Report of Geotechnical Exploration (FINAL)
HAM-71-8.42 Ramp T Wall

PID 121704
Hamilton County, Ohio

October 24, 2024

Prepared for:
Ohio Department of Transportation District 8
Lebanon, Ohio

Prepared by:
Stantec Consulting Services Inc.
Cincinnati, Ohio

Project:
173410733

Stantec

Revision	Description	Author	Date	Quality Check	Date	Independent Review	Date
0	DRAFT	R. Lopina	8/29/24	E. Kistner	8/29/24	J. Swindler	8/30/24
1	FINAL	R. Lopina	10/18/24	E. Kistner	8/29/24	J. Swindler	8/30/24
2	FINAL (updated calculations)	R. Lopina	10/24/24	E. Kistner	8/29/24	J. Swindler	8/30/24

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Prepared by

Robert E. Lopina

Digitally signed by Lopina, Robert
Date: 2024.10.24 13:56:41-04'00'

Signature

Robert Lopina, PE

Printed Name

Reviewed by

Swindler, Jim

Digitally signed by Swindler, Jim
DN: CN="Swindler, Jim", OU=Internal, OU=users, OU=stantec, DC=corp, DC=ads
Reason: I have reviewed this document
Date: 2024.10.24 14:04:53-04'00'

Signature

James Swindler, PE

Printed Name

Approved by

Eric M. Kistner

Digitally signed by Eric M. Kistner
Date: 2024.10.24 15:43:18 -04'00'

Signature

Eric Kistner, PE

Printed Name

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Executive Summary

The Ohio Department of Transportation (ODOT) is planning to rehabilitate a distressed retaining wall along the ramp (Ramp T) from northbound I-71 to Ridge Avenue. The project is located in Norwood, Hamilton County, Ohio. The existing wall is showing cracking in the concrete along one section of wall (seven 4-foot wide panels), distress at the top of the adjacent walls, displacements of approximately 4 inches at the top of the wall, and ground depressions behind the wall. The planned repairs include a ground anchor and waler system, wall repairs, and drainage improvements. Stantec Consulting Services Inc. (Stantec) was contracted by ODOT to perform a geotechnical exploration and provide design recommendations for this project.

S&ME was contracted by Stantec to advance one boring to obtain geotechnical data for the proposed retaining wall rehabilitation. The boring was advanced through the roadway of Geier Drive. The surface materials encountered consisted of 0.5 feet of asphalt pavement underlain by 0.5 feet of granular base material. Below the surface materials, fine-grained soils were encountered. The soils were classified or visually described as sandy silt (A-4a), silt (A-4b), silt and clay (A-6a), silty clay (A-6b), and clay (A-7-6). These soils were described as medium stiff to very stiff, brown and/or gray, moist to wet, and having low to medium plasticity. Groundwater was not observed in the borehole during drilling.

To rehabilitate the distressed section of the existing retaining wall, tie-back ground anchors are proposed. The tie-back anchors would be installed through the existing wall. Calculations were performed to estimate the anchor loads, lengths, spacing, and inclination. Two rows of anchors, spaced 4 feet apart vertically and horizontally) and installed at a 15 degree downward inclination, are recommended. One row of anchors should be installed 7 feet below the top of the existing wall; the second row should be installed 11 feet below the top of the existing wall. Based on the calculated loading, an unbonded length of 15 feet and a bonded length of 35 feet are recommended for the tie-back anchors.

1 Introduction

The Ohio Department of Transportation (ODOT) is planning to rehabilitate a distressed retaining wall along the ramp (Ramp T) from northbound I-71 to Ridge Avenue. The project is located in Norwood, Hamilton County, Ohio. Figure 1 shows the site vicinity, and Figure 2 shows a photograph of the distressed wall.

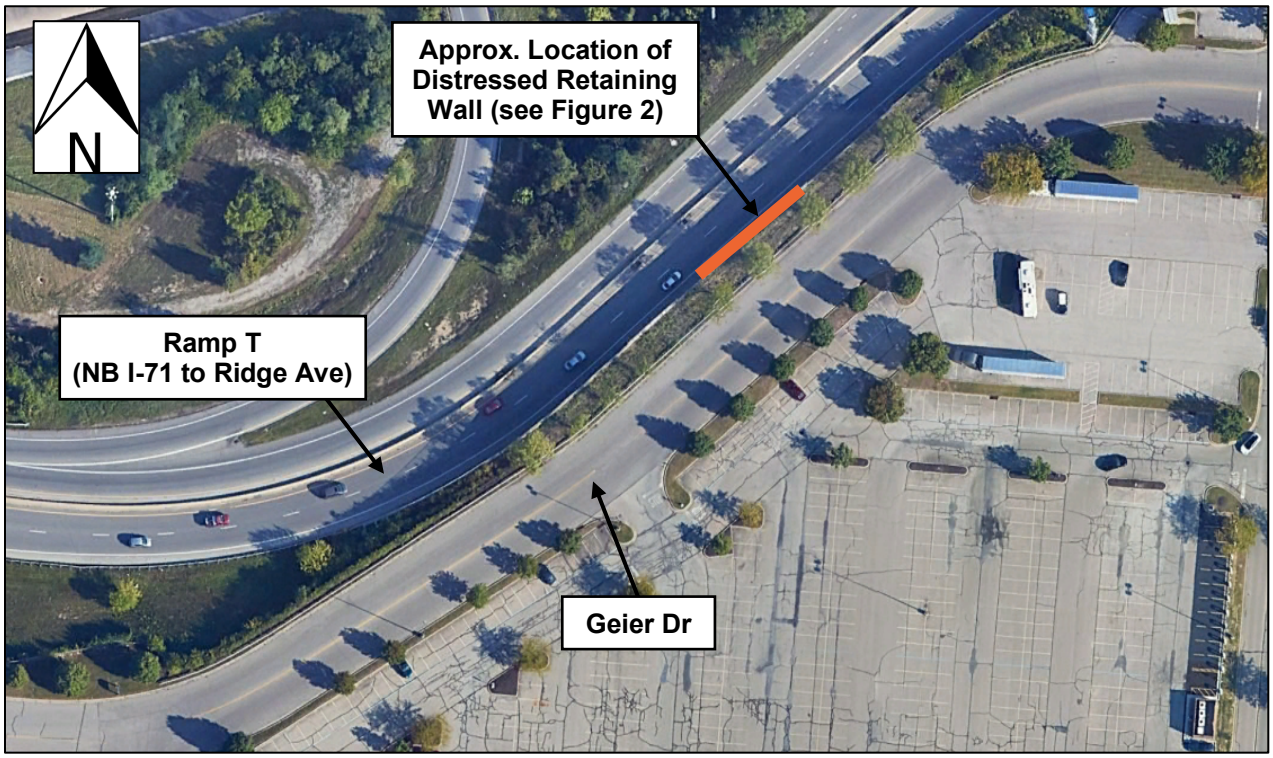


Figure 1: Site Vicinity
(from Google Earth Pro, Imagery Date: 9/10/2023)

Figure 2: Photograph of Distressed Retaining Wall
(from ODOT, looking from Ramp to Geier Drive)

The existing wall is showing cracking in the concrete along one section of wall (seven 4-foot wide panels), distress at the tops of the adjacent walls, displacements of approximately 4 inches at the top of the wall, and ground depressions behind the wall. The planned repairs include a ground anchor and waler system, wall repairs, and drainage improvements. Stantec Consulting Services Inc. (Stantec) was contracted by ODOT to perform a geotechnical exploration and provide design recommendations for this project.

2 Geology and Observations of the Project

2.1 General

The *Physiographic Regions of Ohio Map* (Ohio Department of Natural Resources (ODNR), 1998) indicates that the project is located within the Illinoian Till Plain Region. The Illinoian Till Plain Region is described as having a rolling ground moraine with older till with many buried valleys. The region consists of Ordovician and Silurian age carbonate bedrock with calcareous shale underlying silt-loam Illinois age till. The region has moderately low relief (about 50 feet) with elevations ranging from 600 to 1,100 feet.

2.2 Soil Geology

According to the *Quaternary Geology of Ohio Map* (ODNR, 1999), the project site is underlain by silty loam till covered with 1 to 3 meters of loess from the Illinoian era. These soils are ground moraine deposits, described as flat and relatively continuous. The soil survey (*Web Soil Survey of Hamilton County, Ohio*, United States Department of Agriculture [USDA], 2024) indicates that the project site is underlain by soils from the Urban land-Udorthents complex. These soils are described as 70 percent urban land with a high runoff class. The *Drift Thickness Map of Ohio* (*Ohio Geology Interactive Map*, ODNR, 2024) suggests that the glacial drift thickness ranges from 150 to 175 feet at the project site.

2.3 Bedrock Geology

Bedrock mapping (*Ohio Geology Interactive Map*, ODNR, 2024) and *Descriptions of Geologic Map Units* (ODNR, 2011) indicates that the overburden soils at the project site are underlain by sedimentary bedrock of the Point Pleasant Formation from the Ordovician group. The bedrock from the Point Pleasant Formation is comprised of interbedded limestone (60 percent) and shale (40 percent). The bedrock is described as shades of gray to bluish gray that weathers light gray, with unit thicknesses between 0 to 80 feet.

According to the *Ohio Mine Locator* (ODNR, 2024), there are no recorded mines within a 1-mile radius of the project footprint. The *Karst Interactive Map* (ODNR, 2024) indicates there are no known karst features in the project vicinity. Mapped karst features are located approximately 2 miles north of the project.

2.4 Hydrology and Hydrogeology

A tributary to Duck Creek is located approximately 0.5 miles east of the project site. Duck Creek flows into the Little Miami River approximately 4 miles southeast of the project site.

The *Ohio Geology Interactive Map* (ODNR, 2024) shows that the site is underlain by the Norwood Through Buried Valley Aquifer, which has a yield of 100 to 500 gallons per minute. According to the *Groundwater Resources of Hamilton County Map* (ODNR, 2024), the project site is in an area where wells

with yields of 100 to 500 gallons per minute can be achieved. The principal aquifer in the area is sand and gravel.

A search was performed using the ODNR *Ohio Water Wells Map* (2024) to determine if any water wells are located near the project site. According to the map, nine water well locations have been drilled within a 0.5-mile radius of the project footprint. The well logs indicate bedrock depths greater than 200 feet. The logs also indicate a considerable variation of the static water depth in the area surrounding the site, ranging from approximately 30 to 150 feet.

2.5 Seismic

A review of the seismic data available in the project vicinity was completed using the ODNR *Ohio Earthquake Epicenters Map* (2024). Overall, Ohio has a relatively limited amount of seismic activity. Within a 10-mile radius of the project, there have been five earthquake epicenters with magnitudes between 2.5 and 3.3. The available data reviewed included events that occurred in Ohio from 1804 to present day.

2.6 Site Reconnaissance

Representatives from Stantec and S&ME visited the site on July 1, 2024, to mark the boring location and evaluate site conditions. The area surrounding the project site can be described as commercial. Due to the traffic and narrow shoulder on Ramp T, the existing wall was not observed from below. Lateral displacement at the top of the existing wall of approximately 5 to 6 inches was observed from above the wall. Several indentations in the soil were observed immediately behind the wall. These observations appeared to be consistent with previous inspection photographs provided by ODOT.

3 Exploration

3.1 Historical Exploration Programs

The ODOT Traffic Information Management System (TIMS) provides documentation for the design of Interstate 71, Ramp T, and the retaining wall. The geotechnical exploration was performed in 1965. Borings advanced the near retaining wall were terminated at a depth of 30 feet and encountered predominately fine-grained soil, including silt (A-4b). In the vicinity of the distressed wall, Ramp T appears to be in an area where existing soil was cut to the design elevation.

The design drawings for the retaining wall indicate that the maximum height of the wall is approximately 25.5 feet (from top of wall to bottom of footing), which corresponds to an exposed wall height of 18.1 feet. The wall panels are 4 feet wide with a minimum thickness of 1.5 feet. Behind the wall, a 2-foot wide zone of porous backfill material was proposed.

3.2 Project Exploration Program

S&ME was contracted by Stantec to advance one boring to obtain geotechnical data for the proposed retaining wall rehabilitation. The boring was advanced through the roadway of Geier Drive. Boring information is provided in Table 1. The boring location is shown on the site plan in Appendix A. The locations of the boring was estimated using a handheld GPS unit. The ground surface elevation was estimated using available topographic information.

Table 1. Boring Summary

Boring No.	Latitude	Longitude	Ground Surface Elevation (feet)	Bottom of Boring Elevation (feet)
B-001-0-24	39.163658	-84.427454	597	557

The borings were advanced in accordance with the ODOT Specifications for Geotechnical Explorations (SGE). The borings were performed with a D-50 track-mounted drill rig using 3¼-inch inside diameter (ID) hollow stem augers to advance the borings through soil. Standard Penetration Test (SPT) sampling was performed at 2.5- to 5.0-foot intervals until the termination depth of 40 feet. The energy ratio (ER) of the automatic hammer and drill rod system were measured to be 87.5 percent on August 29, 2023.

The depths and elevations of the SPTs with the corresponding N_{60}-values (blow count corrected to an equivalent road energy ratio of 60 percent) are shown on the boring log in Appendix B. In addition to the SPT sampling, three undisturbed Shelby tube (ST) samples were collected at selected depths.

The materials encountered were logged by a geologist, with attention given to soil type, consistency, and moisture content. The borings were checked for the presence of groundwater during drilling and at its

conclusion with the depth of water recorded. The borings were backfilled with auger cuttings mixed with bentonite chips grout and capped with asphalt cold patch.

The soil samples obtained from the borings were returned to S&ME's geotechnical laboratory for visual classification and tested for water content. Engineering classification testing was performed on samples reflecting each of the main soil horizons. The engineering classification tests conducted on the samples were sieve and hydrometer analysis (ASTM D 422) and Atterberg limits (ASTM D 4318). The samples were classified according to the ODOT classification method. Two undisturbed ST samples were subjected to unconfined compressive strength testing (ASTM D 2166). The results of laboratory testing are included in Appendix C.

4 Findings

The surface materials encountered in boring B-001-0-24 consisted of 0.5 feet of asphalt pavement underlain by 0.5 feet of granular base material. Below the surface materials, fine-grained soils were encountered. The soils were classified or visually described as sandy silt (A-4a), silt (A-4b), silt and clay (A-6a), silty clay (A-6b), and clay (A-7-6). These soils were described as medium stiff to very stiff (N_{60}-values ranging from 7 to 36 blows per foot), brown and/or gray, moist to wet (moisture content values ranging from 9 to 32 percent), and having low to medium plasticity (laboratory tested plastic indices ranging from 6 to 16 percent). Groundwater was not observed during drilling.

Two undisturbed samples subjected to unconfined compressive strength testing resulted in unconfined compressive strength values of 1.08 and 3.02 kips per square foot (ksf). Both of the tests were performed on silt (A-4b) material. The results indicate lower compressive strength values compared to the hand penetrometer values in the silt material (ranging from 5.0 to 8.0 ksf). The samples were noted as dry on the laboratory test results, so the soil may have partially dried out prior to the compression testing.

The boring log and laboratory testing results are presented in Appendix B and Appendix C, respectively.

5 Analyses and Recommendations

5.1 General

The recommendations that follow are based on the information discussed in this report and the interpretation of the subsurface conditions encountered at the site during our fieldwork. If future design changes are made, Stantec should be notified so that such changes can be reviewed, and the recommendations amended as necessary.

These conclusions and recommendations are based on data and subsurface conditions from the boring advanced during this exploration using the degree of care and skill ordinarily exercised under similar circumstances by competent members of the engineering profession. No warranties can be made regarding the continuity of conditions.

5.2 Tie-Back Anchors

To rehabilitate the distressed section of the existing retaining wall, tie-back ground anchors are proposed. The tie-back anchors would be installed through the existing wall. Calculations were performed to estimate the anchor loads, lengths, spacing, and inclination. One row of anchors was initially considered; however, due to right-of-way concerns, two rows of anchors are recommended to decrease the required anchor length behind the wall. Table 2 summarizes the results of the calculations and recommended unbonded and bonded anchor lengths. Appendix D provides the detailed calculations.

Table 2. Summary of Tie-Back Anchor Calculations

Anchor	Depth from Top of Wall (feet)	Anchor Load (kips)	Spacing (ft)	Anchor Inclination (degrees)	Unbonded Length (feet)	Bonded Length (feet)
Top	5	27.8	4	20	15	30
Bottom	9	28.2	4	20	15	30

The calculations were performed using FHWA GEC No. 4, AASHTO LRFD Bridge Design Specifications, and ODOT Supplemental Specification 866. The calculations include assumptions and do not provide detailed design of the anchors, including (but not limited to): anchor material, anchor drill hole diameter, grout mix design, grouting procedures, etc. Stantec's design team will be performing the necessary structural analysis and detailed design of the anchors and waler systems based on the recommendations presented in this report.

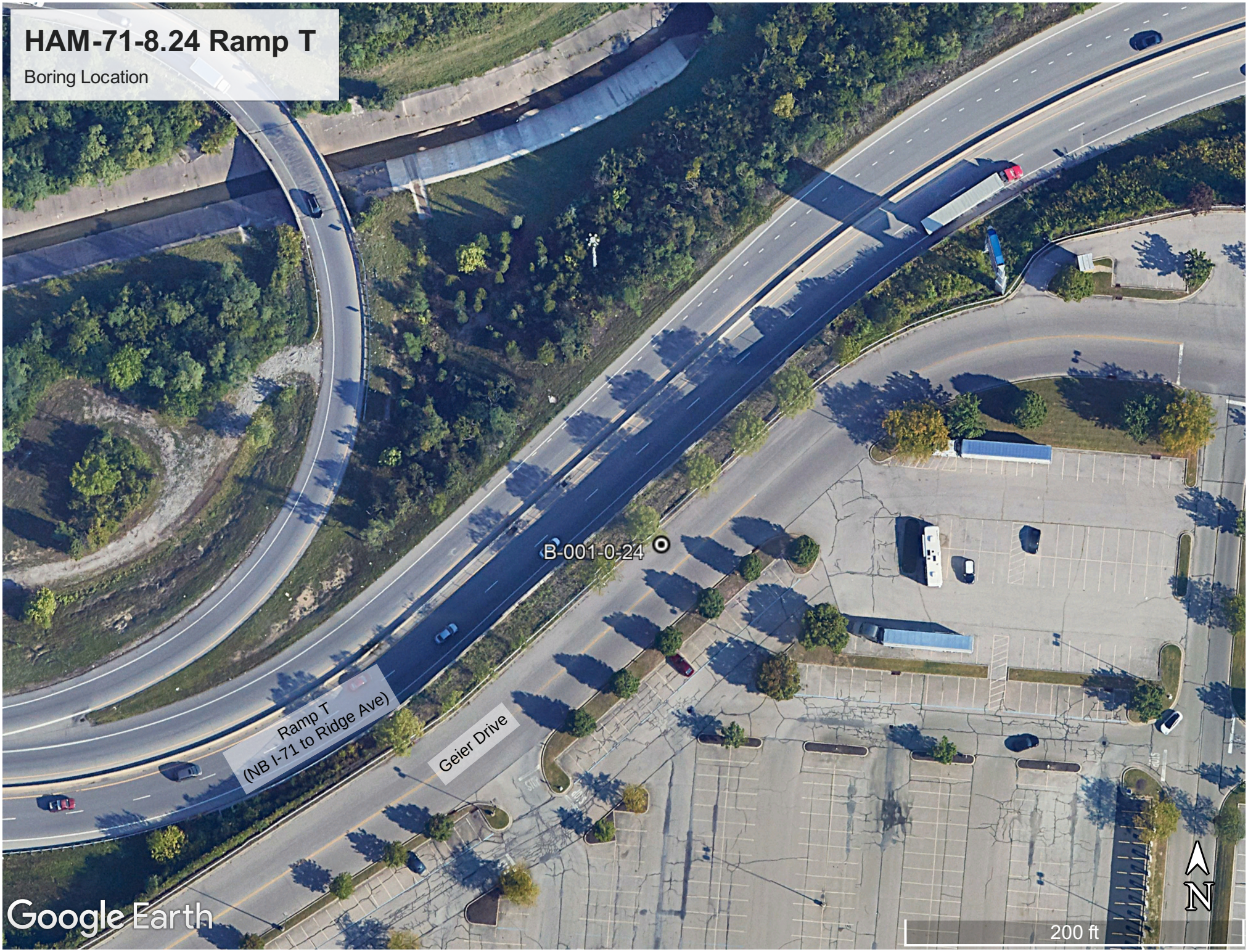
Additional recommendations are as follows:

- A center-to-center anchor spacing of 4 feet was considered based on the existing wall panel width. The anchors should be installed in the center of the existing wall panels.

- A waler system be installed in conjunction with the tie-back anchors to distribute the anchor point loads across the existing wall.
- The waler system and tie-back anchors should span the distressed wall section (seven 4-foot wide panels) and one wall section on either side of the distressed wall section. The total length of this system is approximately 90 feet long.
- Drainage improvements should be implemented behind the wall to improve drainage during future rain events.

Appendix A

Boring Location


HAM-71-8.24 Ramp T
Boring Location
B-001-0-24
Ramp T
(NB I-71 to Ridge Ave)
Geier Drive
Google Earth
200 ft
N

Appendix B

Boring Log

PROJECT: HAM-71-08.24	DRILLING FIRM / OPERATOR: S&ME / BK	DRILL RIG: S&ME D50	STATION / OFFSET: 37+32, 70' RT.
TYPE: GEOHAZARD EXPLORATION	SAMPLING FIRM / LOGGER: STANTEC / JP	HAMMER: CME AUTOMATIC	ALIGNMENT: RAMP T
PID: N/A SFN: N/A	DRILLING METHOD: 3-1/4" HSA	CALIBRATION DATE: 8/29/23	ELEVATION: 597.0 (MSL) EOB: 40.0 ft.
START: 7/9/24 END: 7/9/24	SAMPLING METHOD: SPT / ST	ENERGY RATIO (%): 87.5	LAT / LONG: 39.163658, -84.427454

EXPLORATION ID 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
ASPHALT 6-INCHES OF PAVEMENT	597.0																	
AGGREGATE BASE 6-INCHES OF BASE	596.5																	
MEDIUM STIFF TO STIFF, BROWN, **SILTY CLAY**, SOME FINE TO COARSE SAND, LITTLE GRAVEL, MOIST	596.0	1	10 3 5	12	73	SS-1	4.00	-	-	-	-	-	-	-	-	23	A-6b (V)	
		2																
		3																
		4	3 5 10	22	81	SS-2	4.50	13	7	16	31	33	32	16	16	15	A-6b (8)	
	591.5	5																
VERY STIFF, BROWN, **SILTY CLAY**, SOME FINE TO COARSE SAND, LITTLE GRAVEL, MOIST		6																
		7	10 8 9	25	93	SS-3	4.00	-	-	-	-	-	-	-	-	14	A-6b (V)	
	589.0	8																
VERY STIFF, BROWN, **SILT AND CLAY**, SOME FINE TO COARSE SAND, LITTLE GRAVEL, MOIST		9			90	ST-1	-	16	9	16	41	18	26	13	13	13	A-6a (6)	
		10	7 6 9	22	100	SS-4	3.50	-	-	-	-	-	-	-	-	24	A-6a (V)	
	585.5	11																
VERY STIFF, BROWN, **SILT**, LITTLE CLAY, TRACE FINE SAND, MOIST		12																
		13	3 6 7	19	73	SS-5	4.00	0	0	1	81	18	28	19	9	24	A-4b (8)	
	583.0	14																
MEDIUM STIFF, BROWN, **SILT**, SOME CLAY, TRACE FINE SAND, MOIST		15																
		16	3 2 3	7	67	SS-6	3.50	-	-	-	-	-	-	-	-	27	A-4b (V)	
FROM 16.0' TO 18.0', UCS = 3.02 KSF	580.0	17			100	ST-2	-	0	0	4	63	33	23	17	6	22	A-4b (8)	
VERY STIFF, BROWN AND GRAY, **SILT**, TRACE FINE SAND, SOME CLAY, MOIST		18																
		19	6 10 15	36	33	SS-7	4.00	-	-	-	-	-	-	-	-	19	A-4b (V)	
	577.5	20																
STIFF TO VERY STIFF, BROWN AND GRAY, **SILT**, SOME CLAY, MOIST TO WET		21	0 3 5	12	100	SS-8	2.50	-	-	-	-	-	-	-	-	32	A-4b (V)	
		22																
		23																
FROM 23.5' TO 25.5', UCS = 1.08 KSF		24			100	ST-3	-	0	0	0	76	24	24	18	6	20	A-4b (8)	
		25																
		26	6 6 6	18	100	SS-9	2.50	-	-	-	-	-	-	-	-	22	A-4b (V)	
	570.0	27																
VERY STIFF, BROWN, **SANDY SILT**, SOME CLAY, MOIST		28																
		29	3 6 8	20	100	SS-10	4.00	0	3	23	46	28	19	12	7	15	A-4a (8)	

PID: N/A	SFN: N/A	PROJECT: HAM-71-08.24	STATION / OFFSET: 37+32, 70' RT.	START: 7/9/24	END: 7/9/24	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
VERY STIFF, BROWN, **SANDY SILT**, SOME CLAY, MOIST *(continued)*	567.0	31 32 33																
HARD, GRAY, **CLAY**, LITTLE SILT, TRACE FINE TO COARSE SAND, MOIST	565.0	34 35	7 12 13	36	100	SS-11	4.50	-	-	-	-	-	-	-	-	9	A-7-6 (V)	
		36 37 38																
	557.0	EOB 39 40	11 11 12	34	100	SS-12	4.50	-	-	-	-	-	-	-	-	12	A-7-6 (V)	

NOTES: WATER NOT ENCOUNTERED DURING DRILLING AND AFTER DRILLING. BORING LOCATION ESTIMATED FROM HANDHELD GPS. STATION/OFFSET ARE APPROXIMATE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: ASPHALT PATCH; BENTONITE CHIPS

Appendix C

Laboratory Testing Results

SUMMARY OF LABORATORY TEST RESULTS

BORING	SAMPLE (#)	Top Depth (ft)	MC %	LL %	PL %	PI %	AGGREGATE %	COARSE SAND %	FINE SAND %	SILT %	CLAY %	SILT/CLAY %	D / 50 m m	D / 95 m m	H R B ODOT CLASSIFICATION
B-001-0-24	1	1.00	23												
B-001-0-24	2	3.50	15	32	16	16	13	7	16	31	33		0.0246	13.2704	A-6b (8)
B-001-0-24	3	6.00	14												
B-001-0-24	1	8.50	13	26	13	13	16	9	16	41	18		0.0536	12.5000	A-6a (6)
B-001-0-24	4	9.50	24												
B-001-0-24	5	12.00	24	28	19	9	0	0	1	81	18		0.0209	0.0328	A-4b (8)
B-001-0-24	6	14.50	27												
B-001-0-24	2	16.00	22	23	17	6	0	0	4	63	33		0.0121	0.0724	A-4b (8)
B-001-0-24	7	18.00	19												
B-001-0-24	8	19.50	32												
B-001-0-24	3	23.50	20	24	18	6	0	0	0	76	24		0.0123	0.0628	A-4b (8)
B-001-0-24	9	25.50	22												
B-001-0-24	10	28.50	15	19	12	7	0	3	23	46	28		0.0246	0.3312	A-4a (8)
B-001-0-24	11	33.50	9												
B-001-0-24	12	38.50	12												

PROJECT HAM-71-8124
LOCATION Geier Drive, Cincinnati, Ohio
JOB NO. 24780072 **DATE** 7/26/24

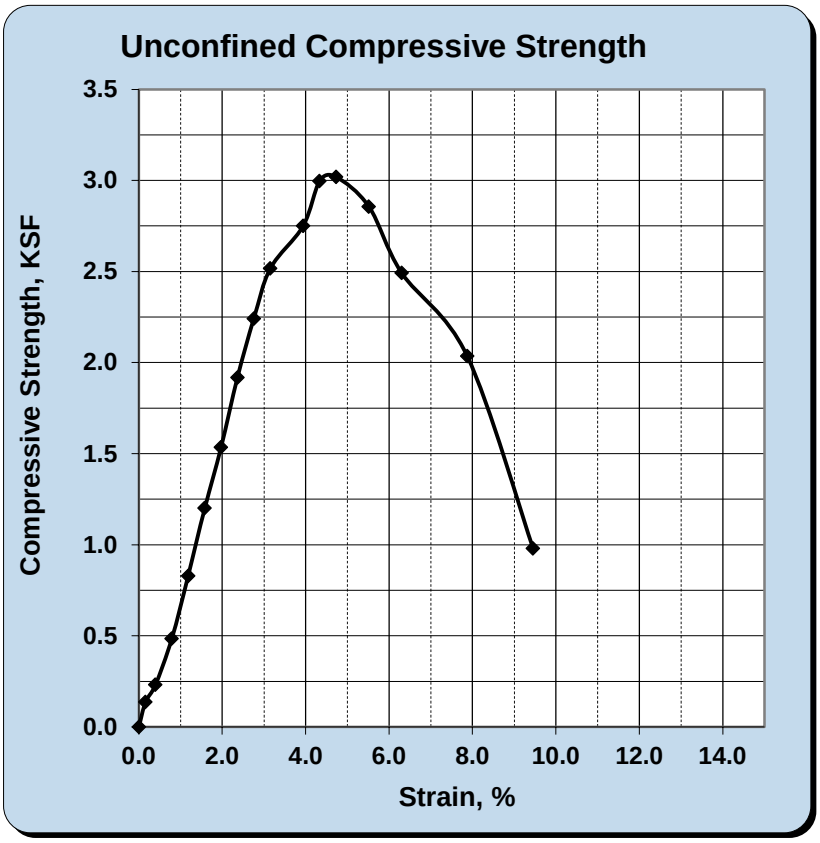
Form No. TR-D2166-01
Revision No. : 1
Revision Date: 08/16/17

UNCONFINED COMPRESSIVE STRENGTH OF COHESIVE SOILS

ASTM D2166

S&ME, Inc. Cincinnati: 862 East Crescentville Road, West Chester, OH 45246

Project No.:	24780072	Report Date:	7/26/2024
Project Name:	Geier Retaining Wall	Test Date(s):	7/18/2024
Client Name:	Stantec Consulting Services Inc.		
Client Address:	10200 Alliance Road Suite 300, Cincinnati, OH 45242		
Location:	B-001-0-24 Sample No. ST-2	Sample Date:	7/9/2024
		Depth:	16.0-18.0
Sample Description:	A-4b(Silt)		



Failed Specimen

Type of Sample: Intact
Source of Moisture Sample: Test Specimen

Initial Dry Unit Weight: 123.1 pcf
Initial Water Content: 20.3%
Unconfined Compressive Strength, q_u: **3.020** KSF
Undrained Shear Strength, s_u: **1.510** KSF

Liquid Limit: 23
Plasticity Index: 6
Height to Diameter Ratio: 2.2
Rate of Strain (%/min.): 0.0086
Strain at Failure: 4.4

References / Comments / Deviations:

Sample was dry.

K. Cannady		QAS	7/26/2024
Technical Responsibility	*Signature*	*Position*	*Date*

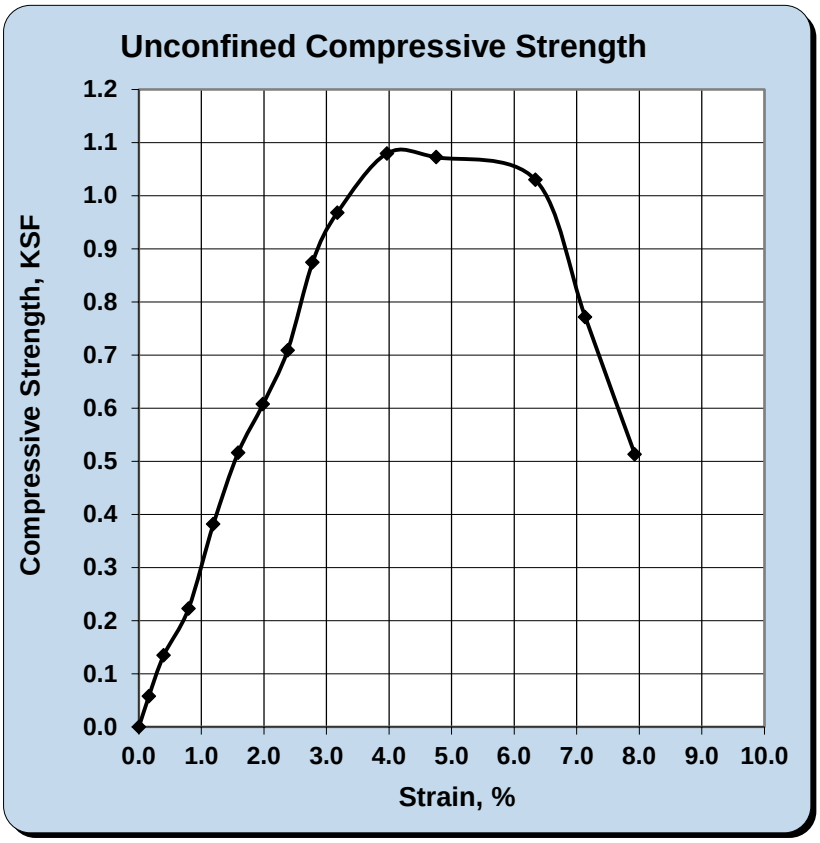
Form No. TR-D2166-01
Revision No. : 1
Revision Date: 08/16/17

UNCONFINED COMPRESSIVE STRENGTH OF COHESIVE SOILS

ASTM D2166

S&ME, Inc. Cincinnati: 862 East Crescentville Road, West Chester, OH 45246

Project No.:	24780072	Report Date:	7/26/2024
Project Name:	Geier Retaining Wall	Test Date(s):	7/18/2024
Client Name:	Stantec Consulting Services Inc.		
Client Address:	10200 Alliance Road Suite 300, Cincinnati, OH 45242		
Location:	B-001-0-24 Sample No. ST-3	Sample Date:	7/9/2024
		Depth:	23.5-25.5
Sample Description:	A-4b (Silt)		



Failed Specimen

Type of Sample: Intact
Source of Moisture Sample: Test Specimen

Initial Dry Unit Weight: 116.3 pcf
Initial Water Content: 24.3%
Unconfined Compressive Strength, q_u: **1.079** KSF
Undrained Shear Strength, s_u: **0.540** KSF

Liquid Limit: 24
Plasticity Index: 6
Height to Diameter Ratio: 2.2
Rate of Strain (%/min.): 0.0086
Strain at Failure: 4.0

References / Comments / Deviations:

Sample was dry.

K. Cannady		QAS	7/26/2024
Technical Responsibility	*Signature*	*Position*	*Date*

Appendix D

Tie-Back Anchor Wall Calculations

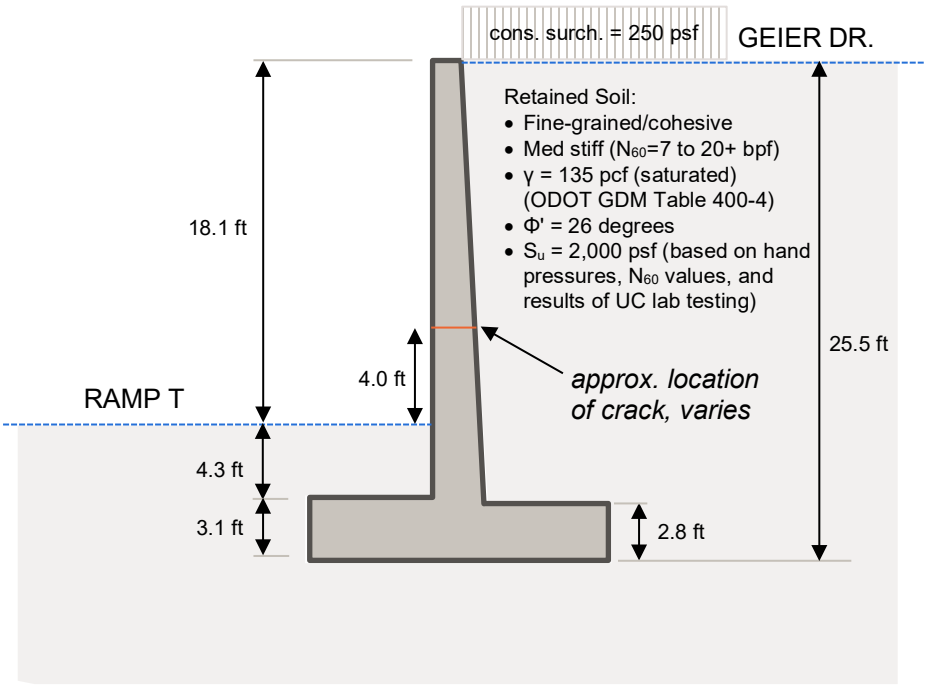
HAM-71-8.24 Retaining Wall (PID 121704)
Wall Anchor Calculations

Existing Wall:

Assumptions

- Maximum height of wall shown, per historical plans Ramp T STA. 38+00 (approx.)
- Assume fully saturated soil
- The crack location is approximate; a lower crack location was conservatively assumed (larger wall loading)

Diagram (not to scale)

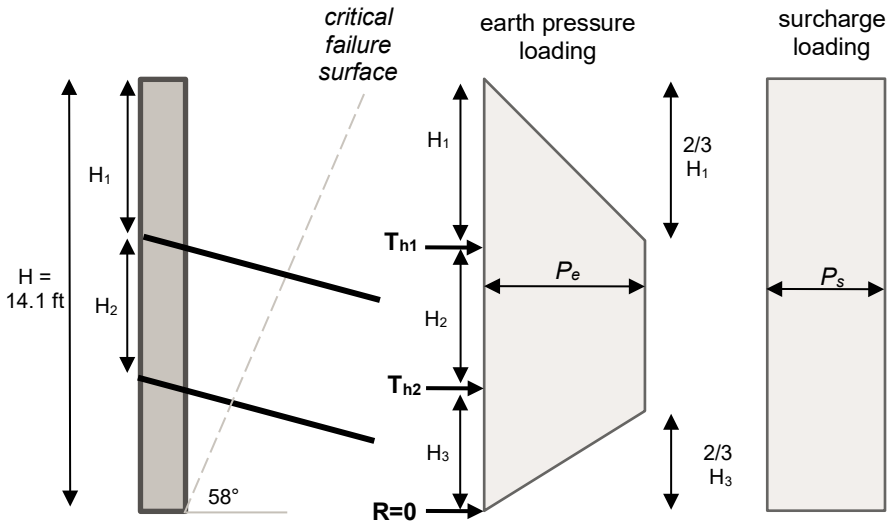


Calculations:

References

- U.S. DOT Federal Highway Administration (FHWA), Geotechnical Engineering Circular No. 4: Ground Anchors and Anchored Systems, June 1999.
- American Association of State Highway and Transportation Officials (AASHTO), LRFD Bridge Design Specifications, 9th Edition, 2020.
- Ohio Department of Transportation (ODOT), Supplemental Specification 866: Ground Anchors, April 21, 2017.
- Ohio Department of Transportation (ODOT), Bridge Design Manual (BDM), July 19, 2024.
- Ohio Department of Transportation (ODOT), Geotechnical Design Manual (GDM), July 19, 2024.

Apparent Earth Pressure Distribution (not to scale)



H_1 = 5 ft
H_2 = 4 ft
H_3 = 5.1 ft

Note: H1 and H2 chosen so that the bottom anchor would be a minimum 2 feet above the top of the crack at all location.

Stantec

Wall Loading – LRFD

Assumed to be above the observed cracking.

Per AASHTO LRFD 3.11.5.7.2, the stability number, N_s, is approximately:
N_s = 135 pcf * 14.1 ft / 2,000 psf = 0.95

Therefore, consider cohesive soil to be stiff to hard (AASHTO LRFD 3.11.5.7.2a). Apparent earth pressure distribution is the same as for the ASD, except load factors will be used. The following load factors are used, per AASHTO LRFD Table 3.4.1-1 and Table 3.4.1-2:

Load Case	EH (Horizontal Earth Pressure)	LL (Live Load)	WA (Water Load)
Strength I	1.35 (for anchored walls)	1.75	1.00
Service I	1.00	1.00	1.00

Per AASHTO LRFD 3.11.5.7.2a, for stiff clays use Eq. 3.11.5.7.1-2: $k_a = \tan^2 (45 – 26/2) = 0.39$

$P_e = 1.35\ k_a\ \gamma\ H = 1.35\ (0.39)\ (135\ pcf)\ (14.1\ ft) = 1{,}002.2\ psf$

$P_s = 1.75\ k_a\ q = 1.75\ (0.39)\ (250\ psf) = 170.6\ psf$

Calculate T_{hn} (total load)

$T_{h1} = 0.5\ [(H_1 + H_2/2) + (H_1 + H_2/2 - 2/3\ H_1)]*P_e + (H_1 + H_2/2)*P_s$

$= 0.5\ (7\ ft + 3.67\ ft)\ (1{,}002.2\ psf) + (5\ ft + 2\ ft)\ (170.6\ psf)$

T_{h1} = 5,346.7 lb/ft + 1,194.2 lb/ft

T_{h1} = 6,540.9 lb/ft of wall

$T_{h2} = 0.5\ [(H_3 + H_2/2) + (H_3 + H_2/2 - 2/3\ H_3)]*P_e + (H_3 + H_2/2)*P_s$

$= 0.5\ (7.1\ ft + 3.7\ ft)\ (1{,}002.2\ psf) + (5.1\ ft + 2\ ft)\ (170.6\ psf)$

T_{h2} = 5,411.9 lb/ft + 1,211.3 lb/ft

T_{h2} = 6,623.2 lb/ft of wall

Anchor Load

Existing wall panels are 4 ft apart. While the recommended minimum spacing Per AASHTO LRFD 11.9.4.2, should be 5.0 feet, the diameter of the tiebacks are relatively small and group effect will likely not occur at 4 ft spacing. The anchor design will assume 20 degree inclination anchors at 4-foot center-to-center spacing.

$Q_{anchor1}$ = 6,540.9 lb/ft (4 ft) / cos (20°) = 27.8 kips

$Q_{anchor2}$ = 6,623.2 lb/ft (4 ft) / cos (20°) = 28.2 kips

Use $Q_{anchor2}$ = 28.2 kips for design.

Anchor Pullout Capacity

Per AASHTO LRFD Eqn. 11.9.4.2-1:

$$Q_R = \phi Q_n = \phi \pi D_{DH} \tau_a L_b \qquad (11.9.4.2\text{-}1)$$

where:

ϕ = resistance factor for anchor pullout (dim.)
Q_n = nominal anchor pullout resistance (kips)
D_{DH} = diameter of anchor drill hole (ft)
τ_n = nominal anchor bond stress (ksf)
L_b = anchor bond length (ft)

Φ = 0.70 for cohesive soils (AASHTO LRFD Table 11.5.7-1)

D_{DH} = 6 inches (assumed)

τ_n = 0.9 ksf for gravity grouted anchors in stiff silt-clay mixtures, for S_u = 2,000 psf (AASHTO LRFD Table C11.9.4.2-1)

Q_R = 0.70 (π) (0.5 ft) (0.9 ksf) L_b

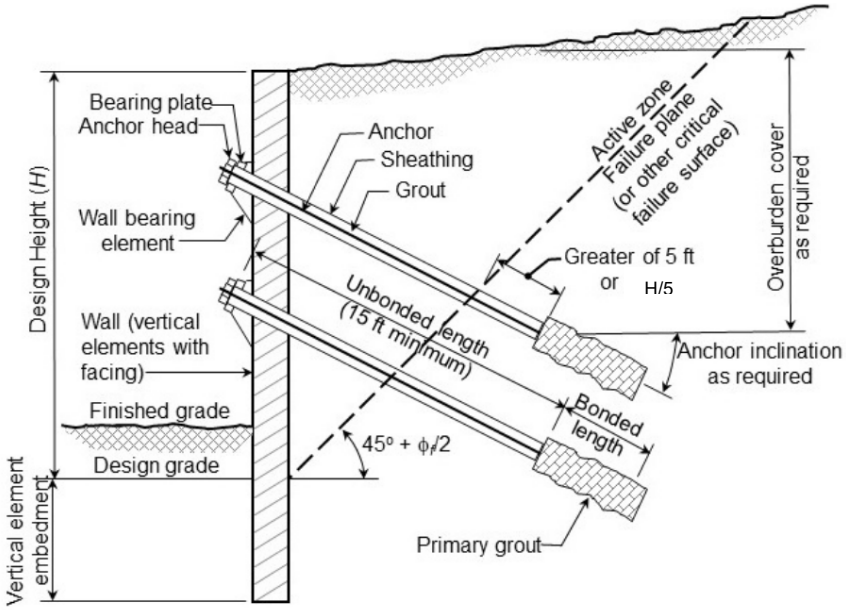
Q_R = 0.99 L_b

$Q_{anchor2}$ = 28.2 kips = 0.99 L_b → L_b = 28.5 ft

Anchor Length/Position

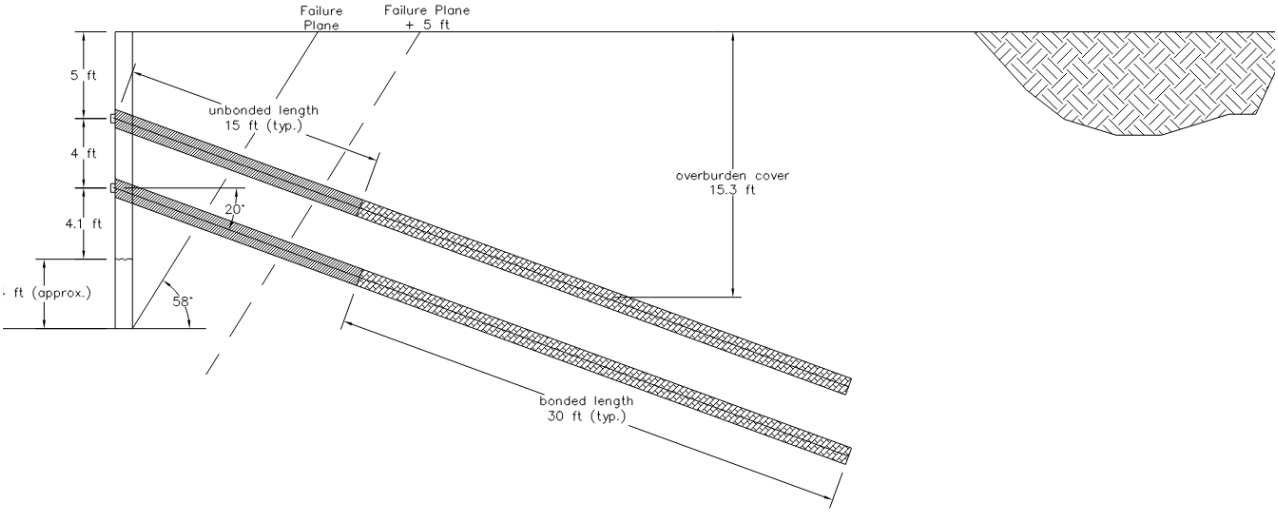
Based on the LRFD calculations, a bonded length of 30 ft is recommended for 20 degree inclination anchors.

Per AASHTO LRFD Figure 11.9.1-1:



Based on geometry, the distance from the wall to the critical failure plane along the anchor location is approximately 7.5 feet for the upper anchor, therefore the unbonded length will be the minimum 15 ft for both anchors per AASHTO LRFD Figure 11.9.1-1. Note this is larger than the minimum bonded length shown in FHWA GEC 4 Figure 37a.

Per AASHTO LRFD C11.9.4.2-1, for tremie-grouted anchors, a minimum overburden cover of 15.0 feet is typically required. Per FHWA GEC 4 Section 5.3.7, the minimum overburden cover for ground anchors installed in soil is 15 feet over the center of the anchor bond zone. To meet the minimum overburden requirement for the 20 degree anchor, the anchor should be installed a minimum of 5.0 feet from the top of the wall. See diagram and calculations below.



Overburden cover of 20 degree anchor = 5 ft + sin 20° (15 ft + 30 ft / 2) = 15.3 ft