Appendix N

ECS Laboratory Test Results

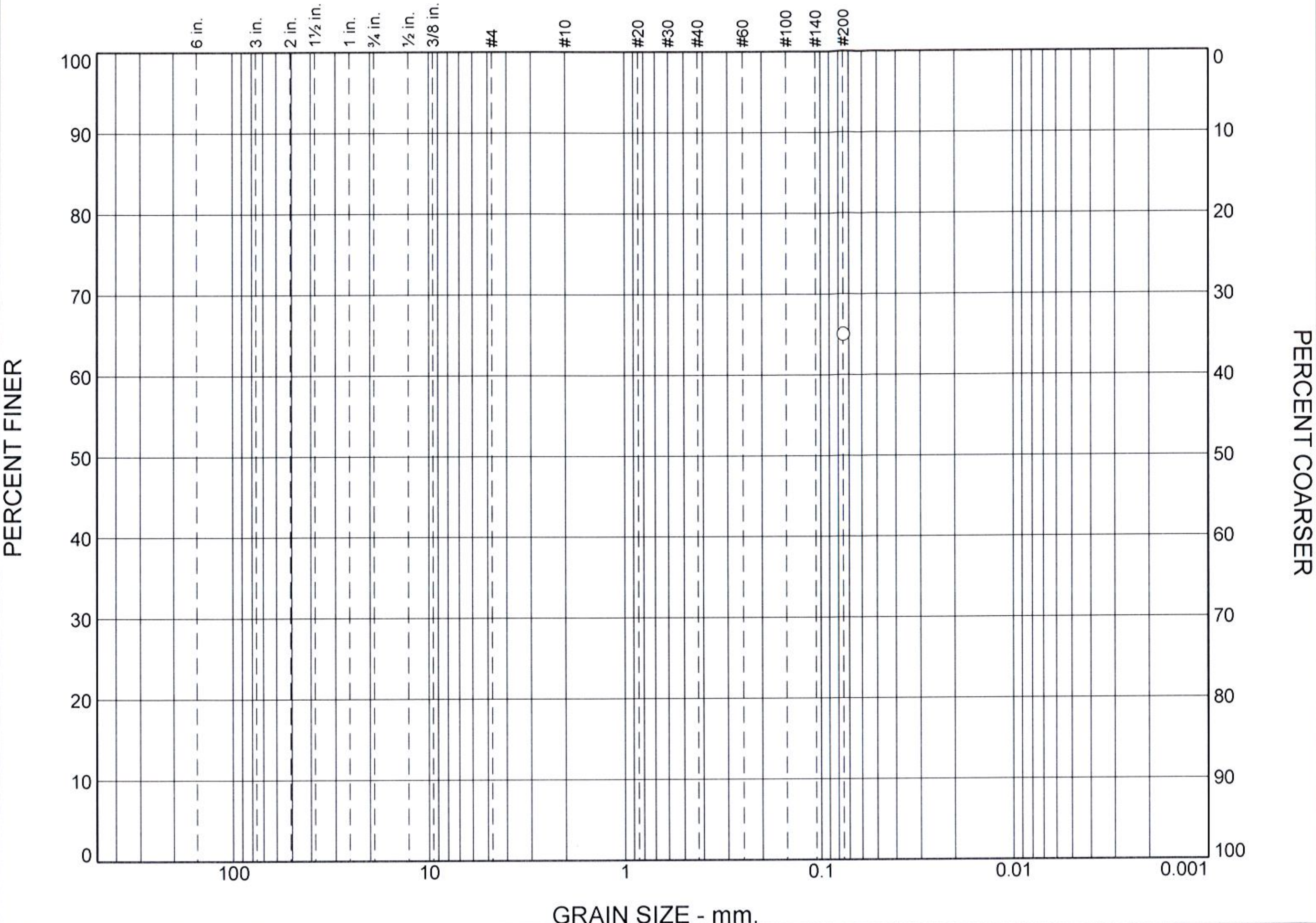
SUMMARY OF LABORATORY RESULTS

PROJECT NAME Group 2 Borings **CLIENT** Civil Engineering Consulting Servies, Inc.

SC PROJECT NO: IM23(009) **PROJECT LOCATION** Greenville, Greenville, South Carolina

Station	Borehole	Depth	Sample No.	Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index	%<#200 Sieve	Class-ification	AASHTO
108+05 12 LT	BX-1-01	13.5	SS-6	30.4	NP	NP	NP	47.7	SM	A-4(0)
74+14 7 RT	BX-1-02	18.5	SS-7	20.5	NP	NP	NP	26.4	SM	A-2-4(0)
33+00 8 LT	BX-2B-01	8.5	SS-5	14.4	33	19	14	30.9	SC	A-2-6(1)
39+68 7 LT	BX-3-01	2.5	SS-2	15.2	NP	NP	NP	47.2	SM	A-4(0)
61+16 4 RT	BX-4-01	4.5	SS-3	22.5	57	31	26	65.0	MH	A-7-5(17)
54+27 CL	BX-8-01	6.5	SS-4	13.9	NP	NP	NP	16.5	SM	A-2-4(0)
31+76 26 LT	BX-10-01	0.5	SS-1	10.2	NP	NP	NP	11.2		A-2-4(0)
345+28 95 LT	BX-385-01	0.5	SS-1	19.4	37	27	10	51.7	ML	A-4(3)
351+73 2 RT	BX-I385NBCD-01	8.5	SS-5	13.8						
351+73 2 RT	BX-I385NBCD-01	18.5	SS-7	12.6	NP	NP	NP	34.2	SM	A-2-4(0)
368+95 19 LT	BX-I385NBCD-02	13.5	SS-6	7.3	NP	NP	NP	10.3		A-3(0)
127+95 7 LT	BX-I385SBCD-01	2.5	SS-2	14.1	NP	NP	NP	35.3	SM	A-2-4(0)
116+46 36 RT	BX-I385SBCD-02	4.5	SS-3	14.4	NP	NP	NP	30.4	SM	A-2-4(0)
206+98 142 RT	I85-100	18.5	SS-7	17.7	NP	NP	NP	21.4	SM	A-2-4(0)
213+00 209 RT	I85-102	13.5	SS-6	10.3	34	21	13	40.7	SC	A-6(2)
329+44 150 RT	R385-108	13.5	SS-6	5.7	NP	NP	NP	20.7	SM	A-2-4(0)
23+34 38 LT	RM-BX1	0.5		27.6	53	29	24	68.8	MH	A-7-6(17)
23+34 38 LT	RM-BX1	3.5	SS-2	83.6	35	25	10	53.8	ML	A-4(3)
23+34 38 LT	RM-BX1	8.5	SS-4	18.8	NP	NP	NP	35.4	SM	A-2-4(0)
23+21 17 RT	RM-BX2	8.5	SS-4	18.2	NP	NP	NP	27.3	SM	A-2-4(0)
27+44 35 LT	RM-BX4	3.5	SS-2	16.5	39	27	12	56.1	ML	A-6(5)
27+44 35 LT	RM-BX4	6.0	SS-3	65.3	43	24	19	49.0	SC	A-7-6(6)
29+63 32 LT	RM-BX5	6.0	SS-3	23.3	42	32	10	58.5	ML	A-5(5)
29+86 17 RT	RM-BX6	6.0	SS-3	20.0	56	31	25	59.9	MH	A-7-5(14)
34+12 14 RT	RM-BX7	4.5	SS-3	12.2	37	15	22	43.2	SC	A-6(5)
34+12 14 RT	RM-BX7	8.5	SS-5	43.8	NP	NP	NP	49.7	SM	A-4(0)

Particle Size Distribution Report



	% +3"	% Gravel Coarse	% Gravel Fine	% Sand Coarse	% Sand Medium	% Sand Fine	% Fines Silt	% Fines Clay
○							65.0	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	57	31								

MATERIAL DESCRIPTION	TEST DATE	USCS	NM
○ Red Brown Fine Sandy SILT		MH	22.5

Project No. 8406 **Client:** Client Name

Project: 08 - I-85/385 Supplemental Exploration

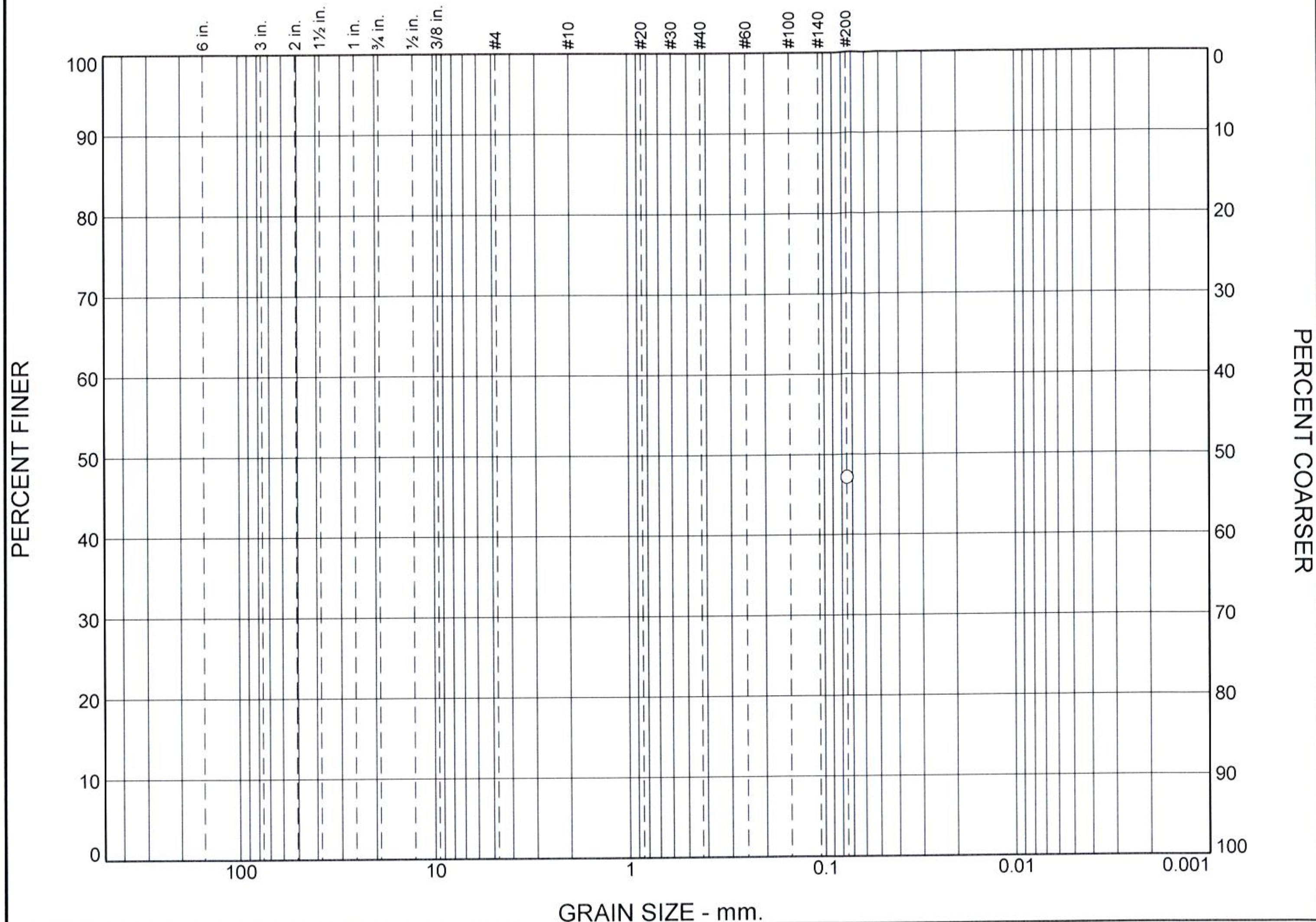
○ **Source:** BX-4-01 **Depth:** 4.50-6.00 **Sample No.:** D4S-28

Remarks:

ECS CAROLINAS, LLP
1200 Woodruff Road, Suite H-12
Greenville, SC 29607
Phone: (864) 987-1610
Fax: (864) 987-1615

Figure

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○							47.2	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	NP	NP								

MATERIAL DESCRIPTION	TEST DATE	USCS	NM
○ Sample Description			15.2

Project No. 8406 **Client:** Client Name

Project: 08 - I-85/385 Supplemental Exploration

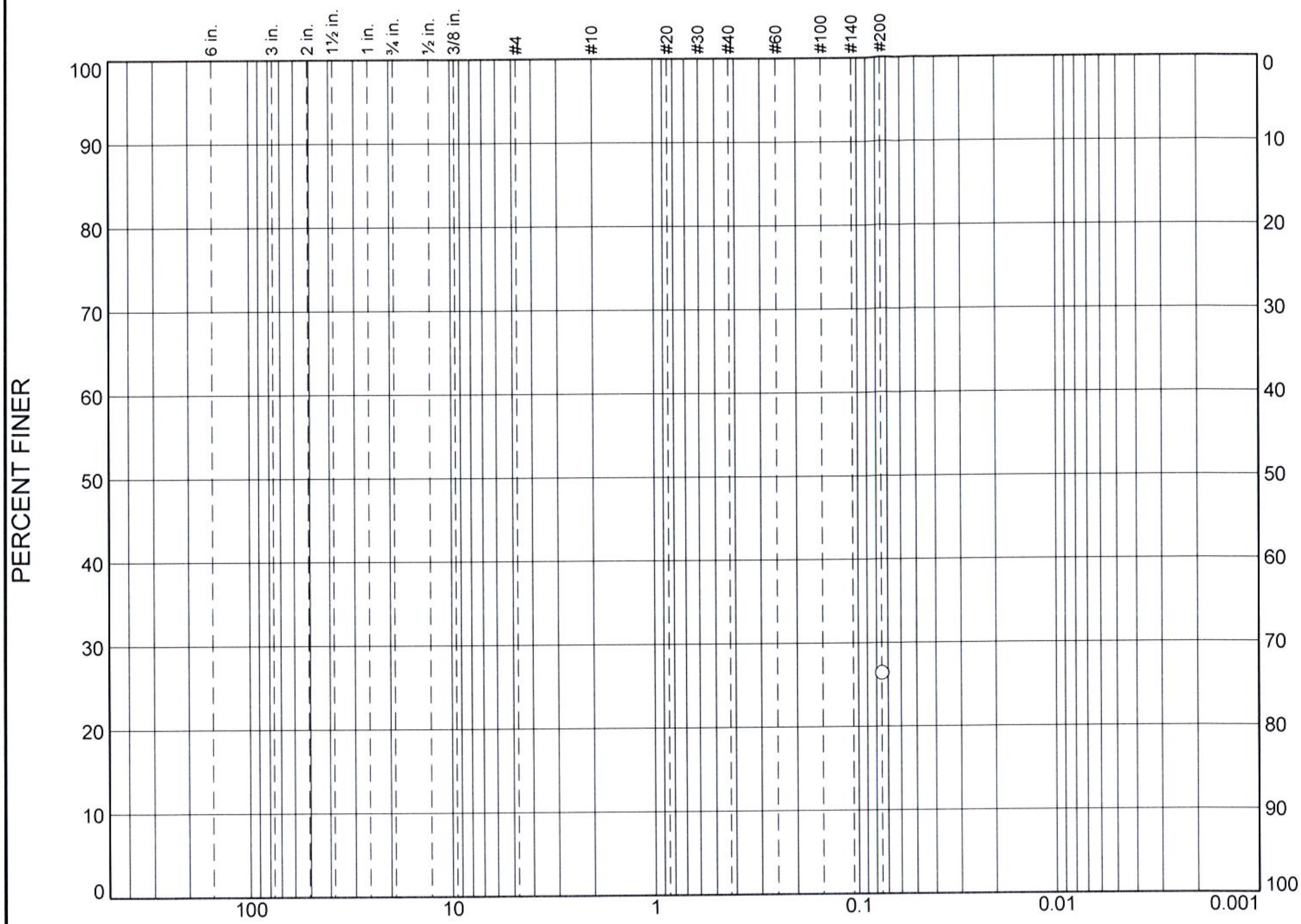
○ **Source:** BX-3-01 **Depth:** 2.50-4.00 **Sample No.:** D4S-25

Remarks:

ECS CAROLINAS, LLP
1200 Woodruff Road, Suite H-12
Greenville, SC 29607
Phone: (864) 987-1610
Fax: (864) 987-1615

Figure

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○							26.4	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	NP	NP								

MATERIAL DESCRIPTION	TEST DATE	USCS	NM
○ Sample Description			20.5

Project No. 8406 **Client:** Client Name

Project: 08 - I-85/385 Supplemental Exploration

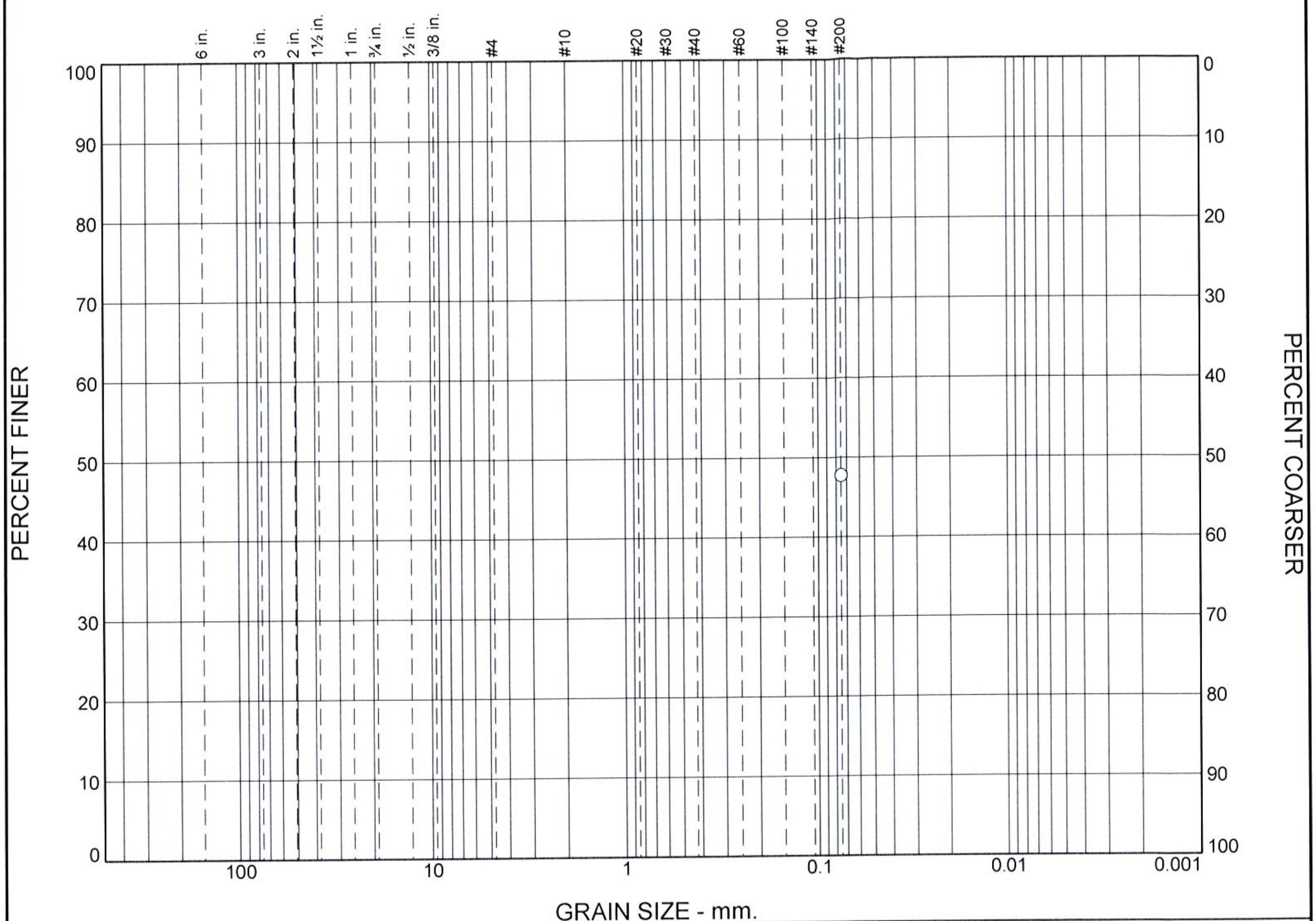
○ **Source:** BX-1-02 **Depth:** 18.50-20.00 **Sample No.:** D4S-27

Remarks:

ECS CAROLINAS, LLP
1200 Woodruff Road, Suite H-12
Greenville, SC 29607
Phone: (864) 987-1610
Fax: (864) 987-1615

Figure

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○							47.7	

╳	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	NP	NP								

MATERIAL DESCRIPTION	TEST DATE	USCS	NM
○ Sample Description			30.4

Project No. 8406 **Client:** Client Name

Project: 08 - I-85/385 Supplemental Exploration

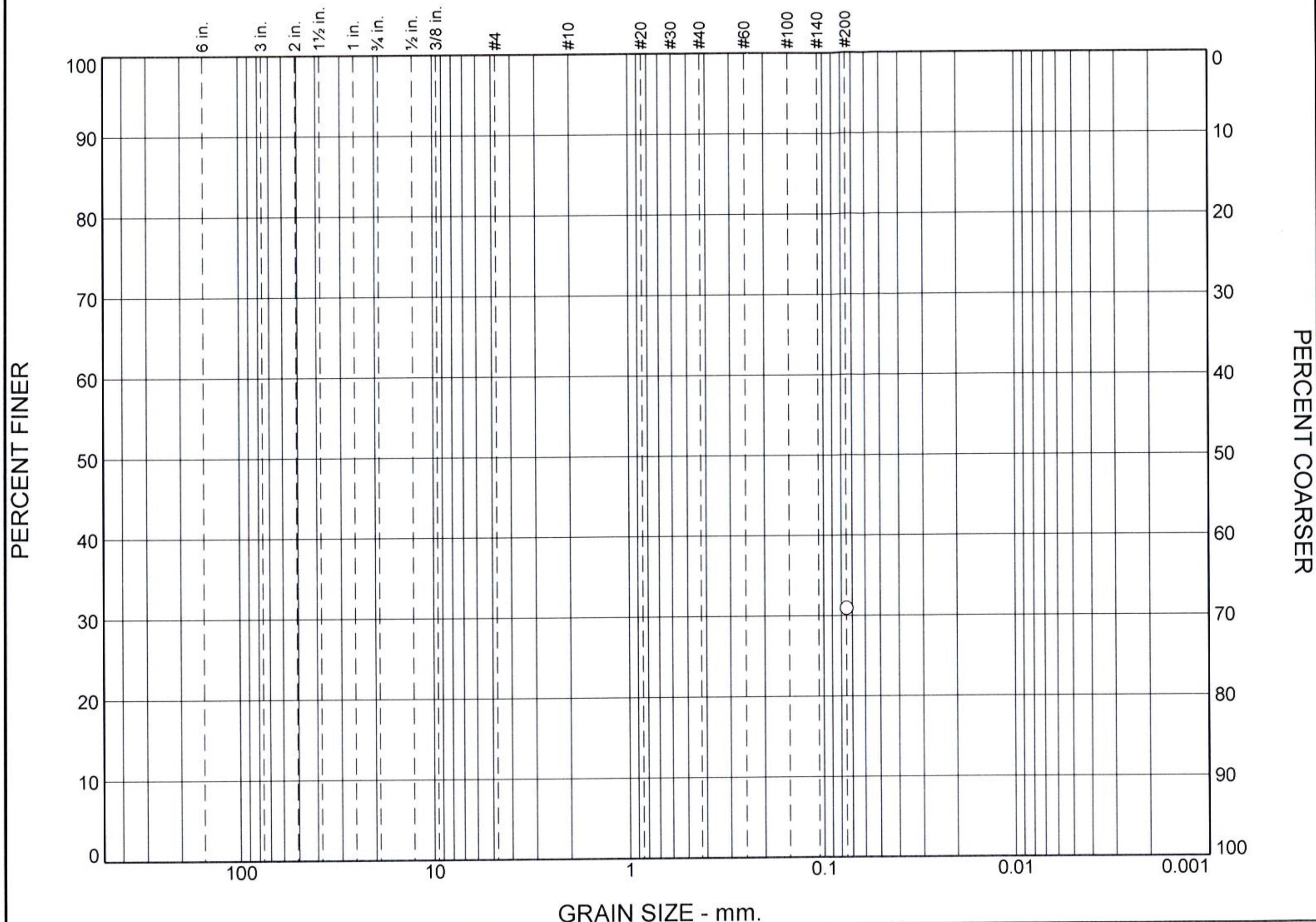
○ **Source:** BX-1-01 **Depth:** 13.50-15.00 **Sample No.:** D4S-26

Remarks:

ECS CAROLINAS, LLP
1200 Woodruff Road, Suite H-12
Greenville, SC 29607
Phone: (864) 987-1610
Fax: (864) 987-1615

Figure

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○							30.9	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	33	19								

MATERIAL DESCRIPTION	TEST DATE	USCS	NM
○ Light Grey Clayey Fine to Medium SAND		SC	14.4

Project No. 8406 **Client:** Client Name

Project: 08 - I-85/385 Supplemental Exploration

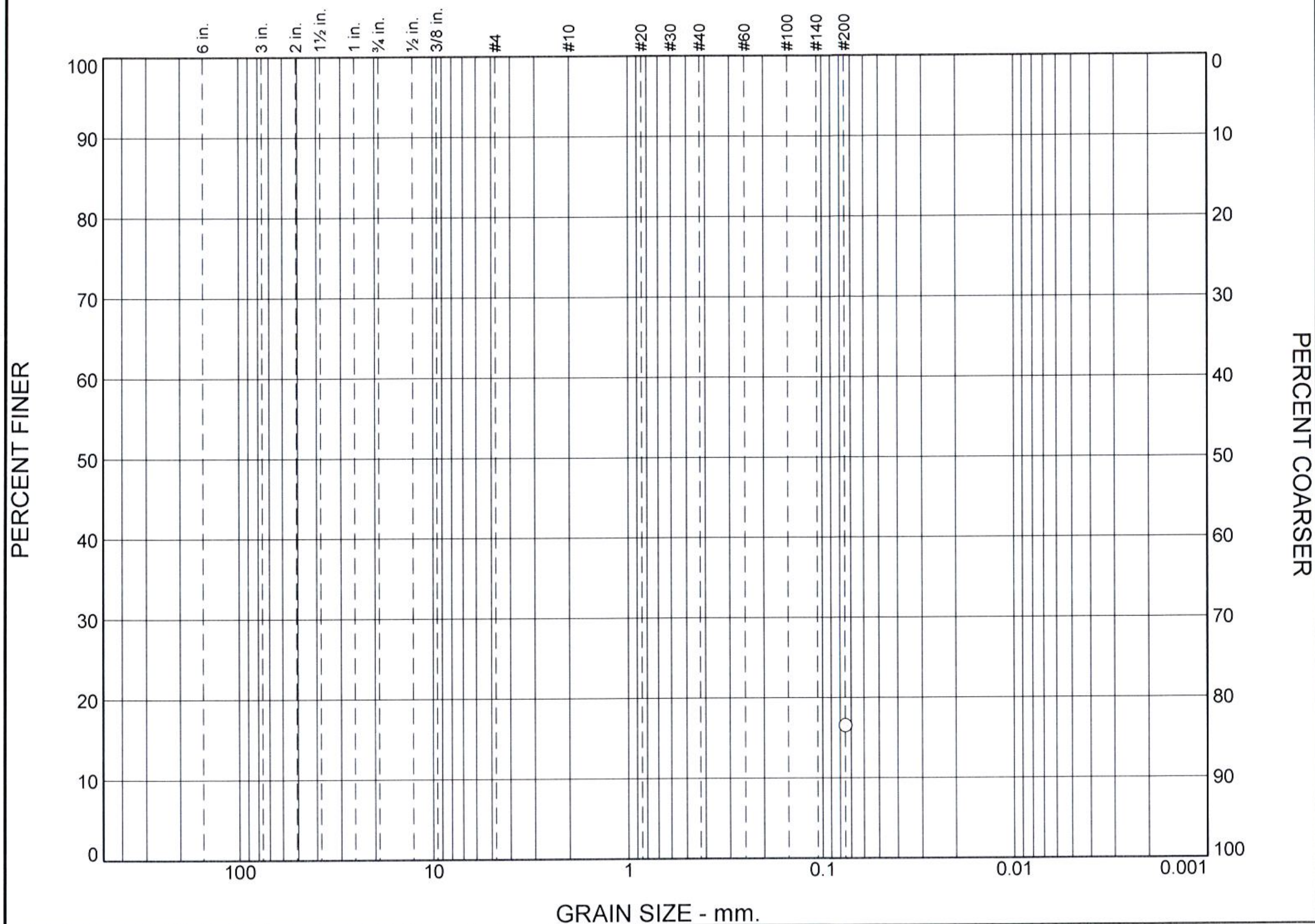
○ **Source:** BX-2B-01 **Depth:** 8.50-10.00 **Sample No.:** D4S-18

Remarks:

ECS CAROLINAS, LLP
1200 Woodruff Road, Suite H-12
Greenville, SC 29607
Phone: (864) 987-1610
Fax: (864) 987-1615

Figure

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○							16.5	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	NP	NP								

MATERIAL DESCRIPTION	TEST DATE	USCS	NM
○ Sample Description			13.9

Project No. 8406 **Client:** Client Name

Project: 08 - I-85/385 Supplemental Exploration

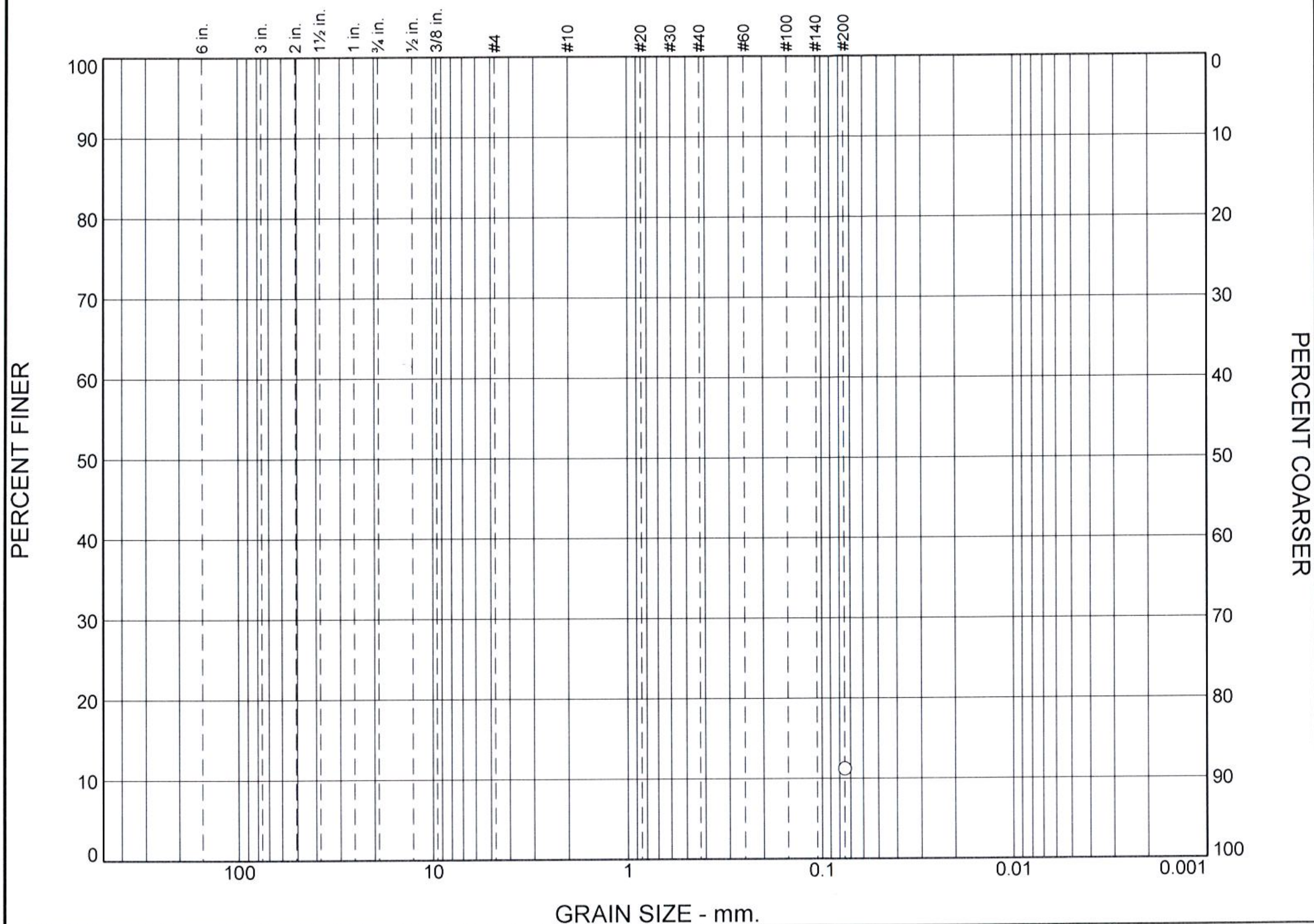
○ **Source:** BX-8-01 **Depth:** 6.50-8.00 **Sample No.:** D4S-19

Remarks:

ECS CAROLINAS, LLP
1200 Woodruff Road, Suite H-12
Greenville, SC 29607
Phone: (864) 987-1610
Fax: (864) 987-1615

Figure

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○							11.2	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	NP	NP								

MATERIAL DESCRIPTION	TEST DATE	USCS	NM
○ Sample Description		SW	10.2

Project No. 8406 **Client:** Client Name

Project: 08 - I-85/385 Supplemental Exploration

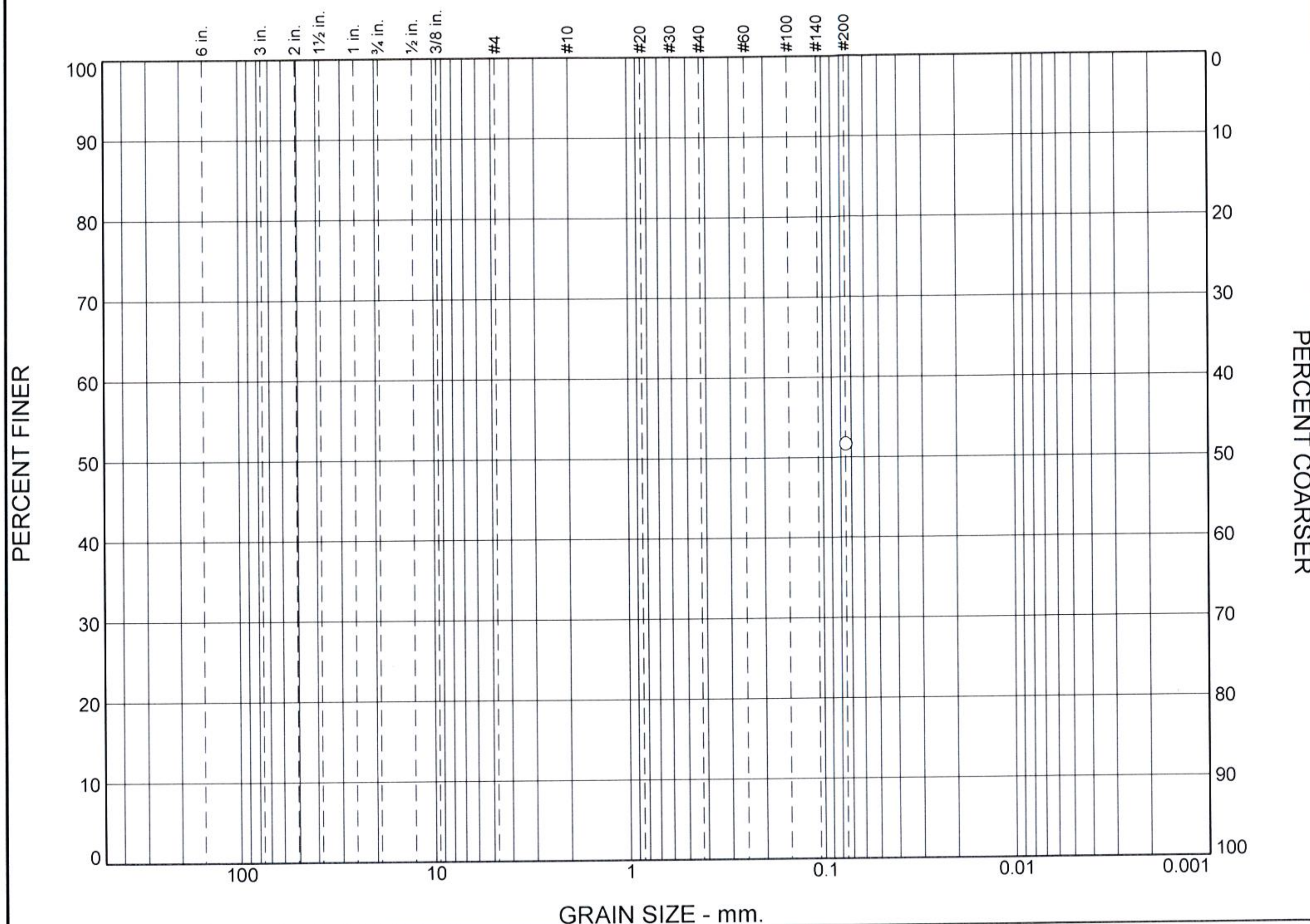
○ **Source:** BX-10-01 **Depth:** 0.50-2.00 **Sample No.:** D4S-17

Remarks:

ECS CAROLINAS, LLP
1200 Woodruff Road, Suite H-12
Greenville, SC 29607
Phone: (864) 987-1610
Fax: (864) 987-1615

Figure

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○							51.7	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○										

MATERIAL DESCRIPTION	TEST DATE	USCS	NM
○ Sample Description			19.4

Project No. 8406 **Client:** Client Name

Project: 08 - I-85/385 Supplemental Exploration

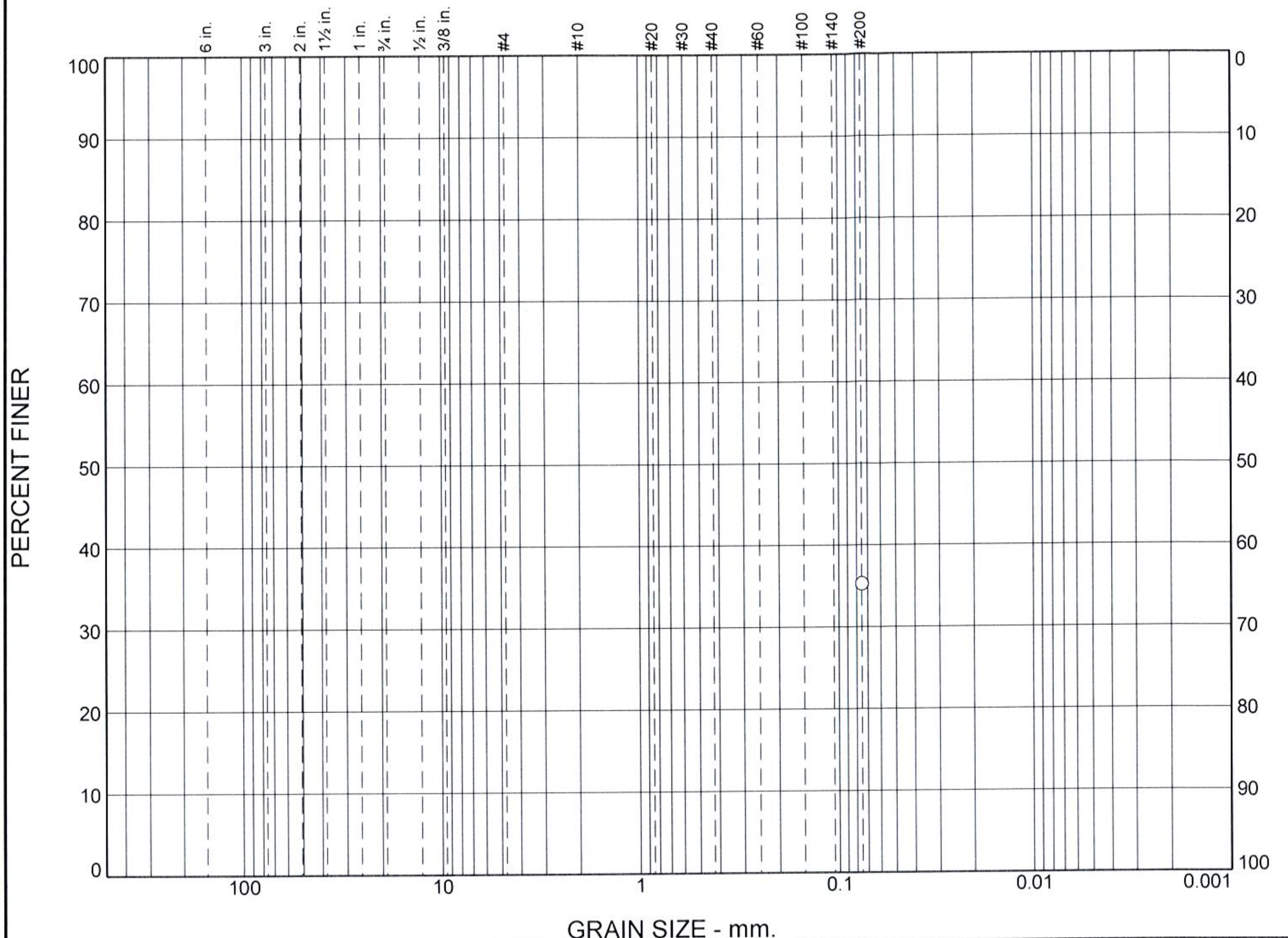
○ **Source:** BX-385-01 **Depth:** 0.50-2.00 **Sample No.:** D4S-22

Remarks:

ECS CAROLINAS, LLP
1200 Woodruff Road, Suite H-12
Greenville, SC 29607
Phone: (864) 987-1610
Fax: (864) 987-1615

Figure

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○							35.3	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	NP	NP								

MATERIAL DESCRIPTION	TEST DATE	USCS	NM
○ Sample Description			14.1

Project No. 8406 **Client:** Client Name

Project: 08 - I-85/385 Supplemental Exploration

○ **Source:** BX-I385 BCD-01 **Depth:** 2.50-4.00 **Sample No.:** D4S-21

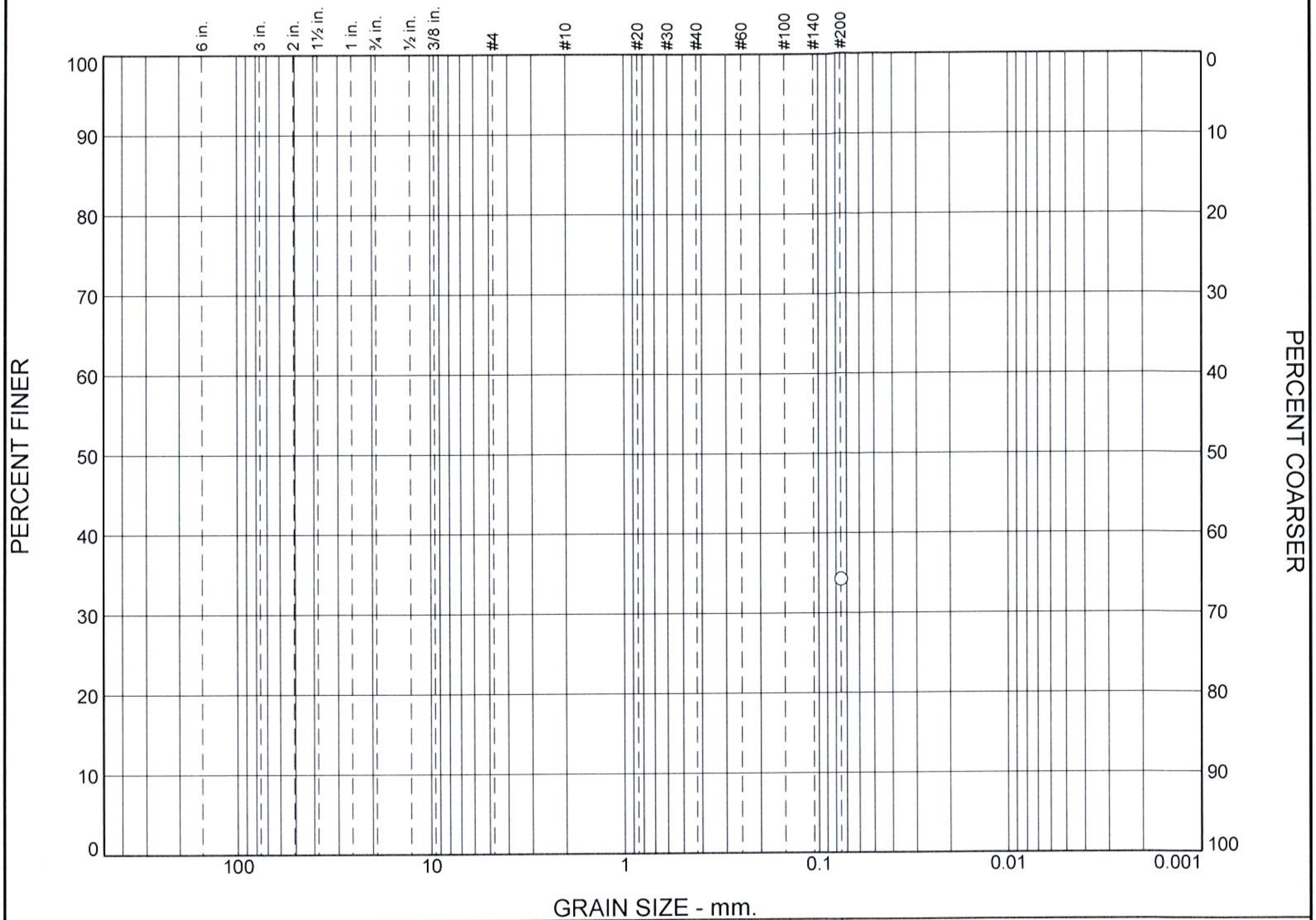
Remarks:

○BX I 385 SBCD-01 @ 2.5' -4'

ECS CAROLINAS, LLP
1200 Woodruff Road, Suite H-12
Greenville, SC 29607
Phone: (864) 987-1610
Fax: (864) 987-1615

Figure

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○							34.2	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	NP	NP								

MATERIAL DESCRIPTION	TEST DATE	USCS	NM
○ Sample Description			12.6

Project No. 8406 **Client:** Client Name

Project: 08 - I-85/385 Supplemental Exploration

○ **Source:** BX-I385 NBCD **Depth:** 18.50-20.00 **Sample No.:** D4S-24

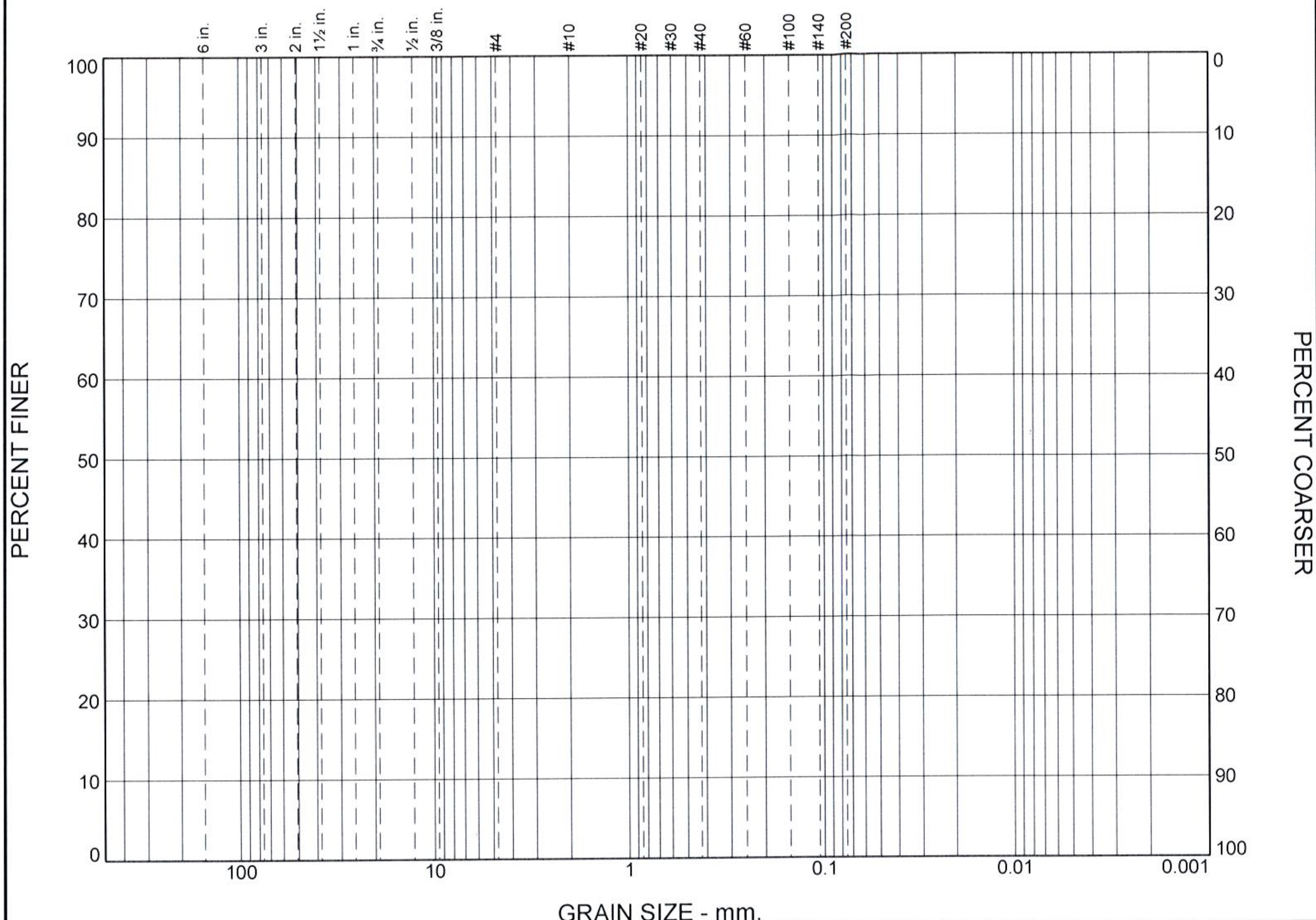
Remarks:

○BX I 385 NBCD-01 @ 18.5' - 20'

ECS CAROLINAS, LLP
1200 Woodruff Road, Suite H-12
Greenville, SC 29607
Phone: (864) 987-1610
Fax: (864) 987-1615

Figure

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○								

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○										

MATERIAL DESCRIPTION	TEST DATE	USCS	NM
○ Sample Description			13.8

Project No. 8406 **Client:** Client Name

Project: 08 - I-85/385 Supplemental Exploration

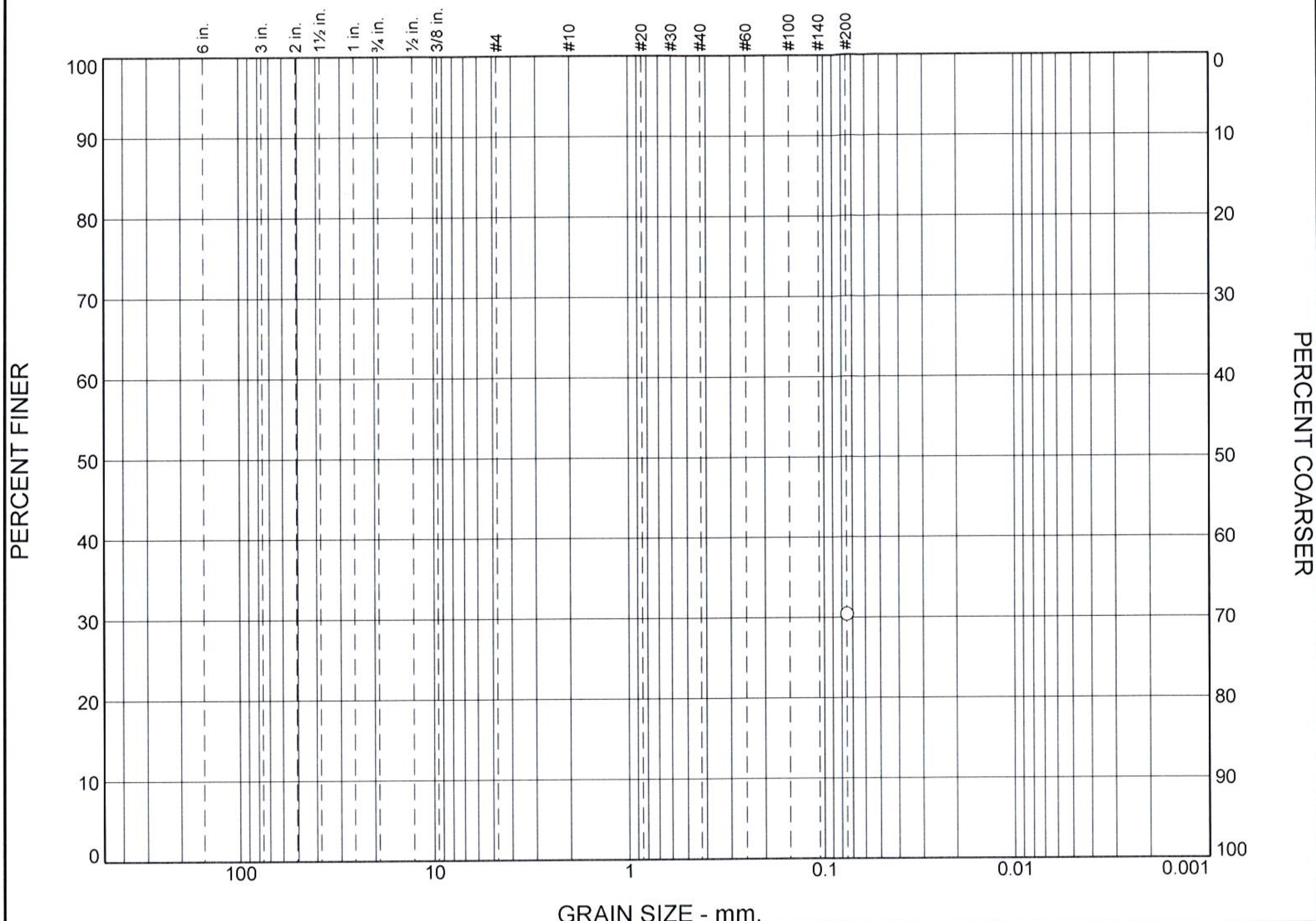
○ **Source:** BX-I385 NBCD-01 **Depth:** 8.50-10.00 **Sample No.:** D4S-34

Remarks:

ECS CAROLINAS, LLP
1200 Woodruff Road, Suite H-12
Greenville, SC 29607
Phone: (864) 987-1610
Fax: (864) 987-1615

Figure

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○							30.4	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	NP	NP								

MATERIAL DESCRIPTION	TEST DATE	USCS	NM
○ Sample Description			14.4

Project No. 8406 **Client:** Client Name

Project: 08 - I-85/385 Supplemental Exploration

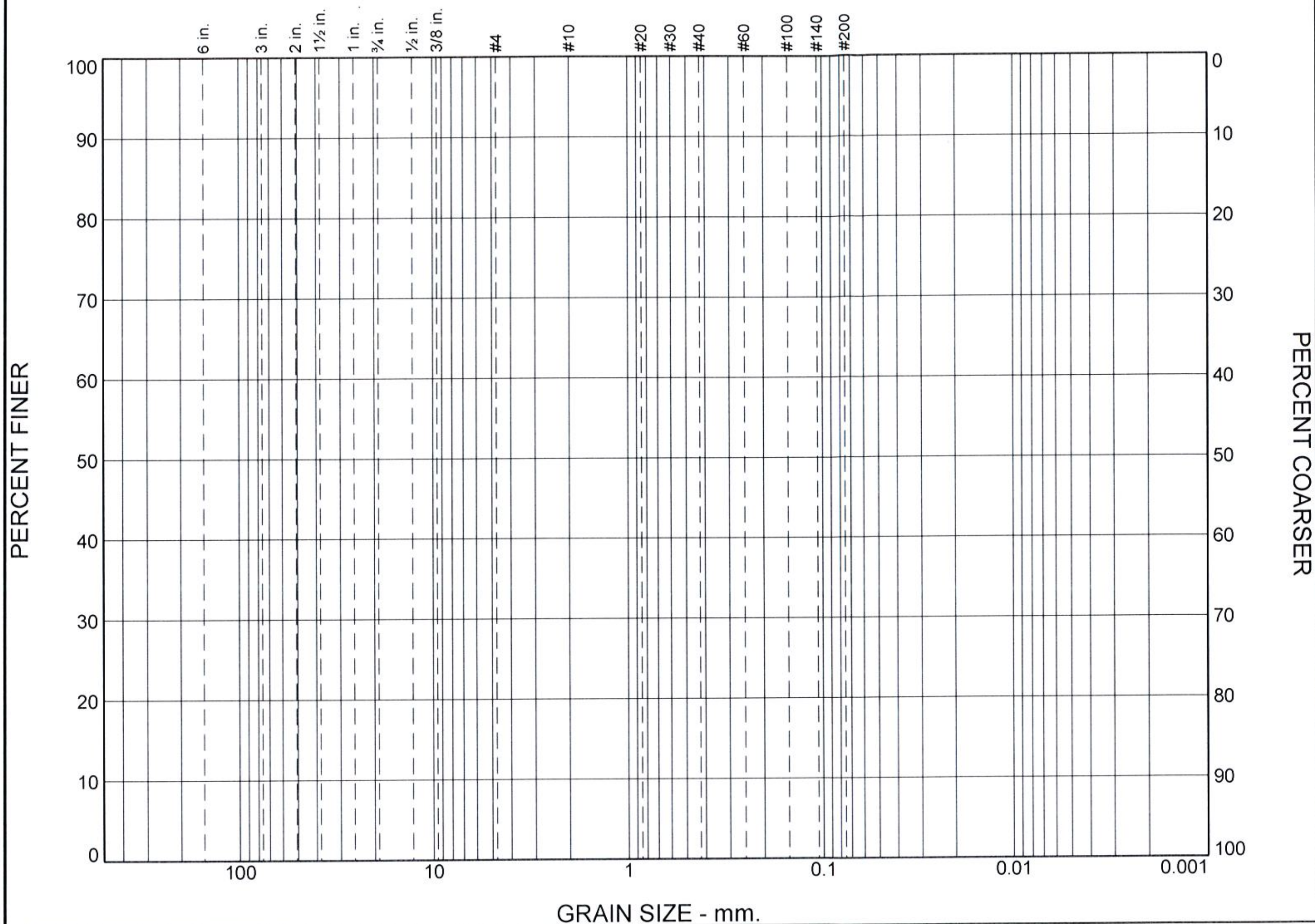
○ **Source:** BX-I385 BCD-02 **Depth:** 4.50-6.00 **Sample No.:** D4S-23

Remarks:

ECS CAROLINAS, LLP
1200 Woodruff Road, Suite H-12
Greenville, SC 29607
Phone: (864) 987-1610
Fax: (864) 987-1615

Figure

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○								

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○										

MATERIAL DESCRIPTION	TEST DATE	USCS	NM
○ Sample Description			13.8

Project No. 8406 **Client:** Client Name

Project: 08 - I-85/385 Supplemental Exploration

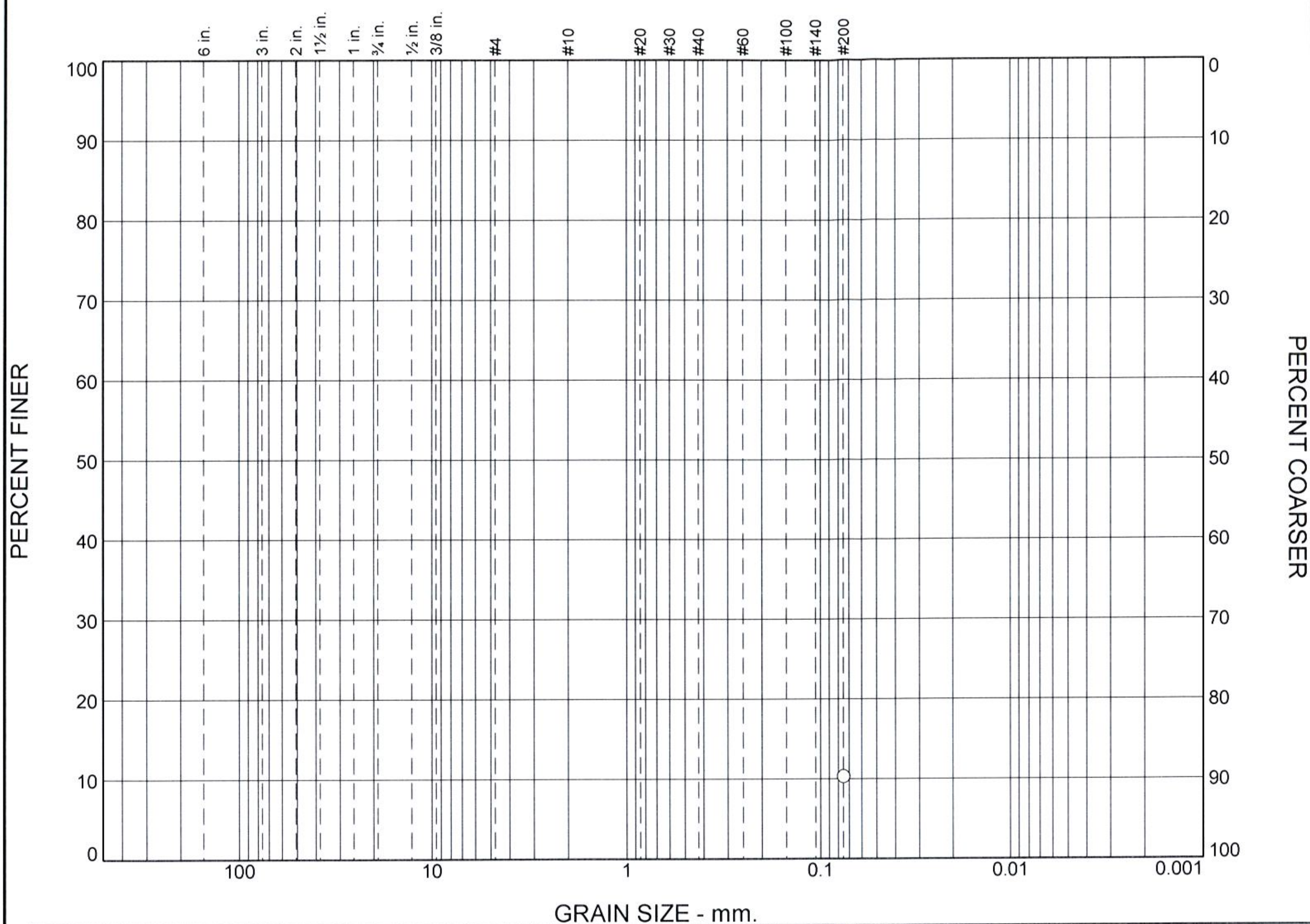
○ **Source:** BX-I385 NBCD-01 **Depth:** 8.50-10.00 **Sample No.:** D4S-34

Remarks:

ECS CAROLINAS, LLP
1200 Woodruff Road, Suite H-12
Greenville, SC 29607
Phone: (864) 987-1610
Fax: (864) 987-1615

Figure

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○							10.3	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	NP	NP								

MATERIAL DESCRIPTION	TEST DATE	USCS	NM
○ Sample Description			7.3

Project No. 8406 **Client:** Client Name

Project: 08 - I-85/385 Supplemental Exploration

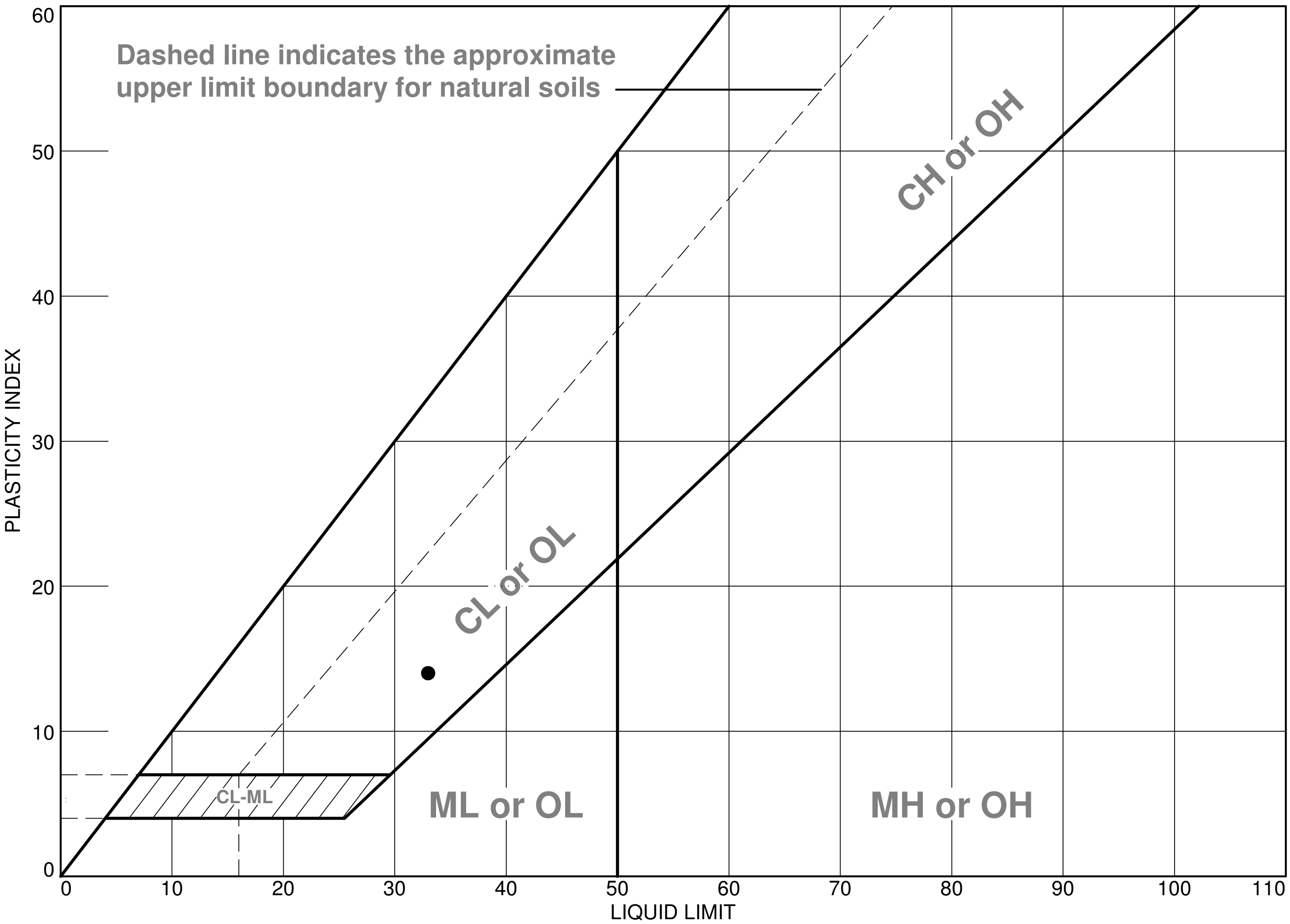
○ **Source:** BX-I385 NBCD-02 **Depth:** 13.50-15.00 **Sample No.:** D4S-20

Remarks:

ECS CAROLINAS, LLP
1200 Woodruff Road, Suite H-12
Greenville, SC 29607
Phone: (864) 987-1610
Fax: (864) 987-1615

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Light Grey Clayey Fine to Medium SAND	33	19	14		30.9	SC
■	Sample Description						

Project No. 8406 **Client:** Client Name

Project: 08 - I-85/385 Supplemental Exploration

● **Source:** BX-2B-01 **Depth:** 8.50-10.00 **Sample No.:** D4S-18

■ **Source:** BX-2B-01 **Depth:** 4.50-6.00 **Sample No.:** D4S-38

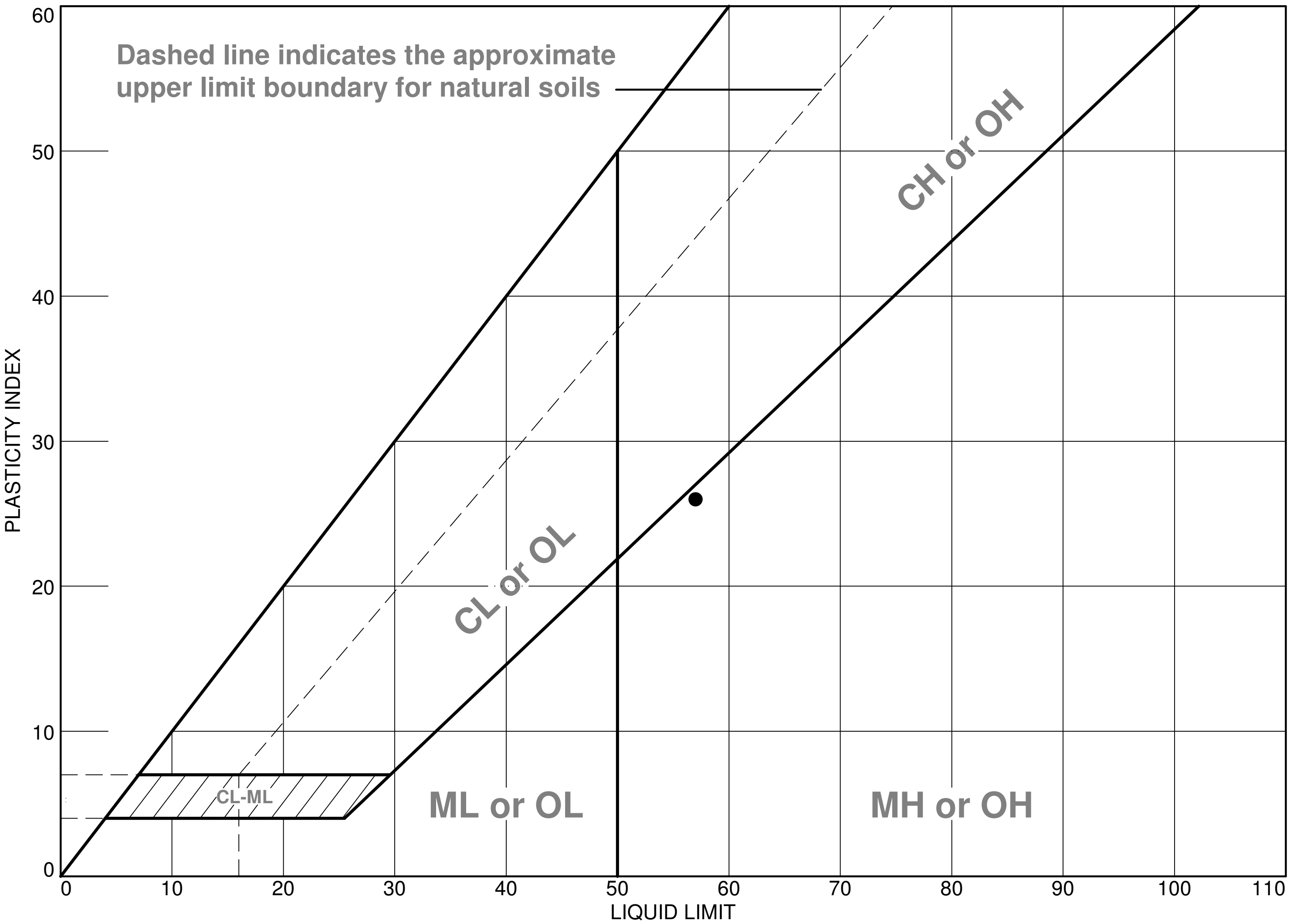
Remarks:

ECS CAROLINAS, LLP
1200 Woodruff Road, Suite H-12
Greenville, SC 29607
Phone: (864) 987-1610
Fax: (864) 987-1615

Figure

Tested By: ws **Checked By:** WGS

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Red Brown Fine Sandy SILT	57	31	26		65.0	MH
■	Sample Description						

Project No. 8406 **Client:** Client Name

Project: 08 - I-85/385 Supplemental Exploration

● **Source of Sample:** BX-4-01 **Depth:** 4.50-6.00 **Sample Number:** D4S-28

■ **Source:** BX-4-01 **Depth:** 13.50-15.00 **Sample No.:** D4S-29

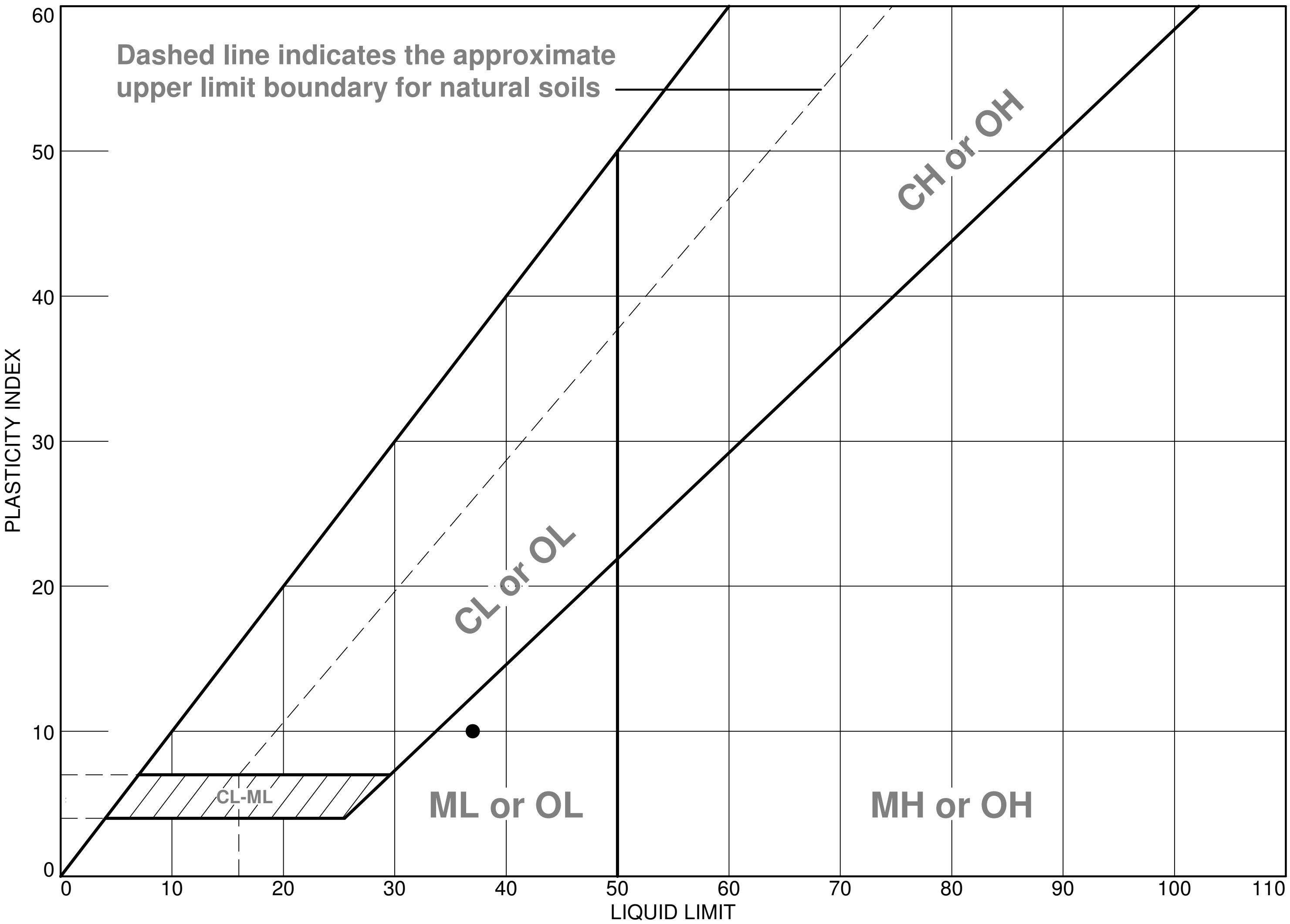
ECS CAROLINAS, LLP
1200 Woodruff Road, Suite H-12
Greenville, SC 29607
Phone: (864) 987-1610
Fax: (864) 987-1615

Remarks:

Figure

Tested By: ws **Checked By:** WGS

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Red Brown Fine to Medium Sandy SILT with Mica	37	27	10		51.7	SM

Project No. 8406 **Client:** Client Name

Project: 08 - I-85/385 Supplemental Exploration

● **Source:** BX-385-01 **Depth:** 0.50-2.00 **Sample No.:** D4S-22

Remarks:

ECS CAROLINAS, LLP
1200 Woodruff Road, Suite H-12
Greenville, SC 29607
Phone: (864) 987-1610
Fax: (864) 987-1615

Figure

Tested By: ws **Checked By:** WGS

Appendix O

ECS Hammer Calibrations

GRL Dynamic Measurements and Analyses engineers, inc.

Job No. 159056-1

Report on: Standard Penetration Test Energy Measurements
Greer, SC

Prepared for ECS Carolinas LLP

By Scott D. Webster, P.E. and Tom Hyatt, E.I.

September 22, 2015

September 22, 2015

Mr. Donald Anderson
ECS Carolinas LLP
1200 Woodruff Road, Suite H-12
Greenville, SC 29607

Re: Standard Penetration Test Energy Measurements
Greer, SC
GRL Job No. 159056-1

Dear Mr. Anderson,

This report presents results of energy measurements obtained on September 10, 2015 during Standard Penetration Test (SPT) sampling. One automatic hammers was tested. The hammer was mounted on a CME 550 truck drill rig. All dynamic tests were performed on AWJ drill rods. GRL Engineers, Inc. obtained the dynamic measurements with an instrumented AWJ subsection and a Model PAX Pile Driving Analyzer®. This report describes the testing procedures and summarizes the test results. Appendix A describes our measurement and analysis methods, Appendix B contains calibration information for the gages and equipment used, and Appendix C is a summary of the field data.

PURPOSE AND SCOPE OF WORK

At the request of ECS, GRL conducted SPT energy measurements at a site in Greer, SC. The SPT energy measurements were obtained in accordance with ASTM D4633-10. Specifically, we recorded SPT energy measurements at 5-foot sample intervals between approximately 18.5 and 50.0 feet below the existing ground surface. In general, drilling was performed to a depth of approximately 18.5 feet where the first sample was collected. SPT samples were then collected at 5 foot intervals until the boring depth of approximately 50.0 feet was reached.

EQUIPMENT

Drilling and SPT Hammer Equipment

CME 550 (Serial # 130883)

SPT energy measurements were made on an automatic hammer mounted on a CME 550 drill rig. The drilling method used to advance the boring was the hollow stem auger method. Energy measurements for this drill rig were collected at a borehole location to a boring termination depth of 50.0 feet below grade. SPT energy measurement tests were performed at 5-foot sampling penetrations beginning at 18.5 feet. A total of seven energy measurement events were monitored for this drill rig.

1973 JN Pease Place, Suite 101 • Charlotte, NC 28262 USA
704.593.0992 • fax 704.593.0993 • www.GRLengineers.com

Instrumentation

A Model PAX Pile Driving Analyzer (PDA) data acquisition system (SN# 3662L) was used to collect and process the dynamic measurements of force and velocity. The data was collected using a two-foot long section of AWJ rod subsection (SN# 168AWJ) with a cross sectional area of 1.19 square inches and instrumented with two full bridge foil resistance strain gages and two piezoresistive accelerometers mounted in the midpoint location of the instrumented rod.

Analog signals from the strain gages and accelerometers were conditioned, digitized, stored and processed with the PDA. The sampling frequency used during the SPT testing was 50 kHz. Selected output from the PDA for each recorded impact included the energy transfer ratio (ETR), maximum rod top velocity (VMX), maximum energy transfer (EFV), maximum rod top force (FMX), and the hammer operating rate (BPM).

MEASUREMENTS AND CALCULATIONS

FV Method (EFV)

Energy transfer to the PDA gage location, EFV, was computed by the PDA using force, F(t), and velocity, v(t), records as follows:

$$EFV = \int_a^b F(t) \cdot v(t) dt$$

The time "a" corresponds to the start of the record when the energy transfer begins, and "b" is the time at which energy transferred to the rod reaches a maximum value. The FV Method is currently recognized in ASTM D4633-10, and is the theoretically correct result; therefore, no other energy calculation methods are reported.

Corrected SPT number (N_{60})

While the primary purpose of SPT energy testing is to calculate the maximum transferred energy (ETR) of each hammer blow, the overall average EFV value can be used to calculate the corrected SPT number (N_{60}). To adjust the SPT N-values for hammer performance, the following correction as suggested by Seed for N-value adjustment to 60% transfer efficiency (e.g. 210 ft-pounds) was used:

$$N_{60} = \left(\frac{E_m}{210}\right) N_m$$

Where:

N_{60} = Corrected N-value
E_m = overall average measured energy transfer (EFV)
N_m =number of blows for last 12 inches of sampler penetration

A general introduction to dynamic SPT testing methods is included in this report as Appendix A. References for more detailed descriptions of our testing and analysis methods are available upon request.

Any cross-sectional area difference between the GRL rod subsection and the drill rods, any loose connections or changes in area at section joints, or any cross-sectional area differences between the individual drill rod sections will result in stress wave reflections that can potentially influence the energy transfer. The EFV transferred energy calculation method, utilizing both force and velocity records, is theoretically correct and gives energy transfer results that are not adversely affected by cross-sectional area changes or loose connectors. The EFV results are included in Appendix C for all records collected and accepted after checking them for consistency.

RESULTS

Upon return to the office, the records collected by the PDA were checked for consistency and accuracy. For example, records from very weak startup or final impacts were not included in average results. Appendix C contains a representative plot of force and normalized velocity versus time, as well as plots and tables of PDA results for all hammer blows at each dynamically monitored sampling depth. The results include the EFV (transferred energy by the FV method, as recommended by ASTM D4633-10), ETR (energy transfer efficiency for the EFV method), BPM (hammer operating rate), FMX (maximum rod top force) and VMX (maximum rod top velocity). The plots show each calculated PDA result versus split-spoon penetration, while the tables show statistical summaries for each 6 inch increment. At the end of each table is a statistical evaluation of the results which include the average and standard deviation of the entire measurement sample. A final summary of the SPT results for all samples collected is provided at the end of Appendix C.

The table below summarizes the average transferred energy values calculated by the EFV method. The records consist of averaged results obtained from hammer blows over the last 12 inches (i.e. N value) at each dynamically monitored sampling depth. The "energy transfer ratio" (ETR) is defined as the ratio of maximum transferred energy EFV divided by the theoretical hammer potential energy of 350 ft-lbs (i.e., computed per the 140 lb SPT hammer and the standard 30 inch drop as specified by ASTM D1586-08). The average hammer operating rate is reported in blows per minute (BPM). A summary of the dynamic measurements of the energy transfer to the drill rods using the EFV equation is provided in the table below.

Drill Rig	Avg. EFV (ft-lbs)	Avg ETR (%)	Range of EFV (ft-lbs)	Range of ETR (%)
CME 550 SN#130883	291	83	274 - 302	78 - 86

CONCLUSIONS

Based upon the dynamic test data obtained, the following conclusions are presented:

1. Loose connections in the drill string were sometimes observed in the force and velocity records. However, energy transfer values calculated using the EFV equation are not adversely affected by the connectors and therefore are considered a better indication of transferred energy.

2. Dynamic measurements of the transferred energy to the drill rods using the EFV equation ranged from 274 to 302 ft-lbs for the CME 550 SN#130883 drill rig. This corresponds to a transfer efficiency ranging from 78 to 86% of the SPT hammer energy of 350 ft-lbs.

Please review both ASTM D4633-10 and ASTM D1586-08 prior to applying these test results. The energy calibrations reported herein are valid for the same hammer/drill rig, with the same drill operator, same anvil dimensions, and same drilling methods.

We appreciate the opportunity to be of assistance to you on this project. Please contact our office should you have any questions regarding this submittal, require additional information, or if we may be of further service.

Sincerely,

GRL Engineers, Inc.

Tom Hyatt, E.I.

Scott Webster, P.E.

SDW:TH:dms

Appendix A

An Introduction into SPT Dynamic Pile Testing

APPENDIX A
AN INTRODUCTION INTO SPT DYNAMIC PILE TESTING

1. BACKGROUND

The Standard Penetration Test is frequently conducted as an in-situ assessment of soil strength. This test requires that a 140 lb weight is dropped 30 inches onto a drive rod at whose bottom a sampler is usually installed. The sampler is driven for 18 inches; the number of blows required for the last 12 inches of driving is the so-called N-value. The N-value may be used as a strength indicator for foundation design or as a means of assessing the liquefaction potential of soils.

Obviously, the SPT hammer efficiency is an important consideration when using the N-values for design purposes. Measurements have indicated that the energy in the drive rod is sometimes only 30% and and may reach 90% of the potential or rated energy of the SPT hammer (E-rated = 0.35 kip-ft or 0.475 kJ). The type of hammer used to drive the rod is the main reason for these variations. On the average, the energy in the drive rod is 60% of the standard rated energy.

Because of the variability of energy, methods based on N-values are considered unreliable. However, measurements during SPT testing using the Case Method can be done on a routine basis and these measurements yield the transferred energy values. With measured energy, EMX, known, an adjustment of the measured N-value, N_m, can be made as follows.

$$N_{60} = N_m \, [E_m / (0.6E_r)] \qquad (1)$$

Thus, if the measured energy value is equal to the normally expected transferred energy of 60% of E-rated then the adjusted and measured N-values are identical. On the other hand, if the measured energy is only 30% then the adjusted blow count will be reduced by 50%.

2. DYNAMIC TESTING AND ANALYSIS METHODS APPLIED TO SPT

The Case Method of dynamic pile testing, named after the Case Institute of Technology where it was developed between 1964 and 1975, requires that a substantial ram mass (e.g. a pile driving hammer) impacts the pile top such that the pile undergoes at least a small permanent set. Thus, the method is also referred to as a “High Strain Method”. The Case Method requires dynamic measurements on the pile or shaft under the ram impact and then a calculation of various quantities. Conveniently, for SPT applications, the measurements and analyses are done by a single piece of equipment: the SPT Analyzer. The Pile Driving Analyzer® (PDA) is also suitable to perform these measurements and data processing.

A related analysis method is the “Wave Equation Analysis” which calculates a relationship between bearing capacity, pile stresses, transferred energy and field blow count. The GRLWEAP™ program performs this analysis and provides a complete set of helpful information and input data. This program can be used very effectively to simulate the SPT driving process.

3. MEASUREMENTS

GRL uses equipment manufactured by Pile Dynamics, Inc. The system includes either an SPT-Analyzer™ (SPTA) or a Pile Driving Analyzer® (PDA), an instrumented rod section and two accelerometers. SPT energy testing is very closely related to and borrows procedures from dynamic pile testing. Those interested in the basis of the SPT energy testing method may obtain extensive literature on dynamic pile testing from GRL Engineers, Inc.

3.1 SPT Analyzer or Pile Driving Analyzer

The basis for the results calculated by the SPTA or PDA are strain and acceleration measured in an instrumented rod section. These signals are converted to rod top force, F(t), and rod top velocity, v(t). The SPTA or PDA conditions, calibrates and displays these signals and immediately computes average pile force and velocity thereby eliminating bending effects. The product of these two measurements is then integrated over time which yields the energy transferred to the instrumented section as a function of time (see Section 4.1).

For convenience and accuracy, strain measurements are usually taken on an instrumented section of SPT drive rod. Ideally, the section properties of the instrumented rod and those of the drive rod are the same, however, using subs, other sections can also be utilized.

For the instrumented section, PDI provides a force calibration in such a way that the output of the instrumented rod is directly calculated without the need for an accurate elastic modulus or cross sectional area of the rod section.

The acceleration measurements are often demanding in the SPT environment, because of high frequency and high acceleration motion components. An experienced measurement engineer, therefore, has to evaluate the quality of this data before final conclusions are drawn from the numerical results calculated by SPTA or PDA.

SPTA or PDA records are taken while the standard N-value is acquired in the conventional manner. This then allows a direct correlation between N-value and average transferred energy.

3.2 HPA

The SPT hammer's ram velocity may be directly obtained using radar technology in the Hammer Performance Analyzer™. The impact velocity results can be automatically processed with a PC or recorded on a strip chart. HPA measurements yield a hammer kinetic energy, but not the energy transferred to the drive rod.

4 RECORD EVALUATION BY SPTA OR PDA

4.1 HAMMER PERFORMANCE

The PDA calculates the energy transferred to the pile top from:

$$E(t) = {}_0\int^t F(\tau)v(\tau)\, d\tau \qquad (2)$$

The maximum of the E(t) curve is often called **ENTHRU or EMX;** it is the most important quantity for an overall evaluation of the performance of a hammer and driving system. **EMX** allows for a classification of the hammer's performance when presented as, e_T, the rated transfer efficiency, also called energy transfer ratio (**ETR**) or global efficiency.

$$e_T = EMX/E_R \qquad (3)$$

where E_R is the hammer manufacturer's rated energy value or 0.35 kip-ft (0.475 kJ) in the case of the SPT hammer.

Often in the SPT literature one finds also reference to the EF2 energy. This evaluation is based on assumed proportionality between force and velocity (see also Section 5):

$$v(t) = F(t) / Z \qquad (4)$$

where Z = EA/c is the pile impedance, E is the elastic modulus, A is the cross sectional area and c is the speed of the stress wave in the pile material..

Combining equations 2 and 4 leads to

$$EF(t) = {}_0\int^t F(\tau)^2 / Z\, d\tau \qquad (5)$$

The EF2 transferred energy value is the EF-value at the time t = 2L/c, where L is the drive rod length and c is the stress wave speed in steel (16,800 ft/s or 5,124 m/s). Since the force is easier to measure than both force and velocity, Equation 5 is preferred by some test engineers. However, the EF method is fraught with errors and certain correction factors have to be applied to make it approximately correct. Among the error sources are the following:

- Proportionality is often violated prior to time 2L/c. The proportionality between force and velocity in a downward traveling wave only holds if the wave does not encounter a disturbance prior to reflecting off the pile toe. Such disturbances include a change in cross sectional area, an open or loose splice or joint, or resistance along the shaft.

- Using only one force measurement precludes a data quality check based on the proportionality between force and velocity. Thus, a force measurement that is for some reason in error may not be detectable, which will lead to errors in the EF2 value. Data quality checks will be discussed further in Section 5.

The use if EF2 is therefore not recommended but it is often included in result presentations for the sake of completeness.

4.2 STRESSES

During SPT monitoring, it is also of interest to monitor compressive stresses at both the top of the drive rod and at its bottom.

At the pile top (location of sensors) the maximum compression stress averaged over the rod's cross section, **CSX**, is directly obtained from the measurements. Note that this stress value refers to the instrumented section. If the rod has a different cross sectional area then the stress in the rod will be different from CSX.

The SPTA or PDA can also calculate, in an approximate manner, the force at the rod bottom, **CFB**. To obtain the corresponding stress, this force value should be divided by the appropriate cross sectional area, e.g. by the rod area just above the sampler or by the sampler area itself. Of course, non-uniform stress components as they might occur at the sampler tip due to a sloping rock are not considered in this calculation.

5. DATA QUALITY CHECKS

Quality data is the first and foremost requirement for accurate dynamic testing results. It is therefore important that the measurement engineer performing SPTA or PDA tests has the experience necessary to recognize measurement problems and take appropriate corrective action should problems develop. Fortunately, dynamic pile testing allows for certain data quality checks because two independent measurements are taken that have to conform to the so-called proportionality relationship.

As long as there is only a wave traveling in one direction, as is the case during impact when only a downward traveling wave exists in the rod, force and velocity measured at its top are proportional

$$F = v\,Z \tag{5}$$

where Z is again the pile impedance, Z = EA/c. This relationship can also be expressed in terms of stress

$$\sigma = F/A = v\,(E/c) \tag{6}$$

or strain

$$\epsilon = \sigma/E = v / c \tag{7}$$

This means that the early portion of strain times wave speed must be equal to the velocity unless the proportionality is affected by high friction near the pile top or by a pile cross sectional change not far below the sensors. Checking the proportionality is an excellent means of assuring meaningful measurements but is only truly meaningful for perfectly uniform rods. Open or loose splices, for example, will lead to a non-proportionality. For SPT rods it is fortunate that usually no soil resistance acts along the shaft and for that reason, proportionality can exist until the stress wave returns from sampler top or rod bottom unless connectors are not sufficiently tightened or have a significant mass.

Velocity data quality can also be checked by looking at the final displacement, DFN, which is calculated from the acceleration by double integration. If the calculated final displacement is much higher or lower than indicated by the N-value, the accelerometer attachment may be loose or the sensor may be faulty. If major drift in the velocity is observed, the EMX value may be in error, even though proportionality from impact to time 2L/c exists. In this case, it may be useful to evaluate the energy transferred to the drill rod at time 2L/c, which is calculated by the PDA or SPTA as the E2E quantity.

Appendix B

Calibrations

SPT Rod Calibration		Pile Dynamics, Inc. Made in USA	
	English		SI
EA Product	35,785.48 kips		159.25 MN
E	30,000 ksi		207,000 MPa
A	1.19 in^2		7.7 cm^2
Rod Serial #:		168 AWJ - 1	
Calibration Factor (me/V):		212.47	
Calibration Date:		21-Sep-15	
Calibration Due:		20-Sep-17	

168 AWJ - 1
168 AWJ - 2
35785.48
212.47
215.16
21-Sep-15

Print to fit and it looks okay!

SPT Rod Calibration		Pile Dynamics, Inc. Made in USA	
	English		SI
EA Product	35,785.48 kips		159.25 MN
E	30,000 ksi		207,000 MPa
A	1.19 in^2		7.7 cm^2
Rod Serial #:		168 AWJ - 2	
Calibration Factor (me/V):		215.16	
Calibration Date:		21-Sep-15	
Calibration Due:		20-Sep-17	

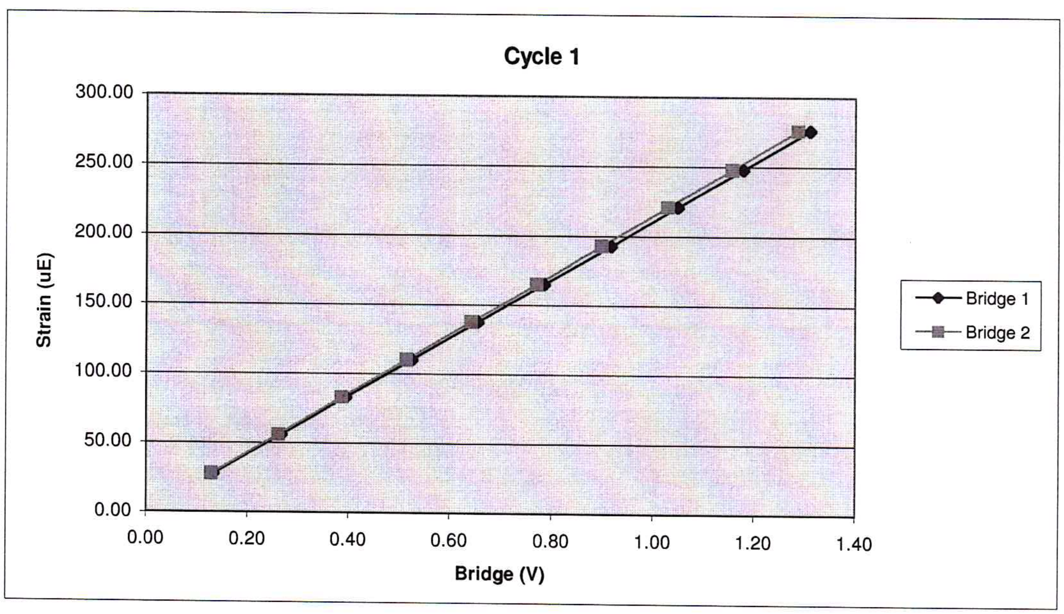
168	Number
AWJ	Type

Bridge 1	168 AWJ - 1	
Bridge 2	168 AWJ - 2	
EA Factor	35785.48	
Calibration 1	212.47	
Calibration 2	215.16	
Date Cal	21-Sep-15	<-- enter

168AWJ		Cycle 1		
Sample	**Force (lb)**	**Strain (µE)**	**Bridge 1 (V)**	**Bridge 2 (V)**
1	0.00	0.00	0.00	0.00
2	985.12	27.81	0.13	0.13
3	1999.42	55.96	0.27	0.26
4	2962.46	82.88	0.39	0.39
5	3948.57	110.23	0.52	0.51
6	4934.08	137.55	0.65	0.64
7	5929.06	165.07	0.79	0.77
8	6918.72	192.89	0.92	0.90
9	7919.02	220.92	1.05	1.03
10	8900.20	247.97	1.18	1.16
11	9910.36	276.00	1.31	1.29

Bridge 1		**Bridge 2**	
Force Calibration (lb/V)	**7574.02**	**Force Calibration (lb/V)**	**7709.66**
Offset	-21.90	Offset	-11.13
Correlation	0.999999	Correlation	0.999999
Strain Calibration (µE/V)	**210.70**	**Strain Calibration (µE/V)**	**214.48**
Offset	-0.24	Offset	0.06
Correlation	0.999999	Correlation	0.999998

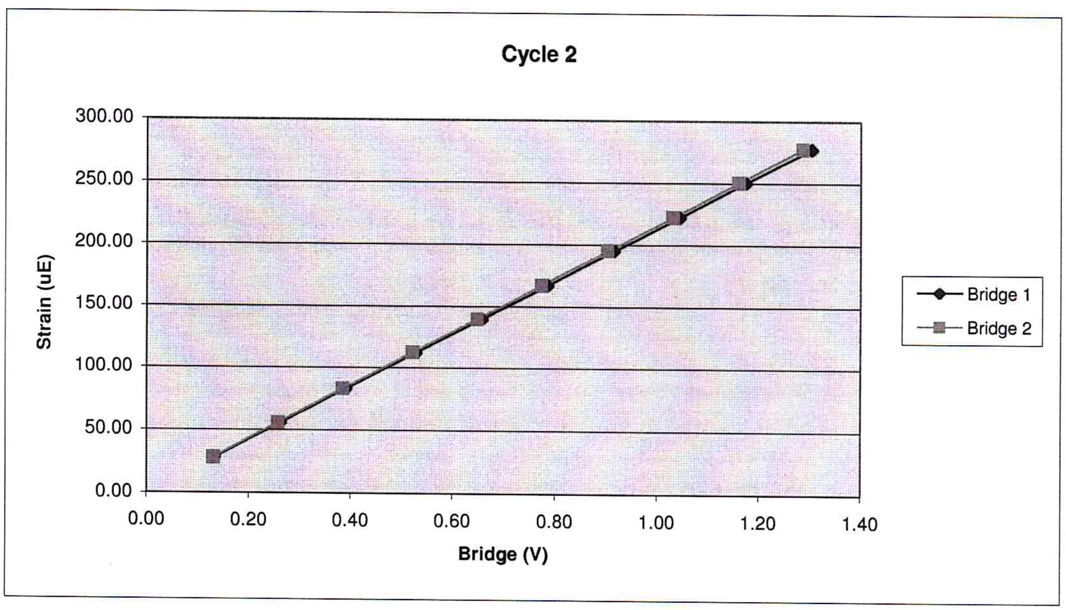
Force Strain Calibration	
EA (Kips)	**35946.33**
Offset	-13.36
Correlation	0.999999



168AWJ		Cycle 2		
Sample	**Force (lb)**	**Strain (µE)**	**Bridge 1 (V)**	**Bridge 2 (V)**
1	0.00	0.00	0.00	0.00
2	982.95	28.05	0.13	0.13
3	1974.19	55.76	0.26	0.26
4	2953.39	82.87	0.39	0.38
5	4000.42	112.22	0.53	0.52
6	4972.13	139.35	0.66	0.65
7	5950.75	167.00	0.79	0.77
8	6945.33	194.94	0.92	0.90
9	7917.84	222.00	1.04	1.03
10	8919.91	250.27	1.17	1.16
11	9896.36	277.50	1.30	1.29

Bridge 1		**Bridge 2**	
Force Calibration (lb/V)	**7606.16**	**Force Calibration (lb/V)**	**7700.14**
Offset	**-19.82**	Offset	**-11.88**
Correlation	**0.999999**	Correlation	**0.999998**
Strain Calibration (µE/V)	**213.01**	**Strain Calibration (µE/V)**	**215.64**
Offset	**-0.22**	Offset	**0.00**
Correlation	**0.999997**	Correlation	**0.999997**

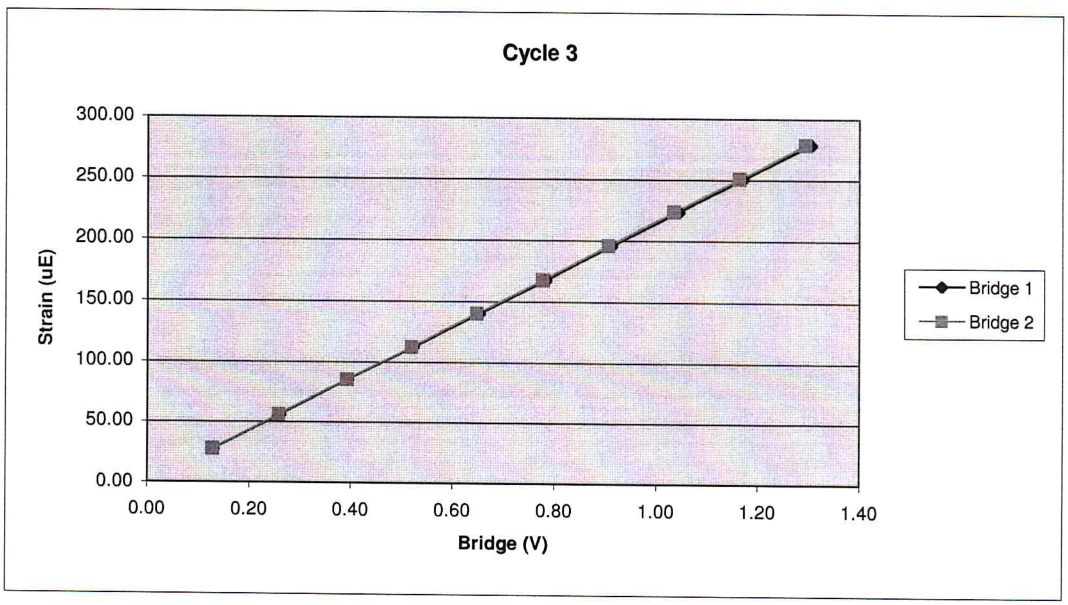
Force Strain Calibration	
EA (Kips)	**35708.56**
Offset	**-11.96**
Correlation	**0.999998**



168AWJ		Cycle 3		
Sample	**Force (lb)**	**Strain (µE)**	**Bridge 1 (V)**	**Bridge 2 (V)**
1	0.00	0.00	0.00	0.00
2	976.84	27.67	0.13	0.13
3	1972.21	55.77	0.26	0.26
4	3006.62	85.22	0.39	0.39
5	3988.79	112.54	0.52	0.52
6	4966.61	140.12	0.65	0.65
7	5959.03	167.81	0.78	0.78
8	6952.23	195.83	0.91	0.91
9	7951.15	223.79	1.04	1.03
10	8937.66	250.72	1.17	1.16
11	9937.17	278.64	1.30	1.29

Bridge 1		**Bridge 2**	
Force Calibration (lb/V)	**7629.36**	**Force Calibration (lb/V)**	**7688.81**
Offset	**-3.45**	Offset	**-7.58**
Correlation	**0.999997**	Correlation	**0.999999**
Strain Calibration (µE/V)	**213.70**	**Strain Calibration (µE/V)**	**215.36**
Offset	**0.65**	Offset	**0.53**
Correlation	**0.999990**	Correlation	**0.999994**

Force Strain Calibration	
EA (Kips)	**35701.55**
Offset	**-26.47**
Correlation	**0.999992**



Bridge Excitation (V) 5
Shunt Resitor (ohm) 60.4k

Calibration Factors	168AWJ		
Bridge 1 (µE/V)	212.47	Bridge 2 (µE/V)	215.16
EA Factor (Kips)	35785.48	Area (in^2)	1.19

Calibrated by: David Bennett
Calibrated Date: 9/21/2015

Pile Dynamics Inc
30725 Aurora Rd
Solon, OH 44139

Traceable to N.I.S.T.

QBTA: ON [ALT-F1/BB=60] Pile Dynamics, Inc. TG F2 DPF

Pile Dynamics
06-Mar-14 11:23
FS — 10
BN 2261
SL 484/ 3440/ 99
PJ:
PN: HOPBAR
A 4
F 2
-- VS 3.3

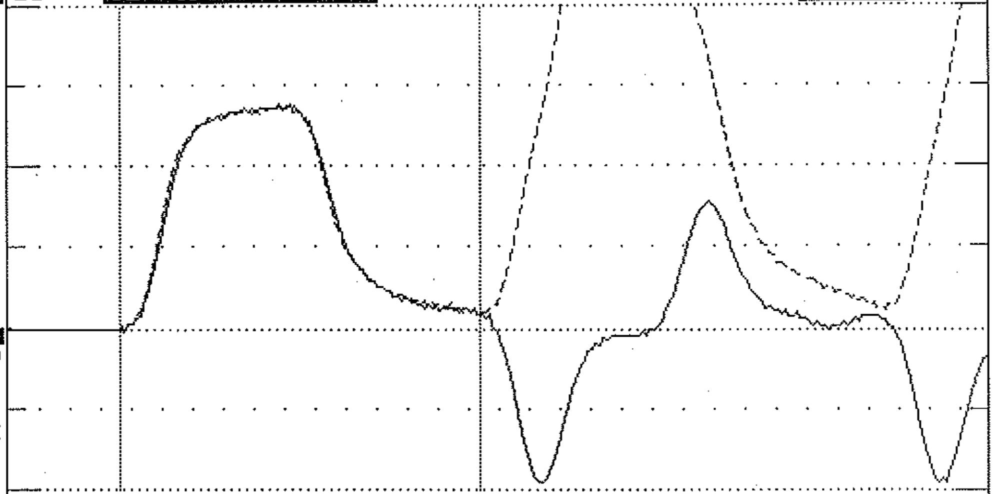
LE 39.6 ft
AR 1.7 in2
EM 30000 Ksi
SP 0.492 K/ft3
WS 16810 ft/s
WC 16862 ft/s

JC 0.40
FM 1.00
VM 1.00

EA/C 30.3 Ks/ft
UN KIPS*0.1
FR 20000 MB 30

DL -31
VT -1
PK 1 TM-PEAK

F1/2 500/ 213
F3/4 213/ 213
A1/2 999/ 999
A3/4 850/ 322



TS 12 E B PD: k2090 LP 0.00 ft
TB 8.0 T1 9.4 2L/C 4.7 VA 1000 VE 1022 LI 1.0

VMX= 4.5 FMX= 69 AMX= 149
EMX= 0.3 MEX= 135 FVP= 1.00

ACCEPT SQ-OFF FL-OFF PR-OFF

ACCELEROMETER CALIBRATION N.I.S.T. Traceable

SERIAL NUMBER: K2090

CALIBRATION FACTOR: .0644 MV/G

PAK (*5000): 322 DATE: 6MAR14

PDA OPERATOR: [signature]

contact Pile Dynamics USA
with your questions
tel USA - 216 - 831- 6131
fax USA - 216 - 831- 0916

<-AT:PIEZORESISTIVE OP: laine [ver:4.05] AT:PIEZOELECTRIC->

Smart Sensor

Smart Chip Programmed By A.M.W. **on** 6MAR14 **CRC Value** 000E

QBTA: ON [ALT-F1/BB=60] Pile Dynamics, Inc. TG F2 DPF

Pile Dynamics 09-Jan-14 07:56 | FS — 10 | BN 4 SL 117/ 3440/ 2 | PJ: PN: HOPBAR | A 4 F 2 | -- VS 3.3

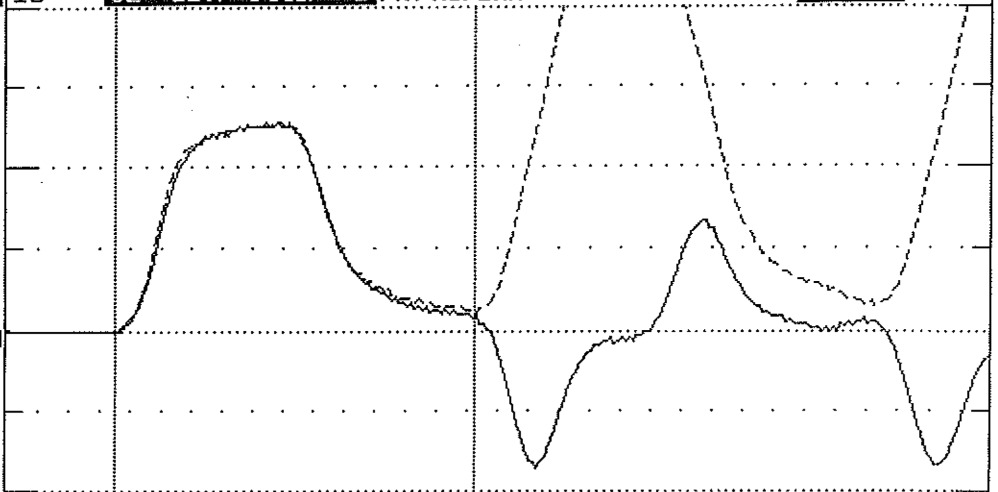
LE 39.6 ft
AR 1.7 in2
EM 30000 Ksi
SP 0.492 K/ft3
WS 16810 ft/s
WC 16862 ft/s

JC 0.40
FM 1.00
VM 1.00

EA/C 30.3 Ks/ft
UN KIPS*0.1
FR 20000 MB 30

DL -43
VT -1
PK 1 TM-PEAK

F1/2 500/ 213
F3/4 213/ 213
A1/2 999/ 1075
A3/4 999/ 340



TS 12 E B PD: k921 LP 0.00 ft
TB 8.0 T1 9.4 2L/C 4.7 VA 1000 VE 1022 LI 1.0

VMX= 4.1 FMX= 64 AMX= 129
EMX= 0.3 MEX= 125 FVP= 1.00

ACCEPT SQ-OFF FL-OFF PR-OFF

ACCELEROMETER CALIBRATION N.I.S.T. Traceable

SERIAL NUMBER: K921

CALIBRATION FACTOR: .068 MV/G

PAK (*5000): 340 DATE: 13JAN14

PDA OPERATOR: J. M. Wray

contact Pile Dynamics USA
with your questions
tel USA - 216 - 831- 6131
fax USA - 216 - 831- 0916

<-AT:PIEZORESISTIVE OP: laine [ver:4.05] AT:PIEZOELECTRIC->

Smart Sensor

Smart Chip Programmed By J.M.W. **on** 13JAN14 **CRC Value** 226F

Appendix C

SPT Calibration Results

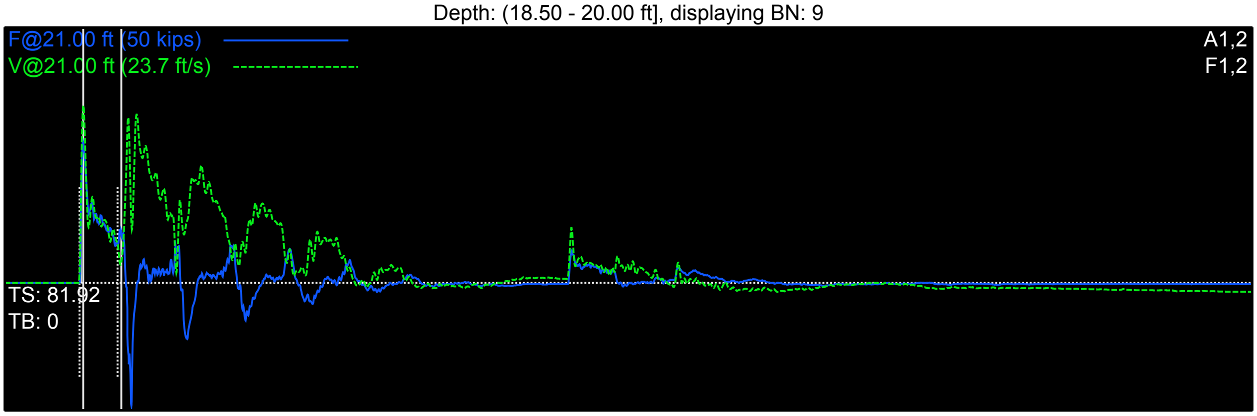
CME 550-SN 130883
TGH

ECS - Southern Drill
Test date: 9/10/2015

AR: 1.18 in^2
LE: 51.00 ft
WS: 16807.9 ft/s

SP: 0.492 k/ft3
EM: 30000 ksi

Depth: (18.50 - 20.00 ft], displaying BN: 9



FMX: Maximum Force
VMX: Maximum Velocity
EMX: Maximum Energy
BPM: Blows/Minute

ETR: Energy Transfer Ratio - Rated
EFV: Maximum Energy
E2E: Energy of FV at 2L/C
FVP: Force/Velocity proportionality

BL#	BC	LP	FMX	VMX	EMX	BPM	ETR	EFV	E2E	FVP
	/6"	ft	kips	ft/s	ft-lb	bpm	(%)	ft-lb	ft-lb	[]
1	3	18.67	28	18.6	278	2	79	278	264	0.82
2	3	18.83	27	17.2	262	45	75	262	249	0.81
3	3	19.00	28	17.0	269	45	77	269	256	0.81
4	3	19.17	28	16.9	277	45	79	277	263	0.80
5	3	19.33	28	16.6	273	45	78	273	259	0.80
6	3	19.50	28	16.7	274	45	78	274	260	0.81
7	5	19.60	28	16.2	273	45	78	273	259	0.78
8	5	19.70	28	16.4	276	45	79	276	261	0.80
9	5	19.80	28	16.5	271	45	77	271	258	0.79
10	5	19.90	28	16.5	274	45	78	274	260	0.78
11	5	20.00	28	16.6	276	45	79	276	262	0.78
		Average	28	16.5	274	45	78	274	260	0.79
		Std Dev	0	0.2	2	0	1	2	1	0.01
		Maximum	28	16.9	277	45	79	277	263	0.81
		Minimum	28	16.2	271	45	77	271	258	0.78

N-value: 8

Sample Interval Time: 13.38 seconds.

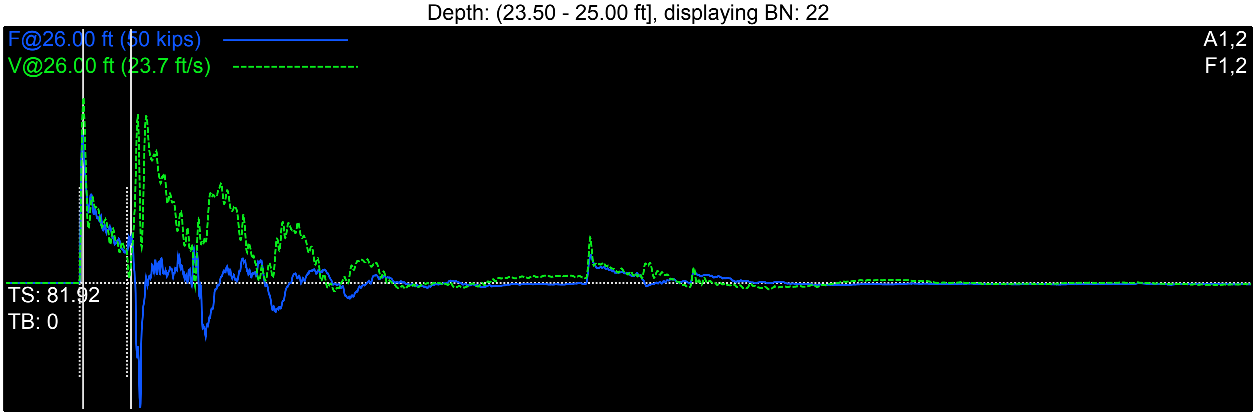
CME 550-SN 130883
TGH

ECS - Southern Drill
Test date: 9/10/2015

AR: 1.18 in^2
LE: 21.00 ft
WS: 16807.9 ft/s

SP: 0.492 k/ft3
EM: 30000 ksi

Depth: (23.50 - 25.00 ft], displaying BN: 22



BL#	BC /6"	LP ft	FMX kips	VMX ft/s	EMX ft-lb	BPM bpm	ETR (%)	EFV ft-lb	E2E ft-lb	FVP []
13	3	23.75	28	18.0	283	2	81	283	278	0.75
14	3	23.88	28	17.7	272	45	78	272	266	0.75
15	3	24.00	28	17.6	279	45	80	279	273	0.76
16	4	24.13	29	17.3	284	44	81	284	278	0.75
17	4	24.25	29	16.7	284	45	81	284	277	0.76
18	4	24.38	28	16.7	282	45	81	282	275	0.74
19	4	24.50	29	16.9	286	45	82	286	279	0.73
20	5	24.60	29	16.9	285	45	81	285	278	0.75
21	5	24.70	29	16.9	282	45	80	282	274	0.73
22	5	24.80	29	17.2	291	45	83	291	283	0.75
23	5	24.90	29	17.2	289	45	83	289	282	0.73
24	5	25.00	28	17.1	291	45	83	291	283	0.74
		Average	29	17.0	286	45	82	286	279	0.74
		Std Dev	0	0.2	3	0	1	3	3	0.01
		Maximum	29	17.3	291	45	83	291	283	0.76
		Minimum	28	16.7	282	44	80	282	274	0.73

N-value: 9

Sample Interval Time: 14.73 seconds.

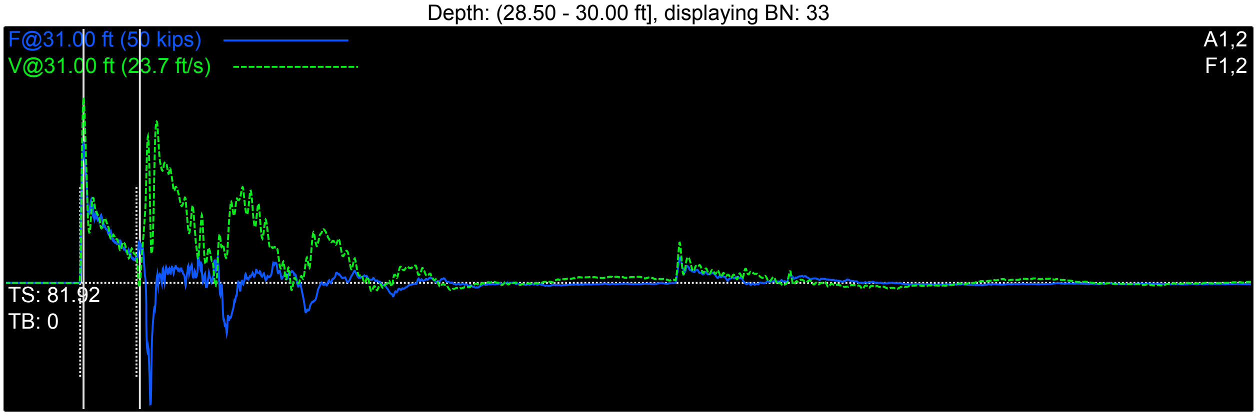
CME 550-SN 130883
TGH

ECS - Southern Drill
Test date: 9/10/2015

AR: 1.18 in^2
LE: 26.00 ft
WS: 16807.9 ft/s

SP: 0.492 k/ft3
EM: 30000 ksi

Depth: (28.50 - 30.00 ft], displaying BN: 33



BL#	BC	LP	FMX	VMX	EMX	BPM	ETR	EFV	E2E	FVP
	/6"	ft	kips	ft/s	ft-lb	bpm	(%)	ft-lb	ft-lb	[]
25	2	28.75	28	17.3	287	45	82	287	282	0.74
26	2	29.00	28	17.2	289	45	83	289	284	0.74
27	4	29.13	28	17.1	287	45	82	287	282	0.76
28	4	29.25	27	17.1	284	45	81	284	279	0.73
29	4	29.38	27	17.3	290	45	83	290	284	0.74
30	4	29.50	27	17.1	283	45	81	283	279	0.73
31	5	29.60	27	17.3	293	45	84	293	287	0.74
32	5	29.70	27	17.4	295	45	84	295	289	0.72
33	5	29.80	27	17.2	288	45	82	288	282	0.74
34	5	29.90	28	17.5	294	45	84	294	288	0.74
35	5	30.00	28	17.5	295	45	84	295	289	0.73
		Average	28	17.3	290	45	83	290	284	0.74
		Std Dev	0	0.1	4	0	1	4	4	0.01
		Maximum	28	17.5	295	45	84	295	289	0.76
		Minimum	27	17.1	283	45	81	283	279	0.72

N-value: 9

Sample Interval Time: 13.38 seconds.

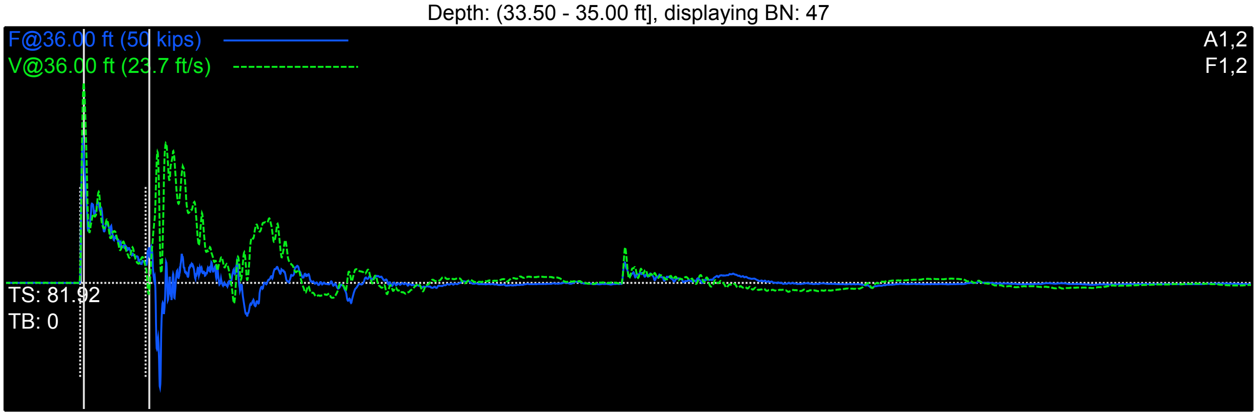
CME 550-SN 130883
TGH

ECS - Southern Drill
Test date: 9/10/2015

AR: 1.18 in^2
LE: 31.00 ft
WS: 16807.9 ft/s

SP: 0.492 k/ft3
EM: 30000 ksi

Depth: (33.50 - 35.00 ft], displaying BN: 47



BL#	BC /6"	LP ft	FMX kips	VMX ft/s	EMX ft-lb	BPM bpm	ETR (%)	EFV ft-lb	E2E ft-lb	FVP []
36	2	33.83	28	18.2	287	45	82	287	287	0.64
37	2	34.00	28	18.3	298	45	85	298	295	0.61
38	4	34.13	28	18.2	280	45	80	280	279	0.62
39	4	34.25	27	18.1	293	45	84	293	290	0.65
40	4	34.38	27	18.2	296	45	85	296	293	0.65
41	4	34.50	27	18.2	302	45	86	302	299	0.62
42	8	34.56	28	18.3	279	45	80	279	279	0.63
43	8	34.63	27	18.2	289	45	83	289	287	0.65
44	8	34.69	28	18.4	296	45	84	296	293	0.65
45	8	34.75	27	18.2	291	45	83	291	289	0.63
46	8	34.81	27	18.3	296	45	84	296	293	0.63
47	8	34.88	28	18.6	303	45	87	303	300	0.62
48	8	34.94	28	18.4	294	45	84	294	291	0.62
49	8	35.00	27	18.2	289	45	82	289	286	0.62
		Average	27	18.3	292	45	83	292	290	0.63
		Std Dev	0	0.1	7	0	2	7	6	0.01
		Maximum	28	18.6	303	45	87	303	300	0.65
		Minimum	27	18.1	279	45	80	279	279	0.62

N-value: 12

Sample Interval Time: 17.42 seconds.

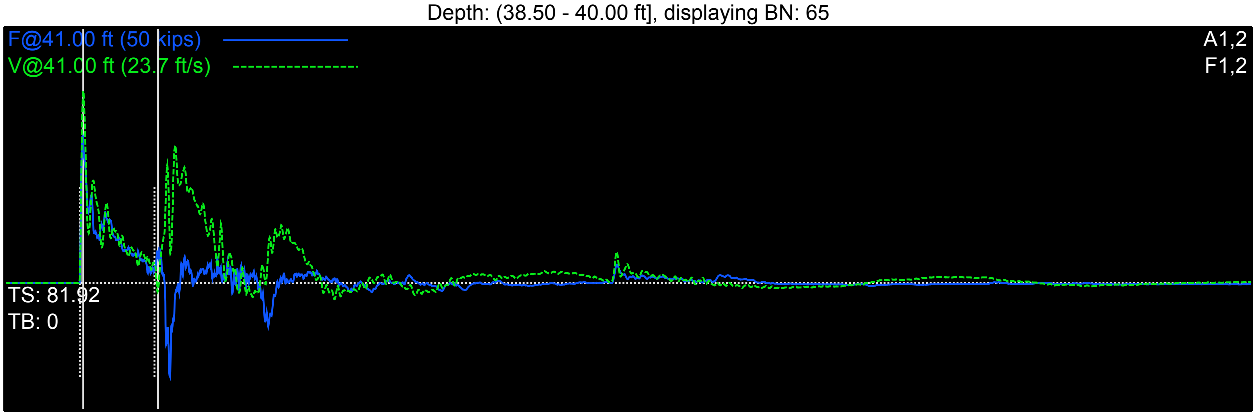
CME 550-SN 130883
TGH

ECS - Southern Drill
Test date: 9/10/2015

AR: 1.18 in^2
LE: 36.00 ft
WS: 16807.9 ft/s

SP: 0.492 k/ft3
EM: 30000 ksi

Depth: (38.50 - 40.00 ft], displaying BN: 65



BL#	BC /6"	LP ft	FMX kips	VMX ft/s	EMX ft-lb	BPM bpm	ETR (%)	EFV ft-lb	E2E ft-lb	FVP []
52	3	38.67	29	18.2	306	45	87	306	304	0.74
53	3	38.83	28	17.4	302	45	86	302	300	0.74
54	3	39.00	28	17.4	304	45	87	304	302	0.74
55	6	39.08	28	17.5	300	45	86	300	299	0.74
56	6	39.17	28	17.2	302	45	86	302	300	0.73
57	6	39.25	28	17.3	270	45	77	270	270	0.74
58	6	39.33	28	17.4	271	45	78	271	271	0.72
59	6	39.42	29	17.7	307	45	88	307	304	0.71
60	6	39.50	28	17.7	307	45	88	307	305	0.73
61	7	39.57	29	18.0	305	45	87	305	302	0.73
62	7	39.64	29	18.0	305	45	87	305	303	0.72
63	7	39.71	28	17.5	310	45	89	310	308	0.72
64	7	39.79	28	17.5	307	45	88	307	304	0.73
65	7	39.86	29	17.8	312	45	89	312	309	0.72
66	7	39.93	29	18.2	311	45	89	311	308	0.72
67	7	40.00	28	17.5	312	45	89	312	309	0.72
		Average	28	17.6	302	45	86	302	299	0.73
		Std Dev	0	0.3	14	0	4	14	13	0.01
		Maximum	29	18.2	312	45	89	312	309	0.74
		Minimum	28	17.2	270	45	77	270	270	0.71

N-value: 13

Sample Interval Time: 20.07 seconds.

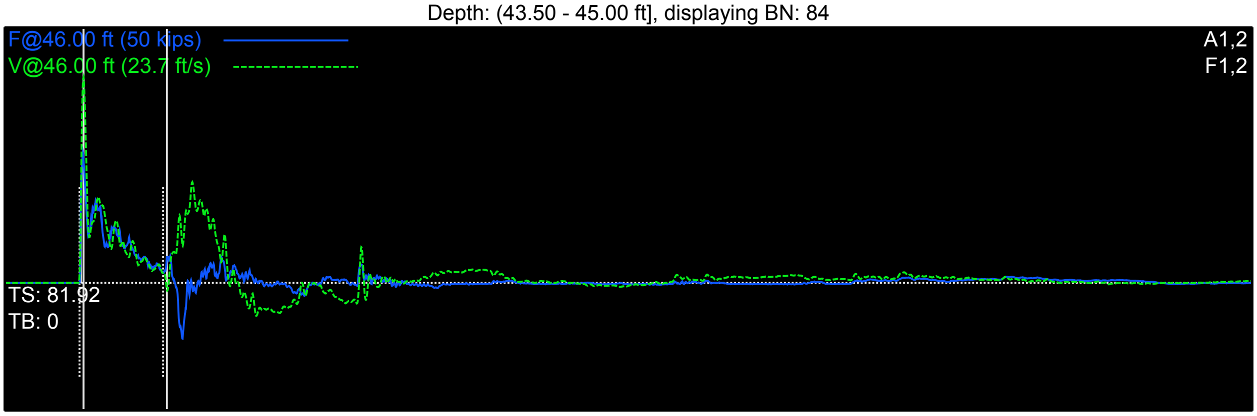
CME 550-SN 130883
TGH

ECS - Southern Drill
Test date: 9/10/2015

AR: 1.18 in^2
LE: 41.00 ft
WS: 16807.9 ft/s

SP: 0.492 k/ft3
EM: 30000 ksi

Depth: (43.50 - 45.00 ft], displaying BN: 84



BL#	BC /6"	LP ft	FMX kips	VMX ft/s	EMX ft-lb	BPM bpm	ETR (%)	EFV ft-lb	E2E ft-lb	FVP []
69	3	43.75	27	18.5	297	2	85	297	296	0.64
70	3	43.88	26	19.0	307	45	88	307	306	0.61
71	3	44.00	27	19.2	308	44	88	308	307	0.61
72	6	44.08	25	19.3	297	45	85	297	296	0.59
73	6	44.17	27	19.2	293	45	84	293	293	0.60
74	6	44.25	25	19.7	282	44	81	282	282	0.59
75	6	44.33	26	19.0	282	45	81	282	282	0.60
76	6	44.42	26	19.5	297	45	85	297	297	0.59
77	6	44.50	25	19.5	306	45	87	306	305	0.61
78	9	44.55	27	19.1	297	45	85	297	296	0.59
79	9	44.60	27	19.1	303	45	87	303	302	0.62
80	9	44.65	25	19.3	296	45	85	296	296	0.60
81	9	44.70	26	19.0	305	45	87	305	304	0.62
82	9	44.75	25	19.1	303	45	87	303	302	0.61
83	9	44.80	27	18.8	310	45	88	310	308	0.62
84	9	44.85	25	19.1	305	45	87	305	303	0.60
85	9	44.90	26	19.1	305	45	87	305	303	0.60
86	9	44.95	26	19.6	312	44	89	312	310	0.60
		Average	26	19.2	300	45	86	300	299	0.60
		Std Dev	1	0.2	8	0	2	8	8	0.01
		Maximum	27	19.7	312	45	89	312	310	0.62
		Minimum	25	18.8	282	44	81	282	282	0.59

N-value: 15

Sample Interval Time: 22.81 seconds.

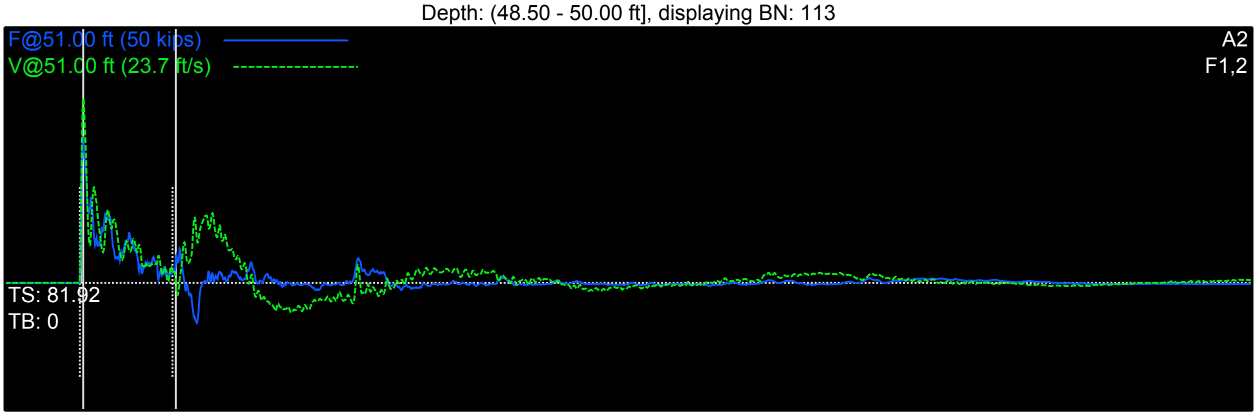
CME 550-SN 130883
TGH

ECS - Southern Drill
Test date: 9/10/2015

AR: 1.18 in^2
LE: 46.00 ft
WS: 16807.9 ft/s

SP: 0.492 k/ft3
EM: 30000 ksi

Depth: (48.50 - 50.00 ft], displaying BN: 113



BL#	BC	LP	FMX	VMX	EMX	BPM	ETR	EFV	E2E	FVP
	/6"	ft	kips	ft/s	ft-lb	bpm	(%)	ft-lb	ft-lb	[]
88	3	48.67	29	17.2	296	2	85	296	295	0.78
89	3	48.83	28	17.8	305	44	87	305	303	0.74
90	3	49.00	29	17.9	308	45	88	308	307	0.74
91	12	49.04	28	17.8	267	45	76	267	266	0.72
92	12	49.08	28	17.8	269	45	77	269	268	0.74
93	12	49.13	29	17.9	279	45	80	279	279	0.74
94	12	49.17	28	17.7	287	45	82	287	287	0.73
95	12	49.21	28	17.6	287	45	82	287	287	0.74
96	12	49.25	29	17.6	298	45	85	298	297	0.75
97	12	49.29	29	17.8	300	45	86	300	298	0.74
98	12	49.33	29	17.5	294	45	84	294	293	0.75
99	12	49.38	29	17.3	293	45	84	293	293	0.79
100	12	49.42	28	17.5	285	44	81	285	285	0.75
101	12	49.46	29	17.2	292	45	83	292	291	0.77
102	12	49.50	29	17.5	297	44	85	297	296	0.76
103	13	49.54	29	17.5	294	45	84	294	293	0.75
104	13	49.58	29	17.5	299	45	85	299	298	0.78
105	13	49.62	29	17.8	299	44	85	299	297	0.74
106	13	49.65	28	17.5	292	45	83	292	291	0.75
107	13	49.69	28	17.7	287	44	82	287	286	0.73
108	13	49.73	28	17.3	289	45	83	289	288	0.75
109	13	49.77	28	16.8	282	45	80	282	281	0.78
110	13	49.81	28	17.3	290	45	83	290	288	0.75
111	13	49.85	28	17.1	283	45	81	283	282	0.76
112	13	49.88	29	17.6	294	44	84	294	292	0.77
113	13	49.92	28	17.2	288	45	82	288	287	0.77
114	13	49.96	28	17.1	289	45	83	289	288	0.78
115	13	50.00	28	16.9	289	44	83	289	288	0.78
		Average	28	17.4	289	45	83	289	288	0.75
		Std Dev	0	0.3	8	0	2	8	8	0.02
		Maximum	29	17.9	300	45	86	300	298	0.79
		Minimum	28	16.8	267	44	76	267	266	0.72

N-value: 25

Sample Interval Time: 36.34 seconds.

Summary of SPT Test Results

Project: CME 550-SN 130883, Test Date: 9/10/2015

FMX: Maximum Force
VMX: Maximum Velocity
EMX: Maximum Energy
BPM: Blows/Minute

ETR: Energy Transfer Ratio - Rated
EFV: Maximum Energy
E2E: Energy of FV at 2L/C
FVP: Force/Velocity proportionality

Instr. Length ft	Blows Applied /6"	Start Depth ft	Final Depth ft	**N Value**	**N60 Value**	Average FMX kips	Average VMX ft/s	Average EMX ft-lb	Average BPM bpm	Average ETR (%)	Average EFV ft-lb	Average E2E ft-lb	Average FVP []
21.00	**3-3-5**	18.50	20.00	**8**	**11**	28	16.5	274	45	78	274	260	0.79
26.00	**3-4-5**	23.50	25.00	**9**	**12**	29	17.0	286	45	82	286	279	0.74
31.00	**2-4-5**	28.50	30.00	**9**	**12**	28	17.3	290	45	83	290	284	0.74
36.00	**2-4-8**	33.50	35.00	**12**	**16**	27	18.3	292	45	83	292	290	0.63
41.00	**3-6-7**	38.50	40.00	**13**	**18**	28	17.6	302	45	86	302	299	0.73
46.00	**3-6-9**	43.50	45.00	**15**	**20**	26	19.2	300	45	86	300	299	0.60
51.00	**3-12-13**	48.50	50.00	**25**	**34**	28	17.4	289	45	83	289	288	0.75
					Overall Average Values:	28	17.7	291	45	83	291	288	0.71
					Standard Deviation:	1	0.8	11	0	3	11	13	0.06
					Overall Maximum Value:	29	19.7	312	45	89	312	310	0.81
					Overall Minimum Value:	25	16.2	267	44	76	267	258	0.59

Appendix P

Thompson Engineering Geotechnical Data Report

Report of Geotechnical Consulting Services

Geotechnical Subsurface Data Report (GSDR)

Interstate 85/385 Interchange Improvements

Roadways and Retaining Walls

Greenville County, South Carolina

SCDOT Project No.: IM23(009)
File No.: 23.038111

Thompson Engineering
Project No.: 14-1101-0276

Submitted By:

Thompson Engineering
August 18, 2015

Celebrating over 60 years in business.

thompson
ENGINEERING

Office Locations: ALABAMA ▪ FLORIDA ▪ GEORGIA ▪ LOUISIANA ▪ MISSISSIPPI ▪ TENNESSEE ▪ TEXAS

Report of Geotechnical Consulting Services

Geotechnical Subsurface Data Report (GSDR)

Interstate 85/385 Interchange Improvements

Bridge 1/2A

Greenville County, South Carolina

SCDOT Project No.: IM23(009)
File No.: 23.038111

Thompson Engineering
Project No.: 14-1101-0276

Submitted By:

Thompson Engineering
May 30, 2015 (REV. July 25, 2015)

Celebrating over 60 years in business.

thompson
ENGINEERING

Report of Geotechnical Consulting Services

Geotechnical Subsurface Data Report (GSDR)

Interstate 85/385 Interchange Improvements

Bridge 2B/3

Greenville County, South Carolina

SCDOT Project No.: IM23(009)
File No.: 23.038111

Thompson Engineering
Project No.: 14-1101-0276

Submitted By:

Thompson Engineering
June 1, 2015

Celebrating over 60 years in business.

thompson
ENGINEERING

Report of Geotechnical Consulting Services

Geotechnical Subsurface Data Report (GSDR)

Interstate 85/385 Interchange Improvements

Bridge 12

Greenville County, South Carolina

SCDOT Project No.: IM23(009)
File No.: 23.038111

Thompson Engineering
Project No.: 14-1101-0276

Submitted By:

Thompson Engineering
August 5, 2015

Celebrating over 60 years in business.

thompson
ENGINEERING

The complete Thompson Geotechnical Data Reports are not bound in this document to limit report size. Complete data report is available through the SCDOT.

Appendix Q

F&H Geotechnical Data Report

Geotechnical Data Report

I-85/I-385 Interchange Improvements

Greenville County, SC

January 25, 2013

Prepared For:

SCDOT
South Carolina
Department of Transportation

Prepared By:

Florence & Hutcheson
An ICA Company

flohut.com

The complete F&H Geotechnical Data Report is not bound in this document to limit report size. Complete data report is available through the SCDOT.