CTL Engineering, Inc.
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e-mail: ctlwv@ctleng.com

March 27, 2025

ODOT District 11
2201 Reiser Avenue
New Philadelphia, Ohio 44663

Attention: Ms. Adrienne N. Slanina, P.E.
Consultant Contract Manager

Reference: Roadway Exploration – Final Submittal
PID No. 119710
Agreement No. 39773
Task Order No. 11-D
BEL-40-23.37, PID 114388
Belmont County, Ohio
CTL Project No. 24050050MOR

Dear Ms. Slanina

CTL Engineering, Inc. has completed the field and laboratory testing for the above referenced project. The following information is attached to this letter. We are also submitting spreadsheets with scour calculations separately.

- Typed Boring Log
- Mechanical Soil Classification Testing
- Rock Core Slake Durability
- Rock Core Uniaxial Compressive Strength
- Rock Core Photos
- Scour Data – Soil
- Scour Data - Bedrock

Exploration

The test boring was drilled on December 30 and December 31, 2024, utilizing 3-¼ inch I.D. hollow-stem augers powered by a Mobile B-57 track-mounted drill rig. Split-spoon samples and Standard Penetration Tests (SPTs) were performed in the test borings using a 140-pound automatic hammer falling 30 inches to drive a 2-inch O.D. split barrel sampler for 18 inches. The automatic hammer was calibrated at an energy ratio of 79.3 percent on May 3, 2023.

Upon encountering auger refusal, the boring was further advanced into bedrock utilizing rock core sampling techniques and an NX size double tube core barrel with a diamond bit.

The test boring was staked in the field by ODOT Dist. 11 personnel. The test boring was drilled at the location shown in the following table.

Borehole	Location Description	Latitude	Longitude
B-001-0-24	East of bridge	40.066709	-80.820546

The recovered split spoon samples obtained during the drilling operations were preserved in glass jars, visually classified in the field and laboratory, and tested for moisture content. Representative samples were subjected to laboratory testing including Atterberg Limits, grain size distribution, and hand penetrometer.

The recovered rock core samples obtained during the drilling operations were preserved in core boxes, visually classified in the field and laboratory, and suitable representative rock core samples were tested for compressive strength and slake durability.

We appreciate the opportunity to be of service to you on this project. If you have any questions, please contact us.

Respectfully submitted,

CTL Engineering, Inc.

Sastry Malladi, P.E.
Project Engineer

Joe Grani, P.E.
Project Engineer

cc: Mr. Cody Notz, P.E. (via email)

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 3/25/25 09:43 - O:\PROJECT\2024\MOR-05\24050050MOR_OHIO DEPARTMENT OF TRANSPORTATION_BEL-40-23-37 PID 114388

PROJECT: BEL-40-23.37	DRILLING FIRM / OPERATOR: CTL / HB	DRILL RIG: MOBILE B-57 #513	STATION / OFFSET: 205+80, 1' LT.	EXPLORATION ID B-001-0-24
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: CTL / HB	HAMMER: MOBILE AUTOMATIC	ALIGNMENT:	
PID: 114388 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 5/3/23	ELEVATION: 716.7 (MSL) EOB: 46.0 ft.	PAGE 1 OF 2
START: 12/30/24 END: 12/31/24	SAMPLING METHOD: SPT	ENERGY RATIO (%): 76.8	LAT / LONG: 40.066709, -80.820546	

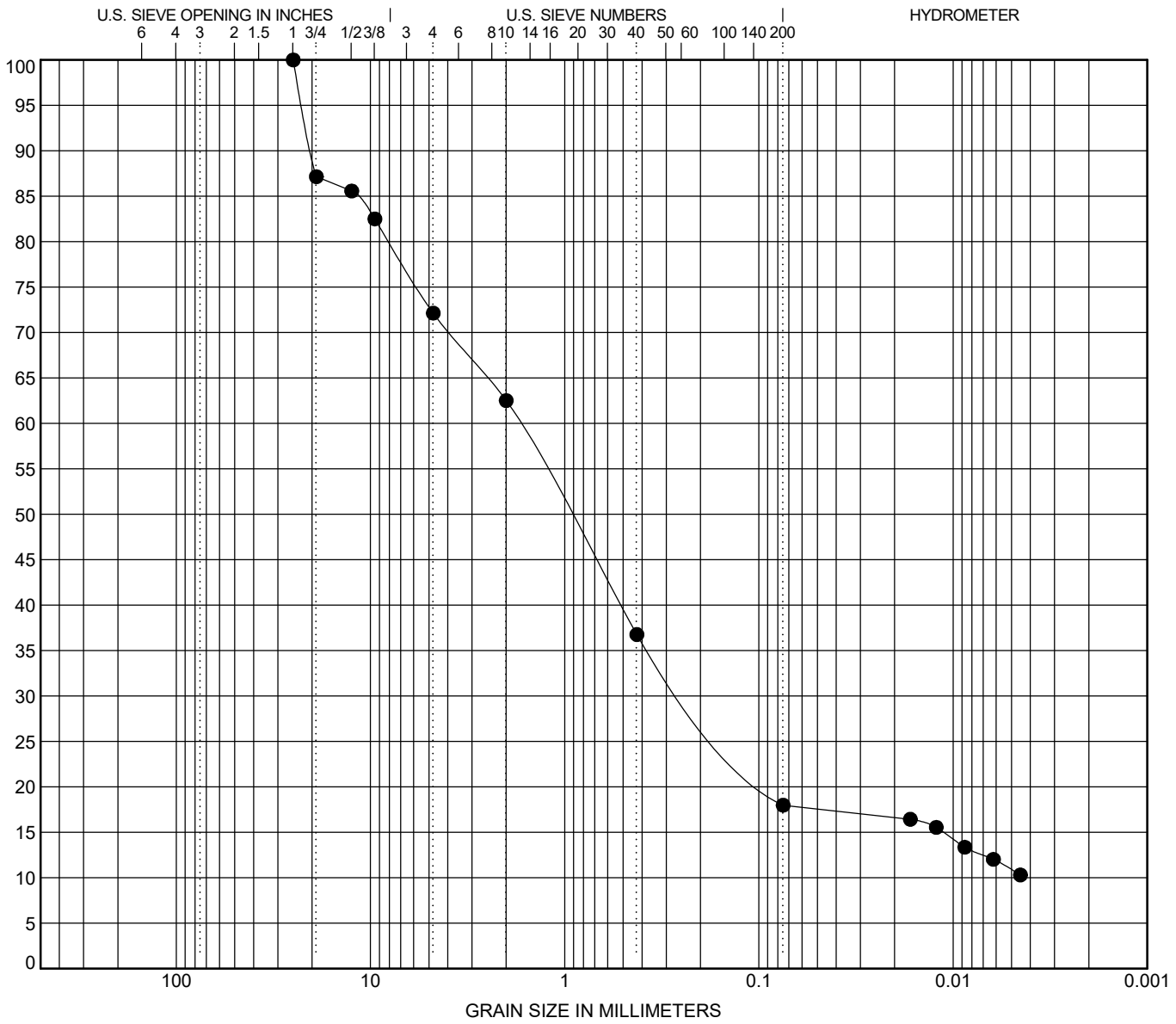
MATERIAL DESCRIPTION AND NOTES	ELEV. 716.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	ABAN-DONED
DENSE, GRAY, **GRAVEL AND/OR STONE FRAGMENTS WITH SAND**, LITTLE CLAY, TRACE SILT, FILL, DAMP		1	19 16 15	40	100	SS-1	1.50	37	26	19	7	11	NP	NP	NP	13	A-1-b (0)	
@1.5'; MEDIUM DENSE, TRACE CLAY		2	12 11 12	29	100	SS-2	-	34	28	20	8	10	NP	NP	NP	12	A-1-b (0)	
@ 3.0'; CONTAINS PIECES OF CONCRETE		3 4	7 7 8	19	100	SS-3	-	-	-	-	-	-	-	-	-	-	A-1-b (V)	
@ 4.5'; LITTLE CLAY		5 6	5 7 9	20	100	SS-4	-	41	21	16	10	12	NP	NP	NP	10	A-1-b (0)	
	710.7																	
MEDIUM DENSE, GRAY, **GRAVEL AND/OR STONE FRAGMENTS WITH SAND**, LITTLE SILT, LITTLE CLAY, DAMP		7	6 6 5	14	100	SS-5	1.00	28	22	26	12	12	NP	NP	NP	12	A-1-b (0)	
@ 7.5'; TRACE SILT, TRACE CLAY		8	5 7 8	19	100	SS-6	2.00	51	17	13	10	9	NP	NP	NP	17	A-1-b (0)	
@ 9.0'; LITTLE CLAY		9 10	6 7 9	20	100	SS-7	-	53	13	13	9	12	NP	NP	NP	17	A-1-b (0)	
	706.2																	
VERY STIFF, GRAY, **SILT AND CLAY**, SOME SAND, SOME GRAVEL, DAMP	704.7	W 704.7 11 12	7 7 9	20	100	SS-8	3.00	27	19	16	17	21	32	20	12	16	A-6a (1)	
HARD, GRAY, **SILTY CLAY**, SOME SAND, SOME GRAVEL, DAMP	703.2	13	7 8 11	24	100	SS-9	4.50	24	12	15	19	30	40	20	20	13	A-6b (6)	
DENSE, GRAY, **GRAVEL AND/OR STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, DAMP	701.7	14 15	10 12 14	33	100	SS-10	1.50	41	14	16	14	15	28	16	12	15	A-2-6 (0)	
MEDIUM DENSE, GRAY, **SANDY SILT**, LITTLE CLAY, LITTLE GRAVEL	700.2	TR 16	8 9 12	27	100	SS-11	-	13	8	25	39	15	NP	NP	NP	7	A-4a (4)	
CLAYSTONE, BROWN, SEVERELY WEATHERED.		17	9 12 15	35	100	SS-12	1.50	-	-	-	-	-	-	-	-	10	Rock (V)	
		18 19	12 16 16	41	100	SS-13	2.50	-	-	-	-	-	-	-	-	8	Rock (V)	
	695.7	20	19 50/2"	-	25	SS-14	-	-	-	-	-	-	-	-	-	10	Rock (V)	
SHALE, GRAY, HIGHLY WEATHERED, SLIGHTLY STRONG; RQD 28%, REC 71%. @21.0' to 26.0'; I_{d2} = 94.2%		21 22 23 24 25	0		50	NQ2-1											CORE	
@26.0' to 31.0'; I_{d2} = 89.6%		26 27 28 29	0		55	NQ2-2											CORE	

PID: 114388	SFN:	PROJECT: BEL-40-23.37	STATION / OFFSET: 205+80, 1' LT.	START: 12/30/24	END: 12/31/24	PG 2 OF 2	B-001-0-24

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	ABAN-DONED
SHALE, GRAY, HIGHLY WEATHERED, SLIGHTLY STRONG; RQD 28%, REC 71%. *(continued)* @ 31.0'; Moderately Weathered @ 31.0' to 36.0'; I_{d2} = 95.1% @32.3' to 32.8'; Q_u = 2,380 psi	686.7	31	72		100	NQ2-3											CORE	
@ 36.4' to 36.9'; Q_u = 2,790 psi	679.3	36																
CLAYSTONE, BROWN AND GRAY, HIGHLY WEATHERED, WEAK TO SLIGHTLY STRONG; RQD 31%, REC 100%.		36	27		100	NQ2-4											CORE	
@ 44.1' to 44.5'; Q_u = 1,620 psi	670.7	41	47		100	NQ2-5											CORE	
		EOB 46																

NOTES: CAVED AT 7'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: GROUT



COBBLES	GRAVEL		SAND		SILT OR CLAY
	coarse	fine	coarse	fine	

Specimen Identification	Depth	Classification	MC	LL	PL	PI	Cc	Cu
B-001-0-24	**0.0**	**A-1-b(0)**	**13**	**NP**	**NP**	**NP**		

Specimen Identification	Depth	D100	D60	D50	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
B-001-0-24	**0.0**	**25**	**1.719**	**0.942**	**0.228**		**37**	**26**	**19**	**7**	**11**

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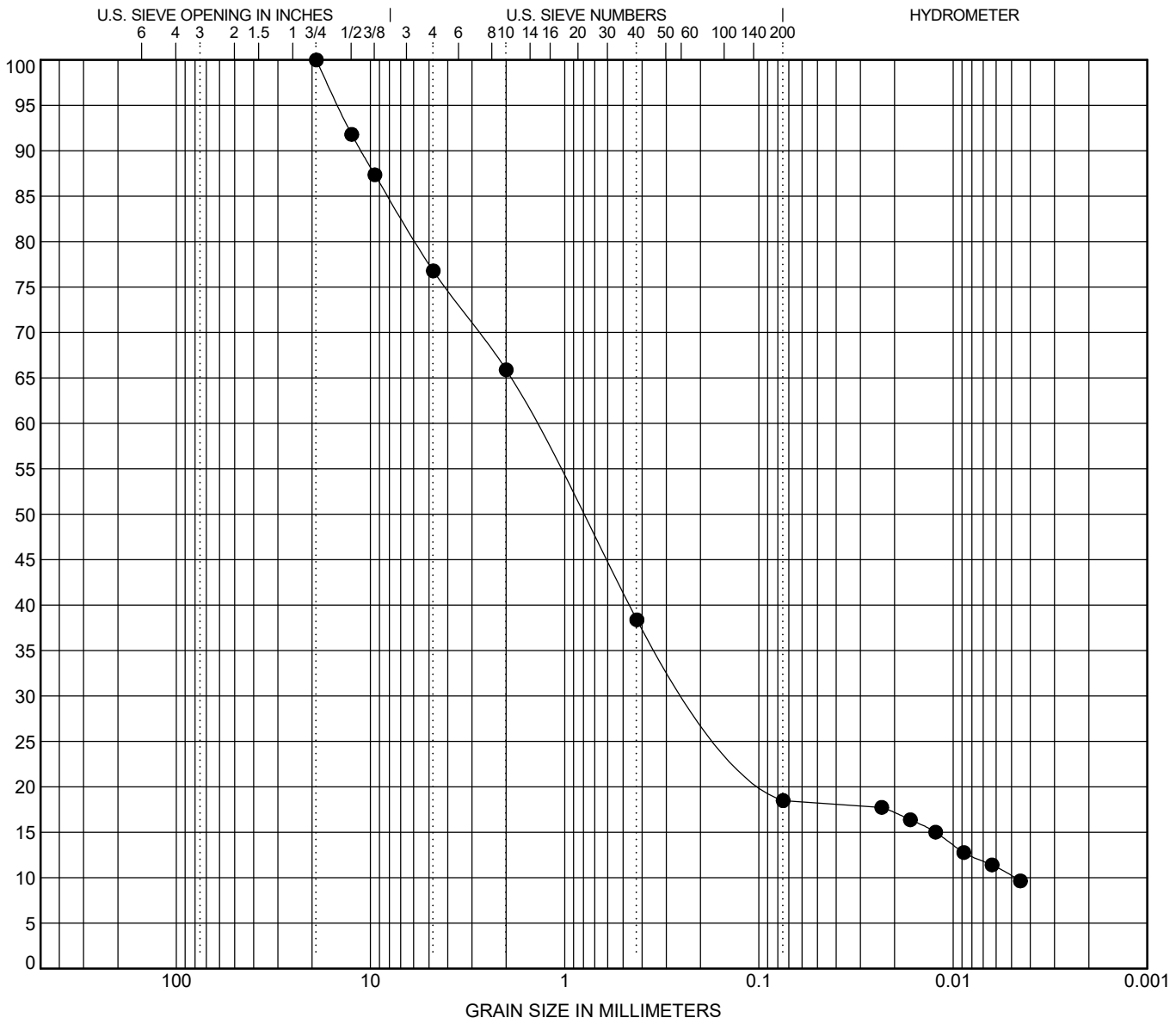
GRAIN SIZE DISTRIBUTION

Project: BEL-40-23.37
Location:BEL COUNTY
CTL Project Number:



COBBLES	GRAVEL		SAND		SILT OR CLAY
	coarse	fine	coarse	fine	

Specimen Identification	Depth	Classification	MC	LL	PL	PI	Cc	Cu
B-001-0-24	**1.5**	**A-1-b(0)**	**12**	**NP**	**NP**	**NP**	**6.06**	**298.29**

Specimen Identification	Depth	D100	D60	D50	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
B-001-0-24	**1.5**	**19**	**1.435**	**0.817**	**0.205**	**0.005**	**34**	**28**	**20**	**8**	**10**

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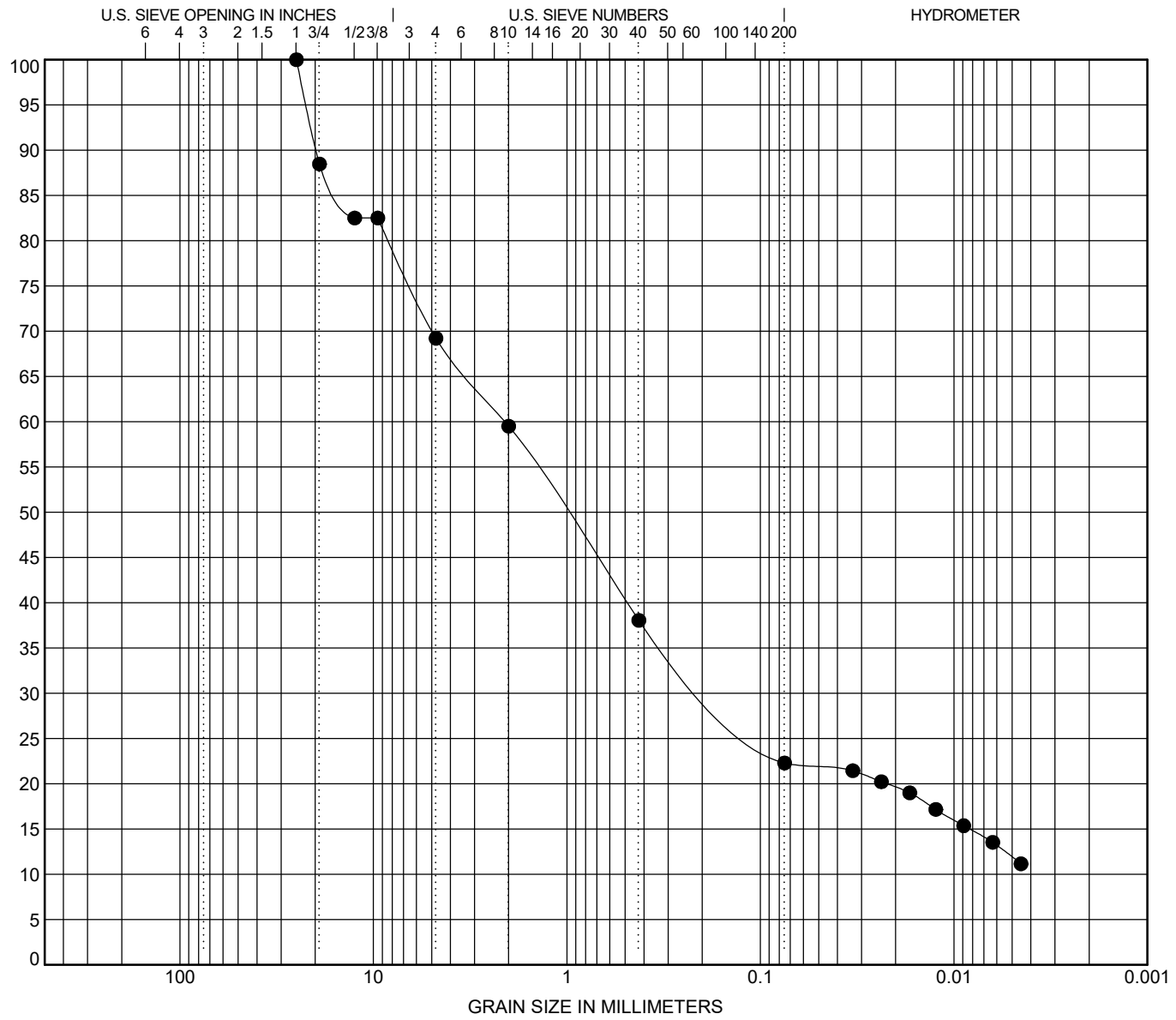

COBBLES	GRAVEL		SAND		SILT OR CLAY
	coarse	fine	coarse	fine	

Specimen Identification	Depth	Classification	MC	LL	PL	PI	Cc	Cu
B-001-0-24	**4.5**	**A-1-b(0)**	**10**	**NP**	**NP**	**NP**		

Specimen Identification	Depth	D100	D60	D50	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
B-001-0-24	**4.5**	**25**	**2.089**	**1.007**	**0.175**		**41**	**21**	**16**	**10**	**12**

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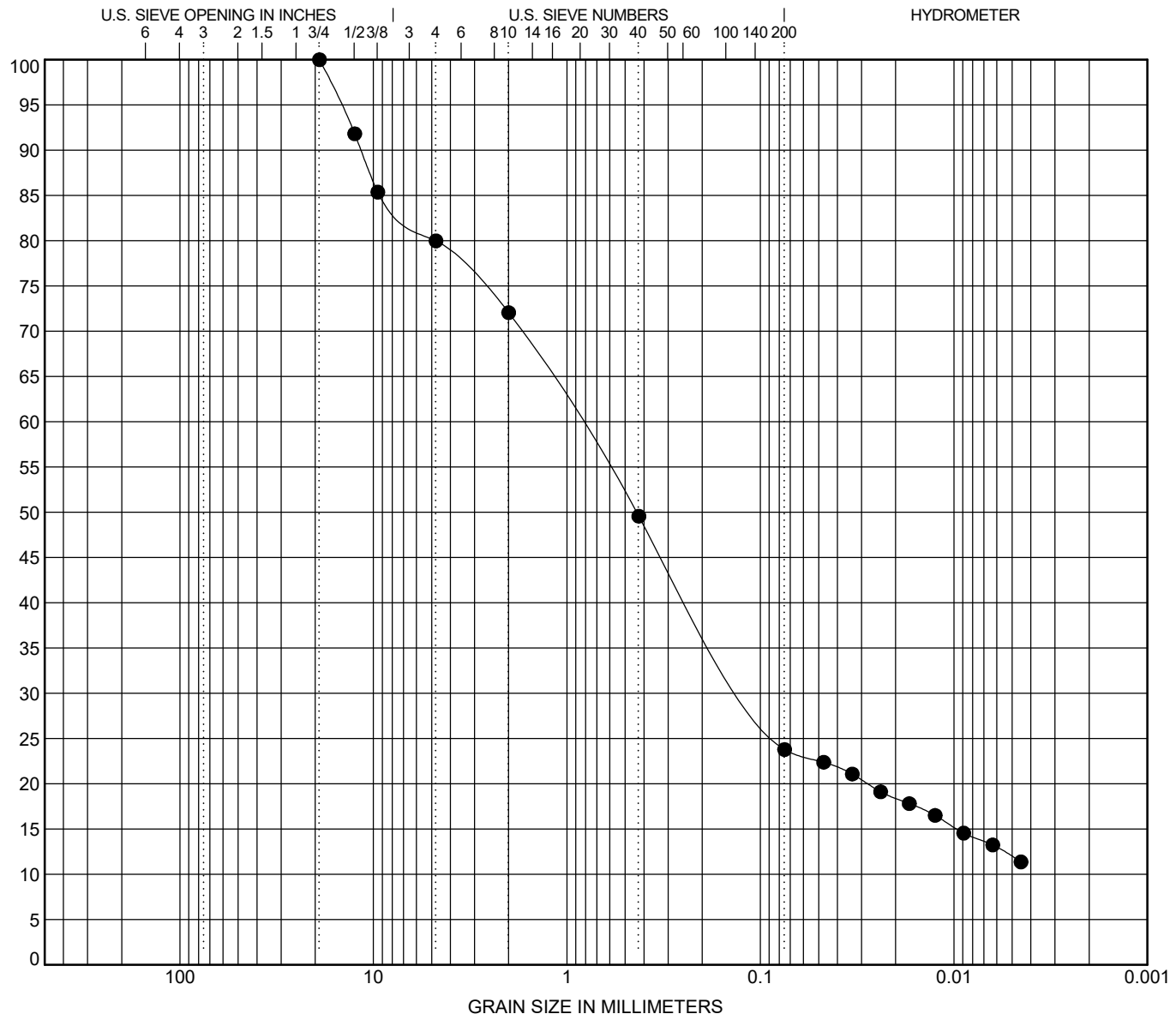

COBBLES	GRAVEL		SAND		SILT OR CLAY
	coarse	fine	coarse	fine	

Specimen Identification	Depth	Classification	MC	LL	PL	PI	Cc	Cu
B-001-0-24	**6.0**	**A-1-b(0)**	**12**	**NP**	**NP**	**NP**		

Specimen Identification	Depth	D100	D60	D50	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
B-001-0-24	**6.0**	**19**	**0.872**	**0.438**	**0.114**		**28**	**22**	**26**	**12**	**12**

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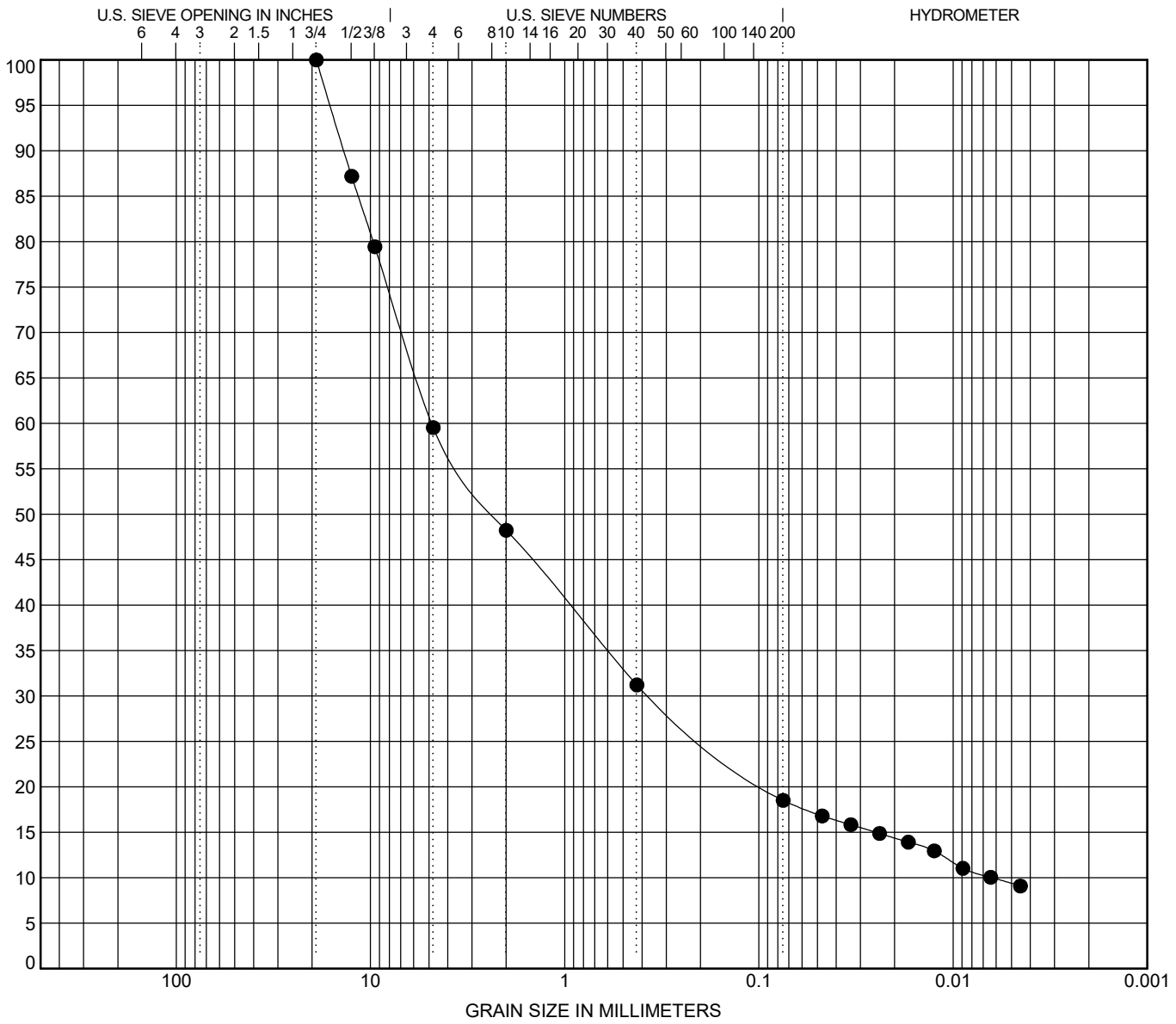

COBBLES	GRAVEL		SAND		SILT OR CLAY
	coarse	fine	coarse	fine	

Specimen Identification	Depth	Classification	MC	LL	PL	PI	Cc	Cu
B-001-0-24	**7.5**	**A-1-b(0)**	**17**	**NP**	**NP**	**NP**	**4.27**	**767.73**

Specimen Identification	Depth	D100	D60	D50	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
B-001-0-24	**7.5**	**19**	**4.827**	**2.29**	**0.36**	**0.006**	**51**	**17**	**13**	**10**	**9**

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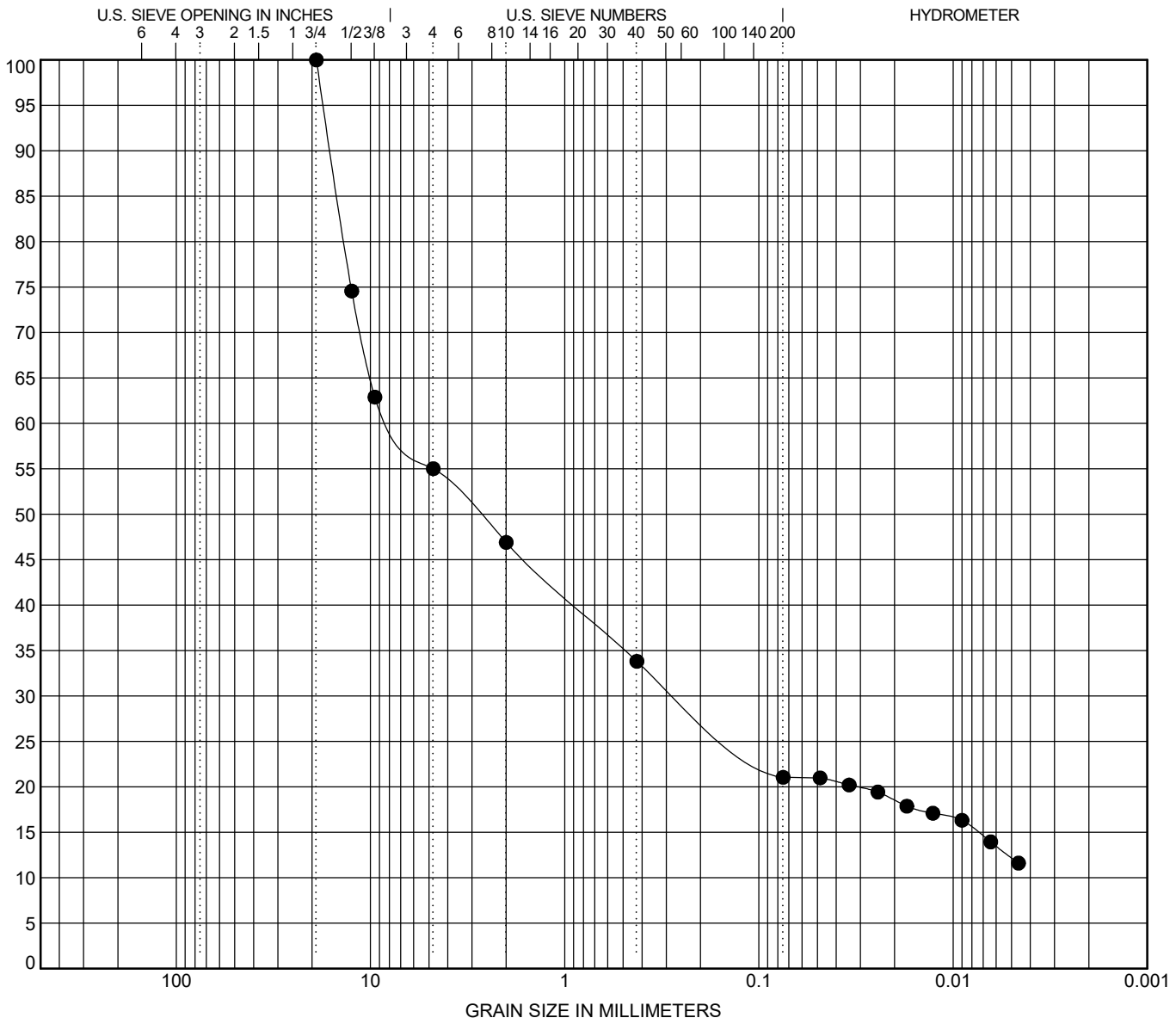

COBBLES	GRAVEL		SAND		SILT OR CLAY
	coarse	fine	coarse	fine	

Specimen Identification	Depth	Classification	MC	LL	PL	PI	Cc	Cu
B-001-0-24	**9.0**	**A-1-b(0)**	**17**	**NP**	**NP**	**NP**		

Specimen Identification	Depth	D100	D60	D50	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
B-001-0-24	**9.0**	**19**	**7.367**	**2.783**	**0.253**		**53**	**13**	**13**	**9**	**12**

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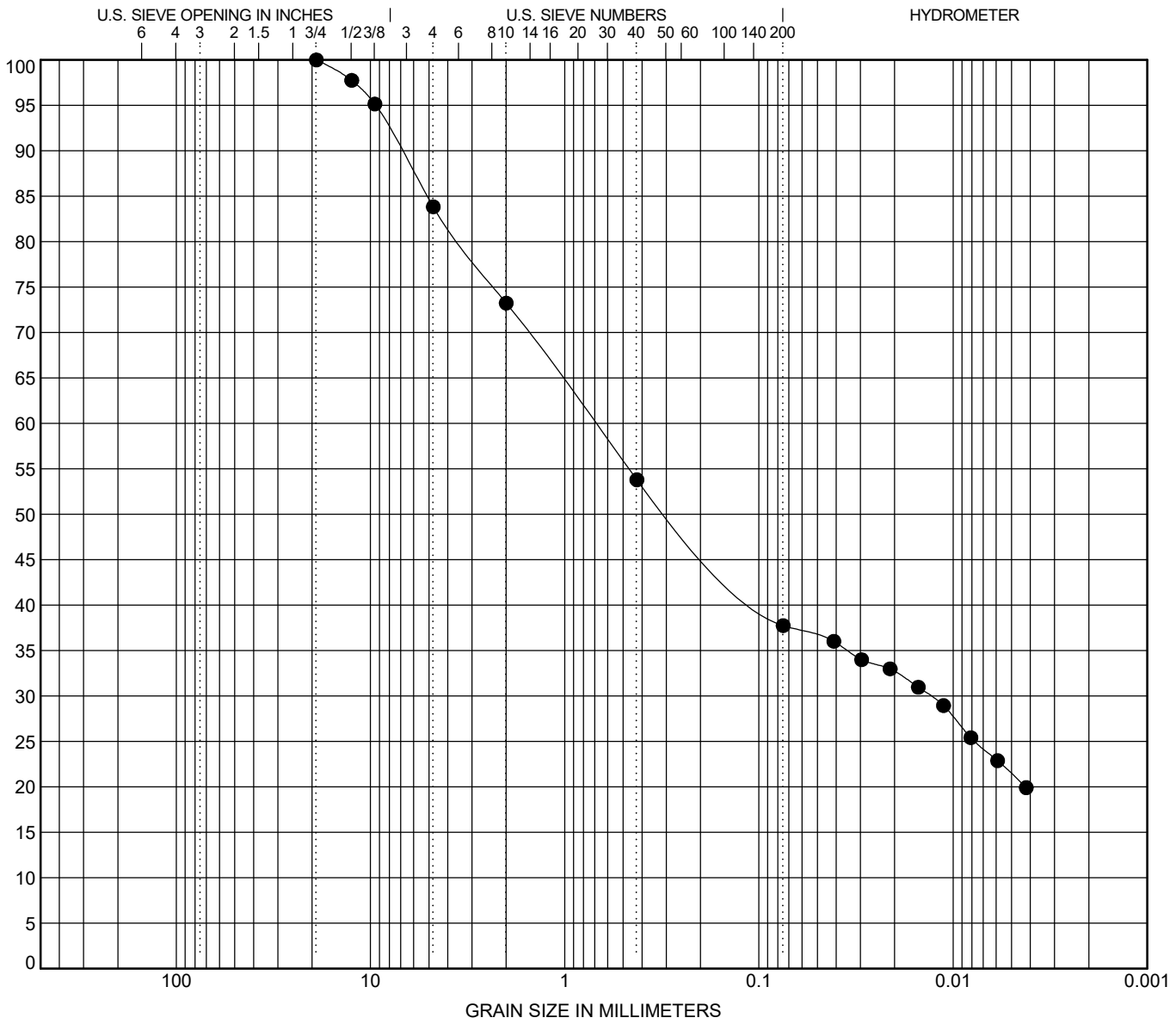

COBBLES	GRAVEL		SAND		SILT OR CLAY
	coarse	fine	coarse	fine	

Specimen Identification	Depth	Classification	MC	LL	PL	PI	Cc	Cu
B-001-0-24	**10.5**	**A-6a(1)**	**16**	**32**	**20**	**12**		

Specimen Identification	Depth	D100	D60	D50	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
B-001-0-24	**10.5**	**19**	**0.697**	**0.282**	**0.013**		**27**	**19**	**16**	**17**	**21**

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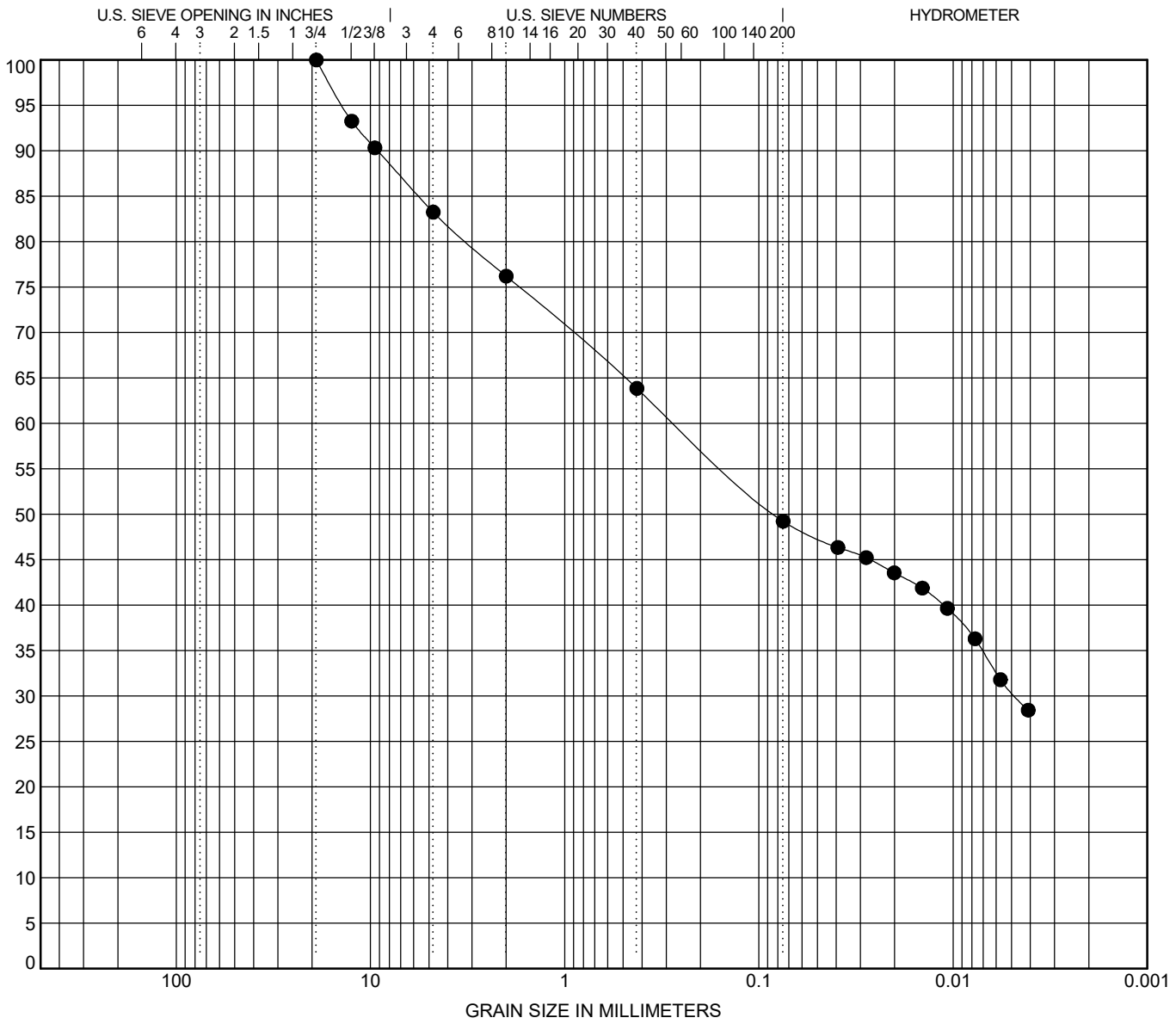

COBBLES	GRAVEL		SAND		SILT OR CLAY
	coarse	fine	coarse	fine	

Specimen Identification	Depth	Classification	MC	LL	PL	PI	Cc	Cu
B-001-0-24	**12.0**	**A-6b(6)**	**13**	**40**	**20**	**20**		

Specimen Identification	Depth	D100	D60	D50	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
B-001-0-24	**12.0**	**19**	**0.269**	**0.082**	**0.005**		**24**	**12**	**15**	**19**	**30**

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GRAIN SIZE DISTRIBUTION

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Location:BEL COUNTY
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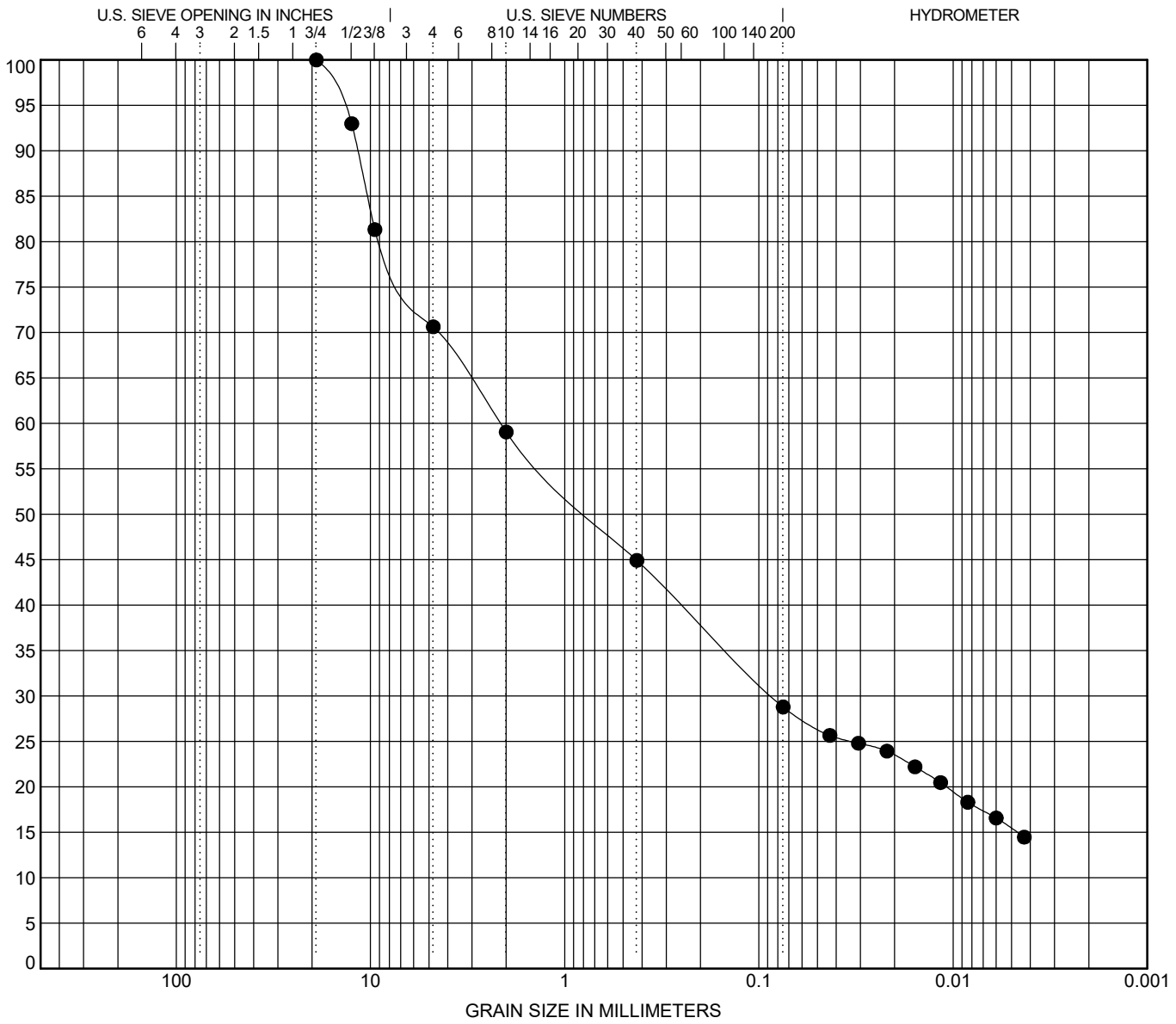

COBBLES	GRAVEL		SAND		SILT OR CLAY
	coarse	fine	coarse	fine	

Specimen Identification	Depth	Classification	MC	LL	PL	PI	Cc	Cu
B-001-0-24	**13.5**	**A-2-6(0)**	**15**	**28**	**16**	**12**		

Specimen Identification	Depth	D100	D60	D50	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
B-001-0-24	**13.5**	**19**	**2.148**	**0.742**	**0.085**		**41**	**14**	**16**	**14**	**15**

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Location:BEL COUNTY
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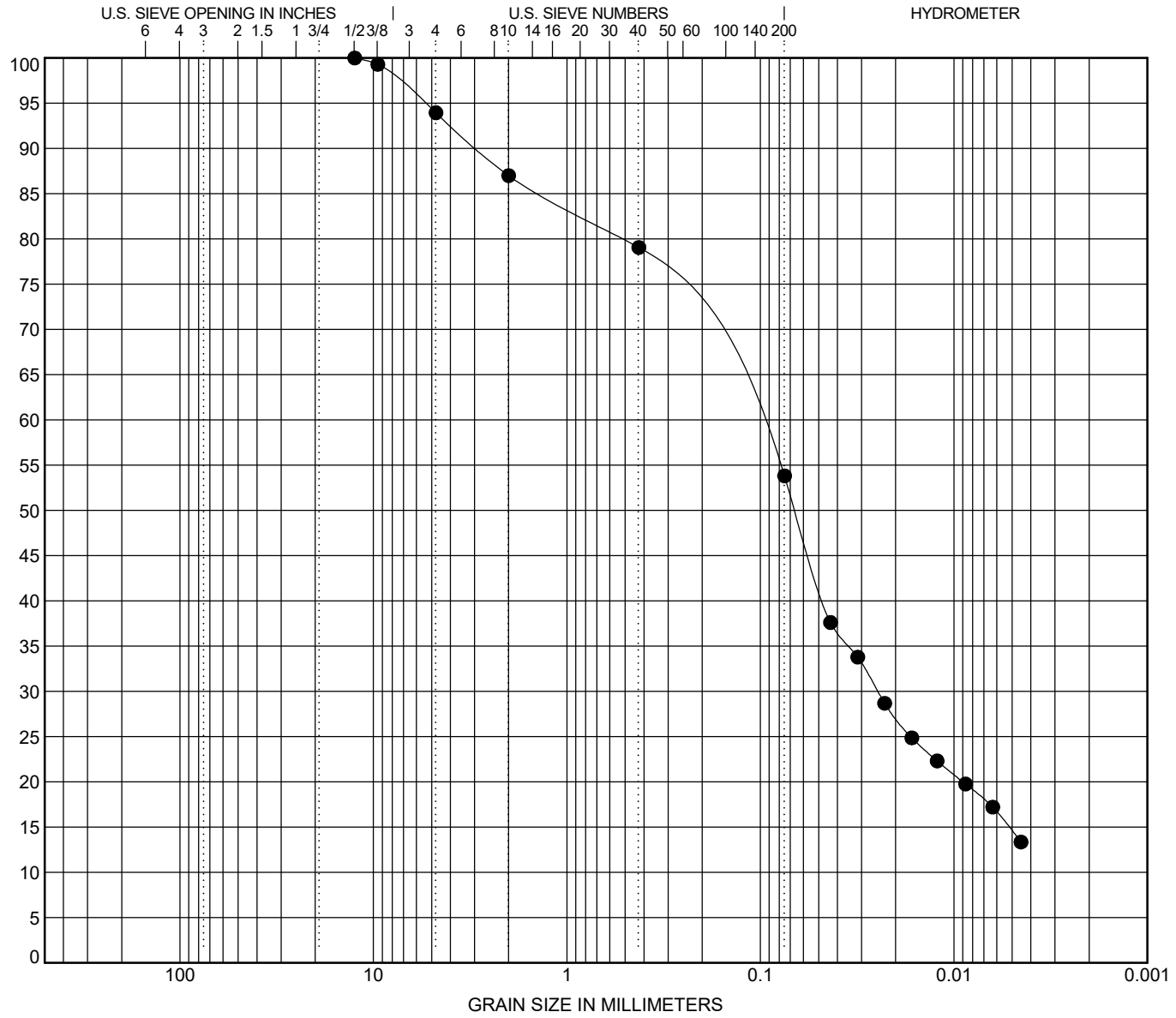

COBBLES	GRAVEL		SAND		SILT OR CLAY
	coarse	fine	coarse	fine	

Specimen Identification	Depth	Classification	MC	LL	PL	PI	Cc	Cu
B-001-0-24	**15.0**	**A-4a(0)**	**7**	**NP**	**NP**	**NP**		

Specimen Identification	Depth	D100	D60	D50	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
B-001-0-24	**15.0**	**12.5**	**0.115**	**0.066**	**0.025**		**13**	**8**	**25**	**39**	**15**

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GRAIN SIZE DISTRIBUTION

Project: BEL-40-23.37
Location:BEL COUNTY
CTL Project Number:

Slake Durability of Shales and Similar Weak Rocks **ASTM D 4644**	**CTL ENGINEERING, INC.** 2860 Fisher Road Columbus, Ohio 43204
Sample ID: B-001-0-24, NQ2-1, 21.0'-26.0' Sample Description: Shale, Gray Slake Durability Index (%): 94.2 (second cycle) Moisture Content (%): 1.8 Temperature Range (°C): 18.4-20.8 Temperature Average (°C): 19.6	Client: Ohio Department of Transportation Project: BEL-40-23.37, PID 114388 Project No. 24050050MOR Lab Code. 25050700COL Date Tested: 1/23/2025 Reviewed by: JG

Pre-Test Sample

Post Test Sample

Remarks:

Post Test Sample Description : Type II—Retained specimen consist of large and small fragments.

Slake Durability of Shales and Similar Weak Rocks **ASTM D 4644**	**CTL ENGINEERING, INC.** 2860 Fisher Road Columbus, Ohio 43204
Sample ID: B-001-0-24, NQ2-2, 26.0'-31.0' Sample Description: Shale, Gray Slake Durability Index (%): 89.6 (second cycle) Moisture Content (%): 2.2 Temperature Range (°C): 18.3-18.7 Temperature Average (°C): 18.5	Client: Ohio Department of Transportation Project: BEL-40-23.37, PID 114388 Project No. 24050050MOR Lab Code. 25050700COL Date Tested: 1/23/2025 Reviewed by: JG

Pre-Test Sample

Post Test Sample

Remarks:

Post Test Sample Description : Type II—Retained specimen consist of large and small fragments.

Slake Durability of Shales and Similar Weak Rocks **ASTM D 4644**	**CTL ENGINEERING, INC.** 2860 Fisher Road Columbus, Ohio 43204
Sample ID: B-001-0-24, NQ2-3, 31.0'-36.0' Sample Description: Shale, Gray Slake Durability Index (%): 95.1 (second cycle) Moisture Content (%): 2.2 Temperature Range (°C): 18.9-20.7 Temperature Average (°C): 19.8	Client: Ohio Department of Transportation Project: BEL-40-23.37, PID 114388 Project No. 24050050MOR Lab Code. 25050700COL Date Tested: 1/23/2025 Reviewed by: JG

Pre-Test Sample

Post Test Sample

Remarks:

Post Test Sample Description : Type II—Retained specimen consist of large and small fragments.

PROJECT NO:	24050050MOR
DATE:	2/11/2025

UNIAXIAL COMPRESSIVE STRENGTH OF INTACT ROCK CORE - ASTM D 7012

Method C

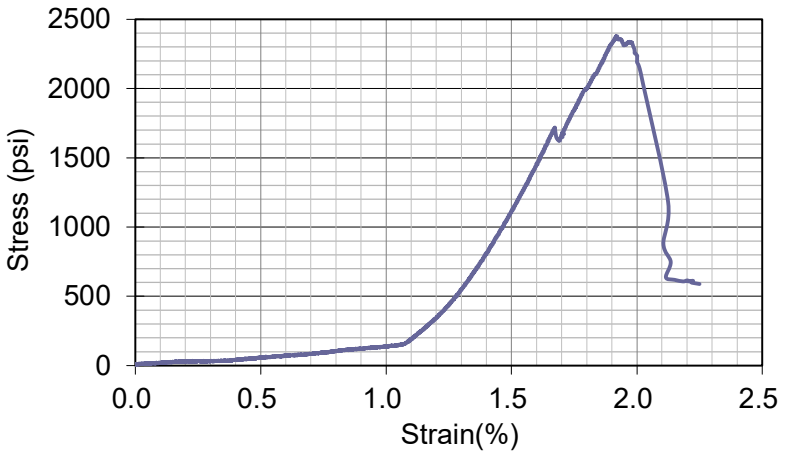
BORING NUMBER	B-001-0-24	TOP DEPTH(FT)	32.3	BOTTOM DEPTH(FT)	32.8
SAMPLE NUMBER	NQ2-3	DISTRICT	11	PID NO.	114388
COUNTY	BEL	ROUTE	40	SECTION	23.37

FORMATION	Conemaugh Group
DESCRIPTION	Shale, Gray, Moderately Weathered, Slightly Strong
MOISTURE CONDITION	As Received

MEASUREMENT	LENGTH(INCHES)	DIAMETER(INCHES)
1	4.026	1.975
2	4.033	1.975
3	4.025	1.976
AVERAGE	4.028	1.975

LENGTH/DIAMETER	2.0
CORRECTION FACTOR	1
AREA(IN^2)	3.1
MASS (GRAMS)	535.6
UNIT WEIGHT(LBS/FT^3)	165.3

RATE OF LOADING (in/min)
0.11
COMPRESSIVE STRENGTH (PSI)
2,380
Equip. ID - 68897
NON-CONFORMANCES - None
TIME OF TEST (MINUTES)
0.87
LOADING DIRECTION
PERP. TO BEDDING
TECHNICIAN - MW
TEMPERATURE - Room



BEFORE TESTING

AFTER TESTING

Physical Appearance after Test - Sample sheared through middle portion - No signs of cracking, spalling or shearing at the platen-specimen interface

PROJECT NO:	24050050MOR
DATE:	2/11/2025

UNIAXIAL COMPRESSIVE STRENGTH OF INTACT ROCK CORE - ASTM D 7012

Method C

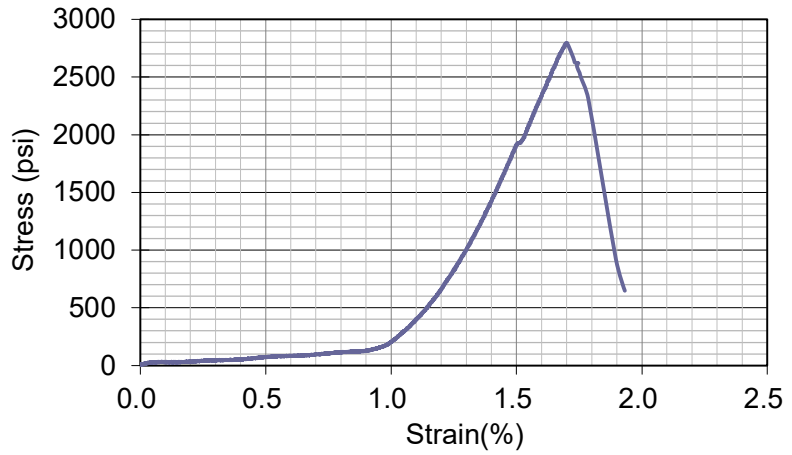
BORING NUMBER	B-001-0-24	TOP DEPTH(FT)	36.4	BOTTOM DEPTH(FT)	36.9
SAMPLE NUMBER	NQ2-4	DISTRICT	11	PID NO.	114388
COUNTY	BEL	ROUTE	40	SECTION	23.37

FORMATION	Conemaugh Group
DESCRIPTION	Shale, Gray, Moderately Weathered, Slightly Strong
MOISTURE CONDITION	As Received

MEASUREMENT	LENGTH(INCHES)	DIAMETER(INCHES)
1	4.010	1.984
2	4.007	1.983
3	4.004	1.984
AVERAGE	4.007	1.984

LENGTH/DIAMETER	2.0
CORRECTION FACTOR	1
AREA(IN^2)	3.1
MASS (GRAMS)	524.3
UNIT WEIGHT(LBS/FT^3)	161.3

RATE OF LOADING (in/min)
0.10
COMPRESSIVE STRENGTH (PSI)
2,790
Equip. ID - 68897
NON-CONFORMANCES - None
TIME OF TEST (MINUTES)
0.85
LOADING DIRECTION
PERP. TO BEDDING
TECHNICIAN - MW
TEMPERATURE - Room



BEFORE TESTING

AFTER TESTING

Physical Appearance after Test - Sample sheared through middle portion - No signs of cracking, spalling or shearing at the platen-specimen interface

PROJECT NO:	24050050MOR
DATE:	2/11/2025

UNIAXIAL COMPRESSIVE STRENGTH OF INTACT ROCK CORE - ASTM D 7012

Method C

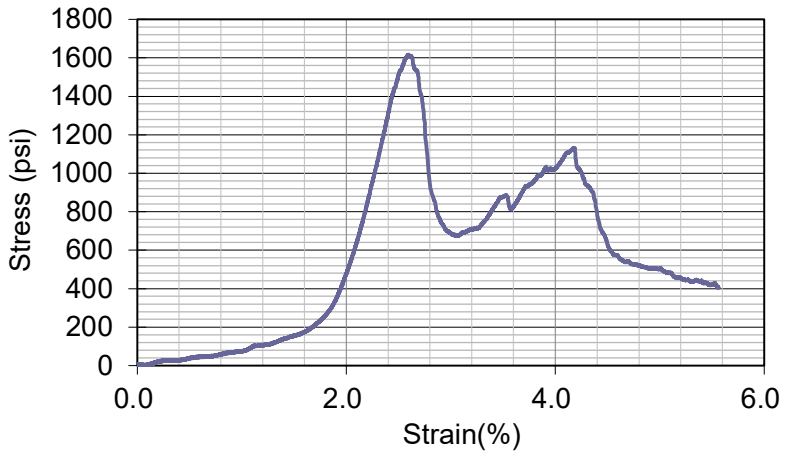
BORING NUMBER	B-001-0-24	TOP DEPTH(FT)	44.1	BOTTOM DEPTH(FT)	44.5
SAMPLE NUMBER	NQ2-5	DISTRICT	11	PID NO.	114388
COUNTY	BEL	ROUTE	40	SECTION	23.37

FORMATION	Conemaugh Group
DESCRIPTION	Claystone, Brown & Gray, Highly Weathered, Slightly Strong
MOISTURE CONDITION	As Received

MEASUREMENT	LENGTH(INCHES)	DIAMETER(INCHES)
1	4.029	1.963
2	4.024	1.968
3	4.025	1.965
AVERAGE	4.026	1.965

LENGTH/DIAMETER	2.0
CORRECTION FACTOR	1
AREA(IN^2)	3.0
MASS (GRAMS)	505.8
UNIT WEIGHT(LBS/FT^3)	157.8

RATE OF LOADING (in/min)
0.12
COMPRESSIVE STRENGTH (PSI)
1,620
Equip. ID - 68897
NON-CONFORMANCES - None
TIME OF TEST (MINUTES)
1.94
LOADING DIRECTION
PERP. TO BEDDING
TECHNICIAN - MW
TEMPERATURE - Room



BEFORE TESTING

AFTER TESTING

Physical Appearance after Test - Sample sheared through middle portion - No signs of cracking, spalling or shearing at the platen-specimen interface

CTL Engineering, Inc.

B-001-0-24 Box # 1

Run #:	Depth:		Recovery		RQD	
NQ2-1	21.0'	26.0'	2.5/5.0	50%	0/5.0	0%
NQ2-2	26.0'	31.0'	2.75/5.0	55%	0/5.0	0%

24050050MOR – BEL-40-23.27

B-001-0-24 Box # 2

Run #:	Depth:		Recovery		RQD	
NQ2-3	31.0'	36.0'	5.0/5.0	100%	3.58/5.0	72%
NQ2-4	36.0'	41.0'	5.0/5.0	100%	1.33/5.0	27%

CTL Engineering, Inc.

B-001-0-24 Box # 3

Run #:	Depth:		Recovery		RQD	
NQ2-5	41.0'	46.0'	5.0/5.0	100%	2.33/5.0	47%

24050050MOR – BEL-40-23.27

Summary of Soil Scour Data

BEL-40-23.37 Bridge - Scour Analysis						
Boring No.	**Sample**	**Elevation (ft)**	**D_{50} (mm)**	**τ_c (psf)**	**$D_{50,\ equiv}$ (mm)**	**Erosion Category (EC)**
B-001-0-24	SS-1	715.2-716.7	0.942	0.0197	0.9420	2.1689
	SS-2	713.7-715.2	0.817	0.0171	0.8170	2.0947
	SS-4	710.7-712.2	1.007	0.0210	1.0070	2.2036
	SS-5	709.2-710.7	0.438	0.0091	0.4380	1.7698
	SS-6	707.7-709.2	2.29	0.0478	2.2900	2.6318
	SS-7	706.2-707.7	2.783	0.0581	2.7830	2.7334
	SS-8	704.7-706.2	0.282	0.0804	3.8504	3.1680
	SS-9	703.2-704.7	0.082	0.4233	20.2654	3.7247
	SS-10	701.7-703.2	0.742	0.0573	2.7445	2.0445
	SS-11	700.2-701.7	0.2	0.2293	10.9810	1.3612

Summary of Bedrock Scour Data

Boring ID	Sample ID	Sample Elevation (Ft)	Erodibility Index (K)	τ_c Value (psf)	$D_{50, equiv}$ (mm)	Erosion Category
B-001-0-24	SS-12 to SS-14	695.7-700.2	0.01	0.6	30.9	3.77
B-001-0-24	NQ2-1&2	685.7-695.7	1.03	5.4	257.4	3.77
B-001-0-24	NQ2-3&4	679.3-685.7	678.26	137.7	6591.9	3.98
B-001-0-24	NQ2-4&5	670.7-679.3	115.42	56.8	2719.2	3.77

DESIGN MEMORANDUM

To: OODT Dist 11
Copy:
From: CTL Engineering, Inc.
Date: March 25, 2025
Subject: BEL-40-23.37 PID 114388; Rock Scour Assessment

At your request, CTL Engineering, Inc. has completed drilling and sampling operations for the referenced project. It is our understanding that the near surface bedrock will be interacting with the proposed foundational elements and rock scour is a concern. The following is the assessment of the encountered bedrock conditions relative to the geotechnical explorations:

Boring Evaluated:		B-001-0-24
Boring Location:		Adjacent to Pier, Sta. 205+80, 1' Lt.
Ground Elevation (ft):		716.7
Bedrock Elevation (ft):		700.2
Bedrock Age:		Pennsylvanian
Bedrock Description:		Claystone, Severely Weathered (Augered)

Testing Characteristics	BDM Threshold Value	Result	Scour Resistant Property
Unconfined Compressive Strength [Q_u]: (ASTM D 7012C)	$Q_u \geq 2{,}500$ psi	76.51 psi 0.53 MPa	NO
Slake Durability Index [Id_2]: (ASTM D4644)	SDI ≥ 90%	0.0 %	NO
Rock Quality Designation: (SGE Section 6)	RQD ≥ 65%	0	NO
Total Unit Weight (pcf):	$\gamma_{tot} \geq 150$ pcf	135 pcf	NO
Rock Mass Rating:	RMR ≥ 75	32	NO
Geological Strength Index (GSI):	GSI ≥ 75	20	NO
GSI Structure:	Massive or Blocky	Laminated	NO
GSI Surface Conditions:	Very Good or Good	Fair	NO
Erodibility Index [K]: FHWA-HIF-12-003 (HEC18)	K ≥ 100	0.01	NO
Rock Joint Set Number [J_n]:	$J_n \leq 5$	1.5	YES
Joint Roughness Number [J_r]:	$J_r \geq 1$	1.5	YES
Joint Alteration Number [J_a]:	$J_a \leq 5$	4	YES
Relative Joint Orientation [J_s]:	$J_s \geq 0.4$	1	YES
Does bedrock meet criteria of scour resistant per BDM:			**NO**

Critical Shear Stress (τ_c) * = $\rho\,(1000\,K^{0.75} / 7.853\,\rho)^{2/3}$

30.9	Pa
0.6	psf

DESIGN MEMORANDUM

Calculated D_{50} equivalent = 30.9 mm 1.218 in

Calculated Erosion Category (EC) = 3.77

CALCULATIONS

$K = (M_s)(K_b)(K_d)(J_s)$ $K =$ 0.01

Where: M_s = Intact Rock Strength Parameter

From Testing : $Q_u =$ psi $M_s =$ Qu for Qu ≥ 10 MPa

$Q_u =$ MPa (0.78) $Qu^{1.05}$ for Qu < 10 MPa

See Last sheet for Qu Determination

$Q_u =$ 76.51 psi

$Q_u =$ 0.53 MPa

$M_s =$ 0.40

Where: K_b = Block Size Patameter

$K_b =$ $RQD/J_n \geq 0.10$

RQD = 0

$J_n =$ 1.5 ≤ 5.0 $K_b =$ 0.10 ≥ 0.1

Where: K_d = Shear Stregnth Parameter

$K_d =$ J_r/J_a

$J_r =$ 1.5 ≥ 1.0

$J_a =$ 4 ≤ 5.0 $K_d =$ 0.38 ≥ 0.2

Where: J_s = Relative Orientation Parameter

$J_s =$ 1.00 ≥ 0.4

Average Joint Spacing = 2 inches 50.8 mm

Re-arrange HEC-18 Equations 7.38 for 'Critical Stream Power' and 7.39 'Approach Flow Stream Power' to derive the critical shear stress for non-scour resistant bedrock as follows:

Critical Shear Stress $(\tau_c)^*$ = $\rho\ (1000\ K^{0.75} / 7853\ \rho)^{2/3}$ 30.9 Pa

Where: τ_c = Critical shear stress (Pa)
ρ = Mass density of water (1000 kg/m^3)
K = Erodibility Index (dim.)

Erosion Category (EC) = $1.2(1.83333 + Log(S_v/2.5))$ EC = 3.77

REFERENCES

Table 4.20: Geomechanics Rating Adjustment for Joint Orientations (after AASHTO 2010)

Orientation of Joints		Very Favorable	Favorable	Fair	Unfavorable	Very Unfavorable
Rating	Tunnels	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	-60

Table 4.21: Geomechanics Rock Mass Classes Determined From Total Ratings (AASHTO 2010)

RMR (Note 1)	100 to 81	80 to 61	69 to 41	41 to 21	≤20
Class No.	I	II	III	IV	V
Description	Very Good Rock	Good Rock	Fair Rock	Poor Rock	Very Poor Rock

Table 4.23. Rock Joint Set Number J_n

Number of Joint Sets	Joint Set Number (J_n)
Intact, no or few joints/fissures	1.00
One joint/fissure set	1.22
One joint/fissure set plus random	1.50
Two joint/fissure sets	1.83
Two joint/fissure sets plus random	2.24
Three joint/fissure sets	2.74
Three joint/fissure sets plus random	3.34
Multiple joint/fissure sets	4.09
Multiple joint/fissure sets	5.00

Table 4.24. Joint Roughness Number J_r

Condition of Joint	Joint Roughness Number (J_r)
Stepped Joint/fissures	4.0
Rough or irregular, undulating	3.0
Smooth undulating	2.0
Slickensided undulating	1.5
Smooth planar	1.0
Slickensided planar	0.5

Table 4.25. Joint Alteration Number J_a

Description of Gouge	1.0 {1}	.0 - 5.0 {2	5.0 {3}
Tightly healed, hard, non-softening impermeable	0.75	---	---
Unaltered joint walls, surface staining only	1.0	---	---
Slightly altered, non-softening, non-cohesive rock mineral or crushed rock infilling	2.0	2.0	4.0
Non-softening, slightly clayey non-cohesive filling	3.0	6.0	10.0
Non-softening, strongly over-consolidated clay mineral filling, with or without crushed rock	3.0	6.0 **	10.0
Softening or low friction clay mineral coatings and small quantities of swelling clays	4.0	8.0	13.0

Joint/fissures either open or containing relatively soft gouge of sufficient thickness to prevent joint/fissure wall contact upon excavation	1.0	Softening moderately over-consolidated clay mineral filling, with or without crushed rock	4.0	8.0 **	13.0
		Shattered or micro-shattered (swelling) clay gouge, with or without crushed rock	5.0	10.0	18.0
hattered or mico-shattered clay	1.0	{1} Joint walls effectively in contact {2} Joint walls come into contact after approximately 100-mm of shear {3} Joint walls do not come into contact at all upon shear ** Also applies when crushed rock occurs in clay gouge without rock wall contact			

AASHTO LRFD Bridge Design Specifications, 6th Ed. (AASHTO 2012)

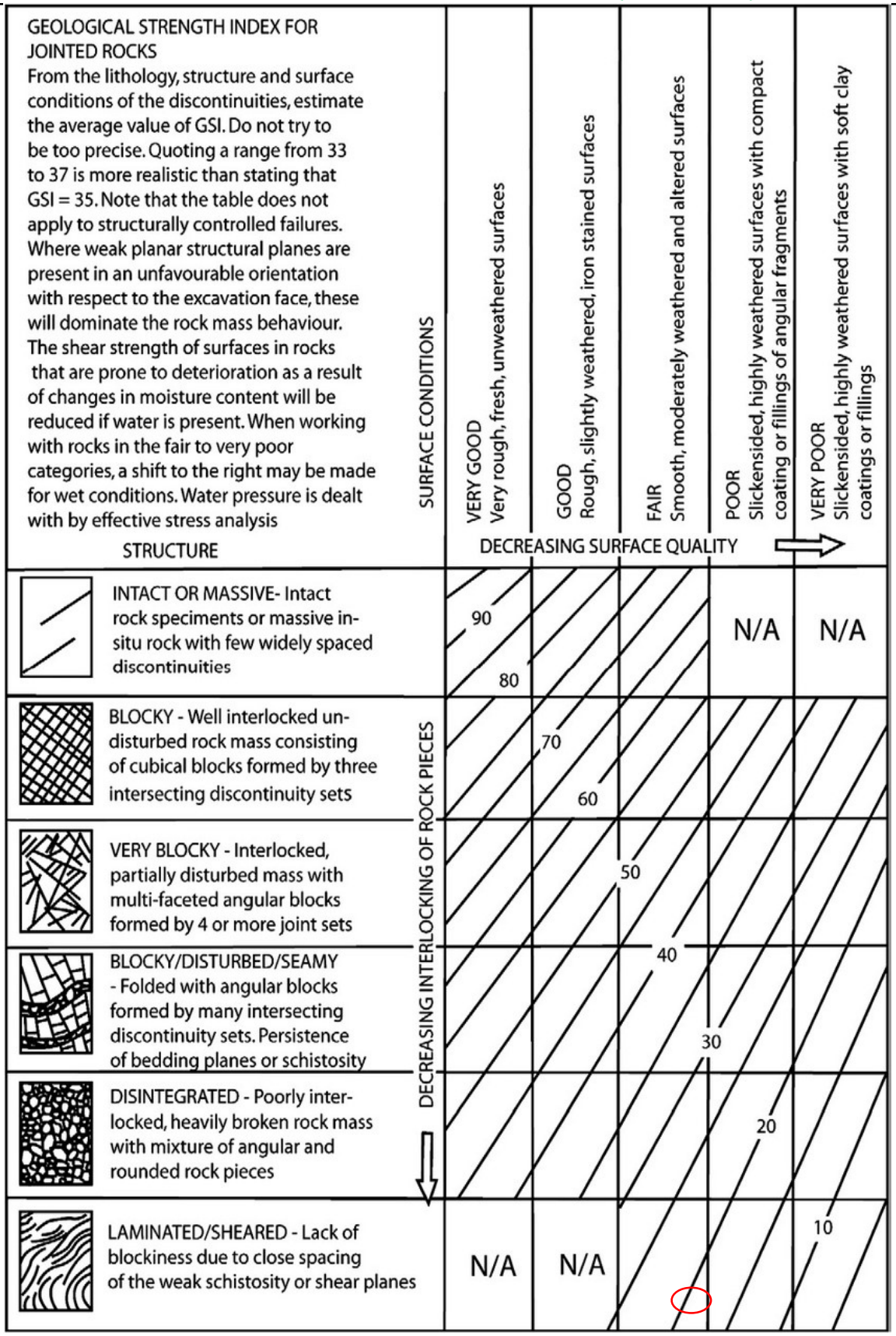
Table 10.4.6.4-1: Geomechanics Clasification of Rock Masses (AASHTO 2012)

Parameter			Range of Values							Score
1	Strength of intact rock material	Point Load Stregnth Index	> 175 ksf	85-175 ksf	45-85 ksf	20-45 ksf	For this low range, uniaxial compressive strength is preferred			0
		Uniaxial Compressive Strength	> 4320 ksf	2160-4320 ksf	1080-2160 ksf	520-1080 ksf	215-520 ksf	70-215 ksf	20-7 ksf	
	Relative Rating		15	12	7	4	2	1	0	
2	Drill core quality (RQD)		90-100%	75-90%	50-75%	25-50%	<25%			3
	Relative Rating		20	17	13	8	3			
3	Spacing of Joints		>10 ft.	3-10 ft.	1-3 ft.	2 in - 1 ft.	<2in.			10
	Relative Rating		30	25	20	10	5			
4	Conditions of Joints	• Very rough surfaces • Not continuous • No Seperation • Hard joint wall rock	• Slightly rough surfaces •Seperation <0.05 in. • Hard joint wall rock		• Slightly rough surface •Seperation <0.05 in. • Soft joint wall rock		• Slickenside surface •Gouge <0.2in thinck •Joints open 0.05 - 0.2 in. • Continuous Joints	• Soft gouge >0.2 in. •Joints open >0.2 in. • Continuous Joints		12
Relative Rating		25	20		12		6	0		
5	Groundwater conditions (for scour only use the General Conditions and either Moist or Completely Dry)		Completely Dry		Moist only (interstital water)		Water under moderate pressure	Severe water problems		7
	Relative Rating		10		7		4	0		
							Rock Mass Rating			**32**

Note:
1 MPa = 145 psi
1 psi = 0.00689 Mpa
1 psi = 0.144 ksf

AASHTO LRFD Bridge Design Specifications, 9th Ed. (AASHTO 2020)

Table 10.4.6.4-1:Determination of GSI for Jointed Rock Mass (AASHTO 2020)



Bedrock Scour Samples						
Boring ID	Sample ID	Sample Elevation (Ft)	Erodibility Index (K)	τ_c Value (psf)	$D_{50,equiv}$ (mm)	Erosion Category
B-001-0-24	SS-12to14	695.7-700.2	0.01	0.6	30.9	3.77

Slake Durability Index [Id_2] = 0% - Estimated from GDM Table 400-5
Total Unit Weight = 135 pcf - Estimated from GDM Table 400-5

Qu Determination

Sample	N_{60}	Nrate	Qu (ksf)	Qu (psi)	
SS-12	35		4.375	30.38	
SS-13	41		5.125	35.59	
SS-14	50/2"	300	23.55	163.56	
			Qu Avg =	76.51	psi
			Qu Avg =	0.53	MPa

For SS-12 & SS-13, Qu=N60*125/1000
For SS-14, Qu Based on SPT (Stark et. al. 2017)

Nrate	300.0	
ER =	76.8	
N_{90} =	256.0	bpf
Qu =	23.55	ksf
Qu =	163.56	psi

DESIGN MEMORANDUM

To: OODT Dist 11
Copy:
From: CTL Engineering, Inc.
Date: March 25, 2025
Subject: BEL-40-23.37 PID 114388; Rock Scour Assessment

At your request, CTL Engineering, Inc. has completed drilling and sampling operations for the referenced project. It is our understanding that the near surface bedrock will be interacting with the proposed foundational elements and rock scour is a concern. The following is the assessment of the encountered bedrock conditions relative to the geotechnical explorations:

Boring Evaluated:		B-001-0-24
Boring Location:		Adjacent to Pier, Sta. 205+80, 1' Lt.
Ground Elevation (ft):		716.7
Bedrock Elevation (ft):		695.7
Bedrock Age:		Pennsylvanian
Bedrock Description:		Shale, Highly Weathered, Slightly Strong

Testing Characteristics	BDM Threshold Value	Result	Scour Resistant Property
Unconfined Compressive Strength [Q_u]: (ASTM D 7012C)	$Q_u \geq$ 2,500 psi	1500 psi 10.34 MPa	NO
Slake Durability Index [Id_2]: (ASTM D4644)	SDI ≥ 90%	89.6 -94.20%	NO
Rock Quality Designation: (SGE Section 6)	RQD ≥ 65%	0	NO
Total Unit Weight (pcf):	$\gamma_{tot} \geq$ 150 pcf	155 pcf	YES
Rock Mass Rating:	RMR ≥ 75	34	NO
Geological Strength Index (GSI):	GSI ≥ 75	35	NO
GSI Structure:	Massive or Blocky	Blocky Disturbed	NO
GSI Surface Conditions:	Very Good or Good	Fair	NO
Erodibility Index [K]: FHWA-HIF-12-003 (HEC18)	K ≥ 100	1.03	NO
Rock Joint Set Number [J_n]:	$J_n \leq 5$	1.5	YES
Joint Roughness Number [J_r]:	$J_r \geq 1$	2	YES
Joint Alteration Number [J_a]:	$J_a \leq 5$	2	YES
Relative Joint Orientation [J_s]:	$J_s \geq 0.4$	1	YES
Does bedrock meet criteria of scour resistant per BDM:		**NO**	

Critical Shear Stress (τ_c) * = $\rho\,(1000\,K^{0.75} / 7.853\,\rho)^{2/3}$

257.4	Pa
5.4	psf

DESIGN MEMORANDUM

Calculated D_{50} equivalent = 257.4 mm 10.13 in

Calculated Erosion Category (EC) = 3.77

CALCULATIONS

$K = (M_s)(K_b)(K_d)(J_s)$ $K =$ 1.03

Where: M_s = Intact Rock Strength Parameter

Est. GDM Table 400-6 : $Q_u =$ 1500 psi

$Q_u =$ 10.34 MPa

$M_s =$ Qu for Qu ≥ 10 MPa

$(0.78)\ Qu^{1.05}$ for Qu < 10 MPa

Based on SPT (Stark et. al. 2017) Where: Q_u (ksf) = 0.092 x N_{90}

$Q_u =$ 0.00 psi $N_{90} =$

$Q_u =$ 0.00 MPa

$M_s =$ 10.34

Where: K_b = Block Size Patameter

$K_b =$ $RQD/J_n \geq 0.10$

RQD = 0

$J_n =$ 1.5 ≤ 5.0 $K_b =$ 0.10 ≥ 0.1

Where: K_d = Shear Stregnth Parameter

$K_d =$ J_r/J_a

$J_r =$ 2 ≥ 1.0

$J_a =$ 2 ≤ 5.0 $K_d =$ 1.00 ≥ 0.2

Where: J_s = Relative Orientation Parameter

$J_s =$ 1.00 ≥ 0.4

Average Joint Spacing = 2 inches 50.8 mm

Re-arrange HEC-18 Equations 7.38 for 'Critical Stream Power' and 7.39 'Approach Flow Stream Power' to derive the critical shear stress for non-scour resistant bedrock as follows:

Critical Shear Stress (τ_c) * = $\rho\ (1000\ K^{0.75} / 7853\ \rho)^{2/3}$ 257.4 Pa

Where: τ_c = Critical shear stress (Pa)
ρ = Mass density of water (1000 kg/m^3)
K = Erodibility Index (dim.)

Erosion Category (EC) = $1.2(1.83333 + Log(S_v/2.5))$ EC = 3.77

REFERENCES

Table 4.20: Geomechanics Rating Adjustment for Joint Orientations (after AASHTO 2010)

Orientation of Joints		Very Favorable	Favorable	Fair	Unfavorable	Very Unfavorable
Rating	Tunnels	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	-60

Table 4.21: Geomechanics Rock Mass Classes Determined From Total Ratings (AASHTO 2010)

RMR (Note 1)	100 to 81	80 to 61	69 to 41	41 to 21	≤20
Class No.	I	II	III	IV	V
Description	Very Good Rock	Good Rock	Fair Rock	Poor Rock	Very Poor Rock

Table 4.23. Rock Joint Set Number J_n

Number of Joint Sets	Joint Set Number (J_n)
Intact, no or few joints/fissures	1.00
One joint/fissure set	1.22
One joint/fissure set plus random	1.50
Two joint/fissure sets	1.83
Two joint/fissure sets plus random	2.24
Three joint/fissure sets	2.74
Three joint/fissure sets plus random	3.34
Multiple joint/fissure sets	4.09
Multiple joint/fissure sets	5.00

Table 4.24. Joint Roughness Number J_r

Condition of Joint	Joint Roughness Number (J_r)
Stepped Joint/fissures	4.0
Rough or irregular, undulating	3.0
Smooth undulating	2.0
Slickensided undulating	1.5
Smooth planar	1.0
Slickensided planar	0.5

Table 4.25. Joint Alteration Number J_a

Description of Gouge	1.0 {1}	1.0 - 5.0 {2}	5.0 {3}
Tightly healed, hard, non-softening impermeable	0.75	---	---
Unaltered joint walls, surface staining only	1.0	---	---
Slightly altered, non-softening, non-cohesive rock mineral or crushed rock infilling	2.0	2.0	4.0
Non-softening, slightly clayey non-cohesive filling	3.0	6.0	10.0
Non-softening, strongly over-consolidated clay mineral filling, with or without crushed rock	3.0	6.0 **	10.0
Softening or low friction clay mineral coatings and small quantities of swelling clays	4.0	8.0	13.0

Joint/fissures either open or containing relatively soft gouge of sufficient thickness to prevent joint/fissure wall contact upon excavation	1.0	Softening moderately over-consolidated clay mineral filling, with or without crushed rock	4.0	8.0 **	13.0
		Shattered or micro-shattered (swelling) clay gouge, with or without crushed rock	5.0	10.0	18.0
hattered or mico-shattered clay	1.0	{1} Joint walls effectively in contact {2} Joint walls come into contact after approximately 100-mm of shear {3} Joint walls do not come into contact at all upon shear ** Also applies when crushed rock occurs in clay gouge without rock wall contact			

AASHTO LRFD Bridge Design Specifications, 6th Ed. (AASHTO 2012)

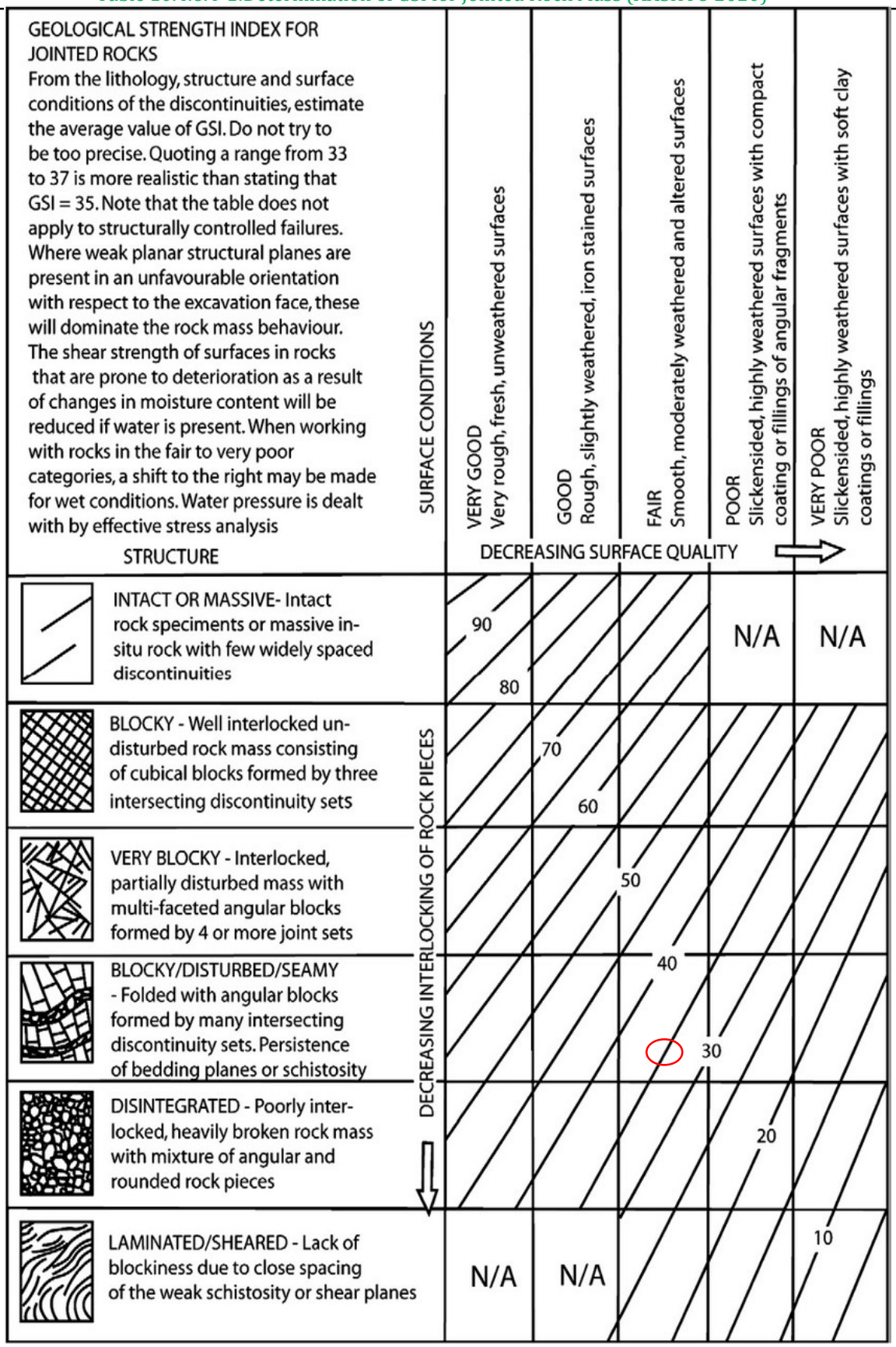
Table 10.4.6.4-1: Geomechanics Clasification of Rock Masses (AASHTO 2012)

Parameter			Range of Values							Score
1	Strength of intact rock material	Point Load Stregnth Index	> 175 ksf	85-175 ksf	45-85 ksf	20-45 ksf	For this low range, uniaxial compressive strength is preferred			2
		Uniaxial Compressive Strength	> 4320 ksf	2160-4320 ksf	1080-2160 ksf	520-1080 ksf	215-520 ksf	70-215 ksf	20-7 ksf	
	Relative Rating		15	12	7	4	2	1	0	
2	Drill core quality (RQD)		90-100%	75-90%	50-75%	25-50%	<25%			3
	Relative Rating		20	17	13	8	3			
3	Spacing of Joints		>10 ft.	3-10 ft.	1-3 ft.	2 in - 1 ft.	<2in.			10
	Relative Rating		30	25	20	10	5			
4	Conditions of Joints	• Very rough surfaces • Not continuous • No Seperation • Hard joint wall rock	• Slightly rough surfaces •Seperation <0.05 in. • Hard joint wall rock		• Slightly rough surface •Seperation <0.05 in. • Soft joint wall rock		• Slickenside surface •Gouge <0.2in thinck •Joints open 0.05 - 0.2 in. • Continuous Joints	• Soft gouge >0.2 in. •Joints open >0.2 in. • Continuous Joints		12
Relative Rating		25	20		12		6	0		
5	Groundwater conditions (for scour only use the General Conditions and either Moist or Completely Dry)		Completely Dry		Moist only (interstital water)		Water under moderate pressure	Severe water problems		7
	Relative Rating		10		7		4	0		
							Rock Mass Rating			34

Note:
1 MPa = 145 psi
1 psi = 0.00689 Mpa
1 psi = 0.144 ksf

AASHTO LRFD Bridge Design Specifications, 9th Ed. (AASHTO 2020)

Table 10.4.6.4-1:Determination of GSI for Jointed Rock Mass (AASHTO 2020)



Bedrock Scour Samples						
Boring ID	Sample ID	Sample Elevation (Ft)	Erodibility Index (K)	τ_c Value (psf)	$D_{50,equiv}$ (mm)	Erosion Category
B-001-0-24	NQ2-1/2	685.7-695.7	1.03	5.4	257.4	3.77

Qu = 1,500 psi Estimated from GDM Table 400-6 (Slightly Strong)

Total Unit Weight = 155 pcf Estimated from GDM Table 400-5

DESIGN MEMORANDUM

To: OODT Dist 11
Copy:
From: CTL Engineering, Inc.
Date: March 25, 2025
Subject: BEL-40-23.37 PID 114388; Rock Scour Assessment

At your request, CTL Engineering, Inc. has completed drilling and sampling operations for the referenced project. It is our understanding that the near surface bedrock will be interacting with the proposed foundational elements and rock scour is a concern. The following is the assessment of the encountered bedrock conditions relative to the geotechnical explorations:

Boring Evaluated:		B-001-0-24
Boring Location:		Adjacent to Pier, Sta. 205+80, 1' Lt.
Ground Elevation (ft):		716.7
Bedrock Elevation (ft):		685.7
Bedrock Age:		Pennsylvanian
Bedrock Description:		Shale, Moderately Weathered, Slightly Strong

Testing Characteristics	BDM Threshold Value	Result	Scour Resistant Property
Unconfined Compressive Strength [Q_u]: (ASTM D 7012C)	$Q_u \geq 2{,}500$ psi	2380 -2790 psi 16.4-19.2 MPa	NO
Slake Durability Index [Id_2]: (ASTM D4644)	SDI ≥ 90%	95.1 %	YES
Rock Quality Designation: (SGE Section 6)	RQD ≥ 65%	62	NO
Total Unit Weight (pcf):	$\gamma_{tot} \geq 150$ pcf	165.3 pcf	YES
Rock Mass Rating:	RMR ≥ 75	44	NO
Geological Strength Index (GSI):	GSI ≥ 75	35	NO
GSI Structure:	Massive or Blocky	Blocky/Disturbed	NO
GSI Surface Conditions:	Very Good or Good	Fair	NO
Erodibility Index [K]: FHWA-HIF-12-003 (HEC18)	K ≥ 100	678.26	YES
Rock Joint Set Number [J_n]:	$J_n \leq 5$	1.5	YES
Joint Roughness Number [J_r]:	$J_r \geq 1$	2	YES
Joint Alteration Number [J_a]:	$J_a \leq 5$	2	YES
Relative Joint Orientation [J_s]:	$J_s \geq 0.4$	1	YES
Does bedrock meet criteria of scour resistant per BDM:		**NO**	

Critical Shear Stress (τ_c) * = $\rho\,(1000\,K^{0.75} / 7.853\,\rho)^{2/3}$

6591.9	Pa
137.7	psf

DESIGN MEMORANDUM

Calculated D_{50} equivalent = 6591.9 mm 259.5 in

Calculated Erosion Category (EC) = 3.98

CALCULATIONS

$K = (M_s)(K_b)(K_d)(J_s)$ $K =$ 678.26

Where: M_s = Intact Rock Strength Parameter

From Testing : $Q_u =$ 2380 psi
$Q_u =$ 16.41 MPa

$M_s =$ Qu for Qu ≥ 10 MPa
$(0.78)\ Qu^{1.05}$ for Qu < 10 MPa

Based on SPT (Stark et. al. 2017) Where: Q_u (ksf) = 0.092 x N_{90}

$Q_u =$ 0.00 psi
$Q_u =$ 0.00 MPa

$N_{90} =$

$M_s =$ 16.41

Where: K_b = Block Size Patameter

$K_b =$ $RQD/J_n \geq 0.10$

RQD = 62
$J_n =$ 1.5 ≤ 5.0 $K_b =$ 41.33 ≥ 0.1

Where: K_d = Shear Stregnth Parameter

$K_d =$ J_r/J_a

$J_r =$ 2 ≥ 1.0
$J_a =$ 2 ≤ 5.0 $K_d =$ 1.00 ≥ 0.2

Where: J_s = Relative Orientation Parameter

$J_s =$ 1.00 ≥ 0.4

Average Joint Spacing = 3 inches 76.2 mm

Re-arrange HEC-18 Equations 7.38 for 'Critical Stream Power' and 7.39 'Approach Flow Stream Power' to derive the critical shear stress for non-scour resistant bedrock as follows:

Critical Shear Stress (τ_c) * = $\rho\ (1000\ K^{0.75} / 7853\ \rho)^{2/3}$ 6591.9 Pa

Where: τ_c = Critical shear stress (Pa)
ρ = Mass density of water (1000 kg/m^3)
K = Erodibility Index (dim.)

Erosion Category (EC) = $1.2(1.83333 + Log(S_v/2.5))$ EC = 3.98

REFERENCES

Table 4.20: Geomechanics Rating Adjustment for Joint Orientations (after AASHTO 2010)

Orientation of Joints		Very Favorable	Favorable	Fair	Unfavorable	Very Unfavorable
Rating	Tunnels	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	-60

Table 4.21: Geomechanics Rock Mass Classes Determined From Total Ratings (AASHTO 2010)

RMR (Note 1)	100 to 81	80 to 61	69 to 41	41 to 21	≤20
Class No.	I	II	III	IV	V
Description	Very Good Rock	Good Rock	Fair Rock	Poor Rock	Very Poor Rock

Table 4.23. Rock Joint Set Number J_n

Number of Joint Sets	Joint Set Number (J_n)
Intact, no or few joints/fissures	1.00
One joint/fissure set	1.22
One joint/fissure set plus random	1.50
Two joint/fissure sets	1.83
Two joint/fissure sets plus random	2.24
Three joint/fissure sets	2.74
Three joint/fissure sets plus random	3.34
Multiple joint/fissure sets	4.09
Multiple joint/fissure sets	5.00

Table 4.24. Joint Roughness Number J_r

Condition of Joint	Joint Roughness Number (J_r)
Stepped Joint/fissures	4.0
Rough or irregular, undulating	3.0
Smooth undulating	2.0
Slickensided undulating	1.5
Smooth planar	1.0
Slickensided planar	0.5

Table 4.25. Joint Alteration Number J_a

Description of Gouge	1.0 {1}	1.0 - 5.0 {2}	5.0 {3}
Tightly healed, hard, non-softening impermeable	0.75	---	---
Unaltered joint walls, surface staining only	1.0	---	---
Slightly altered, non-softening, non-cohesive rock mineral or crushed rock infilling	2.0	2.0	4.0
Non-softening, slightly clayey non-cohesive filling	3.0	6.0	10.0
Non-softening, strongly over-consolidated clay mineral filling, with or without crushed rock	3.0	6.0 **	10.0
Softening or low friction clay mineral coatings and small quantities of swelling clays	4.0	8.0	13.0

Joint/fissures either open or containing relatively soft gouge of sufficient thickness to prevent joint/fissure wall contact upon excavation	1.0	Softening moderately over-consolidated clay mineral filling, with or without crushed rock	4.0	8.0 **	13.0
		Shattered or micro-shattered (swelling) clay gouge, with or without crushed rock	5.0	10.0	18.0
hattered or mico-shattered clay	1.0	{1} Joint walls effectively in contact {2} Joint walls come into contact after approximately 100-mm of shear {3} Joint walls do not come into contact at all upon shear ** Also applies when crushed rock occurs in clay gouge without rock wall contact			

AASHTO LRFD Bridge Design Specifications, 6th Ed. (AASHTO 2012)

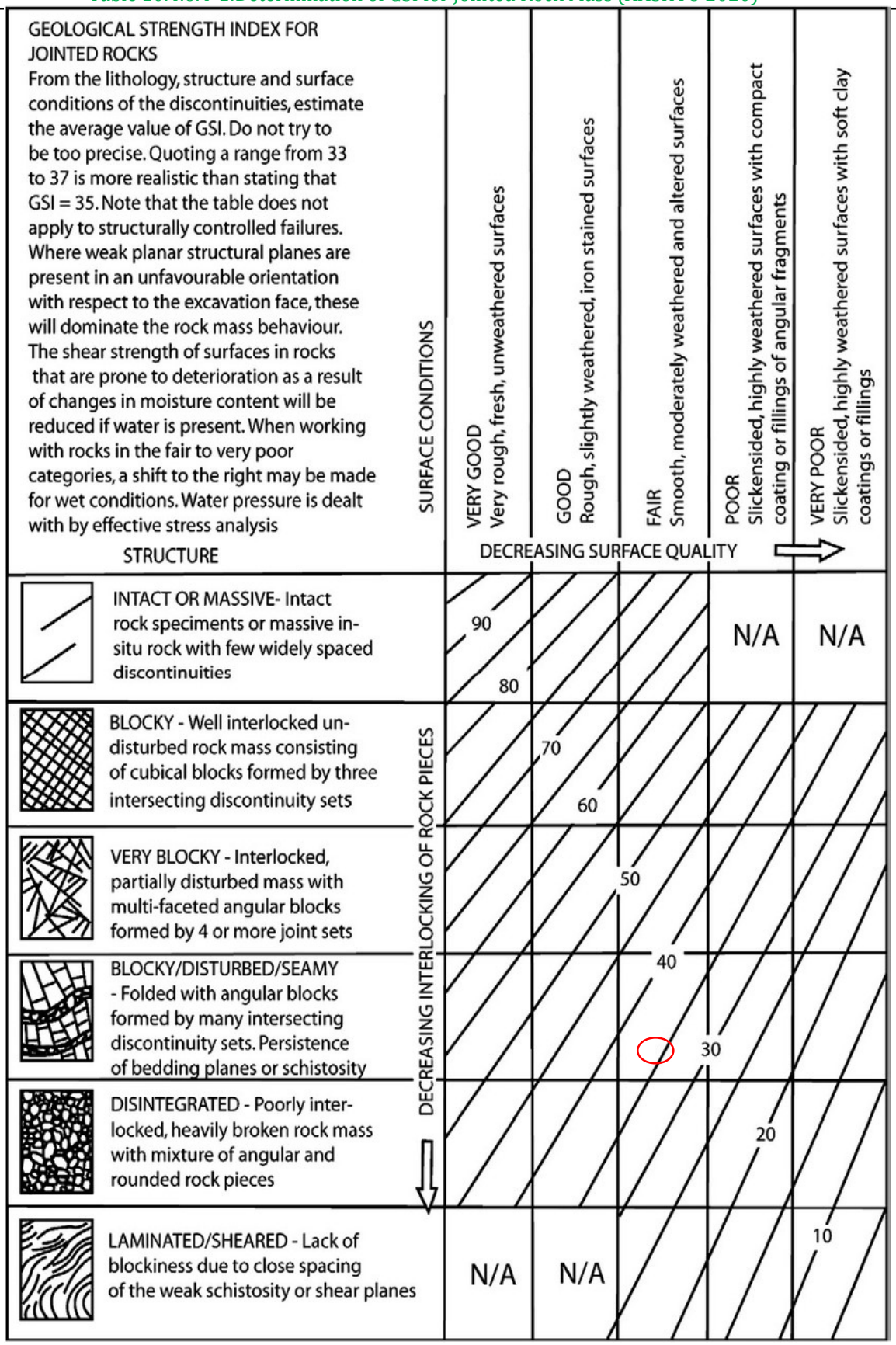
Table 10.4.6.4-1: Geomechanics Clasification of Rock Masses (AASHTO 2012)

Parameter			Range of Values							Score
1	Strength of intact rock material	Point Load Stregnth Index	> 175 ksf	85-175 ksf	45-85 ksf	20-45 ksf	For this low range, uniaxial compressive strength is preferred			2
		Uniaxial Compressive Strength	> 4320 ksf	2160-4320 ksf	1080-2160 ksf	520-1080 ksf	215-520 ksf	70-215 ksf	20-7 ksf	
	Relative Rating		15	12	7	4	2	1	0	
2	Drill core quality (RQD)		90-100%	75-90%	50-75%	25-50%	<25%			13
	Relative Rating		20	17	13	8	3			
3	Spacing of Joints		>10 ft.	3-10 ft.	1-3 ft.	2 in - 1 ft.	<2in.			10
	Relative Rating		30	25	20	10	5			
4	Conditions of Joints	• Very rough surfaces • Not continuous • No Seperation • Hard joint wall rock	• Slightly rough surfaces •Seperation <0.05 in. • Hard joint wall rock		• Slightly rough surface •Seperation <0.05 in. • Soft joint wall rock		• Slickenside surface •Gouge <0.2in thinck •Joints open 0.05 - 0.2 in. • Continuous Joints	• Soft gouge >0.2 in. •Joints open >0.2 in. • Continuous Joints		12
Relative Rating		25	20		12		6	0		
5	Groundwater conditions (for scour only use the General Conditions and either Moist or Completely Dry)		Completely Dry		Moist only (interstital water)		Water under moderate pressure	Severe water problems		7
	Relative Rating		10		7		4	0		
							Rock Mass Rating			44

Note:
1 MPa = 145 psi
1 psi = 0.00689 Mpa
1 psi = 0.144 ksf

AASHTO LRFD Bridge Design Specifications, 9th Ed. (AASHTO 2020)

Table 10.4.6.4-1:Determination of GSI for Jointed Rock Mass (AASHTO 2020)



Bedrock Scour Samples						
Boring ID	Sample ID	Sample Elevation (Ft)	Erodibility Index (K)	τ_c Value (psf)	$D_{50,equiv}$ (mm)	Erosion Category
B-001-0-24	NQ2-3/4	679.3-685.7	678.26	137.7	6591.9	3.98

DESIGN MEMORANDUM

To: OODT Dist 11
Copy:
From: CTL Engineering, Inc.
Date: March 25, 2025
Subject: BEL-40-23.37 PID 114388; Rock Scour Assessment

At your request, CTL Engineering, Inc. has completed drilling and sampling operations for the referenced project. It is our understanding that the near surface bedrock will be interacting with the proposed foundational elements and rock scour is a concern. The following is the assessment of the encountered bedrock conditions relative to the geotechnical explorations:

Boring Evaluated:		B-001-0-24
Boring Location:		Adjacent to Pier, Sta. 205+80, 1' Lt.
Ground Elevation (ft):		716.7
Bedrock Elevation (ft):		679.3
Bedrock Age:		Pennsylvanian
Bedrock Description:		Claystone, Highly Weathered, Weak to Slightly Strong

Testing Characteristics	BDM Threshold Value	Result	Scour Resistant Property
Unconfined Compressive Strength [Q_u]: (ASTM D 7012C)	$Q_u \geq$ 2,500 psi	1620 psi 11.17 MPa	NO
Slake Durability Index [Id_2]: (ASTM D4644) GDM Table 400-5	SDI ≥ 90%	30.0 %	NO
Rock Quality Designation: (SGE Section 6)	RQD ≥ 65%	31	NO
Total Unit Weight (pcf):	$\gamma_{tot} \geq$ 150 pcf	157.8 pcf	YES
Rock Mass Rating:	RMR ≥ 75	38	NO
Geological Strength Index (GSI):	GSI ≥ 75	30	NO
GSI Structure:	Massive or Blocky	Blocky/Disturbed	NO
GSI Surface Conditions:	Very Good or Good	Fair	NO
Erodibility Index [K]: FHWA-HIF-12-003 (HEC18)	K ≥ 100	115.42	YES
Rock Joint Set Number [J_n]:	$J_n \leq 5$	1.5	YES
Joint Roughness Number [J_r]:	$J_r \geq 1$	2	YES
Joint Alteration Number [J_a]:	$J_a \leq 5$	4	YES
Relative Joint Orientation [J_s]:	$J_s \geq 0.4$	1	YES
Does bedrock meet criteria of scour resistant per BDM:		**NO**	

Critical Shear Stress (τ_c) * = $\rho\,(1000\,K^{0.75} / 7.853\,\rho)^{2/3}$

2719.2	Pa
56.8	psf

DESIGN MEMORANDUM

Calculated D_{50} equivalent = 2719.2 mm 107.1 in

Calculated Erosion Category (EC) = 3.77

CALCULATIONS

$K = (M_s)(K_b)(K_d)(J_s)$ $K =$ 115.42

Where: M_s = Intact Rock Strength Parameter

From Testing : $Q_u =$ 1620 psi

$Q_u =$ 11.17 MPa

$M_s =$ Qu for Qu ≥ 10 MPa

$(0.78)\ Qu^{1.05}$ for Qu < 10 MPa

Based on SPT (Stark et. al. 2017) Where: Q_u (ksf) = 0.092 x N_{90}

$Q_u =$ 0.00 psi

$Q_u =$ 0.00 MPa

$N_{90} =$

$M_s =$ 11.17

Where: K_b = Block Size Patameter

$K_b =$ $RQD/J_n \geq 0.10$

RQD = 31

$J_n =$ 1.5 ≤ 5.0 $K_b =$ 20.67 ≥ 0.1

Where: K_d = Shear Stregnth Parameter

$K_d =$ J_r/J_a

$J_r =$ 2 ≥ 1.0

$J_a =$ 4 ≤ 5.0 $K_d =$ 0.50 ≥ 0.2

Where: J_s = Relative Orientation Parameter

$J_s =$ 1.00 ≥ 0.4

Average Joint Spacing = 2 inches 50.8 mm

Re-arrange HEC-18 Equations 7.38 for 'Critical Stream Power' and 7.39 'Approach Flow Stream Power' to derive the critical shear stress for non-scour resistant bedrock as follows:

Critical Shear Stress (τ_c) * = $\rho\ (1000\ K^{0.75} / 7853\ \rho)^{2/3}$ 2719.2 Pa

Where: τ_c = Critical shear stress (Pa)
ρ = Mass density of water (1000 kg/m^3)
K = Erodibility Index (dim.)

Erosion Category (EC) = $1.2(1.83333 + Log(S_v/2.5))$ EC = 3.77

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Slickensided planar	0.5

Table 4.25. Joint Alteration Number J_a

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Tightly healed, hard, non-softening impermeable	0.75	---	---
Unaltered joint walls, surface staining only	1.0	---	---
Slightly altered, non-softening, non-cohesive rock mineral or crushed rock infilling	2.0	2.0	4.0
Non-softening, slightly clayey non-cohesive filling	3.0	6.0	10.0
Non-softening, strongly over-consolidated clay mineral filling, with or without crushed rock	3.0	6.0 **	10.0
Softening or low friction clay mineral coatings and small quantities of swelling clays	4.0	8.0	13.0

Joint/fissures either open or containing relatively soft gouge of sufficient thickness to prevent joint/fissure wall contact upon excavation	1.0	Softening moderately over-consolidated clay mineral filling, with or without crushed rock	4.0	8.0 **	13.0
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AASHTO LRFD Bridge Design Specifications, 6th Ed. (AASHTO 2012)

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Parameter			Range of Values							Score
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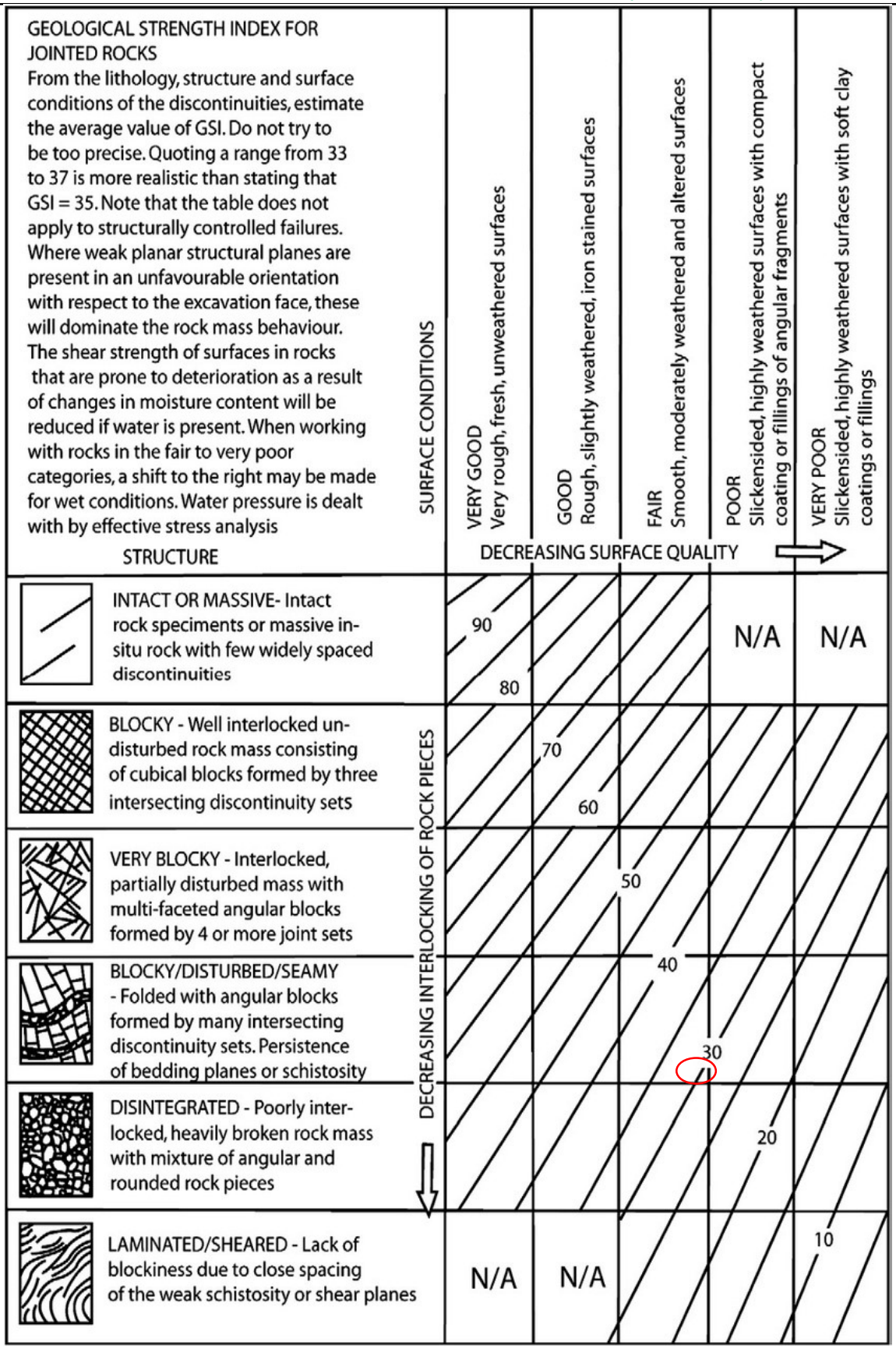
		Uniaxial Compressive Strength	> 4320 ksf	2160-4320 ksf	1080-2160 ksf	520-1080 ksf	215-520 ksf	70-215 ksf	20-7 ksf	
	Relative Rating		15	12	7	4	2	1	0	
2	Drill core quality (RQD)		90-100%	75-90%	50-75%	25-50%	<25%			8
	Relative Rating		20	17	13	8	3			
3	Spacing of Joints		>10 ft.	3-10 ft.	1-3 ft.	2 in - 1 ft.	<2in.			10
	Relative Rating		30	25	20	10	5			
4	Conditions of Joints	• Very rough surfaces • Not continuous • No Seperation • Hard joint wall rock	• Slightly rough surfaces •Seperation <0.05 in. • Hard joint wall rock		• Slightly rough surface •Seperation <0.05 in. • Soft joint wall rock		• Slickenside surface •Gouge <0.2in thinck •Joints open 0.05 - 0.2 in. • Continuous Joints	• Soft gouge >0.2 in. •Joints open >0.2 in. • Continuous Joints		12
Relative Rating		25	20		12		6	0		
5	Groundwater conditions (for scour only use the General Conditions and either Moist or Completely Dry)		Completely Dry		Moist only (interstital water)		Water under moderate pressure	Severe water problems		7
	Relative Rating		10		7		4	0		
							Rock Mass Rating			**38**

Note:
1 MPa = 145 psi
1 psi = 0.00689 Mpa
1 psi = 0.144 ksf

AASHTO LRFD Bridge Design Specifications, 9th Ed. (AASHTO 2020)

Table 10.4.6.4-1:Determination of GSI for Jointed Rock Mass (AASHTO 2020)



Bedrock Scour Samples						
Boring ID	Sample ID	Sample Elevation (Ft)	Erodibility Index (K)	τ_c Value (psf)	$D_{50,equiv}$ (mm)	Erosion Category
B-001-0-24	NQ2-4/5	670.7-679.3	115.42	56.8	2719.2	3.77

Slake Durability Index [Id_2] From GDM Table 400-5