	8.92	43.31	100.0	970	499
249	26	AV5	3.11	3.79	1.66	1.39	8.95	43.49	100.0	985	498
254	26	AV5	3.07	3.77	1.61	1.37	8.77	42.68	100.0	953	493
259	26	AV5	3.10	3.82	1.63	1.39	8.91	43.55	100.0	965	511
265	26	AV5	3.00	3.70	1.55	1.37	8.54	40.80	100.0	917	492
270	26	AV5	2.97	3.67	1.52	1.36	8.48	40.32	100.0	904	495
275	24	AV5	3.07	3.79	1.60	1.38	8.79	42.53	100.0	949	497
280	24	AV5	3.07	3.79	1.61	1.38	8.87	42.97	100.0	955	499
285	24	AV5	3.04	3.74	1.59	1.39	8.72	41.91	100.0	941	492
290	24	AV5	3.00	3.71	1.55	1.38	8.58	41.06	100.0	919	490
295	24	AV5	3.05	3.76	1.58	1.38	8.71	42.35	100.0	937	496
300	23	AV5	2.98	3.68	1.52	1.38	8.49	40.41	100.0	903	491
305	23	AV5	3.06	3.78	1.57	1.38	8.74	42.33	100.0	930	493
310	23	AV5	3.01	3.72	1.55	1.38	8.60	41.23	100.0	921	492
315	23	AV5	3.09	3.84	1.60	1.37	8.83	43.20	100.0	949	499
320	20	AV5	3.05	3.79	1.58	1.38	8.72	42.16	100.0	940	498
325	20	AV5	2.94	3.64	1.49	1.37	8.30	39.67	100.0	889	503
331	20	AV5	3.05	3.76	1.58	1.38	8.65	42.23	100.0	937	509
336	20	AV5	3.12	3.82	1.62	1.40	8.90	43.72	100.0	962	516
341	20	AV5	3.12	3.82	1.63	1.40	8.90	43.99	100.0	970	516
346	20	AV5	3.12	3.82	1.61	1.41	8.92	43.71	100.0	963	518
351	20	AV5	3.11	3.80	1.62	1.41	8.82	43.13	100.0	965	505
356	20	AV5	3.15	3.85	1.63	1.40	8.99	44.11	100.0	970	513
361	22	AV5	3.14	3.85	1.63	1.40	8.95	43.58	100.0	970	511
366	22	AV5	3.12	3.81	1.62	1.39	8.83	42.77	100.0	969	513
371	22	AV5	3.14	3.83	1.63	1.38	8.90	43.39	100.0	973	521
376	22	AV5	3.16	3.85	1.65	1.39	8.93	43.39	100.0	991	529
381	22	AV5	3.15	3.83	1.64	1.39	8.87	42.83	100.0	989	544
386	28	AV5	3.19	3.89	1.67	1.39	9.01	43.18	100.0	1,022	566
391	28	AV5	3.18	3.88	1.68	1.39	8.97	42.84	100.0	1,024	576
397	28	AV5	3.15	3.84	1.62	1.37	8.82	42.13	100.0	998	584
402	28	AV5	3.23	3.93	1.67	1.39	9.12	44.07	100.0	1,035	594
407	28	AV5	3.21	3.90	1.68	1.38	8.98	43.18	100.0	1,042	597
412	21	AV5	3.25	3.96	1.69	1.39	9.13	44.45	100.0	1,048	601
417	21	AV5	3.25	3.96	1.69	1.38	9.08	44.39	100.0	1,049	604
422	21	AV5	3.25	3.97	1.70	1.39	9.06	44.02	100.0	1,057	607
427	21	AV5	3.29	4.02	1.70	1.38	9.16	45.05	100.0	1,065	616
432	28	AV5	3.27	4.00	1.70	1.37	9.09	44.32	100.0	1,069	625
437	28	AV5	3.25	3.97	1.70	1.36	8.95	43.75	100.0	1,071	636
442	28	AV5	3.33	4.06	1.72	1.37	9.20	45.15	100.0	1,092	644
447	28	AV5	3.33	4.06	1.74	1.37	9.19	45.21	100.0	1,104	650
452	28	AV5	3.31	4.04	1.74	1.37	9.07	44.43	100.0	1,108	648
457	28	AV5	3.33	4.07	1.74	1.36	9.09	44.89	100.0	1,108	658
463	31	AV5	3.39	4.13	1.79	1.37	9.31	46.16	100.0	1,140	666
468	31	AV5	3.35	4.08	1.76	1.36	9.12	44.79	100.0	1,122	664
473	31	AV5	3.38	4.12	1.78	1.36	9.22	45.76	100.0	1,132	674
478	31	AV5	3.38	4.11	1.77	1.36	9.18	45.35	100.0	1,127	674
483	31	AV5	3.38	4.11	1.77	1.35	9.16	45.25	100.0	1,134	680

I-4 DEER CROSSING Bridge No. 790207 - CFCC EAST PILE N2 APE D46-42 HAMMER
OP: GRL-MGB Test date: 24-Jan-2014

BL# end	BLC bl/ft	TYPE	CSX ksi	CSI ksi	CSB ksi	TSX ksi	STK ft	EMX k-ft	BTA (%)	RX0 kips	RX5 kips
488	31	AV5	3.46	4.20	1.82	1.34	9.44	46.77	100.0	1,160	688
493	35	AV5	3.42	4.14	1.79	1.33	9.27	45.47	100.0	1,147	686
498	35	AV5	3.33	4.03	1.73	1.32	8.91	42.94	100.0	1,115	681
503	35	AV5	3.46	4.17	1.84	1.34	9.34	46.02	100.0	1,182	695
508	35	AV5	3.46	4.15	1.84	1.34	9.30	45.80	100.0	1,183	692
513	35	AV5	3.31	3.96	1.73	1.31	8.75	42.42	100.0	1,116	688
518	35	AV5	3.53	4.21	1.88	1.33	9.41	47.09	100.0	1,216	703
523	35	AV5	3.58	4.28	1.90	1.31	9.39	47.48	100.0	1,230	710
529	34	AV5	3.54	4.23	1.88	1.30	9.24	46.46	100.0	1,219	711
534	34	AV5	3.59	4.26	1.91	1.31	9.36	47.19	100.0	1,243	709
539	34	AV5	3.38	4.03	1.87	1.20	9.36	41.73	100.0	1,229	669
544	34	AV5	3.72	4.40	2.16	1.33	9.33	48.14	100.0	1,385	711
549	34	AV5	3.72	4.40	2.15	1.32	9.33	48.01	100.0	1,383	716
554	34	AV5	3.72	4.39	2.12	1.32	9.30	48.25	100.0	1,379	725
559	35	AV5	3.74	4.41	2.16	1.32	9.35	48.38	100.0	1,402	726
564	35	AV5	3.74	4.41	2.15	1.32	9.34	48.56	100.0	1,398	731
569	35	AV5	3.73	4.39	2.12	1.32	9.29	48.02	100.0	1,389	727
574	35	AV5	3.71	4.36	2.11	1.32	9.26	47.46	100.0	1,389	731
579	35	AV5	3.79	4.44	2.19	1.32	9.52	49.61	100.0	1,432	745
584	35	AV5	3.70	4.34	2.09	1.31	9.26	47.73	100.0	1,383	736
589	35	AV5	3.70	4.33	2.08	1.31	9.28	47.54	100.0	1,377	740
595	39	AV5	3.73	4.36	2.12	1.30	9.39	48.41	100.0	1,399	750
600	39	AV5	3.76	4.40	2.13	1.31	9.49	49.02	100.0	1,412	755
605	39	AV5	3.73	4.36	2.09	1.30	9.39	48.36	100.0	1,391	756
610	39	AV5	3.72	4.35	2.10	1.30	9.35	48.22	100.0	1,394	753
615	39	AV5	3.70	4.33	2.10	1.30	9.32	47.77	100.0	1,387	748
620	39	AV5	3.69	4.31	2.08	1.30	9.27	47.41	100.0	1,377	745
625	39	AV5	3.74	4.37	2.11	1.30	9.43	48.85	100.0	1,393	748
630	39	AV5	3.75	4.37	2.14	1.30	9.49	49.02	100.0	1,408	740
635	40	AV5	3.70	4.30	2.09	1.30	9.32	47.84	100.0	1,379	730
640	40	AV5	3.73	4.34	2.11	1.30	9.42	48.60	100.0	1,390	735
645	40	AV5	3.73	4.34	2.13	1.30	9.44	48.69	100.0	1,400	727
650	40	AV5	3.71	4.31	2.13	1.30	9.36	48.36	100.0	1,396	729
655	40	AV5	3.82	4.45	2.18	1.31	9.69	50.70	100.0	1,431	723
661	40	AV5	3.74	4.36	2.15	1.31	9.44	48.80	100.0	1,409	711
666	40	AV5	3.71	4.33	2.11	1.30	9.32	48.08	100.0	1,389	715
671	40	AV5	3.76	4.41	2.13	1.31	9.46	49.42	100.0	1,409	717
676	39	AV5	3.73	4.38	2.10	1.31	9.37	48.79	100.0	1,395	708
681	39	AV5	3.77	4.43	2.12	1.32	9.46	49.46	100.0	1,420	699
686	39	AV5	3.71	4.36	2.08	1.31	9.26	47.85	100.0	1,395	695
691	39	AV5	3.71	4.36	2.08	1.31	9.23	47.85	100.0	1,394	688
696	39	AV5	3.72	4.36	2.07	1.31	9.26	47.99	100.0	1,390	698
701	39	AV5	3.73	4.36	2.10	1.30	9.33	48.47	100.0	1,405	710
706	39	AV5	3.72	4.34	2.08	1.30	9.26	48.21	100.0	1,396	708
711	39	AV5	3.76	4.37	2.11	1.31	9.38	48.95	100.0	1,418	706
716	40	AV5	3.66	4.26	2.03	1.30	9.09	46.64	100.0	1,373	705
721	40	AV5	3.73	4.33	2.06	1.30	9.30	48.42	100.0	1,401	714
727	40	AV5	3.76	4.36	2.08	1.30	9.39	49.14	100.0	1,414	721
732	40	AV5	3.73	4.31	2.04	1.30	9.31	48.40	100.0	1,395	719
737	40	AV5	3.75	4.33	2.08	1.30	9.37	48.51	100.0	1,420	720
742	40	AV5	3.72	4.30	2.06	1.30	9.30	47.93	100.0	1,405	717
747	40	AV5	3.73	4.33	2.06	1.29	9.35	48.42	100.0	1,413	718

I-4 DEER CROSSING Bridge No. 790207 - CFCC EAST PILE N2 APE D46-42 HAMMER
OP: GRL-MGB Test date: 24-Jan-2014

BL#	BLC	TYPE	CSX	CSI	CSB	TSX	STK	EMX	BTA	RX0	RX5
end	bl/ft		ksi	ksi	ksi	ksi	ft	k-ft	(%)	kips	kips
752	37	AV5	3.71	4.32	2.06	1.29	9.31	48.06	100.0	1,414	719
757	37	AV5	3.68	4.28	2.01	1.29	9.23	47.44	100.0	1,386	713
762	37	AV5	3.73	4.32	2.05	1.29	9.41	48.64	100.0	1,412	718
767	37	AV5	3.72	4.29	2.03	1.29	9.36	48.45	100.0	1,401	716
772	37	AV5	3.69	4.25	2.01	1.29	9.32	47.53	100.0	1,398	708
777	37	AV5	3.75	4.32	2.04	1.29	9.52	49.03	100.0	1,419	715
782	37	AV5	3.65	4.22	1.95	1.29	9.22	46.72	100.0	1,369	698
787	37	AV5	3.69	4.26	1.98	1.29	9.33	47.78	100.0	1,391	706
793	35	AV5	3.69	4.27	1.98	1.29	9.37	47.88	100.0	1,392	699
798	35	AV5	3.65	4.21	1.94	1.28	9.22	46.87	100.0	1,375	696
803	35	AV5	3.68	4.25	1.96	1.28	9.37	47.93	100.0	1,388	694
808	35	AV5	3.64	4.20	1.93	1.27	9.24	46.88	100.0	1,374	695
813	35	AV5	3.67	4.23	1.93	1.27	9.34	47.66	100.0	1,382	698
818	35	AV5	3.68	4.25	1.93	1.27	9.36	47.74	100.0	1,387	696
823	35	AV5	3.63	4.20	1.92	1.26	9.23	46.90	100.0	1,383	690
828	35	AV5	3.61	4.17	1.89	1.26	9.15	46.02	100.0	1,375	685
833	35	AV5	3.63	4.20	1.88	1.26	9.24	46.12	100.0	1,379	699
838	35	AV5	3.63	4.20	1.87	1.26	9.28	46.24	100.0	1,387	707
843	35	AV5	3.57	4.14	1.83	1.25	9.16	45.38	100.0	1,353	697
848	35	AV5	3.55	4.12	1.79	1.24	9.09	45.15	100.0	1,341	698
853	35	AV5	3.56	4.15	1.80	1.24	9.13	45.42	100.0	1,352	702
859	34	AV5	3.57	4.18	1.81	1.24	9.25	46.24	100.0	1,358	708
864	34	AV5	3.55	4.16	1.74	1.24	9.26	45.92	100.0	1,334	708
869	34	AV5	3.53	4.12	1.71	1.23	9.20	45.30	100.0	1,327	704
874	34	AV5	3.50	4.06	1.67	1.22	9.14	44.69	100.0	1,306	707
879	34	AV5	3.56	4.14	1.71	1.24	9.40	46.24	100.0	1,347	719
884	34	AV5	3.47	4.04	1.65	1.22	9.12	44.29	100.0	1,309	702
889	34	AV5	3.48	4.02	1.63	1.22	9.17	44.48	100.0	1,304	704
894	37	AV5	3.45	3.97	1.61	1.21	9.09	43.75	100.0	1,300	701
899	37	AV5	3.45	3.96	1.62	1.22	9.19	43.63	100.0	1,317	703
904	37	AV5	3.45	3.94	1.59	1.21	9.20	43.86	100.0	1,307	706
909	37	AV5	3.40	3.86	1.51	1.18	9.12	42.84	100.0	1,275	700
914	37	AV5	3.40	3.79	1.54	1.19	9.18	42.88	100.0	1,294	701
919	37	AV5	3.36	3.71	1.51	1.17	9.10	42.10	100.0	1,285	691
925	37	AV5	3.37	3.68	1.51	1.18	9.21	42.56	100.0	1,286	700
930	37	AV5	3.34	3.62	1.51	1.17	9.21	42.40	100.0	1,285	694
935	37	AV5	3.33	3.58	1.46	1.17	9.21	42.40	100.0	1,269	693
940	37	AV5	3.30	3.54	1.44	1.16	9.16	41.59	100.0	1,263	688
945	37	AV5	3.30	3.51	1.44	1.16	9.19	41.89	100.0	1,269	690
950	37	AV5	3.30	3.49	1.42	1.17	9.21	41.77	100.0	1,259	685
955	37	AV5	3.32	3.48	1.43	1.17	9.31	42.23	100.0	1,271	690
960	37	AV5	3.29	3.43	1.39	1.18	9.25	41.53	100.0	1,259	680
965	37	AV5	3.30	3.43	1.41	1.18	9.31	42.17	100.0	1,267	688
970	47	AV5	3.30	3.43	1.38	1.18	9.30	41.83	100.0	1,262	693
975	47	AV5	3.35	3.47	1.42	1.21	9.52	42.89	100.0	1,288	705
980	47	AV5	3.34	3.44	1.41	1.21	9.48	42.13	100.0	1,289	700
985	47	AV5	3.28	3.32	1.39	1.18	9.38	41.38	100.0	1,276	688
991	47	AV5	3.29	3.33	1.34	1.18	9.42	41.46	100.0	1,257	691
996	47	AV5	3.27	3.33	1.37	1.18	9.39	40.94	100.0	1,270	682
1001	47	AV5	3.24	3.32	1.38	1.15	9.28	40.00	100.0	1,278	674
1006	47	AV5	3.27	3.41	1.41	1.17	9.42	40.79	100.0	1,304	683
1011	47	AV5	3.30	3.43	1.40	1.15	9.48	41.17	100.0	1,305	686

I-4 DEER CROSSING Bridge No. 790207 - CFCC EAST PILE N2 APE D46-42 HAMMER
OP: GRL-MGB Test date: 24-Jan-2014

BL#	BLC	TYPE	CSX	CSI	CSB	TSX	STK	EMX	BTA	RX0	RX5
end	bl/ft		ksi	ksi	ksi	ksi	ft	k-ft	(%)	kips	kips
1016	25	AV5	3.32	3.45	1.45	1.16	9.52	41.67	100.0	1,322	675
1021	25	AV5	3.30	3.44	1.43	1.15	9.43	41.34	100.0	1,309	662
1026	25	AV5	3.33	3.47	1.47	1.15	9.50	41.91	100.0	1,328	663
1031	25	AV5	3.33	3.49	1.46	1.15	9.48	41.63	100.0	1,333	663
1036	25	AV5	3.34	3.48	1.50	1.15	9.53	42.05	100.0	1,347	663
1041	36	AV5	3.35	3.42	1.46	1.14	9.55	41.86	100.0	1,330	665
1046	36	AV5	3.34	3.40	1.46	1.13	9.46	41.12	100.0	1,334	659
1051	36	AV5	3.35	3.51	1.42	1.13	9.50	41.46	100.0	1,321	664
1056	36	AV5	3.42	3.60	1.52	1.18	9.57	41.88	100.0	1,363	666
1061	36	AV5	3.47	3.63	1.56	1.19	9.54	42.32	100.0	1,387	669
1066	36	AV5	3.52	3.65	1.65	1.20	9.55	42.72	100.0	1,421	672
1071	36	AV5	3.50	3.58	1.64	1.16	9.48	42.51	100.0	1,416	668
1076	33	AV5	3.62	3.75	1.78	1.18	9.53	43.46	100.0	1,480	677
1081	33	AV5	3.71	3.86	1.92	1.20	9.56	44.44	100.0	1,537	672
1086	33	AV5	3.76	3.95	2.02	1.20	9.60	44.91	100.0	1,582	668
1091	33	AV5	3.75	3.94	2.00	1.19	9.47	44.28	100.0	1,574	656
1096	33	AV5	3.83	3.98	2.04	1.20	9.70	45.64	100.0	1,610	664
1101	33	AV5	3.81	3.92	2.03	1.19	9.59	45.30	100.0	1,602	660
1106	33	AV5	3.76	3.83	1.97	1.19	9.48	44.57	100.0	1,576	656
1111	39	AV5	3.77	3.83	2.02	1.19	9.58	44.80	100.0	1,596	658
1116	39	AV5	3.72	3.82	1.98	1.18	9.51	44.11	100.0	1,578	656
1121	39	AV5	3.71	3.82	1.97	1.16	9.51	44.59	100.0	1,563	658
1126	39	AV5	2.14	2.45	1.00	0.38	8.64	28.66	100.0	1,124	620
1131	39	AV5	3.12	3.57	1.32	0.97	9.04	42.51	100.0	1,334	503
1136	39	AV5	3.46	3.88	1.48	1.16	9.16	45.61	100.0	1,414	558
1141	39	AV5	3.49	3.91	1.53	1.20	8.89	44.57	100.0	1,425	554
1146	39	AV5	3.58	4.00	1.62	1.27	9.12	46.51	100.0	1,449	585
1151	35	AV5	3.58	4.00	1.64	1.28	8.97	45.79	100.0	1,446	578
1156	35	AV5	3.68	4.10	1.69	1.32	9.28	48.15	100.0	1,481	608
1161	35	AV5	3.63	4.06	1.64	1.30	9.01	46.27	100.0	1,451	591
1166	35	AV5	3.75	4.21	1.73	1.36	9.45	49.41	100.0	1,501	624
1171	35	AV5	3.70	4.17	1.69	1.34	9.20	47.76	100.0	1,474	609
1176	35	AV5	3.69	4.18	1.68	1.33	9.12	47.42	100.0	1,474	613
1181	35	AV5	3.77	4.30	1.73	1.38	9.45	49.44	100.0	1,496	641
1186	37	AV5	3.76	4.31	1.71	1.36	9.37	48.86	100.0	1,501	637
1191	37	AV5	3.72	4.27	1.64	1.35	9.19	47.89	100.0	1,475	634
1196	37	AV5	3.76	4.33	1.68	1.38	9.34	48.66	100.0	1,488	655
1201	37	AV5	3.75	4.33	1.68	1.40	9.31	48.25	100.0	1,480	659
1206	37	AV5	3.66	4.24	1.62	1.35	9.02	46.48	100.0	1,449	643
1211	37	AV5	3.73	4.32	1.69	1.41	9.23	47.83	100.0	1,481	664
1216	37	AV5	3.68	4.26	1.66	1.38	9.10	46.74	100.0	1,458	650
1221	37	AV5	3.66	4.24	1.62	1.36	8.97	46.19	100.0	1,434	641
1226	37	AV5	3.70	4.29	1.69	1.40	9.18	47.17	100.0	1,467	654
1231	37	AV5	3.67	4.26	1.66	1.37	9.08	46.57	100.0	1,448	641
1236	37	AV5	3.75	4.36	1.73	1.42	9.37	48.40	100.0	1,476	661
1241	37	AV5	3.66	4.27	1.67	1.36	9.09	46.44	100.0	1,444	631
1246	37	AV5	3.68	4.27	1.72	1.37	9.12	46.70	100.0	1,452	640
1251	37	AV5	3.71	4.25	1.69	1.39	9.22	47.18	100.0	1,449	644
1256	36	AV5	3.66	4.16	1.70	1.37	9.09	46.29	100.0	1,441	624
1261	36	AV5	3.61	4.08	1.64	1.34	8.95	45.27	100.0	1,417	607
1266	36	AV5	3.65	4.10	1.71	1.36	9.08	45.97	100.0	1,442	611
1271	36	AV5	3.59	4.02	1.66	1.33	8.93	44.84	100.0	1,408	591

I-4 DEER CROSSING Bridge No. 790207 - CFCC EAST PILE N2 APE D46-42 HAMMER
OP: GRL-MGB Test date: 24-Jan-2014

BL#	BLC	TYPE	CSX	CSI	CSB	TSX	STK	EMX	BTA	RX0	RX5
end	bl/ft		ksi	ksi	ksi	ksi	ft	k-ft	(%)	kips	kips
1276	36	AV5	3.64	4.05	1.70	1.34	9.10	45.95	100.0	1,429	598
1281	36	AV5	3.63	4.03	1.73	1.34	9.14	45.88	100.0	1,433	595
1286	36	AV5	3.62	4.00	1.72	1.34	9.09	45.76	100.0	1,420	584
1291	36	AV5	3.60	3.97	1.74	1.33	9.06	45.37	100.0	1,424	573
1296	37	AV5	3.60	3.96	1.73	1.33	9.07	45.17	100.0	1,414	567
1301	37	AV5	3.54	3.87	1.71	1.30	8.87	43.76	100.0	1,388	544
1306	37	AV5	3.58	3.91	1.71	1.31	9.00	44.60	100.0	1,392	549
1311	37	AV5	3.51	3.83	1.70	1.28	8.81	43.18	100.0	1,376	529
1316	37	AV5	3.60	3.92	1.73	1.31	9.17	45.62	100.0	1,404	544
1323	37	AV5	3.63	3.92	1.75	1.32	9.33	46.47	100.0	1,416	550
1328	37	AV5	3.58	3.86	1.72	1.29	9.14	45.30	100.0	1,393	537
1333	35	AV5	3.58	3.85	1.75	1.28	9.16	45.52	100.0	1,411	533
1338	35	AV5	3.59	3.85	1.75	1.28	9.19	45.67	100.0	1,415	531
1343	35	AV5	3.57	3.83	1.72	1.28	9.15	45.20	100.0	1,396	522
1348	35	AV5	3.56	3.82	1.72	1.26	9.13	45.22	100.0	1,392	517
1353	35	AV5	3.58	3.84	1.72	1.27	9.21	45.57	98.0	1,394	517
1358	35	AV5	3.59	3.85	1.73	1.26	9.28	46.13	96.0	1,401	513
1363	35	AV5	3.56	3.80	1.70	1.25	9.15	45.22	100.0	1,387	506
1368	36	AV5	3.52	3.77	1.69	1.23	9.05	44.17	100.0	1,383	501
1373	36	AV5	3.51	3.75	1.69	1.22	9.04	43.98	100.0	1,382	497
1378	36	AV5	3.52	3.77	1.69	1.21	9.10	44.40	100.0	1,383	501
1383	36	AV5	3.52	3.79	1.69	1.20	9.13	44.58	100.0	1,384	500
1388	36	AV5	3.55	3.83	1.71	1.20	9.22	45.32	100.0	1,396	503
1393	36	AV5	3.59	3.86	1.74	1.20	9.45	46.61	98.0	1,418	514
1398	36	AV5	3.59	3.87	1.73	1.19	9.43	46.42	100.0	1,415	519
1403	42	AV5	3.58	3.89	1.74	1.18	9.40	46.30	100.0	1,424	521
1408	42	AV5	3.55	3.87	1.71	1.15	9.31	45.61	100.0	1,409	524
1413	42	AV5	3.52	3.84	1.72	1.10	9.23	44.77	100.0	1,420	524
1418	42	AV5	3.57	3.89	1.76	1.10	9.43	46.03	100.0	1,440	531
1423	42	AV5	3.55	3.87	1.79	1.05	9.39	45.61	100.0	1,461	538
1428	42	AV5	3.58	3.89	1.81	1.02	9.51	46.22	100.0	1,482	550
1433	42	AV5	3.59	3.89	1.85	0.98	9.54	46.58	100.0	1,508	589
1438	42	AV5	3.57	3.87	1.88	0.93	9.48	46.05	100.0	1,528	640
1443	54	AV5	3.57	3.85	1.91	0.88	9.47	45.98	100.0	1,554	686
1448	54	AV5	3.62	3.90	1.95	0.88	9.68	47.19	100.0	1,583	720
1453	54	AV5	3.58	3.86	1.94	0.81	9.56	46.23	100.0	1,573	762
1458	54	AV5	3.60	3.85	1.96	0.80	9.59	46.60	100.0	1,587	785
1463	54	AV5	3.62	3.88	2.02	0.80	9.66	47.24	100.0	1,618	801
1468	54	AV5	3.63	3.89	2.02	0.80	9.70	47.22	100.0	1,620	811
1473	54	AV5	3.61	3.88	1.98	0.78	9.54	46.72	100.0	1,597	826
1478	54	AV5	3.60	3.87	1.99	0.77	9.43	45.97	100.0	1,594	840
1483	54	AV5	3.64	3.91	2.00	0.80	9.56	46.89	96.0	1,600	846
1488	54	AV5	3.66	3.94	2.01	0.81	9.61	47.26	96.0	1,607	853
1493	54	AV5	3.66	3.94	2.01	0.82	9.63	47.56	96.0	1,598	850
1498	63	AV5	3.69	3.98	2.02	0.84	9.70	47.86	98.0	1,605	856
1503	63	AV5	3.70	4.02	2.02	0.84	9.75	48.13	92.0	1,606	864
1508	63	AV5	3.71	4.04	2.04	0.84	9.75	48.42	98.0	1,606	867
1513	63	AV5	3.73	4.06	2.06	0.86	9.78	48.74	92.0	1,613	868
1518	63	AV5	3.71	4.03	2.04	0.85	9.64	47.98	98.0	1,596	874
1524	63	AV5	3.73	4.04	2.05	0.87	9.66	48.31	96.0	1,595	876
1529	63	AV5	3.71	4.04	2.05	0.87	9.61	47.97	94.0	1,592	880
1534	63	AV5	3.79	4.13	2.09	0.92	9.83	49.77	94.0	1,614	877

I-4 DEER CROSSING Bridge No. 790207 - CFCC EAST PILE N2 APE D46-42 HAMMER
OP: GRL-MGB Test date: 24-Jan-2014

BL#	BLC	TYPE	CSX	CSI	CSB	TSX	STK	EMX	BTA	RX0	RX5
end	bl/ft		ksi	ksi	ksi	ksi	ft	k-ft	(%)	kips	kips
1539	63	AV5	3.71	4.04	2.05	0.89	9.55	47.72	92.0	1,584	878
1544	63	AV5	3.73	4.06	2.07	0.90	9.61	48.15	96.0	1,588	879
1549	63	AV5	3.75	4.09	2.08	0.91	9.64	48.07	89.4	1,594	876
1554	63	AV5	3.77	4.11	2.09	0.93	9.68	48.74	90.0	1,595	874
1559	78	AV5	3.83	4.18	2.14	0.96	9.91	50.08	89.6	1,620	879
1564	78	AV5	3.81	4.16	2.12	0.95	9.79	49.30	89.8	1,609	885
1569	78	AV5	3.75	4.10	2.09	0.92	9.53	47.89	89.4	1,584	887
1574	78	AV5	3.79	4.14	2.12	0.95	9.66	48.44	89.2	1,598	895
1579	78	AV5	3.83	4.19	2.13	0.98	9.77	49.15	89.2	1,603	900
1584	78	AV5	3.84	4.20	2.14	0.99	9.77	49.52	89.4	1,598	899
1589	78	AV5	3.84	4.18	2.14	1.00	9.77	49.29	89.4	1,589	897
1594	78	AV5	3.84	4.20	2.15	1.02	9.74	49.29	89.8	1,589	890
1599	78	AV5	3.84	4.19	2.14	1.02	9.68	49.06	89.6	1,578	891
1604	78	AV5	3.83	4.17	2.12	1.03	9.64	48.88	89.6	1,558	886
1609	78	AV5	3.86	4.19	2.15	1.06	9.70	49.67	89.8	1,566	886
1614	78	AV5	3.83	4.15	2.12	1.05	9.54	48.83	90.0	1,542	881
1619	78	AV5	3.88	4.21	2.16	1.08	9.64	49.79	92.0	1,555	876
1624	78	AV5	3.89	4.21	2.17	1.09	9.64	50.00	96.0	1,556	872
1629	78	AV5	3.87	4.21	2.16	1.08	9.56	48.97	100.0	1,548	875
1634	78	AV5	3.95	4.30	2.23	1.12	9.75	50.41	100.0	1,588	888
1639	90	AV5	3.97	4.32	2.23	1.13	9.78	50.79	100.0	1,585	890
1644	90	AV5	3.97	4.32	2.23	1.14	9.80	50.49	100.0	1,577	887
1649	90	AV5	3.95	4.30	2.23	1.13	9.70	50.07	100.0	1,571	884
1654	90	AV5	3.95	4.30	2.24	1.13	9.64	49.97	100.0	1,563	878
1659	90	AV5	3.96	4.31	2.25	1.13	9.65	50.58	100.0	1,557	877
1664	90	AV5	4.00	4.35	2.31	1.14	9.76	51.53	100.0	1,587	877
1669	90	AV5	3.97	4.33	2.28	1.12	9.64	50.94	100.0	1,560	874
1674	90	AV5	4.05	4.41	2.34	1.14	9.91	52.75	100.0	1,592	882
1679	90	AV5	4.01	4.38	2.31	1.12	9.75	51.82	100.0	1,572	877
1684	90	AV5	4.01	4.38	2.30	1.12	9.74	51.61	100.0	1,565	879
1689	90	AV5	4.03	4.38	2.33	1.13	9.77	51.93	100.0	1,577	882
1694	90	AV5	4.03	4.37	2.32	1.13	9.78	51.71	100.0	1,569	884
1699	90	AV5	4.05	4.39	2.33	1.13	9.87	52.31	100.0	1,574	890
1704	90	AV5	4.03	4.36	2.33	1.12	9.78	51.82	100.0	1,570	889
1709	90	AV5	4.05	4.36	2.35	1.13	9.83	52.22	100.0	1,576	892
1714	90	AV5	3.99	4.29	2.33	1.12	9.63	50.92	100.0	1,560	888
1719	90	AV5	4.04	4.33	2.34	1.13	9.78	52.19	100.0	1,569	896
1725	90	AV5	4.06	4.36	2.37	1.14	9.89	52.74	100.0	1,583	901
1730	93	AV5	4.08	4.36	2.40	1.14	9.94	52.97	100.0	1,598	909
1735	93	AV5	4.04	4.32	2.35	1.13	9.87	52.26	100.0	1,569	907
1740	93	AV5	4.02	4.28	2.35	1.12	9.79	51.63	100.0	1,568	906
1745	93	AV5	4.00	4.23	2.33	1.12	9.73	51.13	100.0	1,552	908
1750	93	AV5	4.01	4.22	2.33	1.11	9.78	51.62	100.0	1,549	911
1755	93	AV5	3.98	4.16	2.33	1.11	9.74	50.80	100.0	1,551	913
1760	93	AV5	4.01	4.18	2.37	1.12	9.81	51.76	100.0	1,572	917
1765	93	AV5	3.94	4.08	2.30	1.10	9.63	50.29	100.0	1,528	910
1770	93	AV5	3.94	4.06	2.34	1.10	9.64	50.26	100.0	1,546	914
1775	93	AV5	3.99	4.08	2.34	1.11	9.86	51.66	100.0	1,546	922
1780	93	AV5	3.93	4.01	2.33	1.11	9.69	50.16	100.0	1,538	915
1785	93	AV5	3.92	3.99	2.32	1.10	9.65	50.13	100.0	1,527	917
1790	93	AV5	3.90	3.95	2.28	1.10	9.64	49.83	100.0	1,503	914
1795	93	AV5	3.93	3.96	2.33	1.10	9.80	50.97	100.0	1,533	921

I-4 DEER CROSSING Bridge No. 790207 - CFCC EAST PILE N2 APE D46-42 HAMMER
OP: GRL-MGB Test date: 24-Jan-2014

BL# end	BLC bl/ft	TYPE	CSX ksi	CSI ksi	CSB ksi	TSX ksi	STK ft	EMX k-ft	BTA (%)	RX0 kips	RX5 kips
1800	93	AV5	3.82	3.84	2.24	1.08	9.46	48.53	100.0	1,477	909
1805	93	AV5	3.84	3.85	2.25	1.09	9.55	48.97	100.0	1,480	913
1810	93	AV5	3.86	3.88	2.29	1.08	9.70	50.14	100.0	1,506	916
1815	93	AV5	3.84	3.90	2.27	1.08	9.69	49.68	100.0	1,488	915
1820	104	AV5	3.85	3.93	2.27	1.09	9.81	50.46	100.0	1,486	916
1825	104	AV5	3.80	3.89	2.24	1.07	9.64	49.36	100.0	1,466	907
1830	104	AV5	3.80	3.90	2.25	1.08	9.68	49.61	100.0	1,471	912
1835	104	AV5	3.77	3.92	2.22	1.07	9.65	48.96	100.0	1,454	909
1840	104	AV5	3.76	3.95	2.20	1.06	9.69	48.86	100.0	1,441	909
1845	104	AV5	3.71	3.96	2.17	1.04	9.65	48.45	100.0	1,418	904
1850	104	AV5	3.72	4.01	2.18	1.05	9.74	48.85	100.0	1,420	902
1855	104	AV5	3.71	4.08	2.16	1.04	9.83	49.24	100.0	1,412	901
1860	104	AV5	3.73	4.15	2.18	1.06	9.99	50.13	100.0	1,417	901
1865	104	AV5	3.62	4.12	2.10	1.02	9.65	47.52	100.0	1,370	890
1870	104	AV5	3.61	4.18	2.11	1.02	9.72	47.67	100.0	1,376	895
1875	104	AV5	3.60	4.21	2.12	1.02	9.73	47.62	100.0	1,376	892
1880	104	AV5	3.59	4.23	2.12	1.02	9.74	47.52	100.0	1,374	891
1885	104	AV5	3.58	4.28	2.12	1.02	9.76	47.55	100.0	1,378	891
1890	104	AV5	3.54	4.23	2.11	1.00	9.67	46.57	100.0	1,368	883
1895	104	AV5	2.73	3.10	1.89	0.76	9.31	35.85	100.0	1,243	865
1900	104	AV5	2.59	2.78	2.17	0.56	8.86	37.52	100.0	1,462	925
1905	104	AV5	3.30	3.53	2.39	0.87	9.27	46.00	100.0	1,570	917
1910	104	AV5	3.54	3.79	2.36	0.98	9.29	47.42	100.0	1,555	901
1915	104	AV5	3.63	3.88	2.35	1.03	9.27	48.25	100.0	1,547	886
1920	104	AV5	3.68	3.95	2.33	1.06	9.28	48.63	100.0	1,534	875
1926	82	AV5	3.73	4.00	2.33	1.09	9.32	49.35	100.0	1,532	871
1931	82	AV5	3.71	3.99	2.30	1.09	9.19	48.37	100.0	1,515	866
1936	82	AV5	3.80	4.10	2.34	1.13	9.44	50.74	100.0	1,531	867
1941	82	AV5	3.81	4.13	2.32	1.13	9.42	50.41	100.0	1,523	868
1946	82	AV5	3.82	4.15	2.31	1.14	9.42	50.42	100.0	1,518	864
1951	82	AV5	3.84	4.20	2.30	1.16	9.47	50.59	100.0	1,517	868
1956	82	AV5	3.87	4.26	2.30	1.17	9.58	51.34	100.0	1,519	864
1961	82	AV5	3.85	4.23	2.29	1.15	9.44	50.33	100.0	1,507	861
1966	82	AV5	3.93	4.32	2.32	1.18	9.74	52.21	100.0	1,529	860
1971	82	AV5	3.88	4.24	2.28	1.17	9.56	51.18	100.0	1,493	852
1976	82	AV5	3.85	4.19	2.25	1.16	9.47	50.54	100.0	1,472	846
1981	82	AV5	3.86	4.18	2.26	1.17	9.48	50.59	100.0	1,480	844
1986	82	AV5	3.84	4.10	2.23	1.16	9.40	49.82	100.0	1,461	840
1991	82	AV5	3.83	4.06	2.23	1.16	9.41	49.82	100.0	1,458	834
1996	82	AV5	3.87	4.07	2.25	1.17	9.50	50.79	100.0	1,471	831
2001	82	AV5	3.86	4.05	2.24	1.17	9.49	50.23	100.0	1,464	825
2006	76	AV5	3.89	4.06	2.26	1.18	9.56	51.02	100.0	1,475	825
2011	76	AV5	3.86	4.04	2.24	1.17	9.45	50.20	100.0	1,462	817
2016	76	AV5	3.86	4.01	2.23	1.17	9.49	50.42	100.0	1,462	815
2021	76	AV5	3.84	3.96	2.23	1.17	9.45	49.85	100.0	1,458	811
2026	76	AV5	3.88	3.98	2.24	1.18	9.57	50.95	100.0	1,464	813
2031	76	AV5	3.86	3.99	2.22	1.18	9.51	50.34	100.0	1,452	803
2036	76	AV5	3.89	4.03	2.24	1.18	9.61	50.97	100.0	1,468	794
2041	76	AV5	3.85	3.96	2.20	1.18	9.50	50.23	100.0	1,443	792
2046	76	AV5	3.82	3.93	2.20	1.17	9.38	49.31	100.0	1,444	787
2051	76	AV5	3.81	3.92	2.18	1.17	9.40	49.26	100.0	1,429	784
2056	76	AV5	3.87	3.99	2.24	1.18	9.58	50.51	100.0	1,466	782

I-4 DEER CROSSING Bridge No. 790207 - CFCC EAST PILE N2 APE D46-42 HAMMER
OP: GRL-MGB Test date: 24-Jan-2014

BL#	BLC	TYPE	CSX	CSI	CSB	TSX	STK	EMX	BTA	RX0	RX5
end	bl/ft		ksi	ksi	ksi	ksi	ft	k-ft	(%)	kips	kips
2061	76	AV5	3.85	3.98	2.20	1.18	9.54	50.46	100.0	1,447	782
2066	76	AV5	3.83	3.95	2.19	1.17	9.48	49.52	100.0	1,441	773
2071	76	AV5	3.84	3.94	2.19	1.17	9.54	49.69	100.0	1,443	772
2076	76	AV5	3.84	3.95	2.16	1.17	9.55	49.98	100.0	1,431	769
2081	76	AV5	3.85	3.95	2.20	1.18	9.61	50.50	100.0	1,455	772
2086	68	AV5	3.83	3.94	2.17	1.17	9.53	49.69	100.0	1,437	766
2091	68	AV5	3.80	3.90	2.14	1.16	9.45	49.07	100.0	1,422	761
2096	68	AV5	3.79	3.88	2.11	1.16	9.41	49.00	100.0	1,407	763
2101	68	AV5	3.81	3.92	2.16	1.17	9.55	49.49	100.0	1,437	759
2106	68	AV5	3.80	3.92	2.14	1.16	9.53	49.39	100.0	1,430	757
2111	68	AV5	3.78	3.88	2.15	1.16	9.47	48.74	100.0	1,436	749
2116	68	AV5	3.78	3.88	2.14	1.16	9.49	48.49	100.0	1,434	742
2121	68	AV5	3.81	3.91	2.19	1.16	9.63	49.81	100.0	1,462	753
2127	68	AV5	3.81	3.91	2.20	1.17	9.68	49.55	100.0	1,469	744
2132	68	AV5	3.82	3.94	2.20	1.16	9.69	50.02	100.0	1,469	749
2137	68	AV5	3.78	3.91	2.17	1.15	9.53	48.91	100.0	1,456	738
2142	68	AV5	3.71	3.82	2.12	1.13	9.32	46.93	100.0	1,422	724
2147	68	AV5	3.76	3.87	2.16	1.14	9.49	48.18	100.0	1,450	726
2152	63	AV5	3.75	3.87	2.15	1.13	9.46	48.00	100.0	1,444	725
2157	63	AV5	3.73	3.86	2.15	1.13	9.42	47.69	100.0	1,442	724
2162	63	AV5	3.73	3.84	2.13	1.13	9.42	47.71	100.0	1,434	723
2167	63	AV5	3.73	3.87	2.14	1.13	9.44	47.96	100.0	1,434	723
2172	63	AV5	3.76	3.89	2.16	1.15	9.63	48.77	100.0	1,452	722
2177	63	AV5	3.71	3.82	2.11	1.13	9.44	47.23	100.0	1,427	712
2182	63	AV5	3.71	3.83	2.12	1.13	9.45	47.62	100.0	1,429	716
2187	63	AV5	3.73	3.83	2.13	1.14	9.55	48.00	100.0	1,437	711
2192	63	AV5	3.72	3.81	2.11	1.14	9.51	47.62	100.0	1,428	709
2197	63	AV5	3.70	3.78	2.08	1.13	9.43	47.13	100.0	1,414	709
2202	63	AV5	3.71	3.80	2.10	1.13	9.51	47.38	100.0	1,431	707
2207	63	AV5	3.70	3.80	2.09	1.13	9.49	47.29	100.0	1,425	709
2212	63	AV5	3.69	3.77	2.08	1.12	9.44	46.74	100.0	1,418	698
2217	57	AV5	3.63	3.73	2.03	1.10	9.30	45.63	100.0	1,391	694
2222	57	AV5	3.65	3.76	2.04	1.11	9.37	46.16	100.0	1,401	698
2227	57	AV5	3.68	3.77	2.07	1.12	9.45	46.95	100.0	1,415	697
2232	57	AV5	3.67	3.78	2.06	1.11	9.44	46.73	100.0	1,411	696
2237	57	AV5	3.65	3.76	2.05	1.11	9.39	46.19	100.0	1,406	693
2242	57	AV5	3.69	3.80	2.06	1.11	9.50	47.09	100.0	1,418	697
2247	57	AV5	3.67	3.80	2.06	1.10	9.46	46.62	100.0	1,418	693
2252	57	AV5	3.71	3.86	2.07	1.11	9.61	47.81	100.0	1,432	707
2257	57	AV5	3.70	3.85	2.06	1.10	9.60	47.60	100.0	1,428	708
2262	57	AV5	3.68	3.85	2.03	1.09	9.53	46.86	100.0	1,412	704
2267	57	AV5	3.66	3.82	2.02	1.09	9.46	46.33	100.0	1,406	700
2272	54	AV5	3.70	3.85	2.05	1.10	9.59	47.19	100.0	1,428	711
2277	54	AV5	3.65	3.82	2.01	1.08	9.44	45.96	100.0	1,403	698
2282	54	AV5	3.67	3.84	2.02	1.08	9.45	46.25	100.0	1,417	705
2287	54	AV5	3.68	3.86	2.03	1.08	9.50	46.48	100.0	1,423	706
2292	54	AV5	3.69	3.85	2.02	1.08	9.54	46.78	100.0	1,420	711
2297	54	AV5	3.70	3.89	2.05	1.08	9.54	46.85	100.0	1,440	706
2302	54	AV5	3.68	3.89	2.01	1.07	9.50	46.19	100.0	1,417	701
2307	54	AV5	3.73	3.94	2.04	1.08	9.65	47.11	100.0	1,443	707
2312	54	AV5	3.69	3.90	2.01	1.06	9.48	46.11	100.0	1,422	704
2317	54	AV5	3.72	3.92	2.05	1.07	9.54	46.73	100.0	1,446	708

I-4 DEER CROSSING Bridge No. 790207 - CFCC EAST PILE N2 APE D46-42 HAMMER
OP: GRL-MGB Test date: 24-Jan-2014

BL#	BLC	TYPE	CSX	CSI	CSB	TSX	STK	EMX	BTA	RX0	RX5
end	bl/ft		ksi	ksi	ksi	ksi	ft	k-ft	(%)	kips	kips
2322	54	AV5	3.69	3.89	2.02	1.07	9.44	45.79	100.0	1,432	697
2327	47	AV5	3.73	3.93	2.04	1.07	9.56	46.74	100.0	1,442	708
2332	47	AV5	3.73	3.96	2.06	1.06	9.53	46.61	100.0	1,452	708
2337	47	AV5	3.73	3.99	2.05	1.06	9.49	46.67	100.0	1,450	709
2342	47	AV5	3.80	4.08	2.09	1.08	9.73	48.09	100.0	1,475	715
2347	47	AV5	3.75	4.01	2.07	1.06	9.49	46.47	100.0	1,465	701
2352	47	AV5	3.81	4.09	2.11	1.07	9.67	47.88	100.0	1,490	709
2357	47	AV5	3.79	4.06	2.12	1.07	9.56	46.98	100.0	1,492	702
2362	47	AV5	3.83	4.09	2.14	1.06	9.66	47.91	100.0	1,505	715
2367	47	AV5	3.76	3.99	2.10	1.05	9.39	45.88	100.0	1,482	699
2372	45	AV5	3.83	4.05	2.16	1.05	9.60	47.41	100.0	1,519	712
2377	45	AV5	3.85	4.05	2.18	1.04	9.63	47.64	100.0	1,529	715
2382	45	AV5	3.84	4.04	2.18	1.05	9.56	47.46	100.0	1,529	710
2387	45	AV5	3.82	4.00	2.16	1.03	9.50	46.89	100.0	1,522	711
2392	45	AV5	3.91	4.08	2.25	1.04	9.75	48.64	100.0	1,573	715
2397	45	AV5	3.90	4.06	2.23	1.03	9.70	48.38	100.0	1,565	719
2402	45	AV5	3.84	4.03	2.18	1.01	9.47	46.91	100.0	1,539	715
2407	45	AV5	3.85	4.04	2.20	1.00	9.47	46.84	100.0	1,555	712
2412	45	AV5	3.89	4.08	2.22	1.00	9.56	47.50	100.0	1,572	715
2417	47	AV5	3.89	4.08	2.23	0.98	9.57	47.61	100.0	1,576	728
2422	47	AV5	3.89	4.08	2.25	0.96	9.57	47.67	100.0	1,598	734
2427	47	AV5	3.91	4.11	2.27	0.93	9.61	48.31	100.0	1,611	748
2432	47	AV5	3.91	4.12	2.27	0.92	9.51	47.70	100.0	1,618	740
2437	47	AV5	3.99	4.20	2.35	0.92	9.68	49.36	100.0	1,661	755
2442	47	AV5	4.00	4.24	2.35	0.89	9.60	49.12	100.0	1,672	758
2447	47	AV5	3.99	4.22	2.34	0.90	9.50	48.32	100.0	1,660	747
2452	47	AV5	4.00	4.24	2.36	0.85	9.51	49.04	100.0	1,685	775
2457	47	AV5	4.03	4.26	2.38	0.83	9.57	49.94	100.0	1,698	789
2462	47	AV5	4.08	4.32	2.42	0.86	9.75	50.75	100.0	1,717	786
2467	78	AV5	1.76	2.05	1.48	0.31	9.16	23.24	93.4	1,253	914
2472	78	AV5	2.93	3.30	2.44	0.20	9.58	41.96	97.6	1,764	1,001
2477	78	AV5	3.35	3.70	2.62	0.30	9.76	45.44	100.0	1,837	908
2482	78	AV5	3.43	3.76	2.60	0.45	9.58	45.40	100.0	1,819	874
2487	78	AV5	3.47	3.77	2.58	0.51	9.45	45.02	100.0	1,819	858
2492	78	AV5	3.49	3.78	2.56	0.54	9.39	44.66	100.0	1,814	844
2497	78	AV5	3.49	3.76	2.54	0.55	9.33	44.36	100.0	1,804	837
2502	78	AV5	3.53	3.79	2.52	0.59	9.38	44.71	100.0	1,792	827
2507	78	AV5	3.53	3.78	2.52	0.61	9.34	44.37	100.0	1,793	817
2512	78	AV5	3.54	3.77	2.49	0.63	9.34	44.47	100.0	1,778	813
2517	78	AV5	3.53	3.76	2.50	0.65	9.26	43.79	100.0	1,779	807
2522	78	AV5	3.53	3.75	2.46	0.67	9.20	43.45	100.0	1,760	799
2527	78	AV5	3.58	3.80	2.51	0.68	9.40	44.92	100.0	1,785	807
2532	78	AV5	3.54	3.73	2.46	0.68	9.28	43.70	100.0	1,758	797
2537	78	AV5	3.54	3.72	2.43	0.68	9.22	43.55	100.0	1,739	798
2542	58	AV5	3.55	3.73	2.44	0.70	9.28	43.76	100.0	1,741	793
2547	58	AV5	3.55	3.74	2.44	0.72	9.30	44.06	100.0	1,734	783
2552	58	AV5	3.59	3.77	2.43	0.74	9.49	45.06	100.0	1,732	790
2557	58	AV5	3.58	3.75	2.44	0.74	9.46	44.78	100.0	1,734	786
2562	58	AV5	3.61	3.79	2.44	0.76	9.55	45.55	100.0	1,738	788
2567	58	AV5	3.58	3.79	2.44	0.75	9.47	44.91	100.0	1,737	786
2572	58	AV5	3.62	3.91	2.45	0.78	9.63	45.85	100.0	1,744	787
2580	58	AV5	3.57	3.85	2.41	0.74	9.38	44.52	100.0	1,722	788

I-4 DEER CROSSING Bridge No. 790207 - CFCC EAST PILE N2 APE D46-42 HAMMER
OP: GRL-MGB Test date: 24-Jan-2014

BL#	BLC	TYPE	CSX	CSI	CSB	TSX	STK	EMX	BTA	RX0	RX5
end	bl/ft		ksi	ksi	ksi	ksi	ft	k-ft	(%)	kips	kips
2585	58	AV5	3.59	3.85	2.43	0.75	9.41	44.90	100.0	1,729	782
2590	58	AV5	3.58	3.82	2.42	0.76	9.34	44.49	100.0	1,724	780
2595	58	AV5	3.57	3.82	2.39	0.77	9.32	44.39	100.0	1,710	779
2600	57	AV5	3.52	3.80	2.37	0.80	9.31	44.62	100.0	1,694	777
2605	57	AV5	3.57	3.86	2.42	0.83	9.53	46.80	100.0	1,724	792
2610	57	AV5	3.59	3.88	2.39	0.83	9.56	47.13	100.0	1,710	794
2615	57	AV5	3.57	3.87	2.41	0.80	9.50	46.68	100.0	1,723	800
2620	57	AV5	3.57	3.86	2.38	0.81	9.53	46.61	100.0	1,710	797
2625	57	AV5	3.59	3.88	2.41	0.81	9.55	47.11	100.0	1,727	800
2630	57	AV5	3.55	3.82	2.36	0.81	9.45	45.99	100.0	1,699	791
2635	57	AV5	2.83	3.03	1.91	0.64	6.53	36.58	83.6	1,374	635
2640	57	AV5	3.51	3.75	2.36	0.77	9.34	45.04	100.0	1,700	791
2645	57	AV5	3.52	3.74	2.33	0.76	9.40	45.31	100.0	1,686	797
2650	57	AV5	3.50	3.70	2.34	0.74	9.39	45.05	100.0	1,687	798
2655	57	AV5	3.50	3.69	2.33	0.75	9.41	44.82	100.0	1,680	787
2660	63	AV5	3.24	3.35	2.25	0.53	9.18	39.09	100.0	1,623	797
2665	63	AV5	3.70	3.76	2.47	0.62	9.41	45.36	100.0	1,769	816
2670	63	AV5	3.68	3.74	2.45	0.62	9.36	44.76	100.0	1,753	806
2675	63	AV5	3.68	3.74	2.43	0.63	9.34	44.71	100.0	1,738	800
2680	63	AV5	3.70	3.77	2.44	0.64	9.44	45.57	100.0	1,748	804
2685	63	AV5	3.69	3.77	2.42	0.64	9.44	45.23	100.0	1,738	802
2691	63	AV5	3.63	3.70	2.38	0.62	9.18	43.86	100.0	1,715	799
2696	63	AV5	3.64	3.71	2.39	0.64	9.28	44.18	100.0	1,715	793
2701	63	AV5	3.61	3.70	2.38	0.61	9.26	43.55	100.0	1,714	795
2706	63	AV5	3.64	3.72	2.39	0.61	9.40	44.36	100.0	1,719	799
2711	63	AV5	3.61	3.71	2.38	0.59	9.34	43.91	100.0	1,709	797
2716	63	AV5	3.60	3.73	2.38	0.58	9.34	43.95	100.0	1,704	794
2721	64	AV5	3.62	3.74	2.37	0.59	9.41	44.12	100.0	1,701	793
2726	64	AV5	3.60	3.72	2.35	0.58	9.32	43.70	100.0	1,691	795
2731	64	AV5	3.58	3.70	2.36	0.59	9.32	43.67	100.0	1,694	795
2736	64	AV5	3.57	3.68	2.35	0.60	9.39	43.88	100.0	1,693	801
2741	64	AV5	3.55	3.69	2.34	0.60	9.37	43.52	100.0	1,688	799
2746	64	AV5	3.56	3.70	2.34	0.60	9.42	43.82	100.0	1,687	802
2751	64	AV5	3.56	3.70	2.33	0.59	9.43	43.88	100.0	1,684	809
2756	64	AV5	3.54	3.69	2.33	0.58	9.38	43.75	100.0	1,679	813
2761	64	AV5	3.55	3.70	2.32	0.58	9.43	43.87	100.0	1,680	822
2766	64	AV5	3.53	3.67	2.31	0.58	9.38	43.27	100.0	1,671	817
2771	64	AV5	3.54	3.69	2.33	0.58	9.44	43.93	100.0	1,675	825
2776	64	AV5	3.52	3.68	2.32	0.57	9.38	43.17	100.0	1,670	828
2781	64	AV5	3.50	3.65	2.29	0.59	9.29	42.82	100.0	1,653	826
2786	62	AV5	3.52	3.69	2.29	0.60	9.40	43.52	100.0	1,650	828
2791	62	AV5	3.48	3.64	2.26	0.60	9.27	42.49	100.0	1,629	824
2796	62	AV5	3.51	3.68	2.27	0.62	9.38	43.21	100.0	1,634	828
2802	62	AV5	3.49	3.69	2.24	0.63	9.29	42.69	100.0	1,623	832
2807	62	AV5	3.50	3.73	2.26	0.62	9.36	43.09	100.0	1,632	848
2812	62	AV5	3.51	3.74	2.27	0.63	9.45	43.54	100.0	1,634	851
2817	62	AV5	3.50	3.73	2.28	0.61	9.37	43.21	100.0	1,633	862
2822	62	AV5	3.51	3.72	2.28	0.61	9.39	43.08	100.0	1,636	878
2827	62	AV5	3.53	3.74	2.30	0.60	9.52	44.06	100.0	1,646	893
2832	62	AV5	3.50	3.69	2.30	0.59	9.49	43.44	100.0	1,639	905
2837	62	AV5	3.53	3.72	2.33	0.59	9.63	44.43	100.0	1,655	931
2842	62	AV5	3.52	3.71	2.33	0.59	9.63	44.26	100.0	1,648	948

I-4 DEER CROSSING Bridge No. 790207 - CFCC EAST PILE N2 APE D46-42 HAMMER
OP: GRL-MGB Test date: 24-Jan-2014

BL#	BLC	TYPE	CSX	CSI	CSB	TSX	STK	EMX	BTA	RX0	RX5
end	bl/ft		ksi	ksi	ksi	ksi	ft	k-ft	(%)	kips	kips
2847	67	AV5	3.54	3.72	2.35	0.61	9.67	44.64	100.0	1,649	977
2852	67	AV5	3.52	3.70	2.36	0.60	9.56	44.03	100.0	1,646	1,006
2857	67	AV5	3.56	3.75	2.38	0.61	9.73	45.18	100.0	1,656	1,036
2862	67	AV5	3.55	3.73	2.39	0.61	9.73	45.11	100.0	1,656	1,052
2867	67	AV5	3.54	3.73	2.40	0.61	9.71	44.85	100.0	1,657	1,051
2872	67	AV5	3.55	3.74	2.42	0.59	9.72	45.13	100.0	1,668	1,052
2877	67	AV5	3.54	3.73	2.43	0.58	9.70	44.87	100.0	1,675	1,048
2882	67	AV5	3.51	3.70	2.45	0.54	9.55	44.10	100.0	1,680	1,036
2887	67	AV5	3.55	3.74	2.49	0.54	9.74	45.29	100.0	1,706	1,036
2892	67	AV5	3.53	3.70	2.50	0.51	9.64	44.76	100.0	1,715	1,027
2897	67	AV5	3.56	3.72	2.52	0.50	9.75	44.99	100.0	1,725	1,019
2902	67	AV5	3.56	3.71	2.52	0.48	9.75	45.04	100.0	1,734	1,015
2907	67	AV5	3.58	3.74	2.53	0.48	9.85	45.58	100.0	1,740	1,015
2913	67	AV5	3.56	3.71	2.53	0.45	9.77	45.09	100.0	1,738	1,012
2918	67	AV5	3.58	3.74	2.54	0.45	9.77	45.49	100.0	1,749	1,019
2923	67	AV5	3.58	3.74	2.53	0.47	9.79	45.32	100.0	1,740	1,015
2928	67	AV5	3.57	3.72	2.52	0.47	9.76	45.12	100.0	1,739	1,016
2933	67	AV5	3.63	3.77	2.55	0.49	10.03	46.81	100.0	1,761	1,030
2938	67	AV5	3.60	3.73	2.54	0.47	9.87	45.78	100.0	1,752	1,030
2943	67	AV5	3.61	3.75	2.55	0.47	9.89	45.79	100.0	1,761	1,038
2948	67	AV5	3.61	3.75	2.55	0.46	9.86	45.94	100.0	1,760	1,043
2953	67	AV5	3.61	3.75	2.55	0.46	9.82	45.65	100.0	1,759	1,048
2958	67	AV5	3.59	3.73	2.55	0.47	9.78	45.14	100.0	1,755	1,052
2963	67	AV5	3.60	3.74	2.56	0.46	9.77	45.35	100.0	1,758	1,064
2968	67	AV5	3.15	3.26	2.38	0.36	8.81	35.29	97.8	1,634	1,026
2973	67	AV5	3.82	3.93	2.82	0.46	9.89	48.74	100.0	1,908	1,132
2978	67	AV5	3.80	3.93	2.77	0.49	9.71	47.45	100.0	1,877	1,118
2983	73	AV5	3.83	3.96	2.77	0.52	9.81	48.04	100.0	1,881	1,132
2988	73	AV5	3.81	3.96	2.73	0.54	9.79	47.55	100.0	1,860	1,130
2993	73	AV5	3.81	3.97	2.71	0.55	9.78	47.60	100.0	1,843	1,135
2998	73	AV5	3.79	3.95	2.68	0.56	9.71	46.95	100.0	1,821	1,134
3003	73	AV5	3.85	4.02	2.69	0.61	9.93	48.21	100.0	1,826	1,144
3008	73	AV5	3.83	4.02	2.66	0.62	9.87	47.59	100.0	1,807	1,147
3013	73	AV5	3.75	3.94	2.60	0.61	9.57	45.71	100.0	1,761	1,140
3018	73	AV5	3.85	4.05	2.64	0.67	9.91	48.01	100.0	1,790	1,163
3024	73	AV5	3.88	4.08	2.65	0.69	10.03	48.92	100.0	1,792	1,173
3029	73	AV5	3.81	4.00	2.59	0.67	9.82	47.32	100.0	1,755	1,180
3034	73	AV5	3.80	4.01	2.58	0.69	9.73	46.86	100.0	1,742	1,193
3039	73	AV5	3.85	4.08	2.60	0.73	9.93	48.08	100.0	1,751	1,216
3044	73	AV5	3.83	4.02	2.58	0.73	9.84	47.58	100.0	1,734	1,231
3049	73	AV5	3.86	4.05	2.59	0.76	9.94	48.69	100.0	1,738	1,249
3054	88	AV5	3.87	4.08	2.60	0.78	9.94	48.59	100.0	1,740	1,262
3059	88	AV5	3.82	4.01	2.61	0.75	9.81	47.20	100.0	1,744	1,286
3064	88	AV5	3.81	3.99	2.65	0.75	9.80	47.18	100.0	1,763	1,315
3069	88	AV5	3.82	3.99	2.71	0.75	9.82	47.33	100.0	1,790	1,350
3074	88	AV5	3.87	4.04	2.76	0.79	9.96	48.44	100.0	1,819	1,373
3079	88	AV5	3.91	4.11	2.82	0.82	10.12	49.64	100.0	1,847	1,396
3084	88	AV5	3.85	4.05	2.83	0.80	9.91	48.18	100.0	1,845	1,412
3089	88	AV5	3.85	4.06	2.86	0.81	9.91	48.14	100.0	1,862	1,438
3094	88	AV5	3.85	4.05	2.89	0.82	9.92	48.05	100.0	1,871	1,456
3099	88	AV5	3.86	4.06	2.94	0.83	9.90	48.41	100.0	1,895	1,481
3104	88	AV5	3.81	4.00	2.94	0.82	9.72	47.08	100.0	1,894	1,507

I-4 DEER CROSSING Bridge No. 790207 - CFCC EAST PILE N2 APE D46-42 HAMMER
OP: GRL-MGB Test date: 24-Jan-2014

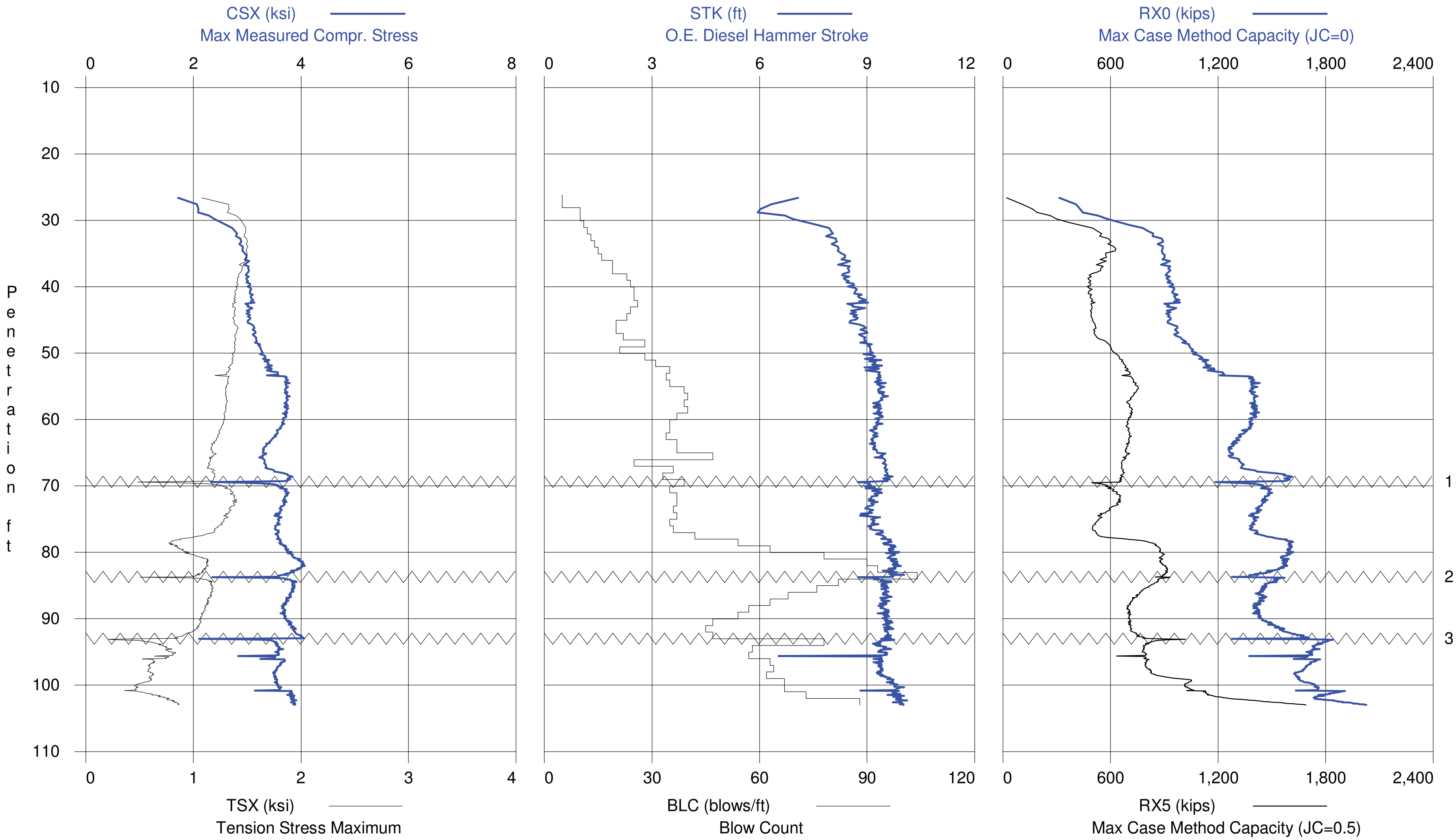
BL#	BLC	TYPE	CSX	CSI	CSB	TSX	STK	EMX	BTA	RX0	RX5
end	bl/ft		ksi	ksi	ksi	ksi	ft	k-ft	(%)	kips	kips
3109	88	AV5	3.88	4.07	3.01	0.85	9.96	48.71	100.0	1,936	1,548
3114	88	AV5	3.88	4.07	3.05	0.85	9.98	48.75	100.0	1,949	1,568
3119	88	AV5	3.86	4.04	3.06	0.86	9.92	48.23	100.0	1,952	1,585
3124	88	AV5	3.89	4.06	3.12	0.86	10.00	48.89	100.0	1,981	1,618
3129	88	AV5	3.86	4.02	3.13	0.86	9.91	48.11	100.0	1,988	1,642
3134	88	AV5	3.89	4.05	3.19	0.86	10.02	49.01	100.0	2,017	1,674
3139	88	AV5	3.88	4.05	3.21	0.87	10.00	48.91	100.0	2,028	1,690

PDIPLOT Ver. 2014.1 - Printed: 25-Jan-2014

GRL Engineers, Inc. - Case Method & iCAP® Results

Test date: 24-Jan-2014

I-4 DEER CROSSING Bridge No. 790207 - CFCC EAST PILE N2



1 - Change Pile Cushion
2 - Change Pile Cushion
3 - Change Pile Cushion

I-4 DEER CROSSING Bridge No. 790207 - CFCC EAST PILE N2 APE D46-42 HAMMER
OP: GRL-MGB Test date: 24-Jan-2014

AR: 576.00 in^2 SP: 0.145 k/ft3
LE: 95.00 ft EM: 6,178 ksi
WS: 14,050.0 f/s JC: 0.50

CSX: Max Measured Compr. Stress
CSI: Max F1 or F2 Compr. Stress
CSB: Compression Stress at Bottom
TSX: Tension Stress Maximum
STK: O.E. Diesel Hammer Stroke
EMX: Max Transferred Energy
BTA: BETA Integrity Factor
RX0: Max Case Method Capacity (JC=0)
RX5: Max Case Method Capacity (JC=0.5)

BL# end	depth ft	BLC bl/ft	TYPE	CSX ksi	CSI ksi	CSB ksi	TSX ksi	STK ft	EMX k-ft	BTA (%)	RX0 kips	RX5 kips
5	27.00	5	AV5	1.71	2.11	0.54	1.07	7.08	29.37	97.6	314	21
10	28.00	5	AV5	2.07	2.58	0.70	1.33	6.33	28.75	100.0	408	109
20	29.00	10	AV10	2.09	2.51	0.75	1.32	5.99	25.62	100.0	438	179
30	30.00	10	AV10	2.34	2.77	0.95	1.42	6.82	32.21	100.0	556	282
41	31.00	11	AV11	2.57	3.04	1.16	1.47	7.50	36.72	100.0	685	404
53	32.00	12	AV12	2.77	3.29	1.37	1.48	7.99	39.93	100.0	805	522
66	33.00	13	AV11	2.83	3.35	1.46	1.48	7.99	40.26	100.0	857	562
80	34.00	14	AV14	2.88	3.40	1.50	1.50	8.11	40.63	100.0	882	600
95	35.00	15	AV15	2.93	3.46	1.51	1.50	8.23	41.21	100.0	892	617
111	36.00	16	AV16	2.97	3.55	1.52	1.49	8.34	41.59	100.0	896	564
130	37.00	19	AV19	3.00	3.59	1.55	1.46	8.41	41.96	100.0	916	553
149	38.00	19	AV18	3.02	3.58	1.57	1.44	8.47	42.07	100.0	926	536
172	39.00	23	AV23	2.99	3.58	1.55	1.42	8.37	40.72	100.0	915	482
196	40.00	24	AV24	3.02	3.63	1.58	1.41	8.52	41.54	100.0	934	484
221	41.00	25	AV24	3.06	3.71	1.61	1.39	8.68	42.24	100.0	952	483
246	42.00	25	AV25	3.08	3.75	1.63	1.39	8.82	42.88	100.0	965	492
272	43.00	26	AV25	3.04	3.74	1.59	1.37	8.70	41.96	100.0	940	497
296	44.00	24	AV24	3.04	3.76	1.59	1.38	8.73	42.20	100.0	940	495
319	45.00	23	AV23	3.03	3.76	1.56	1.38	8.66	41.75	100.0	926	495
339	46.00	20	AV19	3.06	3.76	1.58	1.39	8.68	42.27	100.0	938	510
359	47.00	20	AV20	3.13	3.83	1.62	1.40	8.92	43.78	100.0	968	512
381	48.00	22	AV22	3.14	3.83	1.64	1.39	8.89	43.09	100.0	980	525
409	49.00	28	AV27	3.20	3.89	1.66	1.39	8.99	43.15	100.0	1,026	585
430	50.00	21	AV21	3.27	3.98	1.70	1.38	9.12	44.60	100.0	1,059	610
458	51.00	28	AV28	3.31	4.04	1.73	1.37	9.10	44.68	100.0	1,095	646
489	52.00	31	AV30	3.39	4.12	1.78	1.35	9.24	45.64	100.0	1,136	675
524	53.00	35	AV35	3.44	4.13	1.82	1.33	9.19	45.30	100.0	1,171	694
558	54.00	34	AV33	3.63	4.30	2.04	1.30	9.32	46.85	100.0	1,321	709
593	55.00	35	AV35	3.73	4.38	2.12	1.32	9.34	48.25	100.0	1,395	737
632	56.00	39	AV38	3.73	4.35	2.11	1.30	9.39	48.33	100.0	1,394	748
672	57.00	40	AV39	3.74	4.36	2.13	1.30	9.44	48.89	100.0	1,401	723
711	58.00	39	AV39	3.73	4.37	2.09	1.31	9.31	48.40	100.0	1,402	701
751	59.00	40	AV39	3.72	4.32	2.06	1.30	9.31	48.23	100.0	1,405	717
788	60.00	37	AV37	3.70	4.28	2.01	1.29	9.34	47.90	100.0	1,396	710
823	61.00	35	AV34	3.66	4.23	1.94	1.28	9.30	47.39	100.0	1,383	695
858	62.00	35	AV34	3.59	4.16	1.84	1.25	9.18	45.77	100.0	1,363	699
892	63.00	34	AV34	3.51	4.08	1.68	1.23	9.21	45.09	100.0	1,321	707
929	64.00	37	AV36	3.40	3.81	1.54	1.19	9.17	42.95	100.0	1,294	700
966	65.00	37	AV37	3.31	3.50	1.42	1.17	9.23	41.93	100.0	1,264	688
1013	66.00	47	AV46	3.29	3.39	1.39	1.18	9.41	41.38	100.0	1,284	689
1038	67.00	25	AV25	3.33	3.47	1.47	1.15	9.50	41.81	100.0	1,328	664
1074	68.00	36	AV36	3.44	3.56	1.55	1.16	9.53	42.13	100.0	1,380	668
1107	69.00	33	AV33	3.76	3.90	1.98	1.19	9.56	44.77	100.0	1,573	663

I-4 DEER CROSSING Bridge No. 790207 - CFCC EAST PILE N2 APE D46-42 HAMMER
OP: GRL-MGB Test date: 24-Jan-2014

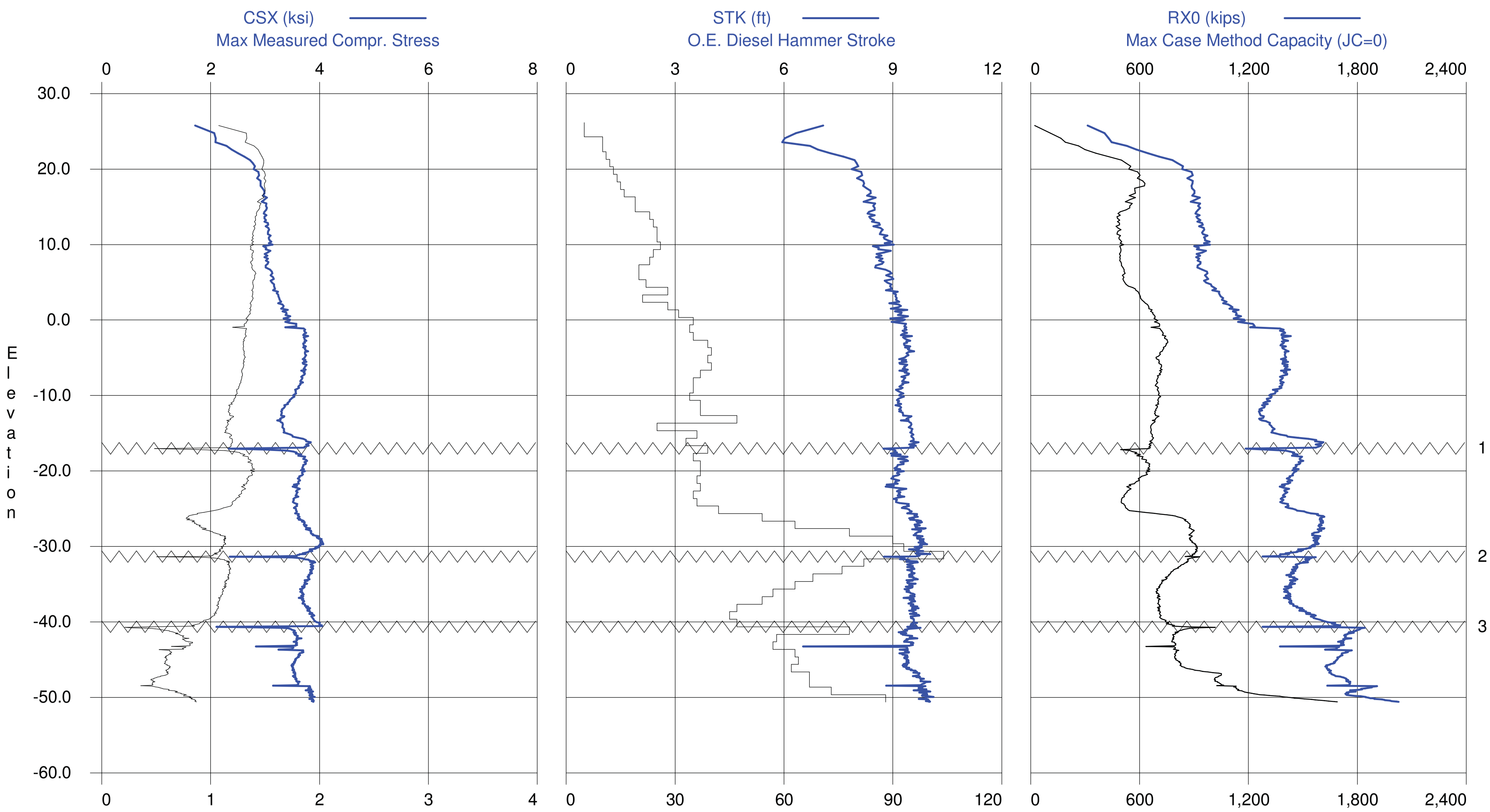
BL# end	depth ft	BLC bl/ft	TYPE	CSX ksi	CSI ksi	CSB ksi	TSX ksi	STK ft	EMX k-ft	BTA (%)	RX0 kips	RX5 kips
1146	70.00	39	AV39	3.36	3.65	1.61	1.06	9.18	42.60	100.0	1,432	597
1181	71.00	35	AV35	3.69	4.15	1.69	1.33	9.21	47.75	100.0	1,475	609
1218	72.00	37	AV37	3.72	4.29	1.67	1.37	9.21	47.73	100.0	1,474	648
1255	73.00	37	AV37	3.69	4.26	1.69	1.38	9.15	46.94	100.0	1,452	643
1291	74.00	36	AV36	3.62	4.04	1.70	1.34	9.05	45.57	100.0	1,426	595
1328	75.00	37	AV35	3.58	3.90	1.72	1.31	9.06	44.87	100.0	1,397	546
1363	76.00	35	AV35	3.58	3.83	1.73	1.27	9.18	45.50	99.1	1,399	520
1399	77.00	36	AV36	3.54	3.81	1.71	1.21	9.22	45.16	99.7	1,396	506
1441	78.00	42	AV42	3.56	3.87	1.79	1.05	9.40	45.78	100.0	1,464	562
1495	79.00	54	AV54	3.62	3.89	1.99	0.81	9.60	46.92	98.7	1,597	807
1558	80.00	63	AV62	3.74	4.06	2.06	0.88	9.70	48.47	93.8	1,601	873
1636	81.00	78	AV78	3.85	4.19	2.14	1.02	9.68	49.27	91.7	1,578	887
1726	82.00	90	AV89	4.01	4.35	2.30	1.13	9.76	51.50	100.0	1,572	885
1819	83.00	93	AV93	3.94	4.07	2.32	1.10	9.72	50.69	100.0	1,533	913
1923	84.00	104	AV104	3.56	3.91	2.19	1.00	9.57	47.16	100.0	1,436	897
2005	85.00	82	AV81	3.84	4.14	2.28	1.15	9.47	50.51	100.0	1,497	852
2081	86.00	76	AV76	3.85	3.97	2.21	1.17	9.51	50.15	100.0	1,451	792
2149	87.00	68	AV67	3.79	3.90	2.16	1.16	9.51	48.93	100.0	1,440	748
2212	88.00	63	AV63	3.72	3.83	2.12	1.13	9.49	47.68	100.0	1,433	714
2269	89.00	57	AV57	3.67	3.80	2.05	1.11	9.47	46.75	100.0	1,414	699
2323	90.00	54	AV54	3.69	3.88	2.03	1.08	9.51	46.44	100.0	1,426	704
2370	91.00	47	AV47	3.78	4.03	2.09	1.06	9.58	47.12	100.0	1,478	708
2415	92.00	45	AV45	3.86	4.05	2.20	1.02	9.57	47.49	100.0	1,547	714
2462	93.00	47	AV47	3.97	4.19	2.33	0.90	9.59	48.86	100.0	1,655	758
2540	94.00	78	AV78	3.36	3.62	2.45	0.54	9.38	42.90	99.4	1,753	845
2598	95.00	58	AV55	3.58	3.81	2.43	0.75	9.43	44.83	100.0	1,728	785
2655	96.00	57	AV57	3.48	3.74	2.33	0.78	9.20	45.15	98.6	1,675	779
2718	97.00	63	AV62	3.62	3.70	2.40	0.61	9.34	44.06	100.0	1,720	800
2782	98.00	64	AV64	3.55	3.69	2.33	0.59	9.38	43.62	100.0	1,681	810
2844	99.00	62	AV61	3.51	3.71	2.29	0.61	9.43	43.42	100.0	1,638	873
2911	100.00	67	AV66	3.55	3.72	2.45	0.55	9.71	44.96	100.0	1,689	1,030
2978	101.00	67	AV67	3.59	3.73	2.57	0.46	9.76	45.19	99.8	1,764	1,047
3051	102.00	73	AV72	3.83	4.01	2.65	0.64	9.84	47.68	100.0	1,791	1,171
3139	103.00	88	AV88	3.86	4.04	2.92	0.82	9.92	48.26	100.0	1,888	1,483

PDIPLOT Ver. 2014.1 - Printed: 25-Jan-2014

GRL Engineers, Inc. - Case Method & iCAP® Results

Test date: 24-Jan-2014

I-4 DEER CROSSING Bridge No. 790207 - CFCC EAST PILE N2



1 - Change Pile Cushion
2 - Change Pile Cushion
3 - Change Pile Cushion

I-4 DEER CROSSING Bridge No. 790207 - CFCC EAST PILE N2 APE D46-42 HAMMER
OP: GRL-MGB Test date: 24-Jan-2014

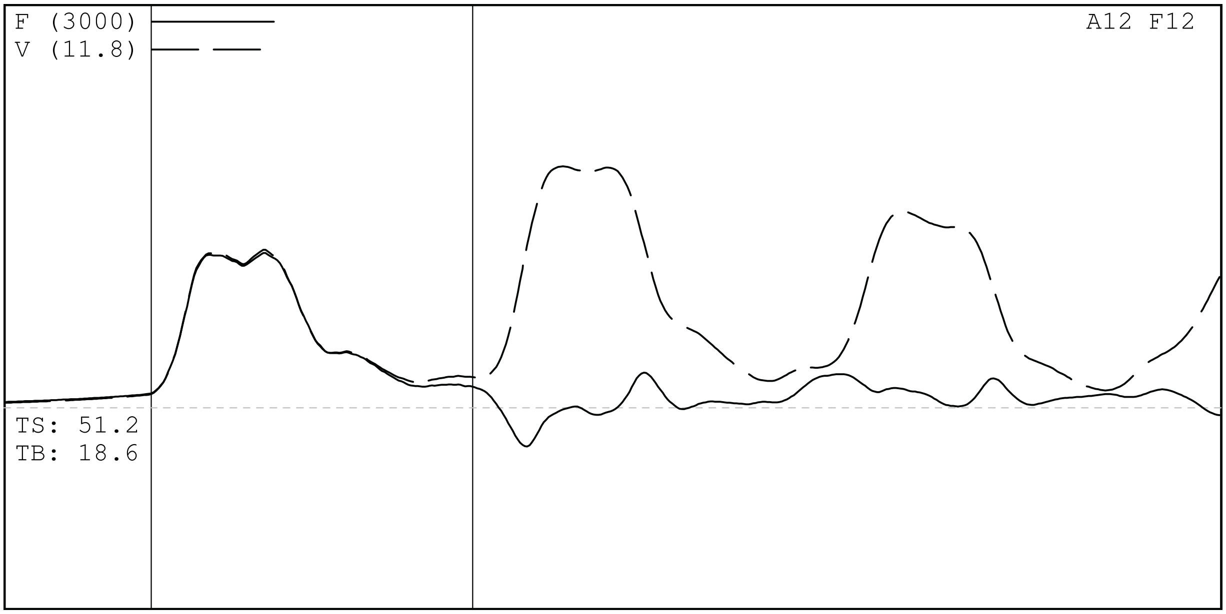
AR: 576.00 in^2 SP: 0.145 k/ft3
LE: 95.00 ft EM: 6,178 ksi
WS: 14,050.0 f/s JC: 0.50

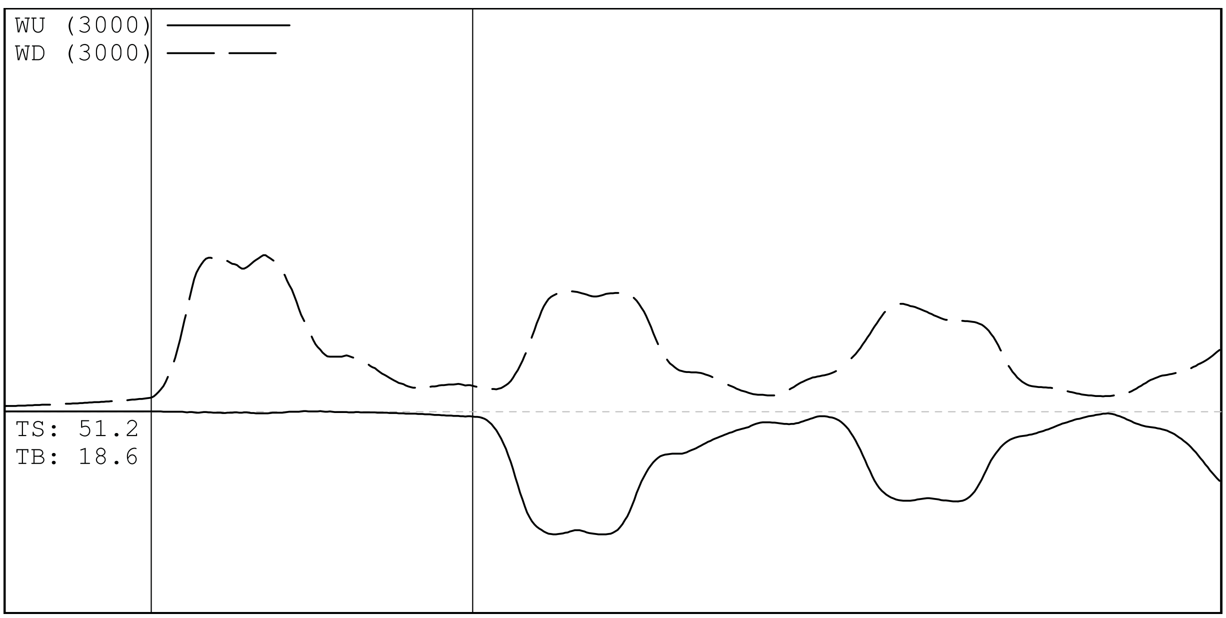
CSX: Max Measured Compr. Stress EMX: Max Transferred Energy
CSI: Max F1 or F2 Compr. Stress BTA: BETA Integrity Factor
CSB: Compression Stress at Bottom RX0: Max Case Method Capacity (JC=0)
TSX: Tension Stress Maximum RX5: Max Case Method Capacity (JC=0.5)
STK: O.E. Diesel Hammer Stroke

BL# end	Elev.	BLC bl/ft	TYPE	CSX ksi	CSI ksi	CSB ksi	TSX ksi	STK ft	EMX k-ft	BTA (%)	RX0 kips	RX5 kips
5	25.4	5	AV5	1.71	2.11	0.54	1.07	7.08	29.37	97.6	314	21
10	24.4	5	AV5	2.07	2.58	0.70	1.33	6.33	28.75	100.0	408	109
20	23.4	10	AV10	2.09	2.51	0.75	1.32	5.99	25.62	100.0	438	179
30	22.4	10	AV10	2.34	2.77	0.95	1.42	6.82	32.21	100.0	556	282
41	21.4	11	AV11	2.57	3.04	1.16	1.47	7.50	36.72	100.0	685	404
53	20.4	12	AV12	2.77	3.29	1.37	1.48	7.99	39.93	100.0	805	522
66	19.4	13	AV11	2.83	3.35	1.46	1.48	7.99	40.26	100.0	857	562
80	18.4	14	AV14	2.88	3.40	1.50	1.50	8.11	40.63	100.0	882	600
95	17.4	15	AV15	2.93	3.46	1.51	1.50	8.23	41.21	100.0	892	617
111	16.4	16	AV16	2.97	3.55	1.52	1.49	8.34	41.59	100.0	896	564
130	15.4	19	AV19	3.00	3.59	1.55	1.46	8.41	41.96	100.0	916	553
149	14.4	19	AV18	3.02	3.58	1.57	1.44	8.47	42.07	100.0	926	536
172	13.4	23	AV23	2.99	3.58	1.55	1.42	8.37	40.72	100.0	915	482
196	12.4	24	AV24	3.02	3.63	1.58	1.41	8.52	41.54	100.0	934	484
221	11.4	25	AV24	3.06	3.71	1.61	1.39	8.68	42.24	100.0	952	483
246	10.4	25	AV25	3.08	3.75	1.63	1.39	8.82	42.88	100.0	965	492
272	9.4	26	AV25	3.04	3.74	1.59	1.37	8.70	41.96	100.0	940	497
296	8.4	24	AV24	3.04	3.76	1.59	1.38	8.73	42.20	100.0	940	495
319	7.4	23	AV23	3.03	3.76	1.56	1.38	8.66	41.75	100.0	926	495
339	6.4	20	AV19	3.06	3.76	1.58	1.39	8.68	42.27	100.0	938	510
359	5.4	20	AV20	3.13	3.83	1.62	1.40	8.92	43.78	100.0	968	512
381	4.4	22	AV22	3.14	3.83	1.64	1.39	8.89	43.09	100.0	980	525
409	3.4	28	AV27	3.20	3.89	1.66	1.39	8.99	43.15	100.0	1,026	585
430	2.4	21	AV21	3.27	3.98	1.70	1.38	9.12	44.60	100.0	1,059	610
458	1.4	28	AV28	3.31	4.04	1.73	1.37	9.10	44.68	100.0	1,095	646
489	0.4	31	AV30	3.39	4.12	1.78	1.35	9.24	45.64	100.0	1,136	675
524	-0.6	35	AV35	3.44	4.13	1.82	1.33	9.19	45.30	100.0	1,171	694
558	-1.6	34	AV33	3.63	4.30	2.04	1.30	9.32	46.85	100.0	1,321	709
593	-2.6	35	AV35	3.73	4.38	2.12	1.32	9.34	48.25	100.0	1,395	737
632	-3.6	39	AV38	3.73	4.35	2.11	1.30	9.39	48.33	100.0	1,394	748
672	-4.6	40	AV39	3.74	4.36	2.13	1.30	9.44	48.89	100.0	1,401	723
711	-5.6	39	AV39	3.73	4.37	2.09	1.31	9.31	48.40	100.0	1,402	701
751	-6.6	40	AV39	3.72	4.32	2.06	1.30	9.31	48.23	100.0	1,405	717
788	-7.6	37	AV37	3.70	4.28	2.01	1.29	9.34	47.90	100.0	1,396	710
823	-8.6	35	AV34	3.66	4.23	1.94	1.28	9.30	47.39	100.0	1,383	695
858	-9.6	35	AV34	3.59	4.16	1.84	1.25	9.18	45.77	100.0	1,363	699
892	-10.6	34	AV34	3.51	4.08	1.68	1.23	9.21	45.09	100.0	1,321	707
929	-11.6	37	AV36	3.40	3.81	1.54	1.19	9.17	42.95	100.0	1,294	700
966	-12.6	37	AV37	3.31	3.50	1.42	1.17	9.23	41.93	100.0	1,264	688
1013	-13.6	47	AV46	3.29	3.39	1.39	1.18	9.41	41.38	100.0	1,284	689
1038	-14.6	25	AV25	3.33	3.47	1.47	1.15	9.50	41.81	100.0	1,328	664
1074	-15.6	36	AV36	3.44	3.56	1.55	1.16	9.53	42.13	100.0	1,380	668
1107	-16.6	33	AV33	3.76	3.90	1.98	1.19	9.56	44.77	100.0	1,573	663

I-4 DEER CROSSING Bridge No. 790207 - CFCC EAST PILE N2 APE D46-42 HAMMER
OP: GRL-MGB Test date: 24-Jan-2014

BL#	Elev.	BLC	TYPE	CSX	CSI	CSB	TSX	STK	EMX	BTA	RX0	RX5
end		bl/ft		ksi	ksi	ksi	ksi	ft	k-ft	(%)	kips	kips
1146	-17.6	39	AV39	3.36	3.65	1.61	1.06	9.18	42.60	100.0	1,432	597
1181	-18.6	35	AV35	3.69	4.15	1.69	1.33	9.21	47.75	100.0	1,475	609
1218	-19.6	37	AV37	3.72	4.29	1.67	1.37	9.21	47.73	100.0	1,474	648
1255	-20.6	37	AV37	3.69	4.26	1.69	1.38	9.15	46.94	100.0	1,452	643
1291	-21.6	36	AV36	3.62	4.04	1.70	1.34	9.05	45.57	100.0	1,426	595
1328	-22.6	37	AV35	3.58	3.90	1.72	1.31	9.06	44.87	100.0	1,397	546
1363	-23.6	35	AV35	3.58	3.83	1.73	1.27	9.18	45.50	99.1	1,399	520
1399	-24.6	36	AV36	3.54	3.81	1.71	1.21	9.22	45.16	99.7	1,396	506
1441	-25.6	42	AV42	3.56	3.87	1.79	1.05	9.40	45.78	100.0	1,464	562
1495	-26.6	54	AV54	3.62	3.89	1.99	0.81	9.60	46.92	98.7	1,597	807
1558	-27.6	63	AV62	3.74	4.06	2.06	0.88	9.70	48.47	93.8	1,601	873
1636	-28.6	78	AV78	3.85	4.19	2.14	1.02	9.68	49.27	91.7	1,578	887
1726	-29.6	90	AV89	4.01	4.35	2.30	1.13	9.76	51.50	100.0	1,572	885
1819	-30.6	93	AV93	3.94	4.07	2.32	1.10	9.72	50.69	100.0	1,533	913
1923	-31.6	104	AV104	3.56	3.91	2.19	1.00	9.57	47.16	100.0	1,436	897
2005	-32.6	82	AV81	3.84	4.14	2.28	1.15	9.47	50.51	100.0	1,497	852
2081	-33.6	76	AV76	3.85	3.97	2.21	1.17	9.51	50.15	100.0	1,451	792
2149	-34.6	68	AV67	3.79	3.90	2.16	1.16	9.51	48.93	100.0	1,440	748
2212	-35.6	63	AV63	3.72	3.83	2.12	1.13	9.49	47.68	100.0	1,433	714
2269	-36.6	57	AV57	3.67	3.80	2.05	1.11	9.47	46.75	100.0	1,414	699
2323	-37.6	54	AV54	3.69	3.88	2.03	1.08	9.51	46.44	100.0	1,426	704
2370	-38.6	47	AV47	3.78	4.03	2.09	1.06	9.58	47.12	100.0	1,478	708
2415	-39.6	45	AV45	3.86	4.05	2.20	1.02	9.57	47.49	100.0	1,547	714
2462	-40.6	47	AV47	3.97	4.19	2.33	0.90	9.59	48.86	100.0	1,655	758
2540	-41.6	78	AV78	3.36	3.62	2.45	0.54	9.38	42.90	99.4	1,753	845
2598	-42.6	58	AV55	3.58	3.81	2.43	0.75	9.43	44.83	100.0	1,728	785
2655	-43.6	57	AV57	3.48	3.74	2.33	0.78	9.20	45.15	98.6	1,675	779
2718	-44.6	63	AV62	3.62	3.70	2.40	0.61	9.34	44.06	100.0	1,720	800
2782	-45.6	64	AV64	3.55	3.69	2.33	0.59	9.38	43.62	100.0	1,681	810
2844	-46.6	62	AV61	3.51	3.71	2.29	0.61	9.43	43.42	100.0	1,638	873
2911	-47.6	67	AV66	3.55	3.72	2.45	0.55	9.71	44.96	100.0	1,689	1,030
2978	-48.6	67	AV67	3.59	3.73	2.57	0.46	9.76	45.19	99.8	1,764	1,047
3051	-49.6	73	AV72	3.83	4.01	2.65	0.64	9.84	47.68	100.0	1,791	1,171
3139	-50.6	88	AV88	3.86	4.04	2.92	0.82	9.92	48.26	100.0	1,888	1,483





Project Information

PROJECT: I-4 DEER CROSSING
PILE NAME: CFCC EAST PILE N2
DESCR: APE D46-42 HAMMER
OPERATOR: GRL-MGB
FILE: CFCC EAST PILE N2
1/24/2014 9:01:06 AM
Blow Number 5

Pile Properties

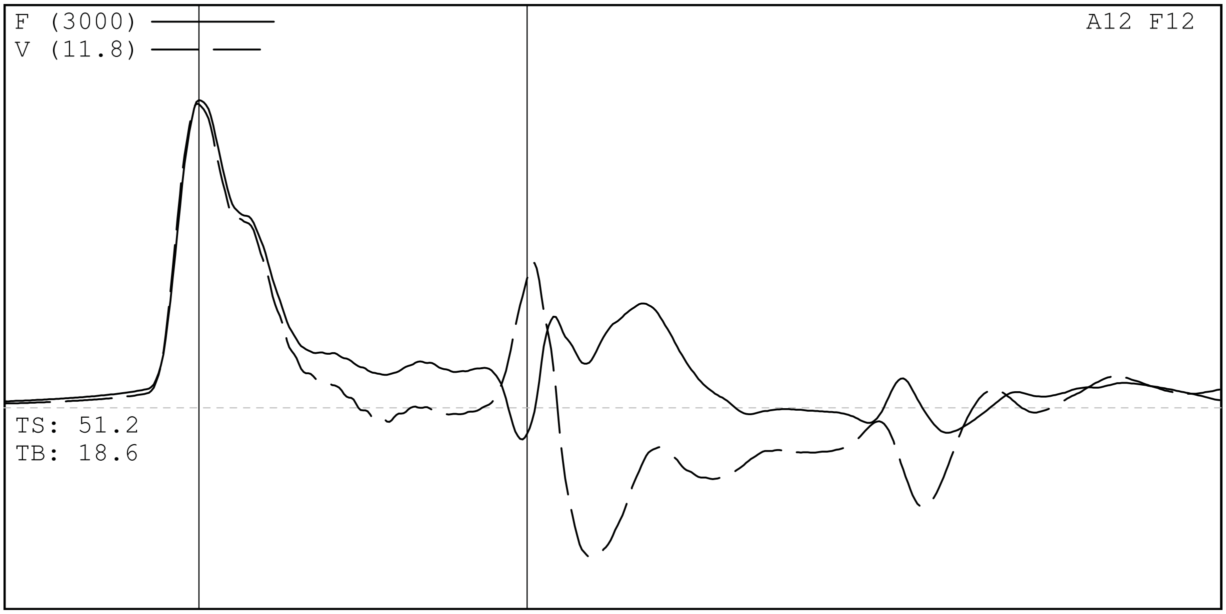
LE	95.00	ft
AR	576.00	in^2
EM	6178	ksi
SP	0.145	k/ft3
WS	14050.0	f/s
EA/C	253.3	ksec/ft
2L/C	13.50	ms
JC	0.50	[]
LP	27.00	ft

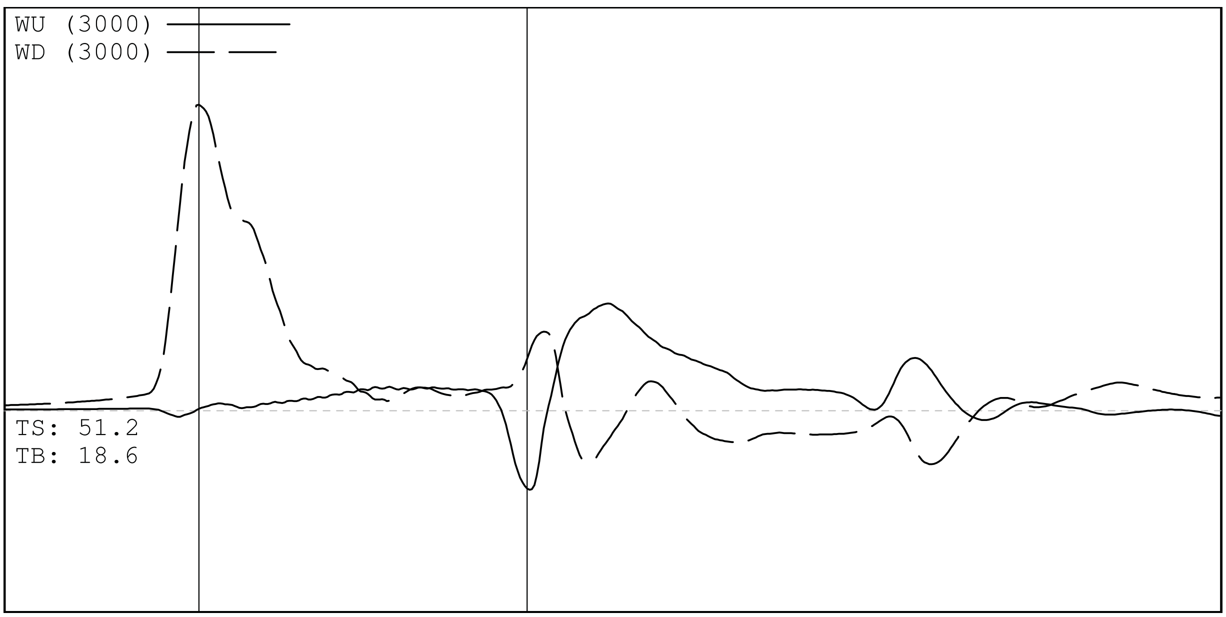
Quantity Results

CSX	2.00	ksi
CSI	2.51	ksi
CSB	0.73	ksi
TSX	1.29	ksi
STK	6.98	ft
EMX	31.75	k-ft
BTA	100.0	(%)
RX0	424	kips
RX5	60	kips

Sensors

F1: [F978] 94.4 (1)
F2: [A407] 99.3 (1)
A1: [19932] 1020 g's/v (1)
A2: [29018] 1150 g's/v (1)
CLIP: OK





Project Information
PROJECT: I-4 DEER CROSSING
PILE NAME: CFCC EAST PILE N2
DESCR: APE D46-42 HAMMER
OPERATOR: GRL-MGB
FILE: CFCC EAST PILE N2
1/24/2014 1:05:15 PM
Blow Number 3139

Pile Properties

LE	95.00	ft
AR	576.00	in^2
EM	6178	ksi
SP	0.145	k/ft3
WS	14050.0	f/s
EA/C	253.3	ksec/ft
2L/C	13.80	ms
JC	0.50	[]
LP	103.00	ft

Quantity Results

CSX	3.97	ksi
CSI	4.14	ksi
CSB	3.28	ksi
TSX	0.90	ksi
STK	10.28	ft
EMX	51.01	k-ft
BTA	100.0	(%)
RX0	2067	kips
RX5	1719	kips

Sensors
F1: [F978] 94.4 (0.98)
F2: [A407] 99.3 (0.98)
A1: [19932] 1020 g's/v (1.02)
A2: [29018] 1150 g's/v (1.02)
CLIP: OK

700-010-60
Construction
11/11

PILE DRIVING INFORMATION

Structure Number: ____________

FIN PROJ. ID # 408464-1-52-01 DATE 1-~~23~~ 24-14 STATION NO. ____________
PILE SIZE 24" ACTUAL/AUTH LENGTH 100.00' BENT/PIER NO. 3-1 PILE NO. N-2
HAMMER TYPE APE D-46-42 RATED ENERGY 114,109 Ft/lbs OPERATING RATE Varies
REF. ELEV 52.37' MIN. TIP ELEV / PILE CUTOFF ELEV /
DRIVING CRITERIA Experimental Pile. No. 2

PILE CUSHION THICKNESS AND MATERIAL Pine Plywood 6"
HAMMER CUSHION THICKNESS AND MATERIAL 3½" (2-1" Micarta + 3-½" Aluminum)
WEATHER Clear TEMP 52° START TIME 9:07 am. STOP TIME ____________

PILE DATA

PAY ITEM NO. N/A WORK ORDER NO. ____________
MANUFACTURED BY ____________ T.B.M./B.M. ELEV N/A GROUND ROD READ N/A
DATE CAST 7-24-13 ROD READ / PILE HEAD ROD READ /
MANUFACTURER'S PILE NO. ____________ H.I. / PILE HEAD ELEV. ____________
PILE HEAD CHAMFER ¾" x 3" PILE TIP ELEV. ____________
PILE TIP CHAMFER ¾" x 3" GROUND ELEV. 41.20'
QUALIFED INSPECTOR'S NAME: Gonzalo Silva TIN #: S 41028067

SPLICE / EACH	PREFORMED HOLE	DYNAMIC LOAD TEST	PAY SET CHECK	NO PAY SET CHECK	REDRIVE	EXTRACTION	DRIVING OF SPLICE	PILE TYPE CODE	BATTER	PILE LENGTH: ORIGINAL FURNISHED	PILE LENGTH: TOTAL LENGTH WITH EXTENSION	PENETRATION BELOW GROUND	EXTENSION / BUILD UP: AUTHORIZED	EXTENSION / BUILD UP: ACTUAL

NOTES: -Predrilled 16'.
- template removed at reference 93' - new ref. 6' below. but log will be filled as some original reference.

total blows 3.143

For Trainee experience evidence only:
Name of CTQP Trainee being supervised by the Qualified Inspector: ____________
CTQP Trainee

I certify the Pile Driving Record accuracy and that the named above Trainee has observed the full pile installation:

____
Qualified Inspector (Signature)

N-2 2

Bridge	Exp. Pile No. 2	
End/Bent		
Pile		No. 2
Reference Elevation		52.37

Depth	Blows	Stroke	Fuel S.		Comments
1.-2					
2.-3					
3.-4					
4.-5					
5.-6					
6.-7					
7.-8					
8.-9					
9.-10					
10.-11	Predrilling				
11.-12					
12.-13					
13-14					
14-15					
15-16					
16-17					
17-18					
18-19					
19-20					
20-21					
21-22	Template				
22-23					
23-24					
24-25					
25-26					Start @ 9:07 a.m
26-27	} 10	5.77			
27-28					
28-29	10	5.91	700		
29-30	10	6.81			
30-31	11	7.15			
31-32	12	7.90			
32-33	13	7.21	760		
33-34	14	8.34	750		
34-35	15	8.16			
35-36	16	7.77			
36-37	19	8.04			
37-38	19	8.31			
38-39	23	8.29	820		

N-2 3

Bridge	Exp. Piles				
End/Bent					
Pile	No. 2				
Reference Elevation	52.37'				

Depth	Blows	Stroke	Fuel S.		Comments
39-40	24	7.99	8.40		
40-41	25	7.53	840		
41-42	25	7.73			
42-43	26	7.64			
43-44	24	7.94	880		
44-45	23	8.48	900		
45-46	20	8.63	920		
46-47	20	8.78			
47-48	22	8.79			
48-49	28	8.78			
49-50	21	8.96			
50-51	28	8.81			
51-52	31	8.85			
52-53	35	8.80			Stop @ 9:19 a.m re-start 9:22 a.m
53-54	34	8.99			
54-55	35	8.84			
55-56	39	8.84			
56-57	40	8.58			
57-58	39	8.43			
58-59	40	8.73			
59-60	37	8.44			
60-61	35	8.72	960		
61-62	35	8.69	970		
62-63	34	8.62	970		Smoke
63-64	37	8.92	980		Smoke
64-65	37	9.12			Burn.
65-66	47	9.22			Burn.
66-67	25	8.25			
67-68	36	8.60			
68-69	33	9.29			1122 blows
69-70	14 / 25	4" / 8.80			Spall in head- Change cushion @ 9:41 a.m re-start : 10:33 am
70-71	35	9.05	N/A		
71-72	37	8.90			
72-73	37	8.83			
73-74	36	8.95			
74-75	37	8.69			
75-76	35	9.19			
76-77	36	9.13			
77-78	42	9.14			

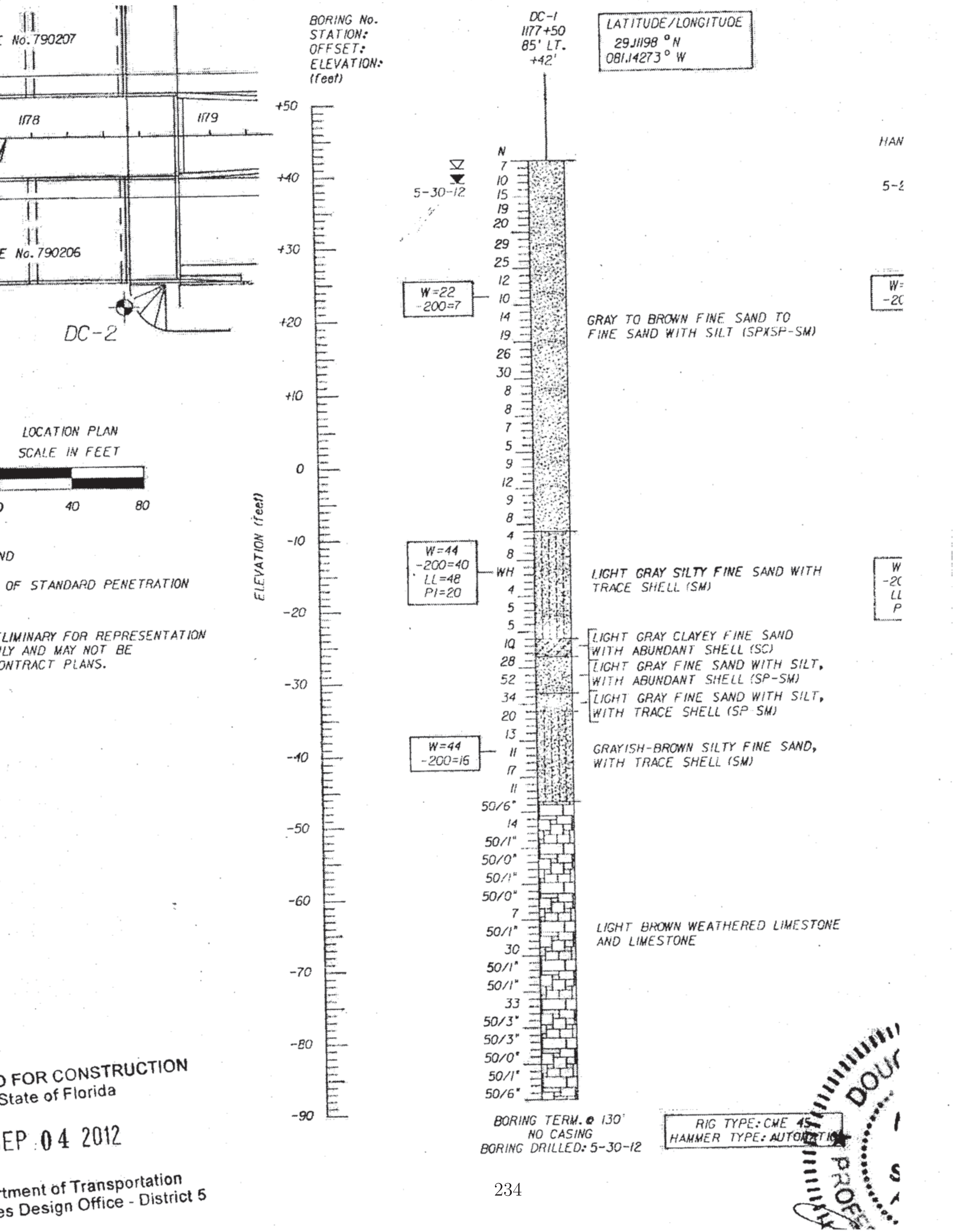
N-2 (4)

VT REVIEW DRIVING LOG					
Bridge	Experim. Pile				
End/Bent		EB-1			
Pile		N. -2			
Reference Elevation		52.37'			

Depth	Blows	Stroke	Fuel S.		Comments	
78-79	54	9.48				
79-80	63	9.35				
80-81	78	9.33		Smoke		
81-82	90	9.60		Smoke		
82-83	93	9.58		Burning		
83-84	73/31	8"/9.23		Stopped to Change cushion 6"		@ 10:49 a.m
84-85	82	9.35				start 11:04 am
85-86	76	9.22				
86-88	68	9.45	N/A			
87-88	63	9.34				
88-89	57	9.23				
89-90	54	8.62				
90-91	47	9.41				
91-92	45	9.55				
92-93	47	9.48		Stopped at 11:18 a.m - Remove temp.		and replace cushion 6"
93-94	78	9.18	980	re-start at 12:46 pm		
94-95	58	9.68				
95-96	57	9.15		Stopped @ 12:54 check gauges		re-star 12:56 pm
96-97	63	8.87	1000			
97-98	64	9.26				
98-99	62	9.29				
99-100	67	9.49				

-

100-101	67	9.49	
101-102	73	9.24	
102-103	88	9.84	Stopped @ 1:11 pm.
103-104			
104-105			


No. 790207
E No. 790206
1178
1179
DC-2
LOCATION PLAN
SCALE IN FEET
40
80
ND
OF STANDARD PENETRATION
ELIMINARY FOR REPRESENTATION
LY AND MAY NOT BE
ONTRACT PLANS.
D FOR CONSTRUCTION
State of Florida
EP 04 2012
rtment of Transportation
es Design Office - District 5
BORING No.
STATION:
OFFSET:
ELEVATION:
(feet)
DC-1
1177+50
85' LT.
+42'
LATITUDE/LONGITUDE
29.11198 °N
081.14273° W
ELEVATION (feet)
+50
+40
+30
+20
+10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
5-30-12
N
7
10
15
19
20
29
25
12
10
14
19
26
30
8
8
7
5
9
12
9
8
4
8
WH
4
5
5
10
28
52
34
20
13
11
17
11
50/6"
14
50/1"
50/0"
50/1"
50/0"
7
50/1"
30
50/1"
50/1"
33
50/3"
50/3"
50/0"
50/1"
50/6"
W=22
-200=7
W=44
-200=40
LL=48
PI=20
W=44
-200=16
GRAY TO BROWN FINE SAND TO FINE SAND WITH SILT (SP/SP-SM)
LIGHT GRAY SILTY FINE SAND WITH TRACE SHELL (SM)
LIGHT GRAY CLAYEY FINE SAND WITH ABUNDANT SHELL (SC)
LIGHT GRAY FINE SAND WITH SILT, WITH ABUNDANT SHELL (SP-SM)
LIGHT GRAY FINE SAND WITH SILT, WITH TRACE SHELL (SP-SM)
GRAYISH-BROWN SILTY FINE SAND, WITH TRACE SHELL (SM)
LIGHT BROWN WEATHERED LIMESTONE AND LIMESTONE
BORING TERM. @ 130'
NO CASING
BORING DRILLED: 5-30-12
RIG TYPE: CME 45
HAMMER TYPE: AUTOMATIC
HAN
5-
W=
-20
W
-20
LL
P

FDOT SUMMARY OF PILE DRIVING OPERATIONS

FDOT

Florida Department of Transportation

SUMMARY OF PILE DRIVING OPERATIONS

CARBON FIBER REINFORCED PILES

January 31, 2014

Structures Design
Florida's Transportation Engineers

General:

On January 23rd and 24th 2014, two concrete piles reinforced with carbon fiber pre-stressing strands where driven at the SR 400/I-4 Widening from SR 44 to East of 95 project, at Bridge No. 790207 (Deer crossing) near Mile Post 127 in Volusia County. The piles were 24 inches in width and 100 feet in length and were driven at non production locations near Bent 3-1. Monitoring of the installation was performed with the use of Pile Driving Analyzer (PDA) and Embedded Data Collector (EDC) systems.

Pre-Stressed Concrete Piles:

The piles were cast on July 24th, 2013 and include 20 carbon fiber strands, 0.6 inches in diameter pulled to 39.45 kips of force, except at the corner locations where strands were pulled to 5 kips of force. From conversations with the Structures Laboratory, we understand the effective pre-stress after losses in the piles is 1,000 psi and the concrete strength was approximately 10,000 psi at the time of driving. Details of the reinforcement are included in Figures 1 and 2 below.

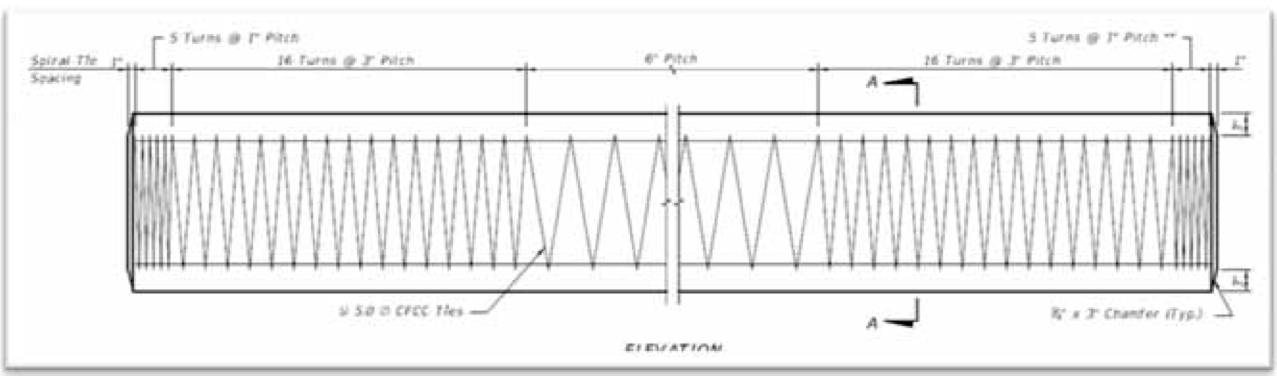


Figure 1 – Elevation

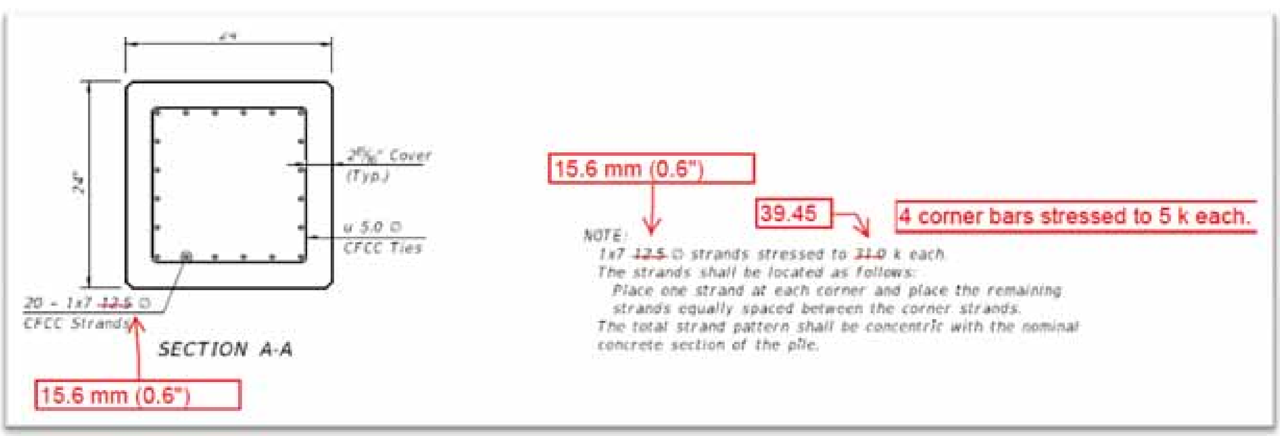


Figure 2 – Strand Details

Pile Driving Operations on Thursday January 23rd (Pile "N1"):

An APE D46-42 single acting diesel hammer with a ram weight of 10.1 kips was used by the Contractor to drive the piles on site. The hammer cushion consisted of two micarta plates of one inch in thickness each, placed between three layers of 0.5 inch thick aluminum plates for a total of 3.5 inches. To protect the head of the pile from impact an 8.75 inch thick pine plywood cushion was used for the initial 1308 blows. A second pile cushion of the same thickness was installed at that point which was compressed significantly and ignited towards the end of the drive. Pile cushion photographs are included in Figure 3.

The initial pile cushion experienced approximately 50 percent compression from its original thickness during the drive, and a slight eccentricity in the hammer strike was noted by the difference between the average stress (CSX), and the maximum stress recorded by an individual set of gages on one face of the pile (CSI) using the PDA system. No visible cracks were noted on the pile during this time. At approximate pile tip elevation -24 ft. pile driving was stopped to replace the pile cushion and remove the guide bars in the template, to allow continued driving without damaging the externally attached instrumentation. Upon resuming driving operations it was noted that the eccentricity on the strike had improved and a more even distribution of stress was recorded, as shown in Figure 4. The pile was subjected to a total of 2765 blows.

Figure 3 –Pile Cushions

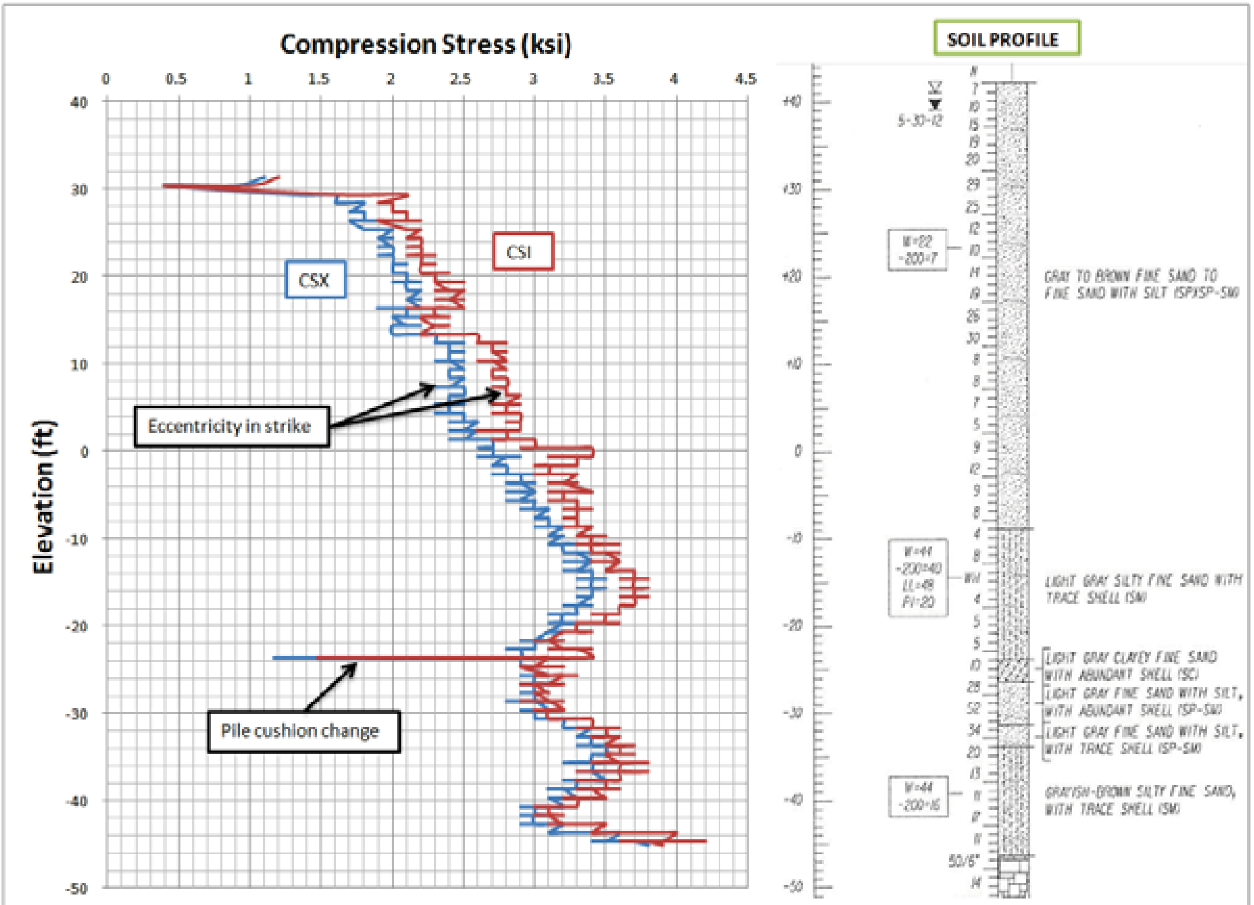


Figure 4 – Average Stress (CSX) and maximum stress from instrumentation on one side of the pile (CSI)

<u>Stress Limits</u>:

Considering the reported concrete strength it became apparent that compression stresses would not control during the drive since the combination the available hammer and the local subsurface conditions would not allow the development of compression in excess of 6.25 ksi:

Maximum compressive stress (Section 455-5.11.2)

$$s_{apc} = 0.7\, f'_c - 0.75\, f_{pe}$$

Sapc = [0.7(10000 psi) – 0.75(1000 psi)] / 1000 = 6.25 ksi

During the drive the stress recorded near the pile tip (CSB) was significantly lower than at the top of the pile (CSX), and neither approached 6.25 ksi, although CSX did exceed the typical limit used in production pile driving under the assumption of f’c = 6,000 psi and initial pre-stress of 1,000 psi (before losses), which yields a maximum allowed compression of:

Sapc = [0.7(6000 psi) – (0.75)(0.8)(1000 psi)] / 1000 = 3.6 ksi

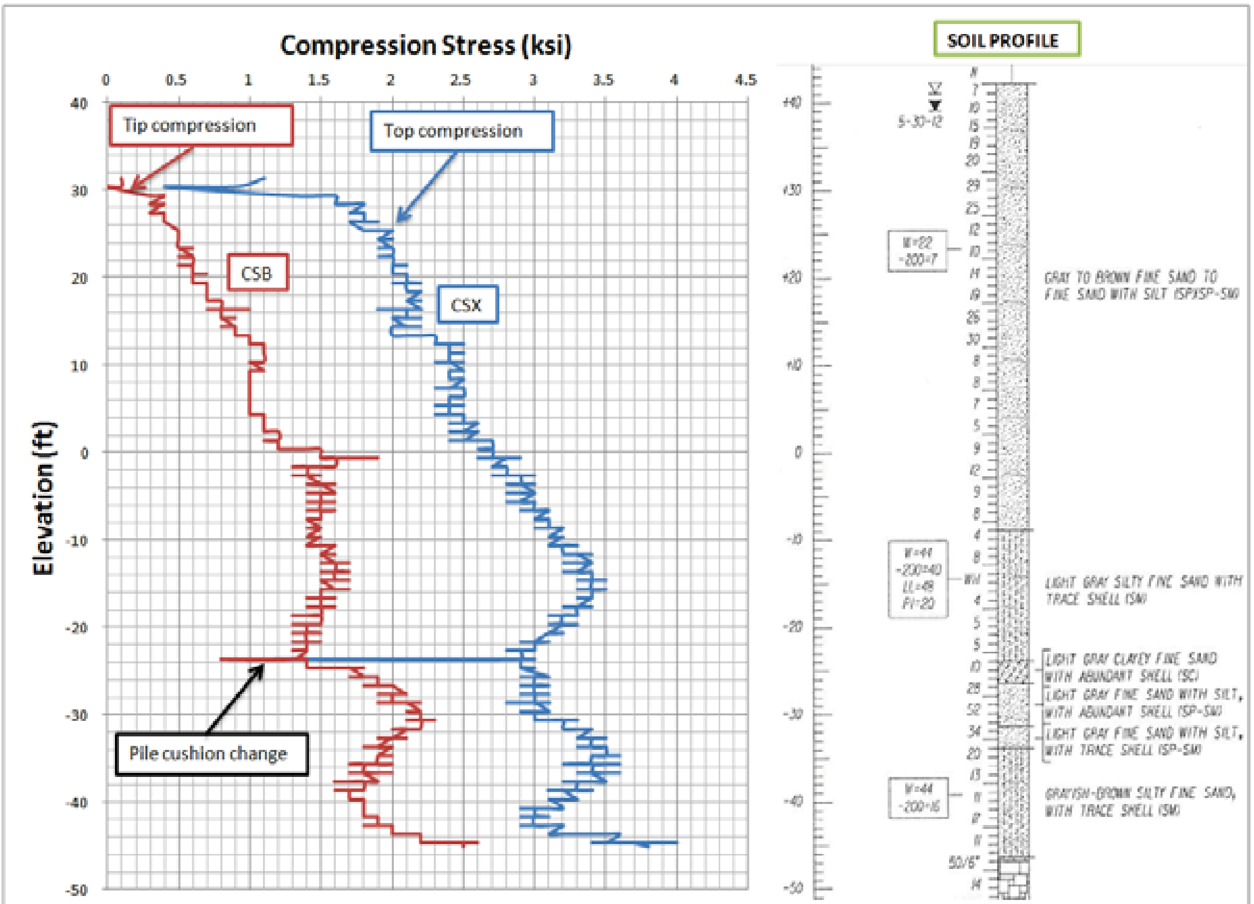


Figure 5 - Top (CSX) and Tip (CSB) Compressive Stresses for Pile N1

Theoretical limit on tension stress:

$$S_{apt} = 3.25\,(f_c')^{0.5} + 1.05\,f_{pe}$$

Sapt = [3.25 (10000 psi)$^{0.5}$ + 1.05(1000 psi)] / 1000 = 1.38 ksi

As shown in Figure 6, the theoretical limit on tension was exceeded (slightly) in portions of the drive between elevation -6.0 and -18.0 ft. without any visible cracking along the pile. As anticipated, high tensile stresses were induced as the pile tip entered a weaker layer in the profile, with SPT “N” blow count in the single digits and weight of hammer conditions.

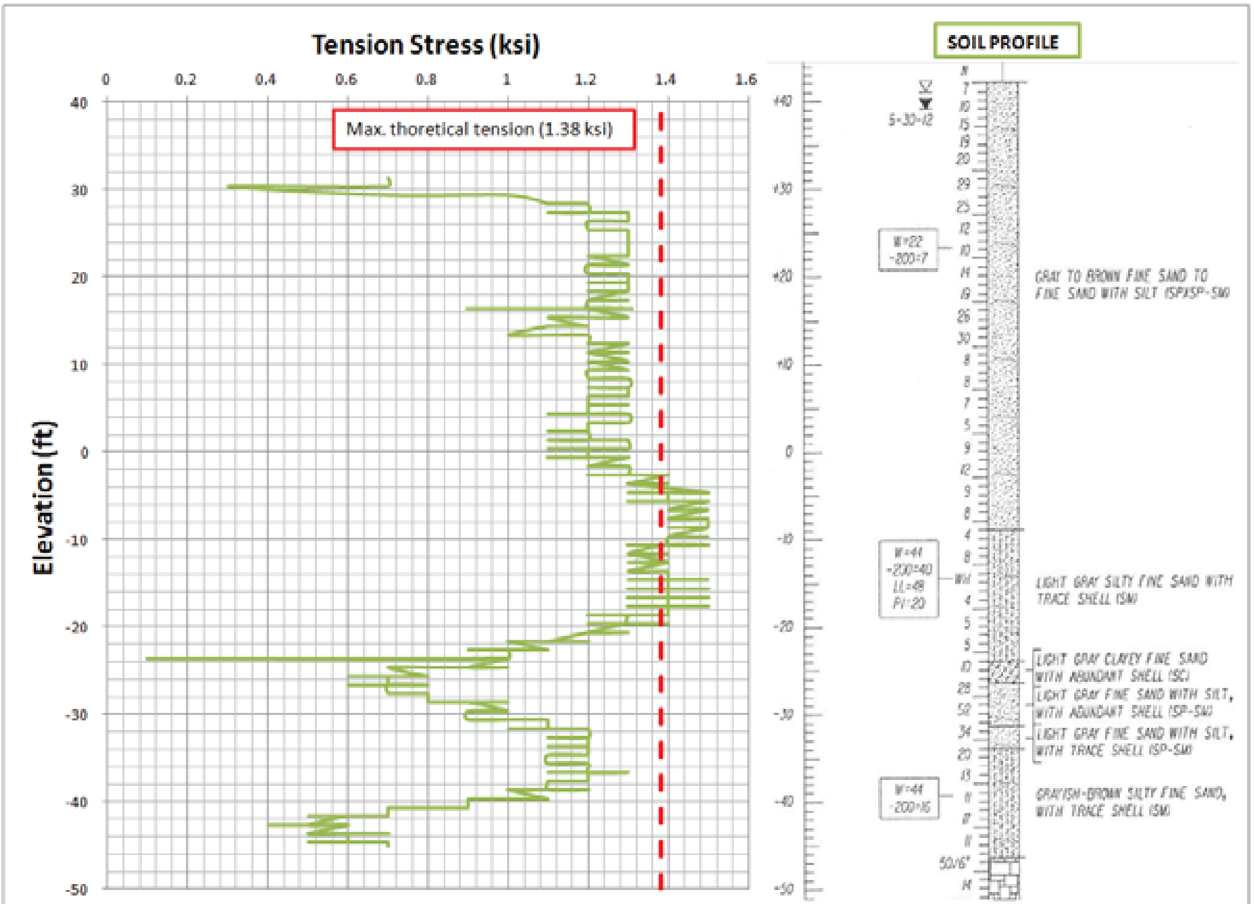


Figure 6 – PDA Tension Stress and Soil Profile

Figure 7 provides a general picture of the estimated tension envelope along the pile at blow number 790 at approximate tip elevation -8.6 ft., indicating high tension values in the upper two-thirds of the object. It should be noted that production pile driving at this level of stress would not be continued without modifications (e.g., lower stroke, increased pile cushion) as it would be in violation of the Specifications.

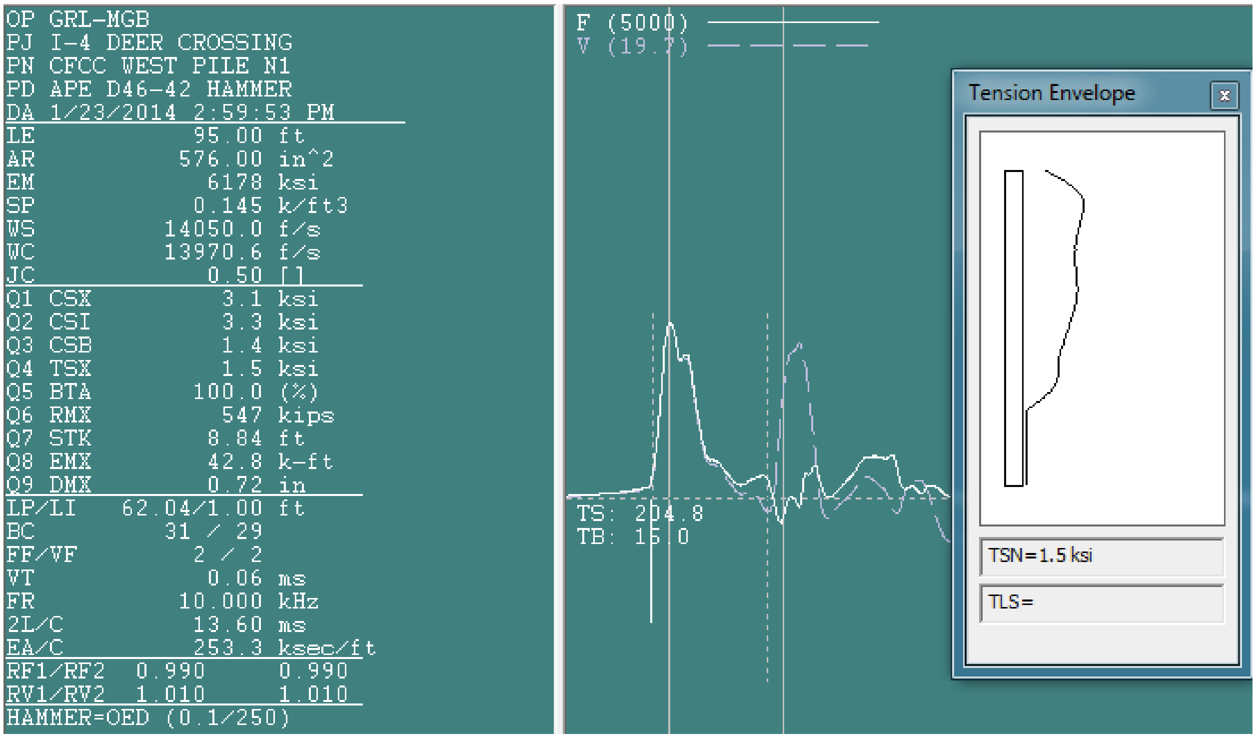


Figure 7 – PDA Screen Capture and Tension Envelope

<u>Pile Integrity</u>:

In the PDA system the BTA parameter represents the percentage of pile cross section compared with the full cross section (PDA-W manual of operation, 2009). This parameter is obtained for every hammer strike, and provides a general picture of estimated pile integrity along the length of the object. Readings below 100% during the early portion of a drive, immediately after changes in pile cushion and at splice locations are not uncommon, however in this instance the latter portion of the drive where none of the above conditions existed did record slight decreases in BTA.

Relatively minor changes in BTA (in the neighborhood of 10%) can be the result of non-uniform resistance as the pile goes through layers of varying magnitudes of friction and could have caused the readings obtained by the PDA. The conservative assumption based on the proposed relationship between damage and BTA included in Figure 8, is that slight damage may have occurred near the pile tip beginning at blow number 2400 (approximate elevation -34.5 ft.), where the recorded BTA values went below 90%. As shown in Figure 8, the slight damage (87%) is estimated to have taken place at a depth of approximately 80 feet below the location of the instruments, or 15 feet above the pile tip as shown in Figure 9.

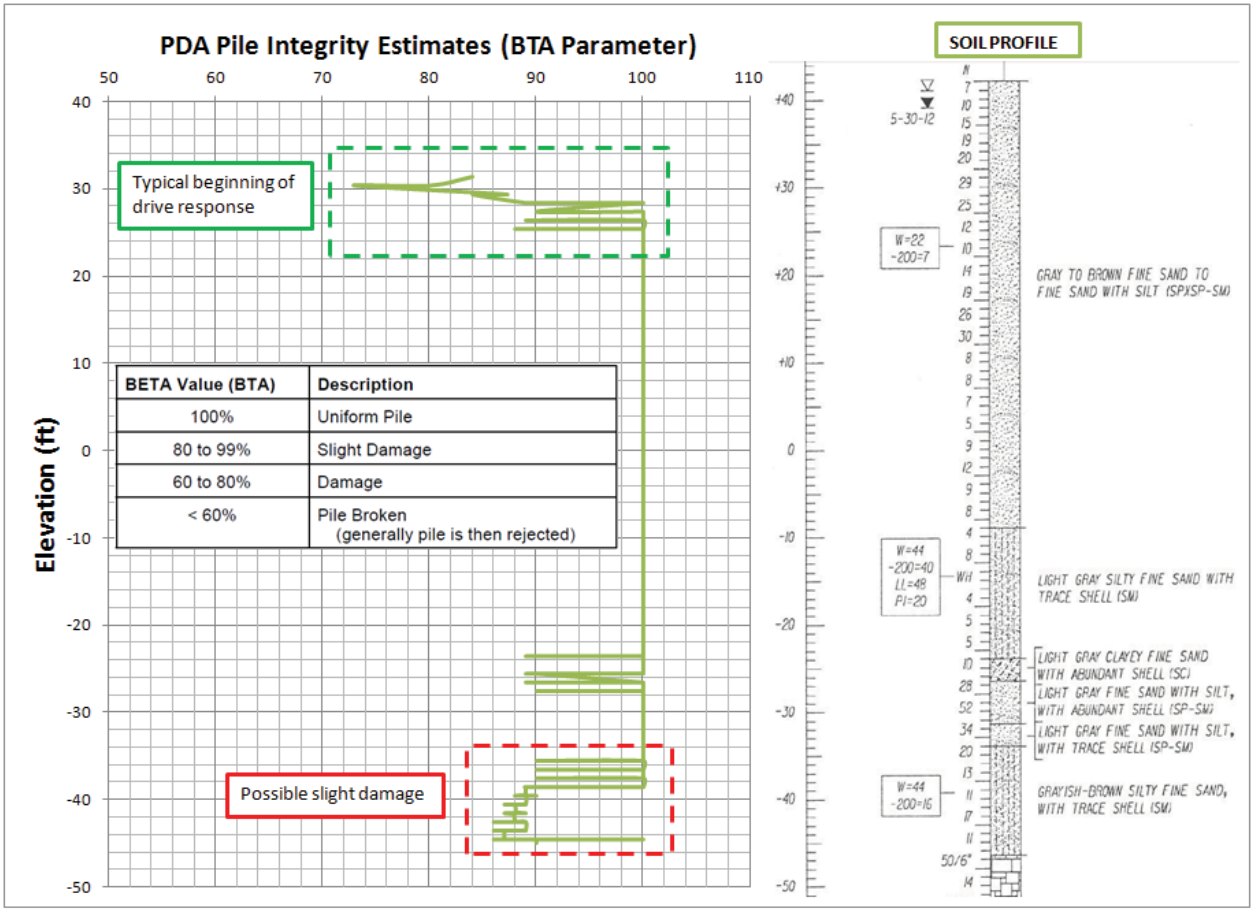


Figure 8 – BTA Parameter

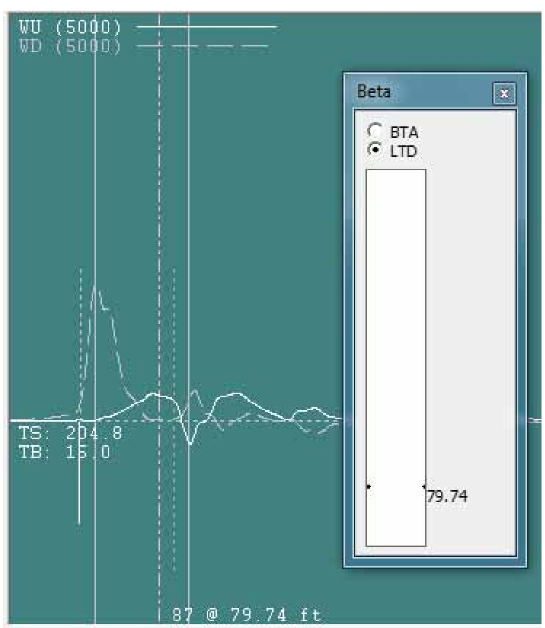


Figure 9 – Wave-down / Wave-up Traces and Estimated Depth of Slight Damage (79.74' below gauges)

The EDC system uses the "MPI" or Measured Pile Integrity parameter to check for damage to the pile during driving, and as with PDA it represents the ratio of pile impedance as described by Rausche and Goble, 1988. In addition, EDC makes use of the top and tip instrumentation to measure losses in pre-stress at the embedded gauge levels (two pile diameters from the head and one pile diameter from the tip). Anytime a change in measured strain reaches 50 micro-strain, the MPI is dropped to a value of 50, and would continue to drop as the loss of pre-stress increases. As an example, if the EDC calculates a drop in BTA to 88% and the measured strain at the pile tip changes by 50 micro-strain from its "zero" value, the reported MPI would be 100 – 12 – 50 = 38. As shown in Figure 10 the MPI value did indicate reductions along the drive, however it never reached or dropped below 50, suggesting no significant loss of pre-stress was measured. Note that EDC reports data in terms of "displacement" (i.e., depth below template) instead of elevation.

Based on the readings obtained from both PDA and EDC it can be concluded that the pile did not suffer any major damage during the drive in terms of integrity or pre-stress level, other than the observed spalling at the pile head during the last few hammer blows.

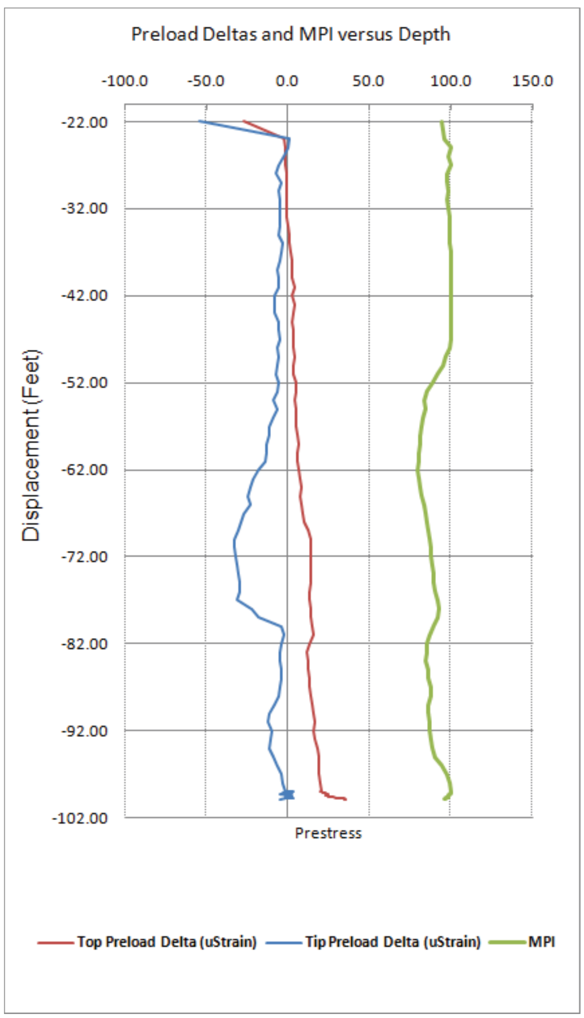


Figure 10 – EDC MPI Record (Green Line)

From top and tip instrumentation measurements obtained by EDC it is also possible to estimate the speed of the stress wave along the pile for every hammer strike, which provides some insight into possible development of micro-cracks during the drive. Although the EDC calculated wave speed has been known to behave erratically in some instances, in this drive it follows an expected trend that begins with a (rather large) value of approximately 14,600 ft/s, followed by a decrease to approximately 13,600 ft/s at a depth of 80 feet that is believed to be caused by the propagation of both vertical and horizontal micro-cracks within the pile.

As the pile enters the bearing layer, the final portion of the drive shows a relative increase of the wave speed to approximately 14,200 ft/s as the horizontal cracks close in compression and allow the wave to travel unimpeded, followed by a slight decrease towards the end of the drive. Although the calculated wave speeds appear to be larger than normal, the relative variations suggest the development of micro-cracks, which has also been observed in conventionally reinforced piles.

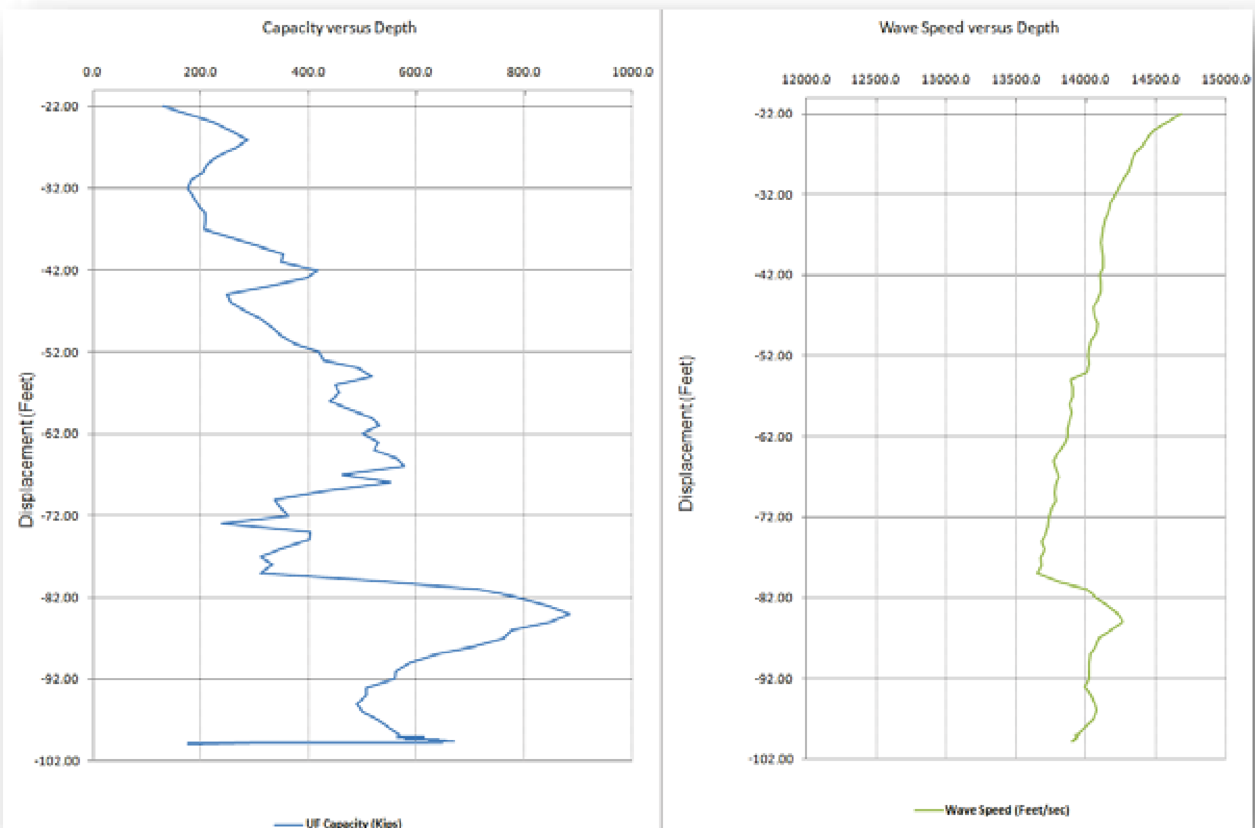


Figure 11 – Pile Resistance and EDC Estimated Wave Speed vs. Depth

Towards the end of the drive the second pile cushion was no longer capable of providing adequate protection and the concrete at the pile head spalled as shown in Figure 12. Driving was stopped at that point.

Figure 12 – Diesel Covered Pile with Spalled Sections

Pile Driving Operations on Friday January 24th (Pile "N2"):

Representatives from the Structures Laboratory and Central Office were not on site during pile driving operations on January 24th. It is our understanding that the only difference in driving for this pile was the use of a thinner pile cushion (6-inches) with the intent of subjecting the second pile "N2" to higher stress than "N1". The Embedded Data Collector was not able to connect to the pile and therefore only PDA data is available.

Eccentricity of the hammer strike was recorded by PDA, and persisted with some improvement upon the subsequent two pile cushion changes as seen on Figure 13. As with the previous pile, the compressive stress delivered to the pile head did not approach the theoretical limit of 6.25 ksi, however it should be noted that the pile inspector's log indicates that concrete spalled at the pile head immediately prior to the first change in cushion at approximate pile tip elevation -16.5 ft. It is possible that the continued hammering of the pile under eccentric loading with a thin pile cushion was the cause of the noted damage. No additional spalling was recorded in the field log.

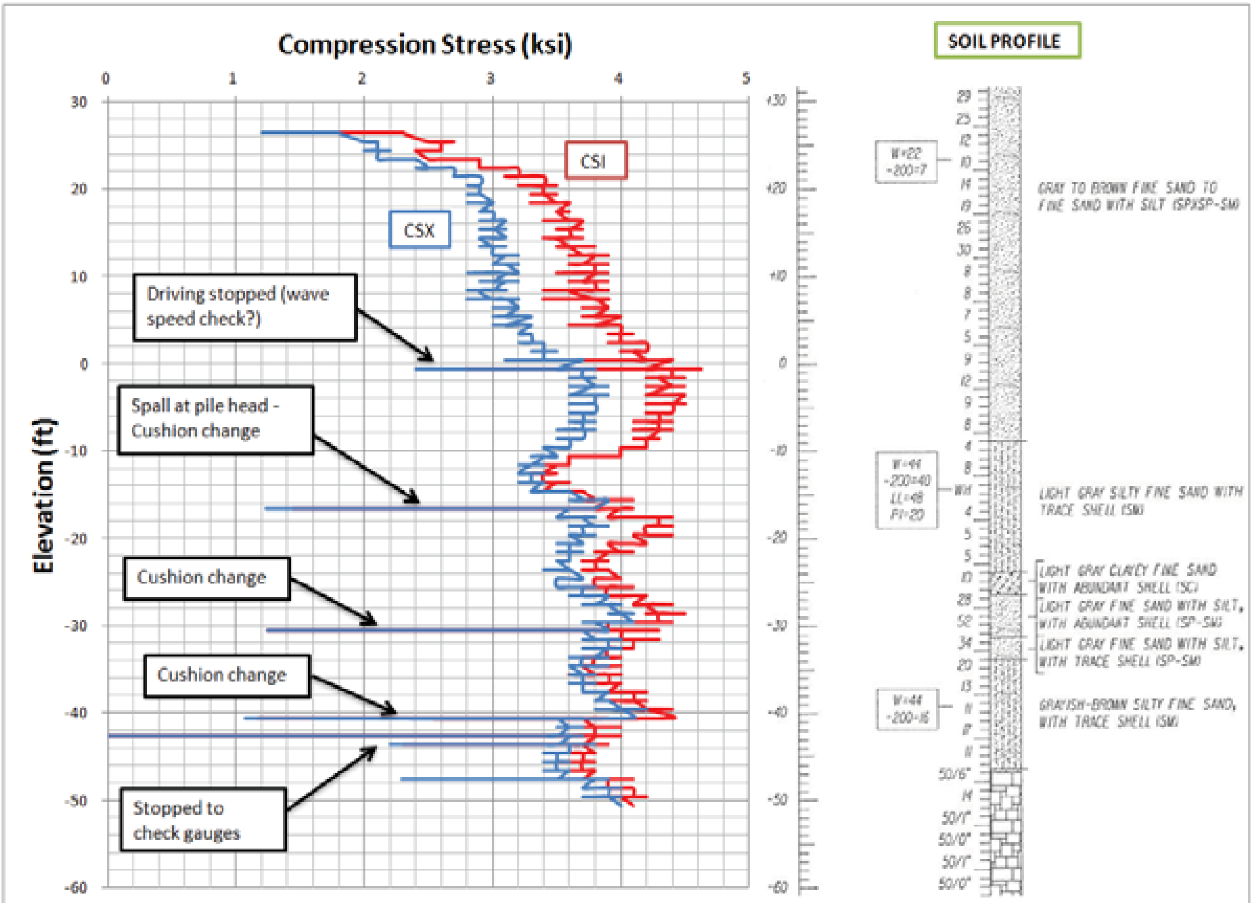


Figure 13 – Average (CSX) and Maximum Compression Stress (CSI) at the Pile Top During the Drive

Figure 14 – Spalling near the Top of Pile N2

The theoretical tension stress limit was exceeded during the early portion of the drive, between elevations +23 and +14 ft, and for a few blows in the vicinity of elevation -19 ft. It should be noted that approximately 600 blows into the drive as the pile tip approached elevation -3.0 ft. (55 feet below reference elevation) two small cracks were observed a few feet apart along the face of the pile, one of them shown on Figure 15.

The pile received approximately 2500 blows beyond that point and the PDA did not detect any major damage below the location of the gauges as reflected in the BTA estimates show in Figure 18.

Figure 15 – Vertical Crack and Close up

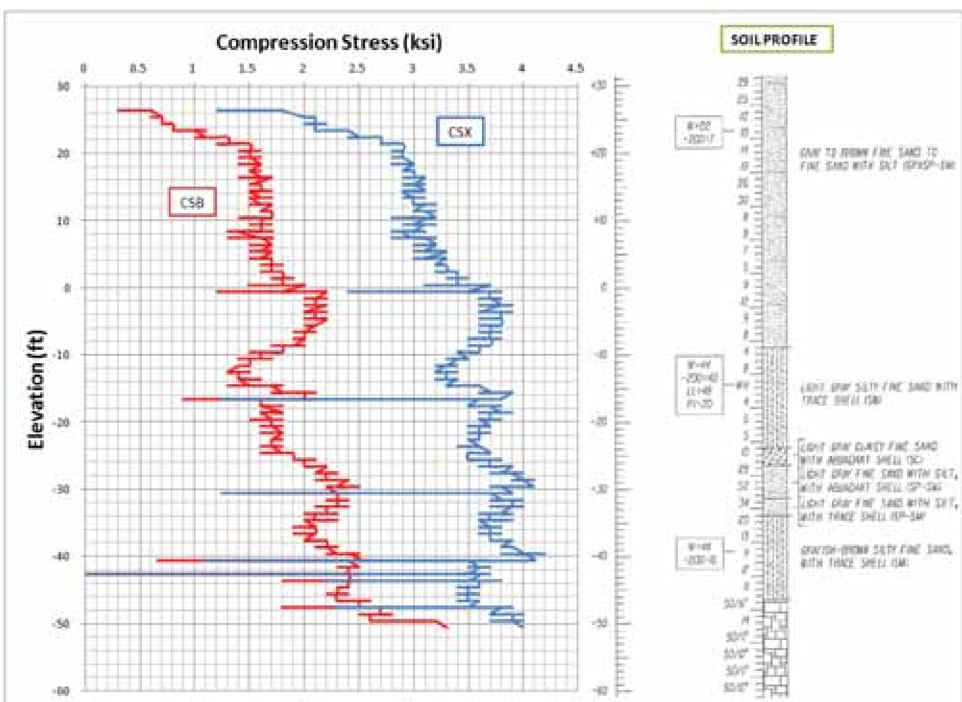


Figure 16 – Tip (CSB) and Top (CSX) Compression for Pile N2

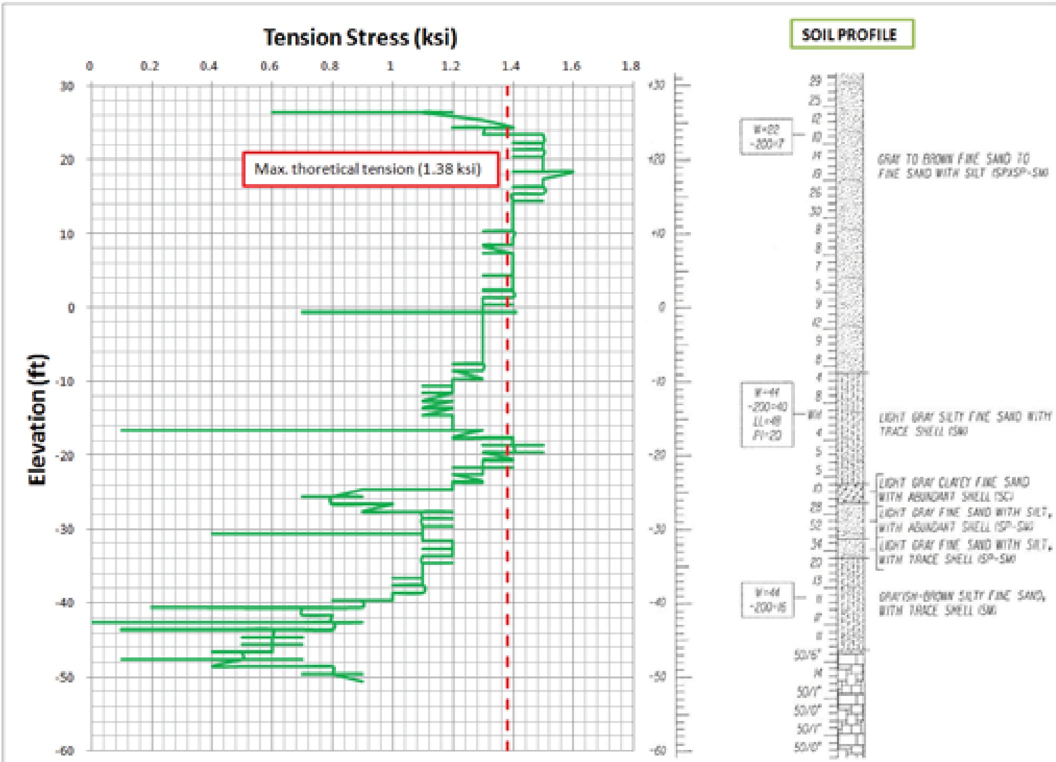
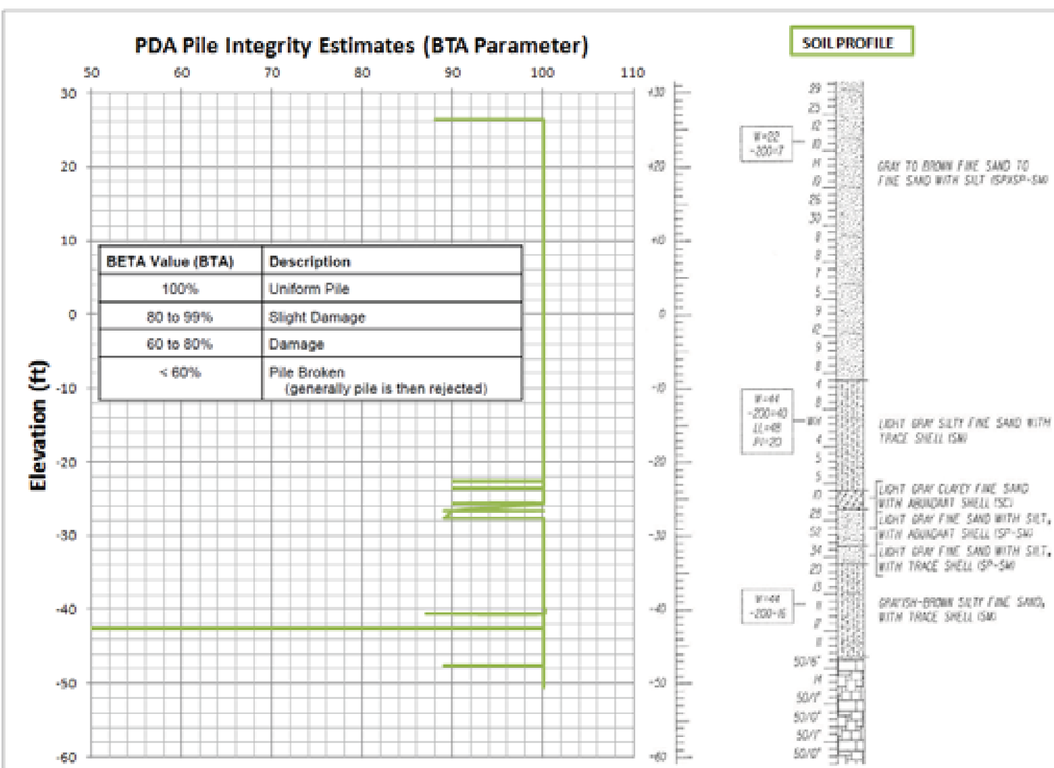


Figure 17 – Tension Stress on Pile N2



BETA Value (BTA)	Description
100%	Uniform Pile
80 to 99%	Slight Damage
60 to 80%	Damage
< 60%	Pile Broken (generally pile is then rejected)

Figure 18 – PDA's BTA Parameter for Pile N2

Pile Resistance:

The general subsurface profile presented layers of granular material with varying amounts of fines and shell overlying a Limestone formation that provided significant resistance, particularly during the end of drive for pile N2. At approximate elevations -29 and -49, pile resistance approached and exceeded the suggested driving resistance currently included in FDOT's Structures Design Guidelines (i.e., 900 kips) for conventional pre-stressed piles 24-inches in width. It is interesting to note that although the suggested limit was exceeded by approximately 800 kips, overall the reinforcement performed well, with spalling occurring only near the pile head in both test piles under eccentric loading of the hammer strike. Figure 19 summarizes the resistance (pile capacity) recorded during both drives.

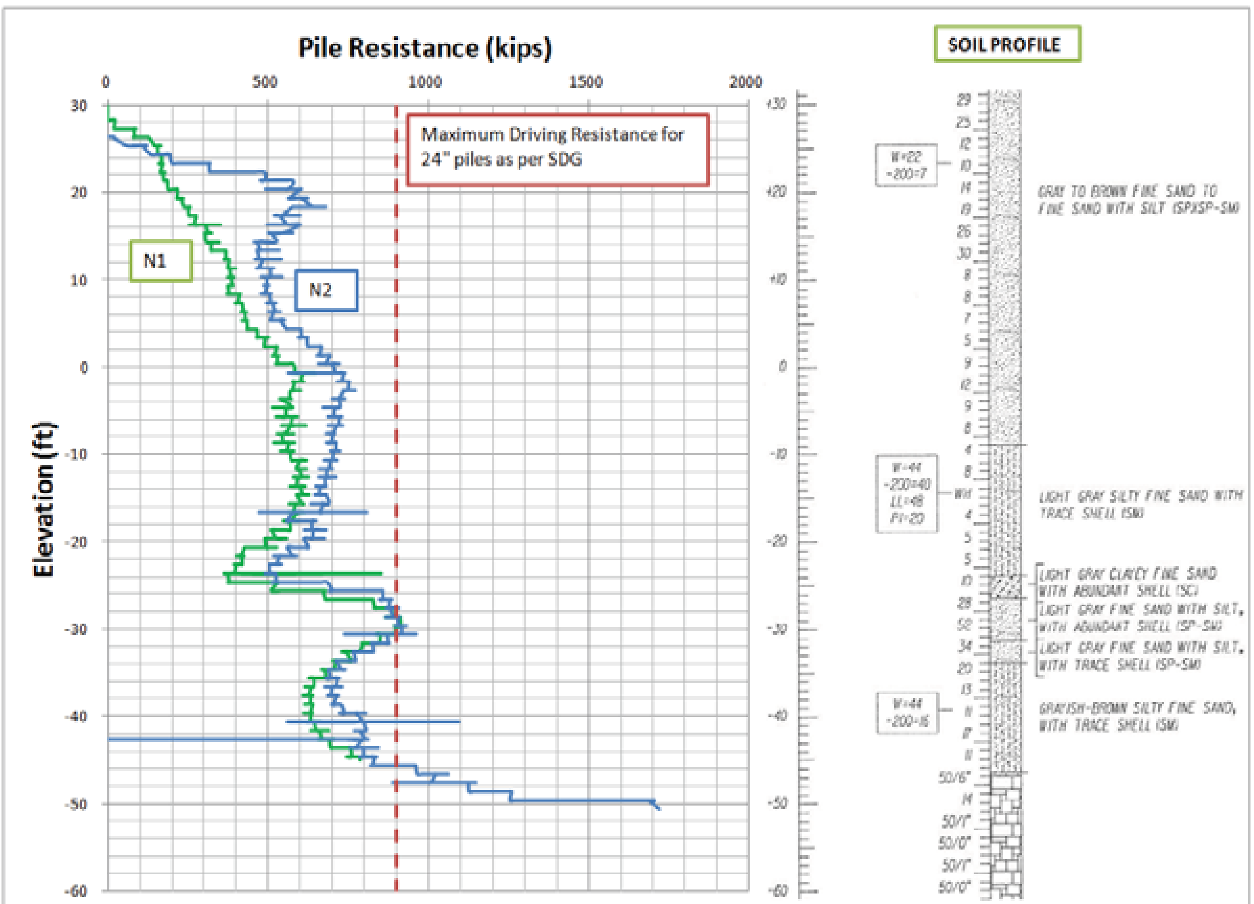


Figure 19 – Pile Resistance vs. Elevation

Summary:

- Two, 24 inch wide, 100 foot long pre-stressed concrete piles reinforced with Carbon Fiber strands were driven in Volusia County, Florida, on January 23rd and 24th 2014.
- Spalling at the pile head was observed on both piles, and was probably the result of slight eccentricities in the hammer strike under high stress blows with thinner than normal pile cushions. It is difficult to estimate whether similar damage would have occurred in conventional piles, however it is likely.
- The piles were monitored with the use of the Pile Driving Analyzer (PDA) and Embedded Data Collector (EDC) systems. No major damage was detected by the PDA on either pile, or the EDC in pile N1 (the system did not collect data for pile N2).
- Both PDA and EDC recorded data that can be interpreted as minor damage, particularly near the pile tip for pile N1. However the estimates, which could be the result of progressive aggravation of vertical and horizontal micro-cracks, were not accompanied by significant losses of pre-stress during the drive.
- Overall the piles had an acceptable performance under driving conditions that exposed them to high levels of stress throughout most of the drive, and received 2765 and 3139 hammer blows, respectively.

Rodrigo Herrera, P.E.

Asst. State Geotechnical Engineer

Florida Department of Transportation

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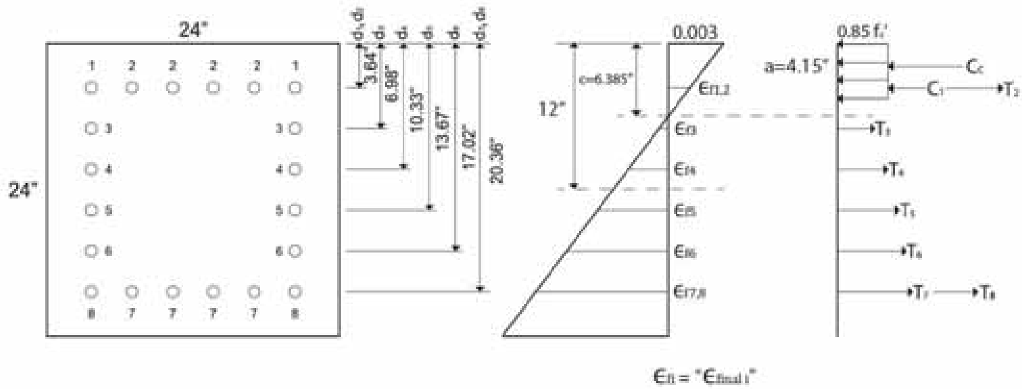
APPENDIX F

MOMENT CAPACITY CALCULATIONS

CALCULATIONS FOR PILE FLEXURAL STRENGTH

24" x 24" pile with 20 0.6" CFCC strands
(4 corner strands stressed to different force)



Parameters:

	16 strands	4 corner strands	
Initial force =	39.45	5	k
Initial stress =	220.15	27.90	ksi
Initial strain =	0.009793	0.001241	in./in.

GUTS =	338	ksi	*(Actual tensile strength likely exceeds this)*
GUTS =	60.7	k	*(Actual tensile strength likely exceeds this)*
c =	6.385	in.	
β_1 =	0.65		
a =	4.150	in.	
f'_c =	9500	psi	
ε_c =	0.003	in./in.	
E_{ps} =	22480	ksi	*(for CFCC strands)*
A_{strand} =	0.1792	in^2	
b =	24	in.	
h =	24	in.	

Force in concrete = C = 0.85 f'_c a b :

C =	-804.3	k	*(Note: See column 11 below to subtract concrete force in holes due to $A_{strands}$)*
Moment of C =	7982.8	k-in.	*(Moment taken about h/2)*

Forces in CFCC prestressing strands:

where

f_{pe} =	Effective stress in prestressing after losses (See PRESTRESS LOSS CALCULATIONS)
ε_{pe} (tension) =	Effective strain in prestressing after losses = f_{pe} / E_{ps}
ε_{final} =	Strain in prestressing steel due to applied moment = ε_c (d/c - 1)
$\varepsilon_{failure}$ =	Strain in prestressing steel at ultimate moment = ε_{pe} + ε_{final}
$f_{failure}$ =	Stress in prestressing steel at ultimate moment = E_{ps} x $\varepsilon_{failure}$
$F_{strands}$ =	Force in prestressing steel at ultimate moment = $A_{strands}$ x $f_{failure}$

Nominal initial force, k	# strands	$A_{strands}$ in^2	d in.	f_{pe} ksi	ε_{pe} (tension) in./in.	ε_{final} in./in.	$\varepsilon_{failure}$ in./in.	$f_{failure}$ ksi	$F_{strands}$ + tens. - comp. k	If in comp., subtract force, k	$F_{strands}$ minus holes k	Moment about h/2 k-in.
corners @ 5 k	2	0.3584	3.64	10.7	0.000476	-0.001290	-0.000814	-18.29	-6.56	-2.89	-3.66	30.62
39.45 k	4	0.7168	3.64	200.7	0.008928	-0.001290	0.007638	171.71	123.08	-5.79	128.87	-1077.33
39.45 k	2	0.3584	6.98	200.7	0.008928	0.000281	0.009209	207.02	74.20	0.00	74.20	-372.19
39.45 k	2	0.3584	10.33	200.7	0.008928	0.001852	0.010780	242.34	86.85	0.00	86.85	-145.26
39.45 k	2	0.3584	13.67	200.7	0.008928	0.003423	0.012351	277.66	99.51	0.00	99.51	166.31
39.45 k	2	0.3584	17.02	200.7	0.008928	0.004994	0.013922	312.97	112.17	0.00	112.17	562.53
39.45 k	4	0.7168	20.36	200.7	0.008928	0.006565	0.015493	348.29	249.66	0.00	249.66	2086.81
corners @ 5 k	2	0.3584	20.36	10.7	0.000476	0.006565	0.007041	158.29	56.73	0.00	56.73	474.21
											804.33	1725.69

Including forces in concrete and prestressing strands:

Sum FORCE =	0.00	k	OK
Sum MOMENT = M_n =	**9708.52**	**k-in.**	
	809.04	**k-ft**	

APPENDIX G

REPORT ON FIRST PILE CASTING ATTEMPT

Investigation of Carbon Fiber Composite Cables (CFCC) Prestressed Concrete Piles

FDOT Research Project BDK83 977-17

Report on Pile Casting Attempt on

September 10-12, 2012

Prepared by Kunal Joshi
FAMU-FSU College of Engineering

Form Preparation & Setup

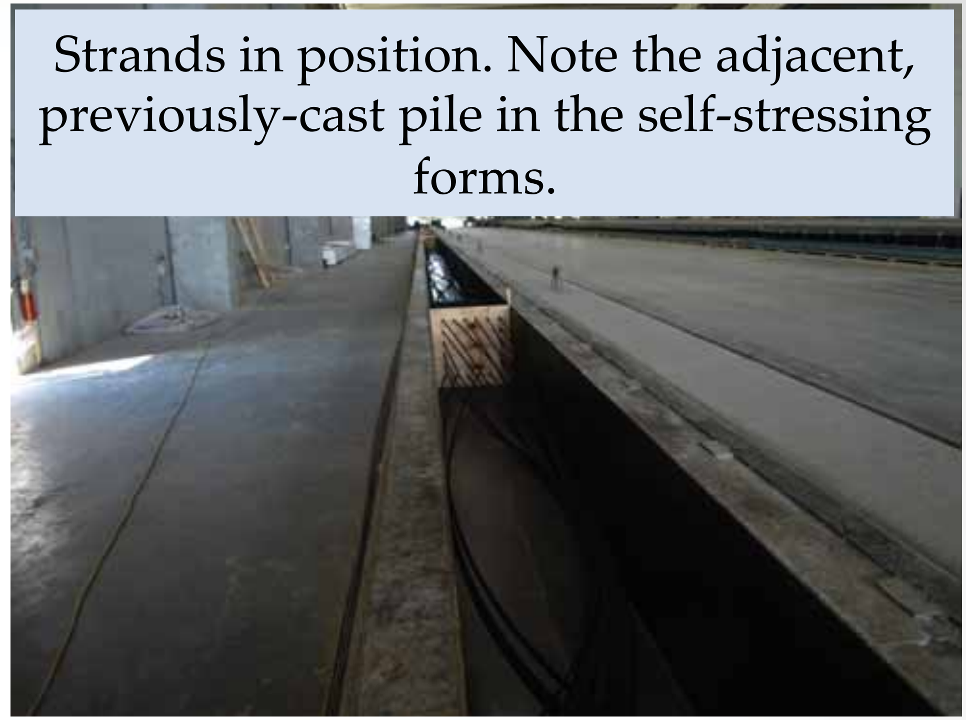
10th September, Monday

- The CFCC delivery was confirmed.
- Checked if the delivered materials were as per ordered.
- 2 stations for installing couplers were set up, one at each end of the pile.
- The space provided in the typical steel headers would not be enough to fit grinder for cutting CFCC (steel is torched), so wooden headers were used instead.
- Wooden headers of size 24x24 in. were set up at each of the pile ends. (Steel headers are normally used, but there was concern about damaging strands when pulling through steel holes).
- It was noted that the holes in the wooden headers were not smooth.
- The holes in the header were corrected by grinding.
- Headers were positioned in approximate locations of pile ends. (Normally they are all pushed to dead end so strands can be fed through all at same time).
- Steel strands are usually bundled and pulled through forms with forklift. CFCC strands, however, were pulled through one at a time.
- GATE installers noted that the CFCC strands were lightweight and quick to install. 2 men easily pulled the strands the 450-ft length of the pile bed.

Strand and Spiral Placement

- The CFCC spirals for each pile were placed in the forms.
- The CFCC spool was mounted on a rod and placed in line with the bed after the setup was checked for correct length.
- The CFCC strands were installed in the bed. Strands were cut every 350 ft.
- The bed length was measured to be 440 ft.
- The product length was measured to be 329 ft, which includes header plywood thickness, 2 ¼ in. gap in each header, and approx. 1 ft between headers at pile ends.

Cutting CFCC strand with circular saw



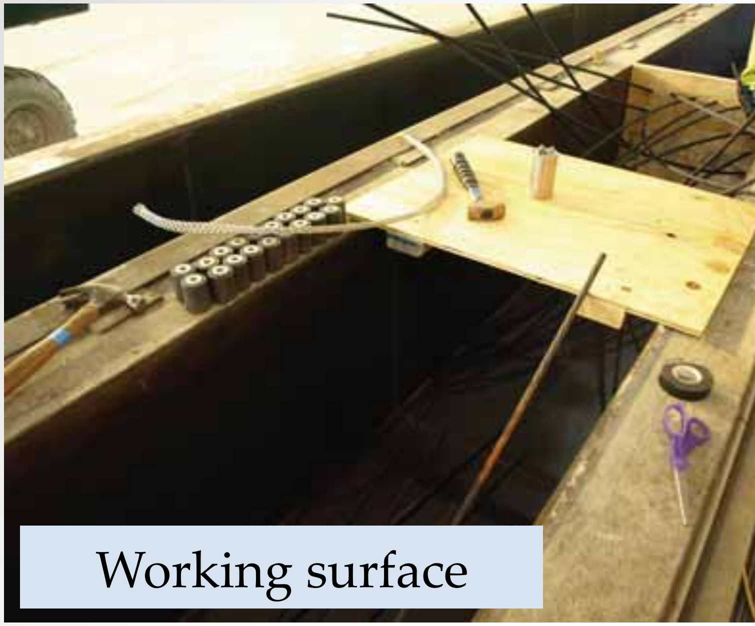
Strands in position. Note the adjacent, previously-cast pile in the self-stressing forms.

Strands and spirals in position

Coupler Installation

11th September, Tuesday

- The couplers were set up on both stations.
- A set of materials required to install 20 couplers was placed on each station.
- Tokyo Rope demonstrated the coupler installation procedure for the first coupler.
- The steel strand was installed from the live end. The direction of twist of the steel strand matched the CFCC strand.
- One coupler was installed by the FAMU-FSU graduate students.
- The coupler installation was then continued by GATE personnel.
- A wooden platform was provided by GATE in order to provide a working surface for the installation process.



Working surface

Installing braided grip to CFCC strand

Coupler installation complete

Cutting steel strand short so that the jack could accommodate estimated elongation

Coupler Installation

- The wooden platform was changed to steel after a couple of installations for sturdiness during hammering of coupler sleeve.
- While coupler sleeves were being installed, another crew installed mesh sheets to the strands to have them ready for the couplers.
- After the installation on the live end was completed, the CFCC strand was pulled manually on the other side to remove any slack in the cable.
- Couplers were staggered by extending the CFCC strand in 3 different lengths from the ends of the outer piles. Otherwise, the couplers would not all fit in the cross-section view.

Stressing

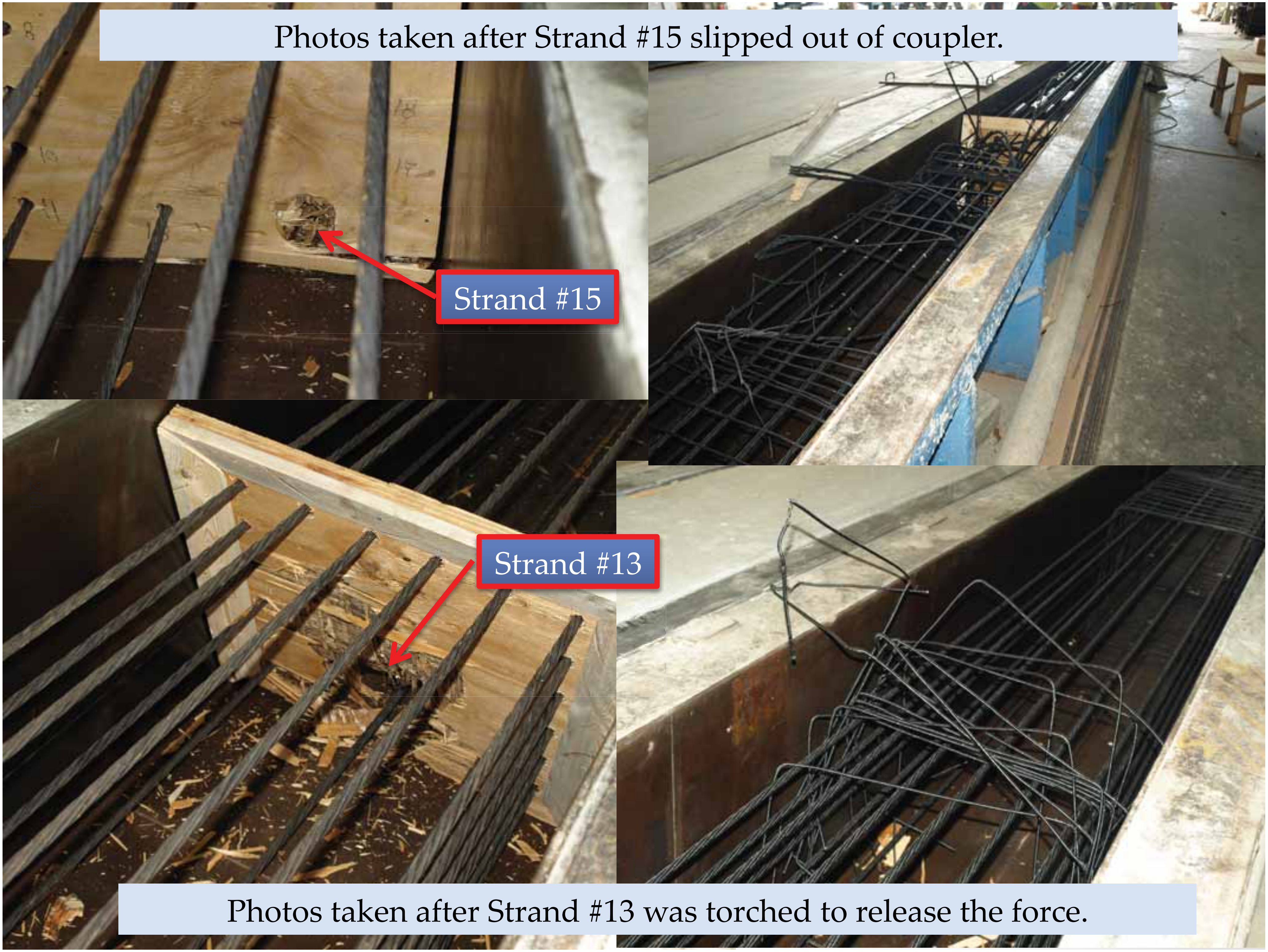
12th September, Wednesday

- The full prestressing force was to be 70% of ultimate strength (0.70*0.118in2*355ksi = 28.9 k)
- The strands closer to the jack were to be stressed first, to avoid coupler interference due to elongation (i.e., the couplers overlap in section view).
- One strand was prestressed to 7 kips (approx. 25% of the full prestressing force).
- A small amount of slip was observed in the CFCC strand where it exited the coupler.
- The remaining strands were stressed to 25% of final force.
- Markings were made on the CFCCs at the header and at the coupler face, to measure elongation and seating, respectively.
- The steel strands on the live end were cut again, so that the jack could accommodate the expected total elongation.


Stressing

- After the first strand (#15) was stressed to the final force, elongation was measured at the jack. The measured elongation matched well with the theoretical.
- The second strand (#13) was stressed to the final force.
- While the jack was about to be installed on the third strand, the first CFCC strand slipped out of the coupler with the braided grip and mesh sheet still attached to the strand.
- Due to safety concerns, further stressing activities were stopped.
- The second strand was torch-cut to release the tension force.
- The cutting and the initial coupler failure resulted in damage to the spirals and also minor damage to the surrounding strands.

Photos taken after Strand #15 slipped out of coupler.

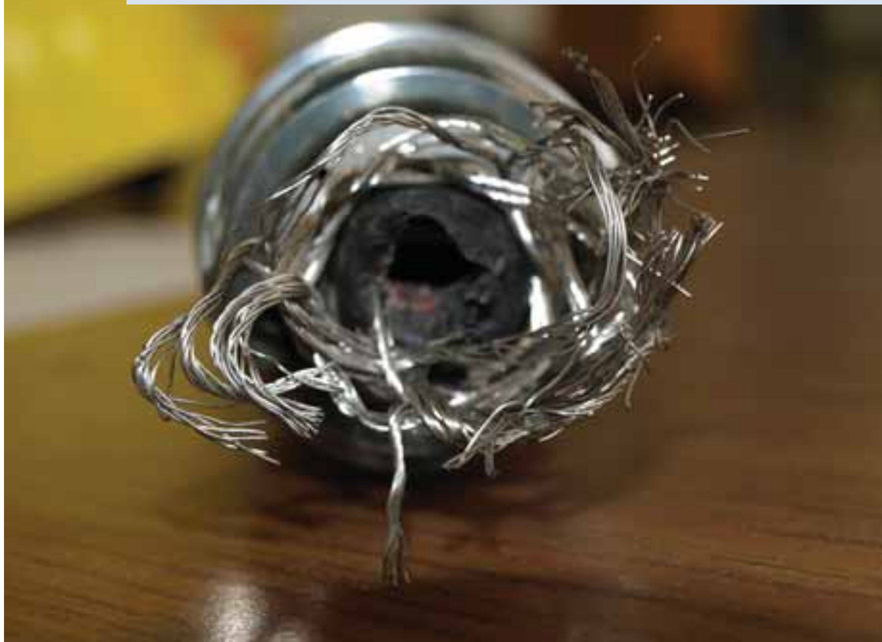


Photos taken after Strand #13 was torched to release the force.

Failed Coupler Analysis

- The failed coupler was taken in the GATE office for further inspection.
- The couplers from the torch-cut strand (and also the 4 couplers from the practice installation at the FDOT Lab on May 18) were dismantled using a device from Tokyo Rope.
- The couplers were removed from the casting bed. Each coupler had approx. 3 ft of CFCC strand extending from it.
- Tokyo Rope took the failed coupler, along with the majority of the other couplers, to their R&D office for further inspection.

Photos of coupler that slipped under force of 70% of CFCC ultimate strength.



Photos of coupler from practice installation at FDOT on May 18. This coupler held a force of approx. 75% of CFCC ultimate strength.

APPENDIX H

PHOTOS

PILE SPECIMEN PRODUCTION

Figure H.1: Spool of CFCC strand

Figure H.2: Steel header used for a conventional steel-prestressed concrete pile (Replaced by wooden header for this research

Figure H.3: View of precasting bed, showing wooden headers

Figure H.4: View of precasting bed, showing bundle of CFCC spirals

Figure H.5: Casting bed with wooden headers and installed CFCC strands

Figure H.6: Couplers, before installation

Figure H.7: CFCC wedges sprayed with Molybdenum Disulfide

Figure H.8: CFCC coupler installation: wrapping the CFCC strand with mesh

Figure H.9: CFCC coupler installation: installing braid grip on CFCC strand

Figure H.10: CFCC coupler installation: placing wedges on mesh-wrapped CFCC strand

Figure H.11: CFCC coupler installation: marking wedges to prepare for pushing

Figure H.12: CFCC coupler installation: coupler in jacking system, ready for pushing

Figure H.13: CFCC coupler installation: pushing wedges into coupler with jacking system

Figure H.14: CFCC coupler installation: ready to screw two parts together

Figure H.15: CFCC coupler installation: screwing two parts together

Figure H.16: CFCC coupler installation: partially-completed couplers, showing 3 stages of installation

Figure H.17: CFCC coupler installation: several partially-completed couplers in precasting bed

Figure H.18: CFCC coupler installation: showing several couplers in casting bed

Figure H.19: Partial installation of several couplers

Figure H.20: Stressing end of self-stressing casting bed

Figure H.21: Non-stressing end of self-stressing casting bed

Figure H.22: CFCC spirals zip-tied to strands

Figure H.23: Lifting loops

Figure H.24: Showing staggered couplers, with CFCC strands already stressed, looking from stressing end

Figure H.25: Showing staggered couplers and close-up of coupler, with CFCC strands already stressed

Figure H.26: CFCC strands, spirals, and wooden headers in position; ready to cast

Figure H.27: Casting piles using self-consolidating concrete

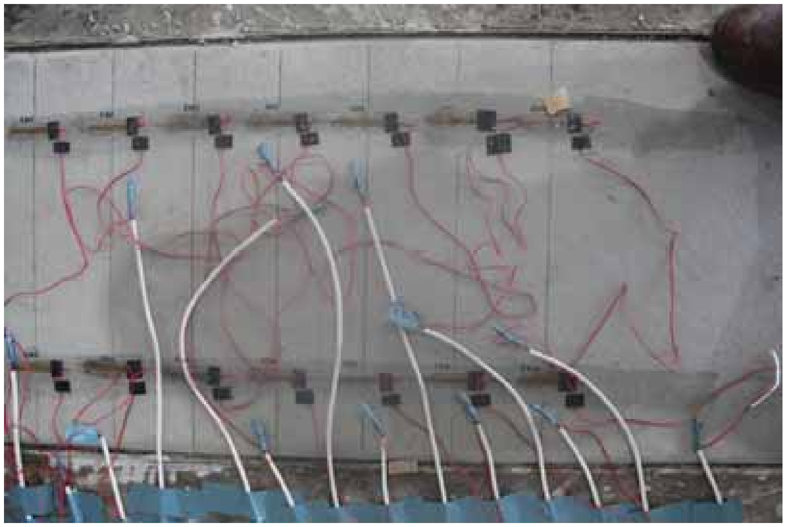


Figure H.28: Strain gages S301 - S314

Figure H.29: Strain gages S320 - S326

Figure H.30: Cutting CFCC strands with a side grinder

PILE DRIVING PHOTOS

Figure H.31: End bent 3-1 on westbound bridge; Two 100-ft piles ready to be driven

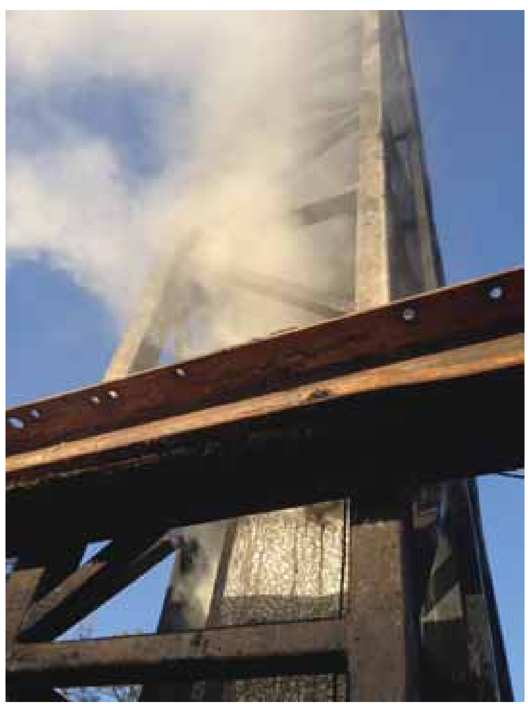


Figure H.32: Smoke during Pile 1 driving

Figure H.33: Charred pile cushion, after Pile 1 driving

Figure H.34: Concrete spalling on head of Pile 1 after being driven

Figure H.35: Leaked diesel and concrete spalling on head of Pile 1 after being driven

Figure H.36: Smoke during Pile 2 driving

Figure H.37: Concrete spalling on head of Pile 2 during driving

Figure H.38: Horizontal (tension) crack in Pile 2

Figure H.39: Horizontal (tension) crack in Pile 2, on other side