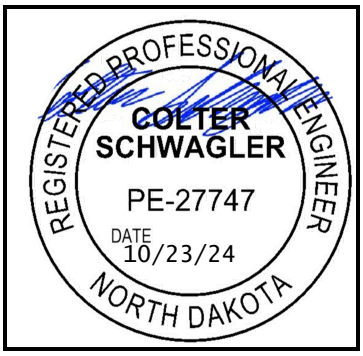
SOIL INVESTIGATION MEMO



TO:	**Design Division**
FROM:	**Aaron Lehman (M&R - Geotechnical Section)**
DATE:	**10/16/2024**
HIGHWAY:	**US 83**
PROJECT NUMBER:	**NH-4-083(142)198**
PCN:	**22048**
LOCATION:	**South of US 2**
SUBJECT:	**Soil Investigation Memo**

Attached to this memo is the soil information collected for the above project. The soil boring location is shown in Appendix A; the soil boring and laboratory data are shown in Appendix B.

Surface elevation of the soil boring was obtained from Google Earth. Based on the soil boring data, it is expected that the existing water table is located at an approximate elevation of 1692 feet. The water table may be encountered during the required excavations needed for this project.

The following lateral earth pressure coefficients were calculated for this project for use in determining lateral earth pressure for at-rest, active, and passive states. The calculations for the lateral earth pressure coefficients were based on AASHTO LRFD 2020 9th Edition.

Lateral Earth Pressure Coefficients (k) for the Project		
k_0	k_a	k_p
0.4910	0.2957	4.8307

The following parameters were determined/assumed for calculations of k coefficients:

- Friction angle of $\varphi'_f = 30.6°$ determined from CU testing
- Soil assumed to be normally consolidated for k_0 calculations
- Steel sheet piles against sand mixed with clay was assumed ($\delta = 14°$)
- Sheet piling assumed to be vertical with horizontal fill behind and in front of the sheet piling ($\beta = 0°$, $\theta = 90°$)

The boring logs are only representative of the exact location and time period from which the data was obtained and soil samples taken. Fluctuations in the water table and soil conditions may occur due to rainfall, spring thaw, drainage, and other factors. Construction planning should recognize the possibility of fluctuations. The NDDOT assumes no responsibility if the water table or soil conditions encountered during construction differ from those shown. The boring location shown is approximate.

Appendix A – Boring Location

Legend

- Reference Point
- Boring Location

0 250 500
Feet

Project Number: NH-4-083(142)198

Appendix B – Soil Boring and Lab Information

NORTH DAKOTA DEPARTMENT OF TRANSPORATION
300 AIRPORT ROAD
BISMARCK, ND 58504

LOG OF BORING SB - 1

PROJECT NUMBER NH-4-083(142)198 **DATE STARTED** 8/6/24 **COMPLETED** 8/6/24

PCN 22048 **ELEVATION** 1718 ft

LOCATION Ward County **Northing** 5341728.23 ft **Easting** 329402.83 ft

DRILLED BY Dallan **LOGGED BY** Jamie **DRILLING METHOD**

ENGINEER

NOTES Coordinate System: NAD_1983_UTM_Zone_14N

ELEVATION (ft)	DEPTH (ft)	MATERIAL DESCRIPTION	AASHTO	USCS	SAMPLE TYPE & NUMBER	RECOVERY (%)	SPT N VALUE	MC / PL / LL / CLAY FRACTION (%)	TESTS & REMARKS
	0	Brown Moist Stiff Sandy Lean Clay							
			A-6	CL	3TW 411	75		MC 16 28	
			A-6	SC	SS 412	50	13	MC 15 28	
1710									
	10		A-6	CL	3TW 413	50		MC 16 33	
			A-6	CL	SS 414	50	16	MC 18 29	
			A-4	CL-ML	3TW 415	85		MC 14 25	
			A-6	SC	3TW 415.1			MC 14 25	
			A-6	CL	SS 416	90	11	MC 15 34	
1700		1699.0 ft 19.0 ft							
	20	Dark Brown Wet/Moist Medium Very Stiff Clayey Sand with Gravel. Water bearing at 26'.	A-6	SC	3TW 417	60		MC 15 32	γ_d = 117.5 pcf γ = 134.6 pcf c'=877 psf, phi'=30.6°
			A-2-6	SC	SS 418	65	22	MC 16 29	
			A-2-6	SC	3TW 419	90		MC 16 32	
					SS	0	17		No recovery, possible rock.
1690									
	30	1687.0 ft 31.0 ft			3TW	0			No recovery, possible rock.
		Grey Moist Very Stiff Sandy Lean Clay	A-6	CL	SS 420	60	16	MC 15 37	
			A-6	CL	3TW 421	75		MC 16 37	
			A-6	CL	SS 422	60	16	MC 15 34	
1680									
	40		A-6	CL	3TW 423	85		MC 16 36	
			A-7-6	CL	SS 424	65	18	MC 17 43	
			A-6	CL	3TW 425	75		MC 15 36	
			A-6	CL	SS 426	75	16	MC 16 33	
1670									
	50		A-6	CL	3TW 427	100		MC 15 32	γ_d = 114.0 pcf γ = 131.0 pcf c'=346 psf, phi'=30.5°
			A-6	CL	SS 428	75	17	MC 15 35	
			A-6	CL	3TW 429	75		MC 17 33	
			A-6	SC	SS 430	65	39	MC 15 30	
1660									
	60	1657.0 ft 61.0 ft	A-6	CL	SS 431	100	23	MC 15 34	

Bottom of borehole at 61.0 ft

SUMMARY OF LABORATORY RESULTS

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION
300 AIRPORT ROAD
BISMARCK, ND 58504

PROJECT NUMBER NH-4-083(142)198 **LOCATION** Ward County

PCN 22048

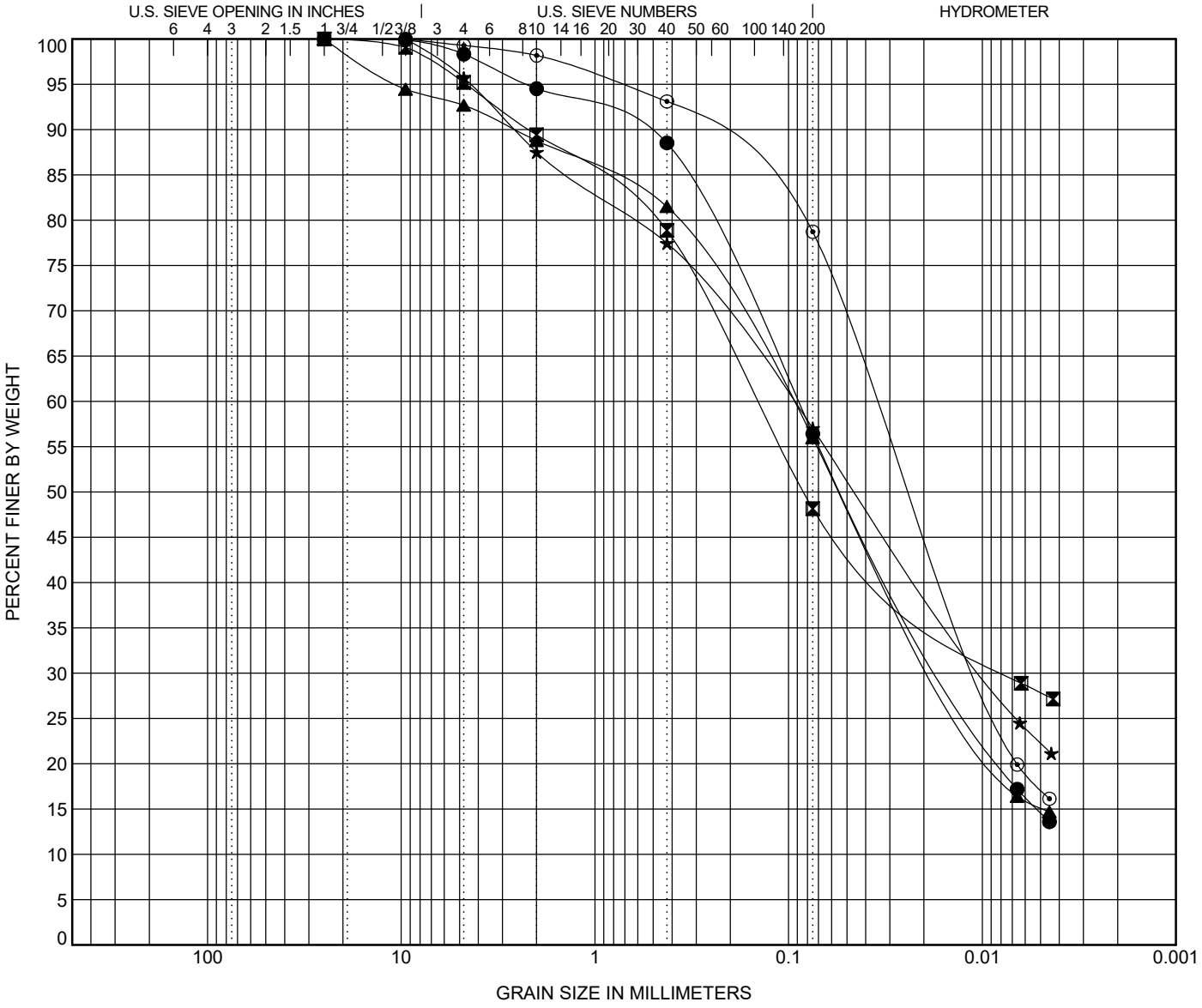
Borehole	Depth	Liquid Limit	Plastic Limit	Plasticity Index	Maximum Size (mm)	%<#200 Sieve	AASHTO Classification	USCS Class-ification	Water Content (%)	Avg. Water Content (%)	Dry Density (pcf)	Satur-ation (%)	Void Ratio
SB - 1	4.0	28	16	12	25	56	A-6 (4)	CL	15.6	15.6			
SB - 1	6.0	28	15	13	25	48	A-6 (3)	SC	19.2	19.2			
SB - 1	9.0	33	16	17	25	56	A-6 (6)	CL	18.1	18.1			
SB - 1	11.0	29	18	11	9.5	57	A-6 (4)	CL	13.5	13.5			
SB - 1	14.0	26	21	5	9.5	79	A-4 (3)	CL-ML	17.3	17.3			
SB - 1	15.0	25	14	11	25	41	A-6 (1)	SC	12.6	12.6			
SB - 1	16.0	34	15	19	25	61	A-6 (9)	CL	19.0	19.0			
SB - 1	19.0	32	15	17	50	47	A-6 (4)	SC	14.6	14.6	117.5		
SB - 1	21.0	29	16	13	25	35	A-2-6 (1)	SC	14.5	14.5			
SB - 1	24.0	32	16	16	50	20	A-2-6 (0)	SC	15.0	15.0			
SB - 1	31.0	37	15	22	25	63	A-6 (11)	CL	18.1	18.1			
SB - 1	34.0	37	16	21	50	58	A-6 (9)	CL	17.6	17.6			
SB - 1	36.0	34	15	19	25	64	A-6 (9)	CL	19.2	19.2			
SB - 1	39.0	36	16	20	25	66	A-6 (11)	CL	18.3	18.3			
SB - 1	41.0	43	17	26	25	58	A-7-6 (12)	CL	17.7	17.7			
SB - 1	44.0	36	15	21	25	64	A-6 (11)	CL	19.2	19.2			
SB - 1	46.0	33	16	17	9.5	68	A-6 (9)	CL	18.8	18.8			
SB - 1	49.0	32	15	17	25	54	A-6 (6)	CL	14.9	14.9	114.0		
SB - 1	51.0	35	15	20	25	70	A-6 (12)	CL	25.9	25.9			
SB - 1	54.0	33	17	16	50	56	A-6 (6)	CL	17.4	17.4			
SB - 1	56.0	30	15	15	25	43	A-6 (3)	SC	14.0	14.0			
SB - 1	59.0	34	15	19	9.5	67	A-6 (10)	CL	18.4	18.4			

GRAIN SIZE DISTRIBUTION

NORTH DAKOTA DEPARTMENT OF TRANSPORATION
300 AIRPORT ROAD
BISMARCK, ND 58504

PROJECT NUMBER NH-4-083(142)198 **LOCATION** Ward County

PCN 22048



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	BOREHOLE	DEPTH	AASHTO Classification	USCS Classification	LL	PL	PI	Cc	Cu
●	SB - 1	4.0	A-6 (4)	CL	28	16	12		
⊠	SB - 1	6.0	A-6 (3)	SC	28	15	13		
▲	SB - 1	9.0	A-6 (6)	CL	33	16	17		
★	SB - 1	11.0	A-6 (4)	CL	29	18	11		
⊙	SB - 1	14.0	A-4 (3)	CL-ML	26	21	5		

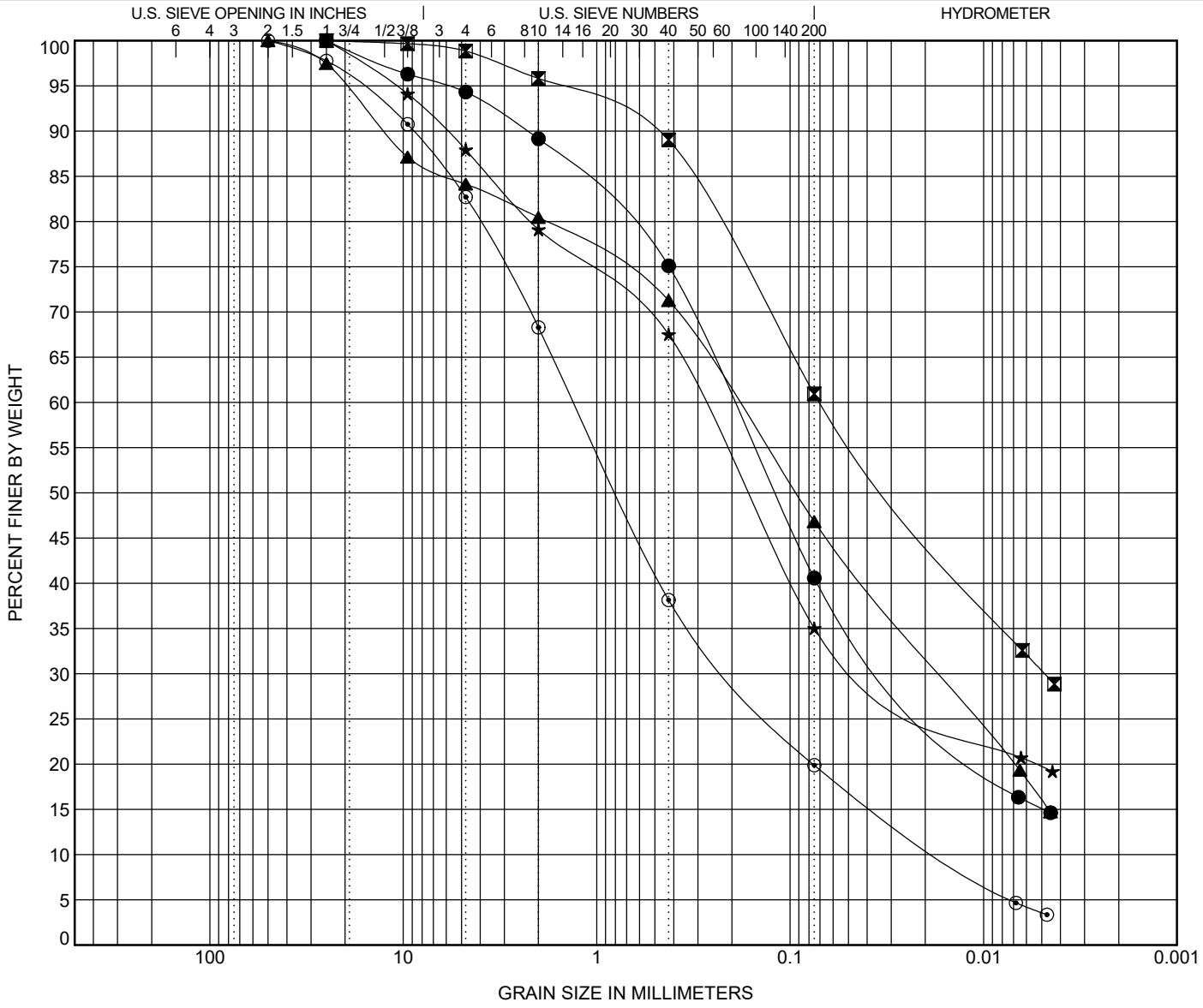
	BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	SB - 1	4.0	25	0.091	0.015		1.7	41.9	56.4	
⊠	SB - 1	6.0	25	0.146	0.007		4.8	47.0	48.2	
▲	SB - 1	9.0	25	0.099	0.015		7.3	36.7	56.0	
★	SB - 1	11.0	9.5	0.096	0.01		4.3	38.7	57.0	
⊙	SB - 1	14.0	9.5	0.035	0.01		0.7	20.6	78.7	

GRAIN SIZE DISTRIBUTION

NORTH DAKOTA DEPARTMENT OF TRANSPORATION
300 AIRPORT ROAD
BISMARCK, ND 58504

PROJECT NUMBER NH-4-083(142)198 **LOCATION** Ward County

PCN 22048



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

BOREHOLE	DEPTH	AASHTO Classification	USCS Classification	LL	PL	PI	Cc	Cu
● SB - 1	15.0	A-6 (1)	SC	25	14	11		
⊠ SB - 1	16.0	A-6 (9)	CL	34	15	19		
▲ SB - 1	19.0	A-6 (4)	SC	32	15	17		
★ SB - 1	21.0	A-2-6 (1)	SC	29	16	13		
⊙ SB - 1	24.0	A-2-6 (0)	SC	32	16	16	1.86	82.76

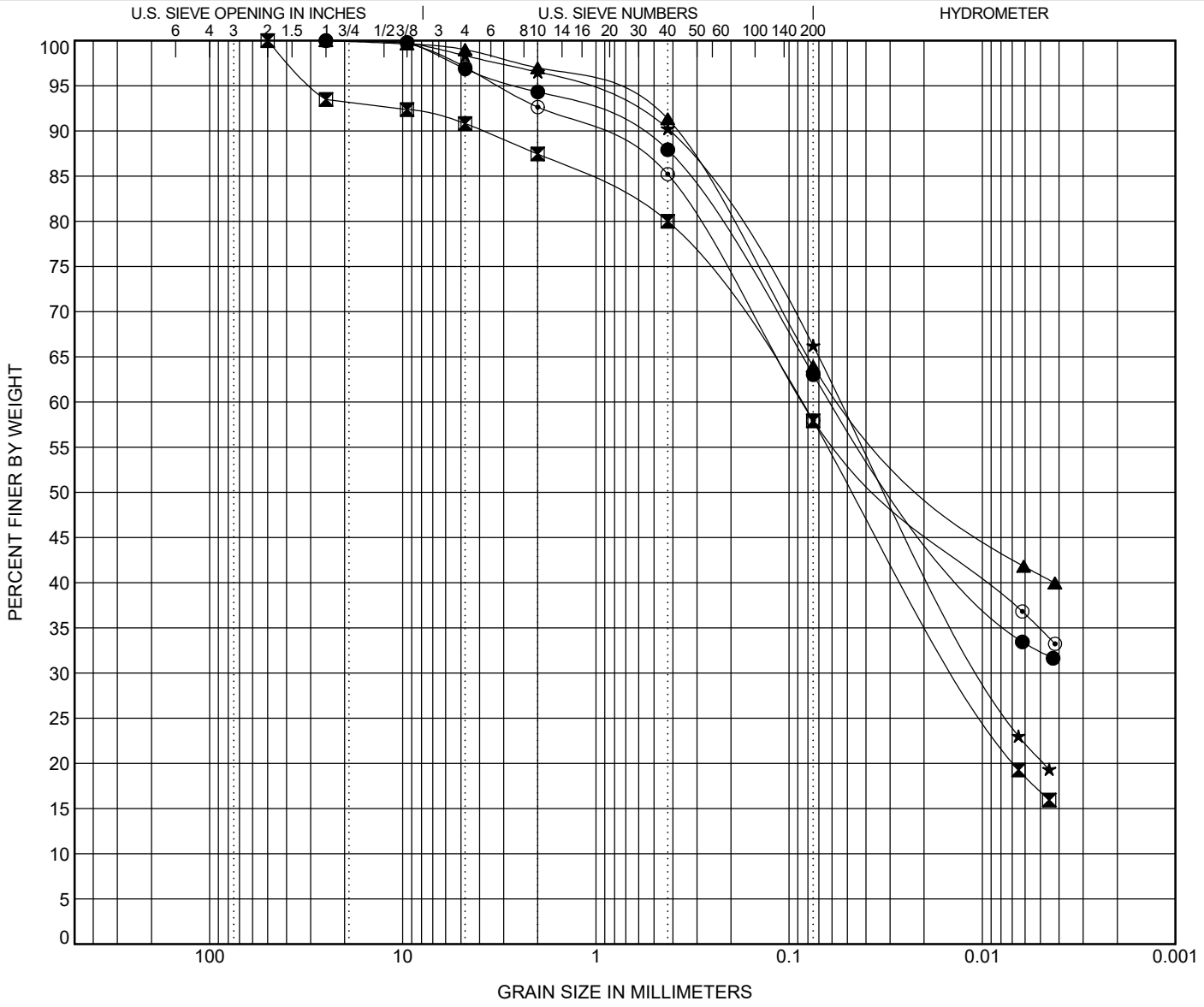
BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● SB - 1	15.0	25	0.199	0.026		5.7	53.8	40.6	
⊠ SB - 1	16.0	25	0.069	0.005		1.2	37.9	60.9	
▲ SB - 1	19.0	50	0.191	0.017		15.9	37.3	46.8	
★ SB - 1	21.0	25	0.284	0.032		12.1	52.9	35.0	
⊙ SB - 1	24.0	50	1.306	0.196	0.016	17.3	62.8	19.9	

GRAIN SIZE DISTRIBUTION

NORTH DAKOTA DEPARTMENT OF TRANSPORATION
300 AIRPORT ROAD
BISMARCK, ND 58504

PROJECT NUMBER NH-4-083(142)198 **LOCATION** Ward County

PCN 22048



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	BOREHOLE	DEPTH	AASHTO Classification	USCS Classification	LL	PL	PI	Cc	Cu
●	SB - 1	31.0	A-6 (11)	CL	37	15	22		
⊠	SB - 1	34.0	A-6 (9)	CL	37	16	21		
▲	SB - 1	36.0	A-6 (9)	CL	34	15	19		
★	SB - 1	39.0	A-6 (11)	CL	36	16	20		
⊙	SB - 1	41.0	A-7-6 (12)	CL	43	17	26		

	BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	SB - 1	31.0	25	0.058			3.1	33.8	63.0	
⊠	SB - 1	34.0	50	0.088	0.013		9.2	32.9	57.9	
▲	SB - 1	36.0	25	0.048			1.0	35.1	64.0	
★	SB - 1	39.0	25	0.053	0.01		1.7	32.1	66.3	
⊙	SB - 1	41.0	25	0.085			2.9	39.1	58.0	

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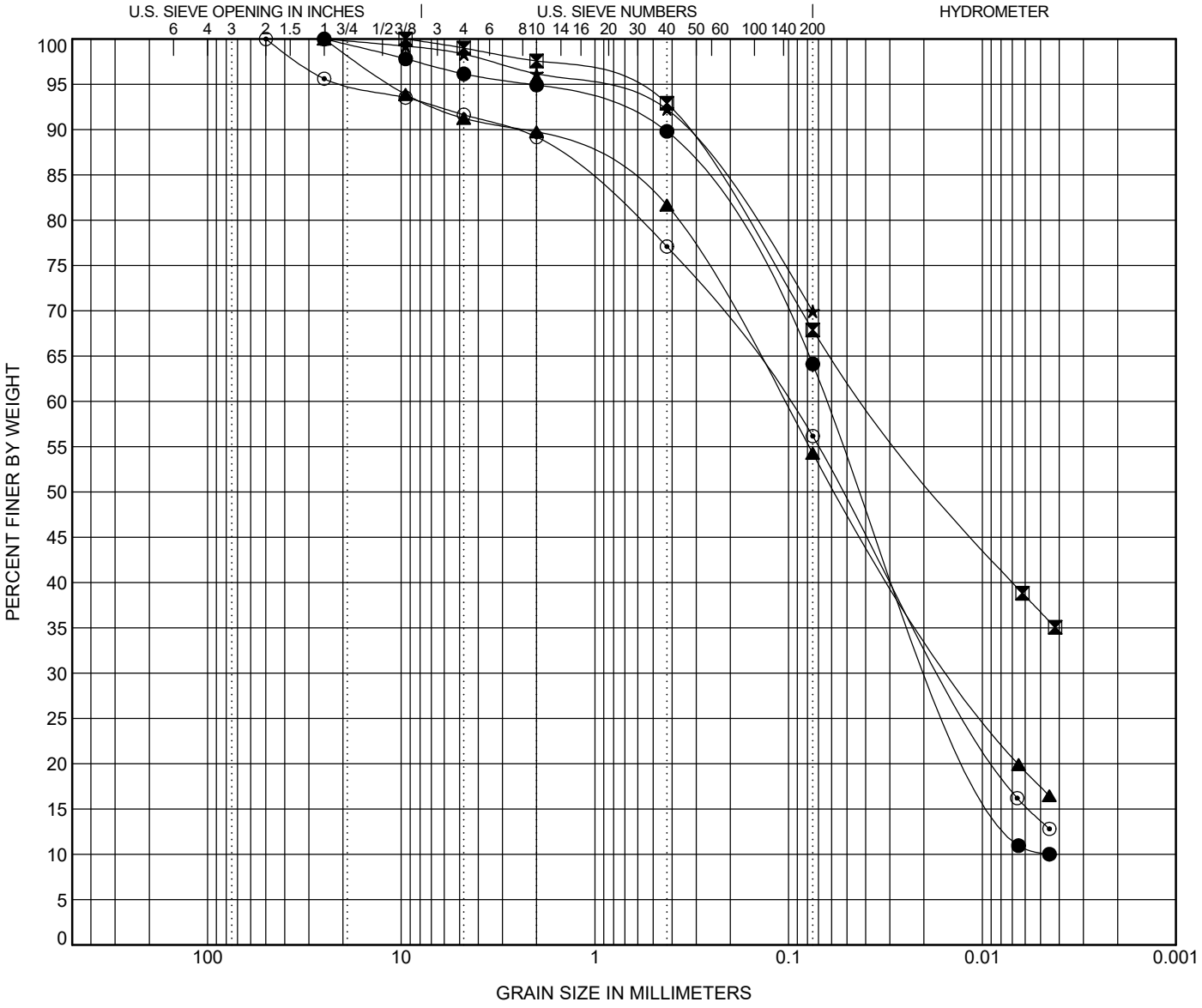
GRAIN SIZE DISTRIBUTION

NORTH DAKOTA DEPARTMENT OF TRANSPORATION
300 AIRPORT ROAD
BISMARCK, ND 58504

PROJECT NUMBER NH-4-083(142)198 **LOCATION** Ward County

PCN 22048



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

BOREHOLE	DEPTH	AASHTO Classification	USCS Classification	LL	PL	PI	Cc	Cu
● SB - 1	44.0	A-6 (11)	CL	36	15	21		
⊠ SB - 1	46.0	A-6 (9)	CL	33	16	17		
▲ SB - 1	49.0	A-6 (6)	CL	32	15	17		
★ SB - 1	51.0	A-6 (12)	CL	35	15	20		
⊙ SB - 1	54.0	A-6 (6)	CL	33	17	16		

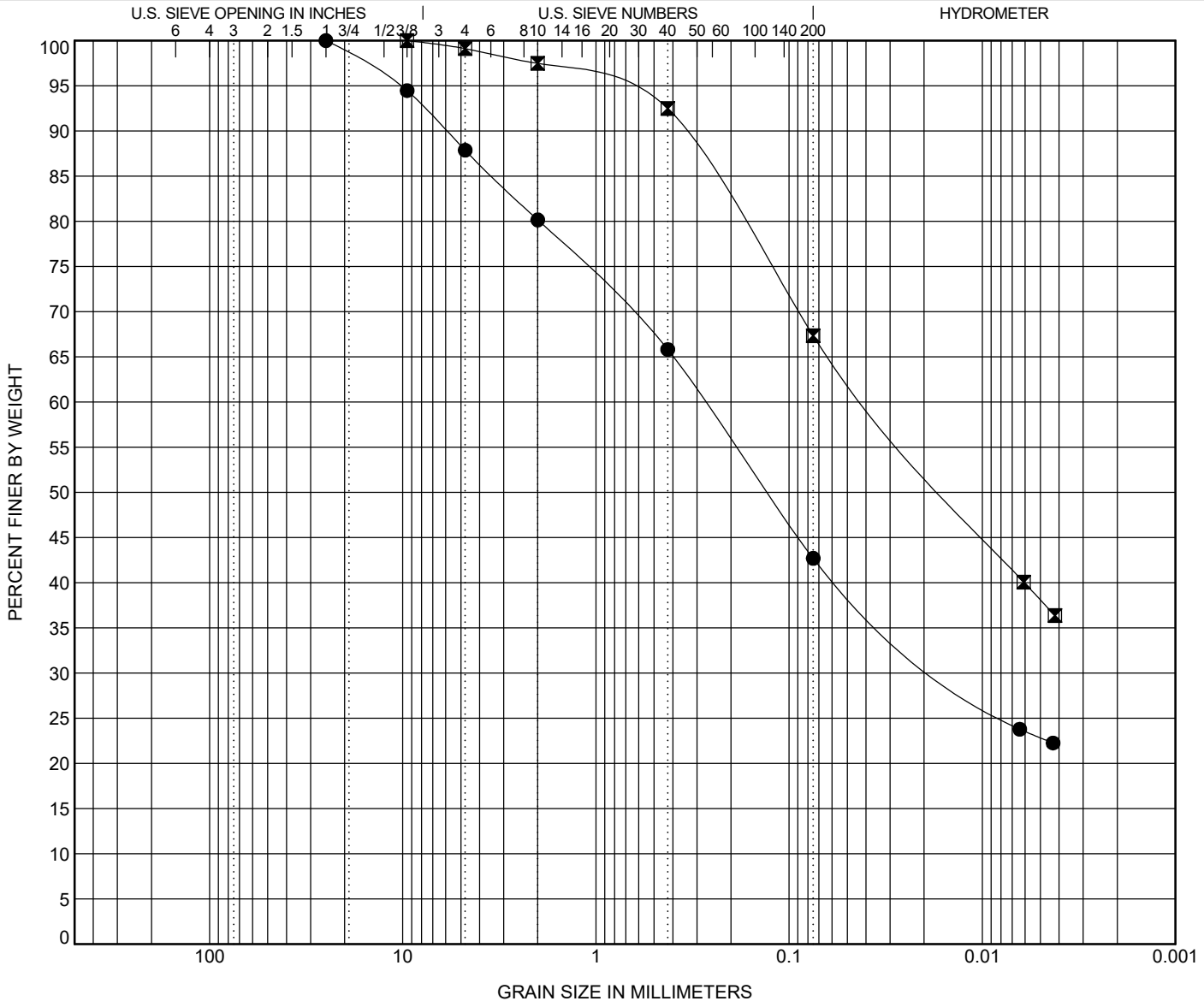
BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● SB - 1	44.0	25	0.062	0.016		3.9	32.0	64.1	
⊠ SB - 1	46.0	9.5	0.038			1.0	31.1	67.9	
▲ SB - 1	49.0	25	0.108	0.013		8.8	37.0	54.3	
★ SB - 1	51.0	25				1.7	28.4	69.9	
⊙ SB - 1	54.0	50	0.103	0.015		8.4	35.5	56.2	

GRAIN SIZE DISTRIBUTION

NORTH DAKOTA DEPARTMENT OF TRANSPORATION
300 AIRPORT ROAD
BISMARCK, ND 58504

PROJECT NUMBER NH-4-083(142)198 **LOCATION** Ward County

PCN 22048



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	BOREHOLE	DEPTH	AASHTO Classification	USCS Classification	LL	PL	PI	Cc	Cu
●	SB - 1	56.0	A-6 (3)	SC	30	15	15		
⊠	SB - 1	59.0	A-6 (10)	CL	34	15	19		

	BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	SB - 1	56.0	25	0.275	0.014		12.1	45.2	42.7	
⊠	SB - 1	59.0	9.5	0.038			0.9	31.8	67.3	

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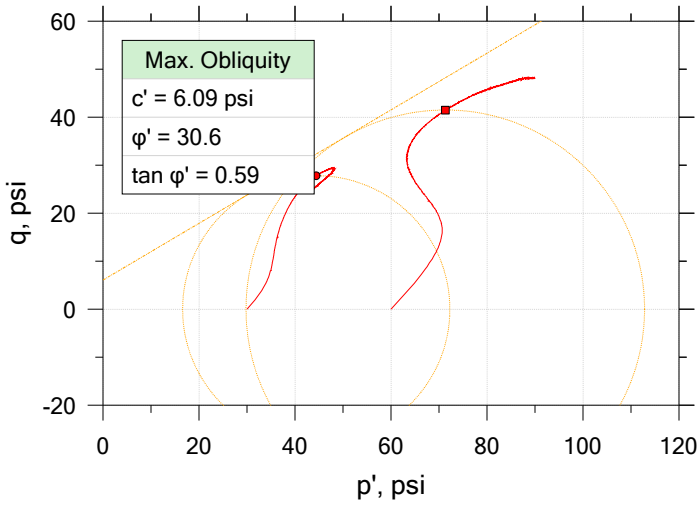
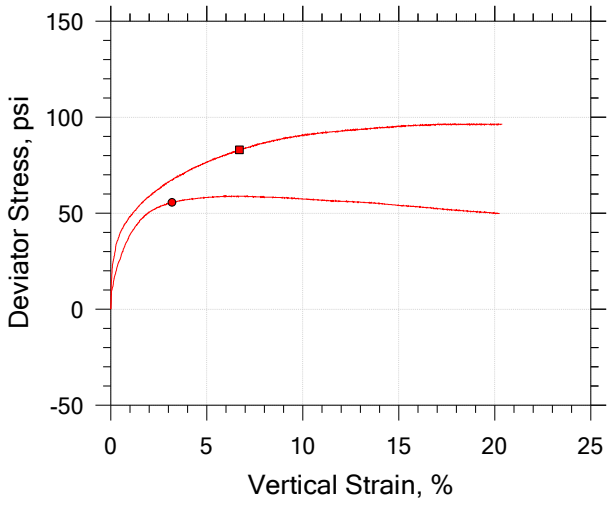
CONSOLIDATED UNDRAINED TRIAXIAL TEST by AASHTO T297



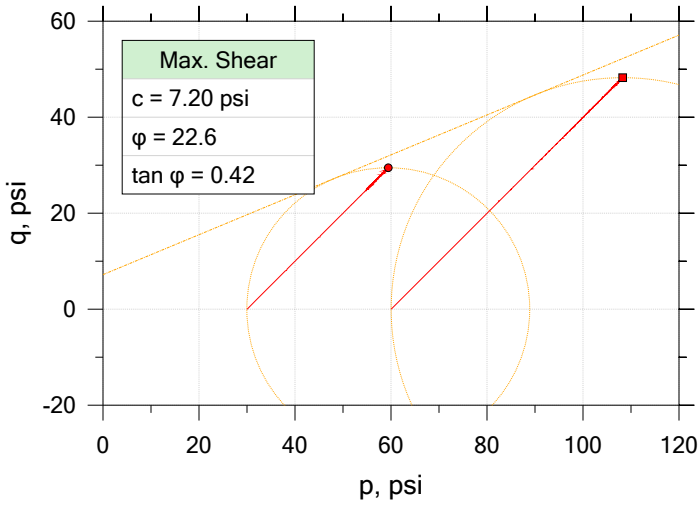


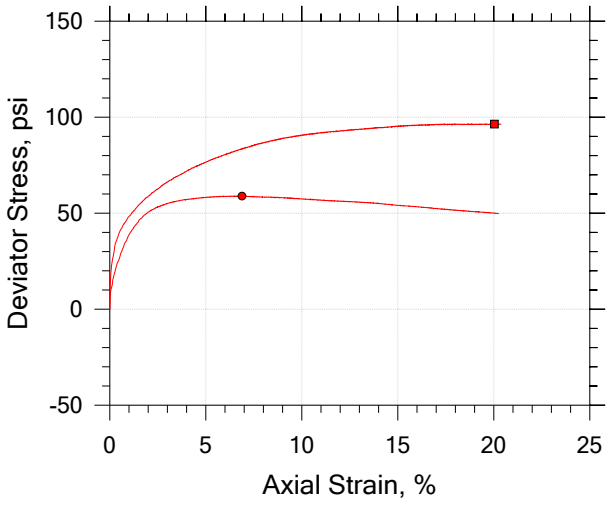
Symbol		■	●		
Sample ID		SS- 417- 24	SS- 417- 24		
Depth, ft		19.0 - 21.0	19.0 - 21.0		
Test Number		CU -28- 24	CU -29- 24		
Initial	Height, in	2.798	2.799		
	Diameter, in	1.427	1.420		
	Moisture Content (from Cuttings), %	14.6	13.1		
	Dry Density, pcf	117.	118.		
	Saturation (Wet Method), %	92.4	86.7		
	Void Ratio	0.418	0.401		
Final	Moisture Content, %	12.7	10.9		
	Dry Density, pcf	124.	128.		
	Cross-Sectional Area (Method A), in²	1.535	1.475		
	Saturation, %	100.0	100.0		
	Void Ratio	0.337	0.288		
	Back Pressure, %	73.98	38.01		
Vertical Effective Consolidation Stress, psi		59.79	29.83		
Horizontal Effective Consolidation Stress, psi		60.02	29.99		
Vertical Strain after Consolidation, %		1.971	1.093		
Volumetric Strain after Consolidation, %		6.228	7.552		
Time to 50% Consolidation, min		0.0000	0.0000		
Shear Strength, psi		41.52	27.84		
Strain at Failure, %		6.70	3.19		
Strain Rate, %/min		0.08000	0.08000		
Deviator Stress at Failure, psi		83.04	55.68		
Effective Minor Principal Stress at Failure, psi		29.79	16.57		
Effective Major Principal Stress at Failure, psi		112.8	72.25		
B-Value		0.96	0.95		

Notes:
- Before Shear Saturation set to 100% for phase calculation.
- Moisture Content determined by ASTM D2216.
- Deviator Stress includes membrane correction.
- Values for c and φ determined from best-fit straight line for the specific test conditions. Actual strength parameters may vary and should be determined by an engineer for site conditions.

	Project: NH-4-083(142)198	Location: Bismarck, ND	Project No.: Minot
	Boring No.: 1	Tested By: MD	Checked By: DT
	Sample No.: SS- 417- 24	Test Date: 8/16/2024	Depth: 19.0 - 21.0
	Test No.: CU -28- 24	Sample Type:	Elevation:
	Description: 20" Dark Brn Sandy Cly with Rocks up to 3/4"		
	Remarks: Sample Test Depth 19.4 - 19.7		

Consolidated Undrained by AASHTO T297



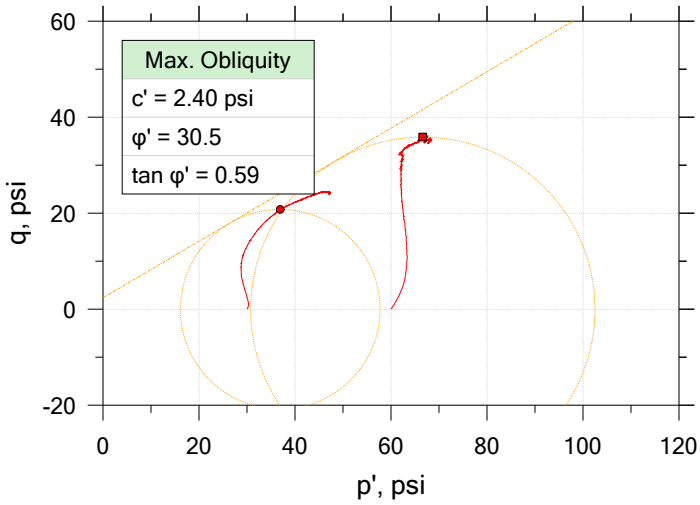


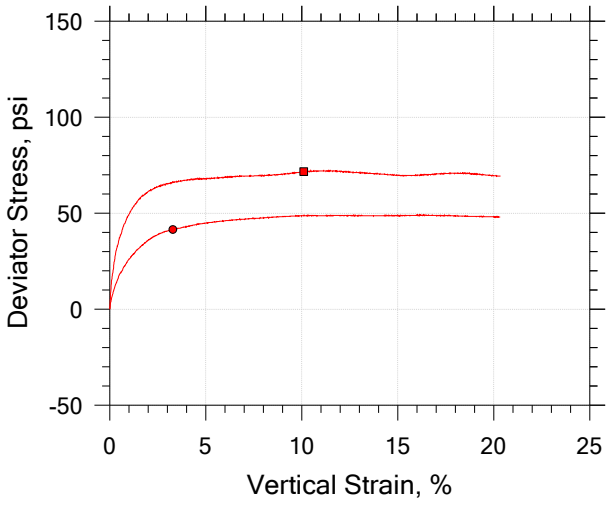
Symbol		■	●		
Sample ID		SS- 417- 24	SS- 417- 24		
Depth		19.0 - 21.0	19.0 - 21.0		
Test Number		CU -28- 24	CU -29- 24		
Initial	Height, in	2.798	2.799		
	Diameter, in	1.427	1.420		
	Moisture Content (from Cuttings), %	14.6	13.1		
	Dry Density, pcf	117.	118.		
	Saturation (Wet Method), %	92.4	86.7		
	Void Ratio	0.418	0.401		
Final	Moisture Content, %	12.7	10.9		
	Dry Density, pcf	124.	128.		
	Cross-Sectional Area (Method A), in²	1.535	1.475		
	Saturation, %	100.0	100.0		
	Void Ratio	0.337	0.288		
	Back Pressure, psi	73.98	38.01		
Vertical Effective Consolidation Stress, psi		59.79	29.84		
Horizontal Effective Consolidation Stress, psi		60.02	29.99		
Vertical Strain after Consolidation, %		1.971	1.093		
Volumetric Strain after Consolidation, %		6.228	7.552		
Time to 50% Consolidation, s		0.0000	0.0000		
Shear Strength, psi		48.23	29.48		
Strain at Failure, %		20.0	6.89		
Strain Rate, %/s		0.1333	0.1333		
Deviator Stress at Failure, psi		96.46	58.96		
Effective Minor Principal Stress at Failure, psi		41.58	18.58		
Effective Major Principal Stress at Failure, psi		138.0	77.53		
B-Value		0.96	0.95		

Notes:
- Before Shear Saturation set to 100% for phase calculation.
- Moisture Content determined by ASTM D2216.
- Deviator Stress includes membrane correction.
- Values for c and φ determined from best-fit straight line for the specific test conditions. Actual strength parameters may vary and should be determined by an engineer for site conditions.

	Project Name: NH-4-083(142)198	Location: Bismarck, ND	Project Number: Minot
	Boring Number: 1	Tester: MD	Checker: DT
	Sample Number: SS- 417- 24	Test Date: 8/16/2024	Depth: 19.0 - 21.0
	Test Number: CU -28- 24	Preparation:	Elevation:
	Description: 20" Dark Brn Sandy Cly with Rocks up to 3/4"		
	Remarks: Sample Test Depth 19.4 - 19.7		

CONSOLIDATED UNDRAINED TRIAXIAL TEST by AASHTO T297



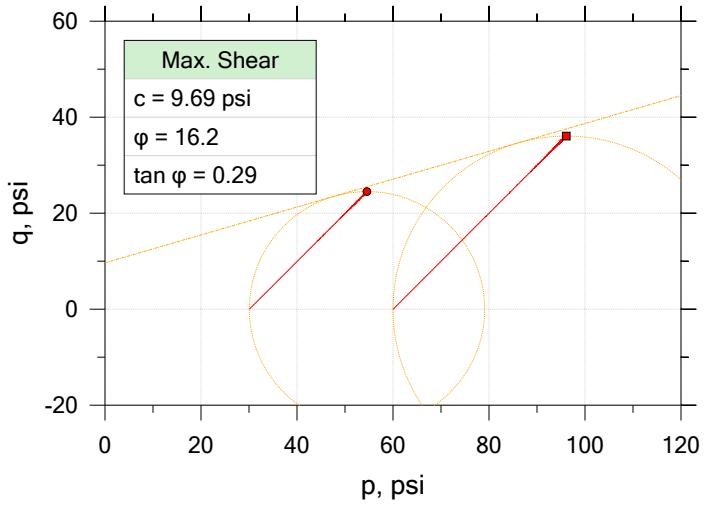


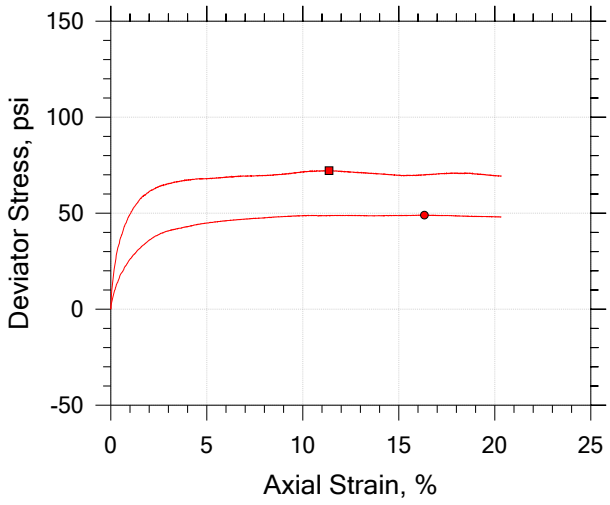
Symbol		■	●		
Sample ID		SS- 427- 24	SS- 427- 24		
Depth, ft		49.0 - 51.0	49.0 - 51.0		
Test Number		CU -32- 24	CU -33- 24		
Initial	Height, in	2.799	2.786		
	Diameter, in	1.416	1.427		
	Moisture Content (from Cuttings), %	17.5	16.7		
	Dry Density, pcf	113.	115.		
	Saturation (Wet Method), %	99.9	101.2		
	Void Ratio	0.465	0.436		
Final	Moisture Content, %	14.1	14.1		
	Dry Density, pcf	120.	121.		
	Cross-Sectional Area (Method A), in²	1.502	1.554		
	Saturation, %	100.0	100.0		
	Void Ratio	0.373	0.373		
	Back Pressure, %	116.0	117.9		
Vertical Effective Consolidation Stress, psi		59.80	29.89		
Horizontal Effective Consolidation Stress, psi		60.01	30.07		
Vertical Strain after Consolidation, %		1.564	1.456		
Volumetric Strain after Consolidation, %		5.770	3.802		
Time to 50% Consolidation, min		0.0000	0.0000		
Shear Strength, psi		35.87	20.80		
Strain at Failure, %		10.1	3.29		
Strain Rate, %/min		0.01600	0.01600		
Deviator Stress at Failure, psi		71.74	41.59		
Effective Minor Principal Stress at Failure, psi		30.75	16.11		
Effective Major Principal Stress at Failure, psi		102.5	57.70		
B-Value		0.95	0.95		

Notes:
- Before Shear Saturation set to 100% for phase calculation.
- Moisture Content determined by ASTM D2216.
- Deviator Stress includes membrane correction.
- Values for c and φ determined from best-fit straight line for the specific test conditions. Actual strength parameters may vary and should be determined by an engineer for site conditions.

	Project: NH-4-083(142)198	Location: Bismarck, ND	Project No.: Minot
	Boring No.: 1	Tested By: MD	Checked By: DT
	Sample No.: SS- 427- 24	Test Date: 8/27/2024	Depth: 49.0 - 51.0
	Test No.: CU -32- 24	Sample Type:	Elevation:
	Description: 20" Dark Gry Silty Cly with Sand Layers Rocks up to 3/4", Coal Deposits		
	Remarks: Sample Test Depth 50.6 - 50.9		

Consolidated Undrained by AASHTO T297





Symbol		■	●		
Sample ID		SS- 427- 24	SS- 427- 24		
Depth		49.0 - 51.0	49.0 - 51.0		
Test Number		CU -32- 24	CU -33- 24		
Initial	Height, in	2.799	2.786		
	Diameter, in	1.416	1.427		
	Moisture Content (from Cuttings), %	17.5	16.7		
	Dry Density, pcf	113.	115.		
	Saturation (Wet Method), %	99.9	101.2		
	Void Ratio	0.465	0.436		
Final	Moisture Content, %	14.1	14.1		
	Dry Density, pcf	120.	121.		
	Cross-Sectional Area (Method A), in²	1.502	1.554		
	Saturation, %	100.0	100.0		
	Void Ratio	0.373	0.373		
	Back Pressure, psi	116.0	117.9		
Vertical Effective Consolidation Stress, psi		59.80	29.89		
Horizontal Effective Consolidation Stress, psi		60.01	30.07		
Vertical Strain after Consolidation, %		1.564	1.456		
Volumetric Strain after Consolidation, %		5.770	3.802		
Time to 50% Consolidation, min		0.0000	0.0000		
Shear Strength, psi		36.08	24.51		
Strain at Failure, %		11.4	16.3		
Strain Rate, %/min		1.600	1.600		
Deviator Stress at Failure, psi		72.15	49.02		
Effective Minor Principal Stress at Failure, psi		31.27	22.52		
Effective Major Principal Stress at Failure, psi		103.4	71.54		
B-Value		0.95	0.95		

Notes:
- Before Shear Saturation set to 100% for phase calculation.
- Moisture Content determined by ASTM D2216.
- Deviator Stress includes membrane correction.
- Values for c and φ determined from best-fit straight line for the specific test conditions. Actual strength parameters may vary and should be determined by an engineer for site conditions.

	Project Name: NH-4-083(142)198	Location: Bismarck, ND	Project Number: Minot
	Boring Number: 1	Tester: MD	Checker: DT
	Sample Number: SS- 427- 24	Test Date: 8/27/2024	Depth: 49.0 - 51.0
	Test Number: CU -32- 24	Preparation:	Elevation:
	Description: 20" Dark Gry Silty Cly with Sand Layers Rocks up to 3/4", Coal Deposits		
	Remarks: Sample Test Depth 50.6 - 50.9		